RESIDUE UTILIZATION
MANAGEMENT OF AGRICULTURAL & AGRO-INDUSTRIAL RESIDUES

Presentations by Participants

Volume 2

The General Assembly of the United Nations at its 27th session late in 1972 adopted Resolution 2997 (XXVII) declaring itself "Convinced of the need for prompt and effective implementation by Governments and the international community of measures designed to safeguard and enhance the environment for the benefit of present and future generations of man".

The Resolution stated further that the Assembly was "Aware of the urgent need for a permanent institutional arrangement within the United Nations system for the protection and improvement of the human environment", and proceeded to create:

1. A Governing Council for the Environment Programme composed of 58 member countries elected by the General Assembly.

2. A small secretariat to serve as a focal point for environmental action and coordination within the United Nations system to be headed by an Executive Director elected by the General Assembly on the nomination of the Secretary General.

3. An Environment Fund to provide additional financing for environmental programmes.

4. An Environment Coordination Board under the chairmanship of the Executive Director.

Industry Sector Seminars

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United Nations Environment Programme

Food & Agriculture Organization of the United Nations

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Waste Bioconversion: Environmental Management for Economic Progress in Developing Countries

by E.J. DaSilva, A.C.J. Burgers & R.J. Olembo

INTRODUCTION

Growth of technology and consumption, characteristic of urbanisation, population increase and mobility, have over the last two decades led to a vast generation and accumulation of agricultural and municipal wastes. Agricultural technology greatly contributes to the volume of wastes. Agricultural and allied industrial wastes in the USA were estimated at 400 million tons per year (1). Oil-palm and rice-mill wastes in 1974 in Malaysia were estimated at 5 million tons (2) and 250,000 tons (3) respectively. On an annual basis 600,000 tons of maize cob, 1.5 million tons of dry rice-straw and 40,000 tons of sugar pith wastes are produced in Egypt (4). Whereas in Korea approximately 6 million tons of dry straw are produced annually as a by-product of the rice-crop (5), the sugar mills in Bangladesh per annum burn about 100,000 tons of cane-sugar bagasse (6). Likewise in many other countries farming, cropping, forestry, industrial and land development processes have greatly contributed to waste generation, and consequently to environment pollution and deterioration.

Wastes dissipate many of our natural resources and generally are difficult to dispose of. When discharged indiscriminately in coastal waters, for example, wastes have led to the disruption of several food-chain processes as well as to a gradual alteration of productivity of these waters. And, because wastes contain many natural resources, the use of such outdated but still conventional waste disposal methods often deprives a nation of valuable recoverable materials which could ultimately lend themselves to economically viable processes.

A majority of the wastes originating from agro-based industries such as molasses, dairy wastes, spent-sulphite liquors, waters from plants manufacturing starch and cellulosic products are rich in carbohydrates. In tropical areas cassava, sago and tapioca wastes contain tremendous reserves of starch which through microbiological conversion processes can yield valuable SCP food and feed supplements. The use of cellulosic and starchy materials as substrates has been widely investigated. A large number of organisms – coulds, bacteria, yeasts – have been deployed in the bio-conversion processes. Food-processing industrial wastes and agricultural residues are ideal substrates as they are relatively cheap and do not pose problems in their recycling. On the other hand, other organic wastes following appropriate micro-biological treatment are valuable sources of fertiliser and fuel.

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* Based mainly on : 'Health and Wealth From Waste: An Economic Incentive for Developing Countries' – D. Silva, E.J. Burgers, A.C.J. and Clembo, R.J. In *Impact of Science on Society*, 1976, Vol. 26,

** Inclusive of contributions from the UNEP/UNESCO/ICRO Panel on Microbiology. The valuable advice of Professor J.W.M. la Riviere, Chairman, International Cell Research Organisation (ICRO), and Professor of Environmental Microbiology, University of Delft, Netherlands is gratefully acknowledged.

Thus, wastes, if viewed in the proper perspective, constitute one of the most readily available sources exploitable for economic development. However, unjustified prejudice on the part of both the public and decision-makers has delayed the full utilisation of these valuable resources until recently.

World hunger and food scarcity accentuated by an unequal distribution system have stimulated increased research and development of relevant appropriate technology for new protein sources (7). The attempts to augment the conventional SCP sources like the traditional fermented foods – yoghurt, cheese and pickled vegetables – have resulted in promising advances with the development of microbial proteins obtained through fermentation processes employing paraffins and hydrocarbon substrates.

These already have passed the pilot-plant stage and several full-scale industrial processes have been established (7, 8, 9, 10, 11). However, as a result of the energy crisis of recent times the production of single-cell food and feed proteins from hydrocrabons has been economically affected. In such a situation the technological feasibility of the bioconversion of agricultural and industrial organic residues into SCP, cheap energy and fertiliser has greatly gained. Examples of what can be achieved already are presented in Table I.

EXAMPLES OF MICROBIAL WASTE UTILISATION PROCESSES

Mushrooms. Mushroom cultivation is an apt and ready example of the recycling of wastes – rice-straw, vegetables, residues, manure, fertilisers and soil organic matter – which through a high temperature fermentation process is transformed into a composted substrate containing the necessary nutrients essential for mushroom growth. The microbial process renders the compost free from competitive and pathogenic organisms. The fermentation residue can also serve as an excellent soil conditioner and fertiliser.

Mushroom cultivation has evolved from a hobby and a horticultural craft into an established scientific process that has implications and potential for village and rural technologies and economies in especially the developing countries. Traditionally based on the deployment of a horse manure straw mix substrate, production processes now make use of a broad variety of cereal and vegetable wastes, animal and bird manures as well as the waste products of a large range of industrial processes, some of which may pose problems in disposal.

Algae. One of the highly significant and rapidly developing methods of applying solar energy to the management of environmental problems is that of waste disposal through the use of photosynthetic oxidation ponds. It is possible to obtain, through the cultivation of micro-algae on animal and human wastes, not only treatment of the waste itself but also valuable protein in enormous amounts together with purified water. The process is based on a symbiosis of algae and bacteria. The bacteria mineralize the organic waste and thus provide nutrients for the algae which in turn capture solar energy and provide the oxygen required for the mineralisation process. Thus the organic waste is largely transformed into algal cell material. The high protein content and nutritive value of algae, have stimulated the recovery of algae for use as animal feed concentrate. Ancillary benefits are the abatement of odour, flies and disease.

Table 1. A few examples of food and other products obtained as a result of microbial action on natural and industrial wastes[1]. (see footnote page 1).

Country	Products obtained	Raw materials used	Reactive organisms
Chile	Microbial protein	Fruit peels, papaya wastes	Yeast
Egypt	Microbial protein	Bagasse pith, rice hulls, distillery slops	*Candida utilis, C. tropicalis*
Guatemala	Animal feeds, enzymes	Bagasse, sugar filter muds, cotton cakes, municipal wastes	Yeasts, bacteria
India	Irrigation waters, fish culture medium, organic acidulants, enzymes	Domestic and industrial wastes, molasses, seaweed, cellulosic materials	
Indonesia	*Ontjom, tempe mata kedele*	Peanut presscake, hypocotyl of soyabean seed	*Neurospora* sp., *Rhizopus* sp.
Israel	Fodder yeasts	Citrus peels, cannery wastes	*C. tropicalis*
Malaysia	Fish sauce, poultry feed, B-vitamins, glutamates	Fish wastes, tapioca rejects, rubber processing, palm oil effluents	Bacteria, *Chlorella* sp.
Nigeria	Single-cell protein compost, poultry feed	Cassava wastes, rice straw and hulls	
Pakistan	Organic acidulants, enzymes	Seaweed, molasses, cellulosic wastes	
Philippines	Vinegar, *nata di coco*	Waters from copra extraction	*Torula* sp., *Leuconostoc* sp.
Senegal	Compost, animal feeds	Millet, sorghum and groundnut wastes	
Sri Lanka	Vinegar, organic acidulants	Copra extraction waters, cellulosic wastes, molasses	*Torula* sp.
Thailand	Single-cell protein, fish sauce, yeast, soft drinks	Municipal wastes, trash fish and fish rejects; coconut water, cassava and vegetable wastes	*Torula* sp., *Chlorella* sp.

1. Data obtained, in part, from work-bench exercises and lectures organized by the United Nations Environment Programme, Unesco and the International Cell Research Organisation in Bangkok, Kuala Lumpur, and Bandung. The objectives of the processing include pollution abatement, technological innovation, industrial growth and increase of production, improved food production, and research and development.

In harvesting algae, various chemicals have been used to concentrate algal cells efficiently and economically through the process of flocculation. Alum has been found a most economic flocculant which can be recovered simultaneously from the algae for re-use in the process (Fig. 1).

Subsequent to the pioneering work on the treatment of wastes by algae in oxidation ponds (done by W.J. Oswald at the University of California), modified versions of the system have been into operation in Czechoslovakia, the Federal Republic of Germany, Israel, Japan, Thailand and the Union of Soviet Socialist Republics.

In this connection, the parameters and mechanics of microbiological solutions to the problems of conversion of large quantities of waste arising from natural products in the regions of Southeast Asia were dealt with in the year of the UN Conference on the Human Environment at a UNESCO/ICRO training course at Kuala Lumpur, Malaysia.

Photosynthetic bacteria. In addition to the use of algal-oxidation ponds, attention has recently been given to the deployment of photosynthetic bacteria for decontaminating a wide variety of wastes (Table 2). The process is based on the cycle of successive populations of micro-organisms in a given ecological niche, and, already wastes from livestock houses and chemical factories have been successfully treated (12). Recently, a pilot-plant was described in detail for the purification of organic waste water (Fig. 2).

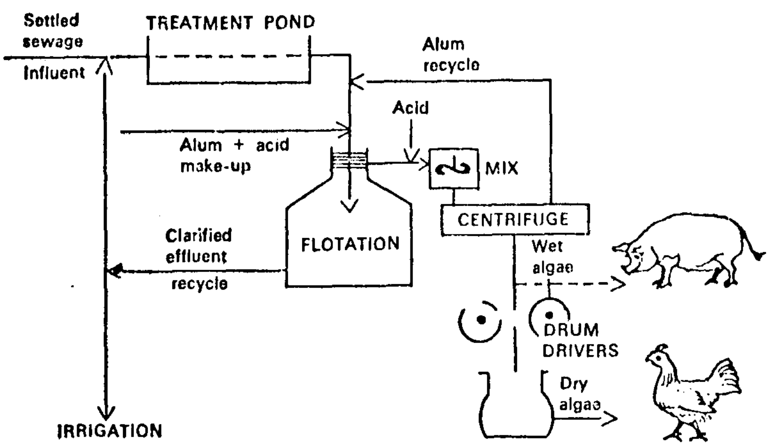

Fig. 1. Process flow diagram showing algal protein production and recycling for the recovery of alum (after M. McGarry, 'Algae Recovery from Wastewater Treatment Ponds: Unit Process Development', in: W. Stanton (ed.), ***Selected Papers from the Unesco/ICRO Work Study,*** **Kuala Lumpur, Ministry of Education, 1972**

Table 2. Waste materials successfully purified by photosynthetic bacteria (12)

Various kinds of microbial industry (beer, antibiotics, amino acids, nucleic acids, etc. fermentations)

Various kinds of chemical synthesising industry (synthetic fibers, synthetic resins, chemical fertilisers, chemicals, etc.)

Various kinds of food industry (canned food, bottled food, cakes, *miso, tofu,* bean cake, etc.)

Petroleum industry

Starch and wool industry

Others: activated sludge, excrement, other organic materials

Table 3. The acid and methane phases of anaerobic fermentation (see footnote page 1)

Phase	Substrates	Organic catalysts	End-products
1	Fats, protein and polymeric carbohydrates	Non-methanogenic bacteria[1]	Acetic and formic acids
2	Acetic acid, formate, H_2 and CO_2	Methanogenic bacteria[2]	Methane and CO_2

1. Mixture of proteolytic (*clostidium* sp.), lipolytic (e.g. *Micrococcus* sp.), cellulolytic (such as *Cellulomonas* sp.), micro-organisms and sulphato reducers (*Desulfovibrio desulfuticans).*
2. The methanogenic bacteria include *Methanobacterium ruminatium, Methanosarcina barkerii, Methanobacterium formicicum* and *Alethanospirillum* sp.

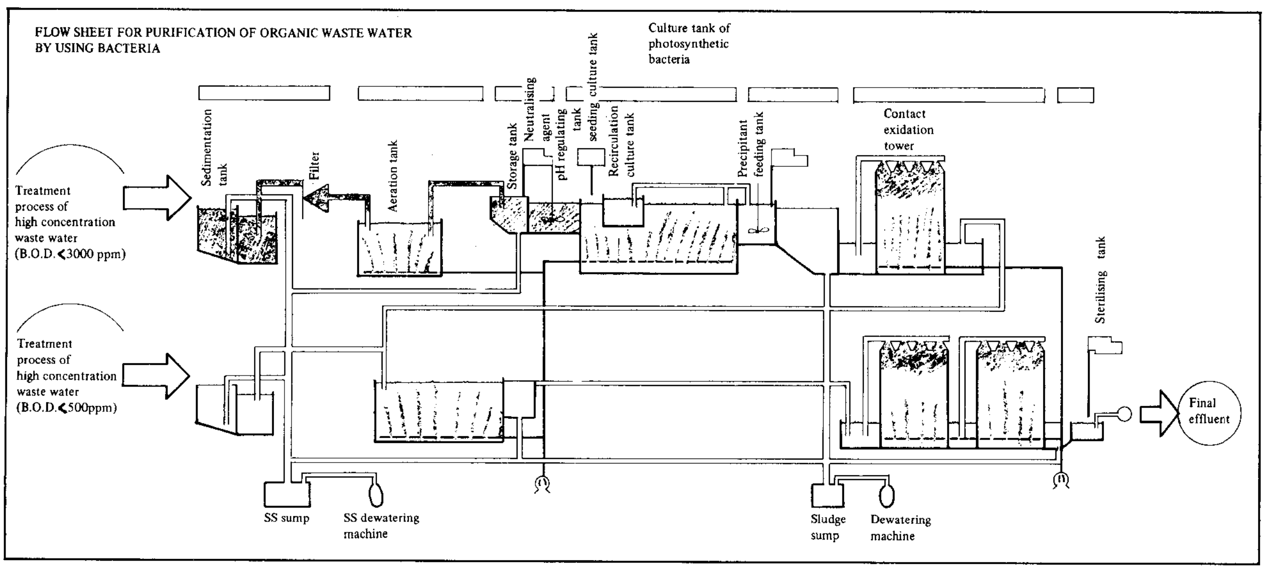

Fig. 2. Flow-sheet: Purification of organic waste-water by photosynthetic bacteria – from: Utilization and Disposal of Wastes by photosynthetic bacteria – paper presented at the Seminar on 'Microbial Energy Conversion' at Gottingen, F.R.G. 4 - 8 October, 1976 (see also 13).

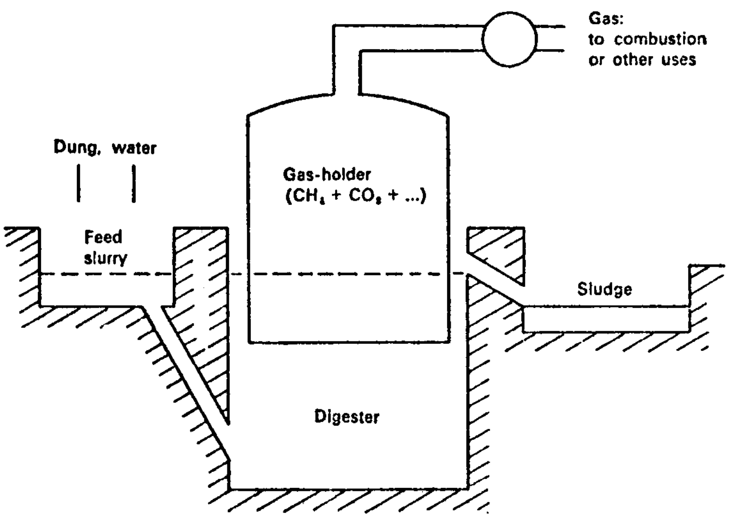

Fig. 3. Cross-section of a 'gobar-gas' plant used for obtaining methane and fertiliser sludge from dung by anaerobic fermentation (14)

Methane fermentation. The utilisation of microbial activity to treat industrial, agricultural and domestic wastes is now common practice since more than half a century; treatment processes include both the aerobic activated sludge process, and the anaerobic or methane fermentation process. In the air-dependent process, organic pollutant material is converted into microbial biomass with the formation of carbon-dioxide and minerals; in the second, airless process, both methane and carbon-dioxide are formed. Among these conventional treatment processes, methane fermentation is the only one that constitutes utilisation of waste as a valuable material.

With renewed interest, methane economy is a direct result of the energy crisis which began in 1973. The use of methane in the past was often limited by economic considerations: other types of energy being more readily available and cheaper than methane. Today, bio-gas plants are of great importance to developing countries, especially because of the rich supplies of low-cost fermentable wastes and other materials that traditional agrarian practices yield. Bio-gas technology is a sufficiently important producer of energy as to have commanded the attention of the twelfth session of the regional group for Asia and the Pacific of the UN's Advisory Committee on the Application of Science and Technology (ACAST) at Bangkok (Thailand), the group pointed out the significance of gio-gas production to the Committee on Natural Resources of the UN's Economic and Social Commission for Asia and the Pacific.

It is estimated that, in India alone, total farm wastes amount to 2,000 million tonnes a year, 50 per cent of which is cattle dung or *gobar.* Other components of the farm refuse are poultry wastes, saw-dust, molasses, cane residue or bagasse, and the rejects and wastes developed by the food processing, dairy, fermentation and pulp industries. Other countries having a similar pattern of wastes include Pakistan, Nepal and Indonesia.

A bio-gas, or gobar-gas, plant consists of two main components: a digester and a gas holder (Fig. 3). Fermentation of dung and other wastes occurs in the digester, producing methane gas (between 50 and 80 per cent of the digester's output), carbon dioxide, hydrogen sulphide and ammonia. The gas holder serves both to collect the gas mixture and to provide the conditions required for anaerobic fermentation which consists of an acid and a methane phase. After dewatering, the residual sludge constitutes valuable fertiliser.

In the acid phase of the process, bacterial activity converts complex polymeric organic molecules into simple organic acids (such as acetic and formic) leading to the methane phase. In the second phase, methaogenic bacteria transform the asetic and formic acids into methane (CH_4) and other gases. The process is shown schematically in Table 3.

The reduction of imports and the expansion of exports that could be achieved by using biodegradable agricultural wastes is of the utmost importance to the economic development of industrializing countries. In India 40 per cent of the country's total consumption of fertilizer (approximately 3 million tonnes) was imported at a cost of Rs 135 crores (the equivalent of US $ 1.8 million). The currently phenomenally high prices of synthetic fertiliser shows no signs of diminishing, so dewatered sludge acquired in the fermentation process – the spent product of digestion, rich in nitrogen, phosporus and potassium – can effectively aid to reduce the importance of naphtha-based (i.e. petroleum-based) fertiliser.

A study (14) in India, has shown that in a village of 250 inhabitants living in 100 dwellings and possessing 250 head of cattle, a relatively low bio-gas yield of 3 cubic feet per pound of dry dung can provide daily energy of 667.5 kWh at a generating cost of about 5 paise (US $ 0.60) per kWh. This output exceeds the 500 kWh per day currently being consumed in a village of this size, energy which is procured from commercial as well as non-commercial sources.The bio-gas energy output of such a community is sufficient for ten pump sets (consuming 200 kWh per day), five manufactories (50 kWh), one light in every house (67.5 kWh per day), energy for cooking in each dwelling (200kWh), and 150 kWh for various other purposes. The bio-gas plants should produce, in addition, roughly 295 tonnes of organic manure annually which corresponds to some 4.4 tonnes of nitrogen – from which a mineral yield of food grain should equal about 22 tonnes. 'Further, fertiliser from bio-gas plants appears to have several advantages over production from large-scale, coal-based plants from the points of view of saving capital and the generation of employment.'

The Khadi and Village Industries Commission of India has officially promoted a bio-gas project, and already 15,000 plants have been installed in several states. There exists approximately 29,000 of these units in the Republic of Korea alone, according to the UN's Economic and Social Council.

INTEGRATION OF VARIOUS MICROBIAL METHODS

The concept of integrating bio-gas plants into a synbiotic unit with aquaculture, agriculture and small-scale industries is an ideal example of how low-cost, appropriate technology can be of great benefit to developing countries as it helps

i. – eradicate potential health hazards
ii. – maximise food production
iii. – minimise manufactured energy inputs, and
iv. – optimise environmental equilibrium

The already successful cattle-fuel-compost-fodder and pig-fuel-algae-fish-crops yield cyclic projects developed in India and the Fiji Islands could serve, furthermore, as useful prototype models in order to streamline, even more, certain rural farming systems (see Fig. 4.).

In 1972, the quantity of hog and poultry feed imported into Belize (formerly British Honduras) came to 2,178 tonnes, costing £144/tonne on the average. The citrus industry in this country produces, on the other hand, about 2,300 tonnes per acre of waste; some of this is used as cattle feed, but most of it is dumped and causes environmental pollution. If the waste material were used as a substrate for fermentation in a 'village technology' plant it would be possible to make hog and poultry feed at somewhere between £80 and £100 per tonne. A cycle of cattle growth and feed production integrated with the growth of algae derived from the conversion of wastes is depicted in Fig. 5.

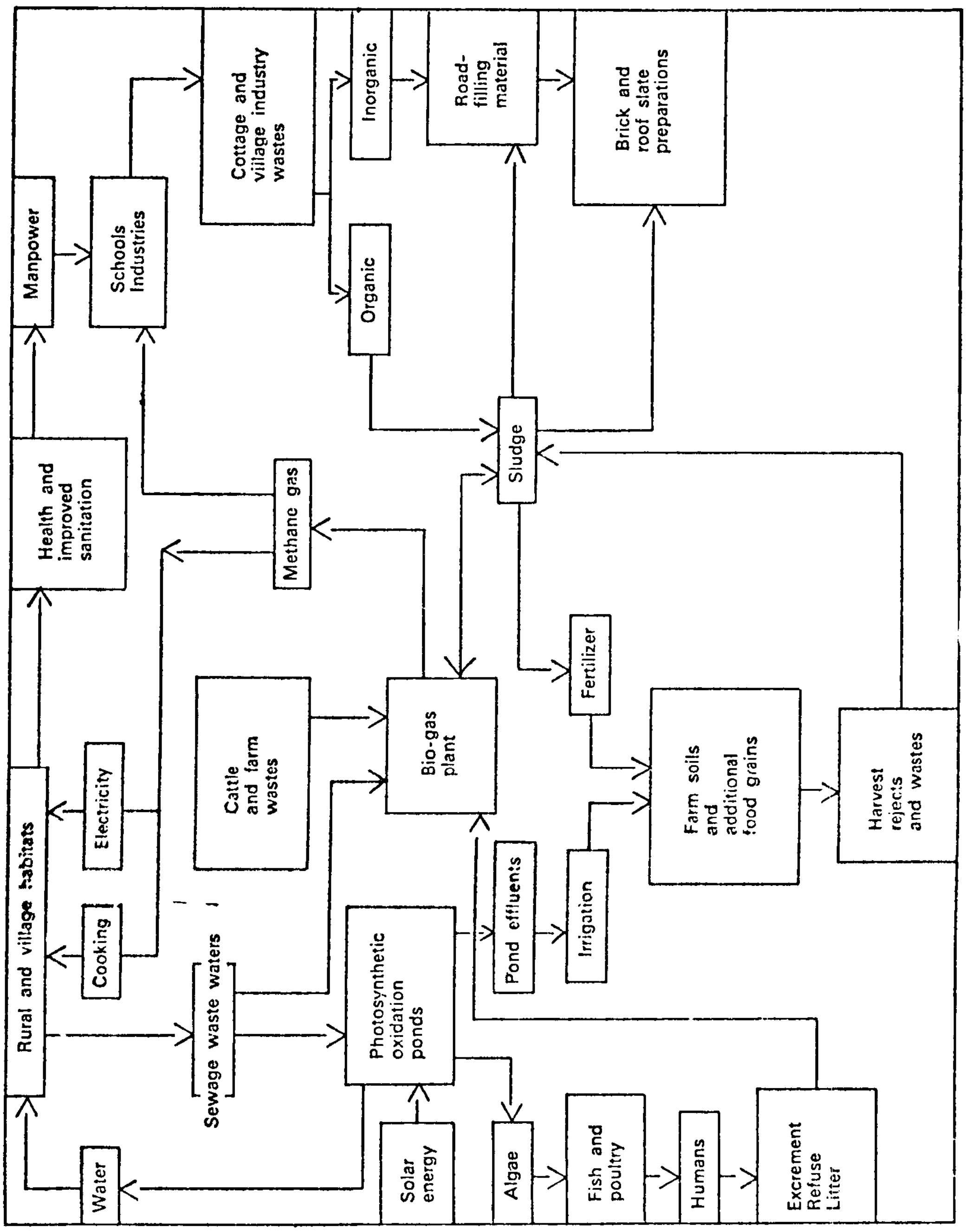

Fig. 4. Interactive loop of rural or village farming system based on bio-gas or methane economy. (see also footnote page 1)

Thus, apart from cash and other material returns accruing to villagers and other rural settlements on the modest capital they have invested, other relevant benefits to the community as a whole include sanitary waste disposal, improved public health, conservation of energy and other natural resources, pollution control, improved crop yields, and savings on foreign exchange.

