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Expert Group Meeting on the Manufacture of
Proteins from Hydrocarbons

Vienna, Austria, 8 - 12 October 1973

THE SOCIO-ECONOMIC SITUATIONS IN DEVELOPING COUNTRIES AND POTENTIALS FOR THE PRODUCTION OF PETRO-PROTEINS[1]

M.C. Krishna*

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Dehra Dun, India.

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SUMMARY

THE SOCIO-ECONOMIC SITUATIONS IN DEVELOPING COUNTRIES AND POTENTIALS FOR THE PRODUCTION OF PETRO-PROTEINS [1]

M. G. Krishna*

The gap in world food protein supply, between the levels prevailing in 1970 and desired in 1975, is estimated at 18 million tonnes, corresponding to 400 million tonnes of all conventional food products. Over 80 per cent of this gap exists in most Asian countries. Conventional food sources drawn from land may be in short supply due to already high demand on land and investments required. Petro-protein can significantly help to fill the protein gap.

Work has processed in several countries on development of strains of yeasts and bacteria which can grow on hydrocarbon medium to yield edible protein concentrates. Although gaseous hydrocarbons are safer substrates, technological problems have not been yet solved. Gas oil and normal-paraffins are the preferred substrates now used in commercial plants, for which technology is well advanced. Problems in supply of n-paraffins could restrict growth of petro-protein manufacture since the

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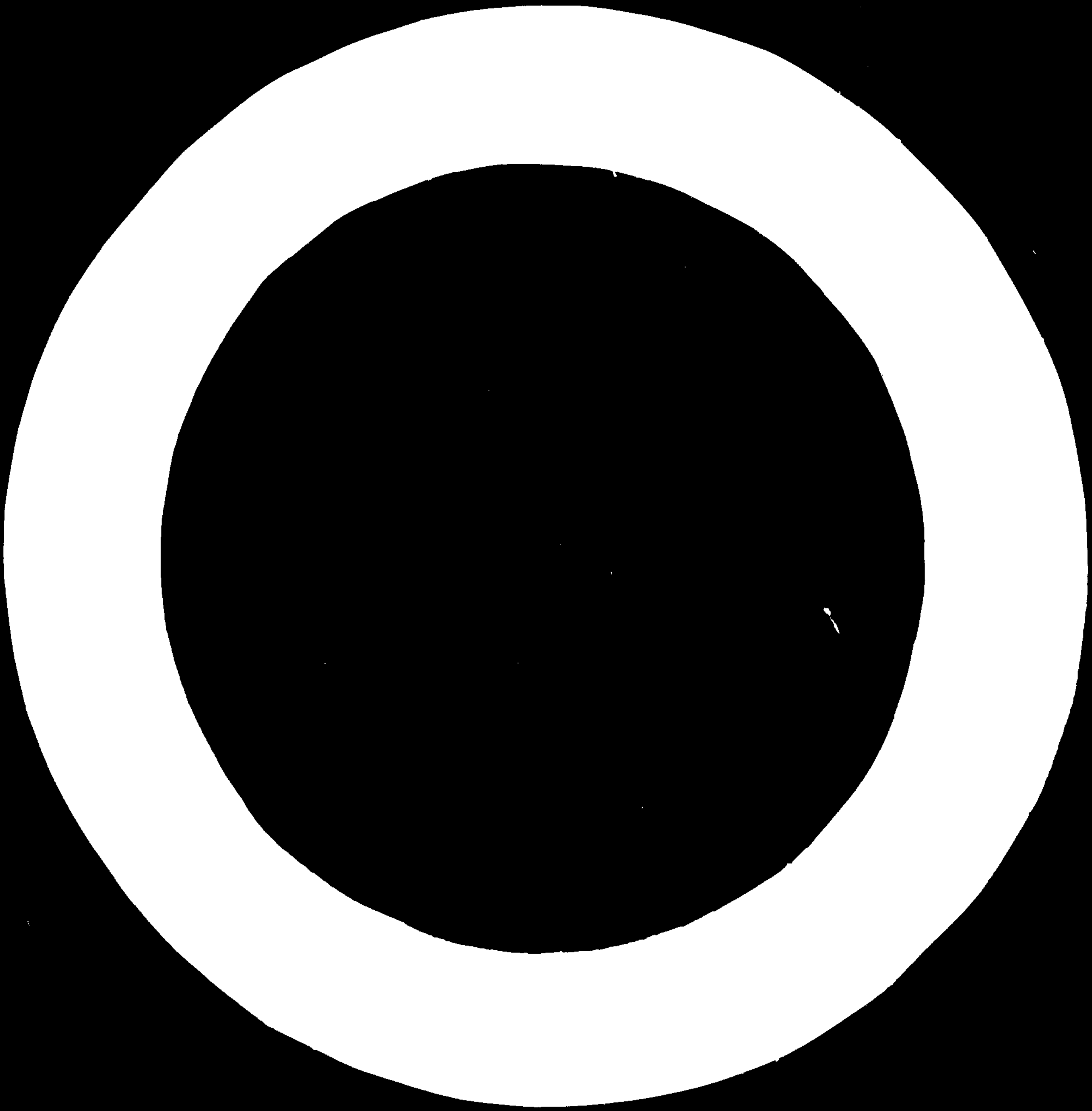
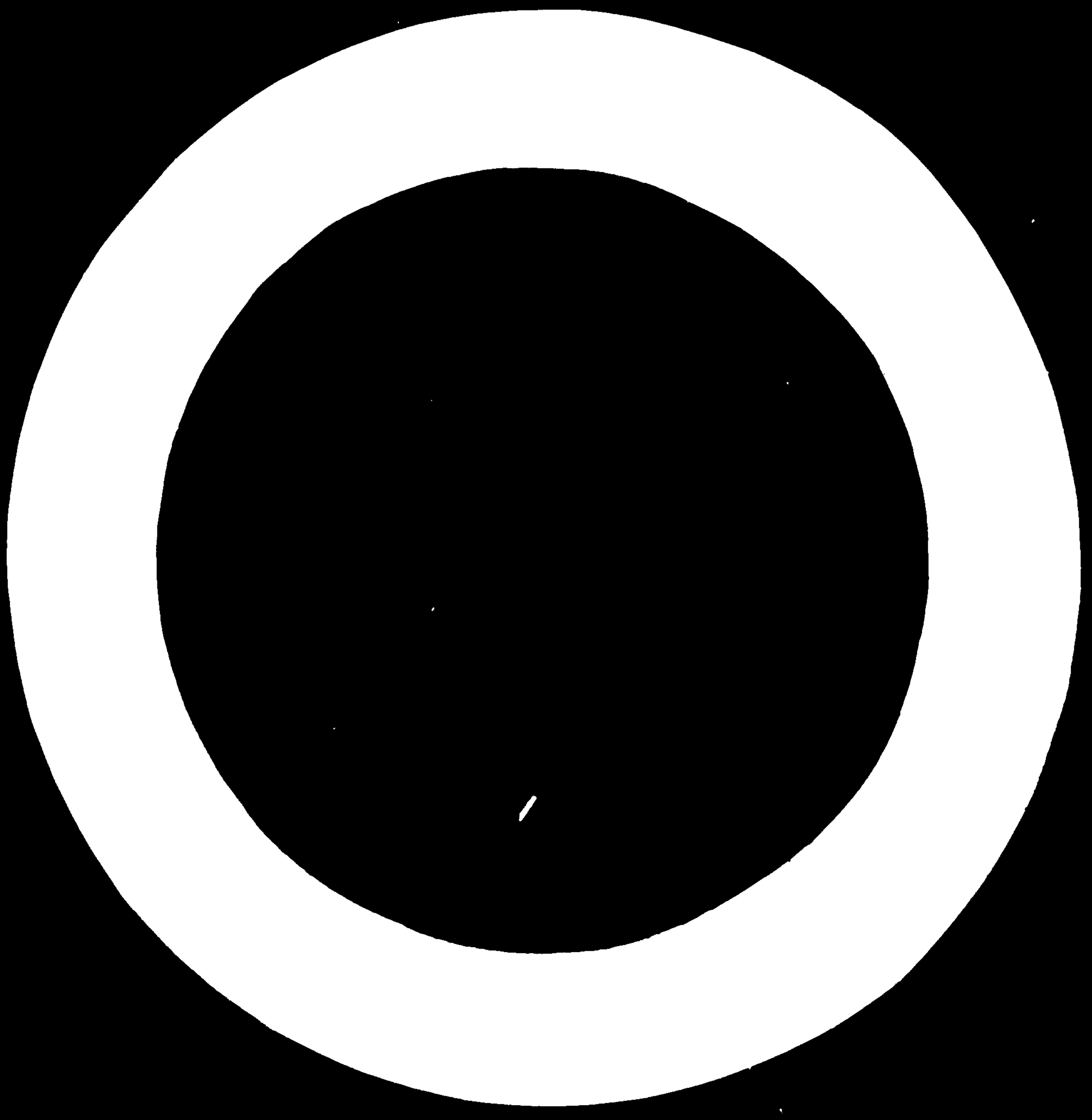


requirement of crude oil is 20-40 times (by wt.) that of n-paraffins and therefore petro-protein. Developing countries are increasing their indigenous refining capacity. It is possible to establish petro-protein plants in several developing countries provided crude oil is available in adequate quantities at suitable prices.

