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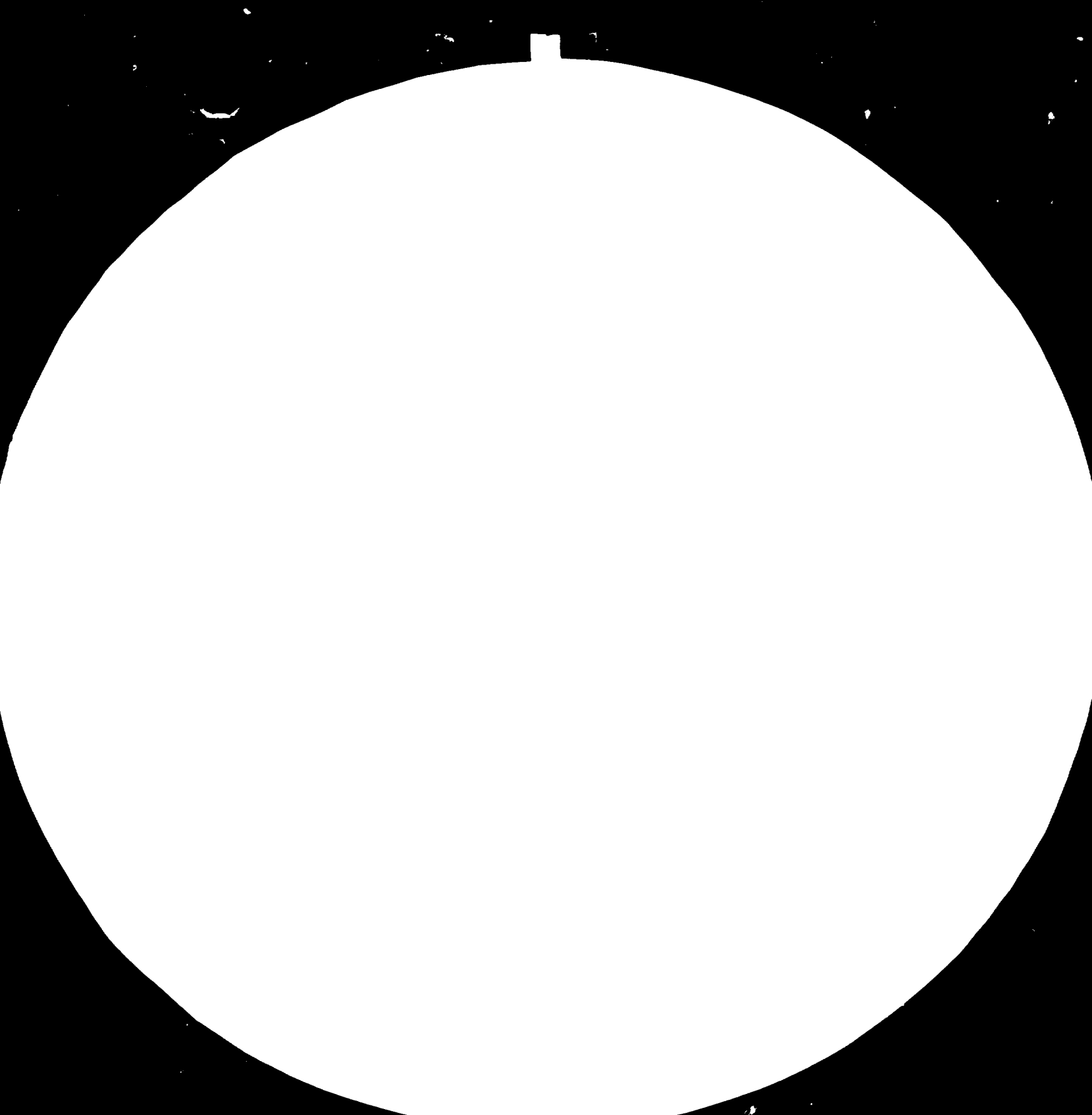
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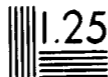
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UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Distr.
RESTRICTED
UNIDO
9 August 1983
ENGLISH

Philippines,

INDUSTRIAL CHEMICALS FROM INDIGENOUS

CARBOHYDRATE RAW MATERIALS

(SUCRO-BASED CHEMICALS)

ST/PHI/81/001

PHILIPPINES

Technical Report*

Prepared for the Government of the Philippines
by the United Nations Industrial Development Organization

Based on the work of Christopher T. Calam
consultant in fermentation technology

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SUMMARY

The visit was made to review the progress of the sucro-chemicals project being supported by UNFSSTD and UNIDO, in collaboration with the Philippines National Science and Technology Authority and the University of the Philippines at Los Baños.

