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New Protein Sources

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Introduction

First, we have to ask an obvious question: Is there really a need for more protein? What about the well publicised protein gap? The so-called world-wide protein deficit has been highly exaggerated in the past. Actually there is enough protein in the world, but the distribution between the different continents and countries and between the different social classes is extremely *distorted.* There is excess on wide side, deficiency on the other.

But even so, actual dietary surveys in many developing countries showed that plain lack of normal food, i.e. food containing an average amount of protein (let us say 8–10%) is much more widespread than specific lack of *protein.* This is also demonstrated by the fact that marasmus is much more frequent that Kwashiorkor. The most urgent and immediate need is therefore for more cheap, average food, especially *cereals,* which contain a fair amount of protein 7.5–12%), that is actually sufficient to cover the needs of the adult.

Well, right now, the world cereal reserves are extremely low, as you all know, they could only cover the world needs for a month or so!

Since more cereals should be the present aim, why do we bother at all with proteins?

There are many reasons to believe that protein is the food constituent that will be in shorter supply in the future than food as such.

- With increased living standard (per capita income) man everywhere increases his protein intake to levels that apparently exceed his physiological needs.
- With increased living standard man switches from cheap vegetable protein to expensive animal protein consumption, and it seems that nothing can be done about it.
- The population pressure in many developing countries will push the production of cheap high caloric crops (manioc) at the expense of cereals in some regions, and the cultivation of high yield cereals at the expense of protein rich pulses in others. *The net result* will always be a decrease of protein concentration in the average diet.

- Finally, it should not be forgotten that there are many *vulnerable* groups of population that have higher protein requirements, which cannot well be covered by average cereals (Small children after weaning, lactating mothers, people recovering from infectious diseases etc.).

For all these reasons it can be foreseen with a high degree of probability that the physiological and especially the commercial demand for more protein will increase considerably in the future.

The concept of the food chain

There are essentially *two ways* of making more protein available:

1. To use more efficiently the protein already available
2. To synthesize new protein.

As regards the first point, we may ask whether it is really possible to use more efficiently the available protein.

The answer is yes, of course, if we shorten the food chain. Now what do we mean by food chain? Man can take his food, and therefore its protein, *directly* from the plant kingdom with a minimum of loss, or *indirectly* from animals, in a highly inefficient way. Still more inefficient food chains are known.

When guano is used as fertilizer for corn that is fed to pigs, we are faced with a very inefficient food chain involving five steps: Fish – sea bird – guano – corn – pig – man. The latter can be made more efficient by reduction to two steps: Fishmeal – pig – man. The most efficient way is of course to eat the fish directly, shortening the food chain to one step: Fish – man.

Another example of an inefficient food chain is the way peanuts are used in India. Peanut meal is used as manure for growing cereals for man. A better way is to use peanut meal to feed pigs to produce meat for man. The most efficient way is of course to use directly peanuts as human food.

These inefficient food chains have generally immediate, practical reasons. In India for instance, cow dung is used to make fire and not as manure, because in some regions there is no other fuel available. The result, however, is a tremendous waste of valuable food material. Providing fuel would be an efficient way to combat this inefficient food chain.

We in the highly industrialized countries are, of course, persuaded that we are doing much better, but I am not so sure we really do. Indeed, the higher our living standard, the more we rely on foods of animal origin, that means, on the *indirect,* inefficient food chain. The animal is unfortunately a very poor converter of vegetable calories and protein into animal food and protein.

75 to 95% of the cereal grain we feed to our livestock is wasted and in the most affluent societies about ⅔ of the protein intake is now animal protein! The huge quantities of excess cereals used to produce this meat, milk and eggs would suffice to cover the world cereal shortage many times. In food production as in most other respects the affluent societies are wasteful societies. Dumont has

