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Final Report

WORKSHOP
ON
FERMENTATION ETHANOL PRODUCTION
FOR USE AS FUEL AND CHEMICAL FEEDSTOCK
IN DEVELOPING COUNTRIES
US/INT/83/037

from 17 September - 12 October 1984
Rajamaeki, Finland

organized by

United Nations Industrial Development Organization
in co-operation with
Government of Finland
and
ALKO Ltd.

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1. SUMMARY AND SOME RECOMMENDATIONS

1.1. Summary

This Workshop on Fermentation Ethanol Production for Use as Fuel and Chemical Feedstock in Developing Countries is part of a programme designed:

- to generally promote technologies for the production of fuels and chemicals from renewable agricultural sources;

- to provide direct technical support to efforts in developing countries in research, development, and adaptation of production technologies for ethanol and related commodities.

In addition to reviewing the latest developments in fermentation ethanol technology and related process technologies and to follow on the spot the daily work in existing plants and research institutions of this field, the workshop provided a forum for detailed discussion of common problems.

The discussions in a group of specialists living close together for a month in a faraway country reach after some weeks a depth which is not easily attained in other forums.

It is a fact that the exchange of information among developing countries and among people working in different developing countries is surprisingly weak. The dialogue between people representing developed and developing nations is much more substantial.

A great deal of important information on process and equipment development in the field of renewable energy is elaborated and disseminated in international conferences, which are generally conducted to meet high standards. The problem is that these conferences are mostly attended by specialists from developed countries and only to a much lesser extent by actually working and influential people from developing countries.

Thus, one of the most important aims of the workshop was to provide a forum for detailed discussions of both the problems and the prospects, on the basis of personal experience in different geographical, economic, political and educational circumstances. The in-depth discussions both between instructors and participants, and among participants themselves were very fruitful and rewarding.

The participants' thorough knowledge of Alko as a research institution and industrial establishment, based on a month's stay with the company also provides a good opportunity for them to further their plans. This "twinning" of institutions is also important for the Finnish counterpart company - it gave the possibility for a larger group of Finnish scientists and engineers to discuss and become more aware of problems and constraints in developing countries.

1.2. Some recommendations

- Fermentation ethanol should be recognised and officially regarded as a permanent alternative source of fuel and chemical feedstock, not only as a gasoline substitute but as an octane booster and as a useful commodity chemical which can be produced with relatively simple, wellknown and reliable technology.

- A national policy on production of alcohol for use as fuel and chemical feedstock is needed. In addition strong government back-up to accomodate and coordinate different and often conflicting needs of various sectors of the economy (industry, agriculture, energy, transportation) is essential.

- A policy on promotion of education, training and research in relevant fields in developing countries as well as contacts, preferably based on personal knowledge of people, with corresponding institutions in developed countries are essential.

- Probably the production of fermentation ethanol for fuel and chemical feedstock needs credit facilities, tax and other financial incentives to be competitive.

2. INTRODUCTION

2.1. Background

The considerable increase in crude oil prices and the problem of access to liquid fuels have during the last decade focussed considerable attention on the production and use of fermentation ethanol from renewable sources as a fuel, a chemical, and as a raw material for other chemicals.

Many developing countries have both the raw material and the production potential needed. By producting fuel alcohol the following advantages can be achieved:

- it helps countries to attain self-sufficiency and independence with regard to basic needs.

- an increase in energy consumption is one of the conditions of economic development, which for a country depending on imported energy causes not only difficulties with the balance of payment but also a growing strategic risk.

- it helps in developing the agriculture, creates new jobs, and prevents urbanization.

- it is a good base for the chemical industry and does not demand a too sophisticated technology.

- in areas with excess sugar or grain the alcohol is a good alternative product with a steadily growing market.

- in cases of international crisis it gives a local alternative for the production of liquid fuels.

The industrial production from renewable raw materials of a range of other fermentation products e.g. single cell protein, methane, acetone and butanol, citric acid, amino acids and vitamins as well as industrial processes related to ethanol fermentation, such as baker's yeast and vinegar production and re-use of waste have also become of increasing interest and importance to developing countries.

2.2 History of the project

This is the first workshop of its kind. The need for theoretical and practical training in this field was expressed to Alko by UNIDO, which regularly receives requests from developing countries in different parts of the world.

Actual planning of the workshop's programme and negotiations on implementation and financing were started in September 1982 Successful in-plant training programs organized by UNIDO for many years e.g. in the fields of oil refining and plastics technology in cooperation with Austrian companies, and in the fields of dairy technology and furniture and joinery industries with Finnish companies, were encouraging examples.

The workshop is intended to be repeated. This first workshop took place from September 17 to October 12, 1984.

2.3 Project organization

2.3.1. The initiator and organizer of the workshop is United Nations Industrial Development Organization (UNIDO) in Vienna, Austria.

Practical arrangements were handled by the Chemical Industries Branch of UNIDO's Division of Industrial Operations.

2.3.2. The workshop was arranged in co-operation with the Finnish International Development Agency (FINNIDA) of the Ministry for Foreign Affairs of Finland and with the financial support of the Finnish Government.

2.3.3. The practical arrangements of the workshop were handled by Alko Ltd, The Finnish State Alcohol Company.

The State-owned Finnish alcohol company is 50 years old, though its experience goes back over 90 years. Alko's biggest factory complex, the Rajamäki factories, was founded in 1888.

Alko holds the State monopoly to produce, import and market industrial ethyl alcohol and alcoholic beverages in Finland. The company is a joint-stock company under public law whose operations are under State control.

Alko has three production plants and in addition to producing alcoholic beverages the company produces industrial ethyl alcohol, baker's yeast, enzymes and fermentation vinegar. Alko's products are exported to more than 60 countries.

