APPENDIX n – EXHIBIT 1

المؤتمر العربي الثاني للبتروكيماويات
أبوظبي (إتحاد الإمارات العربية)
١٥ - ٢٢ مارس
نظم بواسطة
جامعة الدول العربية وهيئة التنمية الصناعية
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Single Cell Protein: Its Status and Future Implications in World Food Supply

by

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FIGURE 11
Single cell protein (yeast) "budding" and dividing. Approximately 15,000 times magnification using electron scanning microscope. (Phillips-Provesta)

FOREWORD

The moat critical single factor in world food supply is protein, vital to human diet. Many nations cannot produce or import enough for their minimum needs. Others face serious shortages and prohibitive costs. Today millions suffer protein malnutrition. Tomorrow, as populations rise geometrically the problem will grow far worse, unless vast new protein sources emerge. Some time ago the Food and Agricultural Organisation of the United Nations predicted an annual protein deficit of 10 million tons by 1980, rising to 22 million tons by the year 2000. Other world estimates suggest even greater shortages.

odem man still uses primitive man's circuitous, grossly inefficient path to producing protein. Fields are tilled, seed sown, prayers addressed for rain and sun, and crops grown, first ravaged by insects, birds and forces of nature. What remains is harvested. Animals are fed the grain, then slaughtered. Finally, a fraction of their carcasses reaches the ultimate customer - man.

Single cell protein (SCP) is a giant' stride forward in simplifying and improving the efficiency of this protein food chain. Groins and meals convert to meat on the table at extremely low "total energy cycle" efficiencies. SCP converts at magnitudes greater, A cow weighing 1,000 pounds creates perhaps 1 pound of effective protein or less per day. In contrast, 1,000 pounds of SCP can produce 100,000 pounds of protein or more per day. And by using SCP instead of grain in animal feeds (later also for direct human consumption) there will be an important "domino effect" because by such means the world would release, for direct human use, vast amounts of grain and legumes now fed to animals.

Through many years of research and development by Phillips Petroleum Company, Provesta Corporation's parent company, using private capital and without government financial support, Phillips-Provesta have developed advanced propriety technologies for highly efficient manufacture of SCP. Commercialization of these technologies would be well suited to the situations of many countries, and especially so in the environments of Arab and other nations having large hydrocarbon energy resources. The processes involved employ various proprietary organisms and various "substrates" or sources of energy for growth of the SCP. The optimum ones employ alcohols such as derived from hydrocarbon gases, preferably methanol.

This paper reviews the nature of SCP and the technologies of Phillips-Provesta for SCP manufacture.

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Protein — an Overview

Millions of words have been written and thousands of speeches made on the world protein shortage, present and future, its dimensions, nutritional effects, and societal and political implications. Words have little caloric value and, except for creating greater awareness, have thus far had little effect on programming adequate future increase in world protein supply. This paper will not attempt to review the many and varying statistics, predictions and recommendations that have been made on the subject. Briefly and broadly they condense to these:

– Many people in many countries get inadequate protein in their daily diets for good nutrition. (Figure 1) The degree of inadequacy correlates roughly, as one might expect, with average annual per capita income.

– The areas of poorest protein nutrition are often also those having the highest birth rat-es, accompanied by lowest per capita income (Figure 2). This means that regardless of how cheaply any present or new form of protein could be produced, such populations will still have great difficulty in buying it until such time as their incomes rise, or unless they receive price supports in the interim.

– Reserves of world food to meet emergencies have dropped steadily over the past two decades (Figure 3). They are now gravely inadequate to provide for even a short major discontinuity let alone a sustained one in current food production. This makes it urgent that major new sources of protein be put into manufacture soon. In the words of the Protein Advisory Group of United Nations (Attachment A):

"We are thus challenged today with an unprecedented convergence of circumstances:

"a) immediate and increasing worldwide demand for protein;

"b) immediate demand for industry as well as agriculture to produce new forms of proteins, including single cell proteins, utilizing available technologies;

"c) immediate demands for many governments to evolve objective regulations controlling the quality and safety of novel protein sources, such regulations to be capable of harmonization at the international level to the greatest possible extent; and

'cd) an almost equally immediate demand to allow unrestricted and unimpeded international export and import of such products, which will require international similarity of national regulations. "

– One of the main reasons for this critical state of affairs – other than the obvious reason that world populations are growing drastically – is that modem man still uses primitive man's circuitous and grossly inefficient path to producing protein (Figure 4). Man tends the fields, sows the seed, nurtures its growth, praying for rain and sun, fighting the ravages of insects, birds, and forces of nature. He then harvests most of what remain%

then feeds much of it to animals to nurture their growth. He then slaughters the animals, discards much of their body weight, cooks the fraction remaining, accepts its large shrinkage, and finally eats what's left.

– In recent years a major improvement has come into being, and is destined to grow dramatically, that offers a protein production "chain" of somewhat improved efficiency. This is the technology of extracting nutritious protein from oil seeds such as soybean and, circumventing the feeding of animals, bringing the concentrated protein directly *into human diet. While* this is a significant improvement in the efficiency of the "chain" it is still weak and complex, having many of the same uncertainties and limitations of the crop-to-animals-to- humans chain.

– In comparison, the "chain" for certain more recent ways of producing protein is far simpler and more efficient. One is single cell protein, called "SCP", the subject of this paper. As seen in Figure 4 it compresses the other "chains" to an almost irreducible minimum.

Quality and "True Price" of SCP Compared to Conventional Proteins

As seen in Table I among all current known sources of protein that can conceivably be used as food, SCP's rank highest in total or "crude" protein content. Milk contains roughly only about 4 per cent crude protein, chicken, beef and other meats about 19, eggs 13 and beans 22. In contrast, SCP's can contain from about 55% (yeast) to 80% (bacteria).

However, as also shown in Table 1, crude protein is not the final measure of protein quality. Only part of such crude protein is nutritively digestible. This "utilizable" percentage varies greatly between proteins from different sources. In this respect, SCP ranks well with meat, poultry, cheese, and ranks above most grains, nuts and legumes.

To the consumer, however, "utilizable" protein is still not the final "value" criterion. For him, one must, as in Table II, divide the cost per pound of the product purchased (whole egg, meat, etc.) by the percentage of utilizable protein therein. This gives the "true cost" of the protein to the consumer. On this basis SCP's rank best among all proteins. If, for example, chicken is being sold to consumers at 68¢/lb it "truly" costs about $4.68 per pound when corrected for amount of utilizable protein present. Beef at $1.50 per pound has a "true" cost of $7.50 per pound. In comparison, SCP's would be less than $1.00.

One of the main aspects of proteins that affect their nutritive quality is amino acid content. Here, as will be shown later, SCP ranks high against soymeal and fishmeal and favorably against the "standards" (FAO and egg) used by nutritionists to measure human food quality.

SCP Productivity

The productivity potential for SCP is so great compared to conventional protein that it staggers the imagination. One SCP plant making 100,000 tons per year can produce about as much protein as that which could be extracted from 120,000 hectares (300,000 acres) of soybeans, or as much beef (cattle) as could be grown on 2 million hectares (5 million acres) of grazing land having substantial grass or other forage such as in the U.S.

TABLE 1

"CRUDE" VS. "UTILIZABLE" PROTEIN

CRUDE		UTILIZABLE	
SCP – BACTERIAL	80%	EGGS	94%
SCP – YEAST	55	MILK	82
SOY FLOUR	42	FISH	80
MEAT, FISH, CHEESE	20– 35	SCP, CHEESE	70
GRAINS	8 – 14	MEAT	65
EGGS	13	SOY FLOUR	62
MILK	4	GRAINS	50-70

TABLE 11

"TRUE COST" OF UTILIZABLE PROTEIN
(U.S. Prices at Time of Comparison)

FRANKFURTERS	$10.00
MEAT	7,50
CHICKEN, FISH, EGGS	4.75
CHEESE, RICE	4.25
MILK	2.60
SCP, SOYMEAL, FISHMEAL	<1.00

Let us assume that all of the gas presently "flared" and thereby wasted in one Middle East country became the basic energy source for making alcohol, which could then act as a feedstock for growing SCP. Certainly, this is a hypothetical case because the country involved is fully aware of the value of the gas and has plans for its use in future petrochemical production. Nevertheless, and simply for illustration, if all of this flared gas were to be used for making SCP, it could produce 12,000,000 tons/year SCP or about as much protein as might. be extracted from about 14.4 million hectares (36 million acres) of soybeans, or 240 million hectares (600 million acres) of good-forage cattle grazing land. At such time as SCP may become approved for direct human consumption this output could theoretically bring the daily diets, 365 days a year, of over 500 million people to an acceptable level for good protein nutrition,

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The Nature of SCP and processes for Making It

SCP (single cell protein) refers to many microorganisms rich in protein that can be bred rapidly when "fed" various nutritive energy (substrates). Some prefer one substrate, others another, SCP as discussed herein refers to those that prefer hydrocarbon and/or hydrocarbon-derived feedstocks such as alcohols, e.g., methanol. Many bacteria and yeasts (SCP) have been discovered by us that use alcohols for growth, Those used commercially would depend on plant design factors, locale and target markets. The final SCP products are whole or extracted parts of the cells. The SCP's also contain other valuable nutrients – fats, carbohydrates, vitamins, minerals, growth factors — all important in a balanced diet.

There are various processes for making such products. The preferred Phillips-Provesta ones, developed after years of research, employ alcohols such as methanol. The processes are highly productive and obviate the possibility of carcinogens or other undesirable components (such as other substrates might pose). They are relatively independent of location, require little land, are independent of drought, insects and other natural hazards, and are not subject to the wide fluctuations in quality, availability and price that characterize protein from crops or animals.

Proteins are made up of about 20 amino acids of which eight are essential for human life. These eight cannot be synthesized by the body and must be ingested. The body can only use these to the extent of the one that is there in the lowest amount. It is like a chain in which the chain is only as strong as its weakest link. All proteins are rated by comparison to a standard and are given a protein score which reflects the concentration of the limiting amino acid. The protein is only as good as this limiting amino acid, Some SCP's have an initial high protein score usually limited by the sulfur-containing amino acids.* Individual strains may rate even higher in particular amino acids such as lysine which is usually limited in cereals. Different cultures have different amino acid compositions.

Thus while the composition of animal, poultry, fish, milk, egg and other tissues or cells cannot be easily altered, the range and opportunity to select different enriched SCP's is unlimited.

*It is in ● sense fortuitous that the sulfur aminos are limiting because these particular aminos are commercially available and, where desired, can be introduced as supplements in the SCP to increase further ita ● lready high "protein score".

This means that one can grow the best SCP for a particular amino acid requirement and, if any one SCP cannot supply all the amino acids in the desired proportions, then two or more complementary cultures can be blended together to achieve the *most* favored mixture.

How SCP Is Made

SCP is made by continuous fermentations in which a select microorganism feeds on a substrate (e.g., methanol) and trace nutrients. The rate of growth (multiplication) of this protein is far higher than that of animals and plants. The cells split, doubling their weight, in as little as about two hours. In contrast, chickens, cattle, etc. take from weeks to months to double their weight and can maintain this rate only briefly during their life cycles.

Fermentation processes somewhat like those for making SCP, albeit far less efficient, have *been* practiced for generations (using other substrates) for making brewers yeast, citric acid, etc. It is only recently that it has become feasible to ferment using hydrocarbon and derivative substrates, thereby converting a non-food raw material into a food.

In the case of SCP the ingestible product can consist of the entire cells, in contrast to animals, much of whose mass is lost in slaughter. The advantages of this and rapid growth become compounded in achieving high end productivity. In addition, such microorganisms have unusually high total protein content, bacteria up to 80% and yeasts near or above 60%. Since such processes require no lend for agricultural or animal farming and are independent of the latter's natural growth hazards, they are not subject to the wide fluctuations in price and quality encountered in protein derived from agricultural crops and animals.

The feedstock can vary and the type chosen governs to a large degree the selection of the microorganism used, its growth condition% and the type of fermentation employed. There are four main processes. These employ either:

— normal paraffins
- mixed hydrocarbons
— methane
or – hydrocarbon derivatives (alcohols)

The yeasts, bacteria or molds employed break down the alcohols or hydrocarbons to carbon "fragments" and then synthesize and convert them into their own cellular structure. The same type catabolic and anabolic processes that occur with sources of energy such as sugars occur also in these metabolisms, while the enzymes and intermediates are different. Some organisms long marketed for human consumption (yeast) by growth on sugars can be adapted to accept hydrocarbon derivatives.

The choice of organism (SCP) for growth is influenced by many factors involved in the structure of the particular substrate. In the case of hydrocarbon substrata, organisms normally "select" the straight chain alkanes therein es their primary source of *carbon for* metabolism. If mixtures of normal paraffins and non-normal (branched) paraffins are present, the organisms will first select and consume the normals, leaving behind or consuming much more slowly the branched hydrocarbon& [This has the effect of concentrating the latter undesirable hydrocarbon compounds in the media and around and in the organism.] Aromatic hydrocarbon structures and substituted chain and ring hydrocarbons are normally more resistant to "attack" by the organisms and non-utilizable at fermentation rates that yield optimum growth.