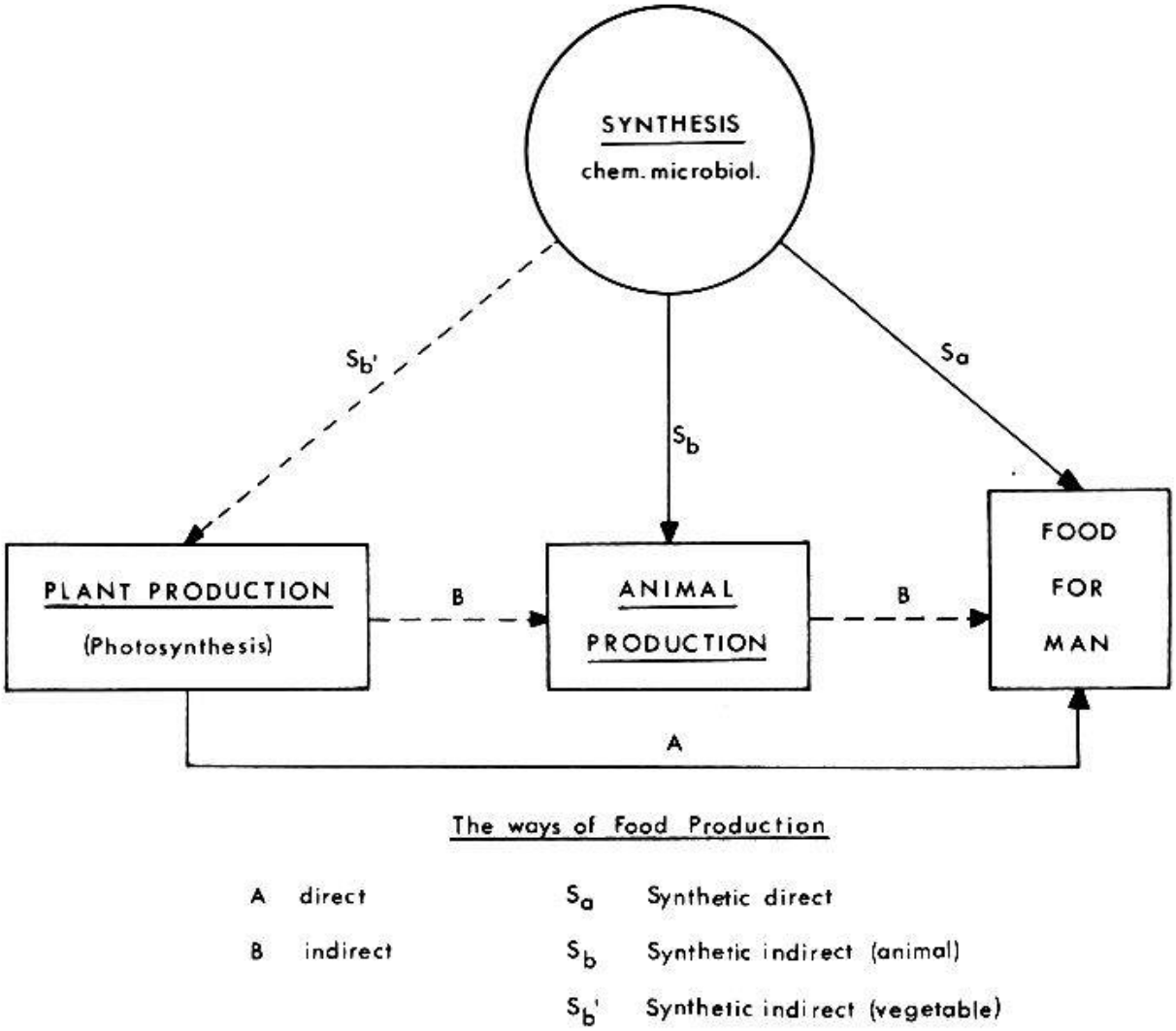

Fig. 1. The ways of Food Production: A = direct; B = indirect; S_a = Synthetic direct; S_b = Synthetic indirect (animal); S_b' = Synthetic indirect (vegetable).

spoken of an indirect cannibalism of the industrialized countries, because they divert an important part of the world cereal crop from the direct use for man to feed their pigs and poultry.

Now, what are the possible remedies? They derive from the concept of the food chain and have already been mentioned: we must try a) to shorten the food chain and b) to make it more efficient by the application of *chemical* and *biological* synthesis.

Increased use of vegetable protein sources

Since more than twenty years great efforts have been made to introduce new kinds of vegetable proteins into human food. Oilseeds have been most widely studied in this respect. The major world oilseed crops are: soya, cottonseed, peanut and sunflower. They are rich in oil and in protein and after oil

extraction a cheap, proteinrich meal is recuperated. At first sight this seems to be a straightforward proposition. In practice, however, it is a long way from the oilseed to the dish. *First,* amino acid composition and nutritive protein value must be evaluated. *Then,* anti-nutritional and toxic factors, such as antitryptic factors, hemagglutinins, gossypol, aflatoxin must be removed or avoided. *Proper processing* has to be developed for maximal oil extraction and concentration of the protein *without* damage to the nutritive value.

Last but not least, these protein-rich ingredients must be introduced into traditional foods or transformed into new types of food and find consumer acceptance.

By long and large, it must be said that all the efforts in this direction have met with very little success so far.

Enrichment of cereals with oilseed concentrates, especially for feeding the preschool child, has not found wide acceptance and only a few projects are surviving (Incaparina, Pronutro). Beverages based on soya have been successfully introduced in the Far East, but have failed so far to find acceptance in any country that had no previous tradition of soy-dishes. Therefore new, more sophisticated technology has been developed during the last ten years, mostly based on soya. The two main processed are: extrusion-cooking and spinning.

In spite of this progress textured meat-like products based on extruded soya flour as well as on the more sophisticated spun soya fibers have been introduced with only *moderate success* in the U.S.A., but their consumption is still insignificant in comparison to meat (about 1% of the beef meat!).

Conclusion

The oilseed story tells us how difficult it is to change not only food habits but, even more, traditional economical circuits (export of oilseed meals for meat production) and traditional ways of doing things.

In the field pertaining to food and agricultural economy *other time factors* must be considered than in purely technological fields!

We are thus in the *paradoxical situation* that for the years to come there are still plenty of untapped sources of vegetable protein available for food purposes, yet the difficulties encountered in making use of this potential has incited several big industries to look for completely new, synthetic sources, avoiding thus to recourse to traditional agriculture.

Protein Synthesis

Yeast and Bacteria:

We refer here to syntheses using microorganisms. The products obtained are called *S.C.P.* = single cell proteins.

