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Final Report

2nd WORKSHOP
ON
FERMENTATION ETHANOL PRODUCTION
FOR USE AS FUEL AND CHEMICAL FEEDSTOCK
IN DEVELOPING COUNTRIES
US/INT/86/128

from 8 September - 3 October 1986
Rajamaeki, Finland

organized by

United Nations Industrial Development Organization
in co-operation with
Finnish International Development Agency (FINNIDA)
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 was the second one of its kind and was part of a programme designed to:

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

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

The workshop 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 a UNIDO Workshop on Fermentation Alcohol for Use as Fuel and Chemical Feedstock in Developing Countries, held in Vienna, Austria in March 1979. That workshop confirmed the interest of many developing countries in research, development, adaption and promotion of technologies for fermentation ethanol production.

Based on the above mentioned meetings the first Workshop on Fermentation Ethanol Production for Use as Fuel and Chemical Feedstock in Developing Countries was organized by UNIDO in cooperation with the government of Finland and ALKO LTD in 1984. The outcome of this first workshop was very encouraging and led to the organizing of the present one.

In addition to facilitating a review of the latest developments in fermentation ethanol technology and related process

technologies and providing on the spot exposure to the daily work in existing plants and research institutions of this field, the workshop provided a forum for detailed discussion of common problems experienced by the participants.

The discussions in a group of specialists living closely together for a month away from their home base reach, after some weeks, a depth which is not easily attained in other forums.

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 decision making and "hands-on" technical people from developing countries.

These conferences also often deal with the latest developements which are not necessarily suited for developing countries where the conditions differ widely from the industrialized countries where the technology is being developed.

On the other hand the every day problems in ethanol production in developing countries seem to be very much the same all over the world and experts from these countries can provide each other with lots of really useful information provided the right forum for exchange of ideas is created.

One of the most important aims of the workshop was to provide a forum for detailed discussions of both problems and the prospects, on the basis of the personal experience of participants from 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 provided the possibility for a larger group of Finnish scientists and engineers to discuss and become more aware of problems and constraints in alcohol production 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 out of local raw materials.

- A national policy on production of alcohol for use as fuel and chemical feedstock is needed. In order to develop a national policy a thorough study should be made including the effects of an alcohol policy on all the various sectors of the economy (e g. agriculture, industry, energy, transportation). Furthermore a strong government back-up is needed to accommodate and coordinate the different and often conflicting needs of the different sectors.

- 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 is essential.

- The production of fermentation ethanol for fuel and chemical feedstock probably 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.

The feasibility of ethanol production from renewable raw material is highly depending on the price of crude oil which is the competing raw material. Currently (autumn 1986) the price of crude oil is extremely low and, as such, discourages projects for ethanol for fuel and chemical feedstock. However, all forecasts predict price increases in the future and the forecasts foresee that the average crude oil price in the long run will be at a considerably high level.

The creation of a national alcohol program and its implementation to the stage where the actual production can start will, depending on how much work has already been done, and can take up to 7 years. In this time the price of crude oil will go up and possibly exceed the highest prices recorded to date. When studying the feasibility this should be borne in mind.

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 sophisticated technology or large capacity plants.

- 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 provides for the supply of fuels form indigenous sources.

- the use of ethanol as an octane booster in gasoline mixtures instead of lead component can considerably contribute to decrease the air pollution in areas with heavy motor traffic.

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.

Also conversion of ethanol to ethylene and consequent down-stream products is gaining interest.

2.2 History of the project

This is the second 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.

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 first fermentation ethanol workshop was held in 1984 and this second one from September 8 to October 3 1986. The workshop is intended to be repeated biannually. An indication of the need for continuity is that UNIDO received over 40 applications for participation of which only 18 could be accepted due to limitations mainly in accomodation.

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 was founded in 1932 though its experience goes back till 1888 when Alko's biggest factory complex, the Rajamäki factories, was founded.

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 technologies 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.

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 institution 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 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 WORKSHOP

3.1. Duration and time

The Workshop took place from September 8 to October 3, 1986. Considering that the participants mostly come from tropical countries, an earlier time could be preferred.

A workshop duration of 4 weeks including the present topics is short and demands hard work from the participants. For future workshops a 5-6 weeks duration might be more 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 as well as in The Technical Research Centre of Finland.