Marketing of petro-protein is feasible and has to account for traditional food tastes and habits and local prejudices. Governmental and institutional support is necessary.

Feasibility of installing petro-protein plants in India has been discussed.

R&D work progressing in India on petro-proteins is reviewed. The author has [illegible] to establish plants with a total capacity of [illegible] t/yr. [illegible] 1980.



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_/ Numbers in parentheses refer to the corresponding numbers in the reference list at the end of the paper.

EXPLANATORY NOTE

On page 2 of the above mentioned paper, the term "Socio-economic Development Index" was introduced and its calculation explained. Since submission of the paper, this author has come across a reference to exactly the same term on page 48 of the Eighth Report of Joint FAO/WHO Expert Committee on Nutrition, November, 1970. This author was totally unaware of this reference when he wrote his paper. However, the values of the index given in table 4 of the reference above and those used by this author in his paper (Fig.II), are totally different in magnitude and order with respect to various countries. The index is reported to have been calculated by the UN Research Institute for Social Development, Geneva, in July, 1970. This author is as yet unable to obtain the original reference and the factors incorporated in the index calculated by the UN researchers.

INTRODUCTION

Much has been written and spoken by renowned authorities in several countries and forums, particularly during the past decade, on protein-deficiency and protein-calorie malnutrition. It is therefore not proposed to repeat in this paper much from previous publications on the subject.

The damaging effects of undernourishment on human health in general, and more particularly on the growth, stature and body-build and mental capabilities, have been well-established. It is recognised that whereas caloric deficiency weakens the body in general, protein deficiency particularly impairs intellectual faculties and stamina. The latter, when persistent and wide-spread over a whole population, would seriously affect the social and economic growth of a nation. This could happen to a country as a whole or to sections of population in one country. Wide disparities in per caput protein availability exist not only between nations but also between sections of population within many nations.

This paper first discusses generally the position of food protein supply in developing countries in relation to the overall socio-economic national development. The extent of protein deficiency and the requirements to improve it are identified and an attempt has been made to quantify the additional requirements. Possibilities for the establishment of petro-protein plants in developing countries are discussed in relation to the refining capacity now existing in these countries. Possibilities for use of petro-proteins as food materials with reference to consumer habits are then considered. Market potentials for food_grade petro-proteins in developing countries are discussed. Possibilities of commercial manufacture and use of petro-proteins in India as a case are discussed.

I. PROTEIN DEFICIENCY IN DEVELOPING COUNTRIES

The subject title of this paper carries three key phrases/words which are: 'socio-economic situations', 'developing countries', and 'petro-proteins'. The former two need to be interpreted in relation to the latter, in the overall context of protein-deficiency in different parts of the world. The obvious implications are: that malnutrition due to protein deficiency is particularly wide-spread in developing countries; that socio-economic situations prevailing in these countries are responsible for the deficiencies; and that the deficiency could be corrected, partly at least through the use of petro-proteins. The first two implications need some elaboration because unless the present sources of food supplies are clearly appreciated, the relevance of petro-protein may not be brought into correct focus.

1. National Development and Nutritional Sufficiency:

The definition and meaning of the term 'developing country' are not constant although the broad meaning is generally clear and accepted. They at best connote a relative positioning of different countries in the overall spectrum of socio-economic development. This depends on the criterion applied to judge the state of development of a country (e.g. industrial growth, agricultural production, education, medical amenities; within industrial growth, food industries, mineral industries, synthetic polymer industries, etc.). What is the minimum necessary level of development in any sector above which a country can be deemed as developed? Need all sectors of the economy be developed to same level to achieve reasonable nutritional standards? This concept is not quite irrelevant if we consider the growing concern about environmental pollution which is interpreted by some as a possible result of 'over-development' or too rapid a development in certain sectors.

For purposes of caloric and nutritional needs, the basis of comparison of different countries needs further consideration. Generally, per caput national income is chosen as a basis. A plot of per caput national income (PCNI) against per caput food protein supply is shown in fig. I, for which data from UN publications$^{(1)}$ have been used for most developing countries having population of one million and higher and for about 15 developed countries. The following can generally be observed:

(1) no satisfactory or precise correlation among countries with comparable levels of PCNI;

(2) however, a broad correlation among groups of countries falling within different zones of PCNI;

(3) much wider scatter for African and Asian countries than for American and European countries.

Fig. I shows that PCNI cannot be considered as a true or sole indicator of protein-sufficiency of countries, although national income is derived from incomes from different sectors, including those contributing to food and nutrition. That is, income as such does not seem to be a satisfactory indicator. Other indicators of social progress have to be applied. With a view to improve the correlation, the term 'Socio-economic Development Index' has been conceived. It incorporates four factors as below:

$$I_{SD} = I_N \times E_e \times I_H \times P,$$

where,

I_{SD} = Socio-economic Development Index.

I_N = Per caput national income (US $).

E_e = Per caput expenditure on education per year (US $).

I_H = Index of health, as number of physicians available per 1000 population.

P = Net food protein availability per caput per day (gm).

As far as possible, consistent data for the years 1966-1968, published in UN Statistical Year Books 1970 and 1971 have been used to calculate values of I_{SD}. In view of the uncertainties in the reliability of data for some of the countries, the absolute values of I_{SD} ranging from 40 to over 100 million units for all countries, are not deemed equally accurate, but are adequate for purposes of broad comparison. A plot of I_{SD} against per caput protein supply (fig. II) seems to show a better correlation than mere PCNI. I_{SD}, incorporating indicators of development of education, public health and nutrition, more truly represents the overall socio-economic state of a country, although some individual cases show anomalies. No doubt, the correlation is likely to improve by using more reliable data for comparable periods. The plot essentially indicates that although per caput protein availability depends generally upon the level of overall socio-economic development of a country, it can be substantially improved at a given level of national development, by adopting social objectives, priorities and policies on food and nutrition, suited to local conditions.

Both the figures reveal some peculiar features:

(1) Most African countries have a generally higher level of protein supply than East Asian countries having comparable PCNI. They seem to depend very much on cereals, pulses and nuts for protein requirements, and partly on milk and much less on meat. This could also mean a better utilisation than in Asian countries, of per caput land

available for agriculture and crops. Higher protein supply has become possible despite the relatively low PCNI, probably due to traditional food habits based on local natural products. The lower I_{SD} values for these countries are subtantially due to lower number of doctors per unit population. Libya (No.9, fig. 2) had the highest PCNI in 1968 among African developing countries and also a very high doctor availability. Its protein availability might have improved since then.

(2) Comparing Libya (No. 9) and Yugoslavia (No.6), the latter has much higher protein availability, though with much lower PCNI; I_H value is also better. Kuwait (No.8) has a very high PCNI and good I_H. Its protein availability is assumed to be 65 in the absence of reliable data. If it is higher, its position in the figure will be among developed countries nearer the dotted line.

(3) France (No.2), New Zealand (No.3), Argentina (No.4), and Uruguay (No.5), are consuming much more protein than others with comparable I_{SD}. The pattern of their protein sources (table 1) is interesting. All of them consume large quantities of meat and milk or its products compared to others with similar I_{SD}. The values used for Japan are for 1968 and since then its position must have substantially improved due to rapid development.

(4) It appears that in countries with manageable levels of population, reasonable levels of per caput protein supply can be maintained despite lower PCNI, provided proper measures are taken to utilize land and livestock. The case of India with a very high population and low per caput land availability has

obvious problems, which will be discussed later.

(5) It therefore appears that food and nutrition can be maintained at reasonable levels in developing countries if they make this as priority objective and adopt suitable policies and methods, giving due importance to improving locally available foods. The latter aspect has been well explained by Dr. Michael Latham(2).

Table 1 shows the sources of protein in selected countries. Several countries have been able to maintain relatively high levels of protein supply through cereals, milk, pulses and nuts. In developing countries, meat seems to be in short supply, probably due to problems in rearing livestock and investments required for it. They depend more on cereals, pulses and oilseeds. Even milk supply is difficult because of inadequate animal nutrition and low milk production. There is heavy pressure on land from man and animal for their food requirements, particularly in countries like India, which has 548 million human beings and about 350 million herbivorous quadrupeds. This pressure has indeed other serious repercussions inasmuch as the large animal population resorts to uncontrolled grazing even on hill slopes, resulting in soil erosion, diminished forest lands and ~~f~~ domestic fuel supply and other interconnected damages.

2. Protein Deficiency and Needs to Decrease it:

Fig. 2 shows that most east and south-east Asian countries, excluding Japan, have been having per caput food protein supply below 50 g. per day, though countries in north and north-east Asia have a much higher supply. Their population in 1970 was 1876 millions, over 50% of world population. Middle-eastern and west Asian developing countries with a total population of about 80 millions in 1970 have about 57 g/day supply. Several African developing countries have also about 57-58 g supply and a substantial number has about 70 g supply. Among the Latin American and Caribbean countries with over one million population each, about 10 countries have a supply of about 50 g per day and the rest have a supply between 60 and 70 g/day. Smaller countries in other parts of the world have not been covered in this correlation plot.

