THE NUTRITIVE VALUE OF MUNG BEANS
AND THE EFFECT OF GRAIN AND
SUNFLOWER SEED SUPPLEMENTATION

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

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1956

THE NUTRITIVE VALUE OF MUNG BEANS AND THE EFFECT OF GRAIN AND SUNFLOWER SEED SUPPLEMENTATION

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A THESIS

Submitted to the College of Home Economics of Michigan State University of Agriculture and Applied Sciences in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Foods and Nutrition

College of Home Economics

Year 1956

THESIS

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ACKNOWLEDGMENTS

The author wishes to express her heartfelt gratitude to Dr. Anna Louise Kelley under whose inspiration, patient guidance, tireless and unfaltering help this study was undertaken.

She is greatly indebted to Dr. Margaret A. Ohlson, Professor and Head, Department of Foods and Nutrition, for her interest, encouragement and helpful suggestions. She extends her sincere thanks to Dr. Selma Bandemer for determining amino acid composition of the protein sources.

Grateful acknowledgment is also due to Mrs. Joan Miller, Mrs. Deloris Kereluk, Miss Amelia Cruz, and Mr. Ricardo Anselmo for their invaluable assistance and to those who have helped one way or another in the completion of this study.

The writer deeply appreciates the financial assistance and scholarship provided by Michigan State University which made it possible for her to finish the investigation.

INTRODUCTION

The Mung Bean

The mung bean is a native of India and is cultivated in all parts of the country either as a second crop after the rice has been harvested or as a subordinate crop with other cereals like corn, millet or sorghum. It is also cultivated in the Malay Peninsula, eastern portions of East Africa, southern half of Asia, the Philippines and in parts of America and Greece. It is a three month crop and can stand prolonged periods of drought and extremely hot weather. It thrives on rather thin upland soil hence it is grown quite extensively in many sections of Oklahoma as an emergency hay crop (Kuhlman, et al, 1937). It is becoming popular in the United States as a forage crop and as a legume for human consumption in the form of sprouted beans. In countries where the mung bean is cultivated widely, it is regarded as one of the most nutritious and economical of the pulses.

People of India are vegetarians and it is the proteins of these pulses that furnish the necessary proteins for life. In Java, they are consumed more for their value to prevent disease than for their food value. Mung bean milk is used as an adjunct

in infant feeding in the Philippines but its extensive use is hampered by the difficulty of its preparation and the lack of data on its biological qualities. Although many babies can tolerate mung bean milk, there are some who develop diarrhea. Tenmatay (1952) has found that the extract has good whipping qualities. The beans are eaten as a gruel with chopped vegetables or meat (usually pork) all cooked together (Aalsmeer, 1954). Rodriguez (1936) found that mung meal is fairly satisfactory for poultry in combination with shrimp meal to supply a part of the protein requirement. Santos (1952) showed that as much as 25 percent of the fish meal could be substituted with mung meal when 1 percent of animal factor protein was supplemented in the chick ration. Mung meal contains a good amount of protein but is insufficient for chick ration when used as the sole source of protein (Lagman, 1952).

According to Embrey (1921) green bean hulls when ground to a pulp are applied to small pox, ulcers and excoriation produced by the urine in Chinese children. The bean is used as a carminative, antifebrant, counterpoisonous remedy and the bean meal is used for poultices in boils and abcesses. The bruised leaves are used for snake bites and the pods are used in dysentery. The flowers counteract the effects of wine and the leaves steeped in vinegar is a cure for cholera.

More than half of the beans grown in the Philippines are classified under the genus phaseolus, locally known as

"mungo" (Aalsmeer, 1954). The mung bean plant belongs to the family Leguminosae. It is an erect or scandent plant that grows to a height of from one to three feet. It has pubescent leaflets that are acute, obtuse or slightly acuminate. Its tiny flowers, usually 12 to 16 mm. in diameter are of different shades of yellow. The pods contain 10 to 15 seeds that are small, globose, green, yellow, or black in color.

There has been some confusion in the nomenclature of the mung bean. Roxburgh transposed the original names given by Linnaeus but Prain made changes in the nomenclature given by Roxburgh. According to Bose (1932), the changes made by Prain are now recognized to represent the true species for mung. There are 40 types of mung beans that have been isolated and bred through. The most important characteristics differentiating one from the others are the seed, color of the flower and color of the ripe pod. There are three leading varieties at present: var. typica, var. aureus, and var. grandis. The type used in this experiment was Oklahoma Jumbo[1].

The Grains

Half of the people of the world derive their calories chiefly from cereals, rice and wheat, ranking first and second respectively. Cereals are the main source of nourishment for those in the low income levels. In the United States, about

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[1]Purchased from Johnson Seed Co., Enid, Oklahoma.

one-third of the total protein in the diet is supplied by cereals; chiefly wheat, corn, oats, rye, barley and rice (Jones, 1948). The Near East consumes essentially a cereal diet with wheat as the principal cereal. Rice is considered to be the most important cereal of the world since more than half of the human race consumes rice as the basic daily diet. Corn is used by low income groups not only for its calories but also for its vitamin and protein content in the Southern States (Sure, 1948) and in different areas of the world. The cereals are called "the backbone of the nutrition of most of the races of the earth" (Gunderson, 1935).

Barley is raised for bread making in the northern countries of Europe and for malting in the temperate zones.

Millet is used for poultry feed in Britain. It is among the oldest of all cultivated crops and was a part of Chinese religious ceremonies conducted by the emperors long before the birth of Christ (Ahlgren, 1949).

Sudan grass was introduced in the United States from Africa as a result of the search for a species of wild Andropogon which did not possess rootstalks as does Johnson grass. It has proved to be valuable for hay, silage, pasture and grain. It is chiefly a hay and pasture crop.

The Sunflower Seed

Sunflower seed, because of its high protein content, interested Bricker and Smith (1951) in testing for its biological value for humans. Sunflower seed meal is used as a feed for poultry. It was shown in the Food Research Laboratory of the Foods and Nutrition Department, University of Illinois, that replacement of as much as 20 percent of wheat flour in certain baked goods with sunflower seed flour resulted in palatable products. Sunflower seed contains 46.7 percent crude protein and 3.9 percent methionine (Grau and Almquist, 1945). According to Alexander (1952), lysine seems to be the principal amino acid deficiency.

Justification of the Problem

The table below which was compiled from several recent dietary surveys, points to the fact that many population groups still live almost entirely on foods of vegetable origin.

Foods	Geographical Area			Recommended Ratio
	USA	NearEast	FarEast	
	(Percent calories from food)			
Cereals, fruits, vegetables	50	85	91	50
Meat, milk, eggs	30	5	7	37
Fats, oils, sweets	20	10	2	13

The right hand column of this table gives the recommended ratios of calories supplied by foods of animal and vegetable origin. Very low income families in most parts of the western world can hardly adhere to the recommended ratios and for many people of the eastern countries it is almost impossible because of socio-economic and religious factors. The diets of these people are inadequate in some minerals and vitamins and contain very poor quality protein. The improvement of the nutritional quality of the diet they can obtain and will accept is a practical approach to their problem.

Enriching cereals with some vitamins and minerals has been found nutritionally and economically practical but enrichment with protein constituents, amino acids, is difficult because the quantitative relationship of amino acids in the diet largely determines protein availability. Most of the protein for people in the Eastern countries and much of the protein for the poorer population groups in the United States is supplied by grains and legumes.

The staple food of the Filipinos is rice. Corn is also grown in the Philippines but not as extensively as rice. It is not as popular as rice for cereal (Carrasco, 1955). However, because of the rice shortage, there has been a proposal to use a rice-corn mixture as a staple cereal in the proportion of two parts rice and one part corn. This mixture does not give protein of high quality but if animal protein is included in the diet, the nutritional value will be improved. It is suggested by Deshpande, Harper, Quiros-Perez and Elvehjem (1955) that the most practical way of improving the nutritive value of rice diets is by supplementation with foods containing nutritionally well-balanced proteins.

As has been mentioned earlier in this paper, the mung bean is regarded as one of the most nourishing and economical pulses of the Far East, Southeast Asia, India and the Middle East. The Philippines produced 41,000 tons of beans in the years 1949-1950, the greater bulk of which was mung (Tenmatay, 1952). Therefore, to alleviate the protein deficiency in the diet of the people, one of the proposed solutions to this problem is to increase the production and consumption of locally grown legumes and nuts, especially that of mung beans.

One of the purposes of this experiment is to investigate quantitative relationships of the mung beans, grains (wheat, rice, corn, barley, millet and sudan grass) and sunflower seeds that might give physiologically satisfactory amino acid mixtures. Although barley, millet, sudan grass and sunflower seeds are not at present popular for human consumption, they are of some value for animal feeds. If positive supplementary relationships between the protein of these seeds and those of more widely accepted types are found, their use as human and animal food could be promoted.

There is very little data on the nutritional quality of mung bean proteins. There is a need for more information as to its nutritional quality especially in countries where rice is the staple food and where socio-economic as well as religious factors limit the use of animal protein. It was therefore the main purpose of the work described herein to investigate the nutritional quality of the unsupplemented and supplemented protein of the mung bean.

REVIEW OF LITERATURE

Mung Beans

Literature on the analytical data and biological value of mung bean proteins is scanty. Some research has been directed toward the determination of the vitamin content of this legume but there is little data on the nutritional quality of its protein.

Hermano (1934) found mung beans (*Phaseolus aureus*) to be high in vitamin B_1. Yeh (1939) reported that after the beans were sprouted vitamin C content of mung beans was increased 5-8 times and the vitamin B_1 content increased about twice. Miller and Hiar (1928) have reported the vitamin content of sprouted mung beans. Sreenivasan and Wandrekar (1950), Rochanapenanda (Tenmatay, 1952) and Simpson, *et al* (1953) have reported the biosynthesis of vitamin C in germinating mung beans and the changes that occur during germination.

Heller (1927) found that cystine seemed to be the limiting essential amino acid in mung beans. She also found that cooking seemed to aid the nutritional value whereas prolonged cooking was detrimental. Sherman (1929) showed that a diet consisting of mung beans as the sole protein source gave normal weight for white mice but noticed that there was subnormal reproduction.

Basu, et al (1936) have reported the biological value of green gram (Phaseolus mungo) at 5, 11 and 15 percent protein levels as 63, 52 and 45 percent respectively. They found that the biological value decreased with an increase in the concentration of protein in the diet. They also reported the protein efficiency ratio of green gram (Phaseolus mungo) to be 1.23 at 15 percent protein level in the diet and 1.16 at 10 percent protein level after 8 weeks of feeding. Esh and Som (1952) reported that methionine supplementation and heat processing at 15 pounds pressure for thirty minutes improved the quality of the protein of Phaseolus radiatus.

Cereal Grains and Sunflower Seeds

There are quite a few references to the nutritive value of cereal grains but many of them cannot be compared because of variations in the composition of basal diets and presence of other deficiency symptoms which might have been due to lack of vitamin and mineral supplements.

Data on the nutritive value of millet, barley, sudan grass and sunflower seeds are scarce. Steenbock, Kent and Cross (1918) reported that barley alone was unable to meet the demands of the growing animal and that its protein was too low for continued growth at normal rate. The National

Research Council Report No. 28 (1933) of the Dominion of Canada stated that barley and corn may be taken as substitute for one another for dairy cattlefeed. Murray (1948) demonstrated that the protein efficiency of peas could be improved by adding corn, wheat or barley at a 5 percent level of protein.

The nutritional values of the cereals may be affected by their environment. Sreenivasan (1942b) reported that dry cultivated rice was less nutritious than wet cultivated transplanted rice. Miller, et al (1950) stated that the nutritional value of wheat protein may be affected by environment due to variation in cystine and methionine content in the protein. Mitchell, Hamilton and Beadles (1952) have shown that the protein content of corn varied by selective breeding, weather conditions, crop and soil management. This makes it quite difficult to compare results from different laboratories. The author found no recorded data on the protein supplements that would improve the biological value of barley, oats, wheat, rye and corn protein.

Willcock and Gowland (1906) reported that zein was unable to maintain growth in young mice. Addition of tryptophane did not make it capable of maintaining growth. Sherman (1918) in his experiment with humans found maize protein deficient in lysine and tryptophane. Maynard, Fronda and Chen (1923) found corn to have a low protein efficiency. Mitchell and Smuts (1932) reported that the first amino acid deficiency of corn protein was in lysine while the second deficiency was in tryptophane. In 1952, Mitchell and Beadles claimed that supplementing lysine and tryptophane would raise the biological value of corn. Kligler and Krehl (1952) found that zein was poorly digested by growing rats and that large amounts of nitrogen were lost in the feces.

Several research workers have reported that the growth promoting value of the protein of rice is comparable, if not superior, to that of corn and wheat. McCollum and Simmonds (1917) demonstrated that protein of rice was comparable to that of wheat and corn. Osborne and Mendel (1918) recognized the superior growth promoting value of protein of rice compared to that of corn. Sure (1946a) demonstrated that whole rice was superior to corn and oats in protein value, and in 1947 he reported that polished rice was superior in growth promoting quality over that of wheat flour. Mitchell (1924b) showed that rice protein had a higher biological value than that of corn and oats.

Sulphur containing amino acids seem to be the limiting factor in rice. Kik (1940) reported that whole and polished rice have a high digestibility and that cystine, methionine, and lysine supplemented the protein of whole rice and polished rice. Tryptophane did not have any effect when added as a supplement to the diet. He also showed that polished rice and brown rice have essentially the same growth value but that brown rice protein was better utilized with a biological value of 72.7 compared to 66.6 for polished rice. (Kik, 1939). Pecora and Hundley (1951) demonstrated that addition of lysine alone did not improve the nutritional value of rice but addition of lysine and threonine produced growth response in white rats three times that obtained with unsupplemented rice diet.

Jones (1948) demonstrated that at the 4.5 percent protein level, protein values of corn, barley, hard and soft wheat showed about the same value but were lower than oats, rye, polished rice and brown rice. At 7.5 percent level, brown rice surpassed all the others in protein value. At 9.5 percent protein level, hard and soft wheat gave practically the same values. He reported that rice was superior to wheat and corn at the protein levels at which they could be compared. Beeson, Lehrer and Woods (1947) reported that wheat germ was a better supplement for Alaska peas than corn germ. Mitchell and Smuts (1932) found that lysine supplemented wheat while cystine did not.

EXPERIMENTAL PROCEDURE

Forty Sprague Dawley male albino rats weighing between 55 and 65 grams were used as experimental animals in this study. The rats were separated into eight groups of five rats each, housed in individual cages and offered diets with approximately ten percent protein and distilled water *ad libitum* for a period of 72 days. During the first 41 days on experiment, control animals received fat extracted dried whole egg as a source of dietary protein. Protein for experimental animals was supplied by mung beans or mung beans supplemented with wheat, corn or rice or by mixtures of these grains. Detailed records of weight change and food intake of individual rats were kept during the first and second diet series. Data for total nitrogen intake and fecal and urinary nitrogen of individual animals were obtained for two ten-day balance periods. The first balance period started on the eighth day and the second balance period on the thirty-first day of the experiment. On the fifty-second day, diets for each group of rats except the group fed the reference diet were changed. These new diets were fed to the rats for twenty one days to determine the supplementary effect of other vegetable sources of protein; namely, millet, barley, sudan grass and sunflower seeds.

Composition and Kjeldahl nitrogen values of experimental diets are given in Table 1. Powdered whole egg which had been fat extracted was the source of protein for the group of control rats (Group R). Animals in Group A received mung beans as the only source of dietary protein for the first 41 days of the study. During this time three groups of rats were fed diets with six percent protein from mung beans and four percent protein from rice (Group B), corn (Group C), and wheat (Group D); two groups were fed diets with six percent protein supplied by mung beans, two percent by rice and two percent by corn (Group E), or wheat (Group F); and Group G was fed a diet with five percent protein supplied by mung beans, two percent by rice, two percent by corn and one percent by wheat.

Mung beans were coarsely ground, placed in aluminum trays in approximately one-fourth inch layers and heated in an autoclave at 15 lbs. pressure for thirty minutes. One-fourth inch layer of coarsely ground corn and wheat and whole grains of polished rice were autoclaved at 15 lbs. pressure for 15 minutes. These materials were vacuum dried in the autoclave for thirty minutes, spread in thin layers on cellophane, air dried at room temperature overnight, and ground. Perishable diet components and prepared rat diets were stored in air tight containers and refrigerated.

Rats were maintained on the diets described above for the two balance periods. During the balance periods the rats were placed in standard metabolic cages. Feces, urine and spilled food were collected every 24-36 hours. Filter paper, previously treated with dilute acid, was placed over the mouth of the cage funnel and an inverted watch glass was used to hold the filter paper in place. This prevented dropping of food and fecal material into urinary collections. Urine was collected in 125 cc. erlenmeyer flasks containing about 25 ml. of dilute hydrochloric acid. Cotton was packed loosely between the mouth of the flask and the funnel stem to prevent any outside contamination. The funnel and watch glass were washed with dilute acid and water. All washings were collected in a 500 cc. erlenmeyer flask. Urine composites were filtered through glass wool, and the filter paper, freed from feces and spilled food, was added to the urine composite before acid digesting. Feces were freed of hair and scattered food with a camel's hair brush and daily fecal collection for individual rats were added to flasks containing twenty percent hydrochloric acid and stored in the refrigerator until digested.

Separate ten-day composites of urine and fecal excretions for individual rats were wet digested with twenty percent hydrochloric acid by weight and made to volume. Suitable aliquots of these digests and weighed quantities of mixed diets were used for nitrogen analyses. Nitrogen was determined by the Keldjhal method.

After the second balance period, rats were kept on the same diets for an additional ten days. For the following three-week period, (second diet series), mung beans and rice supplemented with barley, millet, sudan grass and sunflower seeds which had been oven-heated (15 minutes at 250° F) were used for vegetable protein sources in rat diets. The composition of these diets and the rat feeding pattern are given in Table 2. Four groups of rats were fed diets supplied with six percent protein from mung beans, two percent from rice and two percent from sunflower seeds (Group A), barley (Group B), millet (Group C), and sudan grass (Group D). The other three groups were fed diets with four percent protein supplied by mung beans, two percent by rice, two percent by sunflower seeds, two percent by barley (Group E), millet (Group F), and sudan grass (Group G). Due to the high fat content of sunflower seeds, it was necessary to adjust the amount of fat in the diets (Groups A, E, F, and G) that contained sunflower seeds as part of the protein source (Winton, 1932). The reference diet (Group R) supplied ten percent protein from defatted whole dried egg.

Protein values based on Kjeldahl nitrogen for protein sources are presented in Table 8.

All animals were autopsied at the end of the experiment. The internal organs were examined for gross pathological conditions and any abnormal changes in appearance were recorded.

RESULTS AND DISCUSSION

This discussion is concerned with two experimental phases of the study. The first, and major part of the discussion, deals with growth and nitrogen metabolism responses of the experimental rats to diets containing 10 percent total protein for which mung bean or mung beans supplemented with wheat, corn or rice furnished the only sources of protein. The second part of the discussion covers work which was supplementary in nature and is concerned with growth responses of rats when mung beans were fed in conjunction with rice and other plant proteins, namely, sunflower seeds, millet, barley and sudan grass.

Growth, Protein Intake and Protein Efficiency Ratios of Rats During the First Diet Series

Growth Responses

Figure I shows periodic mean weight changes of the eight groups of rats used in this study and Table 3 presents mean weight gains of these groups of animals for the 41-day experiment.

Rats fed the reference diet, with defatted dried whole egg diet as the protein source, showed rapid gain in weight while those fed mung beans as sole source of protein showed very little change in weight during the forty one days on this diet. The average weight gain of rats fed the reference diet was 188 grams; the average for rats fed mung beans was 21 grams. Mung bean diets supplemented with wheat, corn and rice, alone or in combination, promoted higher growth rates than the unsupplemented mung bean diet. None of the supplemented diets, however, produced growth responses that equaled or approached rat growth responses to the reference diet.