For more than a half century inorganic ammonium salts are converted to

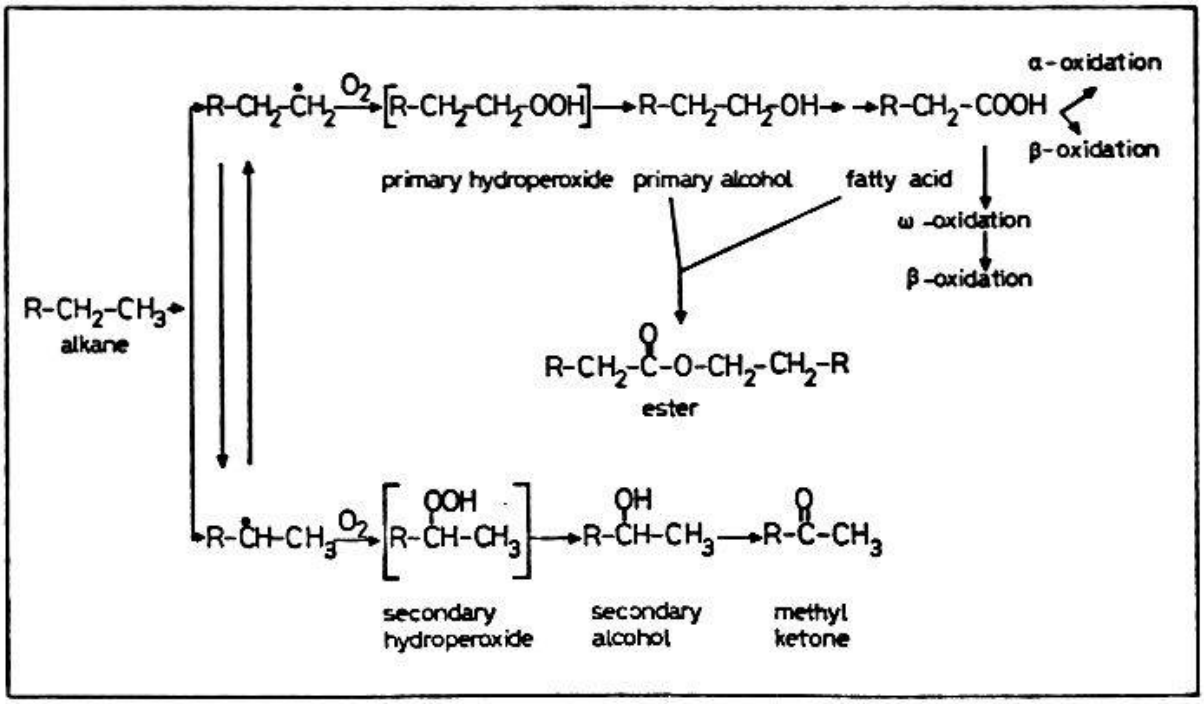

Fig. 2. Microbial oxidation of hydrocarbons.

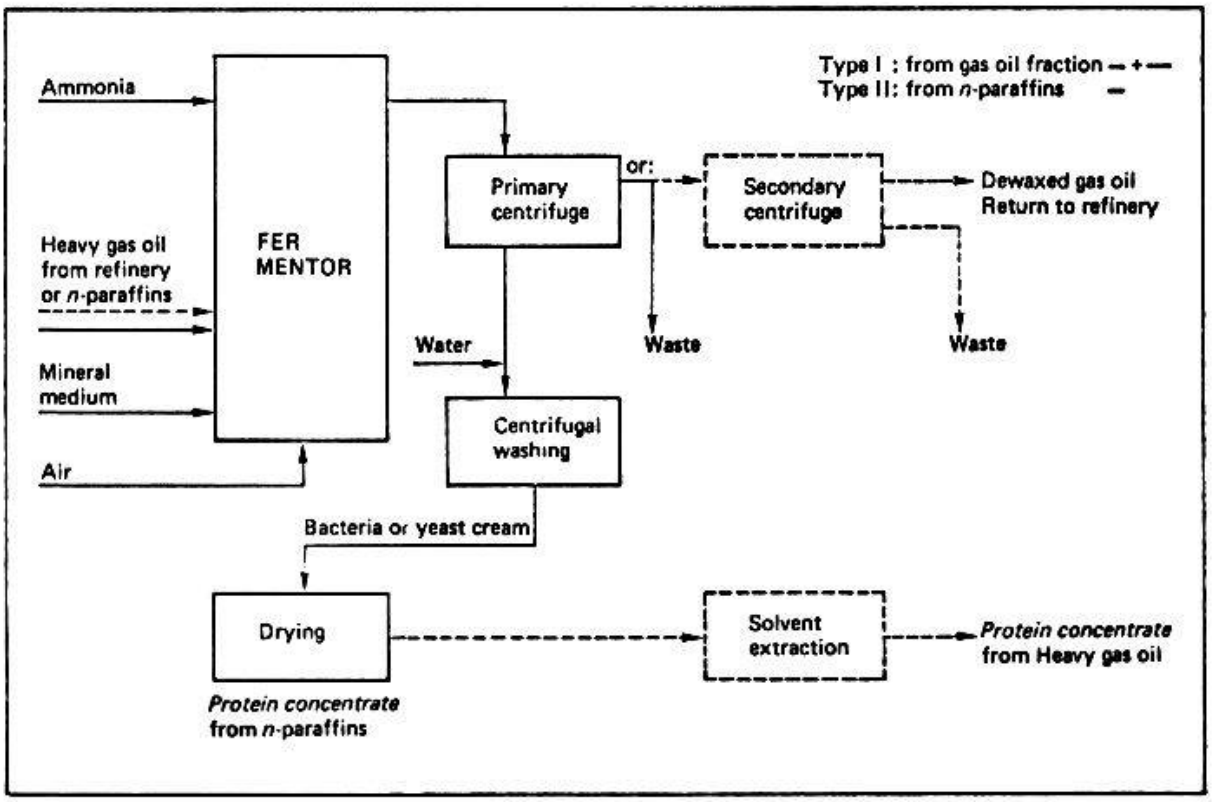

Fig. 3. Protein concentrate from heavy gas oil and *n*-paraffins.

protein by yeast, such as Torula utilis, using carbohydrates as substrate (molasses, sulphite pulp liquor, sugar wastes, etc.). The last decade or so has seen the development of biological protein synthesis using hydrocarbons and hydrocarbon derivatives as substrate.