The company also engages in extensive chemical, physiological, social and economic research and acts as a consultant offering services covering complete or partial processes for alcohol, baker's yeast and enzyme production. A Research Foundation of Biotechnology and the Fermentation Industry was founded by Alko in 1982 to promote and support research, training and development activities and other efforts in this field in Finland.

2.4. Objectives of the project

2.4.1. Development objective

To promote technolcgies for the production of fuels and chemicals from biomass resources, i.e., renewable resources based on agriculture and forestry.

2.4.2. Immediate objectives

The primary objective is to provide direct technical support to the efforts being made in many developing countries in research, development, adaptation and promotion of technologies for the production of fermentation ethanol for use as fuel and chemical feedstock, as well as of related fermentation technologies.

The project may be considered as an activity initiated by UNIDO in accordance with the Nairobi Plan of Action concerning New and Renewable Sources of Energy. It may also be regarded as a follow-up of an UNIDO Workshop on Fermentation Alcohol for Use as Fuel and Chemical Feedstock in Developing Countries, held in Vienna, Austria in March 1979. That workshop then confirmed the interest of many developing countries in research, development, adaptation and promotion of technologies for fermentation ethanol production.

2.5. Project activities

The abovementioned objectives are to be achieved through organizing this workshop and arranging short-term consultancies.

2.5.1. The Workshop

The Workshop and a practical demonstration programme is arranged at the Finnish State Alcohol Company, Alko Ltd in Finland, in order to review the latest developments in fermentation ethanol technology and related process technologies and to exchange experience among the participants from industrial and research organizations in Finland and the developing countries.

2.5.2. Short-term consultancies

Short-term consultancies will be undertaken by Finnish experts to interested developing countries for the purpose of strengthening current R + D programmes, starting new R + D work, carrying out pre-feasibility studies, undertaking trouble-shooting work at existing plants, etc.

2.6. Project outputs

The expected outcome of the Workshop may be described as follows:

2.6.1. Increased knowledge

Upgrading of knowledge and experience of scientists and engineers from selected developing countries on ethanol fermentation and related biotechnologies.

2.6.2. New contacts

Information and contacts leading to improved or expanded R + D programmes in the participating developing countries on ethanol fermentation and related biotechnologies.

2.6.3. Technical assistance

Direct technical assistance to 2 or 3 participating developing countries, upon their request, through short-term consultancies for strengthening current R + D programmes, starting new R + D work, carrying out pre-feasibility studies, trouble-shooting work, etc.

2.6.4. "Twinning"

Possible "twinning" of Alko and appropriate research institutions in developing countries for further co-operation on an expanded and continuous basis.

2.7. Scope of the training

The purpose of conveying to the participants knowledge and practical attainments in modern fermentation and related process technology was achieved by theoretical and practical training in industrial processes related to fermantation ethanol. They included the production of alcohol, baker's yeast, enzymes, vinegar and other fermentation products from a variety of raw materials, as well as the processing and use of by-products and wastes, i.e. stillage, carbon dioxide and waste water. The developing countries are very interested in local production from renewable raw materials of a range of fermentation products which have hitherto been imported.

3. THE WOPKSHOP

3.1. Duration and time

The Workshop took place from September 17 to October 12, 1984. Considering that the participants mostly come from tropical countries, an earlier time could be preferred.

The Workshop could start at the beginning of September. A duration of 4 weeks seems to be appropriate.

3.2 Premises

The facilities and resources of Alko Ltd were used to implement the workshop.

Most of the theoretical lectures were held in Alko's Rajamäki Factories' Training House in Rajamäki, 46 km north of Helsinki. Lectures were also held in Alko's Research Laboratories in central Helsinki and in Alko's Training Centre in Vuoranta near Helsinki.

Practical work was performed in the company's pilot distillery and in the factories' laboratories in Rajamäki. The pilot distillery can produce foodgrade alcohol from fermented mashes of various origins. The capacity of the pilot distillery is 6 000 - 10 000 l concentrated alcohol/d depending on product quality and starting material (1 500 - 2 600 t/a). The distillation columns are interchangeable and the bottoms and caps can easily be changed. The working pressure can vary between 0.3 bar absolute pressure and 10 bar overpressure. The automation level is high, but the distillation can also be operated manually.

The factory laboratories perform control analyses on raw materials, intermediate products, the process itself and final products from the distillery, distillation plant, stillage drying plant, baker's yeast factory, vinegar factory, waste water treatment plant and the process water; on enzymes from Alko's Koskenkorva factory and bottled final products from the bottling plant.

Operation of industrial scale processes of alcohol fermentation and distillation, baker's yeast, enzyme and vinegar production were followed in Alko's Rajamäki factories and Koskenkorva Factory near the city of Vaasa 350 km north of Helsinki.

Accommodation was in two of Alko's Rajamäki Factories' residences in Rajamäki.