In all current SCP processes preference is being given to yeasts or bacteria rather than molds due to the former's ease of cultivation and quality of end product. Choice between the many classes of yeast and bacteria depends on the substrate, recovery system yield (weight of cells per weight of hydrocarbon), incubation temperature, nutrient requirements for growth, amino acid balance of end product, and many other factors. Yeasts are more easily recovered than bacteria due to their larger size (bacteria about 1 micron diameter, yeasts about 5). Growth rates and yields of bacteria are usually higher than yeasts. Such relative features must be cons&red in judging which to grow with a given substrate.

The cells of rapidly growing cultures of yeast and bacteria have high nucleic acids content, for which the tolerance of animals is much greater than that of humans. The safety and value of various SCP's (with certain substrates) used as animal feed have been established. However, the limitation on intake of nucleic acids by man appears to call for the development of techniques for their reduction below the levels normally found in rapidly grown SCP or that tolerated by animals. There are processes for lowering the nucleic acid content of SCP through choice of culture, control of fermentation variables, physical or chemical means, or purification by enzymatic techniques employing ribonucleases. The optimum procedure depends on the particular process and organism employed, and may be a combination of several methods.

In addition to choosing between broad classes of bacteria and yeasts there is the further choice of which specific type and strain within such classes would be best. It is possible deliberately to mutate strains, thus refining selection even more. This flexibility in selection is of great advantage since specific "tailormade" cultures can be employed that will offer operator and consumer the SCP most suited to the desired market.

Since a wide variety of SCP organisms is available, one seeks that SCP, substrate and fermentation procedure that in combination will give optimum SCP reproduction and recovery. Fermentation takes place in vessels which are aerated, agitated or stirred, and cooled to dissipate heat generated by oxidative "attack" by the organism on the substrate. Figure 5 is a generalised diagram of a process using methanol substrate. The SCP organism is inoculated into a sterile vessel containing a sterile nutrient medium containing all factors required for optimum growth of that organism. The minimum requirements for growth are sources of nitrogen (usually ammonia or ammonium salts), minerals such as potassium phosphate, sodium chloride, magnesium sulfate, etc., trace elements such as manganese, iron, etc., and the carbon source (hydrocarbons or hydrocarbon derivatives). Other nutrients such as vitamins, peptones, etc., may be required by more fastidious organisms. The organisms reproduce on these nutrients as long as the temperature remains within their growth range and oxygen is supplied. All SCP fermentations are highly aerobic and large amounts of air or oxygen must be constantly supplied for cellular metabolism to be maintained. With these requirements, the reproduction rate is maintained until one of these factors becomes "limiting", causing slowdown and finally cessation of growth. The small amount of SCP "seeding" or starting inoculum doubles by division in each reproductive cycle of bacteria and by budding and division in yeasts. In each such time interval (generation time) the number of cells doubles.

All fermentation routes proposed for efficient low-cost commercial production of SCP are continuous processes in which new nutrients are continually being added at a rate equal to their utilisation by the reproducing cells. An equal volume of nutrients and cells is constantly being removed so that at each time interval the fermenter volume remains constant as does the ceil density. After the initial "seeding" with SCP, the system continues to operate indefinitely at a steady state with no further addition of cells. The reactor effluent is continually collected and further processed by centrifugation, washing and drying. The four main fermentation routes, as determined by the hydrocarbon or derivative employed, are these:

Normal Paraffin Process

If a source of sufficiently pure normal paraffins is available and if its economics are favorable, then normal paraffins can be used as feedstock to produce protein. However, even the most extensive solvent extraction cannot "guarantee" complete absence of hydrocarbon residuals trapped on or in the cell. Moreover, solvent extraction can be detrimental to the nutritional quality of the product because of removal by extraction of the fat-soluble constituents of the cell. The temperature of fermentation is usually about 30-40°C for yeasts and 35-45°C for bacteria. To maintain the dissolved oxygen level required to support cell "density" of 15-25 gms dry weight of cells per liter of medium, high speed agitation and aeration is required. The high heat load of the exothermic fermentation requires extensive cooling equipment.

The fermentation effluent consists of SCP, spent medium, and traces of the hydrocarbon(s). Purification steps remove small amounts of normal paraffins carried over, plus any non-normal paraffins concentrated in the effluent. It is preferable (albeit expensive) to remove non-normal paraffins prior to the fermentation, rather than later from the effluent and cells (where small levels would be concentrated and removal would involve more complicated purification procedures). If adequate washing by water and/or detergent or solvent is carried out the SCP product will appear as a thick paste after centrifugation, drying to a white powder.

Simultaneous Dewaxing and SCP Production Process Using Mixed Hydrocarbons

This process starts with an impure feedstock usually of high content of long chain normal paraffins, or a feedstock enriched by chemical fractionation to contain a higher than normal percentage of normal paraffins.

Since the particular organisms used in this process can utilize only the normal paraffins (waxes) present in the hydrocarbon fractions or distillate, feed rates must be higher, i.e., the organisms must "search" through the larger volume of hydrocarbons for their desired n-paraffin carbon source. The fermenters thus must handle a larger volume of liquids, and emulsions are encountered. Yeast is the preferred organism here because it is more selective in choice of n-paraffin carbon structure and does not "see" the other branched hydrocarbons. Essentially the same mineral medium is fed as in the normal paraffin process and the same continuous type fermentation is used. However, in this case the fermenter effluent consists of three phases – the unused hydrocarbon, the spent medium and the cells in an oil-water emulsion. To isolate the cells, the purification procedure must be more elaborate and involves a separation of the three phases followed by purification of the cells.

Spent medium is discarded or a portion recycled. The remaining hydrocarbons phase, still present but now depleted of most of the normal paraffins (waxes) originally present, is re-recovered, then channeled into refinery operations. The SCP will at this state be coated with oil and must be exhaustively washed to attempt to remove all traces of hydrocarbons (especially aromatics). Procedures for this include hexane and detergent washes. These can help free the SCP of contaminating oil with the number of washes determining the final degree of purity. The final SCP is in theory about the same as that produced from normal paraffins. While this process starts with a cheaper feedstock, part of the economic advantage is lost because of the expense of the purification steps.

Methane Process

The methane process for producing SCP involves fermentation of gaseous hydrocarbon. Some organisms obtain their energy from such oxidations but at present at least, the process is limited to bacterial fermentations. Of all the natural gases, methane is preferred due to its abundance and favorable cost. An advantage of using gas as feedstock is that there are no separation or residual oil contamination problems involved in isolating the SCP. The disadvantages hinder commercialization. Besides the possible hazard of operating in an oxygen-methane environment there are problems created by the need to adjust gas flows to prevent too great a venting of unused methane while maintaining adequate oxygen level. Also, SCP concentrations in the reactor and SCP yields are low. Reasonable rates of production appear to require very large fermenters or very slow flow rates. The methane route appears to require significant technological advances before it is as attractive as other SCP processes.

Process Using Feedstocks
Derived from Hydrocarbons

SCP fermentations that employ select derivatives of hydrocarbons (namely, alcohols and especially methanol), rather than hydrocarbons themselves, avoid significant processing complexities inherent to the latter. Additionally they do not pose certain critical quality and consumer acceptance questions that confront proteins from hydrocarbon substrates. Processes using such derivatives are inherently simpler from a plant design standpoint than those using hydrocarbon Even though the process involved is essentially the same for gases, the use therewith of derivatives such as alcohols is far preferable in respect to such factors as equipment productivity, sizes of fermenters employed and avoidance of explosive hazards of gases. Simultaneously, growth rates are attained that are at times significantly superior to other systems.

On the basis of extensive background, familiarity with all the processes described above, and knowledge of the state of competitive art, it appears that among all such processes those employing alcohol substrates such as methanol are outstanding. There are many reasons for this statement, explained below. However, all methanol-based processes are not alike. They differ greatly in their efficiency and productivity. Moreover, some can employ only bacteria, in contrast to others (such as Phillips-Provesta) that can use methanol with either yeasts or bacteria at high efficiencies. Moat significantly, some operate at relatively lower fermentation temperatures than others. As explained elsewhere, the ability to ferment at high temperatures, as in the case of certain Phillip-Provesta types, can greatly reduce plant investment and operating costs.

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Feature of SCP processes Using Methanol

There are many advantages to those processes for making SCP that employ alcohols such as "methanol fuel" as their energy source. Such proprietary processes have been developed by Provesta-Phillips. Some of their features are these:

- **It is certain, rather than speculative as with other substrates, that the proteins so pro. duced cannot be contaminated by residual hydrocarbons trapped within or on the surfaces of the protein cells because no hydrocarbons are present in the process. The possibility of various questionable components in the final products is thus eliminated.**

- **There is no need for expensive solvent extraction stages such as required by hydrocarbon substrates. Because alcohols are water soluble, a simple water wash will suffice, solely to eliminate excess trace minerals.**

- **The fermentation phase is continuous and single-stage, giving simplicity, reliability and reduced capital investment.**

- **Recycle of spent fermenter medium (effluent) is feasible. In contrast, in the case of hydrocarbon substrates recycling of spent medium can cause build-up of those hydrocarbons other than normal paraffins that may be present, inasmuch as the former are not utilized by the microorganisms during fermentation.**

- **The alcohol substrate provides a self-sterilizing effect in the fermentation state and in the input feedstock (to the fermenter) sterilizes the mineral medium portion of the feedstock.**

- **The process allows, if desired, the complete integration in production plant complexes of all components needed for making the protein. This is because both the main feedstock components — alcohol and ammonia - call for common feedstocks for their own manufacture — i.e., methane, air and water. The production capacity of such "component" plants in a complex can be designed to match the protein production. Moreover, any excess methanol and ammonia produced would not pose marketing problems. Both could be sold into animal feed, fertilizer and chemical markets.**

- **It is easier and cheaper to oxidize methane to methanol by chemical means, in a separate chemical plant designed for this purpose, than to oxidize it from hydrocarbon to methanol by biological means (fermentation). Moreover, fermentations using alcohol (e.g., methanol) require less oxygen than them using the related hydrocarbon (e.g., methane). This in turn means lower cooling costs.**

- **Productivity measured in terms of lbs SCP/unit fermenter volume/hr is much greater for the alcohol than for the gas process. This allows smaller equipment and attendant Savings.**

- **The rate of SCP production during fermentation can be continuously controlled or varied. This means inherent process control, easily maintained.**

– Either bacterial or yeast (SCP) cultures can be used in the same plant, giving important commercial flexibility.

– Both yeast and bacterial fermentations can, through proprietary technology, operate at temperatures of 40°C (104°F) and above without harming the organisms or their rates of growth. This reduces heat exchange coats and allows fermentation at high input cooling water temperatures such as exist in some parts of the world.

- Absence of a solvent wash permits lipid-type constituents to be included in the protein product if desired.

– Availability of special hydrocarbons such es n-paraffins could at times be limited, or depend on the balance of other stocks available in refining operations. Alcohol substrate processes are not subject to such dependency and limitations.

– The use of a water-soluble substrate significantly reduces or eliminates problems inherent to two-phase (hydrocarbon-water) systems. Better contact is obtained between organism and feedstock (alcohol) during fermentation.

– Basically the same plant equipment can be used with either methanol or ethanol substrates.

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Research and Development of Technologies

Our research in *microorganisms* that use hydrocarbons or hydrocarbon derivatives as sources of energy for growth began over 20 years ago when we discovered that some microorganisms could help to find oil reserves. We then later developed and patented processes that use organisms that employ alcohols as energy (carbon) for growth. Some of these were found suitable for rapid and efficient production for their protein content.

These discoveries were compared in terms of fermentation parameters, product quality, and economics, to organisms that use hydrocarbon feedstocks (gas oil, n-paraffins, methane, etc.). After thorough investigation the alcohol route, preferably methanol, was selected as optimum.* Paralleling studies developed organisms that could employ ethanol in the same equipment, thus giving greater process flexibility.

In still other studies technologies were developed and patented that allow efficient use of “crude” methanol containing levels of aldehydes that, absent such technologies, would normally be inhibitory to cell growth. This further increased the versatility of the processes. Over 800 cultures were studied and/or discovered through thousands of varying trial fermentations to find and to stimulate maximum growth rates and yields, It has generally been assumed in

*The many reasons for this choice ● re reviewed elsewhere herein.

the past that single types of organisms would be preferable for making SCP. In addition to developing technologies with these, we have discovered proprietary, stable and highly productive mixtures of certain organisms. The variety of all these options is too great to describe herein. It can be stated, however, that normally when starting a study with a new culture fermentation temperatures are initially set at some arbitrary value such as *40°C, to* isolate organisms able to use methanol as substrate, in the absence of accessory growth factors and in the presence of some particular minimal medium.