The minimum dietary protein requirements have been recommended and periodically revised by various bodies. These have been critically evaluated by Swaminathan and Parpia(3,4,5). These authors have suggested(5) daily protein requirements separately for developed and developing countries (tables VIII and IX of reference). The dietary protein requirement varies from 30 g/day to 92 g/day (at NPU = 50) depending upon age and sex. For male adults the value is 54 g/day. The national average would depend upon population distribution by different age groups, sex, pregnancy, etc. The daily per caput requirement of children and normal females is lower than for adults. In India, for example, the requirement for adult male is placed at 55 g/day and the national average at 44 g/day(6). The availability on a national average in 1970 was reported as 49 g/day per person. This seems an unrealistic value because the availability is not uniform and it is well-known that a large part of the population suffers from protein-calorie malnutrition. Such situations can be expected to prevail also in most other developing countries. Therefore, for purposes of estimation, a safe margin of national average has to be assumed to compensate for uneven supplies. For a country like India, a value of 60 g/day per caput has to be assumed, for say, 1975 if a more even supply can be ensured by then. This is comparable to the lower level protein requirement estimated for India for 1970 by the Panel on World Food Supply for the U.S. President(7). Similarly, considering minimum human requirements, it may be assumed that all east and south-east Asian developing countries may require 60 g/day per caput. This may be assumed for the less nourished middle eastern countries also. In the case of developing countries from other regions, those which have about 57-58 g/day may be assumed to increase it to 65 g/day and others having about 70 g/day to raise it to 75 g/day.

The approximate additional food protein requirements by 1975, assuming that the range of values in fig. 2 applied for 1970 and that the population would increase by about 10% between 1970 and 1975, are given in table 2 and total to over 18 million tonnes in 1975. Assuming that a total of about 1000 g/day of all food materials in different forms would be needed to provide the daily caloric and protein requirement in each country, about 300 million tonnes of additional food materials have to be made available in the developing countries of Asia, Africa and Americas in 1975 over 1970. This is for actual consumption; providing for losses, stocks, etc., the quantity may be above 400 million tonnes. The bulk of it would be required in east and south-east Asia where land is already nearly fully cultivated within the available resources. It is to be noted that this quantity merely represents a total of all food materials. The quantity of each type (cereals, pulses, meat, milk, etc.)

required to be produced would depend upon the pattern of protein source distribution, which in turn would dictate the magnitude of investments and efforts required.

3. Alternative Source: Petro-Protein

Man derives all his food from plants and animals and not directly from land and water. Ultimately all forms of life have to depend upon available land and water for their food and other necessities. The cycle of inter-dependence among the different components of the total ecosystem is well-known. Considerable progress has been made in many countries to increase the yield of crops per hectare through the use of better land and water management, fertilizers, pesticides, high-yielding varieties of seeds, multiple cropping techniques, newer hybrid seeds, etc. Much still remains to be done and the need for intensification of these efforts has been discussed in specialized studies(8). These efforts make use of soil depth to the extent that vegetative growth is facilitated by soil microorganisms. There is as yet no indication of any discovery which can make use of greater depths in the soil for simultaneous growth of vegetable foods at the top as well as at depths. Efforts are already being made all over the world on the intensive use of marine and inland aquatic areas for growth of fish to supplement human food. Several other sources of additional protein, as single cell proteins such as algae, and multicellular such as microfungi have been under study.

It therefore appears logical that any new source of protein to meet human needs should have as its main aim the reduction of pressure on land. So far,man (or animal) has not drawn bulk of his food from minerals excepting salts as nutritional supplements. Cultivation of proteinous material on hydrocarbons would be a step in this direction. Ideally, such protein should be edible directly as human food so that pressure on land for additional protein is reduced. If this is not possible, the next best method would be to feed it to animals to augment milk and meat supply and also to poultry. Obviously, it can only be a supplement to the main sources of food which are essentially vegetative in origin.

Much literature has been published during the past decade on the possibilities of producing edible proteins by fermentation of petroleum hydrocarbons. Iyengar has made an exhaustive review of the literature up to 1971 in his report to the UNIDO(9). The quality of the petro-protein in regard to its amino acid composition and acceptability results have been repeatedly quoted by several agencies. There can be no doubt on its nutritional quality. Doubts however persist on its toxicity although no publications have appeared either on toxic effects of petro-proteins in feeding trials or on the quantities of carcinogenic compounds actually identified in petro-protein samples prepared by claimant organizations. Nevertheless, concern has been expressed in some countries periodically. As a result of objections from consumer organizations in Japan and a movement by 'Liaison Council to Ban Petroleum Protein', three companies in Japan have 'abandoned' or 'suspended' their commercial projects for petro-protein inside Japan but said they would continue promotion of their product and technology in other countries(10). This is a major and only setback to petro-protein development in the world. It is, however, understood that the two plants of the British Petroleum Co. of UK and France which have been commissioned(11,12,13) are in operation and plans are being continued for a large plant in Italy(14). Although precise information has not been published if any other large capacity pilot or other plants are operating in other countries, the USSR appears to be operating fairly big size plants for several years(15).

II. POSSIBILITIES FOR THE ESTABLISHMENT OF PETRO-PROTEIN PRODUCTION FACILITIES IN DEVELOPING COUNTRIES.

The discussion in Chapter I has shown that petro-protein can be a supplemental source of food protein supply in the world. This Chapter discusses possibilities for the establishment of production facilities, particularly in developing countries. Although the common and general features can be covered here, each country has to assess the local availability of all the plant requirements.

1. Raw Materials

Several microorganisms have been known to selectively utilize normal paraffinic hydrocarbons as a source of carbon in their metabolic process of reproduction. The main raw materials in the fermentation of hydrocarbons are: cultures of micro-organisms such as yeasts and bacteria, hydrocarbons and nutrient compounds.

Cultures

Several cultures have been proposed and tried and are being identified for use in hydrocarbon fermentation. It appears that candida species of yeasts are being preferred in the pilot and commercial scale plants. Many workers seem to prefer bacteria (e.g. Pseudomonas aeruginosa, Micrococcus cerificans etc.) in view of the high protein nitrogen content in the finished product. Yeast protein is however accepted as a better protein. It is very desirable to collect, identify and cultivate the desired strains from local soils in contact with petroleum hydrocarbons, even if a start is made with imported cultures. The cultures reported in many patents, operating conditions used and results obtained have been exhaustively reviewed by Noyes(16). Since most developing countries in Asia have relatively higher ambient temperatures, it is desirable to use thermophyllic strains. The main problem in the selection of strains has been their stability and purity during continuous fermentation. Most cultures do very well in batch fermentation but undergo undesirable changes over long periods. This problem appears to have been almost solved relatively recently.

Hydrocarbons

Several hydrocarbons from methane to waxes have been tried for fermentation. The most successful substrate so far appears to be in the range C_9 to C_{30} alkanes and preferably a fraction of C_{13} to C_{19} alkanes. Many researchers have succeeded in the use of methane, ethane and propane and their mixtures with a view to utilize ultimately the natural gas feedstocks. This feedstock has the great advantage of freedom from aromatic hydrocarbons which is considered undesirable for fermentation as well as for product quality. The range C_4 - C_9 does not appear to have proved useful. It is also a costly fraction in view of its use in motor gasoline production.

The most commonly used substrates are gas oils and n-paraffins separated therefrom. Although hydrocarbon fermentation was started and extensively done using gas oil, n-paraffins separated from gas oil and further purified to remove aromatic hydrocarbons, are now most commonly used. Separation of n-paraffins is affected by urea adduction or adsorption on molecular sieves. Molecular sieves of suitable quality useful for treatment of gas oil have been of recent origin, although they have been available for several years for treatment of kerosine and naphthas. Several commercial processes using 5A type molecular sieves are available for n-paraffin separation.

Separation of n-paraffins from kerosine and gas oil is not normally required to be done in a petroleum refinery producing fuel products, unless it is also connected with production of petrochemicals like synthetic detergents. This would be more true in developing countries whose basic necessity is an indigenous refinery for fuels. Therefore, developing countries interested in establishing petro-protein plants have to either use straight-run gas oil as substrate or establish paraffin separation units attached to existing refineries or import n-paraffins.

Many developing countries having their own refineries, particularly in Africa, have relatively small refining capacities to meet local and neighbouring needs. This is clear from table 3 which gives the number of refineries and their capacities in the developing regions. Most of the smaller refineries would find it difficult to sustain small size paraffin separation plants unless heavily subsidised. On the other hand, if petro-protein is considered a priority product under local conditions, it might be possible to subsidise production of n-paraffins by raising the prices of fuel products. In fact, removal of n-paraffins from gas oil within limits helps to reduce pour point and improve pumping characteristics in cold climates. Too much removal of n-paraffins adversely affects the smoke point of kerosine and cetane number of gas oil. Thus, depending upon the chemical composition of the crude oil, only about half of the n-paraffins can be removed.

Data on n-paraffin contents in different crude oils are not easily available. Tables 4 and 5 give n-paraffin contents of kerosines and gas oils respectively from some Indian and middle-eastern crudes being processed in India. Except in cases of highly paraffinic crudes, it would not be desirable to remove more than perhaps 50% of the n-paraffins present in the total cuts. Alternatively, a part of gas oil or kerosine can be fully deparaffinized and blended with the untreated cuts to maintain the required quality of fuel products. This approach is more economic. It is therefore necessary that each developing country evaluates its crude oil and cuts to assess the potential availability of n-paraffins. This study would be necessary even if one wants to use gas oil as such as substrate.