3.3. Course staff

Course director	Patrick Stelwagen, M.Sc.
Deputy course director	Pentti Hyvärinen, Mr
Course secretary	Pirkko Karjalainen, M.Sc.
Assisting course secretary	Marja-Leena Eloranta, Mrs

3.4. Lecturers and instructors

ANDERSSON, Mats		Finnish Fund for Industrial Development Cooperation Ltd
BAILEY, Michael	Ph.D.	Technical Research Centre of Finland
ELO, Mauri	M.Sc., Eng.	Koseniew Engineering Ltd
ELORANTA, Marja-Leena	Mrs	ALKO LTD Rajamäki Factories
GREF, Brita	M.Sc.	ALKO LTD Research Laboratories
HARJU, Kai	M.Sc.	ALKO LTD Research Laboratories
HENTTONEN, Asko	B.Sc., Eng.	ALKO LTD Rajamäki Factories
HIISVIRTA, Tapani	M.Sc., Eng.	ALKO LTD Process Engineering Division
HYVÄRINEN, Pentti	Mr	Deputy course director ALKO LTD Rajamäki Factories
KARJALAINEN, Pirkko	M.Sc.	Course secretary ALKO LTD Information Service
KORHOLA, Matti	Ph.D.	ALKO LTD Research Laboratories
KORHONEN, Unto	Ambassador	International Development Agency (FINNIDA)
LAAKSONEN, Markku	Mr	ALKO LTD Rajamäki Factories
LAUNO, Ritva	B.Sc.	ALKO LTD Information Service
LEHTOMÄKI, Ilkka	M.Sc., Eng.	ALKO LTD Rajamäki Factories
LEHTONEN, Matti	Ph.D.	ALKO LTD Rajamäki Factories
LEPPÄNEN, Olavi	M.Sc., Eng.	ALKO LTD Research Laboratories
LINKO, Matti	Ph.D., prof.	Technical Research Centre of Finland
MARKKANEN, Pertti	Ph.D., prof.	Helsinki Technical University Dept. Biochemistry
MÄKINEN, Veijo	Ph.D.	Technical Research Centre of Finland
NYBERGH, Paula	Ph.lic.	Technology Development Center
PAAKKARI, Kari		Finnish Export Credit Ltd
PENTTILÄ, Liisa	M.Sc., Eng.	ALKO LTD Rajamäki Factories
PUPUTTI, Erkki	M.Sc.	ALKO LTD Research Laboratories
ROERING, Kim	M.Sc.	ALKO LTD Koskenkorva Factory
ROUHIAINEN, Heikki	Mr	ALKO LTD Rajamäki Factories
SINDA, Eija	M.Sc.	ALKO LTD Rajamäki Factories
STANBELL, Cay	M.Sc., Eng.	ALKO LTD Process Engineering Division
STELWAGEN, Patrick	M.Sc.	Course director ALKO LTD Process Engineering Division
SUIHKO, Maija-Liisa	Ph.D.	Technical Research Centre of Finland
TORKKELI, Tuula	Ph.D.	ALKO LTD Research Laboratories
TUOMPO, Helena	Ph.lic.	ALKO LTD Research Laboratories
VAARA, Timo	Ph.D.	ALKO LTD Research Laboratories
VEHMAANPERÄ, Jari	M.Sc.	ALKO LTD Research Laboratories
VÄISÄNEN, Eino	M.Sc.	ALKO LTD Research Laboratories

3.5. Workshop programme

The training programme consisted of theoretical and practical training, study visits to other plants and research institutions and an evaluation session.

Discussions both in group and privately took place both during working hours and the social programme.

The social programme consisted of dinners, sauna evenings, tourist trips, icehockey match, TV-watching etc.

3.6. Course material

Since this course was the first of its kind the written material to be distributed to the participants had to be prepared and translated into English.

The written course material consisted of the following groups of documents:

- General documents, 100 pages
    - Glossary of terms in Fermentation Ethanol Production and Related Fields, 44 pages.
    - Units and Conversion Factors, 6 pages.
    - Ethanol, a Description, 3 pages.
    - Literature References on Fermentation Processes, Biotechnology and Related Topics, 17 pages.
    - The Use of Ethanol as a Fuel, 30 pages.

They were prepared by the course staff.

- Country reports on fermentation ethanol production, current production, problems and prospects, 177 pages prepared by the participants, edited and distributed by the course staff.

- Process descriptions, flow schemes and activity descriptions 71 pages

- Grain ethanol production	7 pages, 4 flow sheets
- Alcoholic beverages	3 pages, 1 flow sheet
- Baker's yeast production	9 pages, 4 flow sheets
- Amylolytic enzyme production	6 pages, 4 flow sheets
- Vinegar production	5 pages, 2 flow sheets
- Waste water treatment	12 pages
- Production of ethanol from molasses or cane juice	1 page, 1 flow sheet
- Production of ethanol from cassava or other roots or tubers	1 page, 1 flow sheet
- Production of ethanol from cheese whey	1 page, 1 flow sheet
- The role of information service in managing information resources in companies	8 pages
- Process and product quality control	8 pages

- Lecture notes. The content of the lecture is described under para 3.7.

3.7. Lecture notes

The lecture notes were prepared by the individual lecturers. Editing and distribution was made by the course staff.

Content of the notes

1. Industrial micro-organisms and their products
   By: Pertti Markkanen, Ph.D, Prof.

   Industrially used microbes. Cultivation of plant cells. The biotechnical process and its products.

2. Alcohol fermentation systems
   By: Tapani Hiisvirta, M.Sc. (Eng.)

   Nomenclature. Practical calculations. Slow and rapid batch fermentations. Continuous fermentation. Immoblized yeasts.

3. Ethanol fermentation from pentoses
   By: Maija-Liisa Suihko, Ph.D.

   Pentose fermentation by yeasts. Production of ethanol by different strains of Fusarium. D-xylose catabolism.

4. The development of cellulase-producing micro-organisms. (Trichoderma reesei)
   By: Michael J. Bailey, Ph.D.

   Induction, isolation and testing of stable T.r.mutants. Production and some properties of cellulolytic and xylanolytic organisms.

5. Alcohol distillation
By: Olavi Leppänen M.Sc.

Liquid-vapor equilibria. Methods of distillation, batch, continuous, reflux ratio. Construction of distillation columns.

6. Delignification
By: Timo Vaara, M.Sc.

Lignocellulosic materials. Physical and chemical delignifications. Biological delignification. The biotechnology of delignification.