The program also included visits to Finnish companies and institutions according to single participants' wishes. Such visits were done to:

- Brewery
- Helsinki University, Forestry department
- Technical Research Centre of Finland, Fuel laboratory
- Technical Research Centre of Finland, Biotechnical laboratory
- Sugar technology consultant

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 enzyme plant and bottled final products from the bottling plant.

Operation of industrial scale processes of alcohol fermentation and distillation, and baker's yeast were followed in Alko's Rajamäki factories and Agroenergiutvecklings Ab's integrated starch/fuel ethanol plant in Lidköping, Sweden.

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

3.3. Workshop staff

Workshop director	Cay Stambej, M.Sc.
Deputy workshop director	Raimo Palvola, Mr
Workshop secretary	Aila Vierikko, Mrs
Assisting workshop secretary	Marja-Leena Eloranta, Mrs

3.4. Lecturers and instructors

Ahe Sirpa	Ph.D	ALKO LTD. Research Laboratories
Anttila, Erkki	M.Sc. Plant manager	ALKO LTD, Rajamäki Factories
Bailey, Michael	B.Sc.	Technical Research Centre of Finland
Caranna, Ab	M.Sc.	Dorr-Oliver (Holland)
Finland, Marjatta	Information Specialist	ALKO LTD, Library and Information Service
Eloranta, M-L	Mrs.	Assistant Workshop Secretary ALKO LTD, Rajamäki Factories
Halme, Aarno	Ph.D. Professor	Helsinki Technical University
Harju, Kai	M.Sc.(Chemic. Engin.)	ALKO LTD, Research Laboratories
Heinonen, Arni	Chief of Country Programme Unit	FINNIDA
Honttonen, Aake	B.Sc., Engineering	ALKO LTD, Rajamäki Factories
Hiisvirta, Tapani	M.Sc., Engineering	PLANSELL Oy
Karinen, Pertti	M.Sc., Engineering	ALKO LTD, Rajamäki Factories
Kaukinen, Matti	M.Sc., Engineering Vice President	ALKO LTD
Knowles, Jonathon	Ph.D., Professor	Technical Research Centre of Finland
Korhola, Matti	Ph.D.(Microbiology)	ALKO LTD, Research Laboratories
Korhonen, Unto	M.Sc., Ambassador	FINNIDA
Kortteinen, Timo	Ph.D., Research Scientist	ALKO LTD, Social Research Institute of Alcohol Studies
Laaksonen, Markku	Mr.	ALKO LTD, Rajamäki Factories
Larjavaara, Tuomas	Ph.D., Director	FINNISH EXPORT CREDIT LTD
Lehmussaari Antti	M.Sc., Biochemistry	ALKO LTD, Rajamäki Factories
Lehtomäki, Ilkka	M.Sc., Engineering	ALKO LTD, Rajamäki Factories
Lehtonen, Matti	Ph.D.	ALKO LTD, Rajamäki Factories
Leppänen, Olavi	M.Sc., Engineering	ALKO LTD, Rajamäki Factories
Linko, Matti	Ph.D., Professor	Technical Research Centre of Finland
Markkanen, Pertti	Ph.D., Professor	Helsinki Technical University
Moro, Heikki	M.Sc., Economics	FINNFUND
Nupponen, Mikko	Tourist Director	Helsinki City Tourist Office
Nybergh, Paula	Ph.lic.(Chemic.Eng.)	Technology Development Centre
Nylund, Nils Olof	M.Sc., Engineering	Technical Research Centre of Finland
Palvola, Raimo	Mr.	Workshop Assistance Director ALKO LTD, Rajamäki Factories
Penttilä, Liisa	M.Sc., Engineering	ALKO LTD, Rajamäki Factories
Pietilä, Kirsti	M.Sc.	Technical Research Centre of Finland
Rouhiainen, Heikki	Mr.	ALKO LTD, Rajamäki Factories
Simell, Maarit	M.Sc., Engineering	ALKO LTD, Research Laboratories
Sinda, Eija	M.Sc.	ALKO LTD, Rajamäki Factories
Stenbej, Cay	M.Sc., Engineering	Workshop Director, ALKO LTD Process Engineering Division
Stelwagen, Patrick	M.Sc.	ALKO LTD, Process Engin. Divis.
Suihko, M-L	Ph.D.	Technical research Centre of Finland
Tarn, Peter	M.Sc.	AGROENERGIUTVECKLINGS AB (Sweden)
Thorsson, Conny	M.Sc.	ALFA-LAVAL FOOD ENGINEERING AB (Sweden)
Tikkanen, Teuvo	Vice President	FINNFACTS INSTITUTE
Verseuteren, C.	M.Sc.	STORK WERKSPOOR SUGAR (Holland)
Vierikko, Aila	Mrs.	Workshop secretary, ALKO LTD, Technical department
Viro, Maija	Ph.D. (Agric.)	ALKO LTD, Research Laboratories
Williams, Robert	Ph.D.	
Vihiäinen, Eino	M.Sc.(Microbiology)	ALKO LTD, Research Laboratories