Rats fed diets containing 6 percent protein from mung beans and supplemented with 4 percent wheat protein showed better growth responses than rats fed 6 percent mung bean protein supplemented with 4 percent corn protein or 4 percent rice protein. Rats fed mung and wheat gained an average of 87 grams; those fed mung and corn, 71 grams; those fed mung and rice, 59 grams. These results indicate that among the three grains used for supplementing mung beans, wheat produced the greatest growth response, corn ranked next and rice, the least.

The growth responses of rats fed 6 percent mung beans and 2 percent rice supplemented with either wheat or corn indicate a superiority of wheat over corn for supplementing a mung bean and rice protein mixture. Rats fed mung beans and rice supplemented with 2 percent wheat protein gained an average of 72 grams; those fed mung bean and rice protein supplemented with 2 percent corn protein gained an average of 61 grams. However, neither of these mung bean and rice protein mixtures produced as great a growth response as did the mung bean supplemented with either wheat or corn. Rats on the mung, wheat and rice diet gained 13 grams more than those fed 6 percent mung and 4 percent rice protein but 15 grams less than those fed 6 percent mung and 4 percent wheat protein. Those on mung, corn, and rice diet gained two grams more than those fed 6 percent mung and 4 percent rice protein, but 10 grams less than those on 6 percent mung beans and 4 percent corn protein.

Rats fed a mixture of the four plant proteins showed an average growth response higher than that for any of the supplemented mung bean diets except the diet which contained 6 percent mung bean protein and 4 percent wheat protein. Rats fed this diet gained an average of 74 grams, two grams more than those fed mung, wheat and rice; 3 grams more than those fed mung and corn; 13 grams more than those fed mung, rice and corn; and 15 grams more than those fed mung and rice.

Weight changes of individual rats on each diet (Figures III - X) followed similar patterns. Rats B4 and D1 showed sharp decreases in weight at one or two weighings; however, this may have been due to dehydration since water jars were upset and weight losses were recovered rapidly when water was supplied. An analysis of variance of total weight changes of the five groups of animals used for replications in this experiment and the gains in weight produced by the eight diets fed, indicated that the differences in weight changes due to diets were highly significant (P = .01) while those due to replications were not significant at the five percent level.

Protein Intake

Mean protein intakes and protein efficiency ratios based on the 41-day experiment for the eight groups of rats are also given in Table 3. The mean protein intake was 45 grams for rats fed the egg diet and 19 grams for rats fed the mung bean diet. Protein intakes of rats given supplemented mung bean diets ranged from 26 to 34 grams. Rats fed 6 percent mung bean and 4 percent wheat protein had a mean protein intake of 34 grams; those fed 6 percent mung bean and 4 percent corn protein consumed 30 grams protein and those fed 6 percent mung and 4 percent rice protein consumed 26 grams protein. All diets were fed <u>ad libitum</u>; and since protein was always introduced into experimental diets at a 10 percent level, the protein intakes of these animals are in direct relation to total food intake. Thus, these results may indicate a marked difference in appetite or preference of rats for the various diets fed. Rats offered diets that contained mung beans and wheat consumed considerably more food than did those that received mung beans with corn or rice.

When mung bean diets with 2 percent each of wheat and rice proteins were given to rats, mean protein intake was 31 grams; when rice and corn proteins at these same levels were given, mean protein intake was 27 grams. Protein intake was 29 grams for the group of rats given 5 percent mung bean protein supplemented with 1 percent wheat, 2 percent corn and 2 percent rice protein. Again, rats showed a larger appetite for diets containing wheat than for diets to which no wheat had been added.

It is of interest to note that for diets in which the quantity of mung bean protein was held constant, there is a direct relationship between mean protein intake and weight change in the group of animals studied. When the ratio of mung beans in the diet containing 6 percent mung beans, 2 percent rice and 2 percent corn was altered by replacing one percent of the mung bean protein with wheat protein, the growth response of rats on the diet was relatively greater than those on the 6 percent mung protein. The rats offered diets without added wheat ate only two grams less protein than those which had wheat in their diet mixture; however, there was a 13 gram difference in mean weight gains of these two groups of rats. Differences as large as these cannot be explained on the basis of appetite alone and may indicate the presence of some intrinsic differences in biological responses to these diets that cannot be explained on the basis of total protein or food intake.

Protein Efficiency Responses

The efficiency of proteins for promoting weight gains in animals has been widely used as a means of expressing biological availability or effectiveness of the proteins. The method developed by Osborne and associates (1919) uses the grams gain in weight per grams of protein eaten by young rats to express the comparative nutritive value of different proteins. According to Mitchell (1944), "method of measuring protein quality by an efficiency ratio of growth to protein eaten implies that the protein content of the gains in body weight of growing animals is constant regardless of age or size of animal, quality of protein or rate of growth. To the extent that the gains differ in their content of protein, fat and water, they do not represent equal nutritive effects and hence are not comparable. There is a distinct tendency for more rapid gains in body weight to have the greater content of fat and the smaller content of protein." Limitations for this method are that when the dietary protein is capable of promoting growth only at a very slow rate, the amount of protein eaten per gram of weight gain will approach infinity as the gain approaches zero. Age, weight and possibly sex also influence the ratio. Boas-Fixsen (1934) states that higher values are obtained when the experiment is short and that 60 days duration is the minimum for accuracy. However, this method has proved useful and has been widely used (Cahill, 1945).

Protein efficiency ratios of the animals on this study do not completely parallel weight change and protein intake responses.

For the following diet series, there were direct relations between mean weight gains, total mean protein intakes and mean protein efficiency ratios:

	Weight Gain	Protein Intake	Protein Efficiency
Egg diet	188	45	4.14
Mung, wheat	87	34	2.52
Mung, wheat, rice	72	31	2.32
Mung, rice	59	26	2.21
Mung	21	19	1.14

This same relationship holds true not only for mung diets that were supplemented with wheat or wheat and rice, but also for diets with corn or corn and rice:

Egg diet	188	45	4.14
Mung, corn	71	30	2.34
Mung, corn, rice	61	27	2.23
Mung, rice	59	26	2.21
Mung	21	19	1.14

However, for the diet in which 1 percent wheat protein replaced 1 percent of the mung bean protein, weight change, mean protein intake and mean protein efficiency show three different relationships to corresponding values for other diets (Table 3). Here it will be noted that in the series, mean weight gains of these animals ranked third, mean protein intake fifth, and protein efficiency ratio first.

The efficiency ratio obtained with rats fed 2 percent wheat protein and 2 percent rice protein was 7.9 percent lower than that obtained with rats fed 4 percent wheat protein. Rats fed 2 percent corn and 2 percent rice gave a mean efficiency ratio only 4.7 percent lower than rats fed 4 percent corn. However, as far as growth promoting ratio is concerned, wheat appears to be a better supplement than corn or rice for mung and mung-rice mixtures. The amount or quantity of growth attained for a given amount of protein is higher for the mung-wheat mixture than for the mung-wheat-rice mixture, and the greatest response was obtained with the diet which contained a mixture of the four plant proteins. Thus, in protein efficiency response, this last group of animals more closely approaches those on the reference diet than any other group studied even though food intake was lower.

Weight changes, protein intakes and protein efficiency ratios of individual rats are given in Table 10. The range of individual weight changes of rats fed egg diet was 163 to 210 grams; those fed mung bean diet was 18 to 27 grams. Weight changes of rats on mung and wheat ranged from 67 to 129 grams; those on mung, wheat, corn and rice, 61 to 106 grams; those on mung and corn, 58 to 95 grams; those on mung, wheat, and rice, 61 to 93 grams and those on mung and rice, 58 to 76 grams.

Protein intakes for individual rats ranged from 41 to 49 grams for rats fed egg diet; those fed mung diet, 16 to 21 grams. Protein intakes of rats fed mung diets supplemented with wheat ranged from 27 to 44 grams; corn, 26 to 34 grams; rice, 21 to 31 grams. Animals given rice and corn protein at 2 percent level had protein intakes that ranged from 23 to 34 grams; those fed wheat and rice, 28-39 grams and those fed wheat, corn and rice, 26 to 33 grams.

Protein efficiency ratios ranged from 3.78 to 4.30 for rats on egg diet and .99 to 1.50 for rats on mung diet. Protein efficiency of mung diets supplemented with 4 percent wheat ranged from 2.15 to 2.71; corn, 2.12 to 2.76; rice, 1.78 to 2.42; wheat and rice, 2.15 to 2.71; corn and rice, 1.94 to 2.55; wheat, corn and rice, 2.35 to 2.77.

While there appears to be considerable overlapping of results obtained with the individual rats in the groups of animals used, an analysis of variance of protein efficiency ratios of the five groups of animals used for replications in this experiment and the protein efficiency ratios for the eight diets fed, indicated that the differences in protein efficiency ratios due to diets were highly significant (P = .01); and differences due to replications were not significant at the five percent level.

Nitrogen Metabolism of Experimental Animals

While growth and protein efficiency ratios have been widely used as indices of biological values of various protein, much criticism has been directed toward using this method alone to investigate biological availability of proteins. The suggestion has been made that more useful information concerning availability of proteins might be derived from studies which make use of combinations of two or more methods for determining the biological values of proteins (Mitchell and Block, 1946; Murray, 1948; Howe, 1945). To supplement data on growth promoting quality of the diets fed in this experiment, nitrogen metabolism data were obtained for two ten-day periods, one starting on the eighth day and the other on the thirty-first day of the study.

At the beginning of the experiment, mean weights of the eight groups of animals were similar so that data pertaining to protein intakes and weight changes of rats over the entire experiment were comparable. However, differences in mean weights of animals at the beginning of the nitrogen metabolism periods differed widely. It, therefore, seemed feasible to compare nitrogen metabolism data on the basis of unit weight at the beginning of the balance period as well as on absolute nitrogen metabolism values.

Nitrogen Metabolism During the First Balance Period

Nitrogen intake. Mean nitrogen intakes of rats for the first balance period are shown in Table 4. Rats on the egg diet ingested an average of 1870 mg. nitrogen while those fed the mung bean diet ingested an average of 804 mg. Rats fed mung beans supplemented with other plant proteins had mean nitrogen intakes which ranged from 1126 mg. to 1386 mg. Of the groups of animals fed mung bean protein supplemented with 4 percent wheat, corn or rice protein, rats with the wheat supplement had the highest mean nitrogen intake, rats with the corn supplement ranked second, and those with the rice supplement ranked third. Mean nitrogen intake of the animals on wheat, rice or corn supplements were 1386 mg., 1247 mg. and 1126 mg., respectively. For the diet mixtures which contained 6 percent mung bean protein, 2 percent rice protein and 2 percent wheat or corn protein, results show that the group of rats with the wheat protein had a mean nitrogen intake of 1312 mg. while those fed the corn protein had an average intake of only 1138 mg. nitrogen. Mean nitrogen intake of rats fed the diet which contained 5 percent mung bean, 1 percent wheat, 2 percent corn and 2 percent rice protein, was 1279 mg. This represented a nitrogen intake higher than that of rats fed the mung bean, rice, corn mixture but lower than the mean nitrogen intake of animals fed the mung bean, rice, wheat mixture.

Both nitrogen intakes of rats during the ten-day balance periods and protein intakes of these same rats during the entire 41-day growth study are indicative of total food consumption. Except for one case, the ranks of total food intake of the 8 groups of rats studied are the same for the 41 days and the first balance period as shown below.

Mean Protein Intake

	Determined for First Balance Period	10 days
Egg	11.7	11.0[1]
Mung, wheat	8.7	8.3
Mung, wheat, corn, rice	8.0	7.1
Mung, wheat, rice	8.2	7.6
Mung, corn	7.8	7.3
Mung, corn, rice	7.1	6.6
Mung, rice	7.0	6.3
Mung	5.0	4.6

The group of animals fed the mung and corn mixture ranked fourth in total food intake for the 41 days and fifth for the first 10 day balance; however, there was only a one gram difference in the 41 day mean protein intake of this group of rats and the mean protein intake of the group of rats which ranked fifth in protein intake. Thus these results indicate that relative quantities of food eaten by these 8 groups of rats probably changed little during the course of the experiment.

Mean nitrogen intake of the 8 groups of rats based on the weight of individual animals at the start of the balance period are shown in Table 5. The nitrogen intake per gram

[1]As calculated from total food intake for 41 days.

of starting weight for rats fed the egg diet was 21.0 mg. while that for rats fed mung beans as the only source of protein was 12.2 mg. Although absolute nitrogen intakes varied of the three groups of rats fed diets which contained wheat, the mean nitrogen intake per gram starting weight approximated 18.0 mg. for all three groups of rats. Similarly, mean total nitrogen intakes for rat groups fed mung and rice and those fed mung and corn were different; but for both these groups of rats the mean nitrogen intake per gram of starting weight was 16.0 mg. Rats on a 2 percent corn and 2 percent rice protein supplement ingested 16.8 mg. of nitrogen per gram of starting weight.

Nitrogen absorption and apparent digestibility of ingested food. Ten day nitrogen intake and fecal nitrogen values for individual rats were used to calculate total nitrogen absorbed and to estimate apparent digestibility of diets consumed. The mean nitrogen absorbed and apparent digestibilities of the rats on the reference and seven experimental diets are given in Tables 4 and 5 respectively.

Rats fed the egg diet absorbed 1585 mg. nitrogen while those on the mung diet absorbed 609 mg. Mean nitrogen absorption values for the groups of rats that were fed mung beans supplemented with wheat ranged from 969 to 1080 mg. These values were higher than the mean nitrogen absorptions for groups of animals that were fed corn or rice or a mixture of these two grains. Absorption values for rats fed mung beans supplemented with corn or rice or a mixture of these two grains ranged from 814 to 934 mg.

The apparent digestibility (Lingaiah, 1952) of diets for individual rats was estimated as percent of ingested nitrogen absorbed by the intestinal tract. True digestibility was not obtained since the validity of assuming constant endogenous excretion values is questionable (Kelley, 1952). The mean apparent digestibility of the reference diet was 86.9 percent. This figure is comparable to that obtained by Lingaiah (1952) who reported the apparent digestibility of whole egg to be 85.0 percent. The apparent digestibility of mung beans was found to be 77.5 percent. True digestibility as reported by Basu (1936) was 86 percent for Phaseolus mungo. Apparent digestibilities of the supplemented mung diets ranged from 73.7 percent to 78.0 percent. Only the mung bean diets supplemented with 4 percent wheat protein or 4 percent rice protein had apparent digestibilities as high as that of the unsupplemented mung bean diet. These two diets both had an apparent digestibility of 78.0 percent. The apparent digestibility of the protein mixture containing 6 percent mung bean protein, 2 percent wheat protein and 2 percent rice protein was only 73.7 percent, while the apparent digestibility of the mixture of all four vegetable proteins was 76.4 percent. These results indicate that while replacing part of the mung beans in rat diets with either wheat or rice has little or no effect on the apparent digestibility of the protein mixture; replacing part of the mung bean with a mixture of these two grains appears to lower the apparent digestibility of the protein mixture.

The apparent digestibility of the 6 percent mung bean and 4 percent corn protein mixture was 74.8 percent. Thus while a mixture of wheat, rice and mung beans is apparently less digested than mixtures of either wheat or rice with mung beans, a mixture of corn, rice and mung beans is more digestible than a mixture of corn and mung beans alone but less digestible than a mixture of rice and mung beans.

When the four plant proteins were combined in a single experimental diet, the resulting apparent digestibility was 76.4 percent. This value is similar to the apparent digestibility value of a mung, corn, rice mixture (76.3) but higher than that of a mung, wheat, rice mixture (73.7).

Relative protein absorption of rats fed mung bean and supplemented mung bean diets were calculated using egg diet as the reference standard. The relative absorption values of rats on the diets used are presented in Table 7. Relative absorptions of rats fed the mung bean diet was 89.2 percent; rats fed mung and rice and those fed mung and wheat diets both gave relative absorptions of 89.7 percent; those fed mung and corn, 86.1 percent. The mung, corn, rice diet and mung, wheat, corn and rice mixtures gave relative absorptions of 87.9 percent and mung, wheat, rice mixtures gave relative absorption values of 84.8 percent. These values are in the range of the 86 percent true digestibility of mung beans reported by Basu (1936).

Fecal nitrogen per gram of food eaten for both the mung bean diet and the mung and wheat diet was 3.63 mg. (Table 5). Although the apparent digestibility of the mung-rice diet was the same as the mung bean and mung and wheat diets, fecal nitrogen per gram of food eaten was only 3.36 mg. for the group of rats fed mung and rice. Rats fed the mung, rice, and wheat diet excreted 4.20 mg. fecal nitrogen, the highest value of the mung bean and mung supplemented diets and its apparent digestibility, 73.7 percent was the lowest of the mung bean and mung supplemented diets. Although fecal nitrogen for mung, rice, corn fed rats differed from those fed mung, rice, wheat and corn, the apparent digestibilities of the diets were approximately the same.

Nitrogen retention. Table 4 presents mean nitrogen retentions of the eight groups of rats studied based on total nitrogen retention of individual rats and Table 5 presents mean nitrogen retentions expressed as nitrogen retained per gram starting weight.

When mean nitrogen retention values were based on total nitrogen retentions of individual rats, the group of rats fed the reference diet showed the highest mean nitrogen retention and those fed unsupplemented mung beans the lowest. Rats fed diets which contained wheat averaged higher in nitrogen retention than rats fed mung beans supplemented with either rice or corn or with a mixture of rice and corn. Rats fed mung beans and rice showed a lower mean nitrogen retention than those fed a mung bean and corn mixture.

The mean nitrogen retention for rats fed the egg diet was 1204 mg. For those fed mung beans as the only source of dietary protein, the mean nitrogen retention was only 327 mg. Rats fed 6 percent mung and 4 percent wheat protein retained an average of 679 mg. nitrogen while those fed 6 percent mung and 4 percent corn protein retained only an average of 560 mg. nitrogen.

While animals fed rice as the only supplement for mung beans retained an average of 486 mg. nitrogen, those on a rice and corn supplement retained an average of 570 mg. nitrogen and those on wheat and rice supplement retained an average of 581 mg. nitrogen, the group of animals fed a mixture of the four plant proteins retained an average of 672 mg. of nitrogen.

When total nitrogen retentions of the seven groups of animals on experimental rations were compared to the egg diet (Table 7), relative retention of rats fed mung bean diet was the lowest (63.3 percent) and rats fed the mung, wheat, corn and rice mixture gave the highest relative retention (79.8 percent). Relative retention of rats fed mung and wheat was 75.9 percent; for those fed mung and corn relative retention was 69.6 percent and for those fed mung and rice the relative retention was 66.7 percent. Animals which received a mixture of mung, wheat and rice gave a relative retention of 68.6 percent. Rats fed mung, corn and rice gave a relative retention of 77.7 percent, which is higher than the value obtained for rats fed mung and wheat.

When these results are expressed as milligrams nitrogen retained per gram of starting weight (Table 5), the egg diet still gives the highest mean nitrogen retention, the mung and rice mixture is still the seventh in order, and mung beans fed alone ranks the lowest.

For other diets calculated this way, the mixture of the four plant proteins ranks second or next to the egg diet, the mung and wheat mixture third, the mung, rice and corn mixture fourth, the mung, wheat, rice mixture fifth, and the mung, corn mixture sixth.

Nitrogen retained per gram starting weight for rats given the egg diet was 13.2 mg. and for those given the mung bean diet, 5.2 mg. Nitrogen retentions per gram of starting weight for rats fed on the mung bean supplemented diets ranged from 6.8 to 9.4 mg. Animals on mung bean diet supplemented with 4 percent wheat protein retained 8.6 mg. per gram of starting weight; those fed corn, 7.2 mg. and those fed rice, 6.8 mg. This indicates that rats which received the diet containing wheat were able to retain a larger quantity of nitrogen than rats which received either rice or corn as the only supplement for mung beans. Animals fed mung, rice and corn retained 8.4 mg. nitrogen per gram of starting weight; this was 1.2 mg. more than the retention of rats fed a combination of mung and corn. On the other hand rats fed mung, rice and wheat retained an average of 0.6 mg. nitrogen per gram starting weight less than those fed only mung and wheat. The group of experimental rats which received a combination of the four plant proteins retained an average of 9.4 mg. nitrogen per gram of starting weight. This represents the highest mean nitrogen retention for animals on the experimental diets.