Bacterial Fermentations

From the large number of cultures found to accept methanol, those showing exceptional growth or other unique properties were chosen for further development. Throughout, selections and assessments were made using specific media devised for each culture, further to enhance growth. A few examples of isolates are:

Pseudomonas methanica	NNRL B-3449
Arthobacter parafficum	NNRL B-3453
Pseudomonas fluorescent	NNRL B-3452
Methanomonas methanooxidans	NNRL B-3451
Methanomonas methanica	NNRL B-3450
Corynebacterium simplex	NNRL B-3454

In all cases continuous rather than batch fermentations were employed because of the former's greater productivities and yields. The following data present one example of a continuous fermentation taken from earlier studies, employing methanol:

> A fermenter arranged for effective mixing and continuous fermentation and temperature controlled at 40°C ± 1°C was charged with a base medium containing phosphoric acid, potassium chloride, magnesium sulfate, calcium chloride, sodium chloride, and a trace mineral solution. The fermenter was inoculated with Pseudomonas methanica B-3449 and methanol added incrementally to bring the culture to the desired cell density. Medium was then char&d continually to the reactor and the effluent removed, maintaining the culture at steady state operation. Methanol was fed continually to the reactor at 8.5% (V/V) concentration in the mineral medium feed. Supplemental alcohol* was added to maintain the system at a high cell density. No accessory growth factors were required. The pH was maintained at 6.3 with ammonium hydroxide, which also served as the nitrogen source. Air was supplied at a level of 2 V/V/rein with stirrer agitation at 1000 rpm. Additional pure oxygen was often required to maintain a dissolved oxygen level not inhibitory to maximum cell growth. Cells were recovered, washed and dried. Under steady state conditions the fermentation characteristics were:

Dilution rate (hr^{-1})	0.492
Retention time (hr)	2.03
Cell concentration (dry wt)	31.85 gm
Productivity (g/1/hr)	15.81
Crude protein content (%) (N x 6.25) no moisture	60.6

● One of the unusual features of the proprietary processes employed is thet methanol is virtually non-existent in the final SCP products, ● t a level many time. less than that of conventional foods ● nd beverages long established ● nd used in direct human consumption as permitted by the regulatory agencies of the U.S. (FDA) ● nd other countries.

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The amino acid content of this particular culture is as **follows:**

Amino Acid Content of a Typical Methanol-Utilizing Bacterium Grown at 40°C

Essential Amino Acids	Grams/100 grams Product basis	Protein Basis
Leucine	6.16	8.01
Isoleucine	4.01	5.21
Lysine	4.67	6.07
Methionine	1.33	1.73
Cystine	—	—
Threonine	3.53	4.59
Phenylalanine	3.25	4.23
Tyrosine	2.67	3.47
Tryptophan	0.51	0.66
Valine	4.42	5.75
Non-essential Amino Acids		
Alanine	5.50	7.15
Arginine	3.48	4.53
Aspartic Acid	7.34	9.54
Glycine	4.02	5.23
Glutamic Acid	8.44	10.98
Histidine	1.89	2.46
Proline	2.79	3.62
Serine	2.62	3.41

Larger quantities of cells were prepared in fermenters of up to 20,000 gallons in volume, for use in extensive animal feeding teats. These have given excellent results, reported elsewhere herein. Evaluation at high cell densities and minimum generation times verified the greet dependency of plant operating costs on fermentation temperatures. Fermentations maintained at about 40°C, for example, can generally employ cooling water whereas at lower temperatures they may require more expensive refrigeration.

Thermophiles

Since cooling is a major cost factor in the economics of SCP, both in respect to plant investment and operating costs, the use of thermophilic (high temperature) organisms is certainly desirable.

We have discovered and developed proprietary, thermophilic cultures that give excellent results comparable to those mentioned elsewhere herein for 40°C bacterial cultures.

Yeast Fermentations

Although bacteria have certain advantages for SCP production from methanol it was also held to be desirable to be able, alternately, to produce yeast SCP in the same future commercial

mercial plants with the same substrate, methanol. The large capital investments of commercial plants would thereby not be dependent on the gratuitous assumption that one or the other, bacteria or yeasts, would always prove optimum in every marketplace.

After extensive research we succeeded in achieving this dual capability goal, in the course of which a number of proprietary cultures were developed. The same basic screening criteria were followed with the yeasts as with the bacteria, i.e., rapid growth at high cell densities at a temperature such as 40°C on a defined minimal medium requiring only certain vitamins. As example, one of the cultures was a particular strain of Hansenula polymorpha that grew rapidly at 40°C in continuous fermentation in a mixed phase type fermenter. A 10% methanol mineral medium containing, for example, phosphoric acid, potassium chloride, magnesium sulfate, calcium chloride, a trace mineral solution and biotin and thiamine was fed continuously. The pH was maintained at 3.5 with NH_3 which also served as the nitrogen source. Aeration was at the level of 2 V/V/rein. The fermentation was alcohol-limited so the methanol content of the effluent was essentially zero. An example of the fermenter characteristics under steady state conditions is:

Dilution rate (hr^{-1})	0.14
Retention time (hr)	7.2
Cell density (dry wt)	26 gins*
Productivity (g/1/hr)	3.6
Cell yield (baaed on methanol consumed)	32.9
Crude protein content (%) (N x 6,25) no moisture	54

The amino acid content of this methanol-utilizing yeast, grown at 40°C., was as follows:

	Grams/100 grams	
Essential Amino Acids	Product basis	Protein basis
Leucine	4.07	8.56
Isoleucine	3.20	6.73
Lysine	3.22	6.77
Methionine	0.84	1.77
Cystine	0.27	0.57
Threonine	2.04	4.29
Phenylalanine	2.56	5.38
Tyrosine	2.29	4.82
Tryptophan	0.52	1.09
Valine	3.51	7.38
Non-Essential Amino Acids		
Alanine	3.37	7.09
Arginine	2.00	4.21
Aspartic Acid	5.42	11.40
Glycine	2.96	6.23
Glutamic Acid	6.46	13.59
Histidine	1.12	2.36
Proline	2.30	4.84
Serine	1.39	2.92

● In other proprietary Phillips-Provesta technologies cell densities have been achieved that are much greater then the above value.

The fatty acid content of the dried yeast sample was examined by gas chromatography. No odd-numbered carbon fatty acids were identified by GC-mass analysis. Multiple animal tests, some of which are reported elsewhere herein, were concluded with this yeast that showed excellent nutritional qualities.

Chemical "Scores"

The chemical "score" ratings of the above described bacterium and yeast, compared to reference standards (FAO; egg) used in human diet, are shown below in Table III.

TABLE III

	Yeast (% of the Standard Shown)		Bacterium (% of the Standard Shown)	
Standard	FAO	Egg	FAO	Egg
Amino Acid				
Leucine	170	91	146	79
Isoleucine	124	80	110	70
Lysine	174	103	156	93
Methionine) Cystine)	50	40"	61	49*
Threonine	184	129	149	104
Phenylalanine) Tyrosine)	181	126	114	80
Tryptophan	143	100	100	71
Valine	148	95	125	80

" Economical fortification of either SCP with 0.89 gm of methionine per 100 grams of product increases the "score" of the SCP compared to egg) to the next limiting amino acid (isoleucine).

NOTE: Values shown are for only two of a number of proprietary Provesta-Phillips SCP's of differing (higher and lower) values.

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Animal Feeding Tests

Background

To satisfy their protein deficiencies, especially for use in animal feeds, many countries depend heavily on U.S. and Brazil imports of soy protein, and on fish protein from Peru and elsewhere. Serious shortages of these proteins and accompanyingly high prices have occurred from time to time, the most recent being those of 1972 and 1973. SCP holds the great promise of eventually relieving such supply problems because of its potential for extremely large production. As explained, its greatest initial market penetration is expected to be in animal feeds and later in direct human consumption products.

Extensive taste indicate that SCP's such as produced by proprietary Phillips-Provesta technologies can replace soymeal and fishmeal in animal feeding rations. To assure competent and unbiased conduct and evaluation of such teats they were performed, under contract with Phillips-Provesta, by the animal science department of a leading U.S. university over a four-year period (1972-1975). The test species included ruminants (cattle and sheep), swine, poultry, and laboratory clinical-study animals such as rats. The SCP's were compared to conventional high-quality protein products generally accepted by industry as standards for such studies. Quality measurements included apparent biological value (ABV), protein efficiency ratios (PER), and average daily weight gains (ADG) of the teat animals. The studies were conducted with sufficient numbers and types of animals to yield data adequate for statistical analyses. This provided a high degree of *confidence in* the validity and reproducibility of results.

The studies demonstrated the nutritive value and safety of these SCP's at percentages of the total mixed feeds that are commercially significant. Such tests are continuing on still other types of our SCP's. Some of the results obtained to date are reported herein.

Utilization of Protein by Animals

Poultry are known to be more efficient than other animals in converting protein to meat, thereby providing quicker end more economical gains from supplementary proteins added to their diets. In addition, poultry are more easily managed than other animals in "battery-type", i.e., multiple, production units. For these reasons, the production of chickens and other poultry is expected to increase faster, with the availability of new supplementary proteins such as SCP, than other meat animals in those areas of the world where there are deficits of protein accompanied by deficits of feed grains. The approximate gross conversion efficiency of crude protein for poultry versus other animals is illustrated below:

GROSS CONVERSION EFFICIENCY OF CRUDE PROTEIN BY VARIOUS ANIMALS: AVERAGE OF ALL PHASES OF PRODUCTION

spades	Per cent of the crude protein present in the feed that is effectively utilized
Broilers (young chickens)	23
Turkeys	22
Laying hens (for eggs)	26
Dairy cows (for milk)	25
Swine	14
Beef	4
Lambs	4

(Conventionally, poultry and swine consume grains as the main part of their diets, while ruminants consume mainly forage.)

Poultry

In the poultry studies, substantial increases in body weight and feed efficiency were obtained at SCP levels up to 15% of the total ration, when yeast SCP in a special "granulated" form was used to replace soybean meal as the source of supplementary protein in the rations. Smaller increases were obtained (at levels up to 6% SCP in the total ration) when the SCP employed was in a powdered "mash" rather than a granulated form. The "granulated" form, having much larger particle size than the powder, clearly improves the palatability and acceptability of SCP to poultry. The addition of small amounts of supplementary methionine to the total rations still further improved weight gains and feed efficiencies, to a greater extent in the SCP-containing rations than in the zero-SCP basal "control" ration containing soy protein. At a 10% level of substitution of SCP in the total ration, the weight of chicks (young poultry) increased 14% and feed conversion efficiency increased 12% (over the control ration containing soy protein). Weight gain and feed conversion efficiency are shown in the table below:

TABLE IV

EFFECT OF SCP SUBSTITUTED FOR SOYMEAL IN "BROILER" CHICKEN RATIONS

Amount of Supplementary Protein in Total Ration, %		Improvement in Weight Gain, %	Improvement in Feed Conversion Efficiency, %
SCP	SOYMEAL		
0	32.4	----------Control	Ration---------
5	27.4	2.4	0.6
10	22.4	14.1	11.9

NOTES: 1. SCP was a yeast type in these tests.

2. "'Broilers" are young chickens, starting at 7 days and ending at 28 days age.

Ruminants

Conventionally, beef is the preferred meat of a number of countries and is expected to remain a major part of their diets. Lamb is, in turn, the preferred meat of other countries. Thus, growth and weight gains of both ruminants are of much interest. One advantage of ruminants is that they can convert very low cost and low quality forage into meat. However, their weight gains and efficiencies of conversion of their feeds are impeded because of lack of adequate supplementary protein in such forage-type feeds. Accordingly, for improved gains, ruminants are grazed on forages during their growing period and then, where possible, they are fed grains and protein concentrate in their final growth stage to produce more and choicer meet, When this is done the ruminants' protein conversion efficiency is greatly improved.

Phillips-Provesta, having among its proprietary SCP's both yeast and bacteria types grown on methanol, conducted studies to demonstrate how the bacterial SCP could, for one, improve such rations. A number of studies have been made with both cattle (beef) and lambs.

Beef – In many parts of the world where supplementary proteins are unavailable or uneconomical, cattle and other animals must subsist on protein-deficient forage or other rations that greatly inhibit their weight gains and other growth characteristics. At times even seemingly small increases in the protein content of such rations – and, of equal or greater importance, in their protein quality — can substantially improve growth characteristics, This is illustrated by the following teats using conventional protein supplements:

- Two groups of dairy-beef calves (8 weeks old) feeding mainly on corn grain were given ration protein supplements. One was given a ration containing the level of protein recommended by the National Research Council*. The other was given a ration containing 2 percentage points more total protein, The average daily weight gain of the latter (higher protein) group was 11% greater, this being accompanied by a 10% improvement in feed conversion efficiency.

- Another series of tests was conducted with three groups of pregnant beef cows fed low-quality crop residue rations. Group A (control) received a ration containing 6.5% total ration protein, which met National Research Council requirements. Group B received the same "control" ration plus 3.5 percentage units of conventional protein, bringing the total ration protein to 10% level. Group C received the "control" ration supplemental with urea (a source of nitrogen). All tests were conducted during the last 100 days of gestation of the cows. The results were that Group B gained 173% (33 kilograms) more weight and, after calving, gave 22% *more* milk than Group A. Subsequently, the calves from Group B gained 19% more weight than Group A by the time the calves were 14 weeks old, this reflecting the greater milk production of their mothers. In contrast, Group C showed no benefits over control Group A, in any of the parameters, from the added urea in its ration. These results, in effect comparing two different sources of nitrogen for ruminants, demonstrate the importance of protein quality m animal response.

Other tests, made to compare the performance of SCP with that of the conventional protein supplements reported upon above, have shown that SCP gives comparable responses.

