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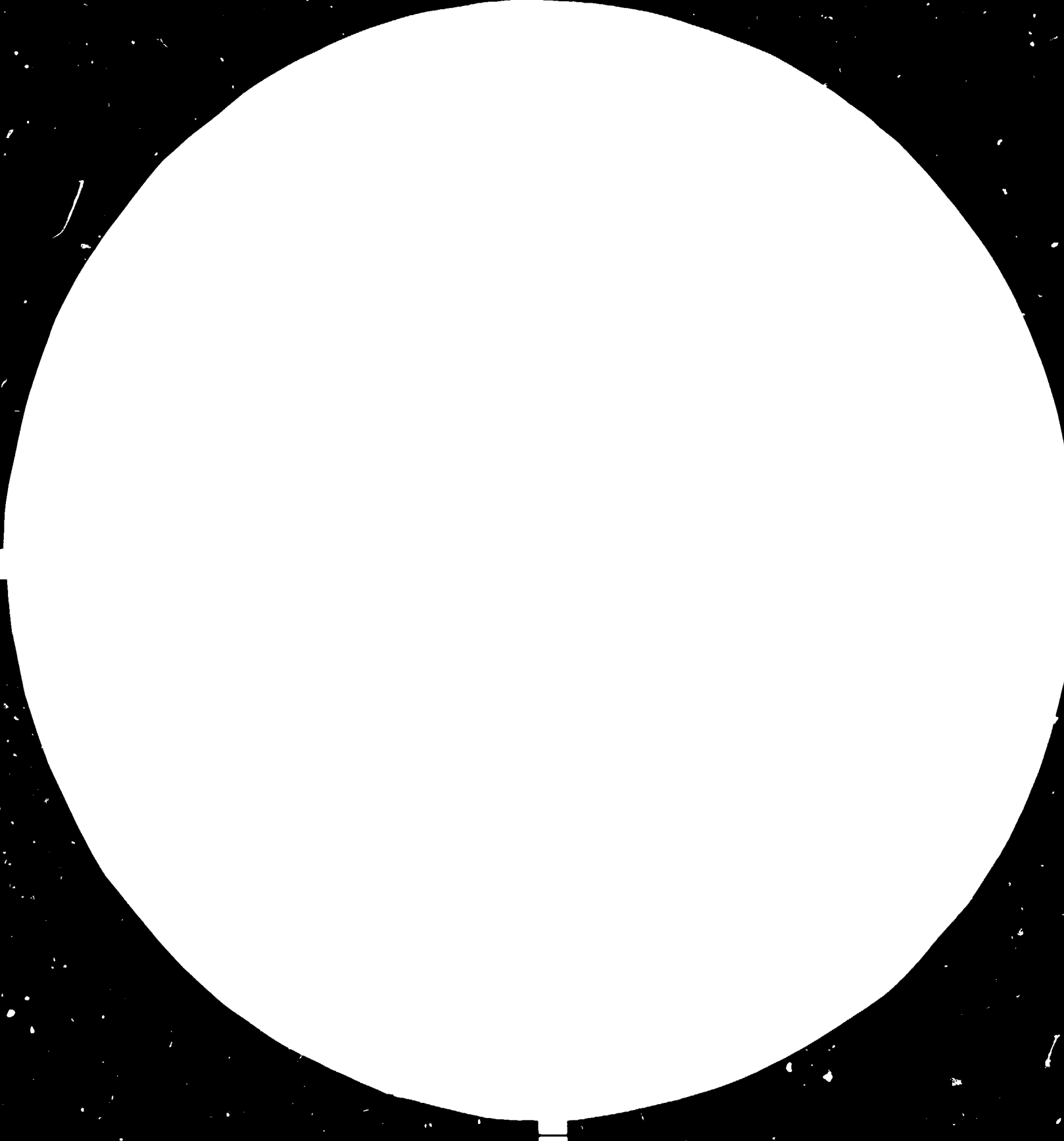


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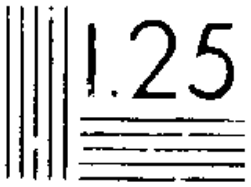
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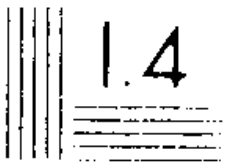
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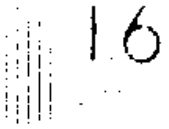
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August 1984
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INDUSTRIAL CHEMICALS FROM INDIGENOUS CARBOHYDRATE RAW MATERIALS (SUCRO-BASED CHEMICALS)

ST/PHI/81/001

PHILIPPINES Single-cell protein production

Technical Report*

4-20 February 1984

Prepared for the Government of the Philippines
by the United Nations Industrial Development Organization,
acting as the executing agency for United Nations Development Programme

Based on the work of Prof. Murray Moo-Young
Consultant in Single-Cell Protein Production

United Nations Industrial Development Organization
Vienna

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1. INTRODUCTION

This UNIDO-sponsored mission to the Philippines called for the technical advice of a consultant on single cell protein (SCP) production, with particular reference to the appropriateness of pilot plant studies, as part of a general program being carried out in that country on "industrial chemicals from indigenous carbohydrate raw materials (sucro-based chemicals)". Details of the consultant's job description is given in Appendix A and an outline of the overall program is given in Appendix B (obtained from the local administration). Four sub-projects, which are being undertaken at two locations - the University of the Philippines at Los Banos (UPLB) and the National Institute of Science and Technology (NIST, in Manila), have been identified with their respective research leaders, as follows:

1. Production of SCP (UPLB; Dr. C.R. Barril)
2. Production of Dextran and Fructose (NIST; Mr. V.C. Borlaza)
3. Biotechnological Production of Simple Organic Chemicals (UPLB; Dr. C.R. Barril)
4. Improvement in the Microbiological Production of Complex Organic Acids (NIST; Ms. N.D. Palo)

The projects are further subdivided into various Study Groups. The director of the entire program is Ms. L.G. Tansinsin located in Manila at the National Science and Technology Authority (NSTA) of the Philippine government.