MANPOWER TRAINING

Since most technology in the developing countries is linked to socio-economic development, decision-makers in these lands should be alert to the potential benefits of applied microbiology. Educational workshops and manpower training programmes can provide for this understanding and the United Nations Environment Programmes (UNEP) and UNESCO have taken the initiative in this direction. In co-operation with the International Cell Research Organisation (ICRO) training courses have been organised in Egypt, Indonesia, India, Mexico, Malaysia, and the Philippines (Table 4).

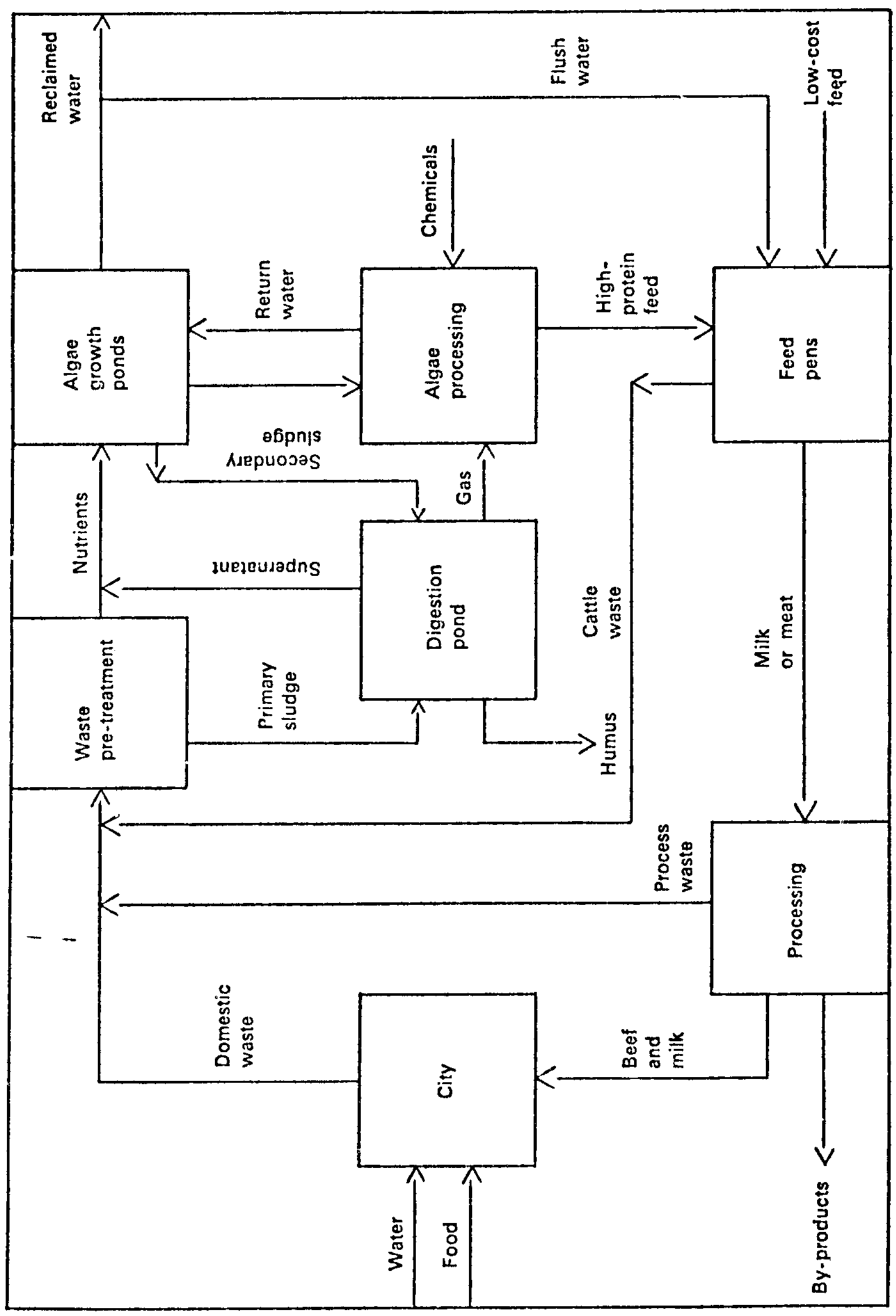

Fig. 5. Cycle of cattle growth integrated with production of waste-grown algae (see footnote page 1)

In these courses, emphasis is laid on the application of basic techniques to indigenous resources. For example in the UNEP/UNESCO/ICRO course at Bandung, Indonesia, the participants working closely together with top-level scientists discussed and experimented with ways to convert wastes into traditional fermented foods eaten in the Southeastern region (Tables 5 and 6). The courses also serve to acquaint scientists in government, industry and university with the microbiological techniques developed for the conversion of low-value waste fractions of both renewable and non-renewable resources into valuable products; – techniques that increase the scope, the hygenic safety and the efficiency of the natural products industries. They also contribute to the ecological improvement of the biosphere by eliminating vast amounts of waste that otherwise would have caused serious pollution problems.

Table 4. Waste Conversion and Environmental Management by Micro-organisms – UNEP/UNESCO/ICRO Course guidelines for Laboratory bench-work exercises and lectures

Course Site	Title and Synopsis
Kuala Lumpur, Malaysia (UNESCO/ICRO Work-Study) 1972	**Waste Recovery by Micro-organisms** – Fermented Foods from Waste Products – Recycling of animal and fish processing wastes into feed supplements – Mushroom production on waste rubber effluents – Disposal of agricultural wastes through composting – Waste recovery through algal treatment systems
Bangkok, Thailand 1976	**Microbial Protein Production from Natural and Waste Products** – Unconventional carbon and energy sources for SCP production – Production of traditional fermented foods – SCP production using whey waste – Mass production of algae on sewage – a process yielding reclaimed water and proteinaceous biomass – Nutritional value of algae
Jogjakarta, Indonesia 1976	**Practical Aspects of Soil and Environmental Microbiology** – Microbial conversion of wastes into mushrooms – Application of principles of microbial physiology to environmental management – Bio-gas production – Composting of garbage
Mexico City, Mexico 1976	**Algal Physiology and Biochemistry in Environmental Management** – Role of algae in photosynthetic oxidation ponds – Utilisation of micro and macroscopic algae for feed, fodder and fertiliser production – Capture of solar energy for microbial conversion of agricultural waste hydrolysates
Cairo, A.R.E. 1976	**Fundamental Research of Microbial Biomass Production with relation to the Environment** – Waste Utilization – Recent trends of SCP production from wastes – Biotechnology of soil innoculant production – Biotechnology of Biomass production
Manila, Phlippines 1976	**Role of Microbiology in the Managemetn and control of the Environment** – Utilization of microbes as indices of pollution – Microbal contributions to the biogeochemical cyclic budgets of carbon, oxygen, nitrogen and sulphur – Composting and production of mushrooms – Micro-organisms as agents of pollution abatement

Table 5. **Some details on Laboratory bench-work exercises conducted at the UNEP/UNESCO/ICRO Training Course on** *'Conservation and Use of Microorganisms for Waste Recovery and Local Fermentation in Southeast Asia'* **at Bandung, Indonesia, 1974**

Exercise Title	Substrate	Microorganisms used	Remarks
Korean khimochi fermentation	cabbage	*ex.* fermented fish and cabbage	Traditional fermented food
Yeast production	molasses	*Saccharomyces cerevisiae*	SCP production
Winogradsky column	pond waters, straw wastes or shredded paper	aerobic organisms, anaerobic photosynthetic bacteria; sulphur and non-sulphur bacteria	study example of cycle of of successive populations of microorganisms for use in microbial conversion systems
Shoyu fermentation	spent soybean, soybean-wheat-brine mix	*Aspergillus oryzae*	Traditional fermented food
Fish sauce fermentation	fish remains	lactic acid bacteria	Traditional fermented food
Tapioca-chicken manure fermentation	Tapioca chips chicken manure	*Rhizopus* sp.	Animal feed
Algal protein production	Rubber factory effluents	*Chlorella* sp.	SCP (animal feed)

Table 6. **Types of Indonesian Fermented Foods Produced from Waste Products (UNESCO/ICRO Work-study, Kuala Lumpur, 1972)**

Product	Raw Material used	Microorganism used
Ontjom	Peanut Presscake	*Neurospora sitophila*
Tempe bongkrek	Coconut Presscake	*Rhizopus* species
Tempe mata kedele	Hypocotyl of soybean seed	*Rhyzopus* species
Ontjom tahu	Solid waste of tahu processing	*Neurospora sitophila*

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A New Look at Crop Residue Management in the United States

by J.F. Parr & R.I. Papendick

A NEW LOOK AT CROP RESIDUE

MANAGEMENT IN THE UNITED STATES

J. F. Parr and R. I. Papendick 1/

On December 1, 1976, at the annual meetings of the American Society of Agronomy in Houston, Texas, a one-day symposium was held on "Crop Residue Management for Resource Conservation, Soil Productivity, and Environmental Protection." The objective of the symposium was to reevaluate various aspects of crop residue management in light of current trends toward minimum tillage and no-tillage cropping systems for soil, water, and energy conservation. The Proceedings will be published by the American Society of Agronomy and be available late in 1977. A total of 14 papers were presented during two consecutive half-day sessions.

SESSION I. CROP RESIDUE MANAGEMENT: EFFECT ON SOILS

(1) "Residues for Resource Conservation, Soil Productivity, and Environmental Protection." W. E. Larson, R. F. Holt, and C. W. Carlson, USDA, Agricultural Research Service.

(2) "Crop Residue Requirements for Controlling Wind Erosion." E. L. Skidmore and F. H. Siddoway, USDA, Agricultural Research Service.

(3) "Crop Residue Requirements for Control of Water Erosion." W. A. Hayes and L. W. Kimberlin, USDA, Soil Conservation Service.

(4) "Effect of Residue Management Practices on the Soil Physical Environment, Microclimate, and Plant Growth." D. M. Van Doren and R. R. Allmaras, Ohio Agricultural Research and Development Center and USDA, Agricultural Research Service.

(5) "Effect of Crop Residues on the Soil Chemical Environment and Nutrient Availability." J. F. Power and J. O. Legg, USDA, Agricultural Research Service.

1/ Chief, Biological Waste Management and Soil Nitrogen Laboratory, Beltsville, Maryland, and Research Leader for Land Management and Water Conservation, Pullman, Washington. The authors are affiliated with the Agricultural Research Service of the U.S. Department of Agriculture.

(6) "Factors Affecting the Decomposition of Crop Residues by Microorganisms." J. F. Parr and R. I. Papendick, USDA, Agricultural Research Service.

(7) "Phytotoxicity Associated with Residue Management." L. F. Elliott, T. M. McCalla, and A. Waiss, USDA, Agricultural Research Service.

SESSION II. CROP RESIDUE MANAGEMENT: PLANT DISEASES, WEEDS, PESTS, AND CROPPING SYSTEMS AND MANAGEMENT

(8) "Relationship of Crop Residues to Plant Disease." R. J. Cook, M. G. Boosalis, and B. Doupnik, USDA, Agricultural Research Service, and University of Nebraska.

(9) "Weed Control Problems Associated with Crop Residue Management Systems." J. L. Williams and G. A. Wicks, Purdue University and University of Nebraska.

(10) "Effect of Crop Residues on Pest Problems in Reduced Tillage Systems of Corn Production." G. J. Musick and L. Beasley, University of Georgia and University of Illinois.

(11) "Crop Residue Management in Crop Rotation and Multiple Cropping Systems." G. B. Triplett and J. V. Mannering, Ohio Agricultural Research and Development Center and Purdue University.

(12) "Crop Selection for Specific Residue Management Systems." W. E. Kronstad, M. L. Swearingin, and C. O. Qualset, Oregon State University, Purdue University, and University of California.

(13) "Alternate Uses of Excess Crop Residues." E. Epstein, J. E. Alpert, and C. C. Calvert, USDA, Agricultural Research Service and Energy Resources Company, Inc.

(14) "Machinery Selection in Residue Management Systems." J. C. Siemens and W. C. Burrows, University of Illinois and John Deere & Company.

The following is a brief summary of pertinent points of discussion during the course of the symposium.

a. The development of more efficient and effective residue management systems in the United States for the conservation of soil and water resources is a matter of utmost importance. Some regions in the United States produce an abundance of crop residues, far in excess of that required to control erosion and maintain good soil tilth. However, in some regions, particularly in the lower rainfall areas, with droughty soils, and with some crops, insufficient amounts of residues are produced for adequate soil protection. Crop residues are highly essential in most areas for protecting agricultural soils from erosion and loss of plant nutrients. Where limited quantities exist careful management methods must be devised to achieve maximum effectiveness of residues for conservation purposes.

b. Where crop residues are produced in excessive amounts they tend to accumulate because of slow rates of decomposition, causing difficulties with tillage and planting. Often excess residues are burned causing air pollution and other environmental problems resulting from lack of soil protection. Certainly, much of these residues could be removed for utilization as livestock feed, fuel, fiber, chemicals, and the production of single cell protein.

c. In consideration of the removal of excess residues for alternate uses, the strong consensus of this symposium was that we must think in terms of <u>partial</u> removal of residues rather than <u>total</u> removal. There was considerable concern expressed regarding certain estimates of the amounts of crop residues that are "available" for alternate uses. Some of these estimates are based on <u>total</u> removal of residues at harvest which is most unrealistic since a portion of the residue must remain on the land for erosion control and maintenance of soil productivity.

d. It was unanimously agreed that agricultural research must be directed, with utmost urgency and with high priority, to evaluate how much crop residue is actually needed to protect the soil from erosion and to maintain its tilth and productivity. The amount required would depend on the type of tillage and cropping practice, as well as the soil, topographic, and climatic conditions. With this information we could then determine where crop residues are being produced in excess and make realistic estimates on how much of a particular residue could be removed for utilization as food, feed, fuel and fiber. Unfortunately, we do not yet have this information in sufficient detail. Currently the Agricultural Research Service of the USDA is directing considerable research effort toward this question.

e. The symposium recognized that the design of effective crop residue management systems depends on a thorough understanding of the factors affecting the decomposition of these residues by microorganisms. These would include the effects of soil physical and chemical properties, the chemical composition and physical properties of the residues, the role of soil microorganisms in the decomposition process compared with the microflora indigenous to the residues, climatic factors, and the method of residue application to soil, i.e., whether it is surface-applied, plowed-under, or mixed with the soil. With this knowledge it should be possible to devise methods to advantageously alter the decomposition rates of crop residues, either increasing or decreasing their period of effectiveness in soil, to enhance soil productivity, to provide environmental protection, and to control plant diseases and insect or non-insect pests.

f. Reduced or minimum tillage systems tend to leave much of the crop residue at the soil surface, compared with conventional tillage which incorporates the residues in the soil. Most of our knowledge of residue decomposition is based on soil incorporation, while little is known about the interplay of factors (i.e., moisture, temperature, particle size of the residue, chemical composition of the residue, carbon: nitrogen ratio, and the indigenous microflora of the residue) which govern the rate and extent of residue decomposition at the soil surface. Research is needed for a thorough evaluation of residue decomposition under conditions of reduced or minimum tillage.

g. Control of the soil water regime both in soil and at the soil surface offers perhaps the greatest opportunity for controlling the rate of decomposition of crop residues. Research was discussed on such aspects as control of evaporation, control of soil wetting properties, use of plant species which transpire excessively and those that transpire comparatively less, use of deep-rooted or shallow-rooted crops, varying plant population and row spacing, and new and improved methods of drainage and tillage. Thus, the rate of residue decomposition might be controlled to greater advantage, i.e., accelerating the decomposition or excess residues (until such time that capital investments can facilitate collecton, transport, storage, and processing of residues for alternate uses), and on the other hand, slowing the decomposition of residues in short supply, thereby extending their period of effectiveness for soil protection.

h. Excess surface residue from high-yielding wheat varieties in the United States has caused phytotoxic or allelopathic effects on both fall and spring wheat planted under minimum tillage or no-tillage conditions. Severe stand reduction and depressed yields often result. Research is needed to determine the nature of these phytotoxic constituents, when and how they arise (including what microorganisms are involved), and something about their persistence in soil. With proper residue management systems we may be able to eliminate or minimize the adverse effects of these compounds.

i. To control phytotoxic effects it may be necessary to breed and select new crop varieties specifically for minimum tillage systems. For example, in the Pacific Northwest of the United States (the Palouse area of Washington State) wheat varieties currently grown were selected under conditions of clean tillage. When these varieties are grown under minimum tillage systems with heavy surface residues they grow poorly, resulting in stand reduction and decreased yields. Research is now in progress to develop varieties for the same type of environment in which they will be grown when released to the farmer. Through crop breeding it may also be possible to vary the chemical composition of the crop residue, e.g. increasing or decreasing the lignin, cellulose, and nitrogen content so that residue decomposition rates might be increased or decreased according to intended objectives.

j. As minimum tillage systems are implemented it was recognized that we must actively monitor plant diseases, insect, and rodent infestations. The same concern was expressed insofar as weed control problems that might be associated with the management of residues in minimum tillage systems. A considerable amount of ongoing research was presented during the symposium that was directed toward plant disease and weed control problems that might be anticipated in non-conventional tillage systems.

k. Crop residues are an important sink for the immobilization and subsequent mineralization of plant nutrients. The plant availability of nutrients (nitrogen, phosphorus, potassium) immobilized in residues is regulated largely by such factors as soil water, temperature, soil properties, and by soil and crop management practices. For nitrogen, the activity of soil microorganisms is usually of prime concern in determining the cycling and potential availability from residues; for phosphorus, both microbial activity and soil mineralogy are involved; and for potassium, mineralogy and soil water movement are important parameters. Soil and crop residue management practices, especially fertilization practices and the amount of residue remaining after harvest, will determine the extent of cycling and plant availability of nutrients from residues. Here again, more is known about conventional tillage systems. A shift toward reduced and minimum tillage systems will necessitate research to determine the rate of recycling and plant nutrient availability under these conditions.

1. Effective utilization of crop residues under systems of reduced tillage will depend upon the development of tillage and harvesting machinery to achieve desired objectives. For example, it may be desirable, in some cases, to leave a predetermined amount of the residue at the soil surface, while incorporating or mixing the remainder into the soil. Proper design of machinery is needed to shred or chop residues to the desired degree of dissection and to distribute them more uniformly upon the soil surface to ensure environmental protection with a smaller amount of residue. This, in turn, would allow removal of greater amounts of residues for alternate uses as food, feed, fuel, and fiber.

CONCLUSIONS

The recent symposium on crop residue management in the United States sponsored by the American Society of Agronomy reviewed pertinent aspects of residue management for resource conservation, soil productivity, and environmental protection. The papers presented considered ways and means for increasing the effective utilization of crop residues for soil, water, and energy conservation. The symposium considered in great detail both current and future research needs to achieve these objectives, and pointed out certain gaps in our knowledge of residue management under conditions of minimum tillage practices which leave greater quantities of residues on the soil surface. The complexity of research on various aspects of residue management (including the factors affecting residue decomposition, effects on soil chemical and physical properties, erosion control, nutrient recycling and plant availability, disease control problems, weed control problems, alternate uses of excess residues, selection of plant varieties for reduced tillage systems, phytotoxic effects of residues, machinery requirements and control of the soil water regime) led to the general conclusion that problems of crop residue management would best be solved by multidisciplinary research teams of scientists working together in a coordinated effort.

Electrodialysis: An Efficient Technique

by SODETEG (Société d'études techniques et d'entreprises générales) France

ELECTRODIALYSIS : AN EFFICIENT TECHNIQUE

by

SODETEG (Société d'études techniques et d'entreprises générales) France

This seminary is of particular importance, being organized under the auspices of the United Nations' program for the environment and the United Nations' program for agriculture and food.

A rapid development of intensive production methods, associated with the conversion, seasonal or not, of large quantities of raw materials mean that the problem of recycling waste matter thus produced becomes increasingly keen.

Processing such waste material, using ecologically acceptable techniques, allows the value of the raw materials used to be increased by recovering an appreciable fraction of the by-products, whilst contributing both to the conservation of resources and protection of the environment.

Numerous processes or techniques have been born out of, or have been adapted to satisfy, this new requirement.

ELECTRODIALYSIS : AN EFFICIENT TECHNIQUE

Electrodialysis is well-known as a purification process for brackish or saline water, used to render it suitable for human or industrial consumption. It also forms an efficient and cost-effective tool for the recovery of a number of liquid by-products. In this guise, it contributes to the protection of the environment since, when used to treat such effluents, it relieves the necessity of rejecting them into water ways.

REMINDER OF BASIC PRINCIPLES

Electrodialysis is an electro-chemical process which allows part or all of the ions contained in a solution to be extracted, whilst retaining all those substances which are not, or are only slightly ionized. It can, therefore, be applied to all purification problems, even those involving « fragile » or « heat-sensitive » liquids.

Figure 1 illustrates the basic operating principle of an electrodialysis unit; two compartments, (1) and (2), are separated by alternately anionic and cationic membranes.

Positive ions migrate towards the cathode, and negative ions to the anode. They cross type C cationic and type A anionic membranes respectively. Ions which are able to cross type C membranes are stopped by type A membranes, and conversely. On this basis, the alternating arrangement of membranes forms ion depletion and ion concentration chambers. Electrodes which allow the electric current to be passed, are fitted at both ends of the unit. The complete unit forms a « filter-press » type structure (figure 2).

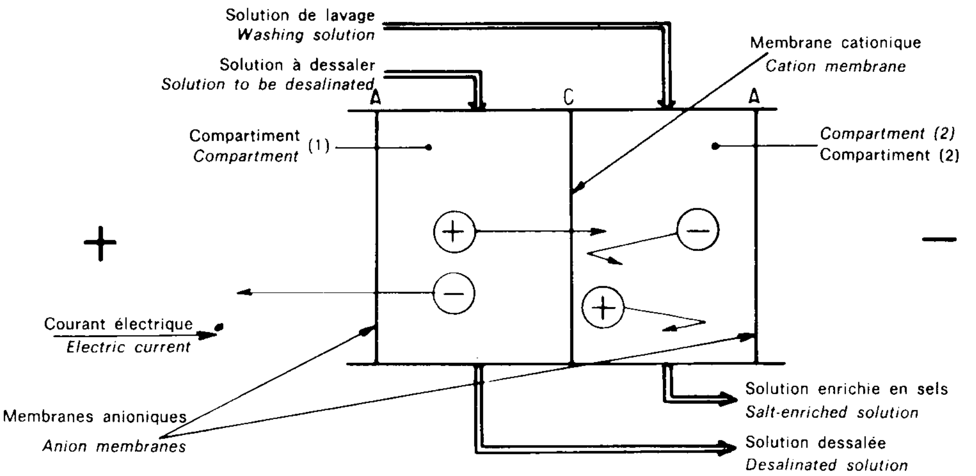


Fig. 1

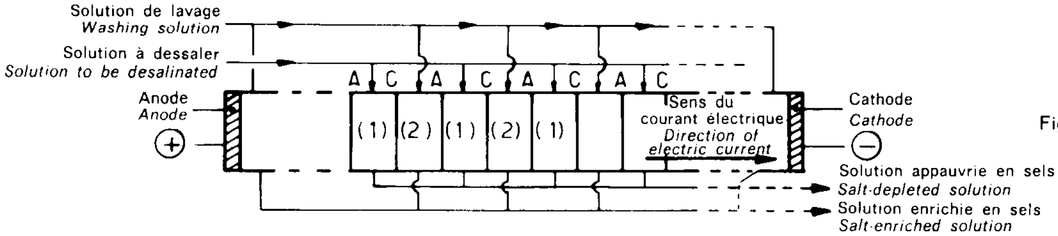


Fig. 2

A single unit may be fitted with several electrodialysis assemblies operating either in series or in parallel.