Table 1. Analyses of protein concentrate produced from hydrocarbons by BP

	Gas oil process	*n*-Paraffin process
Conventional protein (N × 6.25)	70.5	65.0
Fat	0.45	8.1
Ash	7.9	6.0
Moisture	5.0	4.2
Metabolizable energy, kcal/kg	2.550	2.550
Amino acids in g/16 g N:		
Lysine	7.8	7.0
Histidine	2.1	2.0
Arginine	5.0	4.8
Aspartic acid	10.0	9.2
Threonine	5.4	4.9
Serine	5.1	4.8
Glutamic acid	12.1	11.3
Proline	3.7	4.4
Glycine	4.5	4.8
Alanine	5.8	7.4
Cystine	0.9	1.1
Valine	5.8	5.4
Methionine	1.6	1.8
Isoleucine	5.3	4.5
Leucine	7.8	7.0
Tyrosine	4.0	3.5
Phenylalanine	4.8	4.4
Tryptophan	1.3	1.4
Total amino acids	93.0	89.7
Total S-amino acids	2.5	2.9
Total essent. amino acids*	44.7	41.0

* incl. cystine + tyrosine

The mechanisms involved in the microbial oxidation of hydrocarbons are only partly elucidated.

The initial reaction in the pathway is usually the monoterminal oxidation of a methyl-group, characterized by the incorporation of molecular oxygen. It is generally believed that this first step proceeds via the formation of a primary free radical. The next step is the formation of hydroperoxides. The first stable compounds are *primary alcohols.* They are converted to aldehydes and finally fatty acids that are used as fuel (oxidation).

The nitrogen source is ammonia.

The energy developed is very important. Part of it is used for the synthesis of new cellular material and biochemical intermediates. The rest is transformed into heat! This is actually a big drawback.

The RNA content is very high because of the rôle of RNA in protein syn-

Table 2. General chemical composition (in % by weight)*

	(1) Yeast on paraffins	(a) Bacteria on paraffins	(b) Bacteria on ethanol	(c) Bacteria processed on ethanol
Conventional protein (N × 6.25)	50.5	67.0	77.5	79.5
True protein	44.0	51.5	61.0	76.5
Nucleic acids	6.5	15.5	16.5	3.0
Fat	10.6	21.0	5.5	7.0
Carbohydrates	26.5	8.0	10.5	1.5
Ash	9.0	6.5	7.0	3.5
Moisture	4.4	3.5	4.5	3.5
Mineral composition:				
Calcium	0.1	0.2	0.15	0.31
Phosphorus	2.1	2.8	2.31	0.95
Magnesium	0.15	0.4	0.32	0.17
Potassium	2.0	0.7	0.46	0.07
Sodium	0.14	0.7	0.46	0.17

* KALINA, V.: unpublished results (1970).

thesis. RNA content is generally a function of the growth velocity in microorganisms.

The pioneering work in this field was performed by the French subsidiary of BP by Champagnat and Professor Senez from the University of Marseille in the early sixties.

Two continuous processes were finally developed, both with the yeast Candida lipolytica. In the first process, yeast is grown on gas oil as susbtrate. It is subsequently freed from residual hydrocarbon by solvent extraction. The dewaxed gas oil returns then to the refinery.

The second process uses purified normal alkanes as substrate.

The amino acid composition of both variants is very similar and the nutritive value corresponds to 80% of that of casein.

The big difference between the two products lies in the fat content. The product produced on crude gas oil has a very low fat content because of the subsequent solvent extraction. The product grown on the purified alkane has a much higher fat content. The fat contains a certain amount of odd numbered fatty acids.

Another development is that of Exxon-Nestlé using bacteria as microorganism. The bacteria used is Acinatobacter anitratum. The substrate used was first n-alkanes, subsequently ethanol. The first batches produced contained the whole bacterial cells. Later a refining process was introduced to remove RNA. This process removed also some other undesirable substances. It is interesting to compare the effect of a change in strain (yeast or bacteria) and that of a change in substrate (paraffin-ethanol) on composition.

Table 3. Amino acid composition (in g/16 g N)*

	(1) Yeast on paraffins	(a) Bacteria on paraffins	(b) Bacteria on ethanol	(c) Bacteria processed on ethanol
Lysine	7.7	5.4	5.1	6.7
Histidine	2.1	1.7	1.7	2.1
Arginine	4.7	4.4	4.6	7.1
Aspartic acid	9.3	9.1	8.8	10.4
Threonine	4.8	4.0	4.1	5.1
Serine	4.8	2.9	3.1	3.7
Glutamic acid	12.0	12.4	11.4	15.5
Proline	5.2	2.9	2.9	3.7
Glycine	5.1	4.3	4.4	4.8
Alanine	7.1	6.4	6.9	9.7
Cystine	1.1	0.7	0.7	0.8
Valine	5.6	4.9	5.0	6.8
Methionine	1.6	1.9	2.0	2.8
Isoleucine	4.6	4.3	4.7	6.5
Leucine	7.3	6.3	6.7	10.0
Tyrosine	5.3	3.1	2.9	3.8
Phenylalanine	4.4	4.1	4.2	4.6
Tryptophan	0.9	0.8	0.9	1.0
Diaminopimelic acid	0	1.3	1.3	2.1
Total amino acids	93.6	80.9	81.4	107.2
Total S-amino acids	2.7	2.6	2.7	3.6
Total essent. amino acids (incl. cystine + tyrosine)	43.3	35.5	36.3	48.0

* BUJARD and MAURON: unpublished results (1970).