The program has several national and international consultants attached to it , including myself. This is my first mission as consultant to this program. The mission covered the period, February 4-20 (17 days), which included a briefing session with Dr. M. Maung and others at UNIDO Headquarters in Vienna (one day),

rest stops in transit between Manila and Toronto (one night each direction), and report preparation time (two days). An outline of the briefing on substantive matters is given in Appendix C. The required output of this mission is a brief report on the findings and recommendations.

A voluminous collection of 200+ pages of selected previous reports (from project researchers and other consultants) was presented to me by Ms. Tansinsin on my arrival in Manila. In addition to studying these reports and several others subsequently received from Dr. Barril at the UPLB, I have visited all the laboratories involved in the project and met with the key people involved with all four sub-projects, physically covering both the Manila and Los Banos locations. Two seminars, having the following titles, were also presented at the university at Los Banos, for information on background and recent developments in the areas of the specific sub-projects.

1. Bioreactor design and process biotechnology
2. Food and fuel from agricultural biomass residues

In an attempt to learn more about the business and political factors which could affect the possible commercial spin-offs of the project, I was fortunate to arrange impromptu meetings with senior officers of the San Miguel Company and the Canadian Embassy (Commercial Secretary). San Miguel is the largest industrial complex in the Philippines and is significantly involved with food and agriculture. A brief report on my findings and recommendations is given below. (Regretfully, personal illness developed shortly after completion of my overseas visit for this mission and has caused the delay in submission of this report).

2. FINDINGS AND RECOMMENDATIONS

The Philippines, like many other developing countries of the world, is rich in indigenous carbohydrate materials but poor in the availability of industrial chemicals, fuel and food protein which mostly have to be imported. Again, like many other developing countries, the Philippines is hoping to exploit the techniques of biotechnology in the utilization of its agriculturally-generated carbohydrate-based biomass to produce these required products (M. Moo-Young, Editor, "Advances in Biotechnology", Vol. II "Chemicals, Fuels and Food", Pergamon Press, Oxford, 1981). The following observations are in agreement with some of those made by consultants Kaiser and Castor in their report of November 28, 1983. However, we differ on some important specifics as indicated. As a convenience to the reader, a copy of the summary of "Conclusions and Recommendations" of the Kaiser-Castor report is given in Appendix D.

1. There is a significant lack of communication or cooperation between the various research groups, especially between the Manila-based and Los Banos-based efforts. Since all the project goals would be competing for the same raw materials, it is clear that, for techno-economic relevance, the various groups should continually have their projects re-appraised.

2. Although the overall calibre of the research scientists and their supporting technical staff is excellent, there is a significant lack of engineering-type research input into the various projects. With the possible exception of Ms. Tansinsin, who is limited to administrative responsibilities at present, none of the researchers met seem to have any expertise requiring quantitative evaluations of engineering design and operation criteria. Apparently an agricultural, rather than a process, engineer is now collaborating on the UPLB-based project, but no meet-

ing with him was arranged so the quality or quantity of his input could not be assessed.

3. There is an unfortunate lack of local industrial input into the project direction. A tripartite arrangement whereby the researchers in the university and government laboratories have some links with the real-world of industry and commerce is to be recommended. Indeed, I have initiated such a possible contact between staff at one major local industry and UPLB. In addition, UPLB staff has been introduced to the Canadian embassy which may be helpful in generating additional funds for the next proposed stage of the SCP sub-project (see Appendix E and later points).

4. Contrary to the 1983 recommendations of Kaiser and Castor (see Appendix D), the SCP project should be given equal if not higher priority to the citric acid project. In agreement, one of the local industries had carried out a recent techno-economic feasibility study on cost/benefit effects of local manufacture of SCP, citric acid and fuel-grade ethanol and concluded that SCP is the only product of these three which has any potential in the Philippines. It appears that, despite the increasing importation cost for fuel oil, it is cheaper to buy it than to make fuel ethanol in the foreseeable future.

5. The manufacture of citric acid is based on relatively simple and well-known technology. It is difficult to appreciate the need to do any more expensive research and development work on this technology except for possibly generating national pride from the discovery of a new, "better", locally-isolated microbial strain for the fermentation process.

6. Although there are some innovative aspects of the ethanol production project (eg. immobilized-cell, packed-bed reactor system), these aspects are currently competing with other world-class research teams capable of mounting much more

ambiticus programs. In the biofuel area, I would recommend consideration of local infrastructure arrangements whereby various communities close to agricultural operations, could benefit from small to medium size biogas-generating units to assist in cooking and other heating (and possibly illumination) purposes. Regretfully, this fairly low-level technology does not seem to appeal to the present group of researchers.

7. In addition to the above, I agree with the Kaiser-Castor conclusion which also questions the advisability of the other research programs on dextran, fructose, glacial acetic acid, acetone/butanol, butanediol. At this stage, the limited funds available should be focussed on only one or two product orientations for which sensitivity analyses should be conducted with respect to scale of operation, financial constraints of geographic location, etc.

8. Of the various options proposed for SCP products, I found the bacterial and algal sub-projects interesting but only of possible importance later. At present, I recommend concentration on the yeast-from-molasses and fungus-from-cellulosics sub-projects at the pilot plant level. Although Torula-yeast technology for the first product type is well-established, the essential manpower training and learning of business dealings with the local infrastructure constraints can be efficiently developed using the operation of such a pilot unit. With respect to fungal SCP product, the recommended recent innovative Chaetomium -based technology, which is not so sophisticated as to bar village-level adoption, would allow possible use of one of the most economically-attractive SCP processes. In this respect, I have assisted my UPLB colleagues in the preparation of a research proposal for additional funding which we hope will be forthcoming from UNIDO, with or without co-sponsorship with a Canadian government external-aid agency (CIDA). Experience in running and maintaining contamination-free operations would be

invaluable training. In addition, enough product samples could be produced to allow meaningful animal feeding trials. Details of the rationale and the proposal itself are given in Appendix E. This material also summarizes my other findings and views on the SCP sub-project per se.