7. Culture collections
By: Eino Väisänen, M.Sc.

Selection of preservation method. Preservation methods, drying, gelatin discs, freeze drying manifold method. Storage, Viability check. Cryoprotectants, recovery.

8. Industrial enzymes
By: Paula M.A. Nybergh, Ph.lic.

Enzyme sources. Industrial application of enzymes. Use of enzymes in alcohol production, starch industry, breweries, dairies and other industries.

9. Baker's yeast production
By: Liisa Penttilä, M.Sc. (Eng.)

History of yeasts and yeast propagation. Production and consumption figures. Practice of production. Automatization. Alternative raw materials.

10. Microbiological working in the laboratory
By: Eija Sinda, M.Sc.

Pure culture cultivation and handling. Aseptic working. Filtration techniques. Dilution plates. Selective media.

11. Biotechnology - Global priorities
By: Matti Linko, Ph.D., Prof.

Bulk chemicals and fuels. Food, feed and agriculture. Fine chemicals and health care. Special features in developing countries.

12. Ethanol process analysing and product quality
By: Kai Harju, M.Sc. (Eng.)

The ethanol process. Analyses; raw materials, cooking and fermentation, distillation. Product quality criteria. Odour thresholds.

13. Laboratory analysing equipment
By: Brita Gref, M.Sc.

Alcohol determination. The spectrophotometer. Atomic absorption spectroscopy. Gas chromatography. Data systems. HPLC. Mass spectrometer. Infrared spectrometer.

14. Genetic engineering
By: Tuula Torkkeli, Ph.D.

Genetic information, the basis of genetic engineering. Advances in nucleic acid molecular biology. Gene cloning.

15. Industrial vinegar production
By: Jari Vehmaanperä, M.Sc.

Chemistry and microbiology of vinegar production. Industrial vinegar production-methods. Processes. The Acetator, raw materials, production strain. Contaminants, overoxidation.

16. Citric acid production by fermentation
By: Helena Tuompo, Ph.lic.

Production strains; moulds, yeasts. Surface and submerged fermentation the Koji process. Product recovery. Utilization.

17. Pilot-scale production of amylase
By: Matti Korhola and Paula M.A. Nybergh

Materials. Methods. Results. Conclusions.

3.8. Practical work

The participants performed practical work in Alko's 10 000 l/d pilot distillery and in the factories' laboratories in Rajamäki. The work consisted of operation of the pilot distillery for 2 days and performance of actual process analyses in the microbiological and chemical laboratories. In order to enable more individual instruction the participants were divided into two groups.

When Group 1 performed a 2-day distillation trial, Group 2 analyzed raw material and product samples. Then the groups interchanged.

3.9. Participants

The participants to the workshop were selected by UNIDO and Alko in cooperation and approved by FINNIDA.

The twenty participants represented 14 developing countries in Africa, Asia and South America. The countries represented were: Bangladesh, Bolivia, Burma, Peoples Republic of China, Egypt, India, Kenya, Nepal, Peru, the Philippines, Somalia, Sudan, Thailand and Zimbabwe.

One of the participants, not financed by UNIDO, attended the workshop at his government's cost.

The level of the participants was high. They were either highly educated or had a long practical experience of the field, or both.

Also the participants' command of English was good.

A list of the participants and the organizations they represent are presented in Annex 1.

3.10. Financial arrangements

Training and lodging including breakfast as well as all internal travel in Finland related to the workshop were free of charge for the participants.

The value of the daily breakfast and hot meal was 50 FIM/d.

A daily allowance of 100 FIM was also given.

A majority of the participants (12/20) found the daily allowance adequate or good.

For two travelling days a daily allowance of 300 FIM was paid.

The participants' travel expenses were borne by UNIDO. All expenses in the home country including expenditure for passport, visa, medical examination, vaccinations, internal travel and other such miscellaneous items were paid by the participants or their organizations.

3.11. Accommodation

Duly furnished double rooms with shower and WC, and cooking facilities in apartments in two of Alko's Rajamäki factories' residences close to the training facilities were reserved for the participants.

6 participants were accommodated in single rooms.

Breakfast was served every morning in a cafe in Rajamäki center about 150 m away from the residence.

On working days a hot meal and coffee a.m. and p.m. was served in the factories' canteen or in a restaurant when the group was not in Rajamäki.

During weekends food was served at the abovementioned cafe in Rajamäki. During travel-weekends the participants were accommodated in double rooms in hotels, the breakfast and meals were served at the hotels or in restaurants.

3.12. Medical arrangements

The participants were insured against accidents during the course.

Two participants had to attend medical care during the workshop, one because of her advanced pregnancy.

3.13. Other practical arrangements

The organizers helped the participants with laundry-, telephone-, telex-, post-, transport- and other minor practical needs.

4. EVALUATION

4.1. Method

During an evaluation session the participants were asked to write their personal evaluation of different aspects of the workshop. Many participants did a very thorough analysis and provided the organizer with valuable hints for future workshops. The evaluation is also based on public and private discussions.

4.2. Evaluation form and views expressed by the participants

In the evaluation session the participants were asked to answer questions and to comment on e.g. the topics that follow together with some views expressed by the participants.

Only a few questions are commented on here.

1. Information before arrival, pre-course timetable, obtaining of visa etc?
   - Visa sometimes difficult to obtain, information sufficient but arrived late. It should reach the participants a month or so in advance. 5 participants arrived in Helsinki without visa, but were able to get one upon arrival with Alko's help.
2. Pre-course work?
3. Practical arrangements before entering Finland?
4. Reception upon arrival?
5. Accommodation?
   - Single accommodation during a 4-week workshop is almost a necessity.