Among other processes, that studied, developed and marketed by the Société de Recherches Techniques et Industrielles (SRTI)*, under the trade name AQUALYZER®, uses the « high velocity gradient » or « Forced Flow » technique.

This has been found to be particularly suitable for the treatment of agricultural-nutritional solutions, since it encourages ionic extraction whilst reducing the risks of clogging in the cells.

The SRTI* process is noteworthy for :

- a high rate of mineral salt removal,
- low membrane surface area,
- one or two-stage operation,
- a compact technology, and therefore low overall dimensions,
- low consumed electrical power,
- automatic operation,
- high reliability : no clogging, therefore little maintenance
- total suitability for nutritional problems (cleaning in place...)
- reduction of the quantity of effluents and of pollution (low COD and BOD).

A RANGE OF APPLICATIONS :

• *The dairy industry*

The dairy industry is the best current example of the contribution which Electrodialysis can make to the reduction of pollution. The process is used to recover a by-product from this industry : wheys.

By-products from cheese manufacture are wheys having, obviously, a composition which varies dependent upon the manufacturing process. However, they all have a number of common average characteristics which are given in the table below, and to which must be added varying quantities of the following acids :

- lactic acid for cheese and casein wheys,
- hydrochloric acid from hydrochloric casein wheys.

Average composition of wheys (per liter of effluent)

• Lactose	:	45 - 50 g/l
• Protein	:	7 - 9 g/l
• Soluble nitronated matter	:	1.5 g/l
• Fatty matter	;	1 - 2 g/l
• Mineral salts	:	6 - 8 g/l
TOTAL dry matter	:	63 - 70 g/l

Within the category of cheese wheys, two types should be distinguished. They are those which come from cooked cheeses, with a low acidity content : 8 to 12° Dornic (1° Dornic = 100 mg/l of lactic acid) and those coming from soft fermented or cottage cheeses, which have a higher acid content, varying from 20 to 70° Dornic. The former are known as sweet wheys.

For casein wheys, acidity is normally about 45° Dornic.

Wheys were, for a long time, considered as waste products and were normally rejected into the sewage system or rivers, or disposed of by dissipation. *A normal size cheese production plant in France thus threw away 200 t/day of wheys, which contain 12 tons of high nutritional value dry matter.* A statistical report on the USA showed that dairy plants emptied nearly ten million tons of wheys per year into the sewage system. This contains 600 000 tons of dry matter, which corresponds to the pollution created by a town with 2 million inhabitants. The proteins contained in the wheys are sufficient to feed 8 million persons. Moreover, they are proteins originating from milk and of very high nutritional value. The incentive to recover these by-products, with the advantage of protecting the environment, is therefore obvious.

There are two processing possibilities, dependent upon the type of wheys used :

Acid wheys :

These are the most frequently found. Their acid content renders them unsuitable for animal food (except, possibly, for pigs). If they are neutralized by soda or lime, the mineral salt content increases and, again, they are unsuitable for consumption. Moreover, they pose a number of technical problems : corrosion of atomizing towers, clogging, hygroscopicity and mass increase. It is, therefore, essential to reduce their acid and mineral contents to a level at least equal to those found in sweet wheys.

Electrodialysis is particularly suitable for this type of mixed demineralization and deacidification process in order, for example, to standardize a production process and avoid rejecting such waste material into the sewage system.

Sweet wheys :

A powder can be manufactured which replaces part of the milk powder contained in fodder for veal calves. Only 6 to 8 % can be substituted, since whey powder contains less protein than milk.

The final demineralized and de-acidified product may either be obtained cold (10° C) or hot (40° C < + < 50° C) from raw effluent (60 g/l) or after a preconcentration treatment (180 g/l maximum).

Demineralization rate %	Total dry matter in g/l	Ash content as % of dry matter	Acidity in °D	De-acidification rate %
Raw whey	56.34	9.23	14	
57.7	52.66	4.18	10	28.6
77.5	51.42	2.30	7	50.0
88.1	51.20	1.21	6	57.1
90.6	50.68	0.99	5.5	60.7

- ***Sugar industry :***

Electrodialysis may be used for partial demineralization of the second crop syrups, in order to produce more white sugar.

- ***Other agriculture-industrial applications :***

- Processing of gels for standardization :
  of Ca^{++} and SO_4^{--} ions
  of PH values
  of conductivity
- De-acidification of pectines.
- Partial demineralization and standardization of the PH value of vegetal protein basic hydrolysats.

- ***Drinking water***

The use of electrodialysis for treatment of brackish or high magnesium content water, which have a high salt content, to render them suitable for consumption or industrial use, is widespread.

RUNNING COST OF A SWEET WHEY TREATMENT WITH SRTI*AQUALYZER

AQUALYZER®		S P F 2.35 L 50 × 50		
PROCESSING CONDITIONS		18 % D.M. - 40 to 45° C	50 % demin.	90 % demin.
CAPACITY AT 6 % DRY MATTER - FLOWS			340 000 1/22 h/d	90 000 1/22 h/d
OPERATING COSTS	ALLOWANCE FOR : Membranes Electrodes } Miscellaneous items }	140 000 F / 3 years 23 000 F / year	0.77 cts/kg 0.38 cts/kg	2.95 cts/kg 1.45 cts/kg
OPERATING COSTS	Electrical power	47 kW × 22/h × 0.12 F/kWh	0.56 cts/kg	2.15 cts/kg
OPERATING COSTS	Chemical compound { HCL / NaOH	120 kg/day at 0.25 F/kg 3 kg/day at 0.60 F/kg	0.17 cts/kg	0.51 cts/kg
OPERATING COSTS	Manpower (stabilized operation)	4 h/day at 15 F /h	0.43 cts	1.66 cts/kg
TOTAL per kilogram of whey powder			2.31 cts/kg	8.72 cts/kg

Based on : operating period 22 h/24 h 330 days/year (continuous operation)
Indicated price : December 1976 conditions, 1 FF = 100 centimes (cts).

The electrodialysis process used to treat liquid effluents from the agricultural-food industries has proved to be a highly efficient process, simple to operate and of low cost.

Handling of Wastes in the Food Industry

by The National Swedish Environmental Protection Board

THE NATIONAL SWEDISH ENVIRONMENT
PROTECTION BOARD

Handling of wastes in the food industry

A total of approximately 7 million tons of domestic raw materials are annually processed in the Swedish food industry. The residual products amount to approximately 3.2 million tons per year and have a dry matter content of approximately 0.5 million tons. An amount of about 90% of the residual products is utilized at present for various purposes. In some cases the residual products can be used as animal feed directly or after slight treatment. In these cases, utilization may yield a certain economic gain. Examples are molasses, beet pulp, etc. In other cases, however, utilization is an unprofitable business. For example, dealing with the whey from dairies adds to the cost of cheese manufacture by about 30 öre per kilogram of manufactured cheese.

Techniques are available for dealing with the wastes which are not utilized at present. The problem is that the waste-handling costs often exceed the value of the products obtained on recovery.

Thus, the need exists for technical solutions enabling utilization to be rationalized and its cost reduced. The areas needing special study are cheaper separation techniques and techniques for recovering valuable constituents from wastes.

Waste water (40-50 million m^3/year) contains considerable amounts of potentially valuable substances which it should be possible to utilize, instead of allowing them to burden purification plants and recipients.

A very small proportion of by-products is used for producing foodstuffs. By far the greater part is used, directly or after some processing, in the production of animal feeds (Enclosure 1). The waste may contain valuable nutrient substances, such as proteins, carbohydrates and fats (Enclosure 2). Provided that the protein composition is in line with man's requirements, the protein in the waste should be able to meet the protein needs of approximately 2.7 million human beings. The carbohydrates and fats would suffice for the needs of approximately 1.2 million people.

Several factors influence the total quantity of waste and by-products in the food manufacturing industry. Increased processing usually results in increased waste. On the other hand, large industrial units are better able to develop or use modern processes which result in less wastage. Rising feed prices make waste more interesting from the economic angle.

Many waste products contain nutrient-rich components which ought to be suitable for inclusion in animal feed. The reason why these constituents have not hitherto been utilized has been the lack of manufacturing processes capable of rendering the waste suitable for further processing. However, processes are available at present which enable most kinds of waste to be utilized. The reasons why certain wastes are not utilized today are the high energy costs involved and the lack of marketing possibilities.

Moreover, hygienic restrictions demand high-quality water and this requirement counteracts waste recovery. It is thus very important to develop processes which use water sparingly rather than those where water is made to recirculate.

The waste water arising from food handling is most often purified by conventional water-purification techniques. However, the flow of waste water varies greatly both with the time of year and with the time of day, thus making optimal use of the purification plants difficult.

The basic problem which must be solved in the utilization of many troublesome wastes is the feasibility of concentrating and/or separating valuable material from that which is useless. Dehydration of solid waste can be effected by any of several methods — thermal or chemical, for example. However, dehydration costs are high. Modern methods, such as reverse osmosis, ultrafiltration, ion exchange, electrodialysis, gel filtration, etc. are potentially capable of solving many difficult dehydration and separation problems.

To recapitulate, wastes contain considerable quantities of nutrient substances. Techniques for the recovery of by-products and for their preparation in a pure state have been substantially developed, but they are costly. The same by-products can often be prepared more cheaply from other raw materials. Besides, it is important that the products be considered acceptable for inclusion in animal feed or in foodstuffs.

Wastes can also be utilized for methane production. The profitability or otherwise of such utilization is linked, among other things, with energy prices and plant size. Such methods can, in the long run, be important as alternatives for certain types of wastes. However, further R & D is required in this field.

The following account lists the measures instituted by the Swedish food industry to make waste recovery possible.

The dairy industry

The biggest problem in the dairy industry is the whey obtained as by-product in cheese manufacture. Swedish environmental protection legislation prohibits the release of whey into water purification plants. A total of approximately 540,000 tons of whey, having a dry matter content of ca. 5.4% and a biochemical oxygen demand of ca. 40,000 mg BOD_5/l, is produced annually in Sweden. About 70% of the whey is used as raw material for the production of lactose, whey products and whey powder; ca. 30% is used directly as animal feed.

The wash water obtained in butter production contains a high proportion of organic matter measured as BOD_5. Taking care of the first batch of wash water is therefore a compulsory requirement. The protein and fat content of the wash water is utilized for animal feed. This can be done in either of two ways — by adjusting the pH and heating, and subsequently separating off the coagulated protein and fat in a self-cleaning separator, or by the environmentally superior method of evaporation. The concentrate is mixed with buttermilk and used as animal feed.

The borderline products obtained in rinsing dairy equipment prior to scrubbing are utilized in large dairies.

In recent years, the methods of reverse osmosis, electrodialysis and gel filtration have been used in Sweden, as in other countries, for the treatment of whey. In Sweden there is at present one dairy employing electrodialysis of whey and another employing gel filtration and dialysis. The results obtained at both these dairies have been favourable. A proviso from the environmental standpoint is, however, that the dilute aqueous solutions formed should be taken care of. The proteins obtained by these methods are of a quality which makes them fit for human consumption.

The meat industry

A series of by-products and wastes are obtained in the meat industry which, except for the stomach and gut contents, are mainly used for animal feed. It would, however, be of interest to investigate other applications which could make better use of the valuable constituents of the products.

Modern slaughtering techniques, which are now beginning to be introduced, increase the possibilities for effective collection of slaughterhouse wastes. Fat is separated off during slaughter and is processed to edible fat in rendering plants. Blood is collected by means of a special bleeding knife and is used for human consumption. The greater part of the blood drip is collected via a bleeding chute. The amount of blood reaching the waste water depends on the duration of use of the knife and the time of stay of the carcass over the bleeding chute. The blood drip is treated in a converter or the equivalent for conversion to fe[illegible]

Blood, bones, soft carcass parts and naturally dead animals, etc. are treated in converters. The yield of fat and fodder meal depends on the raw material composition. Yields of fat and meat meal in the ranges of 12-18% and 22-30% respectively may be expected, calculated on the weight of raw material.

If a slaughterhouse is situated next to a conversion plant, the waste water from the slaughterhouse can be treated with lignosulphates and the precipitated sludge led to the conversion plant for processing. This method — the Alvatech method — is a Norwegian patent.

Dung and gut cullage are collected in dung silos for further transport either to refuse dumps or to composting heaps. Handling of these wastes has become an increasingly difficult problem owing to the in[illegible] in slaughterhouse size, the high costs for manure handling in agricul[illegible] and the environmental investments required in manure composting and spreading. Experiments are currently in progress with the aim of recovering energy from dung and gut cullage in the form of methane gas. These experiments have not yet been concluded.

Hog hair is a waste causing great problems. Hydrolysis is necessary for processing hog hair to meat meal. At present there is only one hydrolysis plant in Sweden and its capacity is inadequate. The most common method of dealing with hog hair is to tip it on refuse dumps. This method can, however, give rise to problems.

Poultry slaughterhouses

The by-products and wastes arising in poultry slaughterhouses are of the same type as in the slaughter of large livestock. The method of slaughter consists in stunning the animal and then bleeding it. The blood is collected in a vessel for conversion and meal manufacture. The viscera can be utilized for mink feed or be sent for conversion to destruction plants. A large proportion of the waste is however deposited on refuse dumps, which is unsatisfactory.

Feathers are either tipped on refuse dumps — which creates problems — or are processed to feed via hydrolysis and conversion. However, as mentioned above, there is only one hydrolysis plant in Sweden.

The fruit and vegetable industry

Waste-water treatment in the fruit and vegetable industry poses great problems. If treatment of waste water at reasonable cost and utilization of potential by-products are to be feasible, the amount of water used should be reduced to a minimum. In order to achieve this, dry processes should be aimed at where possible. Water transport should be avoided, for example. If water has to be transported, efforts should be made to recirculate or reuse the transport water for other purposes.

A series of cooking waters are obtained in vegetable processing which contain large amounts of potential raw materials. Examples are beetroot water, blanching waters of peas, carrots, etc. Techniques are lacking at present, however, for working up these potential raw materials.

The peeling of potatoes in processing them to the mashed, French-fried, canned or peeled varieties results in large quantities of pollutants. New peeling methods — dry steam or dry alkali peeling — reduce the amount of water greatly, since the fresh-water supply is minimized. The peel is obtained as a slurry having a 10% dry matter content which can be processed to pigfeed, for example.

A so-called Symba plant for yeast manufacture is available for utilizing the starch-rich waste water obtained from the production of mashed or French-fried potatoes. This process aims at recovering microbial protein by growing microorganisms on starch-containing substrates — in this case, potato water. This plant has an annual production of approximately 1,000-3,000 tons of yeast. The cost of production is about 1.50 kronor per kilogram. Further particulars may be obtained from AB Sorigona, Box 138, S-245 00 Staffanstorp, Sweden (see Enclosure 3).

Other wastes from the fruit and vegetable industry consist mainly of culled raw material or parts thereof. This waste is a valuable material which can be used directly as animal feed.

The potato-starch industry

In Sweden there are six industrial plants manufacturing a total of ca. 55,000 tons of starch per year. A residual liquor is obtained in starch production which contains ca. 80% of raw material from the potato. This protein-containing liquor can be converted by suitable processing to protein fit for human consumption.

A process has been developed by Swedish industry whereby a residual liquor is obtained practically undiluted, making further processing possible. The Swedish industrial plants are currently being checked for compliance with environmental protection legislation. The question has therefore not yet been settled of how the residual liquor is to be processed further or whether it is to be spread on fields. Spreading the liquor on fields during the non-vegetative period may cause environmental problems, particularly with respect to the groundwater. Further information may be obtained from Professor Bengt Hallström, The Lund Institute of Technology, Lund, Sweden, or from Göte Olsson, Engineer, The Starch Producers' Association, Karlshamn, Sweden.

The fish and fish-canning industry

In Sweden there are a large number of small fish industries. A distinction is made in the trade between two types of waste — fish waste and herring waste. The former arises from the preparation of, among other things, fish balls and deep-frozen fish fillets. Herring waste arises from the preparation of soused herring and anchovy which results in salted and seasoned cullage. Roe waste from caviar production may also be assigned to this category.

In Sweden there are two fish-meal factories which utilize waste for the manufacture of herring meal, herring oil and fish meal. Other items of manufacture which may be mentioned in this connection are the "Sillfor" feed, made from a mixture of deoiled waste and lucerne, and a free-flowing fish powder which is obtained by mixing fish waste with molasses, followed by the addition of lactic acid bacteria.

Mother liquors and sludge from industrial purification plants are additional wastes. These wastes are currently being investigated for the possibility of processing by membrane techniques, for example. The soused herring liquors which at present run into sewers have a protein content of ca. 100 tons/year.

The sugar industry

Sugar beet cultivation in Sweden amounts to ca. 2 million tons per year, from which ca. 270,000 tons of finished sugar are produced.

The sugar industry is making great efforts to protect the environment from the effects of waste-water release. Its first goal was to reduce the amount of waste water, thus making water treatment feasible. The factory waste-water now consists solely of the water contained in the beets. The industry has developed a special purification process so as to make treatment of the waste water (0.5 m^3/ton beets) possible. The process is a two-stage biological process, consisting of an anaerobic and an aerobic stage (Enclosure 4). Carbohydrates are converted in the anaerobic stage to soluble organic acids, whereby methane gas is formed. The water then passes from the anaerobic stage to an aerobic stage. The BOD_5 content is reduced from 4,000-5,000 mg/l to ca. 100 mg/l. The waste water is then stored in large pools and is used for watering purposes during the following season. After storage, the BOD content is less than 25 mg/l. Further particulars may be obtained from Harald Skogman, AB Sorigona, Box 139, S-245 00 Staffanstorp, Sweden.

The wastes formed in sugar manufacture are of various kinds. Stones, sand and mud separated in the transport water system can only be used for simple filling-in operations or can be dumped. More specific use in concrete or the like is not conceivable owing to the excessively high organic content. Beet tops, pieces and roots are chopped and mixed with the beet pulp supplied to the growers. The lime sludge formed in juice purification contains large amounts of proteins, pectin substances, etc. The greatest part of this waste, ca. 125,000 tons per year, is taken by farmers for use as fertilizer.

The beet pulp amounts to 95,000 tons per year; 35% of this is supplied as feed direct to the growers. The remainder is mixed with molasses and then dried in drum driers to make the "Betfor" feed product.

The molasses formed in sugar manufacture amounts to ca. 80,000 tons. One-third of this quantity is used for the manufacture of "Betfor" and the remainder is sold for use as feed or as raw material for yeast production.

Malted drink production

The by-products and waste obtained from breweries are spent grains, yeast, draff, etc. These wastes are currently used as animal feed. Attempts are being made at increasing the feed value by ensilage, for example. Since the yeast has a very high nutritive value, there are possibilities for developing proteins for human consumption in situations where this may be adjudged profitable.

Utilization of by-products and waste (estimated quantities) from the food industry: IVA (Swedish Academy of Engineering Sciences) Report No. 185

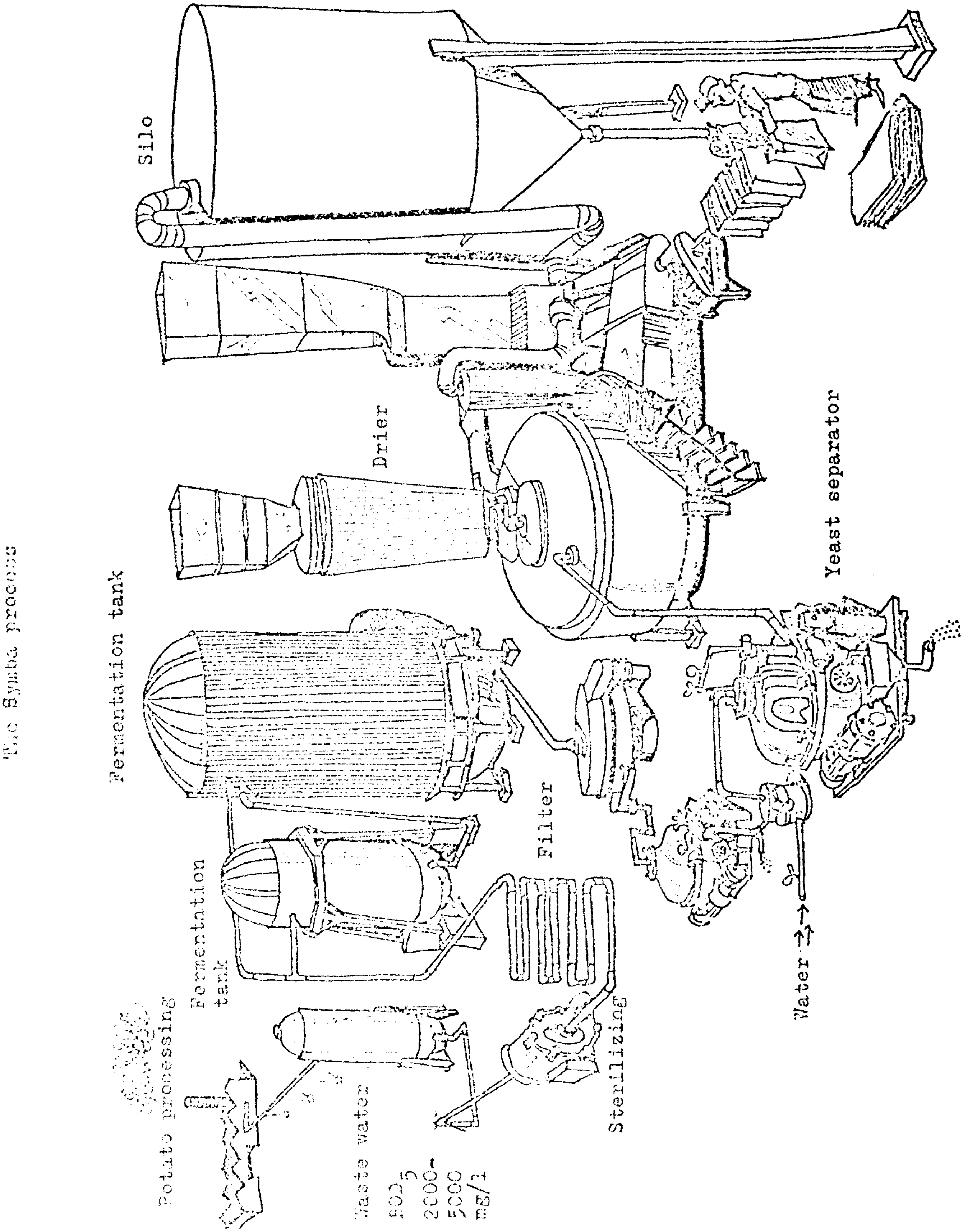
Method of utilization	Solid wastes 1,000 tons/year	Liquid wastes 1,000 tons/year	Total
Foodstuffs or components thereof	7	290	297
Animal feed	965[1]	505	1,470[1]
Fertilizers	85	200	285
Deposition	185	-	185
Burning	20	3	23
To sewers	-	915	915
For preparation or recovery of special components	21	-	21
Total	1,263	1,913	3,176

[1] Ca. 465,000 tons of this from the sugar industry.

Estimated amounts of nutrient substances in by-products and wastes (not waste water) from the food industry: IVA (Swedish Academy of Engineering Sciences) Report No. 185

Branch of industry	Amount, tons/year Proteins	Carbohydrates	Fats	Total
Meat	9,200	-	7,700	16,900
Poultry	1,500	-	500	2,000
Dairy	5,400	27,300	1,000	33,700
Fruit and vegetables	1,000	6,900	100	8,000
Fish	2,000	-	1,400	3,400
Oil and fats	5,000	-	7,500	12,500
Milling	18,000	110,000	4,200	132,200
Baking	2,200	11,800	1,100	15,100
Sugar	20,000	96,000	600	116,600
Chocolate and confectionery	100	100	some	200
Starch	5,300	4,500	-	9,800
Distilleries and wine industry	1,800	2,500	200	4,500
Breweries and soft-drink factories	3,500	2,100	1,000	6,600
Total	75,000	261,200	25,300	361,500
Of these amounts are utilized				
in foods, ca.	5,000	21,000	500	26,500
in feeds, ca.	56,500	216,000	21,100	293,600
for special purposes[1], ca.	2,500	4,700	1,600	8,800
unutilized, ca.	11,000	19.500	2,100	32,600

[1] Bone meal, glue, etc.