When nitrogen retention values are expressed as percent of total ingested nitrogen retained, the egg diet ranks the highest and the mung bean diet the lowest, with mean percentage values of 64.2 percent and 40.6 percent respectively. The mixture of mung beans, wheat, rice and corn ranked next to the egg diet with an average of 51.2 percent nitrogen retention. The mung, rice, corn mixture was third in order with mean retention of 49.8 percent and the mung, wheat mixture ranked fourth with a retention value of 48.7 percent. The mung, corn diet ranked fifth with 44.6 percent retention and mung, wheat, rice, sixth with a retention value of 44.0

percent. The mung, rice mixture ranked second to the lowest with a retention value of 42.8 percent.

Rats on the egg diet showed the highest average percent of absorbed nitrogen retained and those on the mung diet the lowest. Mean absorbed nitrogen retained was 73.8 percent for rats on the egg diet and 52.4 percent for the mung bean diet. Rats fed mung and wheat protein retained 62.4 percent; those fed mung and corn, 59.7 percent and those fed mung and rice, 54.9 percent absorbed nitrogen. A mixture of rice and corn again gave a higher percent retention than one of mung and corn. Percent retention for rats fed mung, rice and corn was 65.3 percent as compared to 59.7 percent for those fed only mung and corn. The mean absorbed nitrogen retained by rats fed mung, wheat and rice was 59.8 percent; this value is lower than the retention value of rats on the mung and wheat mixture. Of the seven groups of rats fed mung beans and supplemented mung bean diets, the rats that were fed a mixture of four plant proteins ranked highest in mean absorbed nitrogen retained. The animals on this diet retained an average of 66.8 percent absorbed nitrogen.

Protein efficiency. In this ten-day balance period, the protein efficiency of egg diet was 5.02 and that of the mung diet, 1.18. Mung and rice as well as mung, wheat and rice diets had protein efficiency ratios of 3.04; that of mung and wheat, 3.07; and that of mung, wheat, corn and rice, 3.58.

This was the highest of the supplemented mung diets. Mung and corn diet had a protein efficiency of 2.78 and that of mung, corn and rice, 2.83. However, this efficiency ratio was obtained only for a period of 10 days so that it is not as accurate as the ratio obtained over a longer period of time.

Summary of results for first balance period. From the results obtained from the first balance period, it is apparent that animals on the egg diet and those on the mung diet presented two extremes. Rats fed the egg diet had high nitrogen intake and high retention values, and those on the mung diet had low nitrogen intake, and retention values. In the case of the mung supplemented diets, nitrogen intakes and retentions were greater than those on the mung bean diet but none of them approached the values obtained from the rats on the egg diet. Although the apparent digestibility of the mung bean diet was higher than some of the supplemented mung diets, it is obvious that the protein of the mung beans was not as well utilized as was the mung bean supplemented with wheat, corn or rice as shown by the percentage of retained nitrogen that was absorbed and the relative retention data. Absorption value was relatively high for rats fed the mung diet but relative retention value was low. Of the mung supplemented diets, that at the 4 percent level of grain supplementation, mung and wheat proteins were best utilized as determined from the percent of absorbed nitrogen retained; mung and corn, next, and mung and rice, the least. With mung-rice mixtures, the mung-rice-corn mixture was better utilized than the mung-rice-wheat mixture. However, the mung-rice-corn wheat mixture was the best of the mung bean supplemented diets. There is a possibility that amino acid imbalance may be a factor for the non-utilization of the protein in mung beans.

Nitrogen Metabolism During the Second Balance Period

It will be noted that the first balance period was carried at the start of the growth study and the second balance period was carried towards the end of the study. It is said that protein efficiency decreases as the experimental period lengthens and that the need for protein in the growing rat is not the same as the needs of the more mature rat. This second balance period was carried for the purpose of supplementing results obtained from the first balance period and to determine differences in nitrogen metabolism for the two balance periods.

Nitrogen intake. Table 4 presents mean nitrogen intakes for the second balance period. The average amount of nitrogen ingested during this balance period was greater than the amount ingested during the first balance period for all groups of rats except the group that was fed mung beans and the group that received mung and rice. Rats on the egg diet ingested an average of 2035 mg. nitrogen while those fed mung bean diet had a mean nitrogen intake of 764 mg. Groups of animals given supplemented mung bean diets had mean nitrogen intakes that ranged from 1126 mg. to 1435 mg.

Although the total nitrogen intake varied for each of these groups of rats, the mean nitrogen intake per gram of starting weight was approximately 10 mg. for five groups of rats, namely, the egg diet (9.8 mg.), the mung bean diet (10.0 mg.), the mung, rice diet (10.1 mg.), the mung, rice, wheat, corn diet (10.1 mg.), and the mung, corn diet (10.2 mg.). Rats on mung, rice and corn ingested 10.5 mg. of nitrogen per gram starting weight; those on mung, wheat diet ingested an average of 11.0 mg.; and those on the mung, rice, wheat diets had a mean intake of 11.6 mg. of nitrogen per gram of starting weight. A comparison of average daily protein intake of rats during the first and second balance periods and during the 41-day growth study indicates little difference in total protein or food intake of these animals (Table 3). However, when results were expressed as milligrams nitrogen eaten per gram starting weight, differences in relative quantities of nitrogen consumed were relatively large for all diets except the mung bean diet. During the second balance period, rats on the egg diet consumed 11.2 mg. less nitrogen per gram of starting weight than during the first balance period. The comparable difference for the mung bean diet was only 2.2 mg. For the other experimental diets these differences ranged from 5.8 to 7.9 mg. per gram starting weight. These differences are related to weight changes of rats; so with these results it appears that the type of available protein in rat diets exercised a greater control over total food intake of these experimental animals than did the size or total weight of the animals.

<u>Nitrogen absorption and apparent digestibility of food studied</u>. Mean absorption values are given in Table 4. Of the eight groups of rats studied, again, those fed egg diet absorbed the most nitrogen (1790 mg.) while those on the mung bean diet absorbed the least amount of nitrogen (553 mg.). Rats fed diets supplemented with 4 or 2 percent wheat protein had mean absorption values of 1048 and 1126 mg. nitrogen respectively. These were higher than the mean nitrogen absorption for groups of animals that were fed corn or rice, or a mixture of these two grains. Mean absorption values for rats fed mung beans supplemented with corn or rice or a mixture of grains ranged from 813 to 992 mg. Rats fed 5 percent mung beans, 1 percent wheat, 2 percent rice and 2 percent corn proteins had a mean absorption value of 983 mg. nitrogen.

The apparent digestibility of egg diet was 88.0 percent and that of the mung diet was 72.5 percent (Table 6). Apparent digestibility of mung and 4 percent wheat protein was 78.4 and that of mung and 4 percent rice was 76.9 percent. However, with mung, wheat and rice protein at the 2 percent level, apparent digestibility was 74.9 percent which is less than diets supplemented with 4 percent wheat or rice. Apparent digestibility of mung and corn diet was 73.9 percent while that of mung, corn and rice was 70.5 percent. The diet with a mixture of four plant proteins had an apparent digestibility of 76.0 percent. The apparent digestibility values for the egg, the mung and wheat, and the mung, wheat and rice diets showed an increase over the values for the first balance period while values for the other diets decreased.

It is also noted that for diets showing a decreased digestibility for the second balance period, there is an increase in the quantity of nitrogen excreted per gram food ingested; while for diets showing increased digestibility, there is a decrease in nitrogen excreted per gram food eaten.

Mean relative absorption values are given in Table 7. There was a decrease in relative absorption for all groups of rats except the group fed mung, rice and wheat wherein there was a slight increase over that of the first balance period. Relative absorption for rats fed mung beans was 82.3 percent. Those fed supplemented mung bean diets are, in descending order, as follows: mung and wheat, 89.1 percent; mung and rice, 87.3 percent; mung, rice, corn and wheat, 86.3 percent; mung, rice and wheat, 85.0 percent; mung and corn, 83.9 percent; mung, rice and corn, 80.0 percent.

The range of values for results relating to digestibility and relative absorption of experimental diets for the two balance periods are relatively small. A comparison of the results obtained for the two balance periods show certain inconsistencies. These two factors make it difficult to point to specific differences in the digestibility of the diets fed. However, the proteins of the mung, corn diet and the mung, rice, corn diet appear to be less completely digested than those of the other five experimental diets. The diet which contained mung and wheat was, apparently, the most completely digested of the supplemented mung diets.

For the second balance period, fecal nitrogen of rats fed egg diet was 1.87 mg. per gram of food eaten (Table 6). Those on the mung, rice and corn diet had a fecal excretion of 4.48 mg. per gram food eaten. The indirect relationship between apparent digestibility and fecal nitrogen values is shown below:

	Apparent Digestibility %	Mg. Fecal Nitrogen per gm. Food Eaten
Egg	88.0	1.87
Mung, wheat	78.4	3.60
Mung, rice	76.9	3.72
Mung, rice, corn, wheat	76.0	3.82
Mung, rice, wheat	74.9	4.12
Mung, corn	73.9	4.44
Mung, rice	72.5	4.48
Mung, rice, corn	70.5	4.62

Nitrogen retention. The mean absolute nitrogen retention values (Table 4) for rats on the egg diet was 1343 mg. while those on the mung diet was 234 mg. Rats on mung and

4 percent wheat protein retained an average of 652.3 mg. nitrogen; those on mung and corn, 628 mg., and those on mung and rice, 453 mg. The mean nitrogen retention values for rats on mung, wheat and rice was 574 mg. and for those on mung, corn and rice 415 mg. These values obtained from rats on the mung-rice mixtures were lower than the values obtained from rats on mung and 4 percent wheat, corn or rice protein. Rats given a mixture of the four proteins retained 634 mg. nitrogen, the highest value obtained among the groups of animals fed supplemented mung diets except for the group fed mung and 4 percent wheat.

When these results are expressed as milligrams nitrogen retained per gram of starting weight (Table 6), the egg diet still gives the highest mean nitrogen retention, and the mung beans fed alone ranks the lowest. However, for the supplemented mung diets the order did not remain the same. For the first balance period the rank was the same for mean nitrogen intakes expressed in these two ways.

Average nitrogen retained per gram starting weight for rats on the egg diet was 6.5 mg. and for those on the mung bean diet, 3.1 mg. The average number of milligrams of nitrogen retained per gram starting weight for rats given supplemented mung diets are as follows: mung, corn, 5.4; mung, rice, corn, wheat, 5.2; mung, wheat, 5.0; mung, rice, wheat, 4.7; mung, rice, 4.2; mung, rice, corn, 3.8.

The average percent nitrogen retained (Table 6) by rats during the second balance period was lower than that of the first balance period for all the groups fed mung beans and supplemented mung bean diets except for the group that received mung and 4 percent corn protein. Rats given the egg diet retained 65.8 percent of ingested nitrogen and those on the mung diet retained 30.0 percent. Percentage retention for rats fed mung and rice was 39.8; those fed mung and wheat, 44.7; and those fed mung and corn, 46.8. Rats fed mung, corn and rice retained 35.9 percent of the nitrogen they ingested; those fed mung, wheat, and rice, retained 41.0 percent. Results indicate that percentage retention is greater for diets in which grains supplement mung beans than for a diet in which mung beans furnishes the only source of protein. The percent ingested nitrogen appears to be greatest (47.9) for animals which received a mixture of the three grain supplements with mung beans.

The amount of absorbed nitrogen retained was 74.7 percent for animals on the egg diet and 41.38 percent for rats on the mung diet. Rats on mung and corn diet retained more of the nitrogen they absorbed than any of the other groups fed the mung supplemented diets. The percent of absorbed nitrogen retained for this group was 63.3 percent; for those on mung and wheat, 56.8 percent, and for those on mung and rice, 51.7 percent. In the case of mung-rice mixtures, rats fed mung, wheat and rice retained 54.7 percent of absorbed nitrogen and those fed mung, corn and rice retained 51.2 percent. These are lower than the percentage of absorbed nitrogen retained by rats on either mung and corn or mung and wheat. The percentage absorbed nitrogen retained by rats fed the four protein mixture was 62.7 percent.

Relative retention values are given in Table 7. For the second balance period, there was a decrease in the relative retention in all groups of rats except the group of rats fed mung and corn wherein there was an increase of about 1.5 percent relative nitrogen retention over the first balance period. Rats fed mung showed a relative retention of 45.6 percent. Those fed supplemented mung diets were as follows: mung, rice, corn and wheat, 72.8 percent; mung and corn, 71.1 percent; mung and wheat, 68.9 percent; mung, rice and wheat, 62.2 percent; mung and rice, 60.5 percent; mung, rice and corn, 54.6 percent.

Protein efficiency. Protein efficiency ratios (Table 6) for the second balance period were lower than that of the first balance period. The protein efficiency of egg was 3.37 and that of mung bean diet, 1.08. Protein efficiency ratios of supplemented mung diets ranged from 1.47 to 2.22. They were 2.18 for mung beans supplemented with 4 percent wheat; 2.11 for the diet containing 4 percent corn; 1.47 for the diet containing 4 percent rice. Mung, wheat and rice mixture had a protein efficiency of 2.08 while mung, corn, rice mixture had an efficiency ratio of 2.02. A mixture of the four proteins had the highest protein efficiency, 2.22. Barnes (1946) states that the fraction of protein utilized for growth rises to a maximum and then declines thus resulting in a fall in the biological value. The decrease in the protein efficiency in the second balance period may have been due to the fact that the animals were more mature. The order or rank of the diets according to protein efficiency in this second balance period is approximately the same as the rank of the diets for the first balance period and is the same for the 41 days growth study.

Summary of results for second balance period. Values for nitrogen metabolism in the second balance period were generally lower than those obtained in the first balance period except for a few cases wherein there were slight increases.

Diets ranked according to apparent digestibility showed egg diet to be the highest, followed by the mung, wheat diet. The mung, rice diet ranked third and the mung, rice, corn, wheat diet ranked fourth in the series. Mung, rice, wheat diet ranked fifth; mung, corn, sixth; the mung bean diet, seventh; and mung, rice, corn diet, last. However, if experimental diets were ranked according to the percent of absorbed nitrogen retained, there is a difference in the order of rank among the mung bean and supplemented mung bean diets. The diets compare according to rank for percent absorbed nitrogen retained as follows and the rank according to digestibility is shown in parenthesis:

1. Egg (1)
2. Mung, corn (8)
3. Mung, wheat, corn, rice (4)
4. Mung, wheat (2)
5. Mung, wheat, rice (5)
6. Mung, rice (3)
7. Mung, rice, corn (6)
8. Mung (7)

When these diets are ranked according to protein efficiency ratios, egg and mung bean diets retain their ranks as first and last in the order. This time, mung, wheat, corn and rice diet rank next to egg, mung and wheat diet, third; mung, corn, fourth; mung, wheat and rice, fifth; mung, corn and rice, sixth; and mung, rice, seventh.

There is some agreement in the ranking of the diets according to apparent digestibilities, percent absorbed nitrogen retained and protein efficiency ratios in that the egg diet always ranked first and mung beans ranked the second to the lowest or the lowest for these three types of protein evaluation. It also appears that wheat-containing diets tended to rank higher than diets with rice or corn alone or mixtures containing rice and corn. According to Mitchell (1944), "nitrogen metabolism studies directly determines the storage of protein in growth rather than assumes that this storage is proportional to body weight gains and can detect differences in digestibility and biological value of proteins of a magnitude of 2 or 3 percentage units." Thus changes in body weights of animals fed different protein mixtures may not parallel relative quantities of protein digested or of nitrogen retained in the animal tissue.

Statistical Analysis

An analysis of variance of the percentage of absorbed nitrogen retained for both the first and second balance periods for the five groups of animals used for replications and the differences in percent of nitrogen retained produced by the eight diets fed, indicated that the differences in nitrogen retained due to diets were highly significant ($P = .01$) while those due to replications were not significant at the 5 percent level.

Analysis of variance of the apparent digestibility of the first balance period for the five groups of animals used for replications and the apparent digestibility produced by the eight diets fed, indicated that the differences in apparent digestibility was highly significant ($P = .01$) while those due to replications was significant at the five percent level. In the second balance period, however, differences in apparent digestibility due to replications was not significant at the 5 percent level.

Apparent Nitrogen Added to Tissues

Another suggested method for evaluating protein availability, is to determine actual increases in nitrogen stores of animal tissues. McCollum and Shukers (Cahill, 1945) suggested a method which involves the determination of amino acid in the animal tissues. However, since animals were not sacrificed at the end of the first growth study, this method of assessing nitrogen uptake of body tissues could not be used. Metabolism data obtained in this study, have been used to estimate relative increases in nitrogen stores of animal tissues. Various factors such as method of feeding (<u>ad libitum</u> versus paired feeding) non-determination of endogenous excretions, experimental errors, and protein factor may influence these values. However, some of the differences observed vary widely enough to appear to give these results some significance.

First Balance Period

Table 5 presents nitrogen intake per gram of weight change. Rats fed defatted whole egg diet had a nitrogen intake of 32.4 mg. for each gram of weight change while rats fed the mung bean diet ingested 139.0 mg. of nitrogen in order to gain a gram of weight. When the rats were sacrificed, layers of fat were noticed around the kidneys and intestines of the rats fed on egg while those on mung beans did not have as much fat as those fed the reference diet. Nitrogen intake of rats fed mung and rice diet and mung wheat and rice was 53.0 mg. Mung beans and corn-fed rats ingested 60.6 mg. of nitrogen per gram of added weight. There was a very slight difference observed in the nitrogen intake of rats fed mung beans and wheat over the nitrogen intake of rats fed mung and rice and mung, wheat and rice diets. The rats fed mung and wheat ingested 52.6 mg. nitrogen for each gram of added weight. Rats fed mung, corn and rice ingested 57.8 mg. nitrogen. This was less than the amount ingested by rats fed mung and 4 percent corn protein but more than the amount ingested by rats that were fed mung and rice diet. Of the groups of rats fed mung bean and mung bean supplemented diets, those that were fed 5 percent mung bean protein, 1 percent wheat, 2 percent corn, and 2 percent rice protein ingested the least amount of nitrogen per gram of weight gain (46.0 mg.).

Rats on the egg diet apparently retained an average of 20.8 mg. of nitrogen per gram of weight change or added 2.08 percent of nitrogen to their tissues and body fluids while those fed mung beans added 5.60 percent nitrogen to tissues and body fluids and retained 56.0 mg. of nitrogen for each gram of added weight. Animals fed mung and 4 percent corn protein retained 26.4 mg. nitrogen per gram of weight change; those fed 4 percent wheat protein, 25,8 mg. and those fed 4 percent rice protein, 22.4 mg. nitrogen. While animals fed rice and corn supplement retained 28.2 mg. nitrogen per gram of weight change, those fed rice and wheat supplement retained 23.6 mg. nitrogen. Rats fed a mixture of 4 proteins retained 23.0 mg. nitrogen.

Nitrogen intake and nitrogen retention per gram of weight gain of rats fed mung bean diets was the highest of the experimental diets. It would seem that the protein of mung beans was not well utilized because in spite of high relative nitrogen intakes and retentions, weight gain was very low compared to the other groups. Very low weight gains can not be due to lack of dietary minerals or vitamins because the diets were adequate in these nutrients. If the protein was being metabolized for energy, there would be an expected increase in urinary nitrogen. Such is not the case with the rats fed the mung bean diet. Kelley (1952) found that 150 gram rats fed Michelete pea bean needed 83.1 mg. of nitrogen for maintaining nitrogen equilibrium while those on the egg diet needed only 37.3 mg. of nitrogen. Arnrich (1951) suggested that part of the nitrogen is probably retained in the non-tissue components of the animal.

The physiological reason for the failure of these relatively high nitrogen retentions to produce growth in animals receiving poor quality protein has not, as far as the author ascertained, been investigated. However, it might be speculated that here a deficiency of methionine is related to an inability or decreased ability of animals to convert ingested food to body fat.