6. Food?
7. Daily allowance?
   - 12 out of 20 participants found the daily allowance of 100 FIM (c. 17 USD) adequate, 8 would have preferred more.
8. Laundry-, telephone-, telex-, post-, transport- and other practical arrangements?
   - Many should have wanted to have a washing machine at their disposal.
9. Course arrangements:
   - length of the workshop?
   - single subjects quality. Mention some bad and good.
   - what should be added?
   - what should be omitted?
   - what was too basic?
   - what was too complicated?
   - the lectures?
   - Half of the participants would have preferred a shorter workshop, five persons specifically recommended a 3 weeks' duration. Eight participants found the duration suitable, two participants would have preferred a longer course.
   - The training programme could perhaps be a little more practical. Seven persons wanted more practical work, only four wanted more lectures.
   - Among subjects, which were considered too complicated was genetic engineering, mentioned by 6 participants. A problem in designing the level of the lectures is of course the varying backgrounds of the participants - engineers, microbiologists, sugar technologists, doctors of chemistry etc. What is too basic for one can be too complicated for another.
10. Course material?
    - The course material was generally found "good", informative", "useful" and "sufficient".
11. Visits to Alko's establishments?
12. Visits to other establishments?

4.3. Follow-up

The follow-up procedure is one of the most important issues when dealing with different kinds of development cooperation activities. Contacts in the future with the participants and their organizations are of great value in order to receive knowledge of the actual development in the countries.

4.3.1. Participants' views

On the topic of follow-up activities the participants recommended contacts in the form of regular information letters or a bulletin to be arranged by UNIDO/Alko or Alko. A short follow-up workshop was also proposed as well as a questionnaire to the participants after 0.5-1.5 years.

4.3.2. The organizers' view

In order to emphasize and to strenghten the follow-up issue the close coope 'on between UNIDO, FINNIDA and Alko should continue. ontinuity of the project would also be strengthe.. if the workshop is repeated.

According to the project proposal the Workshop is also in a natural way followed-up by the short term consultancies which are already included in the project and described in section 5 of this report.

5. SHORT-TERM CONSULTANCIES

5.1. Identified potential short-term consultancy projects

The following possible projects, which emerged during the Workshop shall be considered:

- Feasibility study on the production of active dry yeast in Zimbabwe.
- Feasibility study on the production of baker's yeast in Nepal.
- Study on process improvement of an existing molasses distillery by the recycling of yeast (in Zimbabwe).
- Study on uses or disposal of process wastes from molasses and grain distilleries in the People's Republic of China.
- Feasibility study on the use of molasses and production of fuel ethanol in Sudan.
- Survey of the technical level of existing small distilleries in Nepal.
- Study on alcohol policy in Peru.

5.2. Project development procedure

1. Alko makes detailed project proposals.
   In the proposal the problem is defined and it is indicated how it can be solved and the resources needed.
2. Alko submits the proposals to UNIDO for approval. UNIDO then contacts the Governments in question.
3. UNIDO seeks funds in addition to already earmarked funds (from FINNIDA) for the implementation of the short-term consultancy projects.
4. UNIDO gets an official request from the Government in question.

6. ADVANCEMENT OF FERMENTATION ETHANOL INDUSTRY IN DEVELOPING COUNTRIES

The following analysis of on one hand, problems and constraints in, and on the other prospects for fermentation ethanol production in developing countries is based on country reports prepared by the participants of the Workshop.

6.1. General discussion

Developing countries in general represent tropical regions with high insolation and hence potentially high areal biomass production. This form a basis for production of alcohol for fuel and chemical feedstock and thus could enable the countries to decrease their oil import. This is especially the case in countries with large agricultural areas. There is no doubt that technologies needed both in the agricultural production of raw material, in the processing into ethanol, in using ethanol as a liquid fuel and in converting ethanol into a range of chemicals exist. The question is what this new energy costs. One can argue that alcohol from renewable material is not cheaper than gasoline, it can even be more expensive, but domestic fuel and chemical feedstock production have certain advantages.

The question must be solved from country to country taking a whole range of factors into account. The organizers of the Workshop see as their task, to provide engineers, researchers and decision makers with knowledge in the field of fermentation alcohol production in a broad sense. This will enable them to make the right decisions and to produce cheaper ethanol and to use it in a diverse way.

6.2 Problems and constraints

Without saying it is clear that the lack of financial resources in developing countries is the most serious problem for the development of ethanol industries. Many of the specific problems and constraints mentioned by the workshops participants and shortly discussed here, could be solved or eliminated with the help of appropriate financial aid. Money per se, however, is not a solution to all of these problems.

The problems mentioned by a majority of the participants are:

- The lack of infrastucture for both large-scale production and utilization of ethanol for fuel or industrial feedstock. Huge amounts of raw materials and products must be both transported and stored. Production needs input of both energy and water at the site.
- The utilization of molasses, which often can be considered as a surplus by product, as raw material for ethanol production is also problematic for many producers.
  Constant fluctuations of prices at the international sugar market are reflected in unsteady prices and availability of molasses. Non-uniformity and low quality of the molasses add to the problem.
- Many purely technical problems were mentioned. Typical are scaling of the distillation column, contamination of the fermentations, the cooling etc. The technical problems are often caused by bad molasses but the reason is also high age and poor condition of existing plants. The discussions and interchange of experiences gave new and well-tried solutions to many participants.
- Waste disposal and utilization or treatment of distillery waste is a big problem in a time when government agencies and authorities also in developing countries tighten environmental pollution control norms and demands on the industry.