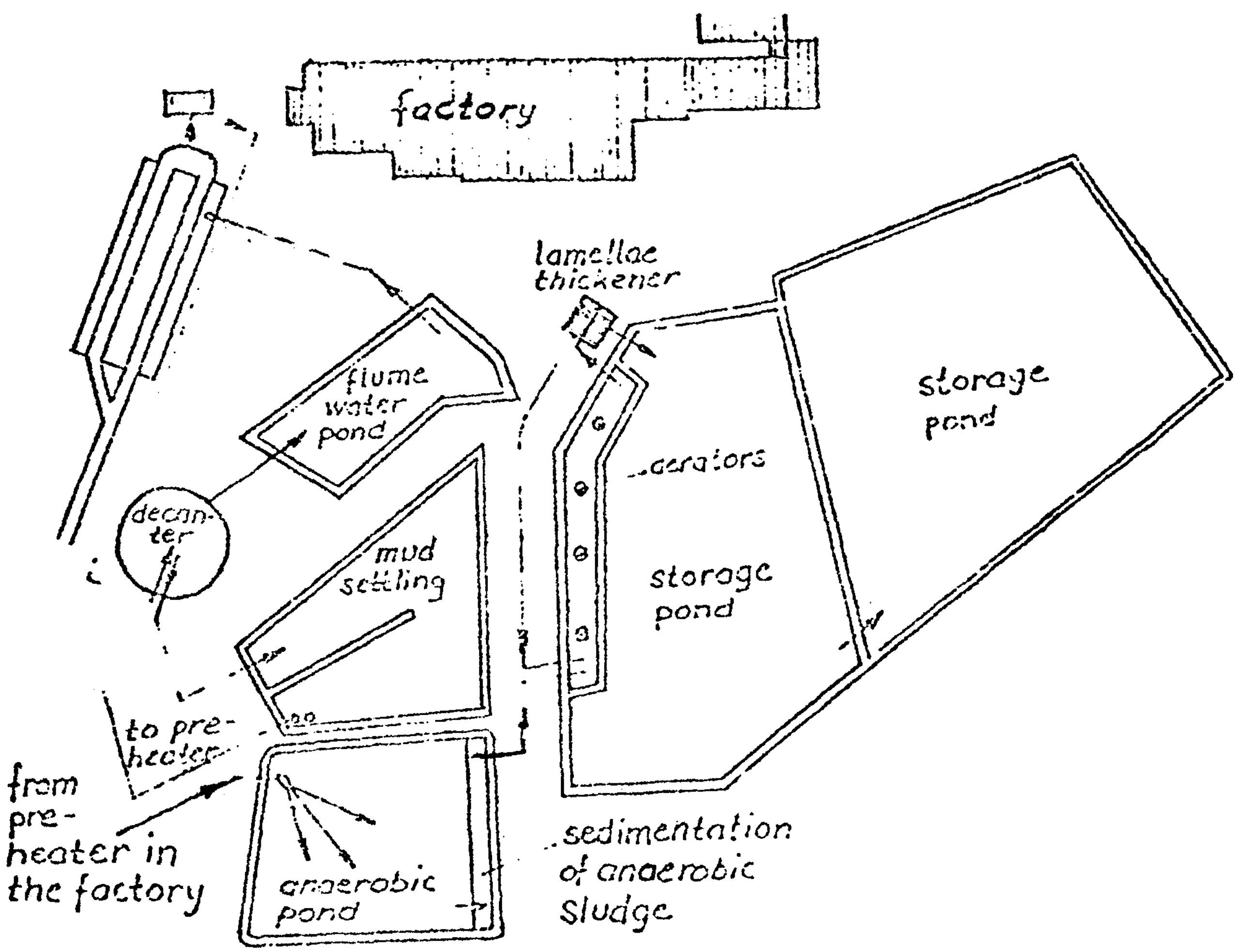


In potato processing the aim is to minimize water requirements by extensive recirculation. The starch imparts a high BOD_5 to the waste water. A process has now been developed to take care of the waste water; it is based on the symbiotic activity of two microorganisms whereby they utilize the starch and transform it into a high-yield yeast product. The process enables the amount of organic matter in the waste water to be reduced by 90%. The nitrogen and and phosphorus concentrations are, at the same time, reduced by about 50%.

SUGAR FACTORIES

Swedish sugar factories have done, and are continuing to do, a great deal to protect their environment from pollution. Their first aim was to reduce water consumption, and work now proceeds only with the water contained in the beets. Having attained this aim, the factories then developed a special method of treating their very dirty water which has a high biological oxygen demand.

The purification process consists of two main steps — successive anaerobic and aerobic treatment. The result of this treatment is to reduce the BOD_5 content of the dirty water from 4,000-5,000 mg/l to 100 mg/l. The water is then allowed to stand until the middle of the summer, when its BOD_5 is found to have fallen below 25 mg/l.



Sugar factory water system

Non Fossil Carbon Sources

by J.C. Shorrock

Non-Fossil Carbon Sources by J.C. Shorrock

GENERAL INTRODUCTION

This research programme was launched in 1974, and was based on a research proposal entitled:

"The Use of Non Fossil Based Carbon Sources as
Raw Materials for the Chemical Industry
- First Phase -
Critical Assessment of Technological and
Economic Feasibilities".

Because of the problems caused by the sudden increase in crude oil prices, it was possible to start work a few months after launching this programme. The results obtained in the first phase have rendered parts of the original research proposal obsolete, and this document complements the 1974 proposal.

After completion of the first phase, results were found to be sufficiently promising for a second phase to be started, involving the design, construction and operation of a pilot plant designed to digest agricultural waste in a novel manner to give useful raw materials. This second phase is due for completion in March 1977.

This document is divided into the following main sections:

SECTION 1. MAIN AIMS OF THE STUDY

SECTION 2. DESCRIPTION OF THE FIRST PHASE PROGRAMME AND INDICATION OF THE SCOPE OF RESEARCH ACCOMPLISHED

SECTION 3. PILOT PLANT

SECTION 4. FURTHER INFORMATION

1. MAIN AIMS OF THE STUDY

This study is aimed at the petrochemical industry, at manufacturers of chemical intermediates and at all industries concerned with cellulose, including the foodstuffs industry.

In the last few years, opinion in industrial and governmental circles has been sensitized to the medium and long-term problems associated with dependence on fossil-based materials as raw products particularly as far as energy requirements are concerned. It is becoming increasingly apparent that the problem is an acute one, and that it extends to industries dependent upon crude oil as a source of raw materials.

Short and medium term solutions have already been proposed for overcoming the energy crisis; however, relatively few solutions have been proposed to overcome the second aspect of this crisis, that is, the supply of raw materials for the chemical industry.

Alternative sources of oil are almost certainly going to be relatively expensive (oil from the North Sea, Alaska, or shale oil and oil from bituminous sands).

Although new technology for the production of energy (more generalised use of enriched uranium reactors, breeder reactors) will probably appear within the next 15 or 20 years, thus diminishing the share of crude oil as an energy source, it seems certain that the recent crisis marks the end of an era of cheap crude oil. This will naturally have permanent repercussions on the price of raw products in the petrochemical industry. This increase, coupled with an increase in energy costs, is beginning to change significantly the price structure of classical petrochemicals and their derivatives.

The social value of certain mass products is being re-examined in the light of increasing prices and more rational use of raw materials. More reasoned mass consumption policies will have to be developed, as well as a partial "re-education" of those responsible for the distribution circuit of products whose social value has become out of proportion with their demands on raw material resources.

In addition to alleviating shortages, other products could become economically interesting per se given that the price of crude oil is unlikely to decrease.

In conclusion, given that the present crisis will have some permanent effects on the supply and price of crude oil, it has become pertinent to examine whether certain degradation products could become economically interesting.
THE DEGRADATION CHEMISTRY DESCRIBED IN THIS RESEARCH PROJECT DOES NOT AIM AT REPLACING PETROCHEMISTRY but must be considered as an examination of possible complementary processes for producing certain well defined chemical products.

In the first phase of the study, we have thus attempted a realistic evaluation of the technical and economic possibilities of using regenerable raw materials for the chemical industry, also taking into account the geographical availability of sufficient quantities of raw materials and competition with other potential outlets for such materials. A detailed survey of the chemical and technological possibilities either available or attainable, together with the relevant process economics, has been carried out. This has led to the establishment of an alternative chemicals circuit, in which certain new products could largely replace conventional products, but in which there are many points of contact with the classical petrochemical circuit. Production costs by both circuits, as a function of relevant variables (crude oil costs, vegetable material costs, energy costs, etc.) have been calculated. It has been shown that, with crude oil at $ 10 per barrel, the alternative scheme is relatively attractive for a certain number of products. As the real price of crude oil increases, many more openings for non fossil chemistry and technology can be taken into serious consideration.

The first phase, at present supported by 18 Sponsors in Europe, the U.S.A., and Japan, was sufficiently positive for some of these Sponsors to request experimental continuation of the programme. This has taken the form of development of a pilot plant for the treatment of agricultural by-products to give a variety of products. The pilot plant is being designed to operate with a variety of feed materials under very simple low capital investment conditions to give a small number of basic chemicals, which can then be further processed by classical procedures. Throughout the research programme, close contact with the sponsoring companies and organisations is being maintained, so that only realistic solutions are proposed and tested. The second phase programme is due to be completed in March 1977, at which point sufficient information will have been obtained to enable sponsors to design and operate a semi-industrial plant.

2. FIRST PHASE PROGRAMME

Since the first phase programme has been completed, this section is no longer a research proposal, but rather a description of the scope of the work carried out and some of the main conclusions.

The work accomplished can be divided into the following parts:

2.1. Survey of Resources

Surveys of agricultural by-products have been carried out for the following countries:

- France
- United Kingdom
- Holland
- Belgium
- Italy
- Spain
- West Germany
- Denmark
- Norway
- Sweden
- Finland
- Japan.

According to the area involved, we have considered cereal straw, maize by-products, sugar beet and sugar cane by-products, potato by-products, viticultural by-products, rice by-products and by-products from the forestry industry. In each case an attempt has been made to evaluate the total production, the present outlets, the actual availability for industrial use and the price, as well as factors and trends which could influence these factors in the years to come.

Problems of transport and storage of raw materials have also been taken into account.

In many cases, maps have been drawn giving the actual distribution of these resources, since transport costs to a central treating unit are very sensitive to dispersion of raw material.

The main conclusions of this section are that, for industrial consumption of the order to hundreds of thousands of tons per year per treatment unit, the most attractive raw materials are, according to area, cereal straw, certain forestry by-products and bagasse.

2.2. Production Costs of Petrochemicals

In order to compare production cost of chemicals prepared by the non-fossil and petrochemical routes, it is necessary to have a common basis of comparison. A computer programme was developed giving real production costs of about 25 key petrochemicals in terms of raw material prices (fuel, naphta, ethylene, benzene, hydrogen, etc) and other costs such as capital depreciation and interest, maintenance, labour, utilities, etc, but excluding profits and taxes. All of these have been reduced to constant dollar values. Influence of production scale has also been taken into account.

Given the very different accounting methods used by various companies, the exact calculation methods and parameters have been give, so that our figures can easily be converted to company figures using other costing systems.

2.3. Furan Chemistry

Since hemicellulose is a major constituent of most agricultural by-products, one of the major degradation products would be the C_5 sugar xylose. This is easily cyclodehydrated into furfural.

A complete study of furan chemistry has been undertaken in order to determine possible chemical circuits starting from furfural.
In addition, the cellulosic part of vegetable material can be degraded to the C_6 sugar glucose, which in turn can be converted into hydroxymethylfurfural.

In carrying out this study, not only has known literature been critically surveyed, but suggestions for improving old reactions by the use of more modern reagents, catalysts and technology have been put forward. The main points studied in this section can be summarised as follows:

2.3.1. Production of Furfural

- from agricultural waste (general process conditions, raw materials, effective furfural yield, process description)
- from sulphite pulping waste liquors (general process conditions, raw materials, effective furfural yield, process description)
- from prehydrolysis solutions.

2.3.2. Production of Hydroxymethylfurfural

- by acid catalyst-high temperature processes
- by acid catalyst-solvent extraction process
- by aluminium salt catalyst processes
- through Amadori intermediates
- by proposed production processes.

2.3.3. Furan Carboxylic Acids

2.3.4. Derivatives of Furfural

- cleavage of furfural nucleus

  . by acid reagents

  . by alkaline reagents

  . by hydrogenolysis

  . by reaction with ammonia

  . by carboxylation

2.3.5. Derivatives of Hydroxymethylfurfural

- amine derivatives
- ether derivatives
- resin formation
- hydrolysis derivatives

2.3.6. 2-Furoic Acid Derivatives

- by decarboxylation
- by oxidation
- by hydrogenation and hydrogenolysis
- by Diels-Adler reactions

2.3.7. 2,5-Furan Dicarboxylic Acid Derivatives

- Diels-Adler reactions
- Side reactions

2.3.8. Other Reactions of Potential Interest

- synthesis of phthalic anhydride
- adipic acid synthesis
- terephthalic acid synthesis
- ethylbenzene synthesis
- synthesis of maleic anhydride
- synthesis of γ-valerolactone and caprolactam
- synthesis of pyrrolidone
- synthesis of 2-cyclopentenone

In all of these cases we have tried to estimate the industrial potential of these reactions (particularly production costs), and also to indicate where research into reactions or reaction conditions (e.g. to increase yield) are necessary.

2.4. Saccharides

The aim of this section was to determine what would be the best method of using polysaccharides. The main points examined were:

2.4.1. A Survey of Naturally Occuring Polysaccharides, and the Particular Features of a Polysaccharide-Based Chemistry.

2.4.2. Fragmentation of Polysaccharides

- acid and enzymatic hydrolysis (for cellulose, hemicellulose, starch, pectins, fructans, gum arabic, alginic acid and chitin)
- hydrolysis of oxidised polysaccharides (selective oxidation of polysaccharides and hydrolysis products)
- alkaline degradation of polysaccharides (including the effect of activating groups in the polymer backbone and hydrolysis products of oxidised polysaccharides)

- hydrogenolysis of polysaccharides (particularly starch, cellulose and hemicellulose)
- thermal degradation of polysaccharides (for cellulose, hemi-cellulose and starch, and taking into consideration different processes such as flash pyrolysis and isothermal pyrolysis.

2.4.3. Considerable attention was given to the possibility of obtaining useful chemicals from polysaccharide fragments. Thus, the possibility of obtaining carboxylic acid and keto derivatives from various sugars was examined. The chemistry of furan derivatives from sugars was treated in detail under section 2.3.

2.4.4. Since a preliminary degradation appeared to be the most promising initial step, various hydrolysis processes were examined in detail (for example, dilute sulphuric acid processes, concentrated hydrochloric acid processes, hydrogen chloride gas processes, enzymatic processes). The process economics and thus transformation costs for such processes were examined.

2.5. Lignin

A very large number of lignin reactions are known, and these were treated in detail under the main headings:

- lignin-containing materials (wood, kraft lignins, lignosulphonates, hydrolysis lignin, etc.)
- solvolytic degradation of lignin
- hydrogenolysis and hydrogenation of lignin
- oxidation reactions
- halogenation and nitration reactions
- alkali fusion and related alkali treatments
- pyrolysis
- microbiological and enzymatic degradations
- polymer and resin formation.

Although, theoretically, lignin should be a useful source of aromatic chemicals, degradation processes invariably give complex mixtures of products, without major constituents.

2.6. Fermentation

Various aspects of fermentation of non fossil sources and their derivatives were examined. In addition to a review of the main processes and basic chemicals obtainable, considerable attention was paid to process economics of fermentation and the various factors which could influence efficient and economic working of fermentation processes.

2.7. Conclusions

The conclusions were presented in two synoptic reports. The first, dealing with the technological aspects of the study, summarised the main features of an integrated non fossil chemistry, in which the main initial products would be C_6 sugars (and hence alcohol, hydroxymethyl furfural and single cell protein), C_5 sugars (principal derived products furfural and single cell protein) and lignin. The various integrated chemical options available were examined and compared with petrochemically based routes.

In the second section, dealing with strategy, we have tried to predict the effect on the chemical industry of introducing a parallel circuit for the production of certain chemicals. For instance the possible saving in crude oil imports has been calculated, and this could be maximised by detailed analysis of the carbon content as carbon or as energy in each individual product. (See figures 1 and 2).

In this report, we also presented various methods for estimating a realistic cost price for raw materials. Finally, for the most promising processes, a detailed study has been carried out on the sensitivity of the production cost of various chemicals to different process-economic parameters (including an evaluation of investment costs).

The principal conclusions were thus as follows

- sufficient raw materials exist to ensure that economically sized treatment units could operate
- a large variety of chemicals could be obtained at attractive costs
- the most promising system would be initial hydrolysis of vegetable materials to give sugars and lignin
- most of the lignin could be burnt, thus making the process practically autonomous in energy
- degradation of lignin would not give useful chemicals, but it could be activated to replace phenol in phenol-formaldehyde resins (some research necessary)
- the principal intermediates obtainable would be glucose, xylose, furfural, hydroxymethylfurfural, alcohol and single cell protein.

The prerequisites for the success of such a scheme would be:

- possibility of obtaining raw materials at a price approximately equal to their fuel value. This would entail rationalisation of the market in which the value of agricultural by-products can vary from negative to several times the fuel value according to the harvest and local conditions

- the price of crude oil must remain superior to $ 10/bbl (constant dollars, January 1975)

- a flexible process for digesting various types of vegetable materials to give either C_5 sugars and derivatives, C_6 sugars and derivatives or mixtures of these together with lignin would have to be developed. The capital expenditure for such a plant should be acceptable.

3. PILOT PLANT (2ND PHASE PROGRAMME)

3.1. Introduction

Consideration of the various known processes for hydrolysis of vegetable materials led us to believe that a modification of the Bergius-Hereng process would be most suitable. This process is based on the use of concentrated hydrochloric acid and hydrogen chloride gas at ambient temperature and pressure for attack on the vegetable material. Given the mild conditions used, the severe corrosion problems encountered in the original plant, could easily be overcome by the use of plastics such as polypropylene or polyvinyl chloride. Our aim in this phase is to conceive and construct a pilot plant capable of digesting continuously about 250 kg per day of assorted vegetable materials such as straw, sawdust or bagasse. It should produce C_5 and C_6 sugars either separately or in a mixture, and these sugars should be suitable for further chemical processing (furfural or hydroxymethylfurfural) or for fermentation (production of alcohol or single cell protein).

The most striking point of this programme, at present underway, is the design, based on comprehensive laboratory and mini-pilot studies, of a simple reactor system capable of digesting vegetable materials of varying physical structure, for both cellulose and hemicellulose degradation, either together or separately. This reactor should not present any problems of scale-up to 100,000 tons/year. The entire pilot plant will be able to deal with:

- digestion of vegetable materials

- sugar recovery (C_5 and C_6 sugar separately or mixed)

- hydrogen chloride recycling.

This pilot plant will be operated in such a way as to obtain sufficient information for conceiving and building a semi-industrial unit (1000-5000 t/yr).

In parallel to this work fermentation studies in a continuous fermenter are being carried out, initially in model solutions to determine parameters for:

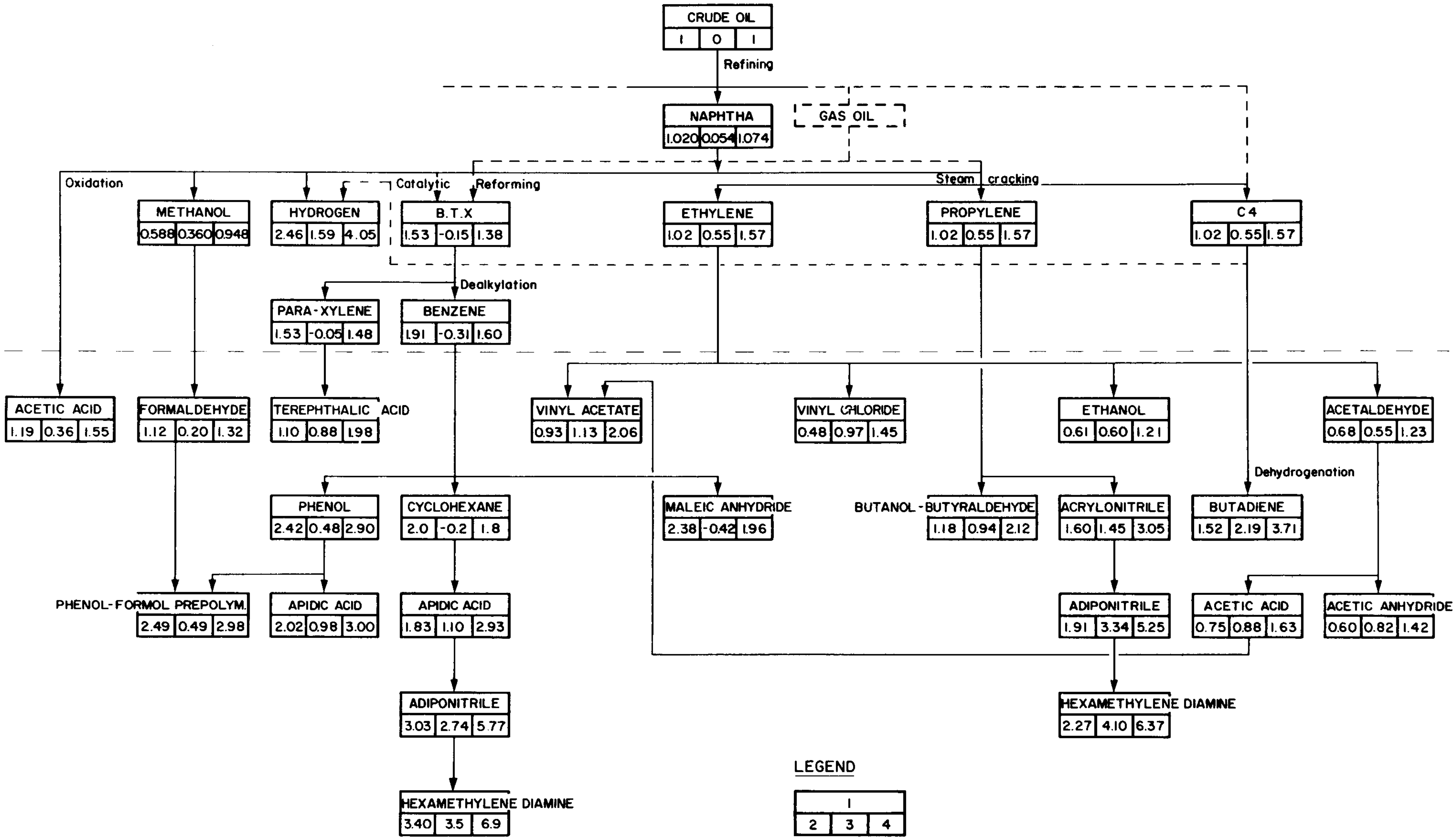
- fermentation of glucose into alcohol
- fermentation of glucose into single cell protein
- fermentation of xylose into single cell protein.

4. FURTHER INFORMATION

Further information on this research programme can be obtained from:

Battelle-Geneva,
CH-1227 Carouge,
Geneva,
Switzerland.

JCS/AR/JHA/193.8168
Geneva, 17.12.76.