9. There are many similarities between this project and another UNIDO-sponsored one being carried out in the National Chemical Laboratory, Poona, India, under the direction of Dr. M.C. Scrinivasan, where they are concentrating on SCP, cellulase and ethanol production. It would appear that regional cooperation between these two laboratories would be of mutual, as well as more global, benefit. In addition, the research expertise and resources of the UPLB-based institute, "Biotech", should be recruited.

3. CONCLUDING REMARKS

This multi-project program is an ambitious attempt to examine the feasibility of producing various products from agro-industrial feedstocks in the Philippines. The various projects serve a useful purpose in training personnel for possible future employment in biotechnology-related industries and they also provide an opportunity for the researchers to develop new intellectual property and exercise their talents. To date, much scientific research has been generated with relatively little useful engineering technology development.

Regretfully, no foreseeable practical result in the form of industrial applications of the research can be identified at present. It is clear that more engineering-oriented research and possible collaboration with local industries (with appropriate confidentiality/proprietary agreements) are required. In particular, further studies on the techno-economic feasibility of SCP at the pilot plant level are highly recommended. In support of my findings, it is the only project of the sev-

eral in progress which seems to make any economic sense in the opinion of one of the largest local manufacturing industries. In order to clarify the ambiguities and contradictions of the various consultants attached to this program, it is proposed that a group meeting be held; hopefully, concensus conclusions may evolve which would be more helpful to our program sponsors and intended users of the project spinoffs.

In closing, I wish to record my thanks for the warm hospitality extended to me by my Philippino colleagues and for the gracious, but efficient, way in which they organized the business meetings.

UNITED NATIONS

APPENDIX A

D. Runca/tug

4 February 1983

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO

JOB DESCRIPTION

ST/PHI/81/001/11-51/32.1.C

Post title Consultant in Single-Cell Protein Production

Duration 1 month

Date required First quarter 1983

Duty station Manila, Philippines

Purpose of project The objective of the project is to develop the production of chemicals from indigeneous carbohydrate raw materials, including by-products and wastes of cane sugar industry and other fermentable raw materials.

This involves also the development of single-cell protein (SCP) production from agro-industrial by-products and residues (sub-project A). It is envisaged

a) to determine the suitability of the different agro-industrial by-products and residues (such as molasses, slops, bagasse, rice straw, rice hull, wood chips, etc.) for single-cell protein production (yeast, fungal and bacterial SCP);

b) to establish optimum growth conditions for biomass production of each of the different micro-organisms in a particular substrate or combination of substrates;

c) to conduct feeding tests and toxicological studies of SCP produced particularly for non-tested strains of bacteria, algae or fungi;

d) to make an economic viability and market study for each of the products that will be produced; and

e) to conduct pilot plant studies for the SCP products that would be potentially and economically viable.

..../..

Duties

In close co-operation with the appropriate Government authorities the consultant will provide technical advice on:

1. strain selection and improvement, including the application of recent techniques;
2. substrate evaluation, especially examining pre-treatment methods and their suitability for different substrate materials (e.g. cellulosics, etc.);
3. establishment of proper culture conditions such as substrate concentration, temperature and pH control, etc.;
4. design of an optimal fermenter, assessment of advantages and disadvantages of different systems, design and fabrication of bench-scale models;
5. suitability of SCP (i.e. different strains of yeast, fungi or bacteria) for animal feed or food for humans and required feeding tests to establish such suitability;
6. design of a pilot plant, and on the conduct of an economic analysis including scaling-up projections.

He is expected to give seminars on some of the above-listed subjects.

The consultant will be required to submit a brief report on his findings and recommendations.

Qualifications

Biochemical or chemical engineer with extensive experience in R+D work on single-cell protein production and utilization.

Language

English.

Background Information

The Philippines own an abundant supply of biomass raw materials from the sugar industries. The fourty-two sugar mills of the country with a total capacity of 186,000 tons cane per day, are producing at present approximately 2.3 million metric tons of sugar per year. The remainder from domestic and foreign sugar sales can be converted into other products, such as sucro-based chemicals. Other carbohydrate materials like rootcrops, corn, nipa sap and other cellulosic materials are found in abundance and can be used too.

At the request of the Government of the Philippines a technical co-operation project has been established with financing from the United Nations Financing System for Science and Technology. The objective is to encourage and support the development of sucro-based chemicals, such as citric acid, acetic acid, acetic anhydride, dextran and fructose, acetone/butanol and single-cell protein. The aim is to pursue an R+D programme for the development of appropriate materials and processes for the sucro-based chemical industries.

The activities comprise four areas of research work:

A. Single-cell protein (SCP) production from agro-industrial by-products, involving algal SCP, fungal SCP, bacterial SCP and yeast SCP with the main focus on yeast SCP. The main objective is to determine the suitability of various agro-industrial by-products as substrate for the production of SCP.

B. Production of dextran and fructose.

C. Biotechnological production of simple organic chemicals.

D. Improvement of the microbiological production of complex organic acids in particular citric, gluconic and itaconic acids.

It is expected that the results of the R+D work will provide technological packages for the production of each selected sucro-based chemical from indigeneous sources including detailed technical processes, market survey and assessment of economical viability.