Second Balance Period

Nitrogen intake per gram of weight gain (Table 6) increased considerably for all groups of rats over that of the first balance period. Rats fed egg diet ingested 48 mg. of nitrogen to gain a gram of weight while rats fed mung beans ingested 163.2 mg. to gain one gram. Rats that were on mung and 4 percent rice ingested 110.4 mg. of nitrogen; those fed mung and 4 percent wheat, ingested 87.0 mg, and those that were on mung and 4 percent corn protein had a nitrogen intake of 76.8 mg. While rats fed rice and corn supplements ingested 80.4 mg. of nitrogen, 30 mg. less than those fed mung and rice, rats fed rice and wheat supplements ingested 79.8 mg. These amounts are approximately the same. Rats that were fed a combination of four proteins ingested 81.2 mg. nitrogen. The increased intake per gram of weight gain may in part be attributed to the greater need for maintenance of the rats since these animals were more mature.

Although there was an increase in nitrogen intake per gram of weight gain, the percent of nitrogen added to the tissue and the amount of nitrogen retained per gram of weight change decreased in the case of rats fed mung bean diet.

However, nitrogen retained per gram weight change for all the rats fed supplemented mung bean diets as well as those fed the egg diet increased during the second balance period.

Growth Responses and Protein Efficiency During the Second Diet Series

Other plant sources of protein were given to the experimental groups of rats during the last twenty one days of the whole study. This was done to supplement the first diet series. For this diet series a mixture of 6 percent mung and 2 percent rice protein was supplemented with 2 percent protein from millet, barley, sudan grass or sunflower seeds for four diets in the series. For the other three diets a mixture of 4 percent mung, 2 percent rice, and 2 percent sunflower seed protein was supplemented with 2 percent protein from millet, barley or sudan grass.

Growth Responses

A comparison of mean growth responses of rats during the second diet series is shown in Figure II. Figures III to X present the growth responses of individual rats. Table 3 shows the mean weight gains and Table 11 gives the individual weight changes. Rats fed mung, rice and millet gained more weight than those in the reference diet during the 51st to the 57th day of the study. Rats fed mung, rice and millet gained more weight than those in the reference diet but later, the group of rats fed mung, rice, millet and sunflower seeds showed greater weight gains than those fed mung, rice and sunflower seeds. Rats fed mung, rice and sudan grass gave a negative response at the beginning of the second study but they gradually gained weight although weight gain was not comparable to the other groups. Rats on the mung bean, rice and millet diet showed the best growth response among the groups of rats that were fed diets that did not contain sunflower seeds. Addition of sunflower seeds to the diets promoted better growth in all groups.

Rats on the egg diet gained 65 grams. Animals that were receiving 6 percent mung bean protein, 2 percent rice and 2 percent sunflower seed protein gained 36 grams; those receiving 6 percent mung, 2 percent rice and 2 percent millet proteins, gained 34 grams; those on 6 percent mung, 2 percent rice, and 2 percent barley gained 24 grams and those fed 6 percent mung, 2 percent rice and 2 percent sudan grass gained only 3 grams. These results indicate that rats on the diet containing sunflower seed gave the best growth response among the groups that were fed mung-rice mixtures that were supplemented with other plant sources of protein. Of the three grains, millet, barley and sudan grass, millet gave growth responses closest to that of sunflower supplemented mung-rice diet, barley ranked next and sudan grass last.

The millet, barley and sudan grass diets mentioned in the preceeding paragraph contained 6 percent mung beans. When 2 percent of the mung bean protein was replaced by sunflower seeds, in the diets, rats fed mung, rice, millet and sunflower seeds gained 46 grams; those fed mung, rice, barley and sunflower seeds gained 38 grams and those fed mung, rice, sudan grass and sunflower seeds, 25 grams. Results show that sunflower seeds with millet or barley gave growth responses better than those fed mung, rice and sunflower seeds. The growth response of rats that received mung, rice, sudan grass and sunflower seed diet was better than the growth response of the rats that were fed mung, rice and barley. An analysis of variance of the weight changes of the five groups of animals used for replications in the second diet series and the gains in weight produced by the eight diets fed, indicated that the differences in weight changes due to diets were highly significant ($P = .01$) while those due to replications were not significant at the five percent level.

Protein Intake and Protein Efficiency

Mean protein intakes and protein efficiency ratios for these diets are given in Table 3. Mean protein intake of rats on the egg diet was 28 grams. Rats fed mung, rice, millet and sunflower seeds had a protein intake of 24 grams;

those on mung, rice, barley and sunflower seeds, 22 grams; and those on mung, rice, sudan grass and sunflower seeds, 20 grams. When only a mixture of three proteins were given to the rats, protein intake was lower than when a mixture of four proteins were fed. Rats on mung, rice and millet ingested 20 grams of protein; those on mung, rice and sunflower seeds ingested 18 grams; those on mung, rice and barley, 16 grams and those on mung, rice, and sudan grass, 14 grams. From these results, it is noted that rats which received diets to which sunflower seeds had been added, consumed more food. The mean protein efficiency of the egg diet during this growth experiment was 2.42. The mung, rice and sunflower seed approached this value with a mean protein efficiency ratio of 2.07. Although mean protein intake and mean weight gain of rats on mung, rice, sudan and sunflower seeds were higher than those fed mung, rice and barley, the protein efficiency was lower than that of the mung, rice, barley diet. The protein efficiency of mung, rice, sudan and sunflower seeds was 1.36 while that of mung, rice, barley diet was 1.58.

There were direct relations between mean weight gains, protein intake and protein efficiency in the following diets:

	Weight Gain	Intake	Protein Efficiency
Egg	65	28	2.42
Mung, rice, millet, sunflower	46	24	1.89
Mung, rice, barley, sunflower	38	22	1.70
Mung, rice, millet	34	20	1.68
Mung, rice, barley	24	16	1.58
Mung, rice, sudan	3	14	.23

There is also a direct relationship for diets in which part of the mung protein was substituted by sunflower seed.

	Weight Gain	Intake	Protein Efficiency
Mung, rice, millet, sunflower	45	24	1.89
Mung, rice, millet	34	20	1.36
Mung, rice, barley, sunflower	38	22	1.70
Mung, rice, barley	24	16	1.58
Mung, rice, sudan, sunflower	25	20	1.36
Mung, rice, sudan	3	14	.23

It appears from the results as indicated above that sunflower seed provides a protein which supplements that of mung and rice, and mung and rice supplemented with other grains.

It was also noted that the protein efficiency of mung, rice, sunflower seed diet gave the highest protein efficiency of this series of experimental diets.

Evaluation of the Essential Amino Acids in the Experimental Diets

One of the factors that limit the utilization of protein is its amino acid make-up. Mitchell and Block (1946) have suggested correlating the essential amino acids with the growth promoting quality of certain food products. According to the authors, exact amino acid requirements for rat growth are unknown hence a comparison of the proportions of essential amino acids present in a certain food with the proportions existing in the amino acid requirements for rat growth cannot be made. However, whole egg protein has been found to contain an amino acid mixture that is very highly digestible and almost perfectly utilizable so that proteins of certain foods can be compared to whole egg protein.

Deshpande, et al (1955) states that before any attempt to determine the limiting amino acids in diets composed largely of cereals from chemical data is done, there is a need for increased knowledge of the availability of amino acids from proteins. It is significant that analytical data show the order of amino acid deficiency but they have found that this does not come in the same order as results of growth studies.

In this study, the amino acids present in mung beans and supplemented mung bean diets were compared to the recommended quantities of essential amino acid for rat growth as reported by Albanese (1950). Calculations were based on amino acid values taken from Block and Bolling (1951) and the laboratory values available for the mung beans, corn and wheat used in this study.[1]

[1]Unpublished data supplied by Selma L. Bandemer, Agr. Chem., Michigan State University.

Amino Acid Composition of Diets

Table 8 presents the calculated quantities of amino acid and the percent of amino acid present in the diets as compared to the recommended quantity. Of the nine experimental diets for which amino acid content was calculated, the whole egg diet came closest to the recommended quantity in the amounts of amino acids present. It was a little low in tryptophane, phenylalanine, methionine, lysine and histidine. The egg diet almost equaled the reommended quantity in threonine and supplied more than the recommended quantity of leucine, isoleucine and valine.

The mung bean diet was generally the lowest in all essential amino acids except for leucine and valine where there was an excess of 71 percent and 19 percent, respectively over that of the recommended quantity. When part of the mung bean protein was replaced with wheat, corn, rice, sunflower seed, alone or in combination, there was a slight increase in the amount of methionine, threonine and histidine over that of the ten percent mung bean diet. In all of the mung bean supplemented diets, except mung and corn diet, leucine value was lower than the mung bean diet. Lysine content of mung, rice and mung, rice and sunflower seed diets was higher than the lysine content of mung bean diet by 2 percent. Methionine was the amino acid present in the least amounts in all mung bean and supplemented mung bean diets, but of these diets, the mung bean diet contained only 18 percent of methionine compared to that of the recommended quantity. On the other hand, sunflower supplemented diet contained 28 percent of methionine, the highest percentage obtained of the supplemented mung diets. Mung, wheat, rice and corn diet and mung, rice, corn diet contained 24 percent methionine. Mung, corn diet contained 27 percent mung, wheat; mung, rice, wheat and mung, rice diets contained 22, 21 and 20 percent respectively. All of the experimental diets, except the egg diet, were very low in tryptophane, methionine, lysine and histidine and threonine. In evaluating these diets for amino acid content, it should be recalled that the protein level was kept at 10 percent. For this reason, amino acid values of all diets, including the egg diet, may be low when compared with growth standards.

It is almost impossible to bring up the methionine content of mung beans and supplemented mung bean diets without the addition of sunflower seeds. To raise the methionine content of mung bean diet to recommended levels would require about 223 grams of mung beans. It is impossible to include this amount in mixed diets. Methionine content may be increased by the addition of methionine or perhaps by another well-balanced protein.

Mitchell and Block (1946) reported that the extent to which food porteins will supplement each other in a ration improvement of the mung diets when supplemented with these grains. Heller (1927) reported that cystine seemed to be the limiting amino acid in mung beans. Esh and Som (1952) demonstrated that methionine supplementation of mung beans (Phaseolus radiatus) improved the nutritional value of its protein.

No studies have been reported on the supplementary effect of wheat, corn or rice on mung bean protein. A few studies on the nutritive value of mung beans when used as sole source of dietary protein or in conjunction with other lentils have been reported. Basu (1936) reported that as the period of experiment increased from four to eight weeks growth per gram of protein intake of rats on mung bean diets diminished. Basu (1936) reported the biological value of mung beans (Phaseolus mung) to be 63, 52, and 45 at 5, 11, and 15 percent protein level, respectively. Protein efficiency increased from 1.16 to 1.23 as the concentration of the mung bean protein increases from 10 to 15 percent level for a period of eight weeks. In 1952, Esh and Som, reported the true digestibility of mung beans variety, Phaseolus radiatus, to be 90.80 and variety, Phaseolus mung to be 90.67. Biological values obtained were 47 and 64 respectively over a period of twenty one days.

Arnrich, Hunt, Axelrod and Morgan (1951) reported a protein efficiency of 2.4 grams per gram of protein intake improvement of the mung diets when supplemented with these grains. Heller (1927) reported that cystine seemed to be the limiting amino acid in mung beans. Esh and Som (1952) demonstrated that methionine supplementation of mung beans (*Phaseolus radiatus*) improved the nutritional value of its protein.

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Arnrich, Hunt, Axelrod and Morgan (1951) reported a protein efficiency of 2.4 grams per gram of protein intake on diets containing 9.5 to 10 percent protein derived from powdered whole egg. Kelley (1952) found that the average protein efficiency of whole egg for 150 gm. rats on a diet containing 6.8 percent protein was 3.0 grams per gram of protein ingested. In this study, a protein efficiency of 3.37 was obtained for the second balance period and after a period of nine weeks, protein efficiency of whole egg was found to be 2.4 grams per gram of protein intake.

Kik (1940) reported a protein efficiency of 1.80 grams on a diet containing 5.5 percent protein derived solely from rice. Sure (1946b) reported the protein efficiency of polished rice as 1.86 grams at 5.8 percent protein level. In this study, a protein efficiency of 2.21 was obtained with a diet consisting of 6 percent mung bean protein and 4 percent rice protein. In making these comparisons, it is noted that the studies reported were diets whose sole source of protein was rice whereas in this study, rice was used as a supplement to mung bean protein.

Gross Changes in Experimental Animals

All the rats appeared normal until about the end of the second week on experiment. Consumption of food by rats fed mung beans was low. This could not be due to vitamin deficiency because the diet was adequate in vitamins. Poor appetite may have been due to lack of one or more amino acids since amino acid deficiency has been found to produce inanition (Rose and Epstein, 1939).

Rats fed mung beans as sole source of dietary protein were irritable. They failed to shed their baby fur as they grew. At about the third week of the experiment, Rats A3, A5 (mung diet), C3 (mung, corn diet), and G5 (mung, rice, corn, wheat diet) started to lose fur on their hind legs. This loss of hair gradually extended to the front legs and then to the abdomen. Also, about the third week of the study, three rats fed mung and wheat developed a coarse reddish hair toward the tail end of the back. There has been no report found as to the cause of the color change. Gartly , Slinger and Hill (1950) found that when lysine was lacking in the diet of poults, there was irregular pigmentation in the feathers.

On the fourth week, several rats in each group developed a reddish tinge on their back. At the end of the experiment even those on the reference diet had a slight reddish discoloration on their fur. This may be attributed to the heat of the summer months as the temperature and humidity of the room was not regulated, or may be related to the relatively low level of protein feeding.

At the end of the second diet series there was growth of hair and the reddish color of the fur became lighter. Esh and Som (1952) reported that methionine supplementation in rats fed mung beans (Phaseolus radiatus) recovered their loss of fur when 0.6 percent methionine was added to the diet. There was insufficient data on the amino acid composition of some of the grains used in this study to permit estimation of dietary amino acid levels. However, the quantity of those of methionine in these diets may be greater than that in diets where hair loss occurred during the first 50 days on experiment.

Livers of rats fed the mung bean diet were paler than the rats in the other groups. There were no subcutaneous fat pads around the kidneys of rats fed the mung bean diets. Rats A2 (mung diet) and F2 (mung, rice, wheat diet) had mottled livers but were not abscessed.

A detailed record of changes in rats during the experiment are presented in Table 16.

SUMMARY AND CONCLUSION

The nutritive value of mung bean protein and mung bean protein supplemented with grains and sunflower seed was studied by the rat growth and the nitrogen metabolism methods using young male albino rats weighing between 55-65 grams. Essential amino acids present in the diet were calculated and correlated with growth responses. Experimental diets contained approximately ten percent protein.

Protein efficiency ratios of a series of diets fed over a 41-day period were found to be, in decreasing order, as follows: defatted whole egg, 4.14; mung, wheat, corn and rice, 2.56; mung and wheat, 2.52; mung and corn, 2.34; mung, rice and wheat, 2.32; mung, corn and rice, 2.23; mung and rice, 2.21; and mung beans, 1.14.

Ten-day balanced period near the beginning of this experiment indicated the apparent digestibility for whole egg diet as 86.9 percent and for mung bean diet, 77.5 percent. Supplemented mung bean diets had apparent digestibilities that ranged from 74.7 percent to 78.0 percent. A second balance study which was carried toward the end of this diet series showed the apparent digestibility of whole egg to be 88.0 percent and that of mung bean diet, 72.5 percent.

A range of 70.5 percent to 78.4 percent was obtained for the cereal supplemented mung bean diets.

The amount of nitrogen added to the tissues for rats on the egg diet during the first balance period was 20.8 mg. per gram of weight gain and for those on the mung bean diet, 56.0 mg. Nitrogen added to the tissues of rats fed the supplemented mung bean diets ranged from 22.4 to 28.2 mg.

Animals on the egg diet during the second balance period added 31.6 mg. of nitrogen to their tissues per gram of weight gain while those on the mung bean diet added 47.6 mg. nitrogen. Nitrogen added to tissues of rats fed supplemented mung bean diets ranged from 28.8 to 43.7 mg.

Protein efficiency ratios for a period during which animals received millet, sudan grass, barley and sunflower seed as supplements to mung beans and rice follow: defatted whole egg, 2.42; mung, rice and sunflower seed, 2.07; mung, rice, millet and sunflower seed, 1.89; mung, rice, barley and sunflower seed, 1.70; mung, rice and millet, 1.68; mung, rice and barley, 1.58; mung, rice, sunflower seed and sudan grass, 1.36; and mung, rice and sudan grass, 0.23.

When essential amino acids present in mung bean and supplemented mung bean diets were compared to the recommended quantities for rat growth, methionine was found to be the essential amino acid that was present in the least amount. With sources of nitrogen used in these experimental diets, it would be impossible to bring the methicnine content of mung bean diet and supplemented mung bean diets to recommended quantities without using sunflower seed as one of the dietary components.

It was demonstrated in this study that rats on mung bean diet at a ten percent level of protein showed very poor growth responses. Supplementing mung with wheat, corn and rice gave a definite improvement in growth responses. Wheat seemed to be the best supplement, corn ranked next and rice, last. Sunflower seed appeared to be the best supplement among the plant sources used to supplement a mixture of mung beans and rice in the second protein efficiency study.

Although cereals have a definite supplementary effect for mung bean diets, there is a need for determining combinations of inexpensive and available food proteins that would be most effective in furnishing a good quality of protein for people whose food supplies are limited. Since the mung bean is one of the most economical legumes from which dietary protein could be obtained in countries where many people depend largely on vegetable protein rather than on animal protein, it might be well to investigate the extent to which sunflower seed and grain proteins, other than rice, are used or could be used in diets of people.

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APPENDIX

TABLE 1

DIETS FOR THE FIRST DIET SERIES

	Reference	Mung Bean Control	Mung Rice	Mung Corn	Mung Wheat	Mung Rice Corn	Mung Rice Wheat	Mung Rice Corn Wheat
Diet Ingredients per 100 Grams Diet								
Whole Dried Egg [1]	15							
Mung [2]		43	26	26	26	26	26	21
Rice [3]			54			27	27	27
Corn [4]				38		19		19
Wheat [4]					40		20	10
Wesson Salts [5]	4	4	4	4	4	4	4	4
Vit. Sup. [6]	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Corn Oil	10	10	10	10	10	10	10	10
Sucrose	10	10	3.8	10	10	10	10	10
Roughage [7]	2							
Corn Starch	58.8	30.8		9.8	7.8	1.8	.8	
Total Protein [8]	9.0	10.16	9.74	10.18	10.32	10.07	10.08	9.98
Diet Composition - Protein Source Approximately 10 Percent								
Whole Dried Egg	10							
Mung		10	6	6	6	6	6	5
Rice			4			2	2	2
Corn				4		2		2
Wheat					4		2	1

1-Fat extracted in the laboratory.
2-Oklahoma Jumbo type, Johnston Co., Enid, Oklahoma.
3-Obtained from local grocery.
4-Supplied by MSU Farm Crops.
5-Salt mixture W. modification of Osborne and Mendel.
6-Vit. Diet Fortification in Dextrose, Nutritional Biochemicals Co.
7-Alphacel.
8-N x 6.25 - analyzed in laboratory.

TABLE 2

DIETS FOR THE SECOND DIET SERIES

	Reference	Mung Rice Sunflower	Mung Rice Barley	Mung Rice Millet	Mung Rice Sudan Grass	Mung Rice Barley Sunflower	Mung Rice Millet Sunflower	Mung Rice Sudan Grass Sunflower
Diet Ingredients per 100 Grams Diet								
Whole Dried Egg	15							
Mung		26	26	26	26	17	17	17
Rice		27	27	27	27	27	27	27
Sunflower Seed		7				7	7	7
Barley			17			17		
Millet				17			17	
Sudan Grass					17			17
Wesson Salts	4	4	4	4	4	4	4	4
Vit. Sup.	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Sucrose	10	10	10	10	10	10	10	10
Corn Oil	10	7	10	10	10	7	7	7
Roughage	2							
Cornstarch	58.8	16.8	3.8	3.8	3.8	8.8	8.8	8.8
Total Protein[2]	9.74	10.03	9.55	10.25	9.64	9.50	10.23	9.59
Diet Composition - Protein Source Approximately 10 Percent								
Whole Dried Egg	10							
Mung		6	6	6	6	4	4	4
Rice		2	2	2	2	2	2	2
Sunflower Seed		2				2	2	2
Barley			2					
Millet				2			2	
Sudan Grass					2			2

1-Furnished by Farm Crops, MSU.
2-N x 6.25 - analyzed in laboratory.