1 Product name
2 Crude oil content as C, H source in tonnes of crude/t of product
3 Crude oil content as energy " " "
4 Total crude oil content " " "

FIG. I CRUDE OIL AND ENERGY CONTENT OF THE MAIN PETROCHEMICALS
(Obtained at competitive production cost in a non fossil chemistry)

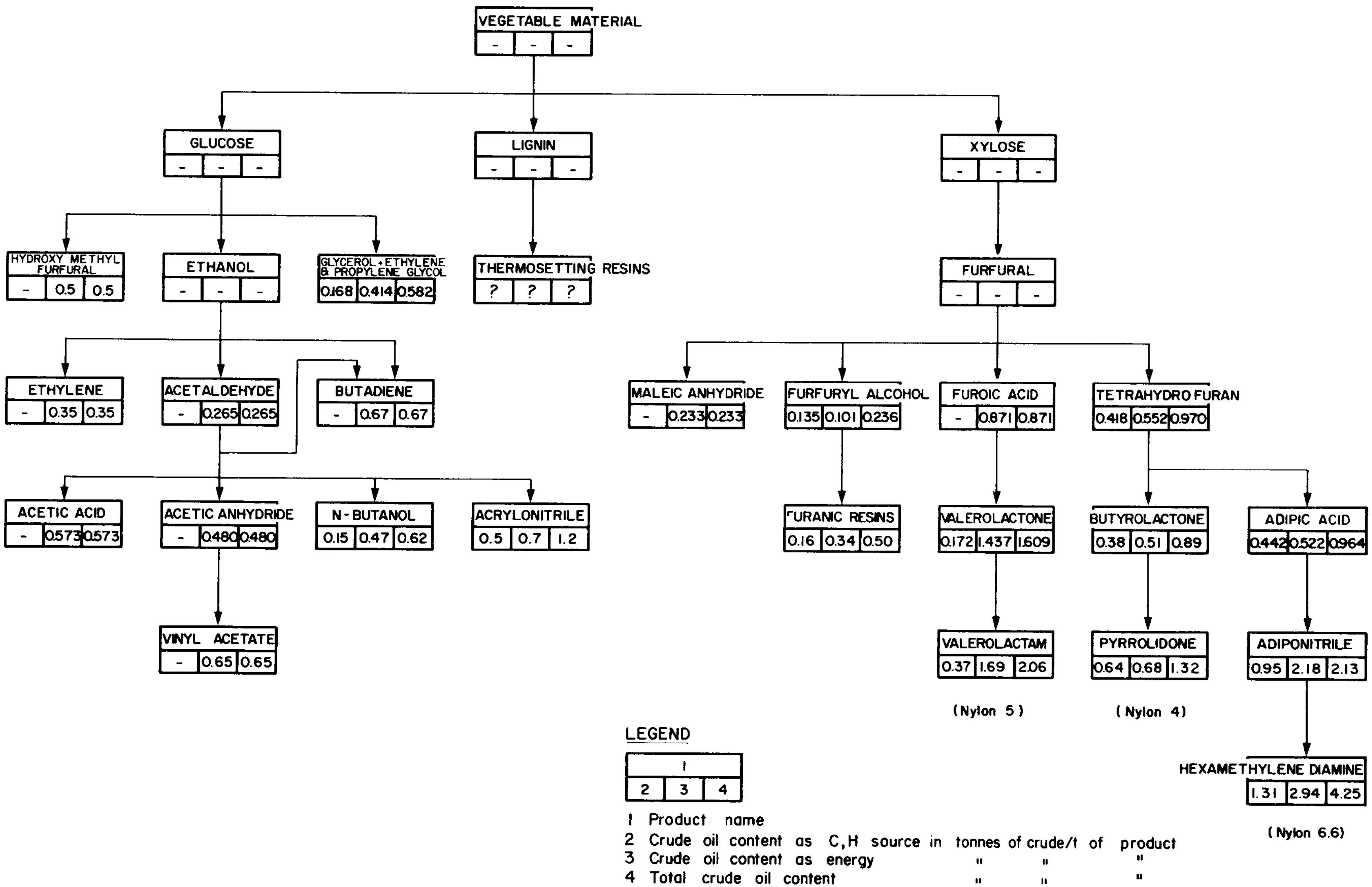
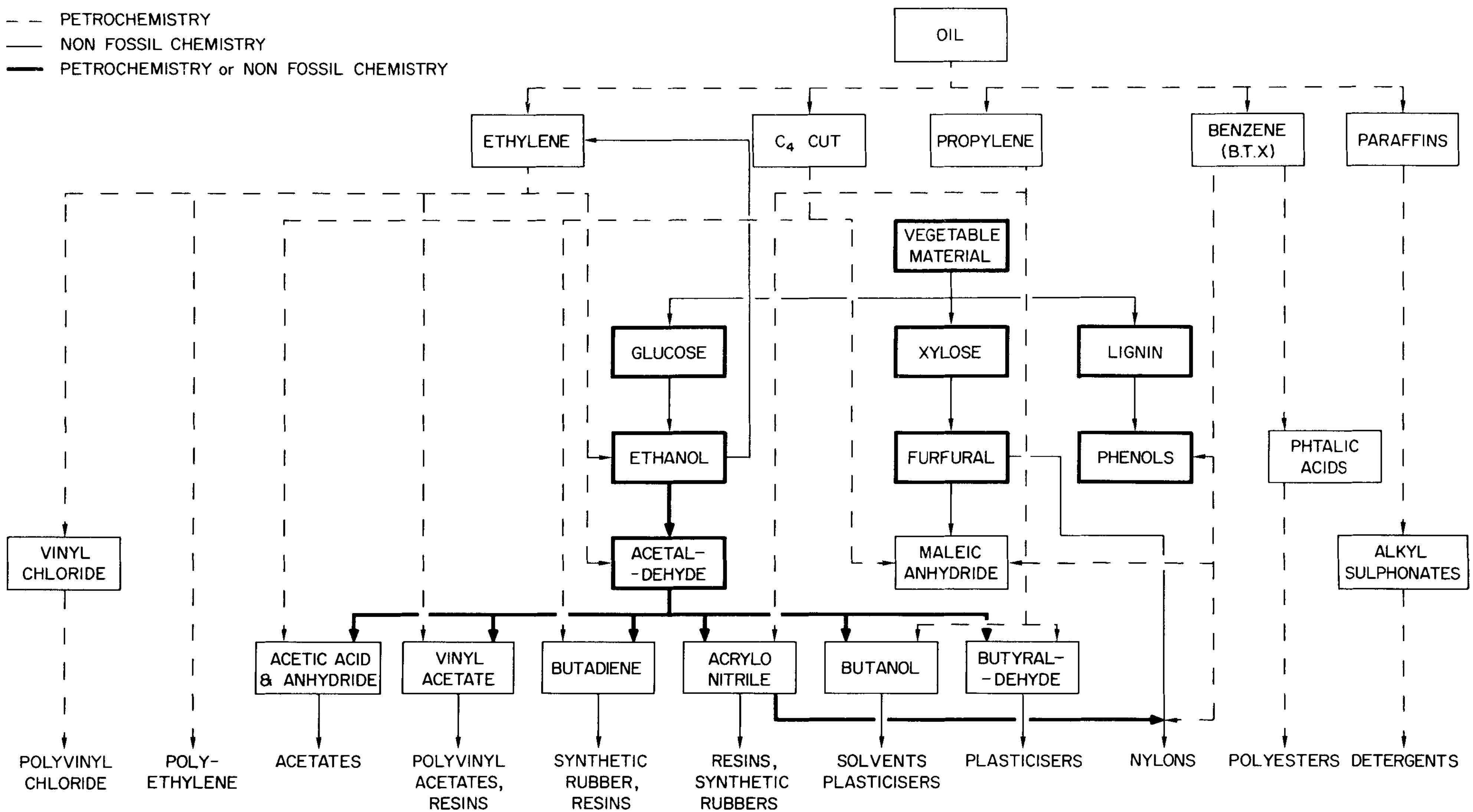


Fig. 2 CRUDE OIL AND ENERGY CONTENTS OF THE MAIN NON FOSSIL CHEMICALS


PETROCHEMISTRY
NON FOSSIL CHEMISTRY
PETROCHEMISTRY or NON FOSSIL CHEMISTRY
OIL
ETHYLENE
C4 CUT
PROPYLENE
BENZENE (B.T.X)
PARAFFINS
VEGETABLE MATERIAL
GLUCOSE
XYLOSE
LIGNIN
ETHANOL
FURFURAL
PHENOLS
PHTALIC ACIDS
VINYL CHLORIDE
ACETAL-DEHYDE
MALEIC ANHYDRIDE
ALKYL SULPHONATES
ACETIC ACID & ANHYDRIDE
VINYL ACETATE
BUTADIENE
ACRYLO NITRILE
BUTANOL
BUTYRAL-DEHYDE
POLYVINYL CHLORIDE
POLY-ETHYLENE
ACETATES
POLYVINYL ACETATES, RESINS
SYNTHETIC RUBBER, RESINS
RESINS, SYNTHETIC RUBBERS
SOLVENTS PLASTICISERS
PLASTICISERS
NYLONS
POLYESTERS
DETERGENTS

An Approach to Waste Utilization in Rural India

by J.J. Patel

AN APPROACH TO WASTE UTILIZATION IN RURAL INDIA

JASHBHAI J. PATEL B. Ag.

Eighty percent of Indian people live in villages. Practically no agro- industrial wastes are encountered with in rural India. Main wastes are of agricultural origin and refuse of domesticated animals and birds. Amonst others, night soil of population and water weeds are wasted without utilization. There is a small quantity of waste wood, twigs and branches of trees and shrubs, all of which is gathered for use as fuel. Even dry leaves are burnt. Urine from animals as well as from the rural population is completely wasted. Fuel wood which supplies about 34.56% of the utilized heat for domestic work-mainly cooking in rural India, is not a waste material, but its under utilization constitute a major waste. About 20% of the wood is bark, which could be utilized as an organic fertilizer in powder form (I do not remember the source of this information) is also burnt with wood.

The present way of utilizing these wastes is highly uneconomic due to under utilization and productive of pollution because of primitive methods of use. The estimates of the wastes arrived at here are at best an intelligent guess and should be regarded as dependably representative rather than accurate. Conditions of climate, of ecology, of social customs, and of agriculture differ widely in India. The nature and proportion of wastes differ widely from place to place. Plans for proper utilization to waste must also differ from locality to locality and from village to village.

The collection of organic wastes except night soil and water weeds is being carried out at present, because each individual family in the low income group, poor or below poverty line gather the wastes for use as domestic fuel. Except 70 percent of animal dung, which is used to make farm yard manure, all the rest is used as fuel. The energy and fertilizer needs of rural India are inseparably linked with waste utilization.

The picture of energy utilization in India is interesting, in that it follows the world pattern. The richer nations use a greater share of the conventional energy resorces than the poorer nations. In India 120 million urban (20%) population uses almost 94.5% of all energy derived from conventional fuels & hydel power leaving only 5.4% for the 480 (80%) million rural population. (1975) estimate) in the rural area nearly all of the energy derived from 5.4 percent fossil fuels electric power, and fuel wood is used by the few rural rich, leaving agricultural and other vegetable waste, wood waste and dried cattle dung (dd fuel) as a source of energy for the large majority of poor village population. The daily collection and use of these waste materials entail labour, which is time consuming. Since the poor do not spend out of pocket for their fuel needs it does not enter the monetised economy. The expense in form of their labour is considerable. It is not uncommon to find children of the poor, hunting for family's daily fuel needs, all day long in some parts. In all such cases at least one child in the family cannot attend school. Thus the manner of present utilization of waste is not only wasteful in its consumption, but also in the human resource. But this phenominon may be the result of poverty alone, and may not have anything to do with the present discussion. One fact which emerges out and is important that, however, poor a family might be it collects and uses the fuel. The rich may be using or wasting more than their share and the poor may be using less, the average use of fuel per person therefore becomes a reliable guide to the estimates of wastes presented here.

I first tried to estimate each waste material and then tallied it with the daily requirement of cooking. The agreement was within limits.

The present picture of waste utilization is miserable, it is both wasteful in the extreme and pollution generating. Table 1, shows the main wastes which are collected and utilized, and also those which are not at present attended to, but can be and must be collected and disposed off for prevention of pollution, of hazard to health and of economic loss.

Considerable amounts of dung from other domestic animals like horses, camels, goats, sheeps, and poultry has been left out of consideration from the present discussion due to scanty data to work with.

Of several estimates of the availability of wet cattle and buffalo dung (wcd), that by Neelkanthan (1) seems to be nearer the actual. It also agrees with my experience in the gobargas (Bio-gas) work during past 25 years. He puts it at 977 million tonnes per year on the basis of 1965 cattle census. The number of cattle have increased and their feeding has also improved, during the years that followed I put the figures of wcd at 1166.4 million tonnes per year at present.

Neelkanthan has also worked out that 69.66% of wcd. is used as F.Y.M. 28.34% is used as dry dung fuel (dd fuel) and 2% is used for other uses. Thus 812.6 million tonnes wcd is turned into farm yard manue (FYM) in pits or open heaps. Of the total oven dry solids (20% of wcd) half are lost during

TABLE 1

The Major Waste Materials of Rural India.

(Million tonnes/year)

Waste material	Total available	Present utilization
Wet cattle dung (W c d)	1166.4	812.6 used to make FYM. 330.5 used for as dry fuel.) 23.3 used for other purposals.
Fermentable agricultural & other vegetable wastes.	31.5	all used as fuel.
Woody or non-fermentable agricultural waste.	27.644	all used as fuel.
Waste wood twigs, thin branches & etc.	15.2	all used as fuel.
Fuel wood (Under utilized)	43.68	all used as fuel.
Water weeds dry matter.	30	totally wasted.
Night soil wet	70	totally wasted.

the long ripening period of 5 to 8 months, due to rain wind and fermentation. In most cases the ripe F.Y.M. contains 60% moisture. Outtum of FYM is 203.15 million tonnes and its price is about Rs. 40 per tonne. The total value realized is Rs. 8,126 million. About half of the total plant nutients are lost in the process, execpt K_2O, in which case loss is about 18%.

Dry dung fuel (dd fuel) is made out of 330.5 million tonnes wcd (28.34%) of 1166.4 million tonnes wcd.). NCAER, (2) Neelkanthan (1) and Reddy (3) have put the yield of dd fuel from wcd at 20%. There are good reasons to differ from their figure. Wet cattle dung has 20% oven dry matter. A small quantity of dry vegetable matter is always mixed with wcd while making dd fuel. A quantity of inorganic dirt either gets mixed or is mixed with it. And the final air dried dd fuel contains an abnormally large moisture percentage. The composition and the total yield is bound to differ

TABLE : 2.

Showing utilization and losses in making farm yard manure from 812.592 million tonnes wet cattle dung.

Material	Quantity.	Oven dry solids (ODS)	Nitrogen	P_2O_5	K_2O	Energy required to manufacture plant nutrients NKP, in factories.*
Wet catte dung.	812.592	162.518 (20%)	2.276 (1.4% of ODS)	1.463 (0.9% of ODS)	0.894 0.55% of ODS)	4.93825×10^{13}
FYM.	203.15	81.259 (40% of FYM)	1.097 (1.35% of ODS)	0.731 (0.9% of ODS)	0.731 (0.9% of ODS)	2.4458582×10^{13}
Loss		81.259 (50%)	1.373 (60%)	0.732 (50%)	0.163 (18%)	$2.49239592 \times 10^{13}$*

* Energy Lost is worth Rs. 7023.7 million at the price of replacable Kerosene (efficiency of Kerosene taken at 38.9%, price in villages Rs. 1.25 per litre).

from locality to locality. I have a small amount of work conducted hurriedly at Bombay which is insufficient to draw final conclusions. But in absence of other reliable data, I use the following figures The outturn of dd fuel is about 30.18% of the wcd used in making it. Its calorific value is 2444 Kcal/Kg.

Heat utilized from dd fuel is 2.0477 x 10^{13} K cal, which is worth Rs. 7213.2 million at the price of replacable kerosene. In addition to the huge loss of energy in the use of dd fuel 925400 tonnes N, 594900 tonnes P_2O_5 and 36550 tonnes K_2O are also lost.

Agricultural and other vegetable waste available in rural India has been estimated by the NCAER in 1965. They have admitted that this estimate is largely based on guess work. The agricultural output has since been doubled. For the sake of this paper I have divided the agricultural and other vegetable waste in two classes. One class is fermentable waste and the other is woody waste, like cotton and tur sticks which are not readily fermentable. I propose to consider the woody waste along with waste wood. I estimate the fermentable agricultural and other vegetable waste at 31.50 million tonnes annualy. This is an under estimate it may also be taken as an intelligent guess. The waste The waste has also doubled. For the agricultural output has doubled since 1965.

TABLE : 3.

Showing dry dung. fuel made yearly.

Wcd used 28.34% of the total million tonnes.	dry dung fuel obtained 30.18% of wcd used million tonnes.	Calorific value of dd fuel 2444 Kcal/kg. dd fuel. K cal.	Heat gainfully utilized 8.4% K. cal.
330.5	99.745	2.4378 x 10^{14}	2.0477 x 10^{13}

In addition to the huge loss of energy in the use of dd fuel 0.9254 x 10^6 tonnes N, 0.5049 x 10^6 tonnes P_2O_5, 0.3086 x 10^6 tonnes K_2O representing 1.78 x 10^{10} K cal energy is also lost.

There is no doubt that a large quantity of Agri-Veg. waste remains un-accounted. This waste material does not enter the monetised economy. It is neither sold nor nor bought. The users, mostly the poorer villagers collect, the agri-Veg. waste for their own use as fuel. The 31.5 million tonnes fermentable waste yield utilizable energy worth Rs. 3,611 million in terms of replaceable kerosene.

TABLE : 4.

Showing use of Agricultural and vegetable frementable waste used directly as fuel in rural India.

Estimated Agri-Veg. Fermentable waste million tonnes, per year	Total energy contained in waste shown in col. 1. (3600 K cal/kg.)	Heat utilized in cooking from the total K cal shown in col. 2. 9.6% K. cal.
1	2	3
31.5	1.134×10^{14}	1.08864×10^{13}

Loss of 1.025×10^{14} K. col energy valued at Rs. 3611 million at the price of replaceable Kerosene.

The Agri. Veg. waste of woody nature consists of sticks of such crops as cotton, tur & etc. thorns and such other material. The woody Agri-Veg. waste is about 27.644 million tonnes and the waste wood like cuttings from shrubs, thin dried branches of trees is about 15.2 million tonnes. Together they make up 41.844 million tonnes annualy. All of it is burnt as domestic fuel by the poor.

The energy content of woody Ag.-Veg. waste is 3200 K. cal Kg. (4) and that of waste wood (non-commercial is 2560 K cal. per Kg. (2)

Total value recovered from agri-veg. waste and waste wood is Rs. 5370.4 million at price of Kerosene which can replace these fuels.

The supply of fuel wood has not kept pace with the increasing use of energy in the villages. In fact it is in short supply. About 43.57 million tonnes is used in the village annualy.

TABLE : 5.

Showing Ultilization of Woody Agri-Veg waste and waste wood in rural India.

Fuel	Quantity million tonnes.	Total Energy content K. Cal	Energy Utilized K. Cal. 12%
Ag.Veg. waste non-fermentable	27.644	8.85248×10^{15}	1.062×10^{13}
Waste wood	15.2	3.85472×10^{13}	4.62567×10^{12}
Total	42.844	1.27072×10^{14}	1.5246×10^{13}

Loss of 1.11826 b 10_{14} K. CAL. valued at Rs. 3939 million at the price of replacable Kerosene.

TABLE: 6.

Showing wastes, their utilization and under-utilization of fuel wood in rural India
—Per year (1975 estimate)

Waste Material	Quantity Million Tonnes	Energy contained in Waste K. CAL	Energy utilized K.CAL (% of Total)	FYM Million Tonnes	Value in Million Rupees Energy	Value in Million Rupees FYM
Wet Dung	812.6			203.15	—	8126
Wet Dung	330 5	2.4378×10^{14}	2.0477×10^{14} (28.75%)		7213.2	
AGR & Veg-Fermentable Waste	31-5	1.134×10^{14}	1.08864×10^{13} (15.28%)		3835	
Agri-veg waste	27.644	8.85248×10^{13}	1.062×10^{13} (14.91%)		3741	
non-fermentable. Waste Wood	15.2	3.85472×10^{13}	4.62567×10^{13} (6.5%)		1629	
Fuel Wood	43.57	2.0512×10^{14}	2.46143×10^{13} (34.50%)		8671	
Total		6.89372×10^{14}	7.1223×10^{13} (100%)		25089	

Note : 10.33% of the total energy in waste & wood is utilized.

Two wastes are completely unutilized. These are night soil of population and Water weeds. Use of latrines in rural India is rare. People go out to ease themselves in open fields, waste land, road sides and banks of ponds, lakes or rivers. The nightsoil left in the open, either ferments, dries up or partly ferments and partly dries up. The dried material gets mixed with dust and becomes airborne. It also gets mixed in the water resources of the village. Generally the approach of a village is heralded by the mixed odour of decaying night soil, dust and smoke from dd fuel, organic waste and wood. In the early hours of morning and in the evening, villages are covered with a canopy of heavy dust laden smoke. In most areas parasites of the digestive tract and hook worm are common. House flies are a major nuisance. I have seen a fly infested village near Delhi, where almost all children suffered from tracoma.

Dry dung fuel generates more smoke than heat. Smoke is also generated by the use of agricultural waste and wood in open chulas (stones) improvised by using bricks on three sides. This type of cooking is nearly as primitive as barbecue. Damage done to the human system by continuous and regular inhaling of smoke is too well known to be detailed. The smoke also settles upon every available surface in the house and gives it a grey blackish tinge and a peculiar acrid smell. These fuels, used as they are, also leave minute particles in the house and kitchen floor, which ultimately get into the food, water and lungs of the incumbants. In addition to the economic loss due to under utilization the human suffering and resultant economic loss due to pollution are more significant.

The economic loss due to the waste of night soil and urine must also be considered. It is huge in the present set up, both by the way of manure and energy. The first step in the recovery of night soil and its subsequent recyling is the provision and use of latrines. In many places there is not enough room in or near the house for a latrine. Community latrines seem to be a good way out. But the resistance of the people to the use of latrines is not easy to overcome. We set up a set of 17 latrines in a village in Maharastra for women, who otherwise lined up on both sides of the only road leading out of the village for easing themselves, morning and evening.

The women started using the latrines to begin with but reverted to their old road side. Picketing by school girls, calling out the women by name from loudspeakars while they went to the road side did not produce lasting results. Then we asked the older women why they did not use the latrines, to find out that they could not communicate with other while using the latrines as they used to do on the road side. One foot diameter openings at face level were made in the walls between the latrines. The latrines are now used, and the whole village has community latrines. The rural population shall ultimately use the latrines if their objections and taboos are taken care of in the begining.

In addition to the economic loss and suffering due to pollution Rs. 3923 million are lost by the way of fuel gas Rs. 1323 million which could be had which could be obtained from it and from its manure each year, by anaerobic digestion.

Water weeds from more than 500,000 acres, of water surfaces; village ponds, canals and many irrigation tanks are a real menace. They block irrigation canals, water ways, get into rice fields and destroy crops. A large sum is being annualy spent to keep out water weeds. It may be necessary to replace other weeds by the most promising one. Water hyacinth is a water weed of choice. Its vigourous growth can supress almost any other, its yield is high and it is easier to harvest. By comparision algae requires careful attention to grow, and special costly equipment to harvest, which makes protein obtained from it prohibitive for any use other than medicinal. Nasa has reported water hyacinth yield upto 85 tonnes of dry material per year, 55 to 65 tonnes dry mass from water hyacinth are common. Nasa scientists report 1.9 ml. gas from 1 gm of green plant water hyacinth. Guha reports 6 litres gas from 80 gm semi dried mass (1|3 of green plant). NASA has reported bigger yields upto 2.9 ml green plant for contaminated plants.

I take 60 tonnes dry mass or 420 tonnes green water water hyacinth yield per acre. 500,000 acres of water area will gives 210 million tonnes water hyacinth per year which may yield 525 x 10^6 cub gas having 1.334 x 10^9 k cal utilizable energy worth Rs. 0.470 million at the price of replacable kerosene. The digested material left out after anaerobic digestion is reported to have 2.05% nitrogen 1.1% P_2O_5 and 2.5% K_2O. It will yield 30 million tonnes manure worth Rs. 2250 million at Rs. 75|- per tonne containing 0.615 million tonnes N, 0.33 million tonnes P_2O_5 and 0.75 million tonnes K_2O annualy.

Anaerobic digestion of cattledung is rapidly making headway in our villages. The family level plant is becoming popular, after our Prime Minister Mrs. Indira Gandhi began taking keen interest in the work from 1974 onwards.

The anaerobic digestion technology is simple, does not require imported know-how or components, is suited to very small family scale as well village scale digestion. The country is favoured with clear skies and good sunshine for most part of the year, and solar-heated anaerobic digesters both small and big are round the corner. Anaerobic digestion yields both fuel gas and organic fertilizer with minimum loss of plant nutrients contained in original material. All these points favour adoption of anaerobic digestion for all fermentable wastes.

Further, the small anaerobic digesters, known in India as gobargas plants are well received. We had 7000 plants upto 1974. During the year our Prime Minister began taking keen interest in the gobargas work. Now there are more than 30,000 plants and the rate of installation is increasing. These are family level plants. A majority are made to produce from 4 to 10 cubic meters gobargas.