3.5. Workshop programme

The training programme consisted of theoretical and practical training, study visits to 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, sports watching, museum visits etc.

3.6. Workshop material

The workshop material was partly based on the material of the previous workshop, partly new. The old material had to be reworked and the new to be prepared and translated into English.

The written 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, 172 pages prepared by the participants, edited and distributed by the workshop staff.

- Process descriptions, flow schemes and activity descriptions 74 pages

  - Grain ethanol production 7 pages, 3 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
  - 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 11 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 workshop staff.

Content of the notes

1. Alcohol as energy - social and economic aspects
   By: Timo Kortteinen, Ph.D

   Fuel alcohol production world wide. National alcohol programmes. Food versus renewable energy.

2. 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.

3. Raw materials for ethanol production.
   By: Patrick Stelwagen, M.Sc.

   Sugar, starch or cellulose containig possible raw materials for ethanol production. Yields of crop and of carbohydrates.

4. Use of ethanol as a fuel in automobils.
   By: Nils-Olof Nylund, M.Sc.

   Alternative fuels. Alcohol as a motor fuel. Motor modifications. Spark Ignition. Diesel. Hybrid engines.

5. Use of ethanol as a chemical feedstock
   By: Patrick Stelwagen, M.Sc.

   Routes for processing of ethanol into other chemicals. Dehydration. Dehydrogenation. Oxidation.

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

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

7. 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.

8. 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.

9. Alcohol distillation
   By: Olavi Leppänen, M.Sc.

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

10. Delignification

By: Maarit Simell, M.Sc.

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

11. 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.

12. Industrial enzymes

By: Paula .A. Nybergh, Ph.lic.

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

13. Library and information service

By: Marjatta Eklund, Information specialist

The present role of an information service. Information process. Use of computers. Data bases and banks. Bio informatics.

14. Baker's yeast production

By: Liisa Penttilä, M.Sc. and Pertti Karinen M.Sc.

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

15. The BIOSTIL fermentation process
By: Conny Thorsson, M.Sc.

The consept of the BIOSTIL process. Practical results for grain and molasses raw material.

16. 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.

17. Laboratory analysing equipment
By: Maija Viro, Ph.D.

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

18. Genetic engineering
By: Sirpa Aho, Ph.D.

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

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

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

20. Management of industrial projects in developing countries
By: C. Vercauteren, M.Sc.

Feasibility study. Project implementation. Contract. Financing. Problem areas.

21. Automation of industrial microbiological processes
By: Aarne Halme, Ph.D., Prof.

General goals. Resent develpoments. Special features of biotechnical processes. Sensor problems.

22. Waste water treatment processes
By: Asko Henttonen, B.Sc.

Effects of waste water to the nature. Distillery wastes. Theory of treatment. Different methods.

23. Integration of starch-ethanol processes
By: Ab Caransa, M.Sc. and Antti Lehmussaari, M.Sc.

Starch crops. Starch process. Applications of starch. Starch-ethanol process integration.

24. Practical applications of industrial microbiology
By: Matti Linko, Ph.D., Prof.

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

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

Materials. Methods. Results. Conclusions.

3.8. Practical work

The participants followed practical work in Alko's 10 000 l/d pilot distillery and in the factories' laboratories in Rajamäki. The work consisted of studying the operation of the pilot distillery for 4 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 4-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 eighteen participants represented 14 developing countries in Africa, Asia and South America. The countries represented were: Bangladesh, Cuba, Ethiopia, Indonesia, Kenya, Malawi, Nepal, Peru, the Philippines, Sri Lanka, Sudan, Tanzania, Thailand and Vietnam.