INDUSTRIAL CHEMICALS FROM INDIGENOUS CARBOHYDRATE RAW MATERIALS (SUCRO-BASED CHEMICALS)

INTRODUCTION

The Sucro-based Chemicals Project was prepared by the Planning and Programming Division of the National Science Development Board (NSDB), now the National Science and Technology Authority (NSTA) in consultation with the Board of Investment (BOI), Philippine Sugar Commission (PHILSUCOM), National Institute of Science and Technology (NIST), University of the Philippines at Los Baños (UPLB) and the private sector. The project was conceived to lessen the country's dependence on the cost-prohibitive petro-based chemicals and intensify the search for other methods of producing these chemicals from renewable sources; to encourage and promote foreign exchange earnings; to generate employment opportunities; to increase the value of agricultural products and by-products; to promote the development of agro-based industries and technical cooperation among developing countries (TCDC). Among the promising substitute chemicals are those derived from carbohydrate raw materials by biological and chemical means such as fermentation, esterification, hydrogenation, etc. Our country has an abundant supply of these carbohydrate raw materials which may be obtained from the sugar industry and other fermenting plants and converted

to industrial chemicals such as acetone, acetic acid, butanol, citric acid, dextran, fructose, single-cell protein, etc.

OBJECTIVES

Generally, the main objective of the project is to develop, encourage and support the production of chemicals from indigenous carbohydrate raw materials including by products and wastes of cane sugar industry and other fermentable raw materials.

EXPECTED OUTPUT

The project expects to have the following outputs, namely:

1. Technological packages for the production of each selected sucro-based chemical from indigenous sources including detailed technical processes, market survey and assessment of economic viability;
2. Trained personnel capable of continuing R & D work and supporting industrial projects in both planning and implementation stages;
3. Improved facilities for R & D microbiology and related fields; and
4. Better TCDC through the establishment of joint R & D

programmes on a long term basis among research institutes working on common problems.

DESCRIPTION OF THE PROJECT

The project consists of four sub-projects, two of which contain four studies and are undertaken at the University of the Philippines at Los Baños (UPLB) and the other at the National Institute of Science and Technology (NIST). The four sub-projects are listed below with their corresponding project leaders and study leaders:

Sub-Project A - Single Cell Protein Production from Agro-Industrial By-Products and Residues

(University of the Philippines at Los Baños)

Project Leader: Dr. Carlito R. Barril

Study 1 : Algal SCP Production
Study Leader: Dr. Macrina T. Zafaralla

Study 2 : Fungal SCP Production
Study Leader: Dr. Elvira C. Fernandez

Study 3 : Yeast SCP Production
Study Leader: Dr. Ernesto J. del Rosario

Study 4 : Bacterial SCP Production
Study Leader: Dr. Asuncion K. Raymundo

Sub-Project B - Production of Dextran and Fructose
(National Institute of Science and Technology)

Project Leader : Mr. Vicente C. Borlaza
Study Leaders : Ms. Araceli M. Lozano
Ms. Daisy C. Binlayo

Sub-Project C - Biotechnological Production of Simple Organic Chemicals

(University of the Philippines at Los Baños)

Project Leader : Dr. Carlito R. Barril

Study 1 : Development of Continuous-Flow Fermentation for Ethanol Production

Study Leader : Dr. Ernesto J. del Rosario

Study 2 : Re-assessment of the Acetone-Butanol Fermentation Process

Study Leader : Dr. William G. Padolina

Study 3 : Improvement of Acetic Acid Fermentation Process

Study Leader : Dr. Ann Maureen E. Ramirez

Study 4 : Polyhydric Alcohols from Saccharine Materials

Study Leader : Prof. Conchita A. Orillo

Sub-Project D - Improvement in the Microbiological Production of Complex Organic Acids

Project Leader : Ms. Natividad D. Palo

Study Leaders : Ms. Lourdes Cunanan
Ms. Elizabeth Chua

The project is headed by a Project Director with a coordinating staff, having its office at the National Science and Technology Authority.

Project Director : Ms. Lydia G. Tansinsin

Coordinating Staff :

Ms. Teresita M. Valdez/Ms. Florita C. de Jesus

Ms. Hermelina H. Bion

Ms. Isabelita H. Lindo

Ms. Alice A. Bustamante

Copy for Mr. Moo Young

APPENDIX C

Cl: Mr. H. May
M. Maung/tug
ST/PHI/81/001

8 February 1984

NOTE FOR THE FILE

Briefing of Mr. M. Moo-Young on 6 February 1984

1. General

COUNTRY	: Philippines
PROJECT	: ST/PHI/81/001 - Production of Sucro-Based Chemicals from Indigenous Sources
DURATION OF STAY	: 17 days
BRIEFED BY.	: M. Maung

2. Substantive Matters

i) The duties described in the job description were discussed. Background information on the project was given and the tripartite nature (UNFSSTD, Philippine Government and UNIDO) of the project was explained. The expert was requested to refer to the evaluation report prepared by Dr. Kaiser and Dr. Castor during the mid-term technical evaluation exercise carried out in October 1983. He was also requested to look at the progress report which the National Project Director Ms. Tansinsin presented at the tripartite review meeting held in Manila on 2 February 1984. These two documents should give him a detailed and up-to-date account of the project activities in order to serve as a basis for his consultancy assignment on the sub-project for SCP production.

ii) The expert was requested to assess the appropriateness and the viability of a pilot plant for SCP production and to advise on the choice of raw material and the design of the pilot plant. He should determine what assistance would be needed for the design of the pilot plant to be completed by the end of 1984.

iii) Possible funding sources for the pilot plant were discussed. The expert was requested to explore whether the Canadian authorities would consider financing the SCP pilot plant project through a Special Purpose Contribution to the UN Industrial Development Fund which is managed by UNIDO. He should also indicate what further work in the form of techno-economic feasibility studies should be carried out before a viable pilot plant project could be formulated.

iv) Since Mr. Moo-Young is familiar with the work done at the National Chemical Laboratory, Puna, India, under the auspices of the UNDP/UNIDO project, he was asked to explore the possibility of establishing a link between the Indian and the Philippino research workers with a view to sharing experience and results and doing some collaborative research work.

cc: Res.Rep
SIDFA
Mr. Moo-Young
Ms. Taylor
Ms. Wegrath
Ms. Mennel
CRO

EXCERPTS FROM:

THE MID-TERM TECHNICAL EVALUATION

OF

INDUSTRIAL CHEMICALS FROM INDIGENOUS CARBOHYDRATE RAW MATERIALS (SUCRO-BASED CHEMICALS)

Prepared by:

Dr. Robert Kaiser and Dr. Trevor Castor

MID-TERM TECHNICAL EVALUATION

OF

INDUSTRIAL CHEMICALS FROM INDIGENOUS CARBOHYDRATE RAW MATERIALS(SUCRO-BASED CHEMICALS)

REPUBLIC OF THE PHILIPPINES

(UNFSSTD PROJECT NO. PH1/81/T01)

FOR

UNITED NATIONS FINANCING SYSTEM

FOR

SCIENCE AND TECHNOLOGY FOR DEVELOPMENT
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November 28, 1983

VI.0.0 CONCLUSIONS

1. Phase I of the sucro-based chemicals program has been successful in building the basic infrastructure necessary to do microbiological research by providing training and modern equipment. The program while in its infancy, can be considered successful as of this date because it has the potential to meet most of its immediate and long term objectives.

2. Citric acid is the best managed and technically most mature program. Results to date have been encouraging, but further research in the areas of microbiology and process research are still required. The equipment is presently lacking for performing batch and/or continuous fermentation experiments with recycling of the main process stream. However, process conditions have to be optimized before a pilot demonstration plant design can be specified. If these specifications can be made by January, 1985, a pilot plant design can be anticipated before April, 1985, and its installation and start-up before 1986.

   The present program in microbiology is well staffed, well-planned, and basically sound. The process research component is inadequately staffed, in that there is only one young and relatively inexperienced chemical engineer attached to the program. However, this young man is able and has made a significant contribution to the project, particularly with regards to the feasibility study which is an excellent planning document.

3. The acetone-butanol project, while still in early stages of development and based on limited results obtained to date, offers the promise of being commercially significant.

4. The continuous ethanol project is a technically sound program and will be a significant contribution to the overall program on biofuels. This project is receiving national support for continuing process studies. The project, however, may require external funding for a demonstration pilot plant in the BIOTECH facility which would be a first class site for such a unit.

5. The SCP projects have to be viewed within the context of their contribution to the training of students at UPLB in the area of fermentation biotechnology. The economic impact of the present SCP projects is of questionable value unless added value benefits can be obtained in terms of environmental pollution abatement.

   The past projects have not focussed on using noxious effluent streams, such as distillery slops. Furthermore, each of the SCP

projects have considered different substrates, making valid performance comparisons difficult if not impossible.

The bacterial SCP project, in particular, is at an impasse. In terms of the algal SCP project, the shift to spironella was sound in that this could ultimately result in the production of a higher value product than animal feed.

6. The dextran project is floundering. The project has been poorly defined, planned, and executed in spite of the fact that is has received significant equipment support.

7. The acetic acid project is also floundering. The project has focussed on the wrong problem, namely fermentation, and is duplicating work that has already been performed at NIST and by industry in the Philippines. The project should have addressed the production of glacial acetic acid from dilute acetic acid.

8. The market and feasibility studies performed by the research groups, with the exception of the citric acid project, were inadequate.

   The researchers are not sensitive enough to the performance goals that ultimately have to be met in planning and executing their research programs. These performance goals include the ability to produce on a commercial scale specification product(s) that are economically viable within the national context.

9. International consultants were not utilized as effectively as they could have been, either in terms of timing of their assignment, or of their proper role as program advisors.

10. The technical staff, while basically competent, is not sufficiently confident in its abilities. There also seems to be little communication between projects, or even, individual activities within the projects.

11. Equipment delivery to the Philippines has been a pacing factor in the technical execution of the program and its ability to meet its objectives. The program has been plagued by slow equipment deliveries which could have benefited from better administrative procedures on the part of all parties concerned (NSTA, UNISO, and the equipment suppliers).

12. Equipment breakdown often results in lengtny work stoppages for lack of maintenance capabilities and spare parts in the Philippines.

13. Study tours and fellowships were beneficial to all the participants. They were, however, carried out fairly late in the program. The projects could have set a faster pace had the trips been made earlier in the program's schedule.

14. Program planning and execution varied widely from project to project, and project leaders are not sufficiently accountable for their activities.

15. Documentation at UNFSSTD does not reflect the technical performance of the projects. The current reports are non-technical administrative reports.

VII.0.0 RECOMMENDATIONS

1. The program should be continued to be funded, but along specific guidelines for each project as outlined below.

2. The present citric acid program should be made the primary priority study. The process research group should be expanded to include at least one senior chemical engineer with industrial experience, and necessary support personnel.

   The necessary equipment needed for the process research studies should be acquired as soon as possible. In order to expedite the study, it would be desirable for the citric acid process to make use of one of the two fermenters now assigned to the dextran project and which has not, as of yet, been utilized.

   Subsequent to the completion of process research studies, a process development group should be formed in the last quarter of 1984 for purposes of designing a citric acid pilot demonstration pland. Funding of pilot plan equipment should be scheduled for 1985.

3. The acetone-butanol project should receive second highest priority. This project should receive support for basic and process research studies during the next phase of the program contingent on the confirmation of preliminary experimental results, and the completion of an engineering and economic feasibility study.

4. Funding of an ethanol pilot demonstration plant should be considered, if required, after process research studies are completed and optimal process conditions established on a bench scale. This is not likely to occur before early 1986.

5. SCP should be funded at the academic level for the duration of the program mainly because of its value as a student training tool.

6. A detailed technical review and audit of the dextran project should be performed by the National Project office with local technical support as soon as possible. Further funding would be contingent on this review. This review should include aspects of the program including the market premise for iron dextran.