Table 4. PER determination*

	(1) Yeast on paraffins	(a) Bacteria on paraffins	(b) Bacteria on ethanol	(c) Bacteria processed on ethanol
PER (casein = 3.0)	2.5	2.0	1.9	2.9

* The products were fed to Sprague-Dawley rats at 10% conventional protein (N × 6.25) level in the feed, for three weeks [MOTTU and MAURON: unpublished results (1970)].

Yeast is generally richer in carbohydrates but lower in nucleic acids. Yeast is richer in lysine and has a higher PER value than the crude bacterial product. The latter also contains more nonamino acid nitrogen in the form of nucleic acids, amines etc.

Table 5. Fat and fatty acid composition[1]

Cn	Fatty acid	Percentage (on total fatty acids)			
		(1) Yeast on paraffins	(a) Bacteria on paraffins	(b) Bacteria on ethanol	(c) Bacteria processed on ethanol
C_8	caprylic	–	0.1	–	–
C_{10}	capric	–	2.65	–	–
$C_{10}=$	capro-oleic	–	5.25	–	–
C_{12}	lauric	0.7	2.95	4.10	4.10
C_{13}	tridecanoic	2.2	3.30	0.70	0.70
C_{14}	myristic	1.4	14.95	0.45	0.45
C_{15}	pentadecanoic	10.2	14.80	trace	trace
C_{16}	palmitic	6.6	10.10	30.65	30.65
$C_{16}=$	palmitoleic	11.2	12.20	16.40	16.40
C_{16}br	phytanoic	12.2	–	0.45	0.45
C_{17}	heptanoic	1.5	13.10	–	–
C_{18}	stearic	trace	3.20	2.10	2.10
$C_{18}=$	oleic	27.2	8.40	44.30	44.30
$C_{18}= =$	linoleic	28.2	3.20	0.70	0.70
$C_{18}= = =$	linolenic	–	6.70	–	–
C_{20}	arachidic	–	2.05	0.20	–
Unsaponifiable (on total lipids) not det.			33.6[2]	8.4[3]	8.4[3]

[1] BRACCO, U.: unpublished results (1969); BRACCO *et al.* (1971).
[2] Mostly paraffins.
[3] Mostly sterols.

The effect of substrates is very interesting. It influences very much the fat content and the fatty acid composition, but has no influence on the amino acid composition. This is perfectly logical as the amino acid composition is fixed by the genetic code. The switch from paraffin to ethanol reduces the fat content in the bacteria and the odd numbered fatty acids disappear.

Finally a purified bacterial product was prepared in which nucleic acids were removed to a large extent. This so-called processed bacterial product has a higher content in amino acids as well as in essential amino acids and its nutritive value measured as PER is almost that of casein (2.9 compared to 3.0 for casein). A summary of all the analytical data is given in the different tables. The BP development, namely yeast on hydrocarbon, is aimed only at feed production, whereas it is foreseen to use eventually the purified bacteria produced by the Exxon-Nestlé process as food.

The BP product is already on sale as animal feed ingredient.

The process using purified bacteria has given relatively satisfactory results so far but because of the energy crisis it has become rather uneconomical.

Table 6*. Analysis of bacterial S.C.P. (Pseudomonas sp.). Conv. protein: 76%. Nucleic acids: 4.5%. PER = 2.6**

	amino acid (g/16 g N)
Lysine	7.0
Histidine	2.1
Arginine	5.3
Aspartic acid	10.0
Threonine	5.0
Serine	3.4
Glutamic acid	10.7
Proline	3.7
Glycine	5.6
Alanine	8.2
Cystine	0.8
Valine	5.9
Methionine	2.7
Isoleucine	5.0
Leucine	8.2
Tyrosine	3.7
Phenylalanine	4.2
Tryptophan	1.1
Diamino pimelic acid	1.3
Total amino acids	93.9
Total S-amino acids	3.5
Total essent. amino acids	43.6

* BUJARD and KALINA, unpublished results 1975.
** MOTTU, F. unpublished results 1975.

Table 7. Evaluation of S.C.P. AA-potential

	Yeast on paraffine	Bacteria on			
	C. lipolytica	paraffine *Acinetobact. anitratum*	ethanol	ethanol processed	methanol *Pseudomonas sp.* processed
Conventional protein (N × 6.25)	65%	67%	77.5%	79.5%	76%
True Protein	58.5%	51.5%	61.0%	76.5%	76.5%
Nucleic A.	6.5%	15.5%	16.5%	3.0%	4.5%
Essential AA/16 g N	43.4	35.5	36.3	48	43.6
Essential AA/tot. AA.	46%	44%	44%	45%	46%
S-AA	2.7	2.7	2.7	3.6	3.5
Lysine	7.7	5.3	5.1	6.7	7.0
PER	2.5	2.0	1.9	2.9	2.6

Table 8. Chemical composition of some representative algae (in % by weight)

	Chlorella pyrenoïdosa No. 71105 (Gen.Dynamics)[1]	*Scenedesmus acutus* var. *alternans* ('Dortmund')[2]	*Spirulina maxima*	
			IFP France, spray-dried[3]	Texcoco Mexico, spray-dried[4]
Conventional protein (N×6.25)	55.5	50–56	65.0	63.9
Fat	7.5	12–14	6.5	5.6
Carbohydrates	17.8	10–17	16.0	not det.
Ash	8.3	6–10	4.6	5.8
Crude fiber	3.1	3–10	not det.	2.1
Nucleic acids	not det.	not det.	4.1	not det.
Moisture	7.0	4–8	7.0	7.9

[1] LUBITZ (1961).
[2] SOEDER *et al.* (1970).
[3] BUJARD *et al.* (1970).
[4] BOURGES *et al.* (1971).