TABLE 3

MEAN GROWTH RESPONSES AND PROTEIN EFFICIENCY RATIOS OF RATS FED EGG DIET, MUNG BEAN DIET AND MUNG BEAN DIETS SUPPLEMENTED WITH OTHER PLANT SEEDS

First Experimental Period[1]						Second Experimental Period[2]			
Diet Fed[3]	Mean Weight Change	Mean Protein Intake: 41 Days	Mean Protein Intake: First Balance Period	Mean Protein Intake: Second Balance Period	Protein[4] Efficiency Ratio	Diet Fed	Mean Weight Change	Mean Protein Intake	Protein[3] Efficiency Ratio
	gms.	gms.	gms.	gms.			gms.	gms.	
Egg (10)	188	45	12	13	4.14	Egg (10)	65.0	28	2.42
Mung (6) Wheat (4)	87	34	9	9	2.52	Mung (4) Rice (2) Millet (2) Sunflower (2)	46.0	24	1.89
Mung (5) Wheat (1) Corn (2) Rice (2)	74	29	8	8	2.56	Mung (4), rice (2) Barley (2) Sunflower (2)	38.0	22	1.70
Mung (6) Wheat (2) Rice (2)	72	31	8	8	2.32	Mung (6), rice (2) Sunflower (2)	36.0	18	2.07
Mung (6) Corn (4)	71	30	8	8	2.34	Mung (6), rice (2) Millet (2)	34.0	20	1.68
Mung (6) Corn (2) Rice (2)	61	27	7	7	2.23	Mung (4), rice (2) Sudan grass (2) Sunflower (2)	25.0	20	1.36
Mung (6) Rice (4)	59	26	7	7	2.21	Mung (6), rice (2) Barley (2)	24.0	16	1.58
Mung (10)	21	19	5	5	1.14	Mung (6), rice (2) Sudan grass (2)	3.0	14	.23

1-41 days.
2-21 days.

3-Numbers in parentheses represent the approximate percent protein contributed to the diet.
4-Efficiency ratio = gm. weight gain/gm. protein consumed.

TABLE 4

MEAN NITROGEN INTAKES, EXCRETION, ABSORPTION AND RETENTION OF EIGHT GROUPS OF RATS

First Balance Period

	Diet Fed[1]	Nitrogen Intake mg.	Fecal Nitrogen mg.	Urinary Nitrogen mg.	Total Nitrogen Excreted mg.	Nitrogen Absorbed mg.	Nitrogen Retained mg.
R	Egg (10)	1871	245	422	667	1585	1204
A	Mung (10)	804	180	297	477	610	327
B	Mung (6) Rice (4)	1126	249	391	640	814	486
C	Mung (6) Corn (4)	1247	313	374	687	934	560
D	Mung (6) Wheat (4)	1386	307	401	708	1080	679
E	Mung (6) Rice (2) Corn (2)	1138	268	300	567	870	571
F	Mung (6) Rice (2) Wheat (2)	1312	343	387	730	969	581
G	Mung (5) Rice (2) Wheat (1) Corn (2)	1279	297	309	607	982	672

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TABLE 4 (Cont.)

Second Balance Period

	Diet Fed[1]	Nitrogen Intake mg.	Fecal Nitrogen mg.	Urinary Nitrogen mg.	Total Nitrogen Excreted mg.	Nitrogen Absorbed mg.	Nitrogen Retained mg.
R	Egg (10)	2035	244	448	692	1790	1343
A	Mung (10)	764	212	319	530	553	234
B	Mung (6) Rice (4)	1126	257	415	672	868	454
C	Mung (6) Corn (4)	1340	348	365	712	992	628
D	Mung (6) Wheat (4)	1435	309	474	783	1126	652
E	Mung (6) Rice (2) Corn (2)	1145	332	398	730	813	415
F	Mung (6) Rice (2) Wheat (2)	1396	347	471	822	1048	574
G	Mung (5) Rice (2) Wheat (1) Corn (2)	1288	305	349	653	983	634

1-Number in parentheses represents the approximate percent protein contributed to the diet.

TABLE 5

MEAN RELATIONSHIPS OF WEIGHT CHANGES TO NITROGEN INTAKES, ABSORPTIONS AND RETENTIONS

First Balance Period

Rat Group[1]	N Intake Start. Wt.	N Retained Start. Wt.	N Intake Wt. Change	N Retained Wt. Change[2]	Fecal N[3]	Apparent[4] Digestibility	N Retained	Absorbed N Retained	Protein Efficiency
	mg./Gm.	mg./Gm.	mg./Gm.	mg./Gm.	mg./Gm.	%	%	%	
R Egg (10)	21.0	13.4	32.4	20.8	2.02	86.9	64.2	73.8	5.02
A Mung (10)	12.2	5.2	139.0	56.0	3.63	77.5	40.6	52.4	1.18
B Mung (6) Rice (4)	16.0	6.8	53.0	22.4	3.36	78.0	42.8	54.9	3.04
C Mung (6) Corn (4)	16.0	7.2	60.6	26.4	3.93	74.8	44.6	59.7	2.78
D Mung (6) Wheat (4)	17.8	8.6	52.6	25.8	3.63	78.0	48.7	62.5	3.07
E Mung (6) Rice (2) Corn (2)	16.8	8.4	57.8	28.2	3.92	76.4	49.8	65.3	2.83
F Mung (6) Rice (2) Wheat (2)	18.0	8.0	53.0	23.6	4.20	73.7	44.0	59.8	3.04
G Mung (5) Rice (2) Wheat (1) Corn (2)	18.0	9.4	46.0	23.0	3.79	76.4	51.2	66.8	3.58

1-Numbers in parentheses represent the approximate percent protein contributed to the diet.
2-Mg. N added to tissues.
3-Mg. fecal N/Gm. food eaten.
4-Gms. N absorbed/Gm. N eaten.

TABLE 6

MEAN RELATIONSHIPS OF WEIGHT CHANGES TO NITROGEN INTAKES, ABSORPTIONS AND RETENTIONS

Second Balance Period

Rat Group[1]	N Intake Start. Wt.	N Retained Start. Wt.	N Intake Wt. Change	N Retained Wt. Change[2]	Fecal N[3]	Apparent[4] Digestibility	N Retained	Absorbed N Retained	Protein Efficiency
	mg./Gm.	mg./Gm.	mg./Gm.	mg./Gm	mg./Gm.	%	%	%	
R Egg (10)	9.8	6.5	48.	31.6	1.87	88.0	65.8	74.7	3.37
A Mung (10)	10.0	3.1	163.2	47.6	4.48	72.5	30.0	41.4	1.08
B Mung (6) Rice (4)	10.1	4.2	110.4	43.7	3.72	76.9	39.8	51.7	1.47
C Mung (6) Corn (4)	10.2	5.4	76.8	35.8	4.44	73.9	46.8	63.3	2.11
D Mung (6) Wheat (4)	11.0	5.0	87.0	37.3	3.60	78.4	44.7	56.8	2.18
E Mung (6) Rice (2) Corn (2)	10.5	3.8	80.4	28.8	4.62	70.5	35.9	51.2	2.02
F Mung (6) Rice (2) Wheat (2)	11.6	4.7	79.8	32.4	4.12	74.9	41.0	54.7	2.08
G Mung (5) Rice (2) Wheat (1) Corn (2)	10.1	5.2	81.2	40.4	3.82	76.0	47.9	62.7	2.22

1-Numbers in parentheses represent the approximate percent protein contributed to the diet.
2-Mg. N added to tissues.
3-Mg. fecal N/Gm. food eaten.
4-Gms. N absorbed/Gms. N eaten.

TABLE 7

MEAN NITROGEN ABSORPTION AND NITROGEN RETENTION OF RATS FED MUNG BEANS AND MUNG BEANS SUPPLEMENTED WITH GRAINS AS RELATED TO RESPONSES OF RATS FED THE EGG DIET[1]

Source of Protein	First Balance Period		Second Balance Period	
	Relative Absorption	Relative Retention	Relative Absorption	Relative Retention
	%	%	%	%
A Mung	89.2	63.3	82.3	45.6
B Mung Rice	89.7	66.7	87.3	60.5
C Mung Corn	86.1	69.6	84.0	71.1
D Mung Wheat	89.7	75.9	89.1	68.0
E Mung Rice Corn	87.9	77.7	80.0	54.6
F Mung Rice Wheat	84.8	68.6	85.0	62.3
G Mung Rice Wheat Corn	88.0	79.8	86.3	72.8

1-Absorption and retention of nitrogen for animals on the egg diet equal 100 percent.

TABLE 8

GRAMS ESSENTIAL AMINO ACID PRESENT IN 100 GRAMS OF FOOD

Essential Amino Acid[1]	Egg	Mung Bean	Wheat	Rice	Corn	Sunflower	Percent Protein as Analyzed[2]	
Tryptophane	1.4	0.7	1.2	1.1	0.6	1.3	Egg	64.1
Phenylalanine	5.6	5.2	4.8	4.6	4.8	5.0	Mung Beans	24.5
Leucine	9.3	13.7	6.6	8.2	14.0	6.6	Wheat	10.1
Isoleucine	7.5	5.0	4.2	5.2	5.6	5.5	Corn	10.7
Methionine	3.7	1.1	1.6	1.4	2.4	3.7	Rice	7.9
Threonine	4.2	2.6	2.8	3.4	3.7	3.8	Millet	14.2
Lysine	6.8	3.2	2.7	3.7	2.2	3.8	Barley	10.0
Histidine	2.1	0.9	2.1	1.3	2.1	1.7	Sudan Grass	10.3
Valine	7.2	8.3	4.2	6.2	5.3	5.3	Sunflower Seed	30.0

1-Calculated from Block and Bolling (1951) and unpublished data on protein sources used in experiment.
2-N x 6.25 - values as determined by Selma Bandemer, Ag. Chem., Mich. State Univ. Protein was heated before analyses.

TABLE 8 (Cont.)

GRAMS ESSENTIAL AMINO ACID PRESENT IN THE DIFFERENT DIETS FED THE RATS AS CALCULATED FROM ABOVE DATA

Essential Amino Acid	Egg 10%	Mung Bean 10%	Mung 6% Wheat 4%	Mung 6% Corn 4%	Mung 6% Rice 4%	Mung 6% Rice 2% Corn 2%	Mung 6% Rice 2% Wheat 2%	Mung 6% Wheat 1% Rice 2% Corn 2%	Mung 6% Rice 2% Sunflower 2%	Recommended Quantity for Growth[3]
Tryptophane	.14	.07	.09	.07	.09	.08	.09	.08	.09	0.2
Phenylalanine	.56	.52	.50	.50	.50	.50	.50	.50	.50	0.7
Leucine	.93	1.37	1.09	1.38	1.15	1.27	1.12	1.20	1.12	0.8
Isoleucine	.75	.50	.47	.52	.51	.52	.49	.51	.51	0.5
Methionine	.37	.11	.13	.16	.12	.14	.13	.15	.17	0.6
Threonine	.42	.26	.27	.30	.29	.30	.28	.30	.30	0.5
Lysine	.68	.32	.30	.28	.34	.31	.32	.30	.34	1.0
Histidine	.21	.09	.14	.14	.11	.12	.12	.13	.11	.4
Valine	.72	.83	.67	.71	.75	.73	.71	.69	.73	.7

3-Albanese, O. O. Ed. 1950. Protein and Amino Acid Requirement of Mammals. Academic Press Inc., N. Y. p. 45.

TABLE 9

PERCENT OF ESSENTIAL AMINO ACID PRESENT IN THE DIFFERENT DIETS FED THE RATS[1]

Essential Amino Acid	Egg 10%	Mung Bean 10%	Mung 6% Wheat 4%	Mung 6% Corn 4%	Mung 6% Rice 4%	Mung 6% Rice 2% Corn 2%	Mung 6% Rice 2% Wheat 2%	Mung 5% Wheat 1% Rice 2% Corn 2%	Mung 6% Rice 2% Sun-flower 2%
Tryptophane	.70	.35	.45	.33	43	.38	.44	.40	.45
Phenylalanine	.80	.74	.72	.72	.71	71	.71	.71	.72
Leucine	116	171	136	173	144	158	140	149	140
Isoleucine	150	100	94	105	102	103	.98	102	103
Methionine	.62	.18	22	.27	.20	.24	.21	24	28
Threonine	84	.52	.54	.61	.58	.60	.56	.60	.60
Lysine	.68	.32	.30	.28	.34	.31	.32	.30	.34
Histidine	52	.22	.34	.34	.26	.30	.30	.34	.28
Valine	103	119	.95	101	107	104	101	98	104
Amino acid present in lowest amount	Histidine	Methionine	Methionine	Methionine	Methionine	Methionine	Methionine	Methionine	Methionine Histidine

1-Compared to recommended quantities given in Table 8.

TABLE 10

GROWTH RESPONSES OF INDIVIDUAL RATS FED DIFFERENT DIETS DURING THE FIRST EXPERIMENTAL PERIOD

Rat No.	Weight Change Gms.	Protein Intake Gms.	Protein Efficiency Ratio[1]
Fat Extracted Dried Whole Egg (10 percent)[2]			
R1	197	46	4.30
R2	196	45	4.36
R3	163	41	3.99
R4	172	46	3.78
R5	210	49	4.29
Mung Bean (10 percent)			
A1	21	21	.99
A2	18	20	.90
A3	22	19	1.13
A4	19	16	1.17
A5	27	18	1.50
Mung Bean (6 percent), Rice (4 percent)			
B1	76	31	2.42
B2	58	25	2.34
B3	65	29	2.24
B4	58	25	2.29
B5	38	21	1.78
Mung Bean (6 percent), Corn (4 percent)			
C1	95	34	2.76
C2	58	27	2.12
C3	71	32	2.21
C4	59	26	2.28
C5	73	32	2.31
Mung Bean (6 percent), Wheat (4 percent)			
D1	129	44	2.92
D2	84	34	2.50
D3	86	34	2.55
D4	67	27	2.50
D5	67	31	2.15

TABLE 10 (Cont.)

Rat No.	Weight Change Gms.	Protein Intake Gms.	Protein Efficiency Ratio
Mung Bean (6 percent), Corn (2 percent), Rice (2 percent)			
E1	61	25	2.39
E2	58	27	2.16
E3	55	26	2.09
E4	45	23	1.94
E5	86	34	2.55
Mung Bean (6 percent), Wheat (2 percent), Rice (2 percent)			
F1	62	28	2.18
F2	64	29	2.18
F3	106	39	2.71
F4	69	29	2.37
F5	61	28	2.15
Mung Bean (5 percent), Wheat (1 percent), Corn (2 percent), Rice (2 percent)			
G1	61	26	2.35
G2	81	29	2.77
G3	73	31	2.38
G4	93	33	2.81
G5	64	26	2.50

1—Grams weight gain per gram of protein intake.
2—All diets furnished approximately 10 percent protein.

TABLE 11

GROWTH RESPONSES OF INDIVIDUAL RATS FED DIFFERENT DIETS DURING THE SECOND EXPERIMENTAL PERIOD

Rat.No.	Weight Change Gms.	Protein Intake Gms.	Protein Efficiency Ratio[1]
Fat Extracted Dried Whole Egg (10 percent)[2]			
R1	66	30	2.16
R2	61	32	1.92
R3	72	28	2.53
R4	62	25	2.48
R5	66	22	3.01
Mung (6 percent), Rice (2 percent), Sunflower Seed (2 percent)			
A1	40	18	2.20
A2	42	18	2.33
A3	48	19	2.55
A4	24	18	1.32
A5	28	15	1.93
Mung (6 percent), Rice (2 percent), Barley (2 percent)			
B1	18	18	1.01
B2	38	13	2.93
B3	19	16	1.21
B4	20	15	1.33
B5	26	18	1.42
Mung (6 percent), Rice (2 percent), Millet (2 percent)			
C1	51	26	1.98
C2	31	16	1.90
C3	35	21	1.69
C4	18	17	1.09
C5	37	20	1.76

TABLE 11 (Cont.)

Rat No.	Weight Change Gms.	Protein Intake Gms.	Protein Efficiency Ratio[1]
Mung (6 percent), Rice (2 percent), Sudan Grass (2 percent)			
D1	-5	18	-.27
D2	15	15	1.02
D3	-4	12	-.33
D4	6	10	.61
D5	2	16	.12
Mung (4 percent), Rice (2 percent), Sunflower Seed (2 percent), Barley (2 percent)			
E1	41	23	1.82
E2	47	24	1.96
E3	33	23	1.44
E4	37	21	1.76
E5	32	21	1.53
Mung (4 percent), Rice (2 percent), Sunflower Seed (2 percent), Millet (2 percent)			
F1	38	21	1.81
F2	42	21	1.97
F3	69	29	2.40
F4	44	24	1.85
F5	35	24	1.44
Mung (4 percent), Rice (2 percent), Sunflower Seed (2 percent), Sudan Grass (2 percent)			
G1	28	18	1.53
G2	14	25	.56
G3	38	16	2.43
G4	23	22	1.02
G5	24	19	1.27

1-Grams weight gain per gram of protein intake.
2-All diets furnished approximately 10 percent protein.

TABLE 12

MEAN NITROGEN ABSORPTION AND RETENTION OF RATS DURING THE TEN-DAY BALANCE ON DIETS USING FAT EXTRACTED WHOLE DRIED EGG AND VEGETABLE SEEDS AS SOURCES OF PROTEINS

First Balance Period

Rat Group	Starting Weight Gm.	Weight Change Gm.	Total Nitrogen				
			Intake mg.	Fecal mg.	Urinary mg.	Absorbed mg.	Retained mg.
Fat Extracted Dried Whole Egg (10%)							
R1	93	65	1726	246	515	1480	965
R2	90	70	2122	257	466	1865	1400
R3	90	48	1714	204	420	1510	1090
R4	90	47	1714	242	323	1472	1150
R5	88	64	2077	275	323	1802	1416
Mung Beans (10%)							
A1	62	6	651	143	191	508	317
A2	64	6	1032	201	357	831	474
A3	65	6	773	191	203	582	380
A4	63	5	734	156	352	579	226
A5	64	6	832	210	384	622	289
Mung Bean (6%), Rice (4%)							
B1	78	27	1499	346	504	1153	649
B2	66	22	1050	218	374	832	458
B3	71	23	1189	262	418	926	508
B4	71	20	1032	234	254	798	544
B5	65	15	859	185	403	674	271
Mung Bean (6%), Corn (4%)							
C1	80	25	1302	306	438	996	558
C2	73	26	1272	285	374	987	614
C3	69	27	1341	336	356	1004	648
C4	80	12	1075	293	385	782	397
C5	84	20	1245	345	316	900	584

TABLE 12 (Cont.)