7. The acetic acid project should either be discontinued or refocussed on the engineering aspects of glacial acetic acid production as a low priority project. The fermentation equipment assigned to this project should be transferred to the acetone-butanol process research group.

8. The preparation of sound feasibility studies should be given a very high priority. The citric acid project has already made a significant first step in this direction. The next projects to be subjected to this review should be acetone-butanol followed by yeast SCP. For reasons of impartiality and control, these studies should be performed by the program management office, and not by the research groups with direct line responsibilities. These studies should not be one-time efforts but should be updated periodically as additional data becomes available. The level of effort dedicated to these studies should increase as the program matures.

   It is recommended that a suitably trained engineer by assigned, attached, or retained by the office to perform such studies.

9. All consultant recommendations should be supported by appropriate documentation, which demonstrates their relevance to program goals.

10. A program of staff seminars and discussion groups should be implemented. At the project level, there should be weekly informal discussions in which the past week's activities are discussed and reviewed. Professional and support staff should both participate. In addition, there should be periodic (e.g. bi-weekly) seminars in which all professional staff members would participate. Each project, in rotation, would form the basis of a seminar and thus receive timely peer review. These seminars would not only build up the confidence of the researchers but also improve program planning. Interested members of the industrial technical community should also be invited to these seminars.

11. It is recommended that special care be given to establishing equipment specifications prior to making a purchase request. Equipment specifications on a purchase order should be detailed and accurate so as to minimize time needed for delivery.

12. Equipment suppliers who have field repair facilities and stock spare parts in the Philippines should be given preference in terms of procurement. Financial support by the UNFSSTD should also be given for equipment repair and maintenance facilities with NSTA.

13. Study tours and fellowships should be continued on a more timely basis.

14. Stronger planning and management controls are required. The technical management capabilities of the National Program Office should be strengthened by assigning a technical committee to that office to provide continuing oversight and audit of the individual projects.

15. Documentation to the UNFSSTD and UNIDO should include detailed technical progress reports to facilitate international peer review and feedback assistance.

Copy for Dr. M Mo-Young

APPENDIX E

PROPOSAL FOR TECHNO-ECONOMIC FEASIBILITY STUDY

1. Title of Project: Pilot-Plant Production and Evaluation of Single-Cell Proteins from Agro-industrial By-products

2. Specific Objectives of the Project:

1. To optimize the pilot plant scale production of single cell protein (SCP) for both the Candida yeast from sugarcane molasses and Chaetomium cellulolyticum from lignocellulosic substrates.

2. To evaluate the nutritional value and acceptability of the SCP produced either as animal feed or food ingredient.

3. To conduct detailed technical and economic evaluation of the pilot plant process for SCP production.

4. To train local technical staff personnel in SCP fermentation technology.

3. Project Description

A multi-purpose pilot plant for SCP production will be constructed which can be used for the culture of either Candida yeast using sugarcane molasses as substrate or Chaetomium cellulolyticum using lignocellulosic substrate materials. The pilot plant fermenter shall have a capacity of 1000 liters and an aspect or height-to-diameter ratio of at least six such that it can be operated as a stirred-tank or airlift fermenter, with and without a mechanical stirrer, respectively. The Candida and Chaetomium SCP shall be evaluated as a protein supplement in animal feeds in actual feeding experiments. Moreover, a dry yeast product shall be prepared for human food preparations, such as soups, and as a flavoring ingredient after extracting most of the yeast nucleic acids

by heat/chemical treatment. The technical feasibility and economics of the pilot plant process will be evaluated for both the Candida yeast and fungal SCP.

4. Significance of the Project

At present the Philippines is suffering from a shortage of animal feeds particularly protein ingredients and about US$ 150 million worth of imported protein rich feeds pose a heavy burden on its ailing economy. The local feed millers are presently looking for all possible sources of feed ingredients including distillery spent and brewer's spent grains. There are two bakers yeast factories and some alcohol distilleries in the country which recover brewers yeasts. The latter, which is a by-product of the distilleries, is sold as animal feed ingredients. However the quantity produced is very limited.

The proposed project aims to produce two forms of single cell protein (SCP) products, namely, Candida yeast and Chaetomium cellulolyticum which contain about 40-45% and 55-60% crude protein (dry basis), respectively. The essential amino acid profiles of these two SCP products compare favorably with the FAO reference protein and soybean meal protein (Table 1).

Animal feeding trials have shown that Candida utilis yeast can replace up to 80% of fish meal (Klose, A.A. and H. Flavold, 1945) and 50-60% of the soybean meal in the ration for chicks without significantly affecting the rate of weight gain. On the other hand,

preliminary feeding trials using fungal SCP, Chaetomium cellulolyticum, indicate that the product is suitably nutritious, digestible and non-toxic in animal feed protein rations (Moo-Young et al., 1979). In developed countries, SCP has been included in commercial feed formulation at rates of up to 20, 23 and 50% in livestock, poultry and fish rations, respectively (Well,s 1980).

Data on demand and supply of animal feeds in the Philippines for the current decade, 1980-1989 indicate a big short fall in supply (Table 2). For instance for 1984, demand and supply for poultry and swine feeds are 1.54 (0.95) Million MT and 2.79 (0.44) M MT, respectively. Protein feeds like fish meal and soybean meal are the most common and best sources of high quality proteins in commercial feeds, but these are mostly imported. Local fish meal is variable in composition and contains a high level of salt which is undesirable in animal feeding. In addition, local fish meal production is inadequate to meet all requirements of the industry, there being not enough fish to process into fish meal. Importation of fish meal amounted to 24.62, 16.50 and 41.05 thousand metric tons for 1980, 1981 and 1982, respectively. Local soybean production cannot meet the demand and importation is likewise resorted to, as shown in Table 3. If SCP can be incorporated at a conservative level of 5%, the quantity of SCP needed for 1984 will be 77 thousand MT for poultry and 139.6 thousand MT for swine or a total of 216.3 thousand MT (Table 4).