The Priority Projects, for the production of citric acid, glacial acetic acid, dextran and yeast SCP were reviewed by visiting the sites and discussion with the workers. Work has been continuing in all cases. The rates of progress and future plans differ. With citric acid and glacial acetic acid there are practical difficulties to overcome, but a clear perspective of the future work can be foreseen, though local expert help will be needed for some parts of the work.

With dextran and yeast SCP there are various problems relating to the type of product to be made, product quality and the need for testing for suitability as foods. These require consideration, as well as scientific development work.

It is recommended that progress be reviewed in September and December 1983 with a view to securing a successful outcome to the work. This work will probably have to continue into 1984, and UNIDO should consider whether further assistance will be possible. The final development of the various programmes will depend largely upon the skill of the workers and Philippine officials in dealing with problems of apparatus and methods, and different kinds of assistance will be needed in each case, and this can only be resolved by on the spot discussion.

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Sucro-chemicals: Visit to Philippines, 23-28 May 1983

C.T. Calam

1. INTRODUCTION

The object of the visit was to evaluate the position of the priority projects and consider the position likely to be reached by 1984, to estimate progress and to consider where action is needed to bring them into action, if difficulties have arisen.

It was also desired to look for "milestones" in each case so as to judge progress, also to hear the views of those concerned.

Both UNIDO and NSTA are desirous of a successful outcome to the programme, which is due to end in December 1983. However, because of practical limitations it seems likely that the programme will have to continue longer. It was understood, during briefing in Vienna, that funds were short, but that some further aid might be possible in future.

All the projects were visited and progress discussed with the workers, and, on the last day, a meeting was held to discuss the situation.

The position of the projects, as indicated in Table 1, found general agreement among the project leaders. Ms. Tansinsin, Head of Planning at NSTA, took part in most of the meetings, and, in addition, we had a long review meeting on the final Saturday morning.

An interview also took place with Dr. Kintanar, Deputy Minister for Science and Technology. Dr. Kintanar expressed the importance attached to the programme, of which he obviously was well informed.

The main change technically, since the last visit (August 1982) was that there was a general move towards thinking about pilot plant work, and the best approach to it. In general, the trend was towards large-scale laboratory work, rather than towards special pilot plants, in order to save time and money. A further large amount of new apparatus had been received from UNIDO, and most of the laboratories seemed well equipped, though a few more items are being sought.

Effort, during the visit, was concentrated on evaluating the present position of the priority projects, with a view to reviews next September and December 1983. The review pointed to a number of things requiring attention, and it was hoped that these could be cleared by September, so that realistic evaluations could be made in December. This date was chosen as it marks the official end of the programme.

The main changes obviously apparent were:

1. The appearance of chemical engineers in some teams.
2. Much increased appreciation of the economic side of the work, and the need for costings.

A number of contacts are starting to be made with local firms, with a view to possible exploitation, though, at present, the projects are insufficiently developed for evaluation at this level.

The practical problems of working in the tropics are now becoming apparent, e.g. the high temperatures, unreliable electricity supplies and the high temperature of cooling water, also, probably, difficulties over some raw materials.

As mentioned, there are considerable variations in the rate of progress. All the programmes require technical skill, but the difficulties encountered are often different. These difficulties may be :

1. Microbiological,
2. In the extraction and purification system,
3. In the product and its quality.

For example, with citric acid, the growth system is critical, but this can be mastered. Crystallisation of the product requires skill, but, as the product is a pure chemical it is easy to define its acceptability. With SCP, however, great process variability is possible, but the specification of the product, in terms of its use as fodder, is much more complicated. Thus, there is no common pattern among the products.

2. STATE OF THE WORK ON PRIORITY PRODUCTS

(1) Citric acid

The NIST laboratory is now well equipped, though stirred or air-lift fermenters are needed. A determined effort has been made over the fermentation, as a result of which world-level yields are being obtained in shaken flasks. Crude crystals have been isolated.