In another study the substitutional value of SCP was compared to urea in "feeder calf"** rations. It was found that when SCP replaced 5% of the urea in the control ration the average daily weight gains and total weight gains of the calves were significantly higher than with the control ration, all rations being isonitrogenous.

Lambs – Lambs, the second ruminant tested, also respond positively to rations which relieve protein deficiencies. In *one* series of tests the total protein content of a basically *corn grain* ration was increased, using SCP, from an 8.5% level (the control ration) to a 12% level. The average daily weight gain increased about 19%, this being similar to the results obtained in paralleling tests with soymeal and/or urea. The main effect, however, was a significant increase (24 to 28%) in wool growth when using the SCP-containing ration, versus only an 11% increase with the urea-supplemented ration, both values being in reference to the control ration.

* A division of the National Acedemy of Sciences, Washington, D. C.

** Young beef immediately after weaning.

These findings again demonstrate the importance of protein quality in supplementary ruminant rations. The more favorable performance of the SCP was also indicated by the blood urea levels of lambs fed higher percentages of SCP. These levels were lower with SCP after 4 hours than those of lambs fed urea or soymeal supplements, indicating better nitrogen utilization with the SCP.

Other Animals – Other studies have assessed the digestability and effective utilization of yeast SCP when fed to swine. In one series of tests with baby pigs it was found that, concurrently, the feed:gain ratio improved, the apparent biological value increased, and the plasma urea nitrogen reduced, all to a significant extent, when the SCP was substituted for conventional supplementary protein. Other studies have demonstrated SCP's value when fed to older "grower" pigs, again comparing the SCP to conventional proteins. Although ADG's were unchanged, feed:gain ratios were significantly improved and the average daily feed intake (consumption) was significantly reduced when using SCP-containing ration.

Summary

Studies have demonstrated the nutritive value and safety of the SCP's tested, when used partially or wholly as the source of supplementary protein in animal rations. The results have often been superior to those obtained with conventional supplementary proteins, at percentages of the SCP in the total mixed feeds that are commercially significant.

# # # # #

Economics

Assessment

Frequently, when new products are evolved that appear suited to markets in which the supply of competing products is short, "demand" seemingly great, sources of potential feedstocks large, prices "good", there is an inclination to assume that the new products are ready forthwith for the marketplace. Such euphoria developed soon after it was learned some years ago that SCP could be made rapidly in massive amounts using hydrocarbon substrates. As time passed there grew better appreciation of the many factors that would influence commercial viability. Concurrently, the world entered into a period of severe monetary inflation and escalations in plant construction costs. At the same time it became apparent that the first-generation technologies around which some had planned early ventures might be rendered prematurely obsolescent by second and third generation technologies such as mentioned herein. In support of these statements one need only recall the many announcements made during the past five years of "imminent" commercial SCP projects, then compare these to the number that has actually reached fruition. This is not to imply that SCP may not have a major role in filling future world protein needs since it is certain to have one. It says only that the assessment of commercial projects has become more knowledgeable, selective, and in the process more conservative.

Markets

The markets for SCP fall into two broad classes, 1) supplements in animal feeds – animals that would later be slaughtered and fed to humans – and 2) products that would be ingested directly by humans rather than through the animal route (Figure 6).

Looking at the animal route, SCP could be used in mixed dry feeds, mixed liquid feeds, as substitutes for milk extenders (casein, whey, etc.) and perhaps in special forms of higher potency. As SCP enters such markets an important and valuable "domino" effect will result: The SCP will displace (from animal feeds) vast amounts of protein-containing agricultural products such as soybeans. The latter would then become available, through the use of known and established technologies for concentrating or "isolating" oil-seed proteins, for direct human consumption. This could bring massive amounts (albeit by an indirect route) of "new" protein into direct human consumption much earlier than when SCP might itself make a large, direct entry into this market.

Where so approved by regulatory agencies, SCP's will to a smaller degree concurrently penetrate direct human product markets. It appears, however, that until such time as nucleic acids contents can be reduced, the maximum amounts of SCP in daily, direct human consumption will be low and markets small compared to SCP in animal feeds. Opinion among nutritionists varies as to what maximum amounts can be ingested daily by humans at SCP's "natural" levels of nucleic acids. This will depend in part upon whether the SCP is a yeast or a bacterium because the nucleic acids levels of the two differ, yeast being significantly lower.

Looking at present and future markets, SCP appears in its least "upgraded" form as whole, dried cells for use in animal feeds. The next step "up" would be whole, dried cells using select SCP's and feedstocks* that could, subject to regulatory approvals, be introduced into foods for direct human consumption.**

The next upgrading, to allow greater direct SCP intake by humans, would involve products from which some of the nucleic acids have been removed. The next after this would be where the protein in the SCP would be extracted** and "isolated", possibly accompanied by further nucleic acids reduction, leading to still greater daily ingestion by humans. Finally, some years in the future one might see the advent of isolated SCP proteins that would also be "structured", textured and flavored in sundry ways to create "analogs"** of conventional animal tissue products.

As the forms of SCP progress in this manner from the least processed to the most sophisticated, and as the markets that these forms enter compete with progressively higher-priced conventional proteins, the economic viability of SCP manufacturing enterprises will correspondingly improve. This is normal, of course, wherever basic raw materials (in this case, SCP

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*In the caae of some of the more advanced technologies the eeme select SCP end feedstock could be uaed for both ● nimal feeds and direct human consumption. Such commonality gives theee technologies important advantages over earlier firet-generetion technologies that were aimed primarily at animal feeds, whose acceptability for direct human consumption may be questionable.
**Presently being done commercially to increasing extent with oil-seed proteins.

cells) are upgraded into higher-priced end products. However, the effects are far greater in the case of SCP economics because of the unusually great "spread" in the prices of the corresponding proteins against which SCP would compete. This "spread" – going from low-priced animal feed protein supplement such as soymeal to high-priced proteins for direct human ingestion (meat, poultry, etc.) – u today over 1,500% in some countries. The spread is destined to become even greater in future years because the prices of human-ingested proteins are rising faster than those of agricultural crops such as soybeans.

This great spread in potential SCP selling prices makes it impossible to generalize on the economics of SCP manufacturing enterprises unless one first postulates the specific product or products "mix" that the enterprise would enter, at the same time keeping in mind that during the life of the plant the SCP types made, markets reached, and "mix" will undergo transition. Such considerations emphasize the value of creating enterprises that are built around advanced SCP technologies that will produce a variety of products of sufficiently high quality to allow change from one type and market to another without major revisions in plant equipment, feedstocks, or operations.

Locale

The feasibility and timing of commercial SCP enterprises also depends upon their sites and the markets they serve. In the United States SCP will for some time have difficulty in competing with soymeal as a supplementary protein in animal feeds, simply because soybean supply is large and its prices are low. This situation does not prevail, at least not at present, in any other country of the world except Brazil. All others lack significant soybean production yet many wish to grow animals to feed burgeoning populations that prefer meat and can afford to buy it.

"Intrinsic" Versus "Effective" Demand

While there is great "intrinsic" need or "demand" for more protein in human diet the "effective" demand, the ability to buy, is low or non-existent in those countries that have greatest need because of low per capita income. From this one might conclude that the first major markets* for SCP will be in countries of higher per capita incomes, where, however, protein need is generally less. This appears inevitable unless, because of the growing severity of protein shortages and their many possible effects, governments are stimulated to create early, meaningful economic mechanisms (financing of plants, price supports and other incentives) that will allow protein to reach the very poor at the extremely low prices they might be able to afford.

Key Process Variables Affecting SCP Economics

Many other variables also affect SCP economics whose nature and significance differ between candidate enterprises. Common to all, however, are certain key process, plant design and operational parameters that, by virtue of their commonality, provide guidelines in planning such enterprises and the conduct of research, development and design to optimize their performance.

* Thb statement applies only to markets, not to feasible locations of plants. The plants could of course be in countries having low domestic consumption but large energy reserves.

Phillips-Provesta has made parametric studies of a variety of possible project situations, using computer and other techniques. For the purpose of this paper these studies are reduced to a few examples that illustrate the influence of some of the more significant variables. The examples are expressed in "dimensionless" units so as not to make the results speciously applicable, in time or place, to any single situation. To arrive at values that would be in proper ratio to each other, investment and operating costs are arbitrarily based on an assumed U.S. Gulf Coast plant completed in 1980. [This assumption will not accurately reflect the differences that exist worldwide in such costs. For accuracy, each specific case requires special study. Nevertheless, the relationships shown are reasonably indicate of the relative sensitivity of the variables represented.] The measure of "economic value" was assumed to be an SCP plant selling price that, while variable and dependent on other factors, would in all cases yield exactly the same return on investment capital, thus eliminating R.O.I. as a variable. The R.O.I. arbitrarily chosen was a moderate one such as might reasonably be obtained with investment capital in other lines of business producing more conventional products. Manufacturing costs were calculated by methods used by Stanford Research Institute in various studies.

Figure 7 illustrates what are perhaps the two most important process variables affecting SCP selling price at constant R.O.I. These are the temperatures of the cooling water used in the fermentation stage and the temperature of the contents of the fermenter during fermentation. Three assumed values of average cooling water temperature (average of inlet and outlet) are shown. The process was arbitrarily assumed to be one in which some chosen SCP organism would give an SCP product yield of approximately 0.5 pound per pound of total methanol fed to the fermentation.* * The cell concentration within the fermenter was arbitrarily set at approximately 40 grams per liter of total fermenter vessel volume and the "residence time" of the organism within the fermenter was set at two hours.

The solid line portions of the graph show those operating regimes in which some fermenter design could conceivably be devised and employed within the framework of the premised conditions. The dashed lines represent those regimes where departure from the set operating conditions would have to occur. The simplest way to illustrate this transition (solid to dashed) is to visualize that point at which the fermenter is completely filled internally with heat exchange surfaces and yet still cannot remove the total heat generated by the fermentation. [The illustrated relationships therefore would not apply to fermenter designs in which some or all of the heat exchange surfaces are external to the inside of the fermenter vessel. However, in such designs the SCP productivity of the total fermentation cycle would probably be reduced, causing an attendant shift (increase) in the SCP selling price needed to achieve the assumed constant R.O.I.]

An alternative to cooling water (for fermentation cooling) is refrigeration. Figure 7 illustrates its effect at a refrigerant-to-fermenter temperature difference of 8.5°C when the average cooling water temperature is 36°C. Thus, while one were to be limited to about 45°C fermenter temperature with an average cooling water temperature of 36°C, one could through refrigeration operate with lower fermenter temperatures if the attendant 20 to 30% increase in selling price required to achieve the assumed constant R.O.I. would be commercially viable.

**"Total methanol employed" is not necessarily the same as "total methanol utilized" in ● fermentation. The tatter, used ● t times by others, may not include "unutilized" methanol that is in effect lost.

One can appreciate from Figure 7 the tremendous incentive that exists for the development of organisms that can operate at higher fermenter temperatures, such as those discovered by Phillips-Provesta, especially in those areas of the world where available cooling water is at relatively high temperatures.

Figure 8 shows the effect of basic feedstock energy cost on SCP selling price. The assumptions are the same as those in Figure 7. To eliminate fermenter and cooling water temperatures as variables, however, in Figure 8 the temperature difference was arbitrarily assumed to be 19°C (34° Fahrenheit). This allows the effects of basic energy (gas) cost on methanol, utility and ammonia costs to be assessed. The values shown for ammonia and methanol assume the existence of separate, large-scale plants for the production of these components. The effect of energy cost on utility costs was derived in a similar manner and reflects the fact that the utility costs are mostly energy.

Figure 9 shows the relationship of gas and methanol prices (dimensionless) to size of plant used for manufacturing methanol at constant, reasonable R.O.I. The figure embraces smaller, leas efficient methanol (MeOH) plants, sized only to the needs of methanol as feedstock for SCP production, as well as larger plants to produce “methanol fuel”. As seen, a smaller MeOH plant sized to a 100,000 tons/year SCP plant requires a methanol charge-in price (at constant R.O.I.) almost twice that of a larger MeOH plant, whose excess output could go into non-SCP markets.

Recent major rises in the costs of hydrocarbons and derivatives such as alcohols, coupled with uncertainty as to where, when and at what level such prices will stabilize, or what trend lines they will follow, has aggravated this sensitivity of economics to feedstock price. Sensitivity is made even greater if one postulates that the upward price trend of such feedstocks will be steeper than that of grains, legumes, and fishmeal, against which SCP must compete in the animal feed market. The implications of such increasing relative price “spread” are of course much leas in the case of SCP made for direct human consumption, competing against proteins such as meat, poultry, etc.

Figure 10 shows how each of the major stages of an SCP plant influences the SCP price needed for constant R.O.I. Two basic plants are premised: The first uses cooling water of any temperature, provided the SCP organism employed can operate with as little es 19°C temperature difference between the average cooling water and the content of the fermenter; the second requires a 24°C refrigeration system, assuming average cooling water temperature of 36°C and fermenter of 32.5°C. Other premises are the same as in Figure 7. Each major stage includes an allocated portion of total off-plot expenses (steam, electricity, cooling, etc.) plus their related capital costs and capital recovery. Such allocations to each stage were made on the basis of relative usage by each. The raw materials and feed preparation stage includes the effects of the costs of raw materials, operation, capital employed and R.O.I.