Purification of n-paraffins after separation is being considered essential, to reduce the aromatic content to below 50 ppm, which is achieved by oleum treatment.

Other raw materials

The most important other raw materials used in the process are ammonia and its salts and other mineral nutrients. These will have to be procured from outside. The composition of the mineral nutrient mix depends upon the strain. Typical compositions have been mentioned in patents and reviewed by Noyes(16).

2. Utilities

Air, power, cooling water are the important utilities required. All the oxygen for fermentation has to be supplied through air or oxygen enriched air. Since hydrocarbon forms an immiscible phase, oxygen transfer rate becomes very important. Improvement of this rate is sought to be achieved by blowing air through a sparger under pressure in a suitably designed fermentor or by agitation. Part of the power requirement is for compression of air, and rest for other process steps. Hydrocarbon fermentation is quite exothermic (about 7500 kcal/kg of product) and quick heat removal is very essential. Cooling water requirements are therefore quite high.

Requirements of utilities for a typical plant are given in table 6. It is presumed that petro-protein plants would be located near a refinery from which utilities can be procured.

3. Personnel

Training of operating labour would not be a difficult problem in most countries in view of efforts being made for industrialization. Training of qualified persons for quality control is essential.

4. Organizational

Manufacture of petro-protein is a truly interdisciplinary project and is best undertaken as a joint venture between refining and food processing industrial organizations. At least, closest collaboration between them should be ensured. Manufacturing and marketing experience of each should be pooled to ensure success. Marketing experience would become particularly important if the product has to be used directly for human consumption but not so much for animal consumption. In either case, however, close working liaison with institutions and officials dealing with nutrition (human and animal) and public health is essential. If these institutions are not already existing, they may have to be established by the governments. Many experts in the field seem to feel that marketing of protein-foods is best done by private food industry sector drawn from within or abroad(17). This is an issue of national policy and would have to be decided by each nation for itself.

Much of the manufacturing knowledge in the field of petro-protein is covered by a large number of patents and these have been listed by Noyes(16) and Iyengar(9). Since most developing countries have to import the technology from developed nations, licence agreements become necessary. It is however desirable to study ways and means of minimising such necessity and avoiding possible restrictive practices, since the subject is an intensely human issue, with the aim of alleviating human suffering and hunger. The United Nations and its organizations may need to play an active role in dealing with the whole subject of protein foods manufacture, in addition to its present laudable efforts on food, nutrition and world health.

III. POSSIBILITIES FOR USE OF PETRO-PROTEINS

It has been stated earlier that petro-proteins can be used, theoretically, either as direct human feed or as animal or poultry feed.

1. Direct Human Feed

Much data has been repeatedly published on the nutritional quality of petro-protein over the past eight years. It is widely accepted that petro-protein is at least as good as the best oil seed protein and comparable to several high quality animal proteins in regard to digestibility and protein utilization, particularly when supplemented with some methionine which seems to be lower than in the FAO standard protein. Efforts are continuing to develop strains to give a product with higher methionine content. Bacteria grown on methane and paraffins are found to be better in this regard.

Considerable work has been done on animal feeding trials and toxicological tests. All published results have given favourable reports on the acceptability of the product. Nevertheless, there is stiff resistance to the idea of starting the use of petro-protein as direct human feed. The main reason is the fear of possible presence of carcinogenic compounds in the product, although none of the existing highly refined techniques could identify any aromatic compounds in a well prepared product. A stage has been reached when developing nations which face the immediate problem of malnutrition and hunger, have to question whether they can afford to continue to share the refined doubts of the better-nourished sections of populations and whether a well-prepared petro-protein is anywhere near the carcinogenicity caused by cigarettes and many other symbols of civilization and modernity. The problem of developing nations is more of today than of long range posterity.

2. Animal Feed

Feeding trials have been made in various countries on petro-protein samples, using rats, pigs, fish and chicken. Feeding studies have been made at the Central Institute for Nutrition and Food Research, (TNO), Zeist, The Netherlands(18) for one year duration using yeasts made by B.P. from gas oil and n-paraffins. Feeding upto 30% dietary levels have not revealed any deleterious effects. Subsequent studies for two year periods are also understood to be satisfactory. Longer duration tests have also been taken up. Tests in USSR have also established the safety of petro-proteins as animal feed materials. In Japan, petro-protein samples prepared by four producers (apparently on pilot plants) have been tested on rats, pigs and chicken and no toxicity, genetic or otherwise, could be observed in first and second generation chicken(19). More recently, the digestibility of nitrogen, amino acids, lipids, carbohydrates and other constituents of yeasts grown on n-paraffins was studied by feeding colostomyzed laying hens(20). The authors found mean true digestibility of the protein to be 90.7% and that of amino acids (except cystine and Tryptophan) 90-96%.

No field tests on animals using petroleum yeast have been reported in developing countries, although there have been news items that some feeding trials were conducted in Africa. It would appear that unless product of reliable quality is consistently available over long periods large scale field trials and regular animal feeding programmes, as a socially acceptable practice, may not be possible. The product must outgrow its present experimental status. The scale of production is not so important as long as the product is adequate for wide-spread feeding programmes.

3. Feeding Methods

The market success of any high-protein food additive depends very much on consumer habits. Laboratory feeding studies ensure that the additive is administered through a food normally acceptable to the test animal. The higher the evolutionary level of the test species (man or animal), the more selective they become in their food preferences. The most diverse and unmanageable is perhaps the human taste. The importance of adequate appreciation of consumer psychology in achieving successful marketing of high-protein foods has been very well discussed by Samuel M. Weisberg in a recent article(17) illustrating with several specific products based on oil seed and milk proteins and also earlier in a study by a batch of Graduate students at the Harvard Business School(21). The same subject in a more general context and also role of religion in food habits have been discussed by Lowenberg et al.(22) Even some animal feeding habits are guided to some extent by religious views of populations.

Developing countries generally, and perhaps of necessity, have more traditional food habits, essentially based on food materials as naturally available. This appears more true for staple diets which have deep sentimental attachments. Therefore, any food additive must be capable of being administered through local foods in a locally acceptable form. The Indian case will be discussed later. For animal as well as human feeding, mixing with wheat flour and oil seed flour might be the best method for several years to come. The next best method would be in the form of prepared foods for human beings like other high protein foods. For animals, the safest may perhaps be in the form of a liquid concentrate which can be added to drinking water.

IV. MARKET POTENTIALS FOR FEEDING GRADE PETRO-PROTEIN

The need to increase food protein availability has been discussed in Chapter I and the approximate quantitative requirements have been mentioned in table 2. Taking the case of Asia where pressure on land appears highest, the increase corresponds to about 20 g/caput/day. Assuming that only 5 g/day/head is in the form of petro-protein, the total for Asia (excluding Japan) would be nearly 4 million tonnes per year. This would mean about 40 plants of 100000 tonnes/yr capacity. The same per caput rate would need about 5 plants of this size for African developing countries.

These estimates are on the basis of human requirements. If animal feed is to be considered, so that additional animal products would meet the increased human requirements, then the efficiency of conversion in the animal to a useful product has to be applied. The requirement may be 4 or 5 times the direct human requirement. This would depend upon the animal and poultry population in each country. It is therefore safe to assume that adequate market exists for petro-proteins even if the level of petro-protein is much less than 5 g/day and even if other food materials are substantially increased.

The major problem however is likely to be availability of n-paraffin feedstock combined with the assured high prices of crude oil in future. For example, one million tonnes of n-paraffins, to produce an equal quantity of petro-protein, would need 20 to 40 million tonnes of light Iranian crude oil to produce adequate kerosine or gas oil for production of n-paraffins. This quantity means a refinery with a capacity of 400,000 - 800,000 barrels per calendar day. There are only two refineries of this magnitude among all the developing countries of the world. The investments required for n-paraffin separation plants are also likely to be excessive. The targets would therefore have to be much more modest, not because of shortage of market but due to problems in hydrocarbon supply. This brings into focus the necessity for developing a suitable culture and process for using gas oil and kerosine directly as substrates and for making a more realistic appraisal of the probable damages to human and animal health from petro-protein grown on gas oil. Further, increasing sulfur content of crude oils would raise the cost of deparaffination but is not reported to be harmful to growth of yeast.

Assuming therefore that adequate n-paraffins would be available at reasonable prices, steps should be taken to introduce the product in the market even on basis of pilot scale operation. The market in general is hearing about the suspicions on possible toxicity more than gaining experience in the use of the product and facing market problems. If it is to be used for human consumption, the methods of publicity and marketing used for high protein foods based on oilseeds and milk products have to be applied. In areas where cereal flours (e.g. wheat) are regularly manufactured and marketed, petro-protein can be mixed with flour before distribution. In rice-eating areas, admixture is not practicable and mixing with secondary foods has to be considered. The most effective way of marketing appears to be through institutional channels, i.e. schools, community centres, hospitals, etc., so that the most needy will receive the product first. Since the poorer and younger sections of the population are more undernourished, marketing network has to penetrate to interior of rural areas and to poorer colonies in big cities where undernourishment is maximum. The normal advertising techniques used in advanced countries are not likely to be useful in rural areas of poor countries. Marketing should, of course, be supported by proper publicity through media effective among poorer sections. The most important question may be the cost of the product, even if it is very low. People who cannot afford even one square meal would not purchase anything.