Equipment is now needed to set up larger scale culture on 4 and 50 litre scales. For this, stirred fermenters are the obvious choice; however, it is clear that aerated tube fermenters or "air-lift" fermenters are often preferred, and fermenters of this type could be made locally. This is being investigated. Expert help (Philippine) is also needed to develop the crystallisation process. An evaporator for this is also needed. The process is well worked out, and is described in the report of 13 October 1982.

Two chemical engineers have been attached to the team, and should make a big contribution as they gain experience. They have already been looking at economics, and are now beginning on crystallisation.

The citric acid project is well ahead of the others, and attempts should be made to accelerate the follow-up.

(2) Glacial Acetic Acid

This involves two stages, (1) making vinegar, (2) conversion to glacial acetic acid. The workers at UPLB have had difficulty with the vinegar stage as the bacterium is difficult to grow. To try to deal with the problem a system has been worked out at Liverpool and a working method provided. Strikingly, it has been found that vinegar starters are grown regularly at NIST, commercially, so the problem should be solved, though a fermenter is needed for further trials.

The extraction (Report, 13 Oct, 82) requires 4 steps:

1. Extraction of vinegar with ethyl acetate to give 40% acetic after distillation,
2. Azeotropic distillation with butyl acetate to give 90% acetic,
3. Addition of acetic anhydride to give 100-102% glacial acetic.
4. Recovery of solvents for re-use.

This involves chemical engineering skills and setting up suitable apparatus, which is being considered. It is possible to buy 10% vinegar, and this can be used to do work to master each stage of the process.

There is every prospect that the project will be working by the end of the year.

(3) Dextran and Fructose

When *Leuconostoc* is grown on sucrose, it produces a polysaccharide, Dextran, and fructose. Dextran may be used for pharmaceutical purposes, also as a food additive. For these purposes it must be hydrolysed to give a suitable molecular weight polymer.

Progress has been held up due to the lack of a centrifuge, now due to arrive, but there is also an argument about which type of dextran to make. The whole question must be clarified quickly.

A crude solution of fructose is produced. It may not be worth-while to try to isolate this but the question is left open.

(4) Alcohol

An ingenious method of production was demonstrated, using immobilised cells. It is considered that alcohol is not a priority in this programme, and it should be left to the Philippine energy project.

(5) Yeast SCP

Yeast (*Torula*) has been grown in small towers, and now a new tower, 2 metres high, has been brought into use; it is referred to as the pilot plant.

Discussions with experts indicate that 50kg of yeast are needed for an animal test. The new tower gives (at present) 600g dry yeast per batch, so 83 batches would be needed, though the position could be helped by fermentation development work.

Therefore there is a need for a thorough review of the position, taking into account economics, raw material supplies, potential sales etc, and UNIDO help is desirable.

Prof. Moo Young (Canada) is due to visit the project in August. He is an expert in the field, though the emphasis of his work is the production of cells from wood by the Waterloo process.

(6) Other products

These non-priority projects, butanol-acetone, SCP from algae, fungi and bacteria have not proceeded far, and can be left at the moment.

(7) Alcohol etc from wood

This is not part of the programme, but is receiving some interest. It may be as well to bring into focus Dr. Moo Young and the Finnish evaluation, so as to avoid confusion.

3. GENERAL POSITION OF THE PROJECTS

A general summary of the position is attempted in Table 1, based on more complicated tables used during discussion sessions. It shows very different positions for the priority projects. While citric acid and glacial acetic acid seem fairly clear, though there is much work to be done, much more complicated decisions have to be made over dextran and yeast-SCP. To a considerable extent this is because these are complex products, which are not so easy to specify. In addition, as they may be used as foods, careful testing will be needed to make sure they comply with safety regulations. In the case of yeast-SCP production would have to be on a large scale, and this makes it necessary to consider manufacturing problems more carefully. The Table looks particularly at the dates when different types of assessments can be made. Initially it was thought that each project would require different dates, but the meeting felt that common dates should be sought, September and December, and that efforts must be made to meet these dates, which will mean a good deal of work. This Table also brings out the amount of help that will be needed to bring this about. It is intended to seek this locally.

It is interesting to note the stress on economic aspects. It is a problem that, in the Philippines, there are no standard lists of the cost of water, steam, electricity, or of standard processes such as drying, or of wages. This makes quick costings difficult. Such data are available in industrial firms in Europe. It is hoped that NSTA will assist with this by compiling a suitable list. It is stressed that such figures give only rough results, but they do enable a quick overview to be obtained, later to be analysed carefully.