Rat Group	Starting Weight Gm.	Weight Change Gm.	Total Nitrogen Intake mg.	Fecal mg.	Urinary mg.	Absorbed mg.	Retained mg.
Mung Bean (6%), Wheat (4%)							
D1	83	41	1867	420	500	1447	947
D2	71	28	1384	326	389	1058	669
D3	80	26	1466	310	412	1156	744
D4	72	17	1042	208	318	834	516
D5	72	23	1173	269	385	904	519
Mung (6%), Rice (2%), Corn (2%)							
E1	68	23	1131	247	301	884	583
E2	71	15	1120	264	393	856	463
E3	68	16	970	217	286	753	468
E4	60	17	938	253	187	685	498
E5	74	31	1531	358	332	172	841
Mung (6%), Rice (2%), Wheat (2%)							
F1	76	20	1202	336	351	866	515
F2	70	26	1274	319	395	955	560
F3	76	34	1605	388	472	1217	745
F4	70	18	1066	288	336	778	443
F5	72	28	1414	386	383	1028	645
Mung (5%), Rice (2%), Corn (2%), Wheat (1%)							
G1	73	16	1011	241	320	770	450
G2	68	36	1429	295	265	1134	869
G3	72	30	1318	310	274	1008	734
G4	70	40	1608	355	336	1253	917
G5	76	24	1029	286	351	743	392

TABLE 13

MEAN NITROGEN ABSORPTION AND RETENTION OF RATS DURING THE SECOND TEN-DAY BALANCE ON DIETS USING FAT EXTRACTED WHOLE DRIED EGG AND VEGETABLE SEEDS AS SOURCES OF PROTEIN

Second Balance Period

Rat Group	Starting Weight Gm.	Weight Change Gm.	Total Nitrogen Intake mg.	Fecal mg.	Urinary mg.	Absorbed mg.	Retained mg.
			Fat Extracted Dried Whole Egg (10%)				
R1	213	47	2093	261	509	1832	1323
R2	218	42	1944	226	508	1718	1210
R3	186	41	1758	203	433	1555	1122
R4	195	41	2251	278	337	1973	1635
R5	228	42	2131	250	456	1881	1425
			Mung Beans (10%)				
A1	76	5	774	217	286	557	272
A2	77	3	800	190	373	610	237
A3	78	8	832	237	195	595	400
A4	73	4	653	162	355	490	136
A5	76	6	762	248	389	514	126
			Mung Bean (6%), Rice (4%)				
B1	126	12	1195	251	520	944	423
B2	110	8	1043	293	358	750	392
B3	115	12	1336	252	424	1084	661
B4	110	12	1094	264	347	830	483
B5	94	8	960	226	424	734	311
			Mung Bean (6%), Corn (4%)				
C1	132	26	1720	434	429	1286	857
C2	104	16	1176	259	248	917	670
C3	112	18	1432	353	530	1079	549
C4	105	15	1107	328	328	779	451
C5	122	14	1264	364	289	900	611

TABLE 13 (Cont.)

Rat Group	Starting Weight Gm.	Weight Change Gm.	Total Nitrogen Intake mg.	Fecal mg.	Urinary mg.	Absorbed mg.	Retained mg.
			Mung Bean (6%), Wheat (4%)				
D1	156	34	1978	438	576	1540	964
D2	122	24	1429	324	504	1105	601
D3	128	18	1381	247	320	1134	814
D4	114	18	1165	267	461	898	473
D5	125	7	1224	271	508	953	446
			Mung (6%), Rice (2%), Corn (2%)				
E1	110	14	1078	337	305	773	435
E2	106	16	1216	508	306	910	403
E3	104	13	1059	505	320	739	234
E4	94	10	978	206	386	592	386
E5	130	20	1394	434	341	1053	618
			Mung (6%), Rice (2%), Wheat (2%)				
F1	116	12	1251	382	389	870	471
F2	112	16	1211	286	446	924	479
F3	140	28	1738	387	622	1351	730
F4	112	18	1382	331	422	1049	607
F5	110	12		lost	457		
			Mung (5%), Rice (2%), Corn (2%), Wheat (1%)				
G1	108	14	1038	232	389	806	417
G2	120	24	1141	338	347	803	456
G3	126	11	1483	313	274	1170	896
G4	132	25	1568	314	343	1254	911
G5	118	14	1208	326	388	882	493

TABLE 14

THE RELATIONSHIP OF WEIGHT CHANGES TO NITROGEN INTAKES, NITROGEN ABSORPTIONS AND NITROGEN RETENTIONS OF RATS FED WHOLE DRIED EGG, MUNG BEANS AND OTHER PLANT SOURCES OF DIETARY PROTEIN

First Balance Period

Rat Group[1]	N Intake Start. Wt.	N Retained Start. Wt.	N Intake Wt. Change	N Retained Wt. Change[2]	Fecal N[3]	Apparent[4] Digestibility	N Retained[5]	Absorbed N Retained	Protein Efficiency
	mg./Gm.	mg./Gm.	mg./Gm.	mg./Gm.		%	%	%	%
Egg (10%)									
R1	19	10	27	15	2.20	85.7	55.9	65.2	6.02
R2	24	16	30	20	1.86	87.9	66.0	75.0	5.28
R3	19	12	37	23	1.82	88.1	63.6	72.2	4.48
R4	19	13	36	24	2.16	85.9	67.1	78.1	4.39
R5	24	16	32	22	2.04	86.8	68.2	78.6	4.93
Mung Bean (10%)									
A1	10	5	108	53	3.58	78.0	48.6	62.4	1.47
A2	16	7	172	79	3.14	80.6	45.9	57.0	.93
A3	12	6	129	63	3.98	75.3	49.1	65.2	1.24
A4	12	4	147	45	3.39	78.8	30.8	39.1	1.09
A5	13	4	139	40	4.04	74.8	28.7	38.4	1.15
Mung Bean (6%), Rice (4%)									
B1	19	8	56	24	3.53	76.9	43.3	56.3	2.88
B2	16	7	48	21	3.16	79.2	43.6	55.0	3.35
B3	17	7	52	22	3.36	77.9	42.8	54.9	3.10
B4	15	8	52	27	3.44	77.3	52.7	68.2	3.10
B5	13	4	57	18	3.30	78.4	31.5	40.2	2.79
Mung Bean (6%), Corn (4%)									
C1	16	7	52	22	3.69	76.5	42.8	56.0	3.07
C2	17	8	49	24	3.48	77.6	48.3	62.2	3.27
C3	19	9	50	24	3.91	74.9	48.3	64.5	3.22
C4	13	5	90	33	4.25	72.7	36.9	50.8	1.79
C5	15	7	62	29	4.31	72.3	46.9	64.8	2.57

TABLE 14 (Cont.)

Rat Group[1]	N Intake Start. Wt.	N Retained Start. Wt.	N Intake Wt. Change	N Retained Wt. Change[2]	Fecal N[3]	Apparent[4] Digestibility	N Retained[5]	Absorbed N Retained	Protein Efficiency
	mg./Gm.	mg./Gm.	mg./Gm.	mg./Gm.		%	%	%	%
Mung Bean (6%), Wheat (4%)									
D1	22	11	46	23	3.68	77.5	50.7	65.4	3.51
D2	19	9	49	24	3.88	76.5	48.4	63.3	3.24
D3	18	9	59	29	3.48	73.8	50.7	64.3	2.84
D4	14	7	61	30	3.30	80.0	49.5	61.8	2.61
D5	16	7	51	23	3.79	77.0	44.2	57.4	3.14
Mung Bean (6%), Rice (2%), Corn (2%)									
E1	17	9	49	25	3.63	78.1	51.5	65.9	3.25
E2	16	7	75	31	3.88	76.4	41.4	54.1	2.14
E3	14	7	61	29	3.74	77.7	48.2	62.1	2.64
E4	16	8	55	29	4.44	73.1	53.1	72.7	2.90
E5	21	11	49	27	3.89	76.6	54.9	71.7	3.24
Mung Bean (6%), Rice (2%), Wheat (2%)									
F1	16	7	60	26	4.48	72.0	42.8	59.5	2.66
F2	18	8	49	22	3.99	75.0	43.9	58.6	3.27
F3	21	10	47	22	3.88	75.8	46.4	61.2	3.39
F4	15	6	59	25	4.30	73.0	41.5	56.9	2.70
F5	20	9	50	23	4.34	72.7	45.6	62.7	3.17
Mung Bean (5%), Rice (2%), Wheat (1%), Corn (2%)									
G1	14	6	63	28	3.82	76.2	44.5	58.4	2.53
G2	21	13	40	24	3.31	79.3	60.8	76.6	4.03
G3	18	10	44	24	3.78	76.5	55.7	72.8	3.64
G4	23	13	40	23	3.56	77.9	57.0	73.2	3.98
G5	14	5	43	16	4.47	72.2	38.1	52.8	3.73

1-Numbers in parentheses represent approximate percent of protein contributed to the diet.
2-Mg. N added to tissue.
3-Mg. fecal N excreted/Gms. food eaten.
4-Gms. N absorbed/Gms. N eaten.
5-Gms. N retained/Gms. N eaten.

TABLE 15

THE RELATIONSHIP OF WEIGHT CHANGES TO NITROGEN INTAKES, NITROGEN ABSORPTION AND NITROGEN RETENTION OF RATS FED WHOLE DRIED EGG, MUNG BEANS AND OTHER PLANT SOURCES OF DIETARY PROTEIN

Second Balance Period

Rat Group[1]	N Intake Start. Wt.	N Retained Start. Wt.	N Intake Wt. Change	N Retained Wt. Change[2]	Fecal N[3]	Apparent[4] Digestibility	N Retained[5]	Absorbed N Retained	Protein Efficiency
	mg./Gm.	mg./Gm.	mg./Gm.	mg./Gm.		%	%	%	%
Egg (10%)									
R1	[illegible]	[illegible]	45	28.2	1.96	87.5	63.2	72.2	3.59
R2	9	6	46	28.8	1.82	88.4	62.3	70.4	3.46
R3	10	6	43	27.4	1.81	88.4	63.8	72.2	3.73
R4	12	8	55	39.9	1.93	87.6	72.7	72.9	3.73
R5	9	6	51	33.9	1.84	88.3	66.9	75.8	3.15
Mung Beans (10%)									
A1	10	4	155	54.3	4.52	72.0	35.1	48.8	1.03
A2	10	[illegible]	267	78.9	3.88	76.2	29.6	38.8	.64
A3	11	5	104	50.1	4.65	71.5	48.1	67.3	1.54
A4	9	2	163	33.9	4.05	75.1	20.8	27.6	.78
A5	10	2	127	20.9	5.28	67.5	16.5	24.4	1.26
Mung (6%), Rice (4%)									
B1	10	3	100	35.3	3.39	79.0	35.4	44.8	1.61
B2	10	4	130	49.0	4.51	71.9	37.5	52.2	1.23
B3	12	6	111	55.1	3.04	81.2	49.5	60.9	1.44
B4	10	4	91	40.2	3.88	75.9	44.1	58.2	1.75
B5	10	3	120	38.8	3.77	76.5	32.4	42.3	1.33
Mung (6%), Corn (4%)									
C1	13	7	66	33.0	4.30	74.8	49.8	66.6	2.11
C2	11	6	74	41.8	3.75	87.0	56.9	73.0	2.18
C3	13	5	80	30.5	4.20	75.4	38.4	50.9	2.01
C4	11	4	74	30.1	5.05	70.4	40.8	58.0	2.17
C5	10	5	90	43.6	4.92	71.2	48.3	67.8	2.11

TABLE 15 (Cont.)

Rat Group[1]	N Intake Start.Wt.	N Retained Start. Wt.	N Intake Wt. Change	N Retained Wt. Change[2]	Fecal N[3]	Apparent[4] Digestibility	N Retained[5]	Absorbed N Retained	Protein Efficiency
	mg./Gm.	mg./Gm.	mg./Gm.	mg./Gm.		%	%	%	%
Mung (6%), Wheat (4%)									
D1	13	6	58	28.4	3.71	77.9	48.8	62.6	2.75
D2	12	5	60	25.0	3.77	77.3	42.1	54.4	2.69
D3	11	6	77	45.2	2.98	82.1	48.9	71.8	2.09
D4	10	4	65	24.3	3.81	77.1	37.5	48.6	2.47
D5	10	4	175	63.7	3.71	77.9	36.4	46.8	.92
Mung (6%), Rice (2%), Corn (2%)									
E1	10	4	77	31.1	4.42	71.7	40.4	56.3	2.08
E2	12	4	76	25.2	3.92	74.8	33.1	44.2	2.11
E3	10	2	81	18.0	4.70	69.8	22.1	31.6	1.96
E4	10	4	98	38.6	6.22	60.5	39.5	65.2	1.64
E5	11	5	70	30.9	3.63	75.5	44.1	58.7	2.30
Mung (6%), Rice (2%), Wheat (2%)									
F1	11	4	104	40.1	5.03	69.5	38.4	55.3	1.53
F2	11	4	76	29.9	3.86	76.3	39.5	51.8	2.11
F3	12	5	62	26.1	3.65	77.7	42.0	54.0	2.58
F4	12	4	77	33.7	3.96	75.9	43.9	57.9	2.08
F5	lost	-	-	-	-	-	-	-	2.12
Mung (5%), Rice (2%), Corn (2%), Wheat (1%)									
G1	10	4	74	29.8	3.57	77.6	40.2	51.7	2.16
G2	10	4	48	19.0	4.69	70.4	39.9	56.8	3.37
G3	12	7	135	81.4	3.36	78.9	60.4	76.6	1.19
G4	12	7	63	36.4	3.20	80.0	58.1	72.6	2.55
G5	10	4	86	35.2	4.29	73.0	40.8	55.9	1.85

1-Numbers in parentheses represent approximate percent of protein contributed to the diet.
2-Mg. N added to tissue.
3-Mg. fecal N excreted/Gms. food eaten.
4-Gms. N absorbed/Gms. N eaten.
5-Gms. N retained/Gms. N eaten.

TABLE 16

APPARENT CHANGES OF INDIVIDUAL RATS DURING THE EXPERIMENT

Rat Group and No.	Source of Protein[1]	Observation
R1 R2 R3 R4 R5	Dried Whole Eggs (10%)	No abnormal changes noted.
A1	Mung Beans (10%)	Hair, rough slightly reddish on 40th day of the experiment
A2		
A3		Hair falling around hind legs on the 22nd day of experiment. Ten days after, hair on the back was turning brownish red.
A4		Hair falling and turning brownish red on 29th day of experiment.
A5		Hair falling around hind legs on 22nd day of experiment.
B1	Mung Beans (6%) Rice (4%)	Hair falling from back on 31st day of experiment; hair turning brownish red on 42nd day.
B2		Hair turning brownish red on 32nd day; on 34th day hair started falling and color change more pronounced.
B3		
B4		Hair falling from the head on 29th day. On 34th day, hair on back was turning brownish red.
B5		Hair turning reddish brown on 29th day and three days after the color was more pronounced.
C1	Mung Beans (6%) Corn (4%)	
C2		Very slight color change of hair at the end of first experimental period.

TABLE 16 (Cont.)

Rat Group and No.	Source of Protein[1]	Observation
C3		Hair falling from hind legs on 24th day of experiment. On 31st day, hair falling from front legs; on 42nd day, hair was turning brownish.
C4		Hair was turning brownish red on 34th day
C5		
D1	Mung Beans (6%) Wheat (4%)	Hair started falling and a coarse reddish hair on the back towards the hind legs was noticed on the 24th day of the experiment.
D2		Hair started falling and a coarse reddish hair on the back towards the hind legs was noticed on the 25th day of the experiment.
D3		Hair near the tail end was coarse and turned reddish brown on the 22nd day.
D4		
D5		Coarse, brownish red hair on the back was noticed on the 24th day of the experiment.
E1	Mung (6%) Rice (2%) Corn (2%)	Hair near the ears was observed to be turning brownish red on the 40th day.
E2		Hair turning brownish red on the 34th day and started falling on the 42nd day.
E3		Hair on back turning brownish red on the 31st day and was more red on the 34th day.
E4		Hair on back started falling on the 30th day and was turning brownish red on the 32nd day.

TABLE 16 (Cont.)

Rat Group and No.	Source of Protein	Observations
E5		Hair on back was observed to be coarse and brownish red on the 24th day of the experiment and hair near the ears was noticed to turn also brownish red on the 40th day.
F1	Mung (6%) Rice (2%) Wheat (2%)	Hair near the ears was turning brownish red on 32nd day; hair near hind legs turning brownish red on 42nd day.
F2		Hair on back turning brownish red and becoming coarse on 22nd day.
F3		Hair turning brownish red on the 32nd day.
F4		Hair on back turning brownish red on 32nd day.
F5		Hair on back turning brownish red on 29th day. On 32nd day hair on the head was turning also brownish red.
G1	Mung (5%) Rice (2%) Corn (2%) Wheat (1%)	Hair on back turning slightly brownish red on 42nd day.
G2		Hair on back turning brownish red on back and was more red on the 42nd day.
G3		Hair on back turning brownish red on 32nd day.
G4		Hair below the ears turning brownish red on 42nd day.
G5		Losing hair on back on the 22nd day; On the 31st day, most of the hair on front and hind legs were lost; on the 38th day, hair on back was turning brownish red. There seemed to be some evidence of new hair on the 42nd day. The skin of this rat was sore.

When the diets were changed, those that lost plenty of hair seemed to recover their fur, and those that were definitely brownish red turned lighter in color toward the end of the experimental period.

1-Numbers in parentheses represent the approximate percent protein contributed to the diet.

Figure I. Growth curves showing mean weights of eight groups of rats fed the experimental diets during the first and second diet series.

First Diet Series	Second Diet Series
Protein Source Approx. 10 Percent[1]	
R - Dried Whole Egg 10	Dried Whole Egg 10
A - Mung Beans 10	Mung 6, Rice, 2, Sunflower seeds 2
B - Mung 6, Rice 4	Mung 6, Rice 2, Barley 2
C - Mung 6, Corn 4	Mung 6, Rice 2, Millet 2
D - Mung 6, Wheat 4	Mung 6, Rice 2, Sudan Grass 2
E - Mung 6, Rice 2, Corn 2	Mung 4, Rice 2, Sunflower seeds 2, Barley 2
F - Mung 6, Rice 2 Wheat 2	Mung 4, Rice 2, Sunflower seeds 2, Millet 2
G - Mung 5, Rice 2, Corn 2, Wheat 1	Mung 4, Rice 2, Sunflower seeds 2, Sudan Grass 2

[1]Numbers indicate per cent dietary protein furnished by food.

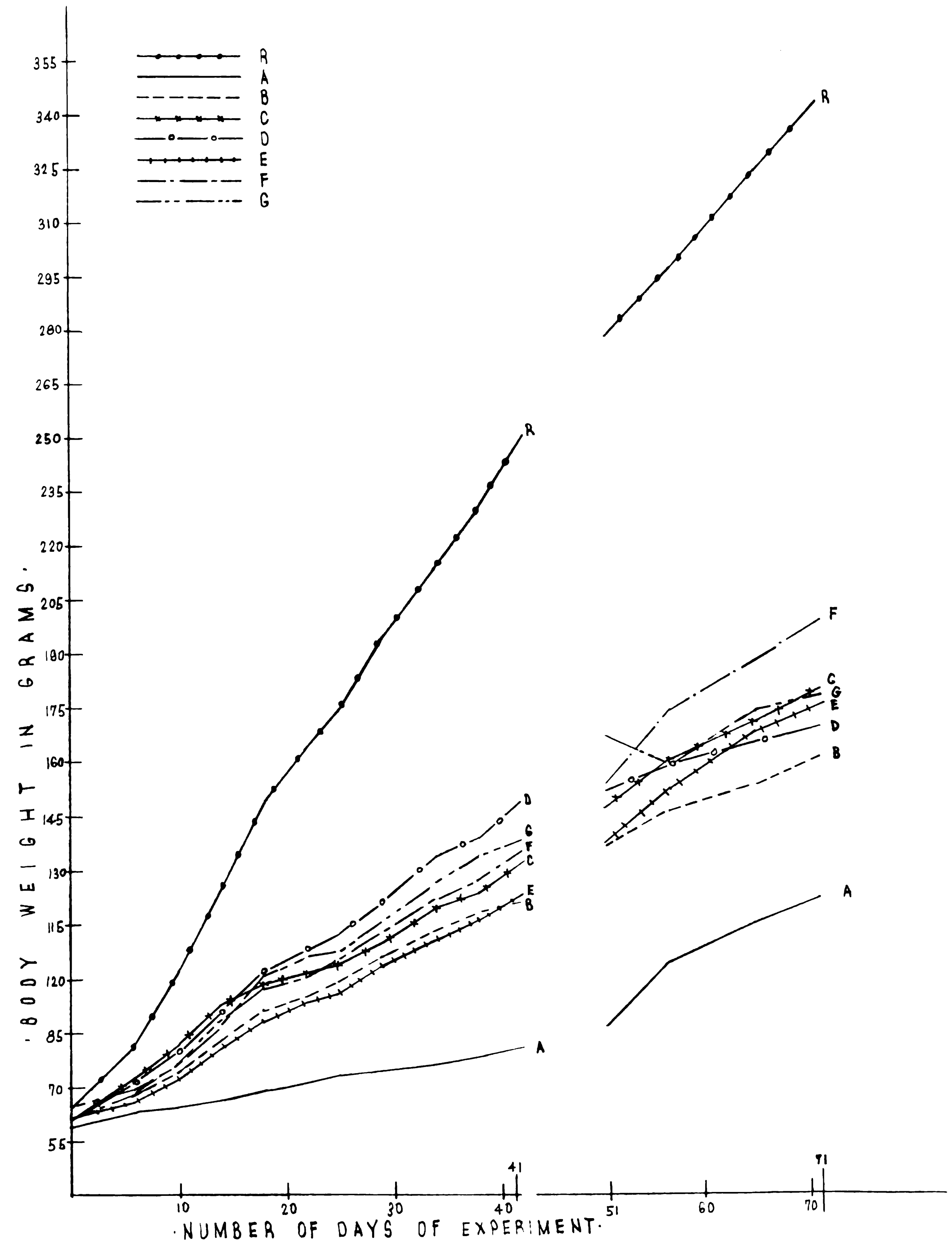

R
A
B
C
D
E
F
G
355
340
325
310
295
280
265
250
235
220
205
190
175
160
145
130
115
120
85
70
55
BODY WEIGHT IN GRAMS
10
20
30
40
41
51
60
70
71
NUMBER OF DAYS OF EXPERIMENT

Figure II. Mean weight changes of eight groups of rats fed experimental diets during the second diet series.