Possibility of free supply with governmental backing has to be seriously considered. Its supply may have to be considered a social cost on the more nourished section of the population. If the product does not reach the really needy people, it will remain a fashion of the rich, making them 'overnourished'.

V. POSSIBILITIES FOR THE COMMERCIAL MANUFACTURE AND USE OF PETRO-PROTEINS IN INDIA- CASE STUDY

1. Land and People

India is the second most populous country in the world, with a density of 178 persons per sq. km. Some basic data on India are given in table 7. Total agricultural land is about 54% of total land area and forests occupy only about 20% of the area. If food production has to be increased to meet the future caloric and nutritional needs, there is very little scope to increase agricultural land except by encroaching on forest areas in plains and on hill slopes. Attempts are therefore being made to increase food crop yield per hectare.This requires additional investments for high-yield seeds, fertilisers, pesticides, irrigation facilities, etc.

2. Protein Deficiency

About 220 million people are officially estimated to live below the minimum levels of consumption. Production of food grains, oilseeds and other food products is shown in table 8. Per caput production of food grains was 540 g/day, in 1971 and some of it is lost in handling, storage, etc. The pattern of consumption (table 9) shows that average cereal availability including sugar, is 441 g/day. Obviously, the undernourished 220 million people would be consuming much less than the average values. Table 9 also shows the varying consumption pattern of a few tribes of India. Tribal people in Andaman islands, about 18000 in number, enjoy the highest nutrition, living on meat, vegetables and honey. Though the tribal people live generally on local natural foods, some of them have nutritional levels well below the minimum needs.

Even among non-tribal population wide variations exist. Assuming that about 30 million tribal people are severely undernourished, about 190 million non-tribal people must be also undernourished. If per caput protein requirement of 220 millions is to be raised from, say, 35 g/day to the current all-India average of about 50 g/day, the additional food protein requirement would be about 1.2 million tonnes per year. If one-third of this increase (5 g) is to be derived from petro-protein, as discussed earlier, 400,000 tonnes of it has to be produced. The rest of the 330 million people of all age groups are obviously having a higher level of protein supply through the more sophisticated and conventional foods.

The foregoing calculation is made only to show the magnitude of the need in India with its large population, low land availability and diversity in living conditions. Table 8 also shows production of protein-rich foods in 1971. Although the protein contents of some of them are much higher than normal foods, the quantities are so small and price levels such that most of them are available only to the richer sections or through institutional supply.

It can thus be seen that petro-protein can play a very significant role in India as a supplemental protein source. It would be ideal if it could be directly used for human feeding, if only because it would avoid intermediate stages of price scale-up and distribution problems.

3. R&D Work on Petro-Protein in India

Two research institutions, the Indian Institute of Petroleum (IIP), Dehra Dun, and the Regional Research Laboratory (RRL), Jorhat, have been directly working on the project for the past 8 years. Both the institutions, functioning under the Council of Scientific and Industrial Research of India, collaborate in their work. The IIP, additionally, has direct collaboration with the Indian Oil Corporation Ltd. (a Govt. undertaking) in India and the Institut Francais du Petrole in France. Both IIP and RRL further collaborate with the National Institute of Nutrition, Hyderabad, and the Central Food Technological Research Institute, Mysore, for acceptability, nutritional and toxicity studies.

3.1. Work at IIP: The IIP has been operating a pilot plant (50 kg/day) for several years, first at its main laboratories at Dehra Dun. It was shifted to the Gujarat Refinery at Baroda in 1969 and was later supplemented by a normal paraffin separation pilot unit. Figs. III and IV show two views of the pilot facilities at Baroda. The IIP has concentrated its work to study process conditions, reactor performance in relation to design, separation of yeast cream and purification, control of yeast cell quality and growth and more recently on separation of n-paraffins by urea adduction and their purification. Under the collaborative programme, the microbiological work of identifying and developing new strains is mostly taken up at RRL-Jorhat. Only limited work on cultures is taken up at IIP.

Most of the fermentation work has been done using Candida lypolytica. For the past two years efforts have been concentrated on conducting long duration experiments. A few yeast strains collected from the local refinery soil, and belonging to the specie Candida tropicalis have been subjected to long duration trials. Table 10 shows data on a typical continuous run upto 4000 hrs. which is still continuing. The nitrogen content in the cells maintained at 8.1-8.2% throughout. The run could be continued without any operational problems even at temperatures upto 37°C. The results from the batch reactor will be transferred to the air lift fermentor pilot unit. The continuous runs proved the good stability of the yeast strain under operating conditions. Normal paraffins separated from gas oil are being used as substrate in all the current studies, although earlier studies have used gas oil. The major part of it is in the C_{16}-C_{23} range. IIP has developed a method(23,24) for separation and purification of yeast cream by treatment with a mixture of acetone and petroleum ether. Use of acetone left a residuary odour on the yeast. Isopropyl alcohol was successfully used replacing acetone to give a good product. Use of n-paraffin substrate avoids necessity of solvent treatment and ensures higher purity of yeast.

As a part of the collaboration between IIP and Groupement Francais des Proteines and IFP, the pilot plant at Baroda is being expanded to include better facilities, including a spray dryer. The new facility is expected to start in two months.

The amino acid composition of the IIP yeast has been reported earlier(9). The product had 1.7% methionine and 7.1% lysine contents. The Central Food Technological Research Institute (Mysore), India, tested the IIP petro-protein(25) and found that its PER could be raised very significantly by supplementation with methionine.

Most of the fermentation work of IIP is not published.

3.2. Work at RRL, Jorhat: The work at RRL has been covered upto late 1971 in detail in the report by Iyengar(9). Since then, the RRL has published several papers on utilization of hydrocarbon by Pseudomonas sp.(26), and Saccharomyces fructum(27), isolated from oil fields of Assam State; nutritive value of yeast grown on gas oil(28) and on a kinetic model for microbial growth on solid hydrocarbons(29). It has standardised the process using Endomycopsis lipolytica, Y-13A, isolated from the soil of the local oil fields and gas oil as the substrate. A dilution rate of 0.1-0.2 hr^{-1} is maintained, achieving a stable propagation of cells with a concentration of 10-15 g/l dry wt.

3.3. Feeding Trials: No large-scale feeding trials have yet been undertaken in the country. These will be taken up as soon as continuous production of consistent quality product on an adequate scale is established, which is expected by the end of this year. Cattle feeding trials should be aimed mainly to increase per caput milk yield to meet the general sentiment of the public. Table 10A shows possible feeding methods.

4. Possibilities of Commercial Plants

The present refining capacity in India is about 22 million tonnes per year. Present estimates based on restricted petroleum demand would need refining capacity to increase to about 32 million tonnes by 1978. An earlier estimate for 1980 was about 49 m.t. and for 1984 about 68. Due to curbs on demand for products, the capacity in 1984 may only go upto about 50 m.t. About 5 m.t. of this has upto 8% n-paraffin content in gas oil cut and 16% in kerosine. Assuming that half of the n-paraffins in gas oil is recovered, about 200,000 tonnes would be available. Crude oil from eastern India contains much less n-paraffins. In any case, Indian crude reserves are limited. Use of natural gas, whose reserves are much larger, has to be explored. The technology for this is not yet adequately developed. Considering all these factors, one or two plants with a total capacity of 100,000 - 120,000 t/yr petro-protein product upto about 1980 may be a realistic possibility.

Estimates of investment for commercial plants are likely to be unrealistic at this stage of development and with rising costs all over the world. The estimates given by Iyengar in his report to UNIDO in 1971(9) are still valid (tables 30, 44 and 45 of his report). According to him, a 50,000 t/yr plant would cost between 15 and 25 million U.S. dollars, depending upon the substrate. A 600,000 t/yr plant using gas oil is expected to cost about $ 67 million for equipment. The cost of final product is estimated at 37 to 57 ¢/kg. depending upon capacity and substrate. Approximate costs of protein from various sources are compared in table 11. Even if the cost of petro-protein yeast doubles, it compares well with many other sources. The rapidly rising crude oil costs may inhibit the development of petro-protein industry unless an entirely new pricing system is evolved.

VI. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions:

This study on needs for food protein requirements in the developing countries shows that there is a big gap to be filled. As years pass the gap is likely to increase due to expected rise in population. The world requirement in 1975, in addition to the food protein available in 1970 is about 18 million tonnes which corresponds to about 400 million tonnes of additional conventional food products. Asia has the biggest gap - about 15 million tonnes of food protein, corresponding to over 330 million tonnes of food products. These supplies will be necessary to raise the per caput daily supply of food protein to 60 g in Asia and 65-75 g in rest of the developing world.

Populations in developing countries depend heavily on cereals and to some extent on nuts. Milk and meat consumption is not adequate.

Petro-protein can be used to significantly augment food protein supply for animal feeding and also for direct human feeding. This would greatly help to relieve pressure on land which is already severe in most Asian countries.

Supply of raw materials- particularly pure n-paraffins, may become a more serious constraint than process technology, on the growth of petro-protein industry. One million tonnes of petro-protein would need about 20-40 million tonnes of light Iranian crude oil to produce adequate gas oil for the process. Due to problems of logistics and refinery capacities petro-protein plants of 100,000 tonnes/yr may be about the largest size to be set up in developing countries.

Although experience on the only commercial plant in the world is not yet adequate nor published, available information shows that problems in process control and plant design are reasonably near solution. A stage has been reached where quick commercialization is possible if a realistic view of product acceptability and quality is taken.