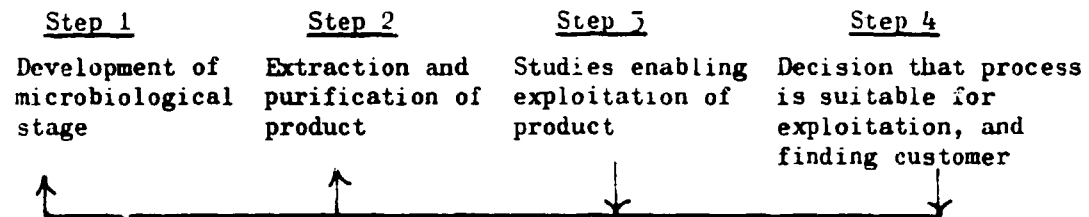
Table 1. Summary of progress of priority projects

Questions by Stages	Citric acid	Glacial acetic	Dextran	Yeast SCP
1) <u>Fermentation</u> (a) Have we cultures and methods? (b) Have good results been obtained?	Yes Yes	Yes Not yet	Yes Yes	Yes Fair
2) <u>Extraction and Purification</u> (a) Have we detailed methods? (b) Can these be put into operation locally? (c) Have products been made?	Yes Probably Crude crystals	Yes Probably No	Probably Probably Possibly	Outline only Probably Crude yeast
3) <u>Product</u> (a) Type (b) Is there a clear specification? (c) Are purity requirements known (d) Are any safety checks needed?	Pure chemical Yes Yes No	Pure chemical Yes Yes No	Polysaccharide Needs decision Needs decision Yes	Dry cells Not yet Needs decision Yes
4) Area next requiring solution	Extraction	Extraction	1) Type of product 2) Method of production	1) Make large quantity 2) Consider quality aspects 3) Consider how to make larger amounts, location etc.
5) <u>Could 1kg be made?</u>	Yes	Yes	With difficulty	Yes
6) <u>Requirements</u>	5-litre stirred fermenter for tests Technical advice re-crystallisation	Technical help re-distillation etc.	Fermenter equipment (unspecified) Technical advice	Advice re-product quality and fermentation methods and economics
7) <u>Review dates:</u>	September and December 1983			

4. GENERAL IMPRESSIONS: MILESTONES FOR FUTURE PROGRESS

The objective, when the project started in 1981, was to give the Phillipinos the opportunity to get experience in planning and developing applied research. In 1982 some progress had been made, and problems of planning and economics were becoming apparent. At the time of the present visit it was possible to get a better grasp of where progress was being made what the obstacles are, and the developments needed to help progress.

Each programme involves three or four steps:-



The two latter stages feed back on the first two, as investigations of the practicability of the process, and its efficiency and economic costings, may show that technical improvements are necessary. It will therefore be seen that Steps 2-4 play as important roles as does Step 1. There is a tendency to put a great deal of effort into Step 1, and to achieve very good results, but to neglect the other steps in the work.

It is desirable to start Step 3 as soon as possible so that Steps 1 and 2 can be better judged and guided. Many industrial firms incorporate a special "Operations Department" to fulfill this function, so as to secure a smooth transition to exploitation. My discussions with Ms. Tansinsin were much involved with this aspect of the programme.

In the original scheme, only the first Step was clearly envisaged, and, since then, the microbiologists have been involved with the other steps, which is too much for them on their own. In particular, Step 2 can present difficult technical problems, which call for expert help in chemical engineering. In the previous report (21.9.82) the formation of a design and advisory panel was recommended, which could help in this area. It is evident that some thought has been given to this in NSTA.

On looking at the position at the end of the visit in May 1983, it was possible to summarise the state of each project as shown in Table 2, which suggests milestones by which progress can be judged later in 1983. While it is hoped that practical results will begin to appear in 1983, it may be that it will only be possible to reach definitions or programmes and objectives by that time.