Alcohol distilleries generate an amount of effluent which is 10- 20 times the volume of alcohol produced. A 100 000 l/d cane molasses distillery produces almost 1 500 m^3 waste water per day. The amount of pollution in a recipient water if the waste is disposed untreated, is equivalent to that of 1 700 000 people. There are, however, solutions to this problem.

- A serious problem mentioned by almost all participants is the lack of all categories of technically trained manpower and of local education and research.
- In some countries the multiplicity of levies as well as complicated price formation of both molasses and alcohol constitute a problem.

The problems mentioned here as well as the more general constraints such as unstable governments, political crises and lack of a well-defined policy are often interrelated making it even more difficult to find the best solutions.

6.3. Prospects

In general the prospect for a fermentation ethanol industry in any country is a function of the country's agricultural potential and energy situation. Developing countries with surplus agricultural production but facing an energy deficit, such as Sudan, Thailand and Zimbabwe are likely to have the strongest incentive to develop a fuel ethanol industry. On the other hand many of the least developed countries are net importers of both agricultural products and energy. In these countries ethanol production is attractive only if based on surplus, low-cost biomass, such as molasses or agricultural crop residues.

- Surplus molasses which cannot be exported to an economical price because of transportation problems or low world market prices, can constitute a prospect for ethanol production.

- An alcohol industry can help to solve a problem of unemployment and a growing use of ethanol as chemical feedstock as is the case in e.g. China, Egypt, India and the Philippines are positive factors.

The following examples of promising progress in establishing fuel ethanol industries in developing countries demonstrate the prospects.

- In the Philippines, production of ethanol for fuel started in 1980 with the marketing of a 15-85 anhydrous ethanol-gasoline blend called "Alcogas". In 1983 the production was 88.9 million liters of hydrous and 4.2 million liters of anhydrous ethanol, mostly from sugarcane molasses.

- Thailand is another example of a country with a development programme to establish a fuel alcohol industry. The goals of the programme is to increase independence on energy by using indigenous material to produce fuel to ease the financial burden of fuel import. Thailand spends now almost 40 % of her export earnings on energy import to develo- and generate employment in agriculture and to lessen pollution from vehicle's exhaust. It is planned that annually 375 million liters ethanol is produced from c. 5.5 million tons of sugarcane or 2 million tons cassava. Thailand Institute of Scientific and Technological Research (TISTR) already successfully operates a pilot plant which produces 1500 1/d alcohol from cassava.

- Zimbabwe is an African example of succesful implementation of a fuel ethanol programme. Strategic considerations, foreign currency limitations and the landlocked situation with politically vulnerable nature of the supply routes led to the establishment of production of ethanol for fuel on a major scale. The annual production at a 120 000 l/d plant is 40 million liters which is 12 % of the present gasoline consumption in the country.

6.4. Recommendations

Some recommendations for the advancement of fermentation ethanol industry in developing countries are presented in the SUMMARY section.

6.5. Country papers

Each participant had written a report about the production and use of fermentation ethanol in his/her country. The following table has been condensed from the information given in these country papers.

PRODUCTION AND USE OF FERMENTATION ETHANOL

Country	Production Ml = million litres	Import/ Export	Consumption	Remarks
Bangladesh	Production 1,1 Ml/a Additional new capacity from 1985 4,4 Ml/a Only molasses used as raw material	Import 13,1 Ml/a	Total cons. 15 Ml/a of which 12,5 Ml/a for pharmacentical industry	Molasses surplus 33 000 t/a
Bolivia	Installed production capacity 78,5 Ml/a Actual average production 26,5 Ml/a Molasses raw material	Export 8,5 Ml/a	18 Ml/a	
Burma	Present production about 9 Ml/a of which about 1,4 Ml/a from rice, rest from molasses	Import about 5 Ml/a	8,1 Ml/a potable 5,9 Ml/a industrial	
China	In 1983 over 870 Ml/a		488 Ml/a as chemical feedstock, rest in food industry	
Egypt	In 1983-84 about 42 Ml/a	Export 10-16 Ml/a	9 Ml/a potable 4 Ml/a chemical feedstock 3 Ml/a denatured technical 14 Ml/a as fuel	
India	536 Ml/a 151 distilleries		Potable only 47 distilleries, 127 Ml/a capacity. Industrial only 62 distilleries, 487 Ml/a capacity. Both 42 distilleries, 401 Ml/a capacity.	
Kenya	6 Ml in 1983		All consumed as a 10 % blend in gasoline. 38 Ml/a capacity under construction.	
Nepal	One modern distillery Molasses raw material			
Peru	Total production in 1980 40,8 Ml		Potable 18,2 Ml Industrial 22,6 Ml	
Philippines	88,9 Ml 96 % alcohol 4,2 Ml anhydrous alcohol produced in 1983	Export 27,3 Ml in 1983	Potable 62,4 Ml Industrial 6,6 Ml Mixed with gasoline 4,4 Ml	
Somalia	1980-81 6,3 Ml produced		Potable 5,4 Ml	Installed capacity 15 Ml/a
Sudan	Production about 0,6 Ml	0,2 Ml	0,8 Ml, industrial alcohol	
Thailand	Production capacity about 320 Ml/a	Export about 30 Ml/a	Capacity: Potable 250 Ml/a Industrial 40 Ml/a	
Zimbabwe	Production capacity about 40 Ml/a			All fuel alcohol

7. SUGGESTED READING

7.1. Alcohol production in developing countries

- Ethyl Alcohol Production and Use as a Motor Fuel.
J.K. Paul, ed., Energy Technology Review No 50, Chemical Technology Review Nc. 144. Noyes Data Corporation, Park Ridge, New Jersey, USA 1979.

- Alcohol Production from Biomass in the Developing Countries.
World Bank, 1818 H Street, N.W. Washington D.C. 20433, USA September 1980.