Marketing of petro-protein has to take into account the traditional food habits of populations in developing countries. The product has to be marketed mostly in admixture with cereal flour. The methods will vary from country to country. No special problems are envisaged in marketing petro-protein except to overcome the general belief that all petroleum products are non-edible. The best way to market the product to the really needy sections of populations would be through institutional mechanisms.

2. Recommendations:

2.1. Developing countries should take more active interest in the potential use of petro-protein and take, in advance, steps to apprise the public about the true quality of petro-protein so as to prepare a less biased market to receive the product. This needs time and institutional organizations.

2.2. There is need to devise ways and means even from now, to avoid stiff terms, in licensing agreements normally used for sale of technology and avoid possible restrictive practices. If possible, patents should be avoided in the development of petro-protein technology in all countries.

2.3. The United Nations may take suitable steps to bring about an agreement among nations and companies to acquire and pool the available knowledge on a more open basis, with a view to ultimately establishing petro-protein plants in developing countries under the auspices of the UN, with the cooperation of the governments.

2.4. In view of the trends in production, supply and pricing of crude oil in the world, possibilities may be explored to obtain concessional prices to the part of crude oil used as feedstock to produce petro-proteins. The UN may use its good offices in this regard.

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Table 1 - AVAILABILITY OF MAJOR PROTEIN SOURCES IN SOME COUNTRIES
(gms per caput per day)

	Cereals (as flour)	Pulses, nuts etc.	Meat	Milk	Protein
1. **Newzealand**	221	10	305	740	106
2. **Australia**	221	12	300	640	106
3. **Uruguay**	260	8	340	581	106
4. **France**	225	14	255	630	104
5. **Argentina**	273	9	322	337	103
6. **Canada**	185	10	253	662	97
7. **U.S.A.**	178	23	302	660	97
8. **U.S.S.R.**	428	19	106	475	92
9. **Yugoslavia**	514	26	93	281	91
10. **United Kingdom**	202	18	205	595	88
11. **Spain**	242	32	120	311	84
12. **Switzerland**	215	21	182	619	84
13. **Turkey**	474	35	39	219	78
14. **Egypt**	600	32	35	120	76
15. **Zambia**	466	60	33	49	73
16. **Ethiopia**	440	61	53	65	72
17. **Upper Volta**	449	77	21	42	70
18. **Kenya**	377	71	55	102	68
19. **Libya**	342	21	66	153	60
20. **Iraq**	317	16	45	148	58
21. **Sudan**	282	23	52	286	58
22. **Saudi Arabia**	412	17	32	94	56
23. **Iran**	362	13	37	164	55
24. **Togo**	247	65	25	7	51
25. **India**	370	49	4	116	48
26. **Indonesia**	306	34	11	3	38
27. **Zaire**	86	32	31	10	33

Nos. 2, 8, 13, 15-18, 20-24, 26, 27 are for the years 1964-66.
Nos. 1, 2, 6, 7, 9, 10, 19, 25 are for the years 1968-69.
Nos. 4 for 69/70; 5 for 67, 11 for 68/70, 12 for 67/68, 14 for 66/67.

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Table 2 - Additional Food Protein requirements for some developing countries in Africa, Asia and Latin America.

Region	Population (millions)		Food Protein Availability (av. per caput, g) (b)		Increase between 1970 and '75 (million tonnes)
	1970	1975(a)	1970	1975	
Asia (East and South-East excl. Japan)	1876	2064	44	60	15.073
Middle East	80	88	55	60	0.321
Africa					
More nourished	90	99	70	75	0.411
Less nourished	254	280	58	65	1.265
Latin America & Carribean area					
More nourished	157	173	67	75	0.741
Less nourished	91	100	55	65	0.646
Total :	2548	2804	--	--	18.457

(a) Assumed 10% increase in 5 years.

(b) Approximate average have been assumed, in the absence of reliable data.

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Table 3 - Refining Capacities in Developing Regions
(as on 1.1.1973)

	No. of Refineries	Total crude throughout (1000 barrels per day)	Largest single refinery capacity (1000 bbl/day)
Africa	28	567.9	60 in Nigeria
Asia Mid.East	35	2738.2	430 in Iran
Far East and Pacific	47	2718.0	250 in Singapore
Latin America and Carribean	77	5524.2	630 in Venezuela

Table 4 - n-Paraffin Content of Kerosines from Different Crudes being processed in India
(Based on studies at Indian Institute of Petroleum, Dehra Dun)

Crudes	TBP cut range, °C	n-Paraffin Content, %Wt.	
		on cut	on crude
Indian			
(1) Ankleswar	140-300	41.4	15.9
(2) Kalol	"	33.1	7.8
(3) Nawagam	"	41.3	9.1
(4) Nahorkatiya	"	7.9	2.5
(5) Lakwa-Rudrasagar	"	2.6	0.8
Middle-Eastern			
(6) Rostam	"	20.9	6.1
(7) Darius	150-300	21.5	5.3
(8) Aghajari	140-300	18.0	5.1

Note: 1. The n-Paraffin content was determined by Molecular Sieves adsorption technique.

2. The carbon number range is C_9-C_{17}.

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Table 5 - n-Paraffin Content of Gas Oils from Different Crudes being processed in India (Based on studies at Indian Institute of Petroleum, Dehra Dun)

Crudes	TBP cut range, °C.	n-Paraffin Content, % Wt.	
		on cut	on crude
Indian			
(1) Ankleswar	300-400	47.0	7.8
(2) Kalol-Nawagam mix.	"	49.0	9.9
(3) Nahorkatiya	"	20.3	3.75
Middle-Eastern			
(4) Rostam	"	15.2	2.5
(5) Darius	"	16.8	2.5
(6) Aghajari	"	15.4	2.65
(7) Saudi-Arabian Mix. (80% light Arabian + 20% Safaniya)	"	12.2	2.0

Note: 1. The n-Paraffin contents was determined by Urea Adduction technique.

2. The carbon number range is C_{17} to C_{24}.

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Table 6 - Requirements of utilities for a typical Petroprotein Plant.

Water: for cooling fermentors:

(at ambient temperature)	closed loop cooling water	775 m^3/t.
	additional (average)	275 "
	for washing (well quality)	345 "
Turbine fuel		800 Kg/t.
Power		610 KWH/t.
Low Pressure steam		1.8 t/t.

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Table 7 - Some Basic Data on India

	1971	1975	1980
		(estimated)	
Population (millions)	547.9	595.4	647.3
Population below 20 yrs. (%)	app. 50		
Tribal population (millions)	38.0		
Rural population %	80		
Land area Sq.Km.	3,280,483		
Density persons/Km^2	178		
Infant mortality (1970) (per 1000 live births)	139		

Land Utilisation

	million hectares
Forests	65
Total agricultural land	178.8
Arable land (1970)	164
Per capita availability :	(hectare/person)
Total land (1971)	0.6
agricultural land (per rural person)	0.46

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Table 8 - Production of Foodgrains in India
(million tonnes)

Crop	1969-70	1970-71	1971-72	1973-74 (Targets)
A. Cereals				
Rice	40.43	42.23	42.73	45.00
Wheat	20.09	23.83	26.48	30.00
Jowar	9.73	8.11	7.76	8.70
Bajra	5.33	8.03	5.36	6.50
Maize	5.74	7.41	5.03	6.50
Others	6.57	6.93	6.25	6.00
B. Pulses	11.69	11.81	11.06	12.00
Total food-grains	99.58	108.42	104.66	114.70
Total Area under food crops (10^6 hectares)	123.54	124.30	122.21	126.25

Other foodstuffs

Oil Seeds	1970
Groundnut (in shell)	5.15
Rapeseed & mustard	1.51
Sesame	0.43
Coconut ('69)	0.89
Cashewnut ('69)	0.18
Others	
Tapioca	5.34
Potatoes	4.09
Sweet Potatoes	1.61

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Protein-rich foods in 1971* (tonnes)

Infant milkfoods	17,000	
Weaning foods	500	
Breakfast foods	3,500	
Malted Milkfoods	11,000	
Fortified Bread (5% protein, etc.)	50,000	
Protein-rich biscuits	500	approx.
Protein-rich commercial powders	2,000	"
Balahar (food mixture for children)	15,000	
Protein-based beverages	2	"

(* Provided by Dr. K.T. Achaya, Executive Director, Protein Foods Association of India, Bombay)

TABLE- 9 . PATTERN OF FOODSTUFFS CONSUMPTION IN INDIA

(per caput per day)

	cereals sugar g.	pul-ses g.	flesh foods etc.g.	Milk and prod-ucts g.	fats and oils g.	Others (a) g.	Proteins g.	calories
All-India (average)	441	51	5	108	10	97	49.0	1945
Some tribes								
Dublas	291	5	-	2	21	51	35.1	1210
Uralis	166	25	-	-	5	906	30.1	1830
Sauria Pahari	584	35	7	-	2	27	74.2	2210
Onges (Andamans)	-	-	725			390 (b)	136.5	2620

(from Reference No. 6, pp.103, 127, 128)

(a) vegetables, fruit, sugar, etc.

(b) 145 honey and 245 vegetables.