Figure 10 again shows the substantial effect of the fermentation stage (refrigeration vs. no refrigeration) on overall economics, and the penalty incurred with organisms that must be employed at lower temperatures.

Proprietary technologies have been developed by Phillips-Provesta that achieve very high efficiencies through the use of organisms (thermophiles) that function well at high temperatures, thereby obviating the need of refrigeration, and that have high oxygen utilization capacity during fermentation, thereby reducing air compressor loads and improving fermenter efficiency.

Figure 11 shows the effects of methanol price and SCP plant investment upon R.O.I. at any assumed constant SCP selling price. Conversely, at any assumed constant R.O. I., it shows the SCP selling price needed to achieve such R.O.I. at varying SCP plant investments and methanol prices. Figure 11 also takes account, through methanol price, of the effects of methanol plant size (Figure 9) on the other parameters.

Some of the foregoing factors may not have high leverage in the commercialization of food products that are not capital intensive. However, SCP is significantly more capital intensive than other proteins. Aggravating this investment-induced sensitivity are the extreme monetary inflations and cost escalations of recent years, uncertainty as to when and how such increases will stabilize into reasonably predictive trend lines, and growing competition for sources of capital. [The estimated cost of construction of large SCP plants has, to illustrate, more than doubled in less than three years.]

The effects of some of these factors on SCP economics are reduced by second and third generation technologies such as referred to herein,

Effects of Governmental Regulations

Significant though they may be, many of the foregoing factors could be overshadowed in their effects on SCP economics by government regulations that control its manufacture, sale and usage. Regulatory bodies of various nations seek to insure, properly so, that “new” proteins such as SCP will not have deleterious effects on the health of their peoples. In this effort some may be tempted to place more stringent demands and restrictions upon the new proteins than those heretofore placed on conventional proteins and food products, not because of the intrinsic characteristics of SCP’s, but because of their novelty. The effects of any such regulatory bias on economics, SCP availability and industry’s motivation to build expensive SCP plants with private capital could be minor and reasonable, or they could prove severe deterrents to commercialization.

Aware of this danger, yet also mindful of the need for SCP quality criteria that safeguard the public’s interests, in a manner and to a degree commensurate with regulations governing conventional proteins and foods, the Protein Advisory Group of United Nations evolved and issued a series of advisory “Guidelines” for use by regulatory bodies in the latter’s issuance of their own national criteria. Another objective of these Guidelines is as stated in Attachment A to create, to the greatest degree possible, a commonality between the regulations of countries, thereby to allow unimpeded international SCP export-import trade between them. Such commonality would also provide planners of commercial SCP enterprises with firm, consistent points of reference, If, however, nations individually deviate significantly from the Guidelines, it will create inconsistencies that could greatly affect SCP prices, availability and commercial timing.

The foregoing statements apply to the need of commonality in SCP quality regulations between nations. They do not imply that the regulations should also assume a non-existent commonality between all SCP's regardless of the feedstock (substrate), organism or process employed. All SCP's are not the same nutritionally nor from a safety (toxicology) stand. point*. Care must be taken by regulatory agencies to write regulations that recognize such differences and distinguish between SCP's, and to avoid the temptation to set the criteria for all SCP's, regardless of their intrinsic quality, at the level of their lowest common denominator, i.e., the "suspect" types. If the latter were done, it would greatly penalize those producers who through years of effort and at great expense have arrived at organisms, processes and substrates that can efficiently and consistently produce SCP's of high quality and safety. If such superior types are arbitrarily burdened with the same stringent testing and quality controls needed for the suspect types, the effects on the superior types will certainly be negative in the form of higher manufacturing costs, higher prices, and possibly reduced availability.

● As example, SCP's made using hydrocarbon derivatives, e.g., alcohols, avoid some of the questions posed by SCP's made using hydrocarbons themselves.

\# # # # #

Conclusions

- The methods that mankind has used in the past to make protein are inadequate to relieve its severe and growing shortage. New technologies that "breed" single cell protein (SCP) efficiently and rapidly using hydrocarbon derivatives can do so with a small fraction of world petroleum reserves.

- The magnitude and timing of SCP's impact on world protein supply - at first mainly in animal feeds, later increasingly in human foods – cannot be accurately predicted because of many influencing factors, Governments, working together, could elect to create economic incentives that would stimulate early, large commercialization. Failing to do so, they may passively allow commercialization to evolve more slowly despite the world's pressing need for more protein,

- All SCP technologies are not alike from the standpoint of efficiency and the products made from them vary in both quality and safety. Many & not use methanol feedstock and thus do not enjoy its advantages. Science is now yielding advanced technologies such as the Phillips-Provesta types outlined herein that could render earlier, less efficient "first-generation" technologies obsolescent and non-competitive with attendantly poor returns (or losses) on investments.

- Categorical assessments cannot be made a priori as to the viability of SCP enterprises. sensitive to many variables, the economics of each will differ and each must be studied as a special case.

- SCP is not a panacea that by virtue of its greater efficiency will displace conventional agricultural and animal sources of protein. The methods of the past will continue to be needed, despite their relative inefficiencies, because of their great infrastructural value in society. Improvement of the old ways and adoption of the new will go hand in hand, complementing each other, thereby better serving mankind in its urgent quest for protein,

- Nations in the Middle East and elsewhere that possess large gas and oil reserves that may not already be fully committed to other endeavors appear to be in the best strategic and economic position to make and sell SCP in world trade. The advanced technologies that use "methanol fuel" as feedstock and operate efficiently at high temperatures, such as those described herein, are ideally suited to such countries.

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Attachment A

PROTEIN ADVISORY GROUP OF THE UNITED NATIONS SYSTEM
GROUPE CONSULTATIF SUR LES PROTEINES DU SYSTEME DES NATIONS UNIES
GRUPO ASESOR SOBRE PROTEINAS **DEL SYSTEMA DE LAS NACIONES UNIDAS**

9 September 1974

The need for urgent action to expand the world supply of protein for human food and animal feed has been well documented. Present and projected critical shortages of protein, in affluent as well as less affluent nations, have stimulated agricultural and industrial research and development in many countries aimed at meeting this need. Novel technologies for massive and economic production of single cell proteins (SCP) from fermentation processes employing various substrates have led to construction of large production plants built by companies in several countries; more are certain to be built in the near future. These developments have several implications. For one, they imply that a revolution in animal and human feeding will take place over a relatively short period; millions of people will consume meat, milk and eggs from animals receiving new forms of protein in their feeding rations. Before very long, humans will receive such protein foods as direct components of their diet. They also imply that private industry will be encouraged by governments, as well as international and bilateral agencies seeking to stimulate development, to make huge investments in plants to produce such forms of protein. Yet another implication is that in anticipation of the introduction of novel proteins into the diets of their populations, the governmental agencies of many nations will seek guidance in the establishment of regulations consistent with those governing more conventional feedstuffs. These will reflect the need to insure that the new proteins will have a beneficial effect on the nutrition and health of their peoples.

We are thus challenged today with an unprecedented convergence of circumstances:

a) immediate and increasing worldwide demand for protein;

b) immediate demand for industry as well as agriculture to produce new forms of proteins, including single cell proteins, utilizing available technologies;

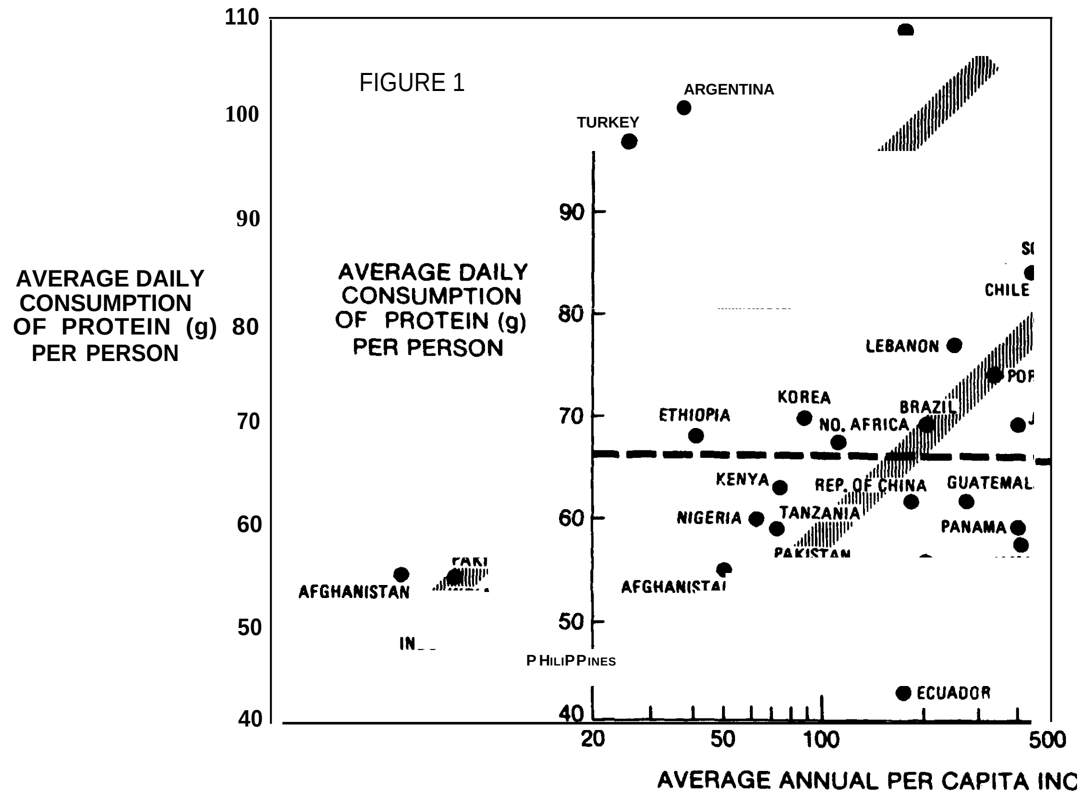
c) immediate demands for many governments to evolve objective regulations controlling the quality and safety of novel protein sources, such regulations to be capable of harmonization at the international level to the greatest possible extent; and

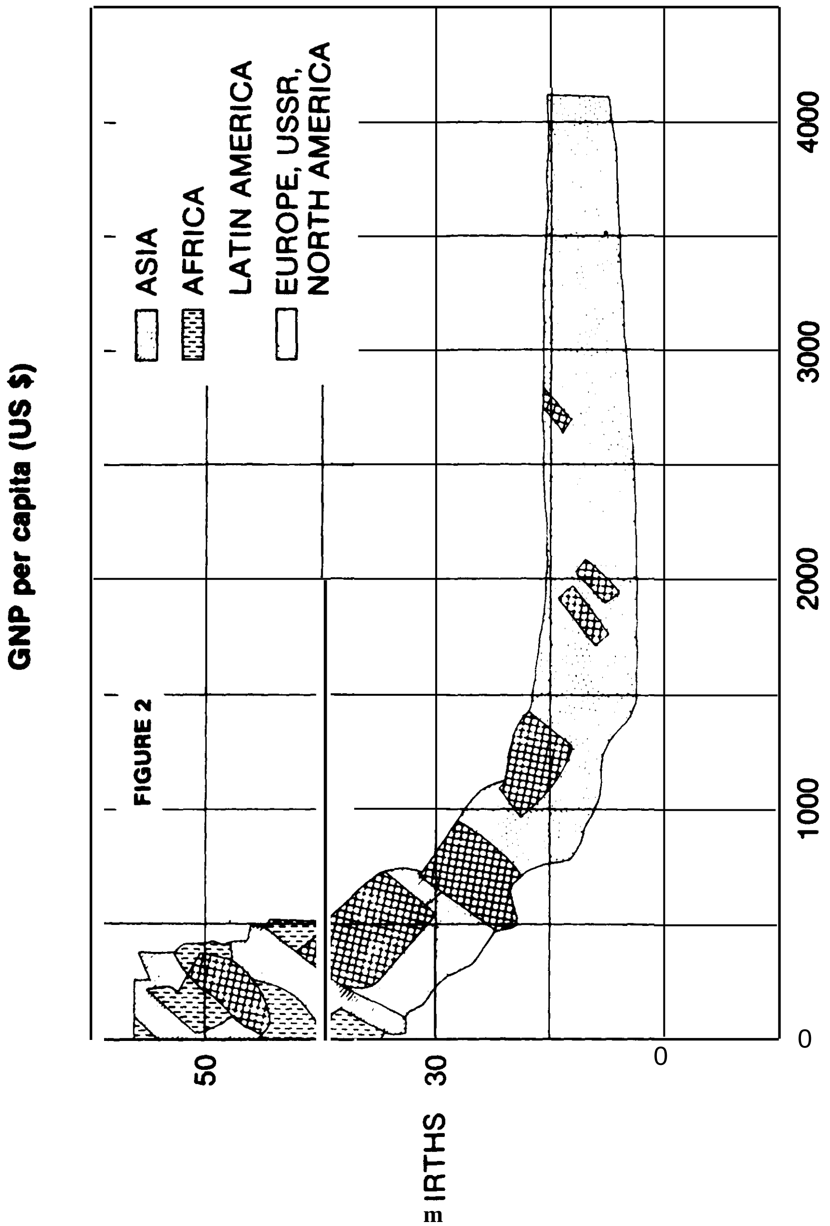
d) an almost equally immediate demand to allow unrestricted and unimpeded international export and import of such products, which will require international similarity of national regulations.