The impact of the gobargas plant on the farmer's family is best illustrated by a letter from an old farmer from U.P. "I have been watching the changes that it has brought upon us. It has taken away labour from women folk, the making of cattle dung cakes turning them for drying and collecting them. The cooking vessels do not blacken, they are a lot easier to clean. Of late I have been noticing their sarees. They are a shade whiter. Their main task seems to be to attend to their children each one has became a queen by herself. Tears no longer roll from the eyes while cooking. And the men folk are taking on the air of richness. Why not? The manure has given a bumper yields. They now intend to white wash the inside of the house. They have other plans too. I do not like every passerby to look with popped eyes at our crops. Our fields stand apart from the surrounding fields of the village. Every crop stands higher, greener and more luxurient. That attracts people's glances not all of them benevolent." In an effort to understand him I went to him. He explained the situation to me. I said "uncle, I have seen the situation, I think your younger members love the gobargas plant. I also feel that the changes are for the better, but your feel otherwise". The oldman replied, "Sir, you will never understand me. Look at the whitecashed walls and the mantle-gas-lamp; my house looks like a tea-shop Both the men and women folk now walk and talk with an air about them. I don't like any of it". I offered if I could help him in the situation. He immediately look relieved and said. "Don't you see Sir, my family is drifting away from the naighbours in every detail of living. I do no know where will this end. You can do a lot. I request you to set up a gobargas plant at each of our neighbours. Only than I will feel secure." Before long there were 450 plants in that area.

Gobargas plants overcome pollution by providing a fuel with least carbon in it, the digested material is innocuous and odourless. Flies are not attracted to it. Fly maggots do not survive even if they are introduced in the digested slurry experimentally.

The organic matter after digestion, becomes finely divided. When applied for the first time the results are almost the same as F.Y.M. Repeated applications year after year show results much superior to F.Y.M. The IARI workers reported these results to the ESCAP workshop on biogas technology and utilization. New Delhi July 28—Aug. 2 1975. In the Technical Bulletin 46. Fuel Gas and manure ICAR, superior soil aggregating properties of anaerobically digested manure are mentioned due to polyuronides present in it. Wet digested manure also shows vastly superior nitrification of nitrogen in soil.

The total yield of organic manure obtained by anaerobic digestion is higher than that obtained from manure pits as F.Y.M. Higher off take of gas by following better methods of digestion should reduce the present high yield of manure without comparable loss of NPK. Best of all, farmers recognise better quality of digested manure and pay more for it than FYM.

It is certain that farmers have found even the small plant economically advantegeous. The economics of bigger plants are better. Large scale adaptation of anaerobic digestion will require heavy capital outlay. The advantages both immediate and long term are even bigger. Table 6 shows that huge amount of extra energy which could be obtained on a renewable basis with enourmous gains in plant nutrients each year by a planned programme to cover the rural area by gobargas plants of village level size, and medium and small family sizes. It is now possible to install a small plant for the farmer who owns one or two heads of cattle to give his family enough gas for cooking economically.

A recent cost benefit analysis by O.P. Verma "Economic Times" Dec. 16 17, 18, 1976) concludes that gobargas plants when viewed as commercial venture, is not only highly feasible but also financially productive, as can be expected from any business enterprise. He has concluded that very small sizes 1, 2, & 3 cu.m. gas day show nil margin of profit and pay back periods are long. He recommends 9, 20, 85, cubic meters gas/day plants as most attractive. These plants can provide enough fuel to 9, 20 and 85 families respectively. The solar heated plants will change this picture for better.

Agricultural woody waste, waste wood and fuel wood are all used at 12% or less efficiency at present. The efficiency can be inproved by installing better wood stoves. Since my proposals of treatment of fermentable waste propases gas as fuel, it would be economical to gasify Ag. woody waste and wood waste.

A swiss firm has recently announced a wood gas generator. I have got an outline of information, from them, in two letters. They claim that total recovery from one kilogram of wood waste is 3700 k cal. in three cubic meter gas having 1233.33 k cal/m3. The gas leaves the generator at 400°C. This heat can be utilized to keep anaerobic digesters warm and the cool gas may be mixed with gobargas for use.

The calorific value of our wood is 4702 k cal/kg. Recovery by the swiss gas generator is therefore 80%. The total heat in 31.5 ag. & vg. Woody waste and waste wood is 9.952×10^{13} k cal and in wood waste it is 4.864×10^{13}. Of the total of 1.4816×10^{14} K. cal approximately 75% or 1.112×10^{14} may be available for use.

Table 7 shows that the wastes could give 4.4×10^{14} K. cal energy and about 500 million tonnes good quality organic manure, containing 4.2245 million tonnes nitrogen 2.8003 million tonnes P_2O_5 and 2.4407 million tonnes K_2O annualy.

TABLE 7

Showing energy and manure that would be available by anaerobic fermentation of all fermentable waste and process wood waste with wood gas generators.

Waste material	Quantity million tonnes.	Plant nutrients million tonnes			Fuel gas $m^3 \times 10^6$	Total energy K.Cal.	Manure million tonnes
		N.	P_2O_5	K_2O			
Wet cattle dung Fermentable	1143.1	3.189	2.126	1.417	57,155	$2\ 694 \times 10^{14}$	400
ag. & veg. waste	31.5	0.300	0.212	0.212	7087.5	3.34×10^{13}	49.6
Night soil	70	0.2205	0.1323	0.0617	4200	2.34×10^{13}	22.05
Water weeds as water hyacinth	210	0.615	0.33	0.75	525	2.8×10^{12}	30.00
Non fermentable Agri. Veg. woody waste	27.644				82932	7.4639×10^{13}	
Waste wood	15.2				45600	3.648×10^{13}	
Total		4.2245	2.6003	2.4407		4.4×10^{14}	501.65

The rural population in India uses 7.1223 x 10^{13} K. cal energy, for domestic use annualy. This is 406.52 K. cal per person per day. The gobargas plants are at present mostly owned by farmers with some means and about five heads of cattle. My experience extending over several years with them is that they use 200 litres of gas per person per day at 47.6% efficiency in cooking and other domestic use. This figure is corroborated by S.K. Subrahmanian ex-secretory NCST in a personal communication. He was on an evaluation mission of gobargas plants. This figure is low compared to that of many countries. It is good enough for the present standard of living of the lower middle class of the urban area and of families with means in rural areas. The net energy utilized is 448.6776 K.cal. per person per day (200 litres gobargas at 47.6% efi.). Every year the rural population may use 7.861 x 10^{13} K. Cal. if supplied in gaseous form, without restrictions.

After providing for 7.861 x 10^{13} **K.Cal.** energy for domestic use 3.614 x 10^{14} K.Cal. energy would be available for other uses. (from 4.4 x 10^{14} K. Cal. table 7). This is enough for generation of 1.261 x 10^{11} kwh, which is equal to 262.65 Kwh per person per year in the villages. Per capital consumption in the country was 96.6 kwh in 1974-75.

The present position regarding electricity for villages is miserable. A few packets, mostly near urban centres are electrified. There is no hope of small distant villages getting electric power for next 50 years or more. It is no secret that rural electrification from central sources is uneconomic due to various reasons.

It may he noted that use of fuel wood has been avoided in this approach. This is necessary to allow the callously exploited forests, which are disappearing, to recoup for a period. They will be ready to supply increased energy needs of the future.

The present supply of manure is 203.15 million tonnes of F.Y.M. annualy. The present approach promises 500 million tonnes. The compost making from farm wastes is uneconomic due to heavy labour costs. It has not made head way.

There is no doubt that the family level gobargas plants will continue to be popular. Introduction of a small plant for the farmer owning one to two cattle (20 kg. wed|day) may be of great service. About 90 per cent of the cattle owners own two or less cattle.

Village level plants are shown to be technically feasible and economically paying as any commercial enterprise may be. The social and political setup may very well put hurdles plants. If the nation is to turn the corner in the matter of energy supply, pollution prevention, manure supply and equitable use of these resources amongst the rural population the village panchayat will have to assume the owner-ship of the cattle and other dungs and organic wastes by legislation. These can supply 75% of the energy proposed to be produced. These wastes must be preserved and sold to the village panchayat for processing. In turn the panchayat should supply fuel gas to each family and distribute the organic manure equally on the cultivated land of village to secure greatest benefit. Fertilizers may be used to supplement the special needs of intensive farming.

O. S. Verma (Economic Times 16-12-1976) places the Nitrogen requirement of the curent agricultural year at 2.6 million tonnes. This is in addition to 1.097 million tonnes nitrogen available in F.Y.M. Against a total requirement of 3.697 million tonnes, the output (including that from F.Y.M.) was 2.632 million tonnes. The short fall was 1.065 million tonnes. It is estimated that by 2000 A.D. the requirement of nitrogen will be 4.6 million tonnes.

"India 1976" on page 185 states that the consumption of fertilizers in terms of nutrients N P K was 2.839×10^6 tonnes in 1973-74 and 2.579×10^6 tonnes in 1974-75, during the same period 2.559×10^6 tonnes of N P K was need from F.Y.M. The approach made in this paper seeks to produce 9.5056×10^6 tonnes N P K by properly utilizing the wastes.

After four five-year plans only 24% of the villages have been electrified. The electricity boards find it very difficult, because of iosses coupled with low consumption. It is unlikely that electricity from centrally generating stations will economically serve poor villagers. Locally produced power can be readily adjusted to its consumption, with great economics in fuel. Gas lamps are uneconomical. One lamp consumes a quantity of gas which can generate enough electricity to burn five lamps.

Another advantage is the use of waste heat of engines to warm up the digesters to produce more gas. The generation of power from gobargas plants or wood gas generators at village level is more suited the present needs.

A plant producing 140 cubic meters gas per day costs about Rs. 70,000 at present. This present plant uses 3.75 tonnes wet cattle dung daily. And the production drops down to less than half of the average in winter and almost doubles up in summer. This is due to the fact that the Khadi and Village Industries commission has tried to use the design factors of the family level plant, which I designed in 1953 for small scale production keeping simplicity of design and operation in mind. Though this plant has become very popular in India at family level it is unsuitable for village level anaerobic digestion. Its depth to diameter ratio becomes rapidly unfavourable to make it more susceptible to ambient temperatures.

The method of wastes utilization indicated above may help the villeges to become self sufficient in energy and manure. The best part of the propasal The best part of the propasal is that it is that it uses local renewable resources, which are at present wasted causing economic loss and high degree of pollution.

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Bio-Gas (Gobar Gas) & Manure from the Waste of Farm Animals

by H.R. Srinivasan

BIO-GAS (gobar gas) and MANURE FROM THE WASTE OF FARM ANIMALS

by H.R. SRINIVASAN

(1) INTRODUCTION:

This paper mainly deals with production of bio-gas on decentralised basis from the droppings of farm animals like cows, bullock, buffaloes, sheep and goat, poultry, swine, horses etc. It also covers manure aspects not only from animal wastes but also compost from vegetable wastes made with enriched fermented slurry of gas plant. This paper is prepared on the basis of work done in India during the past four decades.

1.2 The level and pattern of utilisation of energy from different sources in any country is an index of its industrial development and standard of living. India with per capita energy consumption of 140 kg. of hard coal equivalent belongs to the group of under-developed countries, Nearly half the total energy consumed in India comes from non-commercial fuels and major portion of this supply is consumed in rural areas. Energy from non-commercial sources thus plays a significant role in the energy consumption. More than 75% of the population in India lives in 5.7 lakhs villages and the vast majority of farmers are dependent on agriculture for their livelihood. Due to the steep increase in the cost of inputs particularly cost of fertiliser, output is no longer attractive and remunerative for the small farmers and consequently they are unable to use the latest scientific innovation for increasing their standard of living

1.3 In view of the poor economic condition, farmers are unable to purchase commercial fuel like kerosene, L. P. gas etc. and they have to mainly depend on the non-commercial fuels like fire wood, cattle dung cakes and agricultural wastes which encourages reckless denudation of trees to meet the needs of fuel and also starves the soil by lack of organic manure which is converted into cattle dung cakes and used as fuel. This in turn disturbs the ecological balance and adversly effects the rain fall.

1.4 In the context of energy crisis cost of commercial fuel is increasing day by day. This forces the farmers to mainly depend on non commercial fuels. Cattle dung is one such source which can be used as a source of energy and at the same time it can be used as manure by processing through gobar gas plants.

1.5 It is estimated that 980 million tons of cattle dung is produced in India, over 30% is burnt in the form of cattle dung cakes. If all this could be converted into gobar gas and manure, the country's supply of organic manure will increase by 114 million tons. At the rate of 25 tons per hectare this may suffice for 4.4 million hectares of agriculture land. Besides this it will give fuel enough for kitchen of 27 million families in villages (one family = average 5 persons).

1.6 In India the bio-gas plant is popularly known as gobar gas plant. Over 30,000 gas plants are already installed at the farmers' houses on decentralised basis.

(2) HISTORICAL:

2.1 Evolution of combustible gas in marshy places is known to man for ages. However proper understanding of this phenomenon and its application for digestion of sewage sludge has become possible only during the current century.

2.2 Scientists of Indian Agriculture Research Institute started work on anaerobic digestion of cattle dung in the year 1938. Due to the encouraging results in production of gas they saw that the process had a great future in a predominantly agricultural country like India where about one third of the cattle dung was used as domestic fuel by farmers for want of suitable alternative. One of the Scientists of Indian Agriculture Research Institute Dr. S. V. Desai started the study of anaerobic digestion of cattle dung in the year 1939. His work made available the data of anaerobic digestion of cattle dung for the first time in India. Further work was carried out by Prof. N. V. Joshi of Indian Agriculture Research Institute and a batch type digester was developed around the year 1946. The plant designed by prof. Joshi was having two parts, a digester and a separate gas holder. The cost of the gas plant was around Rs. 1800/- which used to produce 20 cft. gas every day. As the investment on the gas plant was high and the rate of gas production was not commensurate with it this design could not become popular in India.

2.3 Further work was carried out by Mr. Y. N. Kotwal and Mr. Borker of Dadar Sewage Purification Centre, Bombay and it was observed that addition of cattle urine to the gas plant along with cattle dung was helpful and reduces the detention period and also helps in increasing the gas production.

2.4 In the year 1951 Mr. Jashbhai J. Patel, designed a gas plant entitled Gramalaxmi-I with digester and gas holder as a single unit instead of two separate units as designed by the Scientists earlier. The gas plant designed by Mr. Patel also cost Rs. 1800/- and about 200 cft. of gas was produced. The gas plant designed by Mr. Patel was of continuous fermentation type with detention period of 50 days instead of batch type digestion of 7 days as tried by Dr. Desai and Prof. Joshi.

2.5 Further research work was continued by Mr. Jashbhai J. Patel and he designed the Gramalaxmi-II which could not work properly. In the year 1954 Gramalaxmi-III was designed by him which gave better results. The special feature of the Gramalaxmi-III was that the digester was constructed in brick masonry below ground level having 2 pipes one for feeding and another for taking out the fermented slurry and the digester was also divided into 2 parts which almost served as primary and secondary digesters. The detention period was also standardised around 50 days. Similarly the gas holder was designed to deliver the gas with constant pressure of 3- to 4″ water column, without using any counter weights for regulating the gas pressure. The drum was centrally supported by a guide pipe which helped in rotating the gas holder to break the scum and also to help as a stirrer, as stirring of the slurry was found to be helpful in increasing the rate of gas production.

2.6 In view of the initial success and acceptance of the gas plant by the farmers the scheme was adopted by the Khadi and Village Industries Commission (KVIC) as one of the Village Industries for propagation of gas plants, in the year 1962. As there was need to cater the requirement of the farmers who had different number of cattle heads ranging from 5 to 25 or more, 21 different sizes of gas plants were designed by the Commission, the sizes of gas plants varying from 60 cft. to 3000 cft. gas production per day. (Type Design-Annexure-A) Subsequently number of sizes of gas plants have been standardised to 14 sizes ranging from 2 cubic meter to 140 cubic meter.

2.7 With cattle dung it is observed that in India about 37 to 40 litres of gas is obtained per kilogram of green dung. This varies somewhat in different seasons. Maximum gas is produced in summer when the ambiant day temperature is around 35° to 40°C in most part of the country. In winter gas production drops as much as 40-45% in the colder northern Indian States, while in South India, it is affected to an extent of not more than 20%. The work on improving the design was continued. It was found that the digester constructed below the ground level having 12 to 20 ft. depth was more suitable as production of gas is less affected due to variation in atmospheric temperature.

2.8 Further research work was carried out and horizontal design suitable for areas where water table is high or where it is difficult to excavate pits more than 10 ft. deep due to hard rock was finalised (*Annexure-B*). This design was found suitable and was accepted by the farmers. However the cost of the same is 15 to 20% more than the vertical design.

2.9 Research work on designing efficient gas appliances was also carried out by the Commission and gas burners with 60% thermal efficiency were designed taking into account the composition of gas and the pressure at which it is supplied. Introduction of these efficient burners has standardised the consumption of gas for cooking to 8 to 10 cft. per day per person.

2.10 Research was also simultaneously undertaken to develop suitable lamps and also to run petrol and diesel engines on gobar gas. Accordingly suitable kit to run the diesel and petrol engines was developed by the Commission in the year 1966 and used in the field successfully.

(3) INDIA PROVIDES AN IDEAL SETTING FOR THE GOBAR GAS (BIO-GAS) PROGRAMME:

3.1 India perhaps possess more farm animals an ancient practice and every farm house rearing both for milk and farm work is an ancient practice and every farm house invariably possess a few animals.

3.2 Number of cattle in India today exceeds 270 million. Added to this is the number of sheep and goat, horses, pigs etc. Since both agricultural and dairy are conducted in small decentralised units, family gas plants are more feasible and popular than large size gas plants.

3.3 One additional reason for utilising animal droppings for generation of biogas is to avoid the use of cattle dung cakes for burnings as fuel in rural India. The Villagers are forced to do this owing to increase in scarcity of kitchen fuel. Increasing population has gradually depleted the fire wood sources and commercial fuels like kerosene, soft coke are not within the reach of the small farmers in view of their poor economic condition. Some times commercial fuel may not even be available in rural areas. The farmers, though they know fully well the value of cattle dung as fertilizer, resorted to its use as fuel. Biogas plants solve the problem of kitchen fuel and manure simultaneously.

3.4 On an average Indian cattle produces about 10 kg. of cattle dung which can produce 13 to 16 cft. gas per day in the tropical climate. In India the food habits of the rural folk are quite simple and fuel required per person per day is approximately 8 to 10 cfts. of gobar gas. Therefore a small gas plant of 60 to 100 cft.

gas per day can be operated with 3 to 5 animals (depending upon the size of cattle). This will be sufficient for a small village family to meet the requirement of fuel as well as one or two lights for a few hours.

3.5 It is also possible to use the other animal wastes like poultry droppings, sheep and goat droppings and night soil (human excreta) for production of gas. In the case of farmers having one or two cattle it is advisable to construct bigger size community gas plants pooling the available dung and night soil etc. to cater the needs of 8 to 10 families.

3.6 The gas plant can also be used as a means of disposal of human excreta by directly attaching latrines to the gas plant which may provide better aminity and improve the hygiene of the villages. It is also observed that addition of night soil to the gas plant along with animal wastes helps in production of more gas.

3.7 The work on constructing gas plants of community size to cater the requirement of the entire village has also been tried out. Efforts are being made to utilise the entire cattle dung available in the village along with poultry droppings, sheep and goats droppings, night soil, water hyacinth and other vegetable wastes. Few gas plants of this type are being installed, for observation.

3.8 A gas plant of 3000 cft. has been installed and put into operation to run a 10 HP diesel engine for generating a 7.5 kwh. electricity in remote rural area for electrifying a temple and holiday home of 20 houses. The plant is working since last 12 years.

3.9 Gas plants of 2500 cft. & above have also been constructed for industrial purposes like hot water boiler and for small scale soap making in Bombay.

3.10 A gas plant of 2000 cft. has also been installed near Bombay which works entirely on poultry waste and the gas is used for maintaining temperature of brooder house. It is reported by the owner of this plant that 100 kwt. of electricity is saved every day after installation of this plant.

3.11 Large size plants of 3000 cft. have also been installed for supplying energy to farm houses, hostels and hospitals and these plants are working satisfactorily.

(4) GOBAR GAS (BIO-GAS) PLANTS BRING ABOUT ALROUND TRANSFORMATION IN RURAL LIFE:

4.1 Gobar Gas plant supplies to the rural population efficient non commercial fuel which is produced locally reducing the pressure on the commercial fuels like kerosene, refinery gas etc. Non luminous blue flame of this gas makes cooking quick and keeps the kitchen and vessels clear. Rural house wife is freed from smoke and diseases caused by conventional fuels like fire wood, cattle dung cake etc. Since the work in the kitchen is done quickly the house-wives in villages will have time to devote for better purposes. The farmer will have privilege of introduction of modern technology in his house.

4.2 The manure from gobar gas plant is superior to ordinary farm yard manure. Moreover 10 tons of manure is obtained in place of 7 tons of farm yard manure from the same amount of cattle dung. The gobar gas plant manure contains more nitrogen compared to ordinary farm yard manure.

Experience and scientific research have shown that application of organic manure, rich in humus, increases the basic capacity of the soil to produce.

There is almost double as much humus in gobar gas plant manure as that contained in farm yard manure. The manure mixes much more readily with soil, improves its water retentive power and does not allow the plant food to be washed away in heavy rains.

The large quantity of humus contained in the gobar gas plant manure keeps the soils open and well aerated, helps the soils to hold moisture against seepage and evaporation. This is why less ploughing and interculature is required when gobar gas plant manure is applied.

The gobar gas plant manure contains weed seeds, thus the cost of weeding is minimised.

The farmers using gobar gas plant manure get anything from 25 per cent to 33 per cent more yield from their fields.

4.3 In addition to the direct benefits of gas plant narrated above there are some indirect social benefits too. In view of the totally decomposed organic manure produced from the gas plant the growth of mosquitoes and flies is restricted and the environment of the village is improved. Apart from this, the disposal of night soil in an hygienic manner prevents the spreadings of contagious diseases. In addition, the house-wife will get more time to give attention to the children and for other works as the time required for cooking is minimised. So also the time consumed earlier for preparing cattle dung cakes and the time required for cleaning the vessels is saved. The house-wife using gobar gas for cooking is saved from likely diseases of bronchatis, eye trouble etc. which are otherwise found common due to inhaling of smoke with the use of fuel like cow dung cakes and fire wood.

(5) REVIEW OF THE PROGRESS SO FAR:

5.1 The installation of gobar gas plant in rural India was taken up for propagation by the Khadi & V. I. Commission in the year 1962 and over 30000 gas plants have been installed as on date, and it is targeted to install hundred thousand gas plants by 1980.

5.2 The gas production from the gas plants already installed and put into operation in the country works out to 65.70 million cubic meters, which is equivalent to 40.73 million liters of kerosine valued Rs. 41.13 million (4.6 million dollars).

5.3 The manure which is produced from 30,000 gas plants alerady installed comes to 66.9 million tons which was otherwise burnt as dung cakes. The value of the manure as per local market value prevailing in India will be Rs. 33.78 million (3.72 million dollars).

5.4 As mentioned in the foregoing paras to utilise the night soil in the gas plants, 10,000 latrines were constructed and connected to the gas plants.

5.5 For the easy handling and transportation of fermented manure which comes out from the gas plant is in the semi fluid form, farmers are encouraged to compost the same along with other agricultural wastes which helps to produce better quality of organic manure and adds to the income from the gas plant. This also helps economic disposal of agricultural wastes like wastes fodder, weedings etc.

5.6 *Village level plant.*

At present the gas plants are constructed mainly for the farmers who are having the required number of cattle for operating the plant. It is also necessary to make some arrangements for small farmers and the landless labourers who are not owning any cattle, or else the problem of getting them alternative fuel will remain unsolved. In this context it has become necessary to think in terms of establishing village level gas plants. In establishing village level plants, certain factors such as operational and maintenance arrangement, distribution of gas and high initial investment involved on distribution lines, so also the cost involved in collection of cattle dung etc. are to be sorted out and suitable solutions are to be found out. Efforts in this direction are being vigorously persued and a beginning is made in certain pockets.

(6) ORGANISATIONAL SET UP:

6.1 The implementation of gobar gas plants in India has been entrusted to Khadi & Village Industries Commission which spearheads the programme for the rural uplift in the country. It is included as one of the village industries and the programme is implemented with the help of the Commission's massive network spread all over the country. Technical staff, trained workers and State level organisations created for implementing the schemes of Khadi & Village Industries, are harnessed for this work of national importance.