Table 10. - RESULTS OF SEMI-CONTINUOUS AND CONTINUOUS FERMENTATION STUDIES

Capacity : 5 L mechanically agitated and aerated Fermentor.
R P M : 1500 - 2000
Aeration rate : V.V.M. : 0.5
Strain : IIP - 4 "Candida Tropicalis"

Run period (hrs)	D (1/hr)	S0 (g/l)	Substrate Purity (%)	t (°C)	X (g/l)	DX (g/l hr.)	Conversion on feed (%)
0-100	0.1	15.6	75	34±1	8.5	0.85	54
100-200	0.125	15.6	75	34	8.5	1.06	54
200-300	0.15	15.6	75	34	9.5	1.45	61
300-400	0.18	15.6	75	34	8.5	1.53	54
400-500	0.2	15.6	75	34	7.5	1.5	48
500-900	0.2	15.6	75	34±1	7.5	1.5	48
900-1700	0.22	15.6	87	34±1	7.5	1.68	48
1700-1800	0.22	15.6	87	32-36	6	1.32	39
1800-2400	0.22	11.7	87	32-38	6.5	1.43	56
2400-2500	0.22	7.8	87	32-38	6	1.32	72
2500-2800	0.22	7.8	92	32-36	5.5	1.2	70
2800-2900	0.22	7.8	92	34±1	6.5	1.43	83
2900-3300	0.22	15.6	92	32-36	6.5	1.43	42
3300-3500	0.22	11.7	92	32-36	6.5	1.43	56
3500-4000				37.4			

D : dilution rate; S0 : substrate conc.
X : cell concentration; DX : productivity.

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Table 10A- Possible Methods of feeding Petro-protein in India.

1. As Direct human feed	To be mixed with
Average and high income group.	
Rice-eating:	
South India	flours to prepare Idli - a steam cooked preparation or grain for Uppuma.
Bengal	Milk products to prepare Rasogolla - a sweet preparation.
Other regions	thick soups; fermented rice extracts; fried preparations with flour.
Wheat-eating:	wheat flour; country cheese.
Low income groups.	
Cereal-eating (Bajra, Mandua etc.)	Cereal flour
Rice-eating	Ambali and Ganji (Porridge and soup type extract from coarse grain)
All	Special preparations, through institutional distribution systems. Tonics, beverages, biscuits etc.
2. As animal feed	
Cattle	- water, in the form of extract - shredded grass - rice bran and husk - boiled pulses - special preparations.
Other animals	water, as extract special preparations

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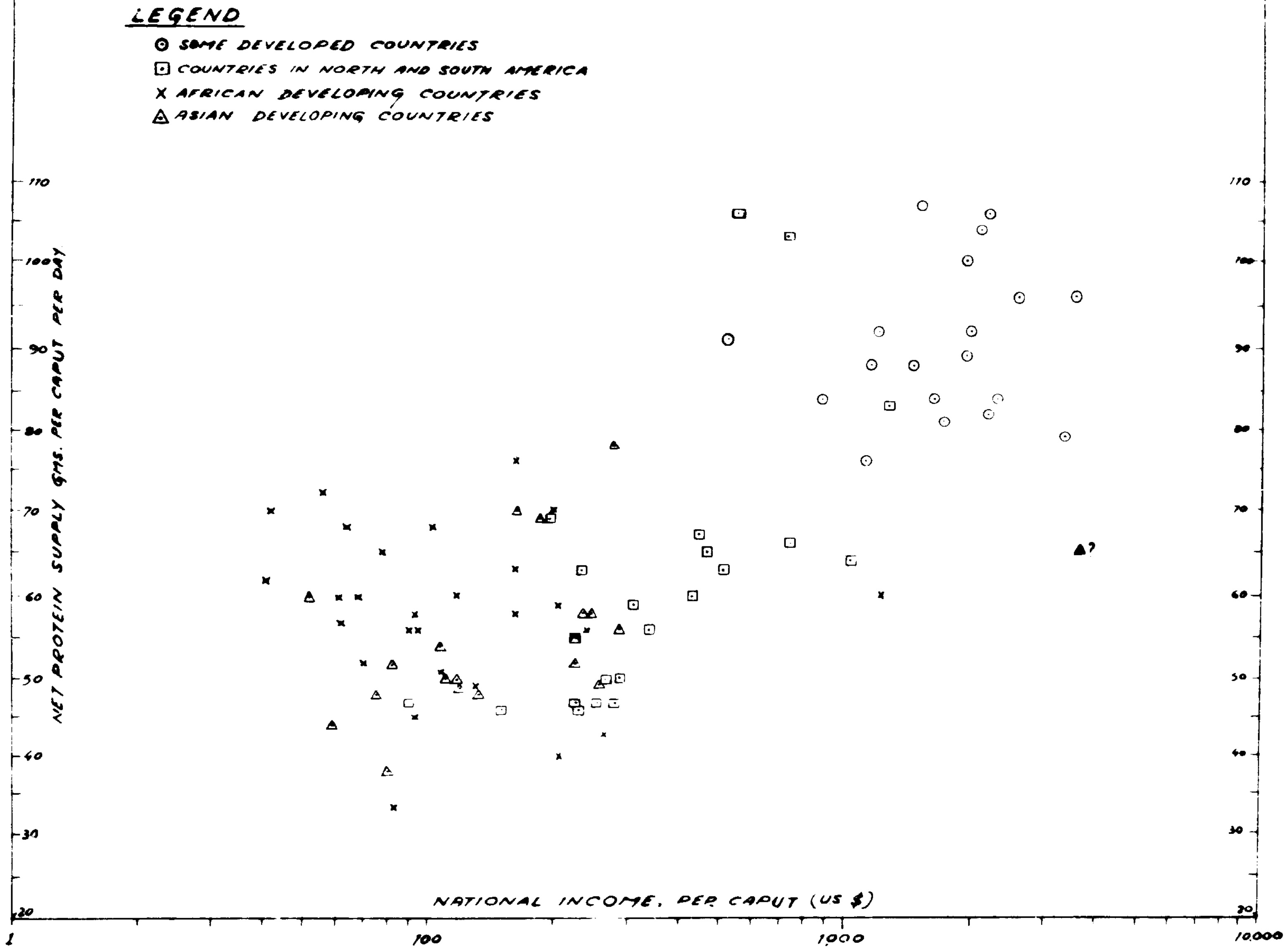
Table 11. - Approximate cost of Protein from various sources (Data compiled in 1972 by Central Food Technological Research Institute, Mysore, India)

Food Products	Price per Kg. of food Rs.	Protein Content %	Cost of Protein per Kg. Rs.
Mutton	9.00	18.00	50.00
Chicken	9.00	21.00	42.80
Eggs	5.00	13.00	38.40
Milk	1.00	3.3	30.00
Dry whole milk	15.00	25.0	60.00
Dry skim milk	10.50	35.0	30.00
Fish	5.25	30.0	26.25
Beef	2.00	18.0	11.00
Dry peas dhal	2.00	20.0	10.00
Bengal gram dhal	1.40	21.0	6.66
Groundnut kernel	3.00	28.0	10.70
Groundnut protein Isolate	5.50	90.0	6.10
Edible groundnut Flour	1.25	50.0	2.50
Edible soybean flour	1.25	50.0	2.50
Edible cotton seed flour	2.00	50.0	4.00
Edible sesame flour	2.00	50.0	4.00
Expected cost of production of petro-protein concentrate	2.00	50.0	4.00

Fig I Variation of Food Protein Supply with National Income



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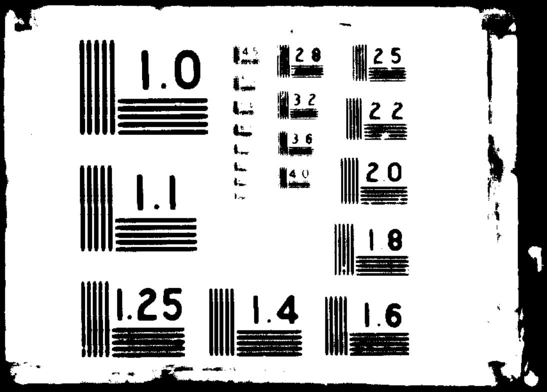
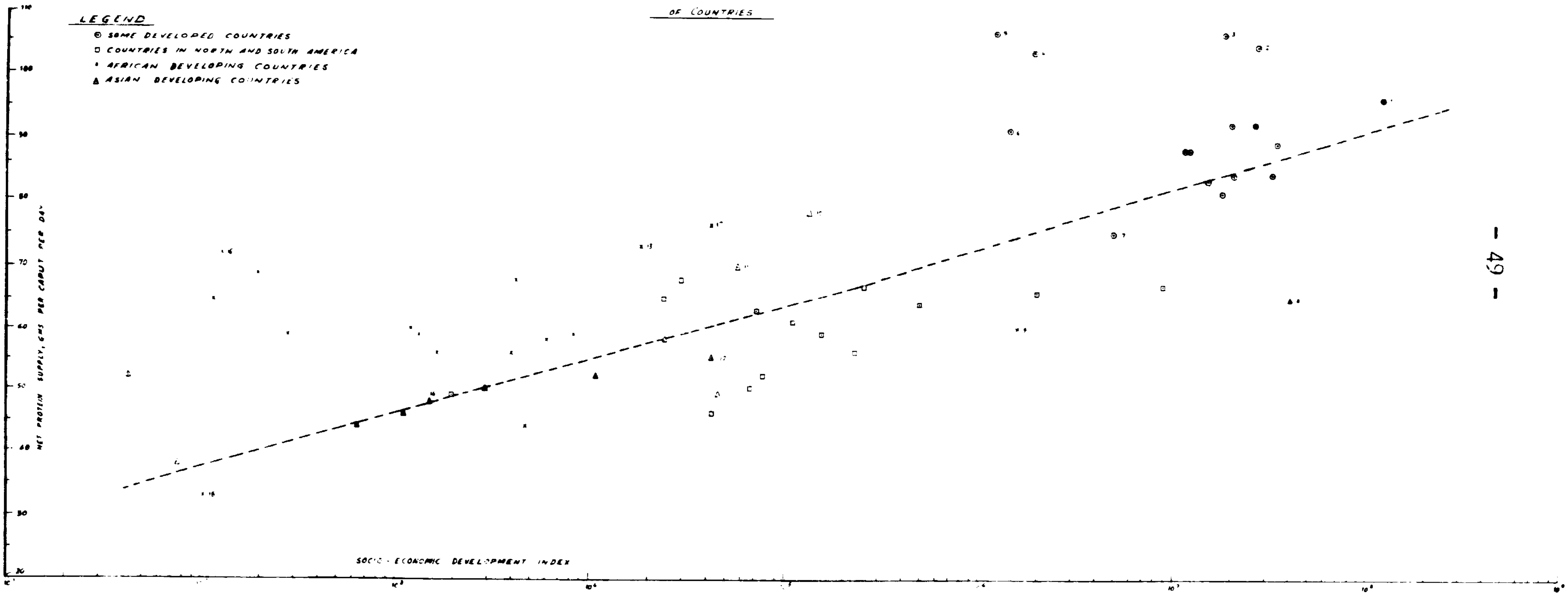