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

Generally the participants' command of English was good. A few participants had some communication problems but their command in English improved considerably during the workshop due to constant practice.

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

3.10. Financial arrangements

Training and lodging including breakfast and one hot meal per day 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 114 FIM was also given. For two travelling days a daily allowance of 414 FIM was paid.

A majority of the participants (13/18) found the daily allowance adequate or good.

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 single rooms with shared shower and WC, and cooking facilities in apartments in three of Alko's Rajamäki factories' residences close to the training facilities were reserved for the participants.

Breakfast was served every morning in a cafe in Rajamäki center within walking distance from the residences.

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 travelling 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 a serious eye disease, the other because of flu.

3.13. Other practical arrangements

The organizers helped the participants with laundry-, telephone-, telex-, mail-, transport,- shopping- and other 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.

Generally the evaluation showed that the great majority of the participants were satisfied with the workshop as a whole. This fact together with the large interest for the workshop proved by the number of applications for participation speaks in favour of more workshops in this field in the future.

Only a few questions are commented on here.

1. Information before arrival, pre-course timetable, obtaining of visa etc?
   - Because of a strike in Finland the pre-course information was badly delayed and reached the participants only a few days before their departure for Finland which caused them problems in developing e.g. the country papers. 12 participants complained about this.
     It was agreed with the Finnish authorities that the participants' visas were to be issued at the airport upon arrival so this caused no problems.

2. Pre-course work?
3. Practical arrangements before entering Finland?
   - Due to the abovementioned strike also this information arrived late or not at all. 6 participants complained about it.
4. Reception upon arrival?
5. Accommodation?
6. Food?
7. Daily allowance?
   - 13 out of 18 participants found the daily allowance of 114 FIM (c. 23 USD) adequate, 4 would have preferred more.
8. Laundry-, telephone-, telex-, mail-, transport- and other practical arrangements?
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?
   - 12 participants considered the four weeks duration adequate, 6 would have preferred a longer workshop. Considering that only one participant suggested one topic to be deleted but 21 additions were suggested a 5-6 weeks workshop might be more appropriate in the future.
   - The training programme could perhaps be a little more practical. Several persons wanted more practical work.
   - Among subjects, which were considered too complicated was genetic engineering, mentioned by 8 participants. On the other hand 3 participants considered the same topic to be too basic.
     A problem in designing the level of the lectures is of course the varying backgrounds of the participants.

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.

Alko is considering some kind of bulletin to be sent to the participants of the two workshops held so far. This bulletin would contain news about development regarding the processes and topics of the workshops and also other thereto releated material e.g. news about projects in the participants' countries, Alko projects etc.

Furthermore Alko personnel will try to visit the participants in their home countries in connection with other business trips to discuss development with them.

4.3.1. Participants' views

On the topic of follow-up activities many of the participants recommended contacts in the form of regular information letters or a bulletin to be arranged by UNIDO/Alko or Alko. A follow-up workshop was also proposed but will obviously be too expensive to realize.

4.3.2. The organizers' view

In order to emphasize and to strenghten the follow-up issue the close cooperation between UNIDO, FINNIDA and Alko should continue. The continuity of the project is strengthened if the workshop is repeated.

According to the project proposal the Workshop is also 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. Potential short-term consultancy projects identified

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

- Study on process improvement of an existing molasses distillery in Bangladesh.
- Study on process improvement of an existing molasses distillery in Nepal.
- Study on the possibility of integrating a starch plant into a cassava fuel ethanol plant under planning in Tanzania.
- Short term in-plant training in distilleries in Ethiopia.
- Study on process improvement in existing distilleries in Ethiopia.

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 gets an official request from the Government in question.
4. UNIDO seeks funds in addition to already earmarked funds (from FINNIDA) for the implementation of the short-term consultancy projects.

6. IMPROVEMENT OF FERMENTATION ETHANOL INDUSTRY IN DEVELOPING COUNTRIES

The following analysis of, on one hand, problems and constraints 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 forms a basis for production of alcohol for fuel and chemical feedstock and thus could enable the countries to decrease their oil imports. This is especially the case in countries with large areas under agriculture. There is no doubt that technologies needed 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.