Table 2. Impressions May 1983 and milestones for next reviews

Subject	Stage 1 Culture	Stage 2 Extraction	Stage 3 Assessments	Stage 4 Exploitation	Next Milestones **
Citric acid	Good progress in submerged culture	Some trials, Chemical Engineers at work. Help needed to get local expert advice	Slight progress	Some talks, too soon for progress	Work out details of extraction. Consult local experts on this. Preliminary trials. Objectives are defined.
Glacial acetic	No progress, but methods are available locally	Starting to be investigated. Help needed to get local expert advice	No progress	Some talks, too soon for progress	As citric. Achieve vinegar production.
Dextran	Some impure products made	No progress due to lack of centrifuge†	The situation is unclear because there has been no decision as to what product should be made, and the lack of the centrifuge has limited work.		Clarification of situation re product. Define future programme and estimate needs. Make products.
Yeast SCP	Some products made in 1982. New 2-meter tower introduced.	The whole project needs careful assessment to define requirements for product, and consider logistics. The present culture process seems aimed at too low yields.			Continue with new tower. Make progress with the assessments.
* Expected to arrive shortly. ** For consideration in Sept. and Dec. 1985					

The table does not refer to the costing aspect of exploitation. This has to be kept in mind, but the actual production of products seems to be the main objective in the first place.

The table gives a superficial view, and does not take into account the difficulties encountered. For example the work at Los Banos has been difficult because the workers have a teaching load. As well, the arrangements for opening the Biotech building have laid a heavy load on some of the workers, while the subsequent difficulty of the water supply there has prevented the transfer of work to the new site.

In the case of citric and glacial acetic acids, the nature of the products makes it possible to define the future work fairly well. For example, the types of apparatus needed are known. The main need is to master the extraction steps, and this will probably require local expert advice. Ms. Tansinsin should be able to help with this, but it may

be difficult for Dr. Maureen Rouhi (formerly Ramirez) at UPLB, due to distance, and the question of re-location may have to be considered.

The positions of Dextran and Yeast SCP are different and more complex. In the case of Dextran, the future objectives are unclear, e.g. the type of dextran, how it should be made, apparatus required, quantities of dextran needed for testing and the type of test programmes required (quality, safety). Hence much work on these definitions is needed as soon as possible.

The case of Yeast SCP is even more complex because of uncertainty about objectives and limitations to progress, for example:-

- 1) The ultimate production goal, e.g. 50,000 tonnes/year.
- 2) The optimal size for a pilot plant, e.g. 1000 tonnes/year.
- 3) What quality of product is needed?
- 4) Levels of consumer and safety tests required by R.P. government and time required for this.
- 5) How will material be provided for these tests?

Other relevant practical problems relate to:-

- 6) Availability of raw materials; 50,000 tonnes of protein would require 200,000 tonnes of molasses, assuming 50% protein in the cells.
- 7) Availability of a suitable site for a factory, with water, cooling, effluent disposal, steam, electricity etc.
- 8) Is there a ready means of utilisation of the protein?
In some countries the absence of a feed industry presents a problem.

It may be noted that there are some investigators who seem to doubt the free availability of molasses etc in the Philippines, and this needs consideration. These points do not suggest that the project should be abandoned, but that consideration should be given any limitations which have to be taken into account. It has to be said that yeast SCP is only made in a few places, because of difficulties that have arisen with the product.

Another factor is that in the current experiments, Dr. Barril is only expecting about 10 grams of dry cells to be produced per litre of medium, compared with attainable levels of 40-50 grams per litre. Such a low yield would obviously greatly increase the size of any plant, thus raising expenses. These comments are not meant unkindly, but they stress the need for an early assessment of the project with the aid of technical and economic advisors. This point was discussed with Ms. Tansinsin who was considering the matter.

5. SUGGESTIONS FOR IMMEDIATE RESEARCH

Various problems, requiring solution, have become apparent. In the case of citric acid and glacial acetic acid these are fairly straightforward. Details of the processes involved have already been given in the report dated 13.10.82, and the main points may be summarised:-

<u>Citric acid</u>	<u>Glacial Acetic Acid</u>
1. Production of acid in fermenters.	Production of vinegar
2. Filtration and production of a water-clear, metal-free solution, using ion-exchange system.	Solvent extraction of acetic acid, to give 40% acid. Recovery of solvent.
3. Evaporation of solution to give pure crystals in the desired form.	Azeotropic distillation of the 40% acetic acid with butyl acetate, to give 99% acetic. Recovery of the butyl acetate.
4. Possible granulation of citric acid, to give desired form.	
5. Drying of crystals.	

Citric acid has been made in shaken flasks in good yield and this should be transferable to fermenters, so the main requirement is to work out the extraction and crystallisation of the product.