At present there is no commercial plant in the Philippines which produces Candida feed yeast nor fungal SCP from lignocellulosic substrates. In Taiwan, Candida utilis yeast is produced commercially from sugarcane molasses (Chang and Yang, 1973) while in the United Kingdom, Candida utilis yeast is produced in a "biocelerator" process using confectionery effluent (Davy et al., 1980). A commercial pilot plant has been built in British Columbia, Canada using the Waterloo process for producing Chaetomium cellulolyticum from wood pulp wastes.

5. Implementing Institutions

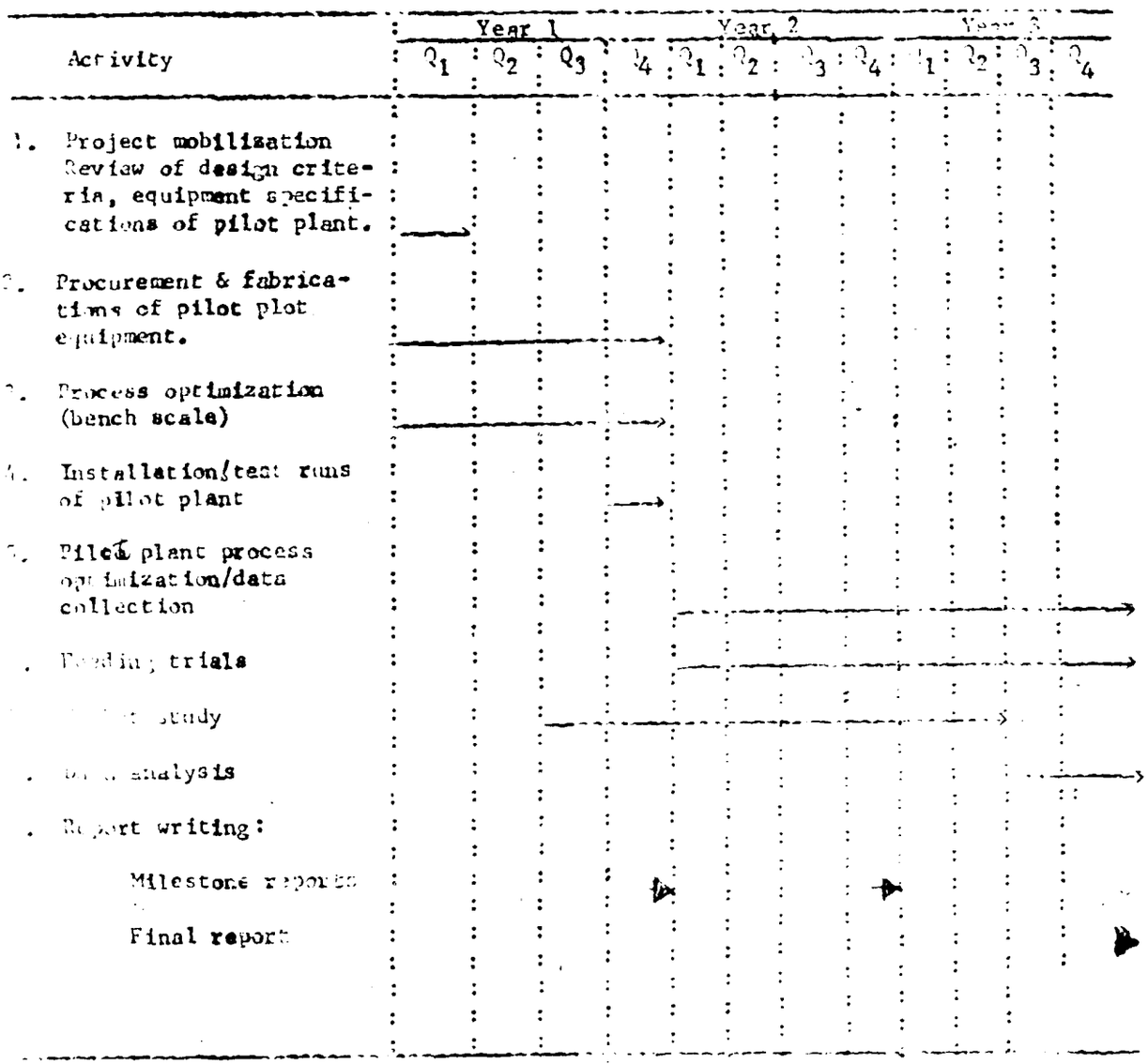
By virtue of its national responsibility and functions, the National Science and Technology Authority will provide control and supervision of the project. However, the project will be done at the University of the Philippines at Los Baños where research facilities and trained manpower are available. Moreover, the involvement of private industry will be encouraged to provide the direct linkage toward immediate commercialization of the technology that will be developed.

6. Work Plan

A detailed work plan for the implementation of the project will be prepared by the project and study leaders in consultation with the Project Director and international expert/consultant assigned to the project. The detailed work plan will be updated periodically depending on the progress of the project. The approved work plan will be attached and will be considered as part of the project document.

In the meantime, the work plan will initially involve the general activities as shown in the attached Ghantt Chart.

Schedule of Activities



7. Mode of Cooperation

The various inputs needed by the project will be jointly provided by the participating agencies - primarily the Philippine government through the NSTA and the counterpart foreign government which is Canada through the Canadian International Development Agency (CIDA) and IRDC. Other inputs may also be provided by the private industrial participants as well as the United Nation Industrial Development Organization which is requested to be the facilitating agency.