Because of the increased price of hydrocarbons and especially of ethanol we had to switch to a cheaper substrate, namely methanol. Because of the switch in substrate we had also to look for another microorganism. The bacteria chosen is a Pseudomonas species. The amino acid composition and the protein nutritive value are very satisfactory, but all fermentation technology must now be readapted to the new strain. This clearly shows the difficulty of research in a moving economic world situation.

The biggest drawback of bacteria and yeast is of course the high energy needs. Feed and food protein can be produced but only at the expense of a lot of valuable, fossile energy. There is, however, a possibility to overcome this drawback by the use of photosynthetic microorganisms.

Algae

The advantage of algae is that they grow on inorganic substrates and convert directly sun-energy into food with minimum of land use. A square yard of algae can actually cover the energy and nutrient needs for a man during a year. To achieve the same result with conventional agriculture 0.4 ha are needed.

Different types of algae are grown for food use.

Historically it should be noted that Spirulina maxima was used as a staple food by the natives of Lake Tchad as well as by the old Aztecs in Mexico.

Industrial cultivation has been taken up by the Institut français du Pétrole together with the company Sosa Texcoco of Mexico in September 1972.

Table 9. Amino acid composition of some representative algae (in g/16 g N)

	Chlorella pyrenoïdosa No. 71105 (Gen. Dynamics)[1]	*Scenedesmus acutus* var. *alternans* ('Dortmund')[1]	*Spirulina maxima*	
			IFP France, spray-dried[2]	Texcoco Mexico, spray-dried[1]
Lysine	7.8	5.7	5.0	3.6
Histidine	1.5	1.5	1.7	–
Arginine	5.4	5.6	7.3	–
Aspartic acid	6.6	8.4	9.8	–
Threonine	3.4	5.2	5.0	5.0
Serine	2.5	3.5	5.0	–
Glutamic acid	9.0	10.5	13.9	–
Proline	3.7	5.6	3.4	–
Glycine	5.5	6.0	4.9	–
Alanine	6.8	8.9	8.3	–
Cystine	not det.	0.8	1.0	–
Valine	5.8	7.2	6.5	5.1
Methionine	2.0	1.4	2.5	2.1
Isoleucine	3.6	4.4	5.8	4.4
Leucine	4.0	9.3	9.9	6.8
Tyrosine	2.9	3.6	4.9	–
Phenylalanine	4.8	4.6	4.6	5.2
Tryptophan	1.5	1.4	1.6	1.1
Diaminopimelic acid	not det.	not det.	0.5	not det.
Total essent. amino acids	32.9	39.2	40.9	33.3
Total S-amino acids	–	2.2	3.5	–

[1] See table 7.

[2] BUJARD and MAURON: unpublished results (1970).

The production so far reaches one ton a day. Part is used as food, incorporated into biscuits, and part as feed ingredient, because it gives a deep yellow colour to the egg yolk!

The advantage of Spirulina is that it grows on alkaline medium using nitrate as nitrogen source. It is therefore very resistant to infections and because of the high solubility of CO_2 in alkaline medium the photosynthesis is very high. But even Spirulina cultivation under these rather good conditions is economically on the borderline. Other projects of growing algae as a food are still less promising. A possible exception is the new strain of Scenedesmus developed at the Max Planck Institute at Dortmund. Small scale pilot operations of a few 100 m^2 are in activity in Germany. A pilot-plant is presently in operation in Thailand and the product is evaluated for its taste in Thailand and in Peru. Commercially the whole venture appears still to be very uncertain. A price of 30 cents/pound for a production of 200 t/year has been stated.

Table 10. Nutritive value of the protein of some representative algae (rat)

	Chlorella pyrenoïdosa No. 71105 (Gen. Dynamics)[1]	*Scenedesmus acutus* var. *alternans* ('Dortmund')[2]	*Spirulina maxima*	
			IFP France, spray-dried[2]	Texcoco Mexico, spray-dried[3]
PER (casein = 3.0)	2.0	2.7	2.8	2.6
Digestibility	86	83	83	–
Biological value	–	68	73	–
NPU	–	57	61	57

[1] LUBITZ (1961).
[2] MOTTU and MAURON: unpublished results (1971).
[3] BOURGES *et al.* (1971).

Chlorella has been studied extensively in the 1960's by the General Dynamics Corporation in the U.S.A. in the first place to feed the astronauts during space travel. Chlorella however is not very interesting as it is expensive, of relatively low digestibility and somewhat poor nutritive value, as compared to the other algae previously mentioned.

In general we may say that algae are interesting in the sense that they do not use up energy sources but convert directly cell energy into food. The nutritive protein value is generally good. The limiting amino acids are the sulphur amino acids. This is actually a rule for all microorganisms. The prospect for the use as food is excellent for Spirulina since it has been used traditionally by some people for centuries. For the other algae the food use is still uncertain because of gastrointestinal intolerance when consumed in high amounts. This is especially true for Chlorella.