The vinegar process is rather tricky for the inexperienced, and success has not yet been achieved at UPLB. It has been found, however, that this is routine at NIST, where "vinegar starters" are prepared for sale. In addition, 10% vinegar can be bought. If glacial acetic acid is taken up by a vinegar manufacturer, the problem would not arise. Hence, in both cases, it is the recovery and purification of the product which most requires attention.

The point is that all the extraction and distillation processes are standard chemical engineering procedures, and there should be no great difficulty in studying them and carrying them out on the small scale, especially if help can be obtained from Philippino experts in these fields. For example, it is known that a teaching distillation column has been installed in one of the branches of the University of the Philippines.

The workers have therefore been advised not to wait for funds or apparatus to arrive, but to improvise with locally available apparatus, and to try out all the steps using solutions of citric acid or vinegar bought locally. It is hoped that later, complete runs through the processes will be possible.

It is felt that sufficient expertise exists in the Philippines to cover the needs of these processes, but in some cases the existing staff will need training, probably at the University. This is because the recovery of the products requires chemical and chemical-engineering skills, unlikely to be understood by microbiologists. Some of these are :-

Citric acid: training in methods used for crystallisation and purification of the product and the use of ion-exchange resins.

Acetic acid: training in the use of methods of solvent extraction and of fractional distillation, used to recover the acid. These are all standard chemical engineering processes, but may not be familiar at present. For acetic acid, chemical engineering help is needed in any case.

With dextran and SCP, the help of experts seems necessary, but it is not so easy to define requirements at present.

In all cases training might be helpful in chemical processes such as filtration etc, which can become a problem when liquid volumes increase above a certain size.

All these subjects need careful on-the-spot discussion so as to achieve the best results.

The situations with dextran and yeast SCP are different. Here there exist the bases for processes, but there are considerable numbers of decisions to take as to the best type of product, what the basic manufacturing processes will be, and what sort of testing is required. It is important, with these, to decide what the next stages of the different programmes are going to be. With yeast SCP, the possible place for larger scale development is important, and the facilities likely to be needed for this purpose. Many aspects of the process are fixed by local conditions, in the case of SCP especially, and large quantities of product are needed (e.g., 10,000 tons/year) so that a pilot plant would have to be large, and the process would be particularly sensitive to tropical conditions, such as high temperatures, effluent problems, power failure and variability of raw materials.

With SCP an understanding of the dynamics of the process is necessary. The productivity of the fermenter depends on the capacity of the system to transfer oxygen to the cells, and to maintain an efficient process at a low oxygen concentration. This requires a theoretical approach and suitable instrumentation.

In all cases, a survey of material costs etc., is desirable, at least to give a preliminary view of the situation.

6. PILOT PLANT DEVELOPMENTS

Some consideration has been given to this aspect. To build pilot plants for each subject would be very expensive. Thus a quote for a pilot plant for citric acid, to make 6 kg per day, from the Swiss firm of Chemap, was 1.0 to 1.5 million Swiss francs, plus installation costs.

It would therefore seem best to consider each case separately, and to map out the likely development programme and consider what is necessary. Thus, if a collaborating firm wishes to take up manufacture, a small manufacturing unit, capable of expansion, could be erected, and used for process development, based on large scale laboratory work such as has been outlined above.

7. FUTURE COLLABORATIVE DEVELOPMENTS

It is evident that possible collaborative ventures are already being discussed with Philippine companies, on a tentative basis. It is important that the next stages of research keep this in mind. Discussions about pilot plants are much concerned here, as a joint venture might provide a pilot plant, later to be scaled up for production. Large-scale laboratory work might be sufficient as a basis for such developments, backed up by economic studies.

For such discussions to take place on a reasonable footing, a number of points must be covered by the research programme. These are :-

- 1) Ability to produce a satisfactory product repeatedly, and provide samples of, say, 0.5 kg.
- 2) To be able to provide a written process description and to perform a practical trial, if requested.
- 3) To show the process is efficient by world standards, though, at first may not be equal to the results obtained by leading manufacturers.
- 4) To have the expertise to start up the process elsewhere, and to help if troubles arise later.
- 5) To have a grasp of the economic aspects of the process.
- 6) To set up the process robustly, so as to cope with the problem of working in the tropics, and problems of supplies, cooling, power, effluent disposal etc.,
- 7) In deciding whether to take up a contract, firms often required a guaranteed production level and efficiency. This is a matter which needs to be carefully thought out, and an attainable target set.