Since the previous workshop held in 1984 the world market price for crude oil has drastically dropped to a level where it makes the production of fermentation ethanol for fuel and chemical feedstock uninteresting if considered only in a narrow financial sense. However, all experts agree that in the near future the crude oil prices can only go up and in a few years they will most propably again be on a level where fermantation ethanol becomes a feasible substitute. Considering the long time the implementation of an ethanol project takes the present low oil prices should therefore not affect the decision making. Furthermore as pointed out elsewhere in this report the production price of ethanol is only one of many factors to consider.

The question is country-specific and requires 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

The problems brought forth by the participants are similar to those raised in the 1984 workshop. However, it can be noted that the governments of the conserned countries, in this short time, have become more aware of the pollution problems and demand actions in this respect from the distilleries. Most of the participants' distilleries are struggling with waste water problems.

Another problem which was now quite strongly discussed was the lack of cooperation between developing countries.

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 workshop participants and 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 problems of ethanol production in developing countries are very much th ame all over the world. Simple and well designed solutions to the problems are often found in one country but, due to lack of appropriate information channels or contacts, the knowledge cannot be transferred to other countries.
- The utilization of molasses, which often can be considered as a surplus by product, as raw material for ethanol productior 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.
- In many countries cassava is a potential crop for ethanol production. However, very little information is available on cassava processing to alcohol as well as on large scale farming of this crop.
- 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 con[illegible]ion 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 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 delivered to watercourses, 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 Cuba, Sudan and Thailand 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. Kenya, Peru 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 1985 the production was 60 million liters of ethanol, all from sugarcane molasses.

- Kenya implemented its own ethanol program in the early eighties. The price of imported oil was going up and the sugar factories of which most are situated upcountry had no outlet for their molasses due to high transportation costs to the coast and low world market price. Today there is one plant producing 18 mill. l/a ethanol which is used in the Nairobi area as a 10/90 mix to give a high premium gasoline. Further plants are under consideration as the molasses problem still remains. The present working plant employs 250 persons which is a significant number in an area with a huge unemployment problem.

- Indonesia is an interesting example as it is an oil producing country. In Indonesia one of the aims with an alcohol program is to produce alcohol out of excess agricultural products to use as a local fuel to substitute oil products which thus can be exported to earn foreign exchange.

- Malawi is in a situation where great advantage can be achieved by a local ethanol fuel production. The country is land locked with difficult access to harbours through countries with poorly working transportation facilities. At times oil for fuel has had to be transported to the country by air. Also export of the country's molasses has been impossible so it has mainly been dumped causing pollution problems.

  In 1982 the country started a fuel ethanol plant producing 60 000 l/d, which is enough for a 20/80 blend in the whole country, and presently there are plans for increasing the capacity and introducing 100 % alcohol vehicles.

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 (1985)

Country	Production Mill. liters/a	Import/ Export	Consumption	Planned fuel projects	Remarks
Bangladesh	5,7 Additional new capacity from 1987 2,7 ml/a			5,4	
Cuba					70 % of the alcohol production is for fuel use.
Ethiopia	2,4			12 + 8	12 000 t/a excess molasses
Indonesia	4,2				Total capacity of 15 existing plants is 7,5.
Kenya	18				All consumed as a 10/90 gasoline blend.
Malawi	8,5 fuel 0,2 potable				All consumed as a 20/80 gasoline blend.
Nepal	ab. 4				4 distilleries 90 % potable.
Peru	82 installed capacity				300 000 t excess sugar
The Philippines	60	22 export	38		Installed capacity 175.
Sri Lanka	6	6 import	12		11 distilleries
Sudan	none			14 + 24	2,3 installed capacity, no production 165 000 t/a excess molasses
Tanzania			10 + 9		One small plant for potable. Shortage of molasses
Thailand	Installed capacities 25 potable (+ ind.) 8 export				
Vietnam	30				2 main distilleries + many small. Main raw materia' grain + molasses.

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 No. 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 fermantation

- 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 Wast · 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.