Prospects of S.C.P. as human food

We must distinguish for this appraisal at least three generations of S.C.P. products.

1st generation: whole cells grown on non-conventional substrates;
2nd generation: whole cells after RNA removal (processed S.C.P.);
3rd generation: protein concentrates + isolates.

First generation S.C.P.: should be used as animal feed only, not, in principle, as human food. The objections to the use as human food are the high RNA content, the gastrointestinal intolerances found with some crude S.C.P. and some allergic reactions observed in sensitive individuals who ingested yeast or bacterial products, sometimes even grown on conventional substrates. In spite of extensive toxicity tests in animals, these intolerances never showed up in the

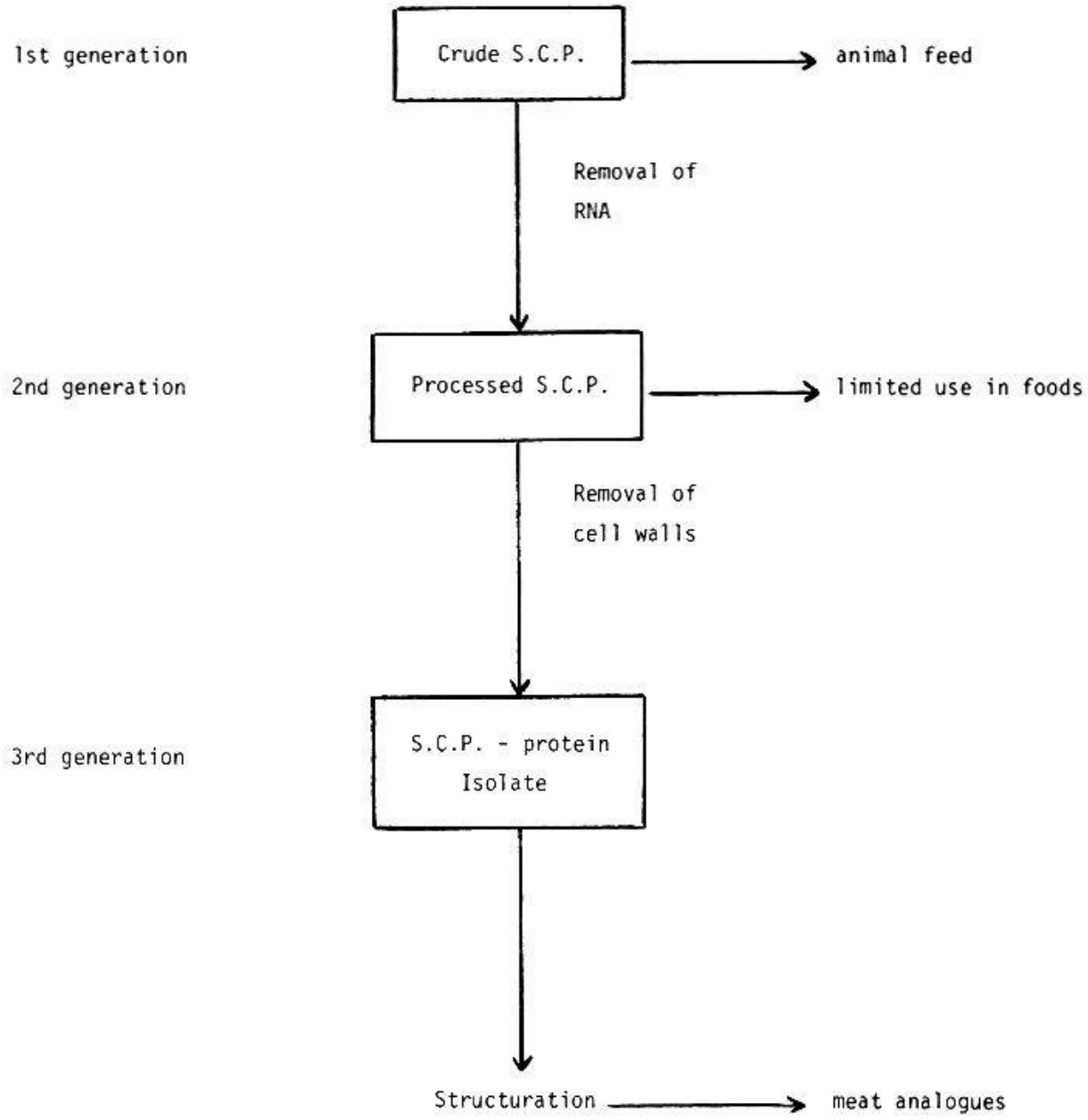

Fig. 4. The use of non-conventional S.C.P.

animal. This clearly shows the limitation of animal tests. Once the wholesomeness of the product has been thoroughly established by animal tests, tolerance tests on humans are always compulsory, before a product can be proposed as human food.

Second generation S.C.P.: could eventually be used as human food, however the data are not yet sufficient for final judgement. Processed bacteria do not provoke the intolerance reactions in man anymore, but the tests so far have been made on a relatively limited number of subjects. It should be borne in mind that even after RNA removal cell-wall substances and other biologically active compounds remain in the product.

For human food use we should therefore envisage still more sophisticated products.

Third generation S.C.P.: protein concentrates and isolates. In these products most of the non-protein substances have been completely eliminated. These highly purified products do not contain deleterious substances anymore.

These protein concentrates can then be used to develop meat analogues, much in the same way as soya is used now. We are presently producing at the pilot-plant stage such protein concentrates from bacteria, that can be spun like soya protein concentrates.