<u>Members of the Drafting Committee</u>

Dr. K. L. Blaxter
Dr. K. Aibara
Dr. A. F. Langlykke
Mr. Emil A. Malick
Professor J. C. Senez
Dr. B. L. Oser, Chairman

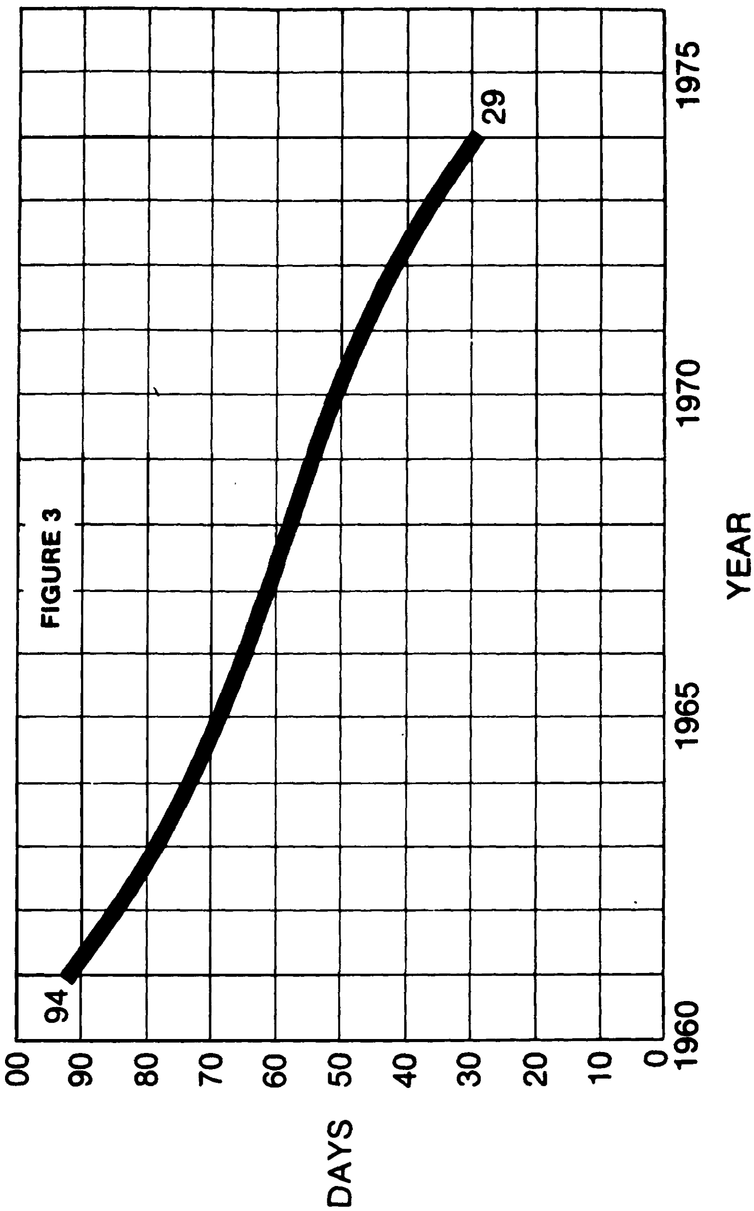
WORLD PROTEIN REQUIREMENTS




GNP per capita (US $)
FIGURE 2
ASIA
AFRICA
LATIN AMERICA
EUROPE, USSR, NORTH AMERICA
0
1000
2000
3000
4000
50
30
0
IRTHS
m

WORLD FOOD RESERVES
AS DAYS OF CONSUMPTION

FIGURE 3



PROTEIN PRODUCTION "CHAIN"

CONVENTIONAL

PLANT SEED
↓
GROW, NOURISH
↓
HARVEST
↓
FEED TO ANIMALS
↓
GROW ANIMALS
↓
SLAUGHTER
↓
COOK, SHRINK
↓
UTILIZE

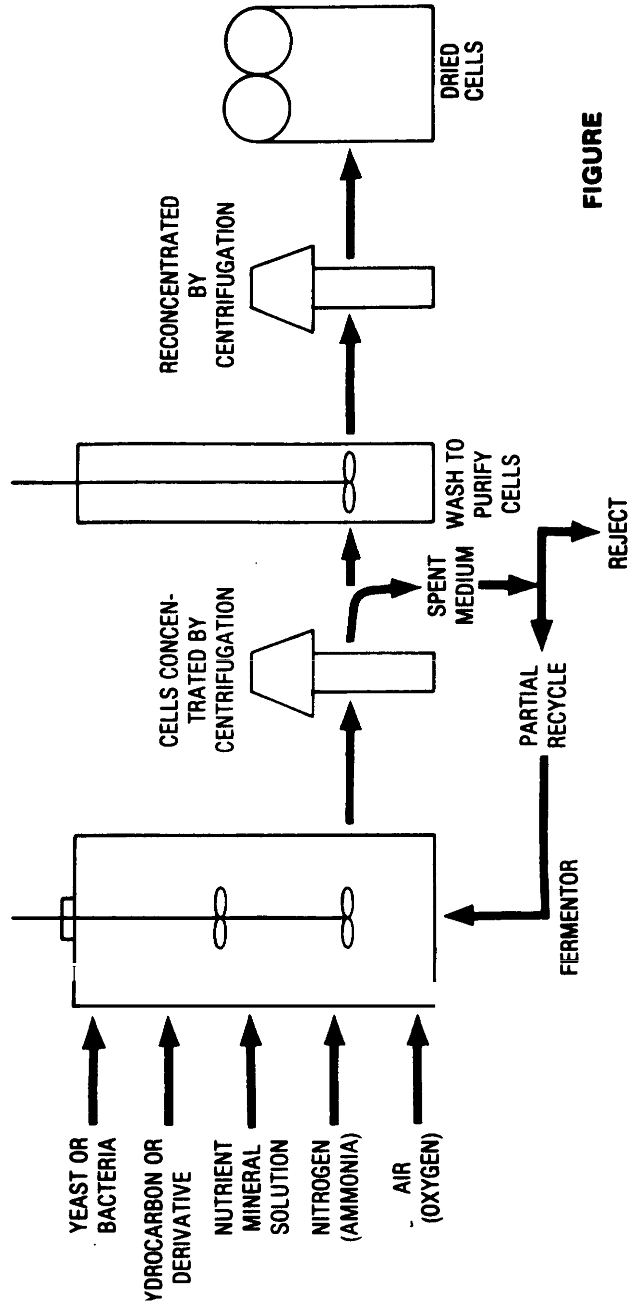
SOYA

PLANT
↓
GROW
↓
HARVEST
↓
EXTRACT OIL, ETC
↓
ISOLATE PROTEIN
↓
UTILIZE

SCP

FERMENT
↓
HARVEST
↓
UTILIZE

FIGURE 4


YEAST OR BACTERIA
YDROCARBON OR DERIVATIVE
NUTRIENT MINERAL SOLUTION
NITROGEN (AMMONIA)
AIR (OXYGEN)
FERMENTOR
PARTIAL RECYCLE
CELLS CONCEN-TRATED BY CENTRIFUGATION
SPENT MEDIUM
REJECT
WASH TO PURIFY CELLS
RECONCENTRATED BY CENTRIFUGATION
DRIED CELLS

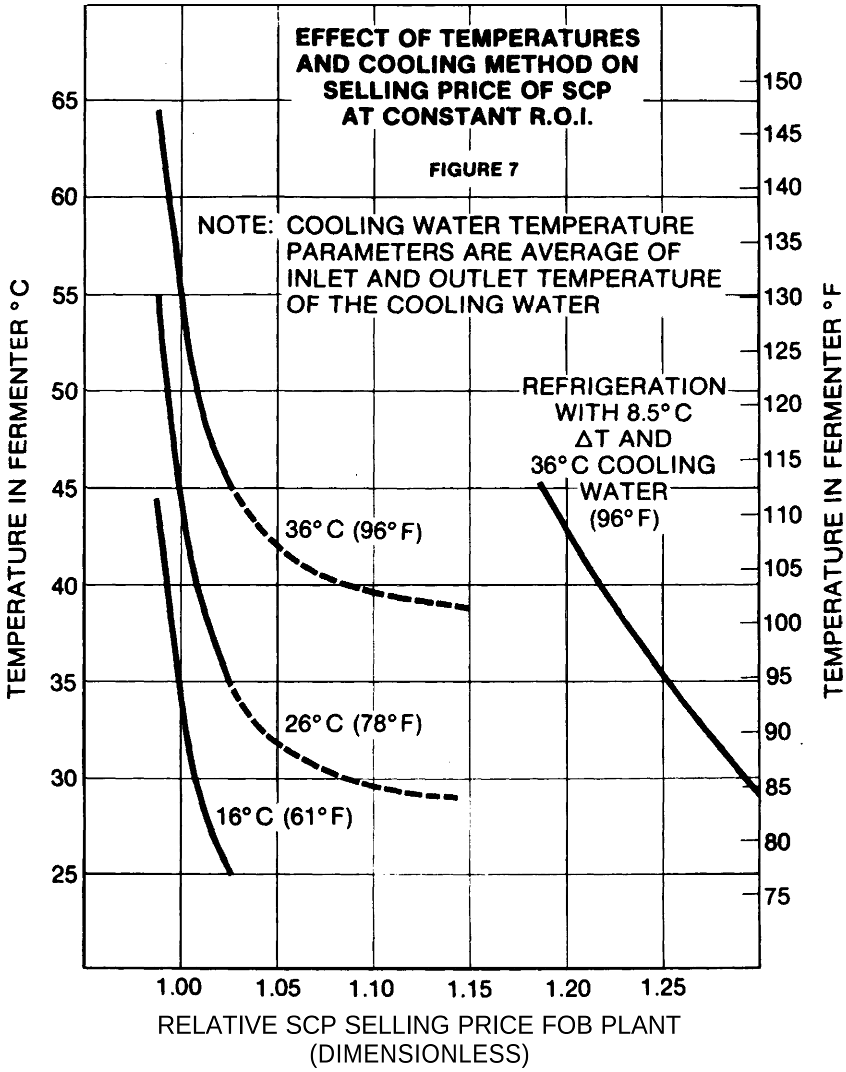
FIGURE

COMMERCIALIZATION

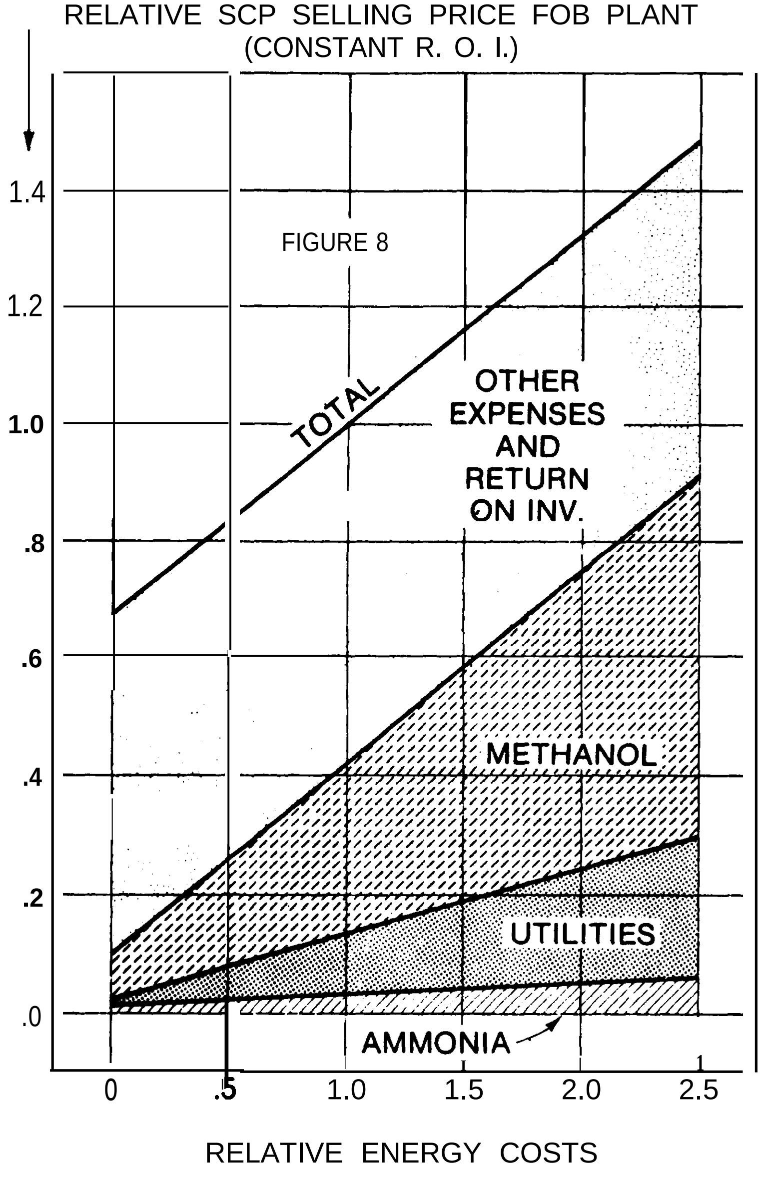
SCP MARKETS

FIGURE 6

- **ANIMAL**
  - IN MIXED DRY FEEDS
  - IN MIXED LIQUID FEEDS
  - AS MILK EXTENDERS
  - "DOMINO" EFFECT
- **HUMAN**
  - WHOLE CELLS
  - ISOLATED PROTEIN
  - "STRUCTURED" ANALOGS
- **LOCALES**
- **INTRINSIC VS. EFFECTIVE DEMAND**


EFFECT OF TEMPERATURES
AND COOLING METHOD ON
SELLING PRICE OF SCP
AT CONSTANT R.O.I.
FIGURE 7
NOTE: COOLING WATER TEMPERATURE
PARAMETERS ARE AVERAGE OF
INLET AND OUTLET TEMPERATURE
OF THE COOLING WATER
REFRIGERATION
WITH 8.5°C
ΔT AND
36°C COOLING
WATER
(96°F)
36°C (96°F)
26°C (78°F)
16°C (61°F)
TEMPERATURE IN FERMENTER °C
TEMPERATURE IN FERMENTER °F
65
60
55
50
45
40
35
30
25
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
1.00
1.05
1.10
1.15
1.20
1.25
RELATIVE SCP SELLING PRICE FOB PLANT
(DIMENSIONLESS)

EFFECT OF ENERGY COSTS ON SELLING PRICE OF SINGLE CELL PROTEIN AT CONSTANT R.O.I.
(DIMENSIONLESS UNITS)



METHANOL PRICE EFFECT IN PRICE OF SCP,
FOR CONSTANT R.O.I.