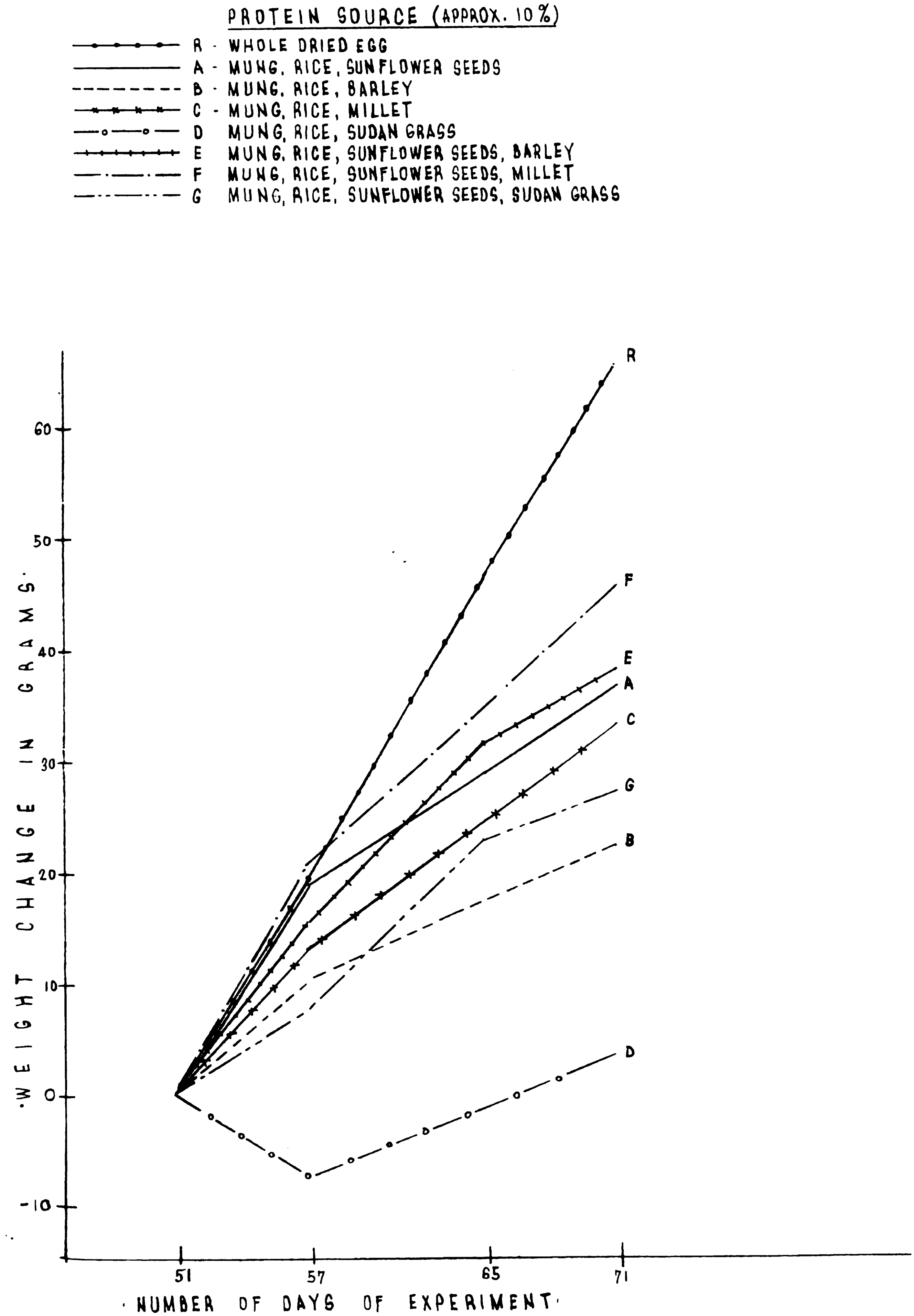

PROTEIN SOURCE (APPROX. 10%)
R - WHOLE DRIED EGG
A - MUNG, RICE, SUNFLOWER SEEDS
B - MUNG, RICE, BARLEY
C - MUNG, RICE, MILLET
D MUNG, RICE, SUDAN GRASS
E MUNG, RICE, SUNFLOWER SEEDS, BARLEY
F MUNG, RICE, SUNFLOWER SEEDS, MILLET
G MUNG, RICE, SUNFLOWER SEEDS, SUDAN GRASS
WEIGHT CHANGE IN GRAMS
60
50
40
30
20
10
0
-10
R
F
E
A
C
G
B
D
51
57
65
71
NUMBER OF DAYS OF EXPERIMENT

Figure III. Growth curves showing weights of individual rats fed ten percent protein from defatted dried whole egg during the first diet series (41 days) and the second diet series (21 days).

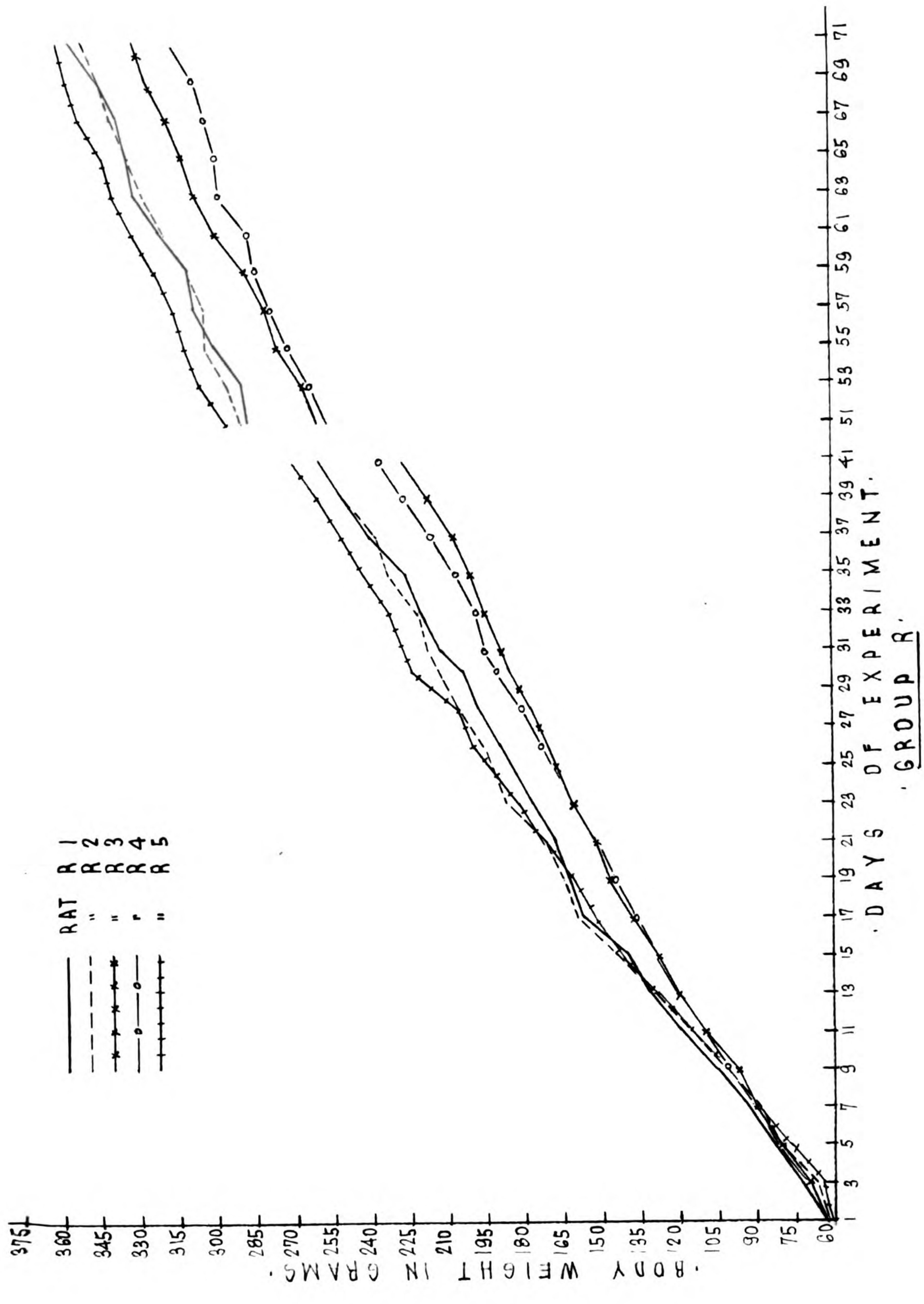
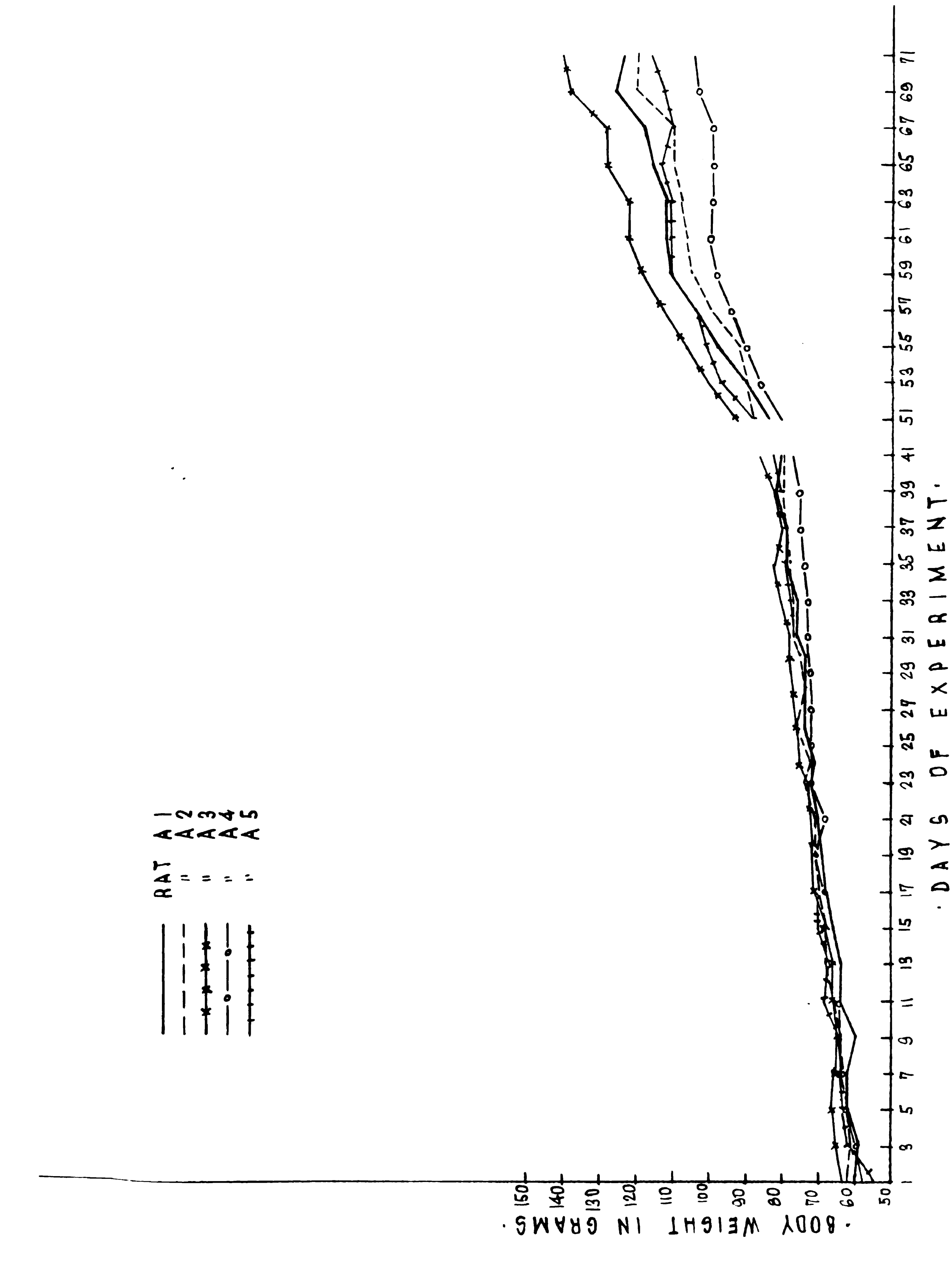

RAT R 1
" R 2
" R 3
" R 4
" R 5
BODY WEIGHT IN GRAMS
375
360
345
330
315
300
285
270
255
240
225
210
195
180
165
150
135
120
105
90
75
60
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 51 53 55 57 59 61 63 65 67 69 71
DAYS OF EXPERIMENT
GROUP R

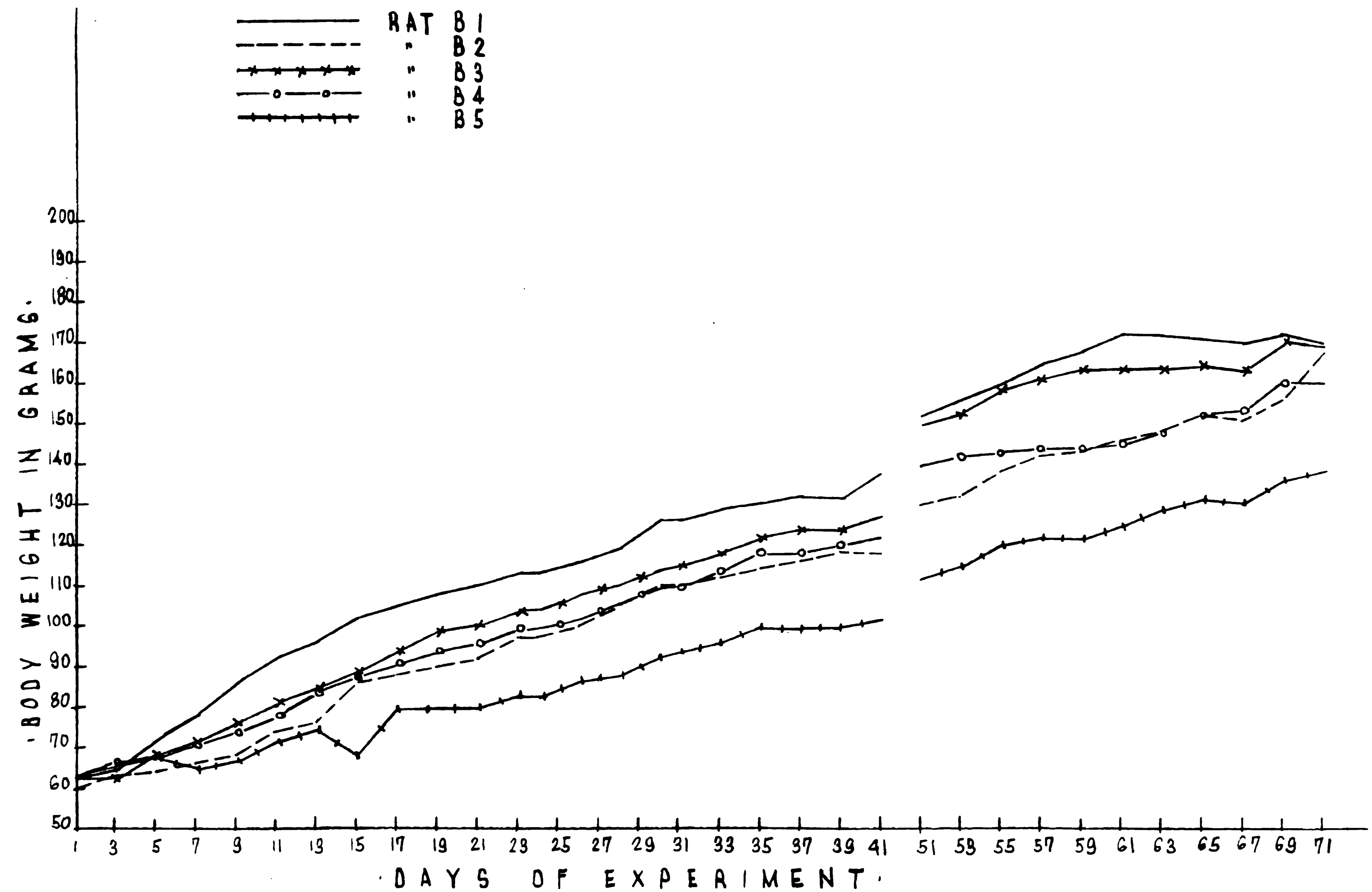
Figure IV. Growth curves showing weights of individual rats fed 10 percent mung bean protein during the first diet series; 6 percent mung bean protein, 2 percent rice protein and 2 percent sunflower seed protein during the second diet series.