US/INT/86/128 - 2nd Workshop on Fermentation Ethanol Production for Use as Fuel and Chemical Feedstock in Developing countries, Rajamäki, Finland, from 8 September to 3 October 1986.

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2ND WORKSHOP ON FERMENTATION ETHANOL PRODUCTION FOR USE AS FUEL AND CHEMICAL FEEDSTOCK IN DEVELOPING COUNTRIES. RAJAMÄKI, FINLAND, FROM 8 SEPTEMBER TO 3 OCTOBER 1986

PROGRAMME

Saturday 6 September
Sunday 7 September

Arrival of participants

Monday 8 September

8.30	Departure by bus from Rajamäki to Alko's training centre Vuoranta near Helsinki	
10.00	Opening address/UNIDO	Williams
	Opening address/FINNIDA	Korhonen
	Opening of the workshop/ALKO	Kaukinen
11.00-12.00	Introduction of the workshop participants	
13.00	Introduction of the participants continues Alko's production film	
15.00	Facts about Helsinki Helsinki City Tourist Office	Nupponen
16.00	Facts about Finland Finnfacts Institute	Tikkanen
17.00	Sauna (voluntary)	
18.30	Dinner	
21.30	Back to Rajamäki	

Tuesday 9 September

8.30-12.00	Rajamäki factories and its production processes: - distillery - distillation plant - stillage drying plant - vinegar factory - technical alcohol plant - factory museum	Stelwagen
13.00-17.00	Helsinki sightseeing	Palvola Eloranta

Wednesday 10 September

8.30-12.00	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	Williams Stambej
13.00-15.00	Discussion on country papers continues	
15.00-16.00	Alcohol as energy - social and economic aspects	Kortteinen

Thursday 11 September

8.30-10.30	Industrial microbiology: Industrial microbes and their products, the biotechnical process	Markkanen
10.30-11.00	Raw materials for ethanol production	Stelwagen
11.00-12.30	Use of ethanol as a fuel in automobiles	Nylund
13.30-14.30	Use of ethanol as a chemical feedstock and quality requirements for ethanol for different uses	Stelwagen
14.30-17.00	The ethanol fermentation process	Hiisvirta

Friday 12 September

7.30	Departure by bus from Rajamäki for Eastern Finland	Palvola Stambej Vierikko Eloranta
11.00	Lappeenranta. Visit to Chymos: fermentation plant and processes	
14.30	Ylämaa spectrolite village gem and granite industries - visit to gems factory and exhibition	
20.00	Dinner at "Imatran Valtionhotelli" in Imatra	
	Overnight stay at the hotel	

Saturday 13 September

9.00	By bus from Imatra to Savonlinna	Palvola Stambej Vierikko Eloranta
11.00	Visit to Olavinlinna Castle	
13.00	Boat cruise on Lake Saimaa	
	By bus from Savonlinna via Mikkeli and Heinola to Lahti	
17.30	Visit to Lahti Winter and Summer Sports Centre	
20.30	Back in Rajamäki	

Sunday 14 September

F r e e

Monday 15 September

8.15	Departure by bus to the Technical Research Centre of Finland's Biotechnology Laboratory (VTT) in Espoo	
9.00-12.00	Visit to VTT	
	- Welcome	Knowles
	- lecture 1: The development of cellulase producing micro-organism/ Trichoderma reesei	Bailey
	- lecture 2: Fermentation of pentoses to ethanol	Suihko
	- presentation of the institution	Pietilä
	Back to Rajamäki	
13.30-17.00	Distillation of ethanol Theory and distillation systems. Discussion	Leppänen
19.00	Cocktail party	Anttila

Tuesday 16 September

7.30	Departure to Helsinki	
8.30-9.30	Visit to Alko's plant in Helsinki	Stambej
9.30-11.00	Alko's Research Laboratories	
	- functions of the laboratory and lab.tour	Korhola
11.00-12.00	- industrial enzymes	Nybergh
12.00-13.00	- microbe strain collection	Väisänen
14.00-15.00	- delignification - how to make lignocellulosic material more accessible to hydrolysis	Simell
15.00-16.00	Library and information service	Eklund