6.2 To promote this scheme a pattern of financial assistance was formulated. Initially financial assistance was given in the form of part grant and part loan, free of interest repayable in 10 years. With this pattern the Commission introduced the scheme in villages and constructed about 6,000 gas plants by December 1973. In view of the successful working of these gas plants the demand quickly increased. At this stage the scheme for financing the installation of gas plants by the Banks was introduced. Since the Banks charge interest on the loan sanctioned by them as against the Khadi & Village Industries Commission's loan given interest-free for longer duration, the Govt. of India introduced a scheme of subsiding the capital cost as a sort of incentive. The subsidy is for five years, beginning with 25% of the estimated cost of the plants for first two years and then 20% for next two years and 15% in the final year.

6.3. After October, 1973 the demand for gas plants increased steeply due to the fuel crisis and the sharp increase in the cost of petrolium products. Vigorous efforts were made and the field machinery was geared up, to meet the demand. In consequence in the year 1974-75, 10,000 new gas plants were installed against 6,000 gas plants constructed in the previous one decade. It was then decided to install 1,00,000 plants by 1980.

6.4 The Khadi & Village Industries Commission has designed different types of gas plants to meet the requirement of farmers and assist the farmers in construction of plant in the rural area by providing free technical guidance through Commission's technical staff posted all over India. In addition to regular technical staff of the Commission a large number of educated unemployed persons are given training and then in turn help the farmers in installation of gas plants. They are given remuneration for rendering the service by the Commission or local Government. Arrangements are made for manufacturing and supplying equipments, such as gas holders, burners, lamps etc. through recognized workshops situated all over the country.

(7) PROSPECT FOR FUTURE:

7.1 It is possible to establish 4 to 5 million gas plants in 550 thousand villages of India. This would provide energy to substitute commercial fuel equivalent to 5431 Million liters of kerosene valued Rs. 5484 Million (609 Million dollars) and it will also be helpful in conserving organic manure to the extent of 89.3 Million tons valued Rs. 4464 Million (496 Million dollars) which is otherwise burnt as dung cake. Only a beginning has been made in that direction. The task before collosal that all possible resources will have to be pooled to fulfil the target.

(8) RESEARCH & DEVELOPMENT:

8.1 Commission is engaged in further improving the efficiency of the existing gas plant, appliances and other gadgets. Research work is in progress for reducing the cost of gas plant by using alternate materials of construction. Some research projects undertaken by the Commission are:

1. Study of fermentation kinetics.
2. Improvement in domestic burners.
3. Use of alternate materials for cost reduction.
4. Maintenance of optimum temperature in the digester during winter for optimum gas production.
5. Development of small I.C. engines to operate on small size gobar gas plants to provide energy for domestic use.

Research work is also carried out by other national research laboratories like

Indian Agriculture Research Institute, Planning & Action Research Institute, National Environmental Research Institute. Central Building Research Institute, Indian Institute of Science etc.

(9) TRANSFER OF TECHNOLOGY:

9.1 Designs of gobar gas plant used in India are suitable for adoption in tropical countries like Africa, Asia and the pacific. The Khadi & Village Industries Commission is giving technical know-how to the following countries.

1. Tanzania
2. Botswana
3. Sri Lanka
4. Iraq
5. Nepal

9.2 Besides, technical know-how the Commission is also sending technical experts to some of these countries as and when called upon to do so. Moreover the Khadi & V. I. Commission is arranging training for the personnels deputed by other countries in installation and maintenance of gas plants.

(10) INTERNATIONAL ASSISTANCE:

10.1 As already mentioned the cause ot spreading the programme everywhere is of such importance and is so stupendous that time has come for seeking global cooperation in meeting the challenge. Through Bank finance, it has been possible to extend the programme at gallopping speed during the past four years. However, the heavy rate of interest involved still keeps some of the needy farmers beyond the orbit of the programme. India is in immediate need of about 30 million dollars of soft loan for keeping pace with accelerating demand. In fact the demand is almost growing in geometric proportion as can be gauged from the following figures.

GAS PLANTS:

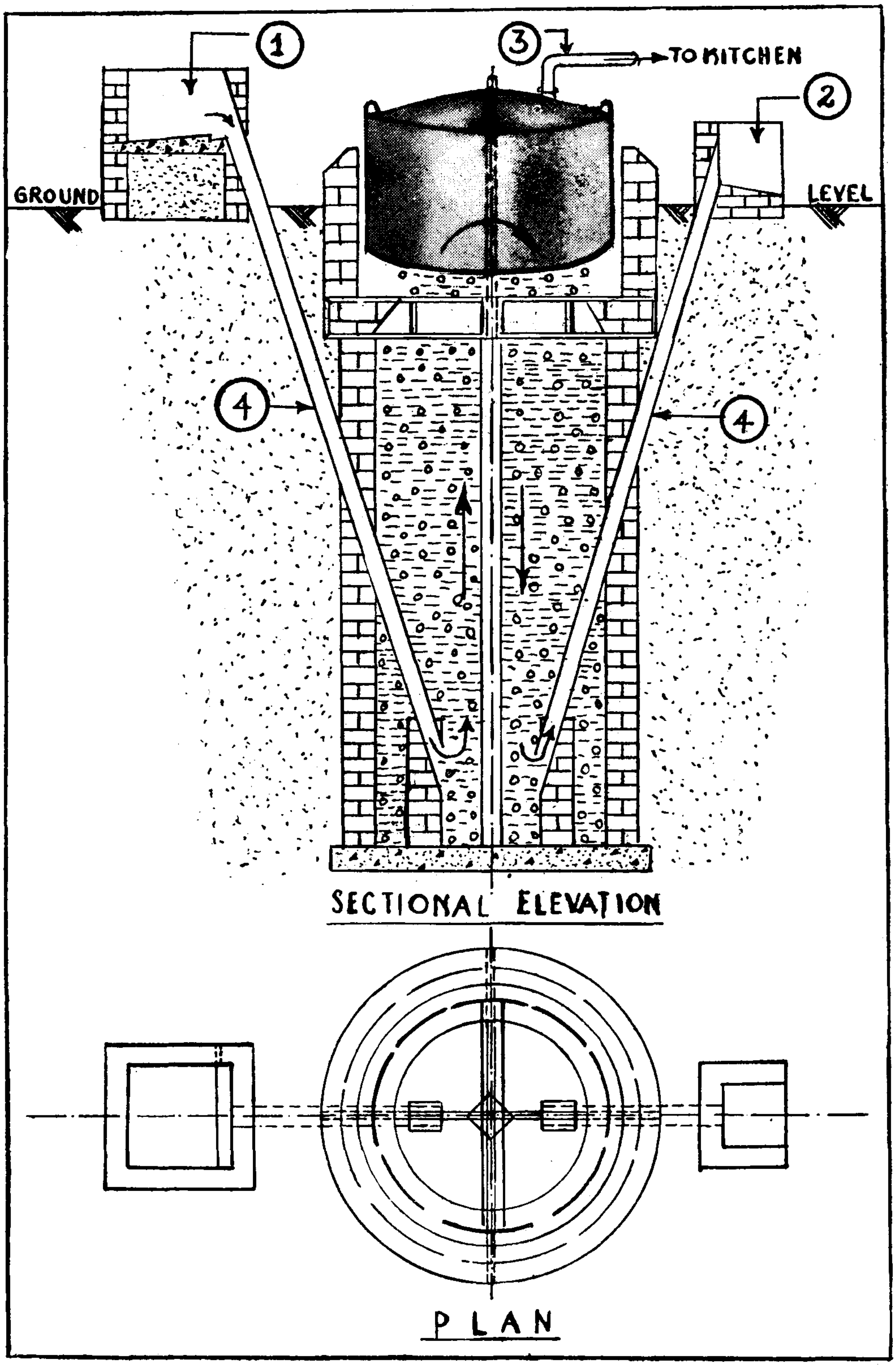
Year	*Gas plants completed*
1962-1973	6002 nos.
1973-1974	856 nos.
1974-1975	6650 nos.
1975-1976	13476 nos.

Complete report yet not received. The figure represents projection on the basis of available information.

I therefore appeal to this august assembly to consider this problem and to make suitable recommendation.

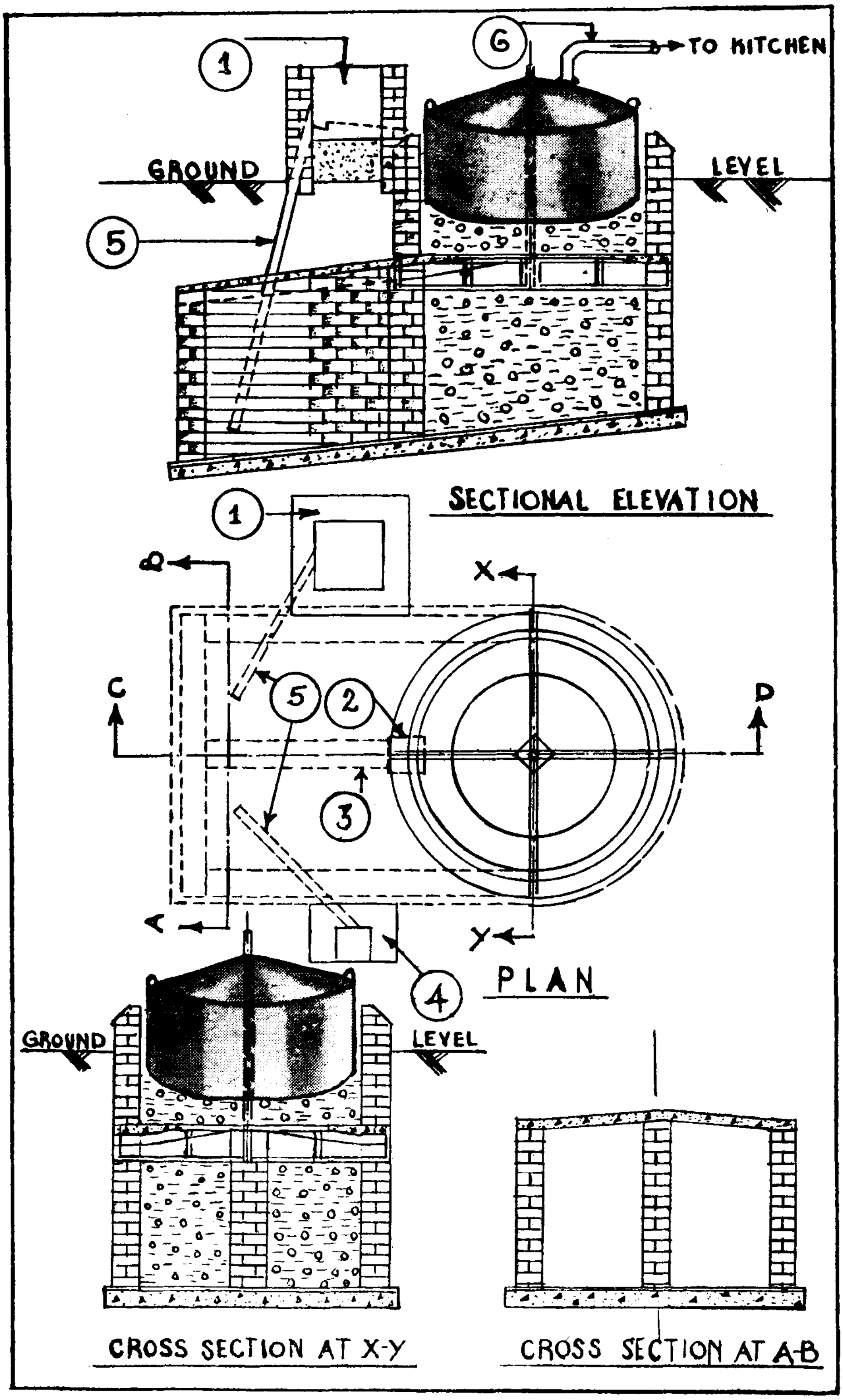
10.2 It is also necessary to establish a comprehensive Research Organisation to deal with all the unsolved problems The number of such problems is a legend. India can aptly provide the infrastructure for such an international effort.

Annexure - A



Vertical Type Design

Annexure - B



Horizontal Type Design

Pig & Poultry Wastes in Hong Kong

by P.G.C. Isaac and J.E. Revell

PIG AND POULTRY WASTES IN HONG KONG*

Peter C.G. ISAAC

and J.E.J REVELL

Hong Kong is a small British colony, consisting of 236 islands and islets, and territory on the mainland of China, not far from Canton. The population of Hong Kong is over four million, principally Chinese, who have a very strong preference for freshly slaughtered meat and fish, and for very fresh vegetables. This preference, which must be accepted at present as a basic factor in the problem of agricultural pollution, calls for the import of 7-8000 live pigs per day, and stands in the way of the development of frozen food as part of the diet. In the face of this demand for very fresh food Hong Kong's agriculture has developed on just over 110 of the territory's 1000 km^2. A slightly smaller area is built on and the remainder consists of steep, unproductive hillside.

At present the territory's farmers, just over 2% of the economically active population, supply about one-half of the fresh vegetables, one-half of the poultry and one-ninth of the pigs eaten in Hong Kong. The growing of vegetables and the raising of livestock are carried out in urban as well as rural areas, wherever tiny pieces of land can be put to agricultural use. Farming is carried out mainly in the New Territories and livestock raising is principally in the northwestern parts. Although this area is described as rural, a helicopter flight over it showed that the extent of building on the habitable parts provided a more urban pattern with strip development along almost all major roads. Industry, housing and agriculture are closely interspersed, and render it almost impossible to prevent completely pollution from agricultural wastes.

The livestock population varies with profitability, and the number of both pigs and poultry have risen from the pre-1965 low level. There are at present some 5 million poultry and 400 000 pigs. The livestock industry is very sensitive to feed costs and the current high cost of animal feed tends to restrain these numbers, and offers a possible outlet for dried poultry manure. For comparison, it may be said that the human population of the New Territories is some 400 000. The 'population equivalent' of the pollution from livestock is, therefore, substantially greater than that of the inhabitants of the area.

*This note is published with the permission of the Director of Agriculture and Fisheries, Hong Kong.

Environmental Resources Ltd., in a major survey of pollution in the colony, carried out in the course of advising the Hong Kong Government on proposed legislation for the control of all kinds of all kinds of pollution, estimated that the total BOD reaching Hong Kong waters was some 334 000 kg/d, of which just over 13% was contributed by agriculture. Only some 15% of this BOD reaches fresh waters, and of this 52 000 kg/d of BOD Environmental Resources Ltd. estimates that 86% is contributed by agriculture. Probably four-fifths of this pollution comes from pigs, and the remainder from poultry. This causes considerable pollution of the lower reaches of the stream courses, many of which are more or less without water in the dry season, which fortunately falls in the cooler months of the year.

The effects of this pollution are very greatly aggravated by the dumping of relatively inert rubbish in stream courses and on the banks of rivers. The organic wastes are dammed by obstructions formed by plastic sheets, bamboo baskets, dead animals and other solid refuse from the neighbouring community.

No doubt, pollution from agriculture could be completely prevented by eliminating the raising of livestock in the territory. This is, clearly, quite unrealistic, since this livestock would provide a vital 'strategic' buffer of the most important protein sources, if the daily imports should be cut off for any reason. The industry offers an outlet for considerable quantities of waste food which in itself could become a serious pollutant and it is estimated that 30% of the local pigs are currently swill-fed. A relatively stable agricultural industry also prevents a mass exodus to towns in search of work which would further aggravate current housing problems.

MITIGATING THE POLLUTION

It is no longer proposed to use the polluted streams in the north-western New Territories as a source of potable water. On the other hand, they are widely used for irrigation and by pond-fish farmers. It is necessary, therefore, materially to reduce the pollution reaching these stream courses and this requires at least four parallel lines of attack:

1. More effective collection of solid refuse.
2. A change in the wet-cleaning husbandry methods for pig houses.
3. 'Disposal' of the separate solid pig manure.
4. 'Disposal' of poultry manure.

Only the last two of these are of immediate concern to the Seminar, but the first two must also be briefly discussed, since they bear on the overall problem of agricultural pollution.

Collection of Solid Wastes

It is clearly essential to the alleviation of the stream-pollution problem that the refuse collection should be improved and extended, so that such collection is more convenient to the farmer (and his neighbours) than dumping the solid wastes in or by the nearest stream course. Some form of collection of the solid wastes from pigs and poultry will also be necessary if these are to be centrally treated for disposal or reuse. Arrangements can, at a cost, be made to collect solids where the premises can be reached by road, but this is not the case for all farms; many of the farms can be reached only by narrow, winding and often steep paths, too narrow for anything but hand-trucks. Perhaps half of the farms fall into this category and, in their case, it may be necessary to offer some incentive to the farmer to bring his solid wastes (refuse, or pig or poultry manure) to a central collecting point.

It should be remembered that all such farmers currently transport pig feed to their farms, including swill and grain, and pigs from their farms to market. It should, therefore, be possible with their existing facilities to transport manure to central collection points. If on-farm storage techniques can be developed to partially dewater these manures and encourage anaerobic degradation, to make them less offensive, the task of moving the solids to collection centres would be made easier. In the early stages of such collection schemes nominal prices could be paid for manure, providing farmers were on hand at collection times to help load it onto the lorries, and that other wastes, such as dead animals, refuse, bottles etc. were kept out of the manure.

Several small pig farmers already muck out dry using a flat bucket into which the faeces are brushed. This simple system is quick and does not place a heavy demand on labour. Manure is normally stored in cane baskets which allow it to dewater and which are readily transportable. However, as yet, it has proved difficult to develop mechanical means to lift and move manures. Manure augers have been found effective when the moisture content is above about 75%, or when it is dried to a granular form, but in the region of moisture contents between these states, when it has a very cohesive nature, it has proved difficult to ensure that manure 'flows' into the auger as it tends to 'tunnel'. Such difficulties make manure-collection systems very demanding on labour.

Initially it is essential that farmers and others in the rural community are educated to the need for pollution control. Several successful 'keep Hong Kong Clean Campaigns' have already been mounted in urban areas and a similar approach will probably be tried for rural areas. The emphasis will always be on self-help, but clearly farmers need to be shown reasonable means of treating and disposing of their wastes, to make such schemes effective, and workable legislation is required to penalize those who refuse to cooperate.

Cleaning of Pig Houses

The majority of pig farms have less than 100 pigs (this includes weaners, porkers, sows) and are worked by a farmer, who may be part-time, and by members of his family. The farmer, therefore, adopts the simplest method of cleaning out his pig houses - he hoses out urine and faeces directly to a stream course or drainage channel. The pollution could be very substantially reduced if the faeces were handled dry for off-site disposal, and if only urine and relatively clean washings were discharged to the stream. As an alternative, or complementary system, which may not be possible in every case, it is envisaged that the outlet from the pig house could be made to flow through a sump or settling tank, which would serve to trap the solids, allowing the supernatant to overflow to the stream. The settled solids would have to be removed by special suction equipment. With pig manure such systems are normally complicated by the large volume of lightweight coarse solids which form a floating scum in settling tanks. These can only normally be separated by mechanical means such as vibrating screens, roller presses etc. which, because of their cost, are only suited to large farms. The first alternative is the simpler and is generally preferable for Hong Kong's conditions. It is paralleled by the methods of handling cattle faeces in lairages, but would require much greater cooperation from the farmer, and, again, may require incentives.

'Disposal of Manure'

At present cattle manure from the airy farm at Pokfulam on Hong Kong Island is sprayed by sprinkler systems as a slurry onto hillsides planted with Napier Grass, which is later cropped and fed to the cattle. Although much of Hong Kong is steep hillside the scope for such disposal for pig and poultry manure is, however, severely limited by the lack of social acceptance of such systems. Also cropping hillside grass is expensive, and an alternative such as sheep grazing would pose difficult management problems and would be unpopular as the local Chinese community do not like lamb or mutton.

Wet poultry manure is already widely used as a source of nutrients by pond-fish farmers. Cane baskets full of manure are hung around the sides of the fish ponds and nutrients leach out from these into the ponds. The fish cultivated in these ponds, mainly carp, feed on the plant and animal life supported by these nutrients. The extent to which poultry manure can be used in this way is limited by deoxygenation problems in warm summer nights. Currently work is being carried out to look into the feasibility of mechanical aeration for such ponds which will increase this outlet for the manure and considerably increase their yield.

Red worms (chironomid larvae) used for feeding tropical fish are also cultivated in shallow ponds fertilized with poultry manure. These ponds are usually about 0.3 m deep and the worms are sieved out from the mud on their floor. There is a limited outlet for this purpose, but it is a very profitable enterprise and all avenues of disposal, however, small, need to be encouraged.

Sun and air-dried poultry manure is already used as a fertilizer during winter months, but in summer farmers feel that the rapid decomposition of the manure 'burns' their crops. Partially dried pig manure is generally more popular than poultry manure with vegetable farmers and flower growers in summer months but is not readily available.

It is estimated that 50% of poultry manure is currently recycled, but increases in existing outlets will probably require the manure to be at least partially dried and more easy to handle. To investigate this a pilot continuous-fed drum-drier was installed in 1974 at Pat Heung to dry poultry manure from neighbouring poultry farms. As a result of experience with the continuous drier a batch-drier has been ordered for testing on pig and poultry manure, and should be operating by the beginning of 1977. At the same time as the experimental drying of poultry manure tests are being carried out on the use of dried poultry manure as a fertilizer and as an additive to animal feed.

In addition to thermal drying techniques simple on-farm storage-drying systems are being developed, which will not only make manures drier but also less noxious. In all such systems a balance is needed between optimum moisture content of the dried manure, its sterility, and the cost of meeting these conditions.

POULTRY MANURE

The pilot drum-drier was supposed to dry poultry manure from about 40 000 birds from a moisture content of 75% to 10%, when operated for about 60h per week. This is equivalent to drying 450 kg/h at 75% to 120 kg/h at 10% moisture content. A small drier was selected because it was to be used as a pilot scheme.

A private haulage contractor collects the raw wet manure from the farms and delivers it to the drier. A very small number of largish farms have been involved in the scheme, so that the collection system operates well. The wet manure is collected in baskets or drums, and these are emptied directly into a storage hopper. This tank has only about one ton capacity and when full the baskets have to be stored alongside it. This has given rise to localized fly and odour problems.

The rate of the throughput is controlled at two stages: by means of the screw feed at the bottom of the storage tank, and by the speed of rotation of the drying drum, which governs the retention time. This produces a control system which is both sensitive and complicated, and which requires almost contant, skilled supervision.

The moisture contents of poultry manure collected from a number of farms can vary appreciably and with drier cohesive manures it is often difficult to regulate flow into the drier. Trials are now being carried out with a weighted cover on the storage tank which it is hoped will squeeze manure into the screw feed system.

The dried product is carried away from the drum by a belt conveyor to a vibrating screen to separate coarse solids. The plant, as installed, took the screened, dried manure to a storage hopper, but it has been found that this caused the dried product to retain its heat for a considerable time. Bagging the manure while hot may give rise to odour problems in the bagged product. The hot, screened, dried manure is now spread out on the concrete floor, which allows it to cool and permits remaining noxious gases to escape.

At least two people are required to lift and empty the baskets into the storage tank, and two are required to bag the cooled dried product, one to hold the bag while the other fills it. During the experimental period three staff were employed at the drier; this could be reduced to two on the present equipment. The cooling and bagging arrangements, and the method of collecting and handling the wet manure would require to be improved before it was possible to reduce the labour to a single man, and he would need to be a skilled operator.

The moisture content of the wet manure varies quite widely, from 65% in winter to 80% in summer, but the product must be dried to a consistent moisture content. The performance of the drier varied very widely, but never reached that claimed by the manufacturers, as shown in Table 1. It will be seen that the fuel requirements are substantially higher than claimed by the manufacturers, with a consequent increase in operating cost.