7.1. Description of Philippine Government Inputs

a. Assignment of National Staff	Estimated Cost in P (3 yrs)	
Project Director (1)		
Project Leader (1)	101,520	
Study Leaders (3)	297,600	
Research Personnel (4)	264,000	
Support Personnel (2)	72,000	
		P735,120
b. Maintenance and Operating Expenses		
Travel (local)	45,000	
Supplies	120,000	
Raw materials	300,000	
Sundries	60,000	
		P525,000
c. Equipment/research facility		
Laboratory space/pilot plant	3,000,000	
Equipment	300,000	
		P3,300,000
	TOTAL.....	P4,560,120

7.2. Description of Counterpart Contribution (In-Kind)

	[illegible]	[illegible]	[illegible]	Estimated [illegible] (US$)
a. Assignment of international expert (1)	1 m/m	1 m/m	1 m/m	[illegible]
b. Training				
Short training (6)	[illegible] m/m			36,000
Study tour (3)	3 m/m			18,000
c. Equipment				
- Pilot plant ([illegible] complete with [illegible] accessories for [illegible] control				[illegible]
- Ancillary equipment for [illegible] and downstream processing				120,000
- Sundry including service vehicle				[illegible]
				[illegible]

8. Financial Requirements (Summary)

1. Philippine Government

a. Personal Services	[illegible],120
b. Maintenance and Operating Exp.	[illegible],000
c. Equipment/research facility	[illegible]
TOTAL	[illegible],000

2. Counterpart Contribution

a. International expert/consultant - 2 m/m		[illegible],000
b. Training		
Short training (6)	[illegible] m/m	36,000
Study tour (3)	3 m/m	18,000
c. Equipment		
Pilot plant plus accessories		[illegible],000
Process equipment		[illegible],000
Sundry (communication, [illegible]		[illegible]
TOTAL		[illegible]

9. Proponent Agencies/Lead Persons

National Science and Technology Authority - Lydia G. Tansinsin
University of the Philippines at Los Baños - (Institute of Chemistry and National Institutes of Biotechnology and Applied Microbiology)

Carlito R. Barril, Ph.D.
Ernesto J. del Rosario, Ph.D.
Elvira C. Fernandez, Ph.D.
Amelia Gerpacio, M.S.

10. Project Duration -

The proposed project is planned for a duration of three years. It is an extension of an on-going project which terminates on December 31, 1984. This project is financially supported by the UNFSSTD and National Science and Technology Authority (NSTA). During the 20-month period that the project has been operational, several yeast strains were evaluated in terms of growth and yield characteristics. Two yeast strains were selected for process optimization, namely Candida utilis NRRL Y-900 and Candida tropicalis UPLB 1 (a local isolate). Laboratory-scale studies on the batch and fed-batch production of Candida utilis NRRL Y-900 were done using a 9-liter airlift fermenter. The laboratory results showed maximal values of the sugar-into-biomass yield coefficient ($Y_{x/s}$) of approximately 0.40. Although the ($Y_{x/s}$) values experimentally obtained were less than the expected 0.5, further optimization of the fermentation conditions and nutrient supplementation is expected to improve the results. This is based on the result reported by Lawford et al., (1979) who were able to get a yield coefficient of 0.55 g dry biomass/g

reducing sugar and a biomass productivity of 1.7 to 2.6 g/l-hr at the optimal dilution rate under continuous culture conditions. However, they obtained these results after supplementation of the sugarcane molasses medium with zinc. Pilot plant yeast production shall be done using a scaled-up versions of the 9-liter fermenter.

11. Preferred Commencement Date

It is proposed that the commencement date be January 1, 1985 to coincide with the termination date of the first phase of the project.

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Scrimshaw, S.S. 1975. Single-cell protein for human consumption - An overview. In S. Tannenbaum and D. Wang (eds.) Single-cell Protein II, the MIT Press, Cambridge, Mass. U.S.A.

Wells, J. 1980. Analysis of potential markets for single proteins. Paper presented at a Symposium on SCP of the American Chemical Society Meeting, Philadelphia, April 1975.

Table 1. Profile of essential amino acids (% DM protein) in the yeast and Waterloo fungal SCP and other protein products.

Amino Acid	FAO Ref.	Soybean Meal	Waterloo SCP[1]	Fodder Yeast[2] (C. utilis Y-900)
Isoleucine	4.2	4.2	4.7	4.5
Leucine	4.8	7.7	7.5	9.0
Lysine	4.2	6.4	6.8	9.1
Methionine / Cystine	4.2	2.2	2.6	1.8
Phanylalanine	2.8	4.7	3.8	5.2
Threonine	2.6	3.6	6.1	5.5
Tryptophan	1.4	1.7	N.A.	-
Tyrosine	2.8	2.7	3.3	-
Valine	4.2	4.4	5.8	5.5

[1] Moo-Young et al., (1979)

[2] Lawford et al., (1979)

Table 2. Estimated demand and supply of animal feeds in the Philippines, 1980-89 (in million MT).

Year	Poultry	Swine
1980	0.89 (0.78)*	2.24 (0.36)
1981	1.02 (0.82)	2.37 (0.38)
1982	1.18 (0.86)	2.50 (0.40)
1983	1.35 (0.90)	2.64 (0.42)
1984	1.54 (0.95)	2.79 (0.44)
1985	1.77 (1.00)	2.95 (0.46)
1986	2.03 (1.05)	3.12 (0.48)
1987	2.33 (1.10)	3.29 (0.51)
1988	2.67 (1.16)	3.47 (0.53)
1989	3.06 (1.21)	3.67 (0.56)

*Estimated supply values in parentheses
(Source: Bureau of Animal Industry)

Table 3. Philippine soybean production and importation (in thousand MT).

	Production	Importation
1980	9.40	11.94
1981	10.06	0.02
1982	11.47	31.42

Source: Bureau of Agricultural Economics, Quezon City, Philippines.

Table 4. Projected sales quantity of feed yeast (Candida utilis) in the Philippines based on 5% incorporation into mixed feed (in thousand MT).

Year	Poultry	Swine	Total
1984	77.2	139.6	216.8
1985	88.6	147.5	236.1
1986	101.5	155.8	257.3
1987	116.4	164.5	280.9
1988	133.5	173.7	307.2
1989	153.0	183.5	336.5