- Organic Chemicals from Biomass.
I.S. Goldstein, ed., Boca Raton Florida, USA, CRC Press Inc., 1981.

- Study on the Production and Use of Ethanol Methanol and Methane from Biomass (Alternative Fuels). United Nations Economic and Social Commission for Asia and the Pacific. ST/ESCAP 195, Bangkok 1982.

7.2. Biotechnology and fermentation

- Industrial Microbiology and the Advent of Genetic Engineering. A. Scientific American Book, San Francisco: W.H. Freeman 1981.

- Microbial Enzymes and Biotechnology: Fogarty, W.M., ed. Elsevier, New York, USA 1981.

- Trends in the Biology of Fermentations for Fuel and Chemicals. Hollaender, A. et al, eds. Plenum Press, New York, USA 1981.

- Advances in Biotechnology, Vol I, Scientific and Engineering Principles. Vol II, Fuels, Chemicals, Foods and Waste Treatment. Moo-Yuong, M. C.W. Robinson and C. Vezina, eds. Pergamon Press, Toronto, Canada 1981.

- Microbial Technology Vol I, Microbial Processes. Vol II, Fermentation Technology. Peppler, H.J and D. Perlmann, eds. Academic Press, New York USA 1979.

7.3. Implementation

- Manual for the Preparation of Industrial Feasibility Studies. UNIDO, Vienna.
United Nations Publication. Sales No.: E.78.II.B.5, United Nations, New York 1978.

- Preliminary Cost Estimating of Process plants.
M.B. Desar, Chemical Engineering July 27, 1981 p. 65.

- Plantsite selection
J.E. Granger, Chemical Engineering June 15, 1981 p. 88.

ANNEX 1

US/INT/83/037 - Workshop on Fermentation Ethanol Production for Use as Fuel and Chemical Feedstock in Developing countries, Rajamäki, Finland, from 17 September to 12 October 1984.

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US/INT/83/037 - Workshop on Fermentation Ethanol Production for Use as Fuel and Chemical Feedstock in Developing countries, Rajamäki, Finland, from 17 September to 12 October 1984.

PROGRAMME OF THE WORKSHOP
17.9 - 12.10.1984

Monday 17 September

8.30	Departure by bus from Rajamäki to Alko's training centre in Vuoranta near Helsinki.
9.30	Breakfast
10.00	Opening address/UNIDO Myint Maung Senior Industrial Development Officer Chemical Industries Branch, Division of Industrial Operations UNIDO/Vienna Opening address/FINNIDA Unto Korhonen Ambassador Ministry for Foreign Affaires, Finnish International Development Agency Helsinki Opening of the workshop Alko's Deputy General Manager, Director Matti K...
11.00	Introduction of the workshops participants.
12.00	Lunch
13.00	Introduction of the participants continues Alko's production film
14.30	Coffee
15.00	Facts about Finland Teuvo Tikkanen, Vice President Finnfacts Institute
16.00	Facts about Helsinki R. Nupponen, Chief Helsinki City Tourist Office Sauna (voluntary)
18.30	Dinner
21.30	Back to Rajamäki

Tuesday 18 September

8.30-12	Discussion on country papers on current fermentation ethanol production and problems and prospects for future expansion of production of fermentation ethanol as fuel and chemical feedstock	Maung Stelwagen Stambej
	Lunch	
13-16.30	Rajamäki factories and its production processes: - distillery - distillation plant - stillage drying plant - vinegar factory - technical alcohol plant - factory museum	Stelwagen

Wednesday 19 September

8.30-10	Discussion on country papers continues	Maung Stelwagen
10-11	Methane production theory	Henttonen
	Lunch	
12-16.30	Visit to YIT methane production plant in Jokioinen	Henttonen Stelwagen

Thursday 20 September

8.30-10.30	Industrial microbiology; Industrial microbes and their products, the biotechnical process. Dep. Professor Pertti Markkanen PhD. Department of Biochemistry, Helsinki Technical University	
10.30-11	Raw materials for ethanol production. Use of ethanol as a fuel	Stelwagen
11-12	Use of ethanol as a chemical feedstock	Stelwagen
	Lunch	
13-15	The ethanol fermentation process	Hiisvirta
15-16.30	Discussion	Stelwagen Hiisvirta

Friday 21 September

7.30	Departure by bus from Rajamäki for Eastern Finland	Hyvärinen Stelwagen
9.00	Break for coffee	
11.00	Lappeenranta. Visit to Chymos; fermentation plant and processes	
	Lunch	
14.00	Ylämaa spectrolite village gem and granite industries	
	- coffee - visit to gems factory and exhibition	
20.00	Dinner at Imatra Valtionhotelli in Imatra	
	Overnight stay at the hotel	

Saturday 22 September

9.00	By bus from Imatra to Savonlinna	Hyvärinen Stelwagen
11.00	Visit to Olavinlinna Castle	
12.15	Lunch	
13.00	Boat cruise on Lake Saimaa	
	By bus from Savonlinna via Mikkeli and Heinola to Lahti. Coffee break in Heinola	
16.30	Visit to Lahti Winter and Summer Sports Centre	
19.00	Back in Rajamäki	

Monday 24 September

8.15	Departure by bus to the Technical Research Centre of Finland's Biotechnology laboratory in Espoo	Stelwagen
9-12	Visit to TRCF	
	- welcome	Veijo Mäkinen
	- presentation of the institution	Liisa Viikari
	- lecture 1: The development of cellulase producing micro-organisms (Trichoderma reesei)	Dr. Michael Bailey
	- lecture 2: Fermentation of pentoses to ethanol	Dr. M-L. Suihko
	Back to Rajamäki	
	Lunch	
13.30-17	Distillation of ethanol. Theory and distillation systems. Discussion	Leppänen