Wednesday 17 September

8.30-12.00	History of baker's yeast, its worldwide production and use	Penttilä Karinen
and		
13.00-15.00	Yeast biology and biochemistry; theory of yeast production.	
	Visit to Rajamäki yeast factory	
	Practice of yeast production: - raw materials and their pre-treatment - propagation and down stream processing - active dry baker's yeast	
	Quality control in baker's yeast production	
17.00	Departure by bus to Turku	Palvola Stambej Vierikko Eloranta
21.30	Departure by ship to Stockholm/Sweden	

Thursday 18 September

7.00	Arrival in Stockholm. Departure by bus to Lidköping	
13.00-16.00	Visit to Agroenergiutveckling's fuel ethanol plant	Thorsson/Tern
	- presentation of the Biostil Fermentation - presentation of the distillation - plant tour	
20.00	Dinner and overnight stay at hotel in Örebro.	

Friday 19 September

9.00	Departure by bus to Stockholm	
11.00-13.00	Sightseeing in Stockholm	
13.00-19.00	**F r e e**	
19.00	Departure by ship to Turku/Finland	

Saturday 20 September

8.00	Arrival in Turku	
9.30-10.30	Visit to Turku Castle	
13.30	Back in Rajamäki	

Sunday 21 September

F r e e

Monday 22 September

8.30-10.00	Ethanol process analysing. Product quality.	Harju
10.00-11.00	Analysis equipment	Viro
11.00-12.00	Genetic engineering	Aho

The participants will be divided into two groups.

Group I

13.00-16.00	Distillation tests in Alko's pilot distillery	Stelwagen
	- start-up	Karinen
	- running	Laaksonen
	- trouble shooting	

Group II

13.00-16.00	Laboratory analyses praxis	Lehtomäki
	- microbiological sampling	Lehtonen
	- microbiological purity	Sinda
	- fermentation control and inoculum prep.	
	- introduction to quality control	
	- raw materials quality control	
	- fermented mash	
	- control of distillation	
	- product quality control	
	- asepsis	
	- selective media	
	- test baking with baker's yeast	

Tuesday 23 September

9.00-11.00	Management of Industrial Projects in Developing Countries	Vercauteren
12.00-16.00	Distillation tests continue (Group I)	
	Laboratory analyses praxis continue (Group II)	

Wednesday 24 September

8.30-14.00	Distillation tests continue (Group I)	
8.30-14.00	Laboratory analyses praxis continue (Group II)	
14.00-16.00	The ethanol fermentation process (cont.)	Hiisvirta
	Visits to Finnish companies according to each participant's wishes	Stambej Palvola Stelwagen

Thursday 25 September

8.30-11.00	Automation of industrial microbiological processes	Halme
12.00-16.00	Distillation tests continue (Group I)	
12.00-16.00	Laboratory analysis praxis continues (Group II)	

Friday 26 September

8.30-11.00	Water and waste water treatment processes and technologies	Henttonen
12.00-16.00	Distillation tests (Group II)	
12.00-16.00	Laboratory analyses praxis (Group I)	

Saturday 27 September

F r e e

Sunday 28 September

	Visit to Tampere. Ice-hockey match. aquarium	Palvola Eloranta Stambej Vierikko

Monday 29 September

8.30-11.00	Integration of starch-ethanol processes	Lehmussaari
12.00-16.00	Distillation tests (Group II)	
12.00-16.00	Laboratory analyses praxis (Group I)	

Tuesday 30 September and Wednesday 1 October

8.30-16.00	Distillation test continue (Group II)	
8.30-16.00	Laboratory analyses praxis continue (Group I)	
	Visits to Finnish companies according to each participant's wishes	

Thursday 2 October

8.30-11.00	Practical applications of Industrial Microbiology	Linko
12.00-16.00	Visit to YIT methane production plant in Jokioinen	Henttonen

Friday 3 October

9.00	Departure to Alko's training centre, Vuoranta	
10.30-12.00	Final discussions and course evaluation	
13.00	Ministry for Foreign Affairs of Finland. Finnish International Development Agency, FINNIDA - a presentation	Heinonen
	Finnish Fund for Industrial Development Cooperation Ltd, FINNFUND - a presentation	Noro
	Finnish Export Credit Ltd - a presentation	Larjavaara
16.00	Closing of the workshop. Diplomas.	Anttila
19.00	Farewell dinner	Anttila

Saturday 4 October and Sunday 5 October

Departures