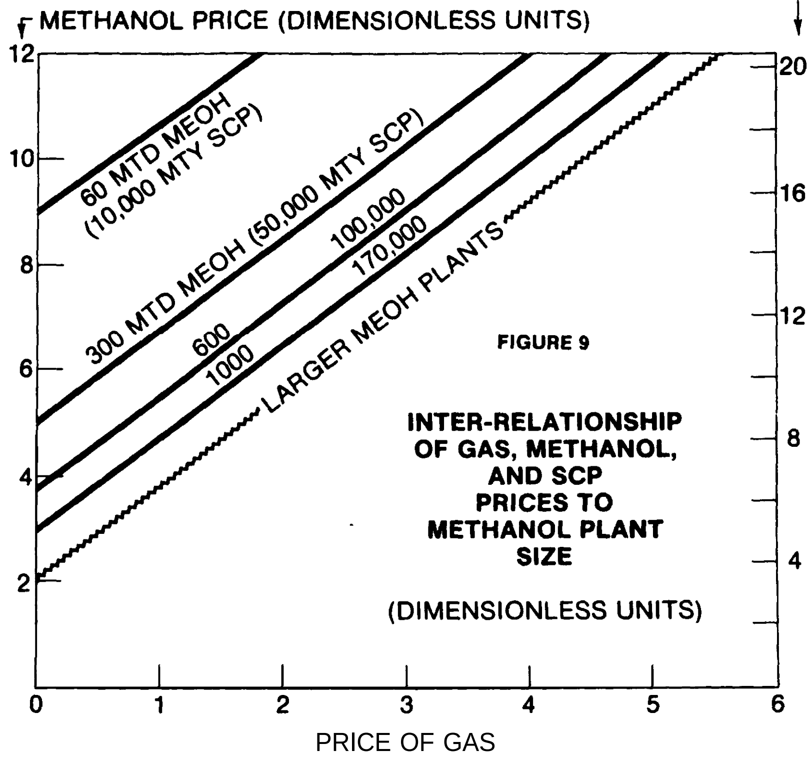


FIGURE 9

INTER-RELATIONSHIP OF GAS, METHANOL, AND SCP PRICES TO METHANOL PLANT SIZE

(DIMENSIONLESS UNITS)

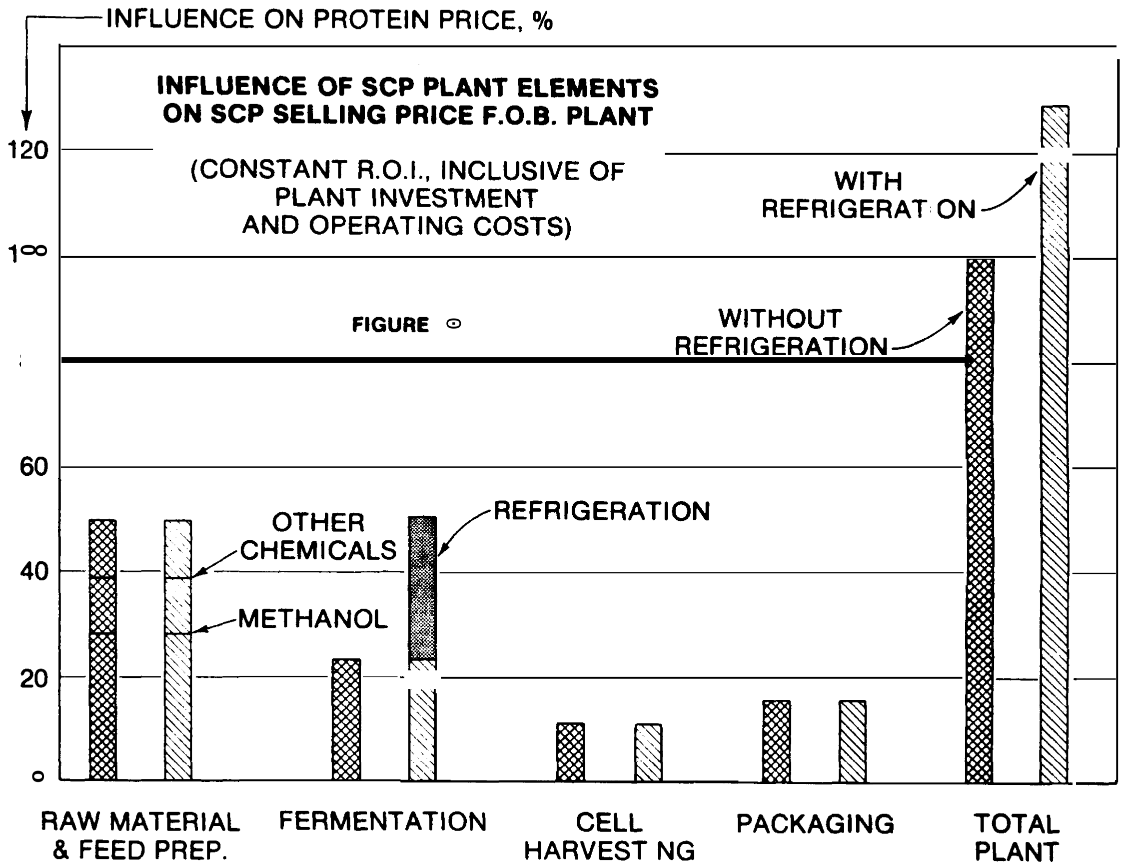
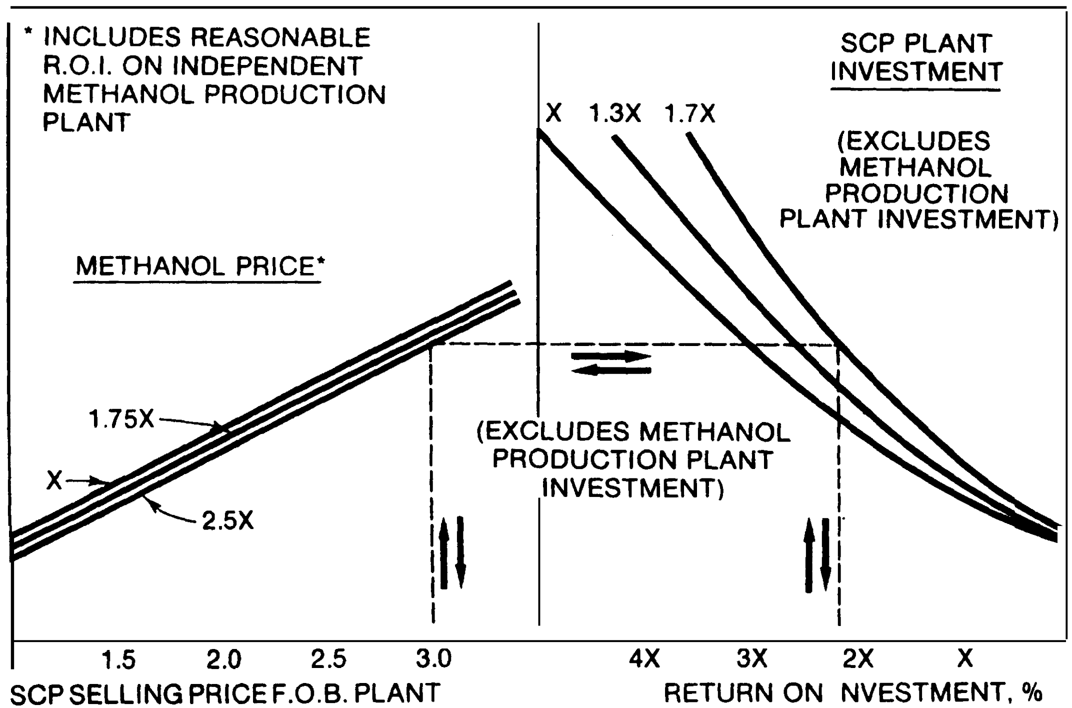

INFLUENCE ON PROTEIN PRICE, %
INFLUENCE OF SCP PLANT ELEMENTS ON SCP SELLING PRICE F.O.B. PLANT
(CONSTANT R.O.I., INCLUSIVE OF PLANT INVESTMENT AND OPERATING COSTS)
FIGURE
120
100
60
40
20
0
WITH REFRIGERATION
WITHOUT REFRIGERATION
OTHER CHEMICALS
METHANOL
REFRIGERATION
RAW MATERIAL & FEED PREP.
FERMENTATION
CELL HARVESTING
PACKAGING
TOTAL PLANT

FIGURE 11

SINGLE CELL PROTEIN PLANT
100,000 TM/YR CAPACITY
MIDDLE EAST LOCATION
(DIMENSIONLESS UNITS)



APPENDIX B--EXHIBIT 2

[Excerpt from the Journal of Commerce, Aug. 27, 1973]

WORSENING FOOD SHORTAGES CALL FOR GLOBAL PLANNING

(By Emil A. Malick)

For decades international experts have warned of the need for massive, globally-integrated actions to relieve growing world food shortage. Yet the overall trend still goes from bad to worse, with protein most critical.

Paradoxically, in the face of shortages, science, agriculture and industry today have the latent ability to close the food gap to a greater extent than ever before in man's history.

New and improved technologies could, if the world works in concert, provide the foundation for orderly long-range relief of malnutrition-malnutrition that reveals itself not only as severe starvation but also, in its more insidious forms, as retarded mental and physical development of children and reduced intelligence and physical capacity for productive work in adults.

Like Gulliver straining at his bonds, industry is held back from making such inputs because of many unnecessary impediments to effective execution of new projects in many parts of the world.

Only government can cut the bonds . . . (by legislative actions that would) . . . transform high-risk, high-sensitivity ventures into ones that meet the minimum criteria under which private enterprise must work if it is to stay solvent.

In the past it was held that food demand would pivot on population growth, and that short-term upsets in grain production, which makes up 52 percent of man's food worldwide, could be covered by surplus reserves.

Now two new factors, both negative, have crept into the food equation.

One, rivaling population growth in its effect, is the rising affluence of many nations reflected by a desire for more meat. The other is the recent depletion of surplus agri-product stockpiles.

The yellow caution lights of the past have now turned red, clear to all except the color-blind. On a global scale the gap between supply and demand grows greater and world prices will hit unprecedented highs, hard to cope with by the affluent, impossible by the poor.

The half-hearted, disjointed efforts of the past have done little to curb population growth and world population will still probably double by the next generation, meaning three billion more mouths to feed.

If the present trend holds, fully 80 per cent of this growth will be in poorer nations where per capita income, often a scant $50 to $100 a year, cannot buy enough food to avoid malnutrition and starvation even at today's prices let alone those of the future.

The effect of rising affluence on greater meat demand may trend along U.S. lines, where per capita beef consumption rose from 55 pounds per year in 1940 to 117 pounds in 1972, roughly 900 per cent more per person than in Asia, and it is still rising.

Coupled with 60 per cent increase in U.S. population, U.S. consumption tripled in the same period and despite increased domestic production made the U.S. the world's leading importer of beef.

The feeding of animals for growth of meat protein requires great amounts of grain and legumes. Yet some of these same agri-products make up almost the entire directly-consumed diets of many people of the world.

Of today's three billion people one-third uses roughly as much grain to feed animals as the other two-thirds uses directly as food. In many poorer countries people eat on the average 400 pounds of grains a year, whereas in some more affluent countries per capita average runs nearly 2,000 pounds a year, of which only 150 pounds is consumed directly, the rest being fed to animals.

As a result agri-resources to support the average North American are seen to be some five times greater than those needed to support peoples elsewhere.