TABLE 1

PERFORMANCE OF DRUM DRIER AT PAT HEUNG
(December 1974 - December 1975)

	Maximum	Minimum	Average	Manufacturer's claim
Wet-manure feed rate kg/h	355	102	238	450
Dry-manure output rate kg/h	71	31	48	124
Oil fuel used per tonne dried product -litres	630	326	467	227
Water driven off per litre fuel used - kg	6.9	3.3	4.7	11.6

The costs have been determined over the trial period, but this was not a commercial operation, and required a relatively large staff. Calculations have been made for 'commercial' operation for 40h per week, assuming a regular supply of wet manure. The staff would be reduced to a single skilled person. The drier was written off over a working life of 15 600 h, but no interest was allowed on the capital cost. The average costs for power, maintenance, manure collection and miscellaneous were determined from the trial period. These costs, which are given in Table 2, show that dried poultry manure costs HK$650 per tonne, which is high. This represents about HK$9.75 per bag of 25 catties (15 kg), which is probably rather more than they can be sold for. (But it must be remembered that, in Hong Kong, the primary reason for drying is to prevent pollution; the recovery of a reusable product is valuable chiefly in reducing the cost.) At present dried poultry manure is sold for HK$25 per picul (60 kg), but this price is set to encourage farmers to test its use and value for themselves. Already the demand for dried manure greatly exceeds the supply.

TABLE 2

ESTIMATED COSTS FOR COMMERCIAL PRODUCTION OF DRIED POULTRY MANURE AT PAT HEUNG

	Cost per tonne dried product HK$	%
Fuel oil and electricity	217	33.5
Maintenance	24	3.6
Staff	103	15.8
Manure collection	116	17.8
Depreciation	159	24.5
Miscellaneous	31	4.8
TOTAL	650	

If the pilot drying scheme at Pat Heung is to continue the system will have to be modified so that it can be operated by one person and the capacity needs to be increased to justify his full-time employment. This would need two or three batch driers to be installed on the site. Bagging the dried manure can readily be improved using a portable bagging machine fed by an auger and capable of bagging 5 tons per hour; such machines are available commercially. The major problem is in devising equipment which will feed manures of varying moisture contents, consistencies, etc. into the driers.

It is possible that many of the problems experienced with small-capacity continuous-feed driers can be overcome with larger machines. However, such large machines are not at present considered suited to Hong Kong's conditions.

PIG MANURE

The Agriculture and Fisheries Department decided to look into the feasibility of setting up a system for collecting and drying pig manure, similar to that currently used for poultry manure but using a batch drier. The experience of operating the continuous drum-drier has led to the conclusion that a batch drier would be more suited to Hong Kong conditions, and the trial would not only look into the feasibility of pig-manure collection systems, markets for the dried products, and the economics of the system but would also test the use of such driers locally. A batch-drying process is much simpler to control; the time of drying is directly related to the input moisture content and is simply controlled by a time switch. Overdrying must be avoided, but underdrying can be simply dealt with by a short continuation of the drying operation. Agricultural batch driers can deal with organic materials as wet as blood from a slaughterhouse or as relatively dry as poultry manure. (Operating costs of batch driers, which we have seen in operation in the U.K., are substantially lower than those of the Pat Heung continuous-feed drum-drier.)

A batch drier has been ordered for pig manure and has just been installed. There is, therefore, no operating experience in Hong Kong.

Even if the pig manure is handled dry, as discussed above, it is likely to be wetter than poultry manure, with a moisture content of 80-85%. Preliminary estimates, for drying only one batch per day, give costs of HK$430 per tonne from 85% to 10% moisture content and HK$318 per tonne for 80% initial moisture content. The principal reductions are in depreciation and labour; the mechanical equipment is assumed to have a life of ten years and labour is limited to about one man-hour per batch. (These costs do not include the cost of collection, which can be substantial.) Batch driers also require minimal housing.

At present, costs for machine-drying pig manure are likely to be prohibitively high unless the moisture content of the collected faeces can be reduced prior to this. The Hong Kong Department of Agriculture and Fisheries has, therefore, designed a simple roofed bunker with underfloor drainage for preliminary drying of the wet pig manure. In addition to this the effect of varying times of storage in cane baskets on the nature of the manure is being investigated. Stacked baskets of manure will allow liquids to drain and, with anaerobic digestion, to become less offensive. However, during storage farmers may experience localized fly problems and odour problems, which may help to educate them to the problems that they are causing others by hosing manure into streams.

On-farm reductions in the moisture content of raw manures will not only reduce future machine drying costs, but will also reduce collection charges, since the weight of the manures will be reduced. Experience elsewhere has shown that it may be possible to reduce the initial moisture content to 60-70% by simple air-drying, at least during the dry season.

Uses of Dried Manure

The range of uses of raw wet poultry manure have already been mentioned, and at present it is estimated that 50% of this manure is recycled within the farming community. Little pig manure is used in this way, not because it has a low fertilizer value, but because faeces are not removed from buildings prior to hosing down and are not available for farmers' use. Many vegetable and flower frowers favour the use of pig manure, but its high percentage of coarse lightweight solids prevents its use as a source of nutrients by pond-fish farmers.

Partially dried pig and poultry manures have much the same uses as in their raw state; however, their reduced weight and less noxious nature make them more convenient to handle. Both raw and partially dried manures are capable of transmitting pathogens when used as fertilizers for vegetables. However, almost all vegetables are consumed by the local Chinese community, who have long since been aware of possible disease-transfer problems, and this has considerably mitigated possible public-health problems from the use of raw manures and polluted irrigation waters. Nightsoil has been used for many years by local farmers.

Machine-drying poultry and pig manure sterilizes the product and allows its use as an animal feedstuff. Elsewhere dried poultry manure has found favour as a substitute in the feedstuff for ruminants, but unfortunately this market is almost negligible in Hong Kong. Trials have been carried out with pigs but, although it was found palatable, reductions in weight gains made it uneconomical. It appears from local experience that for non-ruminants dried poultry manure is only suited to subsistence diets. No feed trials have yet been carried out with dried pig manure.

Machine-dried poultry manure has already proved popular with vegetable and flower growers, although prices have been subsidized by the Government to encourage its use. The current manure drier cannot meet local demands. Where available sun-dried pig manure is already popular with farmers, and it seems reasonable to presume that the machine-dried product will be popular also. The advantages of such dried manures are their sterility, convenience in handling and storage, and inoffensive nature. Trials on the use of these manures for the popular local type of vegetables, which are seldom seen outside China, are being carried out on Government Research Farms to determine the value of such manures. Values can be assessed, in terms of nutrient contents, but such an approach is rather academic, since several other factors affect its value.

It seems likely that nutrients in such organic manures will not leach out as easily as those in artificial fertilisers, and this is of considerable importance in countries with high rainfall. Nutrients from organic fertilizers are less readily available than artificial fertilizers, which is a drawback when the farmer requires immediate crop response but has the advantage that his land is gradually enriched. However it should be noted that, in countries with higher temperatures nutrients from manure are normally more readily available. Organic fertilizers also act as soil-conditioners. In order to accelerate the development of the use of machine-dried manure the product is sold at subsidized prices, and in some instances given away for specific trials. In this way farmers find uses for it themselves and assess its value. Once the product has been widely tried the sensitivity of the market to increases in price will dictate what farmers consider its value to be.

Wet poultry manure is already widely used as a source of nutrients by pond-fish farmers, but this gives rise to localized anaerobic conditions where manure leaches out from the baskets into the ponds. This effectively reduces the area of the ponds available for fish cultivation. Machine-dried manure can be broadcast over the pond to overcome this problem, and it also has the advantage that it is sterile. Wet manure provides nutrients setting up a food chain where the fish eat flora and fauna in this chain. Dried manure will also permit this, but also opens up the possibility of direct feeding as well. Trials are currently being carried out on the extent to which poultry manure can be used in this way and these will be extended to pig manure when the product becomes available. Similar trials will also be carried out with liquid effluents from pig farms.

CONCLUSION

In the northwestern New Territories of Hong Kong pig and poultry wastes cause more than three-quarters of the organic pollution of the stream courses. Landspreading of these manures and their direct use on the farm can, in the very crowded conditions of Hong Kong, do only a little to mitigate the problem. Artificial drying of these manures is necessary, therefore, to make them more easily reusable as fertilizer or animal-feed supplement. Continuous drying of poultry manure has been tried on the pilot scale, and results are briefly reported. Costs of the dried poultry manure are high, and the process requires continuous skilled supervision. A batch drier for pig manure has recently been installed and a pilot test will also be carried out on this. This paper outlines these tests and indicates the possible markets for the dried manures and their value in these markets.

There is no one solution for such pollution problems. Measures taken, and restrictions imposed, vary according to individual circumstances. The onus for tackling such problems must eventually rest with those causing them but advisory services are essential.

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The Problem of Utilization of Organic Waste of Italian Livestock Farms

by Ministry of Agriculture & Forestry, Rome.

THE PROBLEM OF UTILISATION OF ORGANIC WASTE OF ITALIAN LIVESTOCK FARMS

Ministry of Agriculture & Forestry, Rome

General survey of the problem

The demand for the so-called noble proteins is constantly increasing throughout the world, whereas production of the same is not able to satisfy demand. The method that has proved to be able to meet increasing demand is intensive livestock farming.

It is quite correct to say, therefore, that this method will make considerable progress, often because of "lack of land" and will not allow for a natural agronomic re-utilization of organic waste.

The waste is composed essentially of:

- liquid cattle manure
- swine waste
- chicken dung

LE The utilization of such organic waste realizes:

- savings in farm management, in that it replaces, even if only partially, mineral fertilizers the production of which besides requiring considerable energy (power) is becoming increasingly expensive and with an uncertain future ahead of it;

- greater agronomic fertility of the soil, based essentially on its organic content, which tends to decrease as a result of the massive use of mineral fertilizers;

- improved quantitative and qualitative production of the crops in the sense that organic fertilizers are, as everybody knows, more complete than mineral fertilizers;

- avoids discharge into surface waters,their pollution and eutrophisation;

- encourages the return to intensive livestock farming within the ambit of farms, moderating the phenomenon of "landless" cattle farms;

Finally, it should be held in mind that this type of utilization pursues not only an economic scope, but keeps an eye on ecology and health.

There exist, on the contrary, possibilities of damage:

- to crops and soil, if the doses are too heavy;
- to water beds, if the soil if permeable;
- to water in the canals, if there is surface runoff of liquid waste onto the farmed land;
- to man's health, if technical devices are lacking in the phase of transportation and spreading.

These issues are present in the same terms also in Italy, and some of their aspects are even more accentuated than elsewhere insofar as the self supply of meat is equal to two thirds of consumption and an increase in intensive livestock farming is predictable: so that recycling is all the more necessary in our Country.

According to national statistics the cattle herd is unfortunately decreasing in numbers on account of its scarce economic conveniency as regards both meat and milk production: the consistency of poultry is in a static phase, national and international markets having reached saturation; whereas the number of hogs and pigs is constantly increasing. From 1960 to 1975, in fact it has doubled and this rythm of growth is expected to continue. It must be held in mind, furthermore, that the present rate of growth of livestock in Italy will be concentrated exclusively on intensive industrial farms with little or no land at all.

Amount of waste

Surveys and appraisals indicate that the "constant load" of live weight - limitedly to our cattle, swine herds and poultry flocks - should be equal to 35.5 million quintals, 77% of which cattle, 17% swine and 6% poultry.

Livestock breeding in Italy: constant load, excrements and urine produced each year

(estimates in millions)

Species	N.of heads	Live weight (tons)	Excrements and urine (tons)
Cattle	8,5	2,75	83,0
Swine	9,0	0,60	12,0
Poultry	150,0	0,20	5,0
Total:	- - -	3,55	100,0

Said animal load produces each year a mass of waste equal to 100 million tons, four fifths of which are made up of manure coming from traditional livestock farms and are noramally re-employed on the farm itself.

The remainder, which is estimated at around 20 million tons and is produced by intensive livestock farms of the industrial type with little or no land at all, represents a problem of recycling, unless recourse is made to expensive purifying plants.

These 20 million tons - which tend to escape from agronomic re-utilization - are produced by intensive livestock farms the percentage appraisal of which is as follows: cattle 10% of the entire consistency, swine equal to 50% of the total number of the same and poultry flock 100%.

It is essentially all liquid or semi-liquid material produced by modern industrial livestock breeding, especially by swine breeding which makes use of huge quantities of water for scouring and cleaning purposes.

The aforesaid quantity might appear rather modest if referred to the national territory; but one must consider that such types of farms are almost entirely concentrated in the Po plain, wherefore the present degree of water pollution will further deteriorate.

The contamination affects, for the time being, to a modest extent intensive cattle and poultry farms, insofar as they utilize only minimum quantities of water for scouring purposes. Large quantities of water are employed instead for intensive swine breeding which leads to a problem of waste storage and utilization.

Therefore swine farms are the ones which actually represent a problem of how to re-utilize their waste, since this is diluted in a volume of water 4 to 6 times the amount of excrements and urine produced (on the whole an average of 10-15 cubic meters per head a year).

In short, if for every head of swine reared on intensive farms there are from 10 to 15 cubic meters of discharge water per year then for 4,5 million heads per year, which represent the consistency of our intensive farms, the polluting material should be around 45 to 70 million cubic meters.

Composition and value of waste

The composition of the 20 million tons of waste produced by industrial livestock farms - not always conveniently utilized as mentioned before - is synthesized in the following table:

Intensive industrial livestock farms in Italy: average content of the main fertilizing elements in excrements and urine

Species	Kg/ton		
	N	P_2O_5	K_2O
Cattle	5	2	5
Swine	10	6	7
Poultry	15	11	6
Total	30	19	18

It is a mass of fertilizing elements N,P,K, touching half a million tons and worth 100 million dollars.

To this must be added the enormous amount of scouring water, estimated around 45-70 million cubic meters, which could be utilized for irrigation.

Technical solutions

The economic impact of non recycling the liquid waste of livestock can be traced not only in the loss of the fertilizing nutritive value of the waste itself, but also to the environmental pollution a disorderly discharge is likely to determine.

Its utilization on the farm seems to be therefore the only possible way to guarantee, at the same time, the natural productive destination of waste thus avoiding the problem of water pollution with all its social and health repercussions, particuarly as regards swine owing to the enormous quantity of discharge produced and to the impossibility of equipping the Italian swine farms of unexpensive purifying plants. Moreover, the water discharged from the purifying plants are considerably eutrophysing.

It is nevertheless necessary to face the problem of storage and distribution which has found in Italy, among those concerned in intensive livestock farming, a solution in the so-called "lagoni" (small ponds scarcely deep) and in the distribution on the fields by means of fixed pipelines (1).

This allows to overcome the autumn-winter period when it is impossible to distribute the liquid waste with barrels, whereas during the spring-summer period the administration of the liquid waste is no problem at all.

Experiments have shown that the crops that better thrift by the administration of discharge water of swine farms are graminaceous forage and more in particular: sorghum, maize and "loiessa" whose production increases up to levels of distribution touching and exceeding 250 cubic meters per hectare. Such agronomic doses should not be surpassed if maximum productivity is to be obtained, avoiding losses, even when it is possible to double the doses without causing damage to the soil. Also the quantity of produce, and particularly its proteic content, are increased by treatments with liquid waste.

The presence in the liquid waste of additives normally added to feed - as also of medical products - does not seem to represent a problem for crops and farm soil. The latter, in particular, becomes enriched with nutritive fertilizing elements and demolishes, by means of microbic action, enormous quantities of organic substance.

(1) An efficient storage requires separation of solid matter which is normally buried under ground.

Finally it should be noted that the adoption of dry scouring systems which are already practiced in the most up-to-date farms of the north would solve by itself the entire problem of recycling.

The waste, being free from water, could be re-utilized by being buried under ground.

Summary and conclusions

The growing demand for proteic foodstuffs in Italy as throughout the world will increase the number of intensive livestock farms and this cannot but worsen the problem of the disposal of waste.

Italy, whose coefficient of meat self-sufficiency is equal to 2/3 consumption, has a constant livestock load in live weight, appraised at 3.5 million tons, that produces an amount of waste equal to 100 million tons.

Of these 100 million tons, 20 are produced by intensive industrial livestock farms, have an uncertain destination and tend to escape from agronomic re-utilization. They determine, therefore, losses and environmental pollution, especially in the Pò plain where livestock farms are concentrated.

Should the waste of intensive livestock farms, whose composition can be valued 100 million US $, be re-utilized it would produce savings for the farms, a reduction of energy expenses for the Country, increased fertility of the soil, better quality of plant products and cleaner waters.

However, the irration utilization of such waste could cause damage to the water table, to the crops, to surface waters and to man's same health.

The waste of intensive cattle and poultry farms does not represent at the present moment a problem, because it is used according to the traditional fashion.

The real problem is the one caused by the disposal of swine waste in that it is diluted in enormous quantities of scouring water estimated at about 45 to 70 million cubic meters a year.

Italy has adopted the system of "lagunaggio" (small shallow ponds) upon separation of the solid matter and distribution or spreading of the liquid part on graminaceous crops. Also dry scouring - which is already being practiced in the most up-to-date farms - resolves the problem of utilization.

Considering the fact that purifying plants are responsible for the eutrophisation of the waters of last destination, agronomic recycling seems to be the only possible means liable to guarantee a thrifty management for the farm and full respect for the environment.

"Salol" System for Simultaneous Recovery of Single Cell Protein (SCP) & Leaf Protein Concentrate from Grasses

by A.S. de Oliveira

In developing nations, to feed the growing population, to meet its energy requirements and to find a means of obtaining foreign currency, are among the problems facing their respective governments. Any contribution to their solution, based on the utilization of local renewal resources, should represent a permanent help to raise the standard of living of those peoples.

All those visiting the wet tropics are impressed by the massive quantities of spontaneous grasses, growing there which according to ancestral habits, are burned during the dry season. This burning which represents the destruction of proteins, animal feeds, edible oil, alchohol, potentially contained in this fantastic renewal source, yielding up to 300 tons of grass per Ha. and per year.

It is the intention of this Paper, not only to contribute to the utilization of spontaneous grasses of the wet tropics, but also to try an improvement of the processes actually used for alfalfa dehydration in developed nations.

Considering the enormous availability of spontaneous grasses in the wet tropics, the mills may have much higher capacity than in developed countries, so our considerations will be based on a hypothetic plant conceived for 25 tons of green grasses per hour.

According to the end product required, we may develop several types of plant, all of which producing juice as shown on Plate I.

The liquids cyclone assembly, as mentioned in Plate I, is impelled by a high pressure pump which delivers a pressure of $50kg/cm^2$ (750 psi) originating from the cyclones of 25mm internal diameter a centrifugal force of about 10,000 G, which is sufficient for the separation of part of the supended solids which pass the vibrating screen, as will the cellular material formed during the fermentative processes, which will be described later on.

The pump delivers about 12,000 litres per hour, and may be divided into two independent circuits, each producing 6,000 litres per hour or working at different pressures if required.

The following systems all obtain haylage for local consumption in attached feedlots, and/or grass meal, that eventually may be transported from the locality of production, but differ from one to another in their utilization of grass juices, as we shall see.

I. Single Cell Protein only

This is the system which requires the most reduced investment, and its flow-sheet can been seen in Plate II. The clarified juices are aerobically and anaerobically fermented.

During aerobic fermentation, the juices are recirculated by means of the pump of the liquid cyclones, through the O_2 dissolver. In the closed deposits of the liquid cyclones, a paste of cellular material is concentrated, which periodically is evacuated to the silo decanter,, where a solution of formaldehyde is added, in a proportion of 2% of the paste.

The action of the formaldehyde is to react with the membrane of the microorganisms, increasing its density and thus speeding the sedimentation and also preserving and sterlizing.

Over 65% solids have been produced in laboratory concentrations by this process.

After fermentation, the fermentor is drained and the effluents treated. The O_2 dissolver (mentioned in Plate II), is composed of two shell and tube condensers, equipped with a recirculating pump. This pump and the internal tubes are calculated in order to obtain Reynolds numbers of the order of 50,000.

As the liquids and air are injected simultaneously, and the back pressure valve keeps the internal pressure to about 15 psi inside the system, so by the action of turbulence and pressure, the liquid becomes satturated with 0_2, which assures a better utilization of the power than in an atmospheric pressure, in which the microorganisms use only 5% of the injected air.

The compressor supplying air to the 0_2 dissolver is based on a specially converted automobile engine, of air-cooled type, and this way we have been able to obtain a much cheaper machine than a conventional one of the same air capacity.

II. Leaf-Protein Concentrate, Edible Oil, and Single Cell Protein

The flow-sheet will be according to Plate III. The clarified juices are ultrafiltrated and their concentrate centrifugated to obtain edible oil, and then the defated solution is spray dryed. The permeate of the ultrafiltration is split by reverse osmosisin an effluent of low BOD_5 and the concentrate sent to the continuous fermentor.

Liquid cyclones remove the yeasts and send the clarified juices to a sub-micron filter prior to entering another reverse osmosis system, then passes through the 0_2 dissolver and returns to the fermentor. The permeate of this second reverse osmosis system will have a low BOD_5 effluent, as it is natural.

The yeast suspension concentrated in the closed deposits of the under-flow of the cyclone passes at determined intervals into the silo decanter to receive the formaldehyde treatment.

Alternatively, if desired, it may be spray or roller dried, in separate or mixed with the leaf protein concentrate.

III. Leaf Protein Concentrate, Edible Oil, Alchohol and Single Cell Protein

As can be seen from Plate IV in the present flow-sheet, the acquisition of oil, LPC, dried SCP and the fermentor supply are exactly as described above. For obtaining alchohol, the fermentation will be anaerobic and the bach type. By the precedent reverse osmosis system, the worth concentrated to the desired level will be used. After fermentation, the worth passes through the liquid cyclones to separate the SCP material, which will be spray dried. The loss of alchohol in this operation will be compensated for by the quality of the SCP obtained. The overflow of the cyclones is diverted to distillation systems for alchohol recovery. The hot stillage passes through a heat exchanger to produce hot air for the drying operation used in this system. If required, it may be considered for the use of stillage effluent treatment, with further SCP recovery, by the system that will be suggested in the final part of this paper.

Considering the large areas of the world where this process may be used, proper economic data is difficult to give due to the diversity of local conditions. Nevertheless some possible figures may encourage deeper studies in place, from which the proper decisions may be taken.

The total investment for a plant with a capacity of 25 tons/hour of green grasses, is estimated at $500,000; the required power at 180 hp; the yield for each ton of grass would be roughly 170 kg of a meal dried to 8% moisture, and 350 kg juice. Out of this juice, 1 kg oil is expected, 9 kg LPC of about 50% protein, and finally the choice of 2.5 kg or alchohol or 4 kg SCP. Taking for the grass meal the value in the international market of $100 per ton, the same as alfalfa meal, from each ton of green grass, we consider a gross income in the case of Plate II of $18; plate III of $20.50 and in the case of Plate IV, $20, even neglecting the value of the edible oil, which we think will be more than sufficient to cover the expenses of power, labour and administration. The alchohol recovered, we think, should be taken as a gazoline additive to save imports, and we admit that for the mentioned purpose, priced at 25 ¢ per liter would not be far from reality, considering the actual price of petrol.

The LPC and SCP for our considerations, was taken at $250, per ton, a figure we consider prudent, because is much lower than the actual price for fish meal in the international market. We have to deduct from the previous values of the recoveries:

1st – The cost of the grasses, which being spontaneous, is limited to the corresponding cropping expenses, plus the transport to the mill.

2nd – The fuel for drying operations, and eventually for distillation, which may be based on wood locally grown, usually having a low cost per calorie.

Stillage Effluent Treatment

In the present days of environmental conscience, the state and the public opinion are in strong favour for the reduction of pollution in waste waters, so its processing for removal of suspended solids and organic matter is no longer an option. The problem remains of how to meet the legal requirements without impairing the economy of the industry, considering the high investment and operational costs of a traditional waste water treatment station. This is the reason why we devised a system, having a mind to obtain SCP as a saleable product for animal feeding, to balance the costs and redeem the investment.

Fundamentally the system is based on alternative anaerobic and aerobic fermentation, thermophyle or mezophyle, followed by a centrifugation with liquid cyclones, chemical stabilization of the SCP obtained, and finally the UF and/or RC of the effluents already partially treated in the preceeding operations.

Very unfortunately it is not possible to present data and conclusions from our pilot plant, based now in four fermentors, having a total capacity of 90 m^3, because it is operational only a few days ago, but nevertheless the results already obtained, although they must be confirmed, points to its feasibility.

The system may be described as follows:–

A. **Primary Treatment** (plate V)

The effluent (I) passes through a static filter (2) and afterwards from the sedimentation tank (3) to the equilibrium and equalising tank.

B. **Secondary Treatment** (plate VI)

The pump (4) distributes the primary treated effluent simultaneously by the bottom of the anaerobic fermentors (5) in parallel, which overflow enters also through the bottom of the aerobic fermentors (6) placed in serie.

The pump (7) provided of by-pass, aspires from the aerobic fermentors