RAT A1
" A2
" A3
" A4
" A5
BODY WEIGHT IN GRAMS
50
60
70
80
90
100
110
120
130
140
150
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 51 53 55 57 59 61 63 65 67 69 71
DAYS OF EXPERIMENT

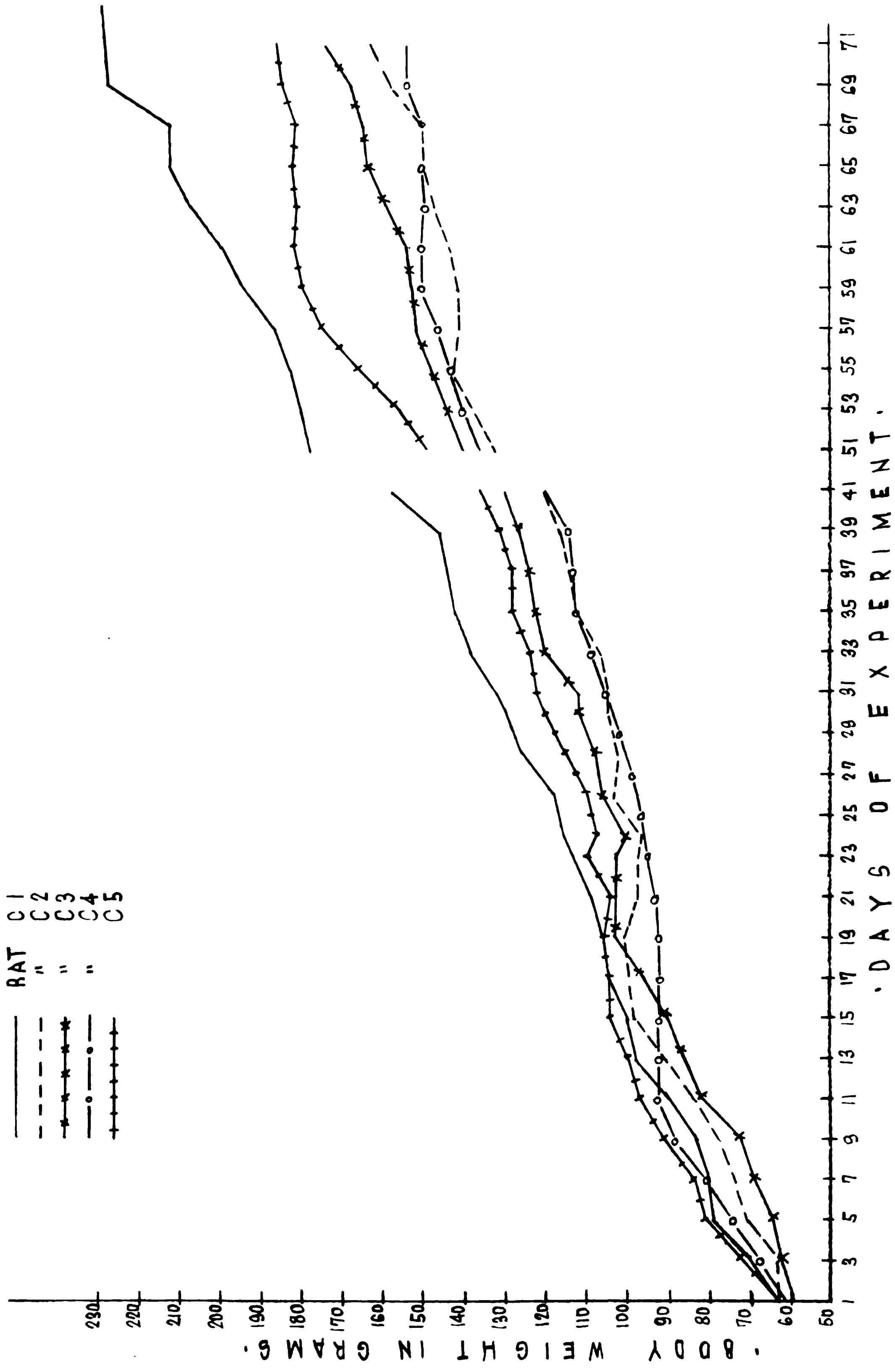
GROUP A

Figure V. Growth curves showing weights of individual rats fed 6 percent mung bean protein, 4 percent rice protein, during the first diet series; 6 percent mung bean protein, 2 percent rice protein and 2 percent barley protein for the second diet series.


RAT B 1
" B 2
" B 3
" B 4
" B 5
· BODY WEIGHT IN GRAMS ·
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 51 53 55 57 59 61 63 65 67 69 71
· DAYS OF EXPERIMENT ·

· GROUP B ·

Figure VI. Growth curves showing weights of individual rats fed 6 percent mung bean protein, 4 percent corn protein during the first diet series; 6 percent mung bean protein, 2 percent rice protein, and 2 percent millet protein during the second diet series.


RAT C1
" C2
" C3
" C4
" C5
BODY WEIGHT IN GRAMS.
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 51 53 55 57 59 61 63 65 67 69 71
DAYS OF EXPERIMENT.

GROUP C.

Figure VII. Growth curves showing weights of individual rats fed 6 percent mung bean protein, 4 percent wheat protein during the first diet series; 6 percent mung bean protein, 2 percent rice protein and 2 percent sudan grass protein during the second diet series.

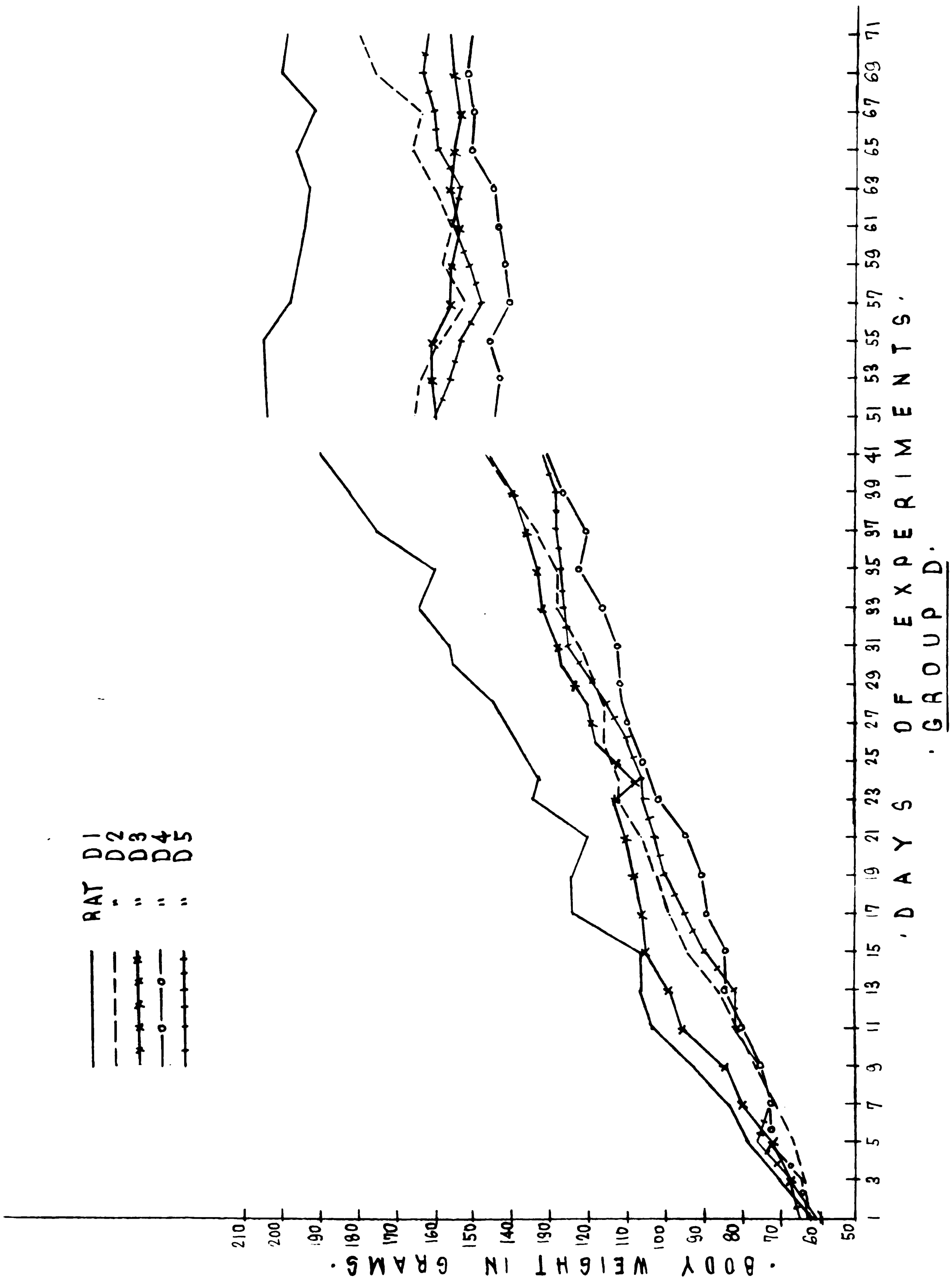
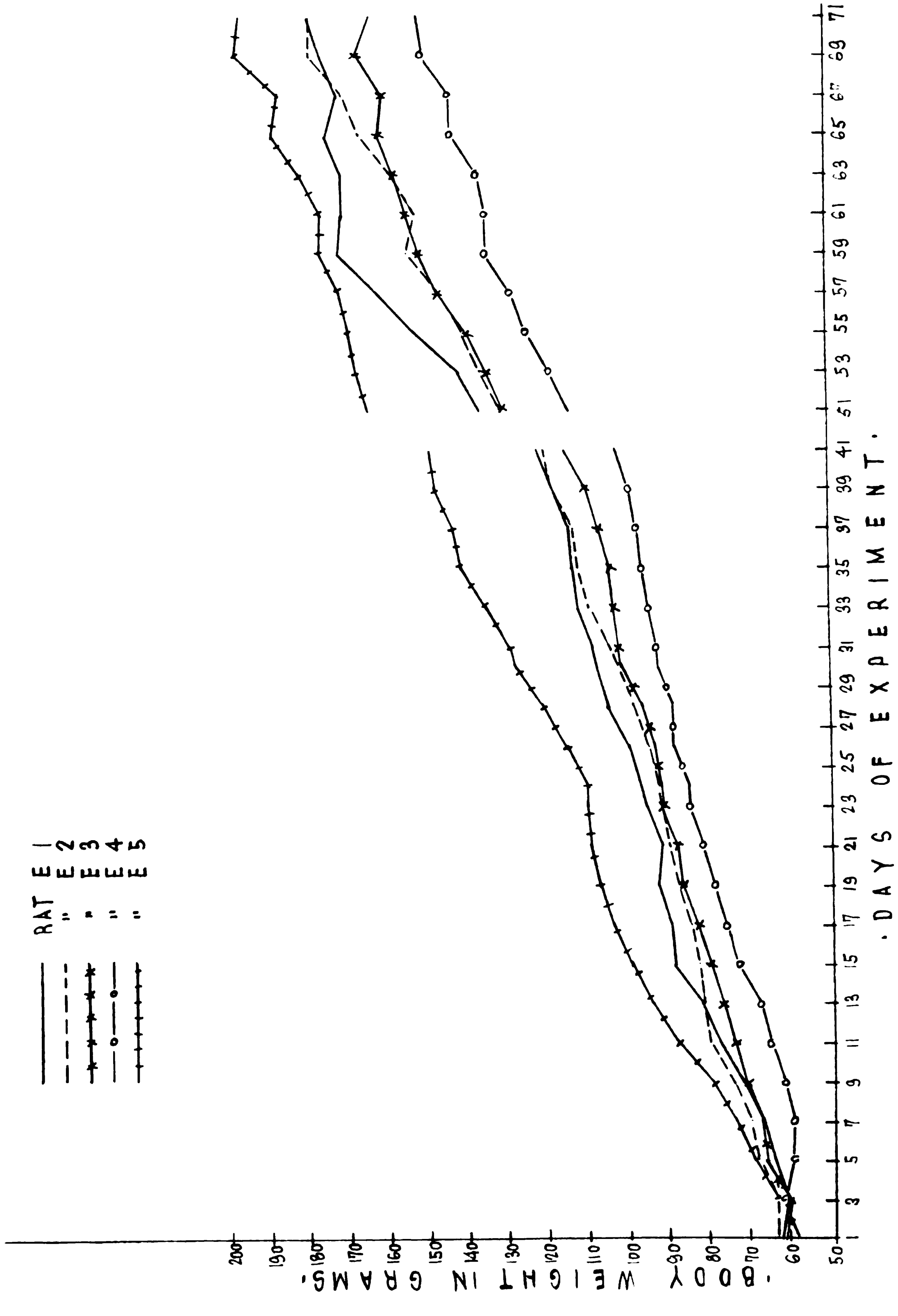
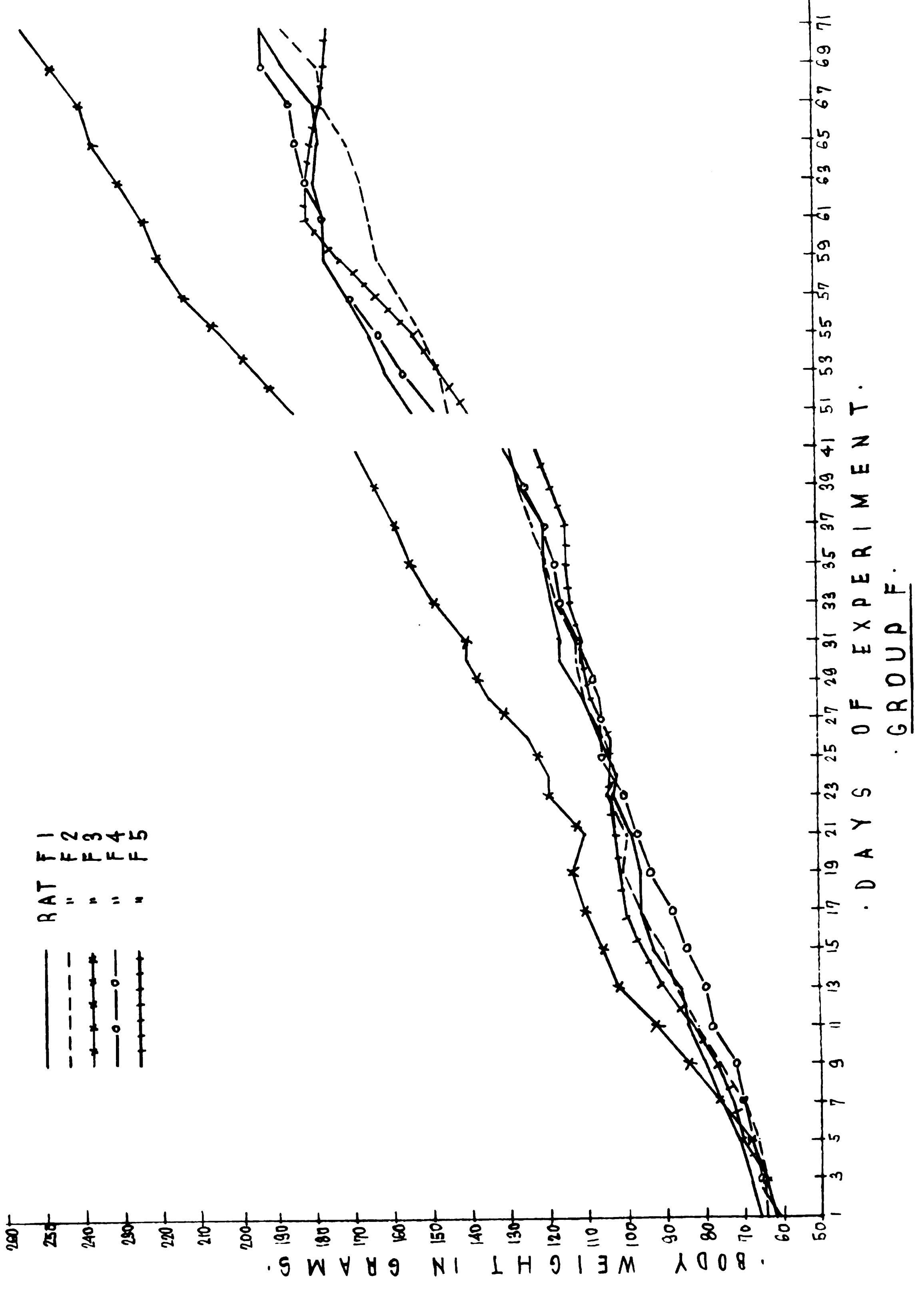

RAT D1
" D2
" D3
" D4
" D5
BODY WEIGHT IN GRAMS
DAYS OF EXPERIMENTS
GROUP D
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 51 53 55 57 59 61 63 65 67 69 71

Figure VIII. Growth curves showing weights of individual rats fed 6 percent mung bean protein, 2 percent rice protein, 2 percent corn protein during the first diet series; 4 percent mung bean protein, 2 percent rice protein, 2 percent sunflower seed protein, 2 percent barley protein during the second diet series.


RAT E 1
" E 2
" E 3
" E 4
" E 5
BODY WEIGHT IN GRAMS
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
DAYS OF EXPERIMENT
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 51 53 55 57 59 61 63 65 67 69 71

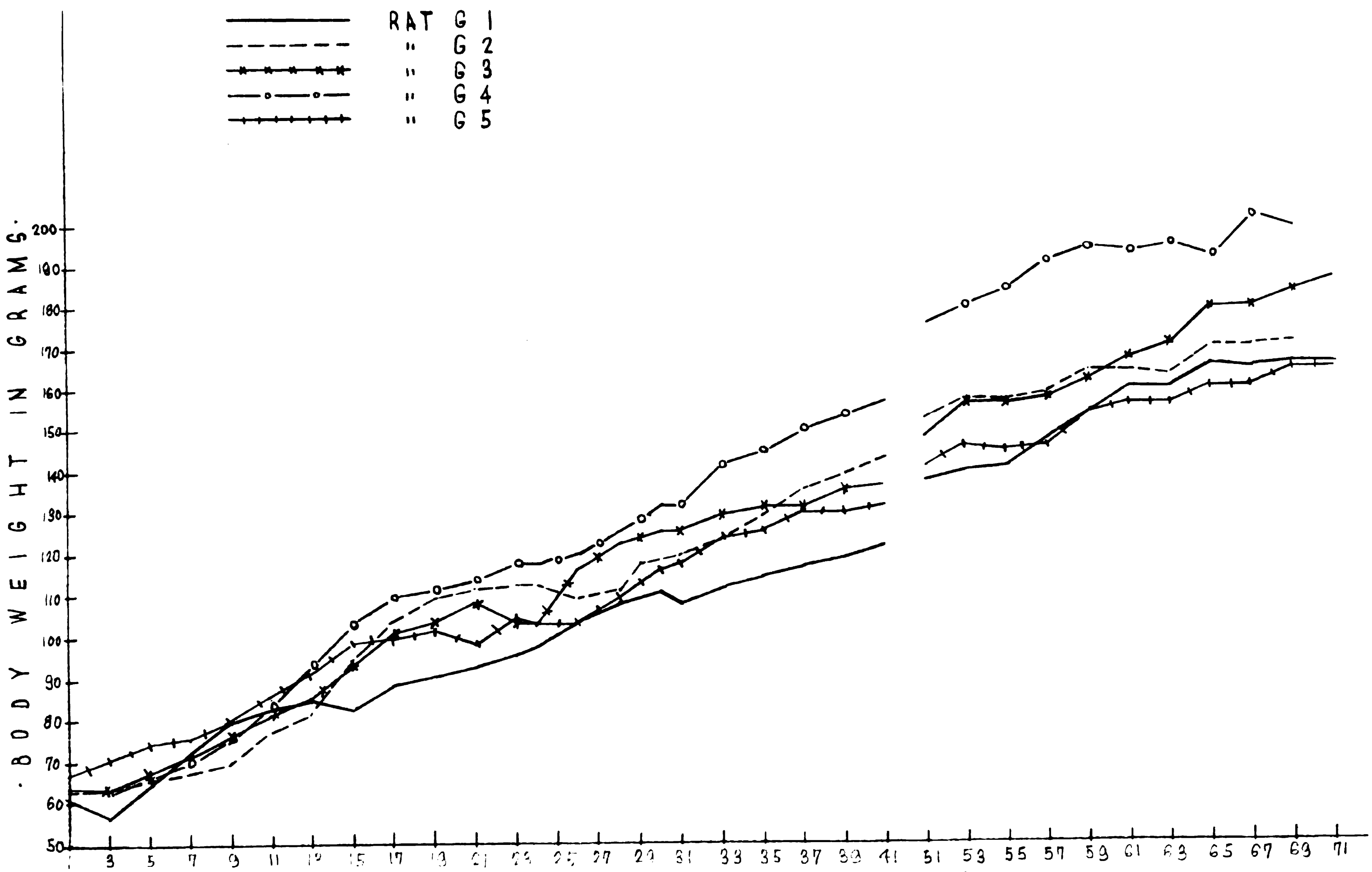
GROUP E

Figure IX. Growth curves showing weights of individual rats fed 6 percent mung bean protein, 2 percent rice protein, 2 percent wheat protein during the first diet series; 4 percent mung bean protein, 2 percent rice protein, 2 percent sunflower seed protein, 2 percent millet protein during the second diet series.



RAT F 1
" F 2
" F 3
" F 4
" F 5
DAYS OF EXPERIMENT.
GROUP F.
BODY WEIGHT IN GRAMS.

Figure X. Growth curves showing weights of individual rats fed 5 percent mung bean protein, 2 percent rice protein, 2 percent corn protein, 1 percent wheat protein during the first diet series; 4 percent mung bean protein, 2 percent rice protein, 2 percent sunflower seed protein and 2 percent sudan grass protein during the second diet series.



·DAYS OF EXPERIMENT·

·GROUP G·