Feeding more grain to animals to meet rising meat demand will thus to some degree take grain out of the mouths of the people of poorer nations unless the latter, aided by massive domestic agri-programs, produce far more than in the past.

There is a way to break this "domino" effect. It calls for making better human use of the nutritious protein contained in oilseed crops, especially soybeans. Such protein can be extracted and "isolated" from oilseeds by means of currently available processes. The "isolates" can then be used for direct human consumption, either as bland supplements in other foods or, in more sophisticated forms, as tasty, nutritious high-protein "analogs" that resemble meat, poultry and fish.

By such means people would utilize "natural" agri-crop proteins at about 70 per cent "efficiency." In contrast, feeding soybeans, for example, to animals to cause them to grow protein for human use results in only 7 per cent "efficiency" of utilization of such "natural" proteins. The new technologies, now in limited production, thus permit man to make far better use of his agricultural resources.

Using oilseeds in this manner would, however, mean less of them for use as feeds for growth of animals. This could force lower per capita meat consumption, unless man creates new, less critical feeds to make up the deficit.

Here, the most exciting candidate is single cell protein (SCP) made by breeding, at rapid and efficient rates, select species of micro-organisms high in protein content. The "fermentation" processes employed use various substrates—hydrocarbons, hydrocarbon derivatives, others—as sources of energy to grow the SCP.

As yet such products have not been fully proven in the marketplace but their promise is great and massive in scale. Commercial plants are now being built abroad and may soon in the U.S. In time, with more development, some types of SCP may also become usable in human diet, adding still more needed protein to man's supply.

At best, however, neither the U.S. nor other nations can expect the U.S. to continue as the world's "breadbasket" for grains and feeds. Other nations must in time stand on their own feet in such respects.

Today the U.S. produces, for example, roughly 75 per cent of the world soybean crop. Of this an astonishing 90 per cent enters the world market. The U.S. has upped soybean output 400 per cent in the last 20 years, but mainly by planting more acres.

Now, roughly one out of seven acres in the U.S. is in soybeans and we are running out of suitable land and water for further increase, at least to the degree needed to meet growing world demand.

The new technologies are not just sophisticated "space age" types but also "grass roots" agricultural know-how that could open the way in less developed areas to tremendous increases in output of arable land and utilization of water. Rice yields per acre in India, for example, today average around one-third of Japan's and yield of corn in Brazil is aid to be one-third of U.S. acreage. There is much room for improvement, given the means-technology, financial support, incentives.

Acting in concert, world governments can use as a springboard for their efforts the extraordinarily thorough "Indicative World Plan (IWP)" of U.N.'s Food and Agriculture organization. Despite its detail (700 pages) the "IWP" is incomplete in many important aspects, as FAO itself points out, dealing as it does mainly with the developing countries but saying little about the developed nations which must interact with the others in any truly meaningful global plan. Still, the "IWP" can serve government and industry as a cornerstone. If governments continue to drag their heels and shortages get worse there will inevitably be the temptation to hit the panic button and to institute "crash", spot-remedy programs that will be far more costly and far less effective than orderly, well-integrated global planning. Awareness of this pitfall is growing.

All efforts, well-planned or not, will be futile in the long run unless the more developed countries demand that those that they would help, the nations today responsible for 80 per cent of the world's population growth, concurrently take forceful measures to check such growth. For unless the world simultaneously attends to both variables--population growth and food supply—the entire rationale fails to pieces and we can't get there from here.

And even under ideal conditions it is extremely unlikely that shortages, malnutrition and starvation can truly be "eliminated" in the foreseeable future. Maybe in distant years new sciences will achieve this utopian goal. Meanwhile, all we can do is to strive much harder to alleviate the problem.

APPENDIX B—EXHIBIT 8

[Excerpts of Statement by E. A. Malick* in the *Congressional Record* of Apr. 1, 1969]

WORLD FOOD DEVELOPMENT--ITS CHALLENGES AND OPPORTUNITIES

There are two words which characterize the present world food picture--*contradictions and confusion.* We read and hear that, on the one hand, there is a world food crisis that may bring civilization down to its knees and, on the other hand, that the crisis is not really a crisis, even though it looks like one to some, because better agriculture and other new technologies can cope with the crisis in time to avert worldwide disaster.

It is true. The specter does loom close. And it may exact its toll, not just in the form of starvation, but through many other side effects that starvation creates. These include social instability and greater susceptibility by the hungry to manipulation by those who would use hunger as a political weapon. Of concern to industry is also the prospect of potentially irreparable disorder and setback that mass hunger and attendant intellectual decline could create for future worldwide industrial growth.

The greatest tragedy, however, is none of this. It is that there is no *reason for the world to lack food. The* tragedy is not that industry lacks the ability to create vastly greater supplies of food, and with startling speed. It is that we are still *floundering on how to get the job done.* The greatest tragedy is the current lack of a hardhitting, single-minded, systems-oriented programming of effort to eradicate the food shortages in all corners of the earth. Working together, industry and government could without question assure an ample world food supply that can keep up with any presently projected growth in world population.

What the world is also starved for is innovative management and pragmatic programming of food development on a global scale. I use the word "management" to include both government and industry, each operating in its own sphere and planning broadly rather than piecemeal.

The chasm can be bridged only by an industry that is ready to apply bold new management insights that will result in programs as yet unconceived—programs that reflect integrated short and long-range considerations. And these must be built on the rock of economically viable enterprises rather than the sands of short-range problem solving and subsidies that in the long run weaken the recipients and dissipate the strength of the providers.

In such new programs industry will not be able to get by with conventional market development thinking regardless of how effective such patterns have been in the past in developed marketplaces. World food development is far more complex and is not susceptible to a same-song-second-verse approach. Of course, many of the variables are the same-financing, operations, promotion, marketing, distribution and the like. But these take on new forms in the case of world food development. Superimposed upon them in the case of food are new variables as well, the weighting of which may differ from program to program. Penetration of developed markets with products and services is one thing. Penetration of new food markets with new technologies, particularly in underdeveloped areas, is a horse of another color.

Each situation must be searched out and developed for itself, not by rote--and we, *rather than the customer,* must adjust to fit. We cannot equate the market with one or another (new) product or technology. Each is useful, Each has its place. But somewhere, not *everywhere.* Each is only a tool, and to insure successful application of these particular tools *innovative thinking* is essential. Lack of such innovative programs, custom fitted to each job, is what has made this market appear to many to be like punching a rubber bag.

In addition, programming has been badly fragmented. There are too many overlapping groups involved, each with a small piece of the action and each with a

* President of Provesta Corporation, a wholly-owned subsidiary of Phillips Petroleum Company.

different angle-political, social or economic. Governments everywhere must remodel their thinking to produce effective broad-spectrum programs, adopting viable economic patterns conceived by industry, rather than trying to have industry adapt itself to the varied, shifting and at times disoriented policies of momentary expediencies.

The potential sources of supply of new food are great. Altogether, such (new and improved) technologies could, according to some, support a world population of 50 billion people compared to the world's present 3½ billion or so. Here again, the accuracy of the projection is not important. What is important is that a great cleat more *can be done, even with today's know-how.*

These technological advances can be brought into highly developed countries as well as underdeveloped ones in a smooth, evolutionary manner, although the time scales and phasing for the two types of markets will differ. New sources of agricultural protein do not displace farming. They augment it. Protein from the sea and from microorganisms does not displace livestock and poultry. It adds to it, providing new sources of feed to more animals as well as directly to humans in time. Farming, animal growing and new technologies therefore phase together harmoniously.

There are many critical questions such markets pose: Corporate restraints on doing business; price controls; restrictions on choice of raw materials; poorly developed marketing and distributing; low per capita income; lack of domestic investment capital ; body english by government groups, and others.

But the job can be done if business management takes the initiative, devises the modus operandi, and government helps to clear the path. Both industry and government must accept these complementary roles (and) do the job in a manner that will create economically *sound industrial development.*

So far, governments have in the main part failed to adopt this (cooperative, cofunctioning) posture and industry has not been too clear on its own posture. But there are now encouraging signs that both see the light. Industry must bear the child. Government, as the sire, can benefit from the counsel the U.S. Navy used to give expectant fathers when they asked for leave to attend the birth of their offspring: The father is necessary only at the laying of the keel-not at the launching.

Actually, government and industry have very similar fiduciary responsibilities. Government must always, in principle at least, use the money of its stockholders, the taxpayers, to obtain good social and economic returns of investment of funds. Business works the same way. Each segment has the responsibility to its own stockholders to use its money to get a good return.

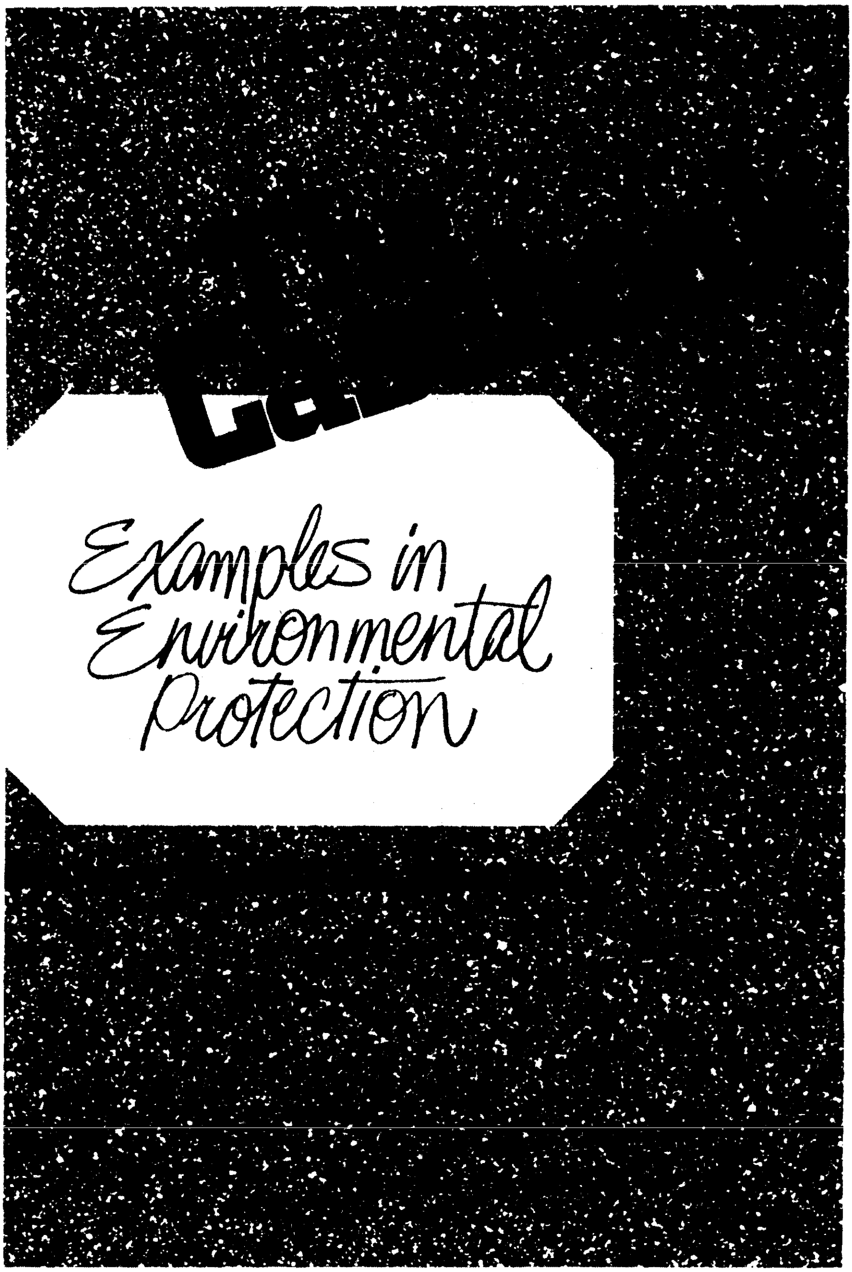
Government must relate to business. Business must relate to government. And both have to bend. Both have to help architect new vehicles to get the job done. In dealing with the food crisis, however, broad and concrete end-objectives have not yet been set, integrated timetables are non-existent, organization is not pinpointed, and lines of responsibility are not clearly delineated and not delegated—at least not to the degree needed.

There is growing awareness of this "organizational gap." But *there are as yet no strong signs that such a globally-planned effort (in food) will be put into being on the scale needed in time to avoid severe* social and *human disorder.*

Industry must apply all its skills of persuasion and capability for efficient performance to the task if for no reason other than to assure its own continued health and growth. It cannot flourish. without a healthy, alert, energetic and intelligent humanity. In nutrition, as in no other field, we now know that unless humans receive adequate and balanced diets early in life, actually starting prenatally, they will suffer to one degree or another irreparable damage to their brain cells. If the diet is grossly deficient at early stages, as it now is for large and growing numbers throughout the world, the net result will be people who throughout their lives will be underproductive in society.

Neither industry nor government could support *or* thrive under the burden of such an incapacitated mankind.

APPENDIX B.—EXHIBIT 4



To obtain the complete copy of this booklet, write: Public Relations Division, 4 D4, Phillips Petroleum Company, Bartlesville, Oklahoma 74004.