Fig. II. VARIATION OF FOOD PROTEIN SUPPLY WITH LEVEL OF SOCIO-ECONOMIC DEVELOPMENT

(countries numbered in figure)

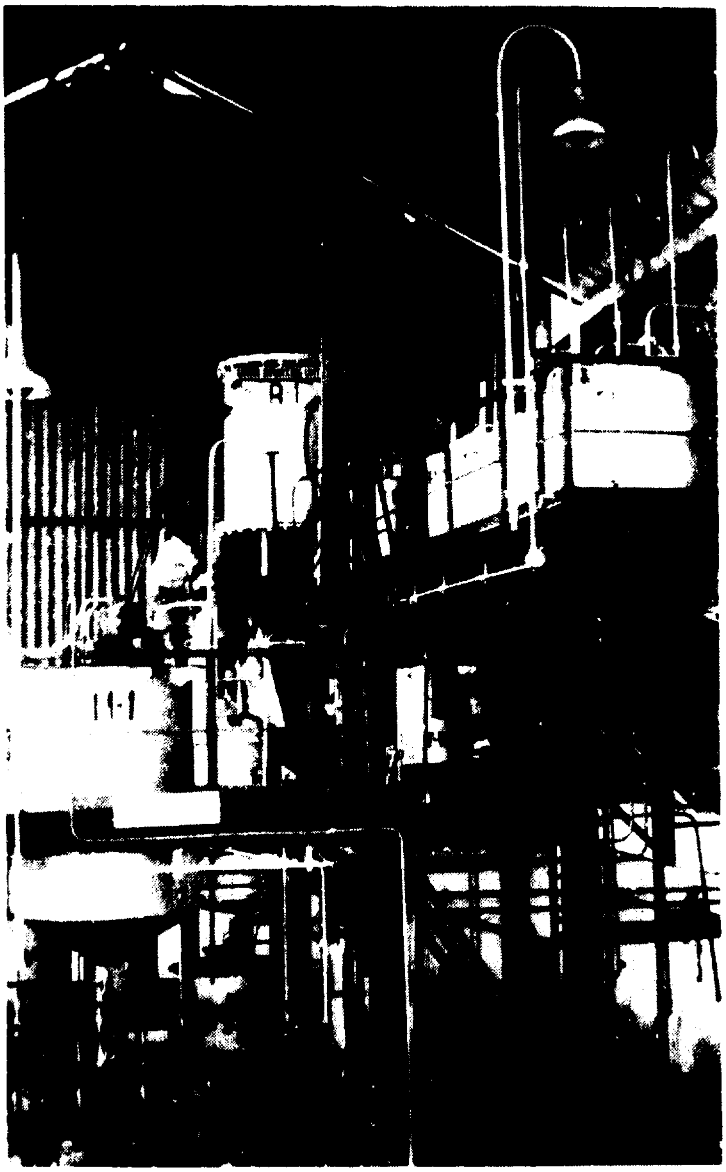
1. U.S.A.
2. France
3. New Zealand
4. Argentina
5. Uruguay
6. Yugoslavia
7. Japan
8. Kuwait
9. Libya
10. Turkey
11. Republic of Korea (South)
12. Iran
13. Zambia
14. India
15. Zaire
16. Ethiopia
17. Mali
18. Niger
19. Nigeria
20. Kenya
21. Nepal
22. Indonesia

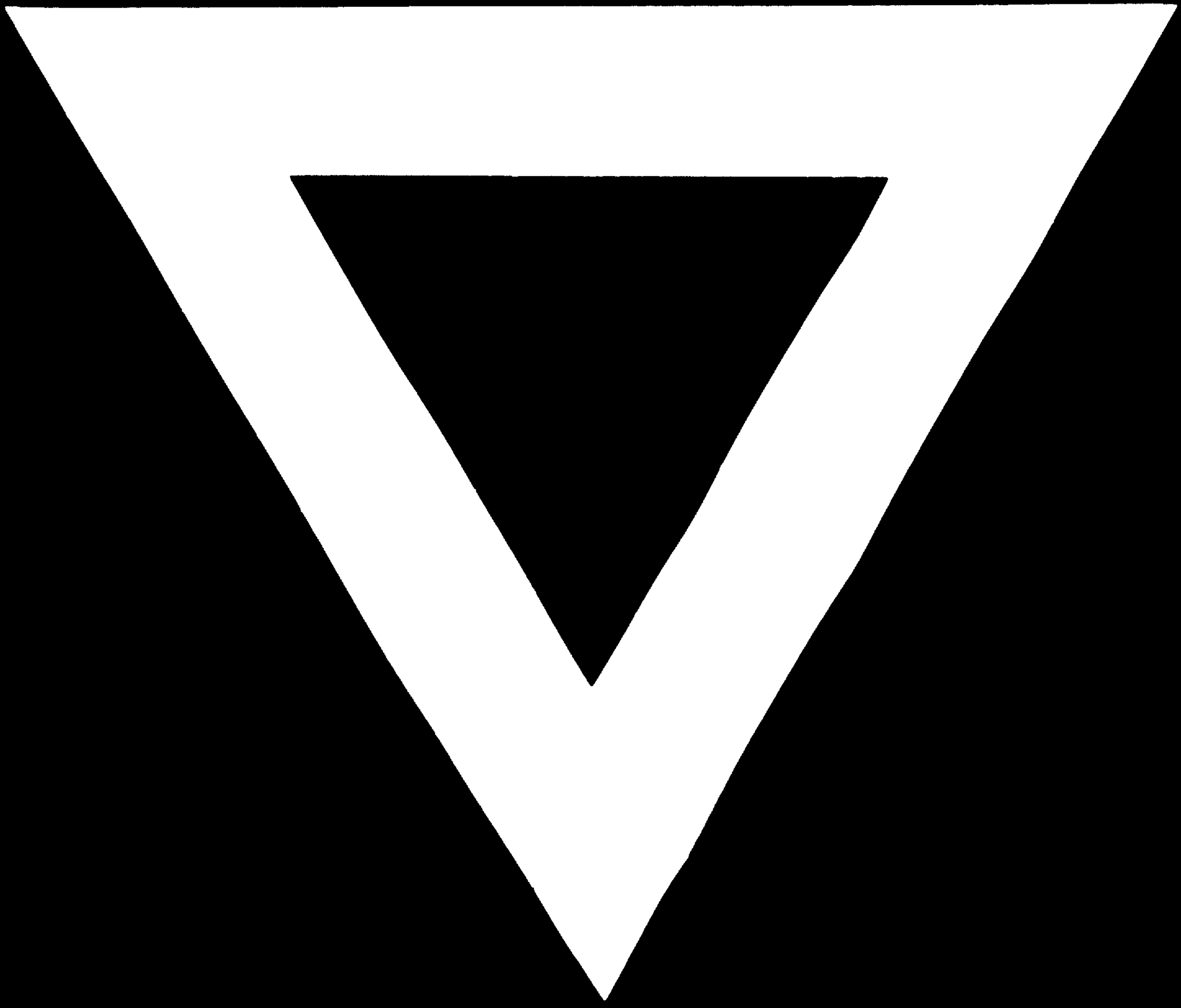
FIG II. VARIATION OF FOOD PROTEIN SUPPLY WITH LEVEL OF SOCIO-ECONOMIC DEVELOPMENT OF COUNTRIES



IIP PETRO-PROTEIN PILOT PLANT: PILOT FERMENTOR

IIP PETRO-PROTEIN PLANT: UREA DEWAXING AND CREAM TREATMENT UNITS





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