Conclusion

It will take at least ten years from now, until S.C.P. can be introduced into human food, because the whole, dried microorganism is not suitable for this. Removal of nucleic acids and other undesirable substances is compulsory. The situation is somewhat similar to that we encountered with plant proteins. S.C.P. must be considered a new raw material, much the same as the oilseed meals, from which a sophisticated technology will prepare protein concentrates for fabricating foods. The technology already at hand from the oilseed processing will be of great help for this development. However, the safety evaluation remains a formidable task in the case of S.C.P., because of the complete lack of previous experience of this material as a food. In the meantime, S.C.P. will already make a contribution as *animal feed* and save valuable vegetable protein *for direct use* by *man.*

There is little doubt that we would have here two potent means to improve the protein supply for man without further strain on the agricultural resources.

Summary

The question whether there is a real need for more protein is first critically reviewed and the two main ways of making more protein available are then exposed. They comprise the more efficient use of the protein already available and the synthesis of new protein. The possibilities offered by the oilseeds are then briefly expounded and the difficulties encountered in their practical application are evaluated. The textured meat-like products based on extruded soya and the more sophisticated spun fibers are mentioned. Protein synthesis using yeast, bacteria and algae as microorganisms is then described. The single cell protein (SCP) products obtained on different substrates (paraffins, alcohols or inorganic substrates) are evaluated as regards their general composition, amino acid content and nutritive value. The problems of wholesomeness and tolerance are briefly touched upon and the development of three generations of SCP products is envisaged, each having a higher degree of purity and being more suited as a food. Finally the prospects of SCP as human food are discussed.

Zusammenfassung

Nach kritischer Überprüfung der Frage eines grösseren Bedürfnisses an Proteinen werden die zwei hauptsächlichen Möglichkeiten, vermehrt Eiweissstoffe zur Verfügung zu stellen, beschrieben: die eine ist der ausgiebigere Gebrauch der bereits vorhandenen Proteine, die andere deren synthetische Neuherstellung. Die durch Anwendung von Ölsamen gebotenen Möglichkeiten werden kurz erwähnt und die in ihrer praktischen Anwendung anzutreffenden Schwierigkeiten untersucht. Man erinnert an die strukturierten fleischähnlichen Produkte aus der Sojabohne und an die raffinierteren aus gesponnenen Fasern. Anschliessend wird die Proteinsynthese durch Hefen, Bakterien und Algen als Mikroorganismen beschrieben. Die auf verschiedenen Substraten (Paraffin, Alkohol und anorganische Substrate) erhaltenen einzelligen Proteinprodukte («single cell protein», SCP) werden hinsichtlich ihrer Zusammensetzung, ihres Gehalts an Aminosäuren sowie ihres Ernährungswerts beurteilt. Die Fragen der Bekömmlichkeit und Verträglichkeit werden kurz angedeutet und es wird die Entwicklung dreier Generationen von SCP-Produkten vorgesehen, jede einen höheren Reinheitsgrad aufweisend und als Nahrungsmittel besser geeignet. Schliesslich werden die Aussichten diskutiert, SCP als menschliche Nahrung zu verwenden.

Résumé

La question de savoir s'il y a vraiment un manque réel d'une plus grande quantité de protéines est d'abord discutée et deux principaux moyens d'augmenter leur disponibilité sont proposés: un emploi plus efficace des protéines existantes et la synthèse de nouvelles protéines. Les possibilités offertes par les tourteaux d'oléagineux sont rapidement citées ainsi que les difficultés rencontrées dans leur application pratique. Sont mentionnés les produits texturés, imitant la viande, faits à partir de soya extrudé et ceux, plus sophistiqués, faits à partir de fibres filées. La synthèse de protéines à partir de microorganismes (levures, bactéries et algues), leur développement sur différents substrats (paraffines, alcools, milieux inorganiques) sont décrits. La composition générale, le taux en acides aminés et la valeur nutritive des produits obtenus à partir de ces organismes unicellulaires (S.C.P. = Single Cell Protein) sont donnés. Les problèmes de l'innocuité et de tolérance sont brièvement abordés ainsi que le développement de trois sortes de produits S.C.P., ayant chacun un plus haut degré de pureté, donc étant plus apte à l'alimentation. Enfin, les perspectives d'utiliser les S.C.P. dans l'alimentation humaine sont évaluées.

Riassunto

Viene dapprima riesaminata criticamente la realtà del problema di un maggior fabbisogno di sostanze proteiche e vengono esposti i due principali

modi per ottenerne più grandi quantità: si tratta da una parte dell'uso più efficace delle proteine già accessibili e dall'altra della loro preparazione sintetica. Vengono esposte in breve le possibilità offerte dall'uso di semi di olio e si valutano le difficoltà legate alla loro utilizzazione pratica. Si ricordano i prodotti intessuti simili alla carne derivati dalla soia e quelli ben più sofisticati filati con delle fibre. Viene poi descritta la sintesi delle proteine, basate sull'uso del lievito, di batteri o di alghe quali microorganismi. I derivati proteici unicellulari («single cell protein», SCP), ottenuti da diversi substrati (paraffina, alcool o substrati anorganici) vengono valutati sulla base della loro composizione generale, del loro contenuto in aminoacidi e del loro valore nutritivo. Si considerano brevemente i problemi della salubrità e della tolleranza e si prevede lo sviluppo di tre generazioni di derivati «SCP», ognuna con un grado maggiore di purezza et più adatta quale sostanza alimentare. Si discutono infine le possibilità future delle «SCP» quale cibo per l'umanità.

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