Tuesday 25 September

8-10	Visit to Alko's Head office and plant in Helsinki	Stambej Stelwagen
	Coffee	
10-12	Alko's Research Laboratories in Helsinki	Karjalainen
	- Functions of the laboratory	Korhola
	- Delignification - how to make lignocellulosic material more accessible to hydrolysis	Vaara
	Lunch	
13-14	... continues	Vaara
14-15	Microbe strain collection	Väisänen
15-16	Industrial enzymes	Nybergh

Wednesday 26 September

8.30-12	History of baker's Yeast, its worldwide production and use	Penttilä
	Yeast biology and biochemistry; theory of yeast production	
	Visit to Rajamäki yeast factory	
	Practice of yeast production I	
	Raw materials and their handling	
	Practice of yeast production II	
	Propagation and after-treatment	
	Lunch	
13-16	Quality control of yeast production	Penttilä
	Review and test	

Thursday 27 September

8.00	Departure by bus to Pori (at Finland's West Coast)	Hyvärinen Karjalainen
	Visit to W.Rosenlew Ltd Engineering Works	
11.00	Refreshments and presentation of Rosenlew, its products and production.	Mauri Elo
12.30	Lunch	
13.15	Lecture: Construction of distillation columns.	Mauri Elo
14.00	Tour around the factories.	
14.45	Visit to Rauma Repola Mäntyluoto Works	
17.00	Check in at Hotel Satakunta.	
19.30	Dinner	
	Overnight stay at the hotel.	

Friday 28 September			
	8.30	Departure by bus from Pori to Turku (in the South-West corner of Finland)	Hyvärinen Karjalainen
	11.30	Visit to Marli's fermentation plant.	
		Lunch	
	14.30	Visit to Turku Castle	
	18.00	Back in Rajamäki	
Weekend 29-30 September		Free	
		Sunday evening: Ice hockey match in Helsinki	
Monday 1 October		The participants will be divided into 2 groups.	
	8-16	Distillation trial in the pilot plant (10 000 l/d capacity) (Group 1)	Hiisvirta
		Practical laboratory analyses for the Group 2	Lehtonen
Tuesday 2 October	8.30-10	Practical applications of Industrial Microbiology.	
		Professor Matti Linko, PhD, Department of Process Technology, Technical Research Centre of Finland	
	10-16	Distillation trial continues for Group 1	Hiisvirta
		Practical laboratory analyses for Group 2	Lehtonen

Wednesday 3 October	7.30	Departure to Alko's Reserarch laboratories in Helsinki	Karjalainen
	8.30-9.15	Ethanol process analysing. Product quality	Harju
	9-10	Analysis equipment	Puputti
	10-12	Genetic engineering	Torkkeli
		Lunch	
	13-14	Industrial vinegar production	Vehmaanperä
	14-15	Citric acid fermentation	Tuompo
	15-16	Library and information service	Launo
		Back to Rajamäki	
Thursday 4 October Friday 5 October	8.30-16.30	Lectures and practical work in Rajamäki factories laboratories (Group 1)	
		- Microbiological sampling	Sinda
		- Microbiological purity	
		- Fermentation control and inoculum prep.	
		- Introduction to quality control	Lehtonen Lehtomäki
		- Raw materials quality control	
		- Fermented mash	
		- Control of distillation	
		- Product quality control	
		- Asepsis	Sinda
		- Selective media	
		- Test baking with baker's yeast	
		- Conclusion	
	8-16	Group 2 performs the distillation trial in the pilot distillery	Hiisvirta
		Visits by single participants to Finnish companies according to wishes	Stelwagen Stambej Karjalainen Pollari

Saturday 6 October	7.00	Departure by bus to Alko's Koskenkorva Factory in Middle Finland near Vaasa	Hyvärinen Stelwagen
		Breakfast in Hämeenlinna	
	12.00	Arrival in Koskenkorva	
		Lunch	
	13.00	Koskenkorvas distillery and enzyme production processes Tour around the factories	Roering
	15.00	Departure by bus to Tampere	
		Visit to the Aquarium and Planetarium in Tampere	
		Snacks	
	20	Back in Rajamäki	
Monday 8 October	8.30-16.30	Water and waste water treatment processes and technologies	Henttonen
		Visit to Helsinki City Water Works	
Tuesdays 9 October	8.30-11	... continues	Henttonen
	11.30-16.30	Visit to Riihimäki Glass Works and Museum	Hyvärinen Henttonen
		Lunch	
		Tour around the factory	
		Presentation of the production	
		Glass museum	
	19	Dinner Rajamäki Factories' General Manager Erkki Anttila	

Wednesday 10 October	8.30-12	Final discussions and course evaluation	Stelwagen Karjalainen
		Press conference	
		Lunch	
	13-	Preparation for departures	
Thursday 11 October	8.30-12	Visit to Finlands National Museum	Stelwagen Henttonen
	12.30	Lunch	
	14-	Alko's training centre, Vuoranta	
		Ministry for Foreign Affaires of Finland, Finnish International Development Agency, FINNIDA - a presentation, Ambassador Unto Korhonen	
		Finnish Fund for Industrial Development Cooperation Ltd, FINNFUND - a presentation, Deputy Director Matts Andersson	
		Finnish Export Credit Ltd - a presentation, Credit Manager Kari Paakkari	
	19	Farewell dinner Director Matti Kaukinen	
Friday 12 October	9.30	Closing of the workshop. Diplomas	Stelwagen Vento
		Lunch	
	11-	Departures	
Saturday 13 October Sunday 14 October		Departures	