In connexion with this, pilot-plant work might be needed, but this would have to be of a type which suited the situation. This would depend on the product and the raw materials to be used, and other factors, such as the production rate that would ultimately be required.

It is also important that the process is well thought out theoretically, and understood in terms of general literature knowledge. It is only if this is so, that results can be properly presented and assessed, and workers can understand production difficulties and correct them.

8. CONSIDERATION OF DEVELOPMENTS IN 1984

Attempts to discuss the future were made, with individual workers, but without much success. Their attention is concentrated on the present. The subject was therefore reviewed with Ms Tansinsin. The results of this are given in Table 3.

Possible requests for help from UNIDO are indicated. These are partly financial. These need discussion between the parties. For example, a pilot plant for citric acid is suggested, however it is not clear what is really necessary, of whether a potential customer would share.

The other main question relates to SCP. Advice is needed from experts on (1) required levels of production, (2) product quality and safety requirements, and, (3) the general viability of the project in the Philippines. Such information may be available already, or perhaps an economics and industrial expert could go out for a time and have a thorough look at the matter. On the whole, although many yeast SCP projects have been started, most have been abandoned.

Table 3. Continuation of programmes beyond January 1984

Subject	Position expected by January 1984	Next step in 1984	Leads to:	Possible UNIDO help
Citric acid	Beginning to Make crystalline citric acid	Think they have a customer; put process on firm basis	NSTA will progress the situation	Collaboration with start up of joint operations eg. pilot plant
Glacial acetic acid	Ability to run all process steps separately	Need bigger fermenter and distillation apparatus. Details need discussion	The Lazatine Co. (Vinegar makers) are willing to consider.	Help and advice over apparatus. Possible collaboration.
Dextran	Expect to decide which product to make and have some samples.	Producing more and testing. Needs link with Industrial Toxicity unit	Market studies	UNIDO help with large scale laboratory fermenter, driers etc.
Fructose Alcohol	Depends on work on dextran, low priority Belongs to other Philippines project			
Yeast SCP	2-Meter tower should have produced some material. Doubtful whether clear re toxicity etc.	Develop bigger tower	Needs careful design study, also study of economics and local conditions.	Advice from expert study group with world experience on all aspects.

9. CONCLUSIONS

The results achieved so far within the different priority projects indicate that work in these fields should be continued. However, it appears that not enough information is available for a realistic assessment.

Frequent evaluation of the status of the projects will help to overcome difficulties at an early stage and therefore will help to increase the potential for their successful completion. UNIDO's role in this process needs also to be considered.

More efforts should be made for obtaining enough economic information to support the viability of the programmes. Many points are still unclear regarding the validity of the projects, especially of the SCP project.

It is evident that now attention must be paid to bringing the projects to a conclusion in the near future. The main tasks will be to identify obstacles (scientific, financial, practical) which interfere with the progress and find measures for their removal.

It is essential that some equipment must be provided soon. In view of the limited funds available, local sources should be explored, too.

In the case of citric acid and glacial acetic acid, the main scientific problems are clear and can be tackled. With dextran and yeast SCP a number of problems needs to be settled, such as the type of product required, quality of product, scale of working needed during the next stage of the programme, and the location of large-scale development. These cannot be solved on a purely scientific basis.

With some of the products, there are possibilities of development in collaboration with industrial firms. This could affect the requirements for development work. In all cases feasibility studies and economic studies are required, as well as prices and costs in the Philippines. Process operation under tropical conditions needs to be considered, too.

Most of these points will have to be investigated and reviewed locally, and steps are being taken to do this at NSTA.

10. RECOMMENDATIONS

1. It is important that NSTA makes studies on the future of the various projects including their costings and the viability of the products.
2. By end September 1983, all information on purification of citric acid and glacial acetic acid should be collected and screened. Also the apparatus for laboratory experiments should be ready, so that trials can be carried out before December 1983.

For dextran and yeast SCP specifications for the products and a list of test requirements, including data on laboratory tests should be set up.

3. It is recommended to purchase two 5-liter MICROFERM fermentors from New Brunswick for the citric and acetic acid projects. None of the two projects has a stirred fermentor, therefore, system should consist of drive unit and fermentor.
4. UNIDO should assist in finding the best way for bringing the envisaged programme to an end by December 1983.
5. UNIDO should give advice on further development of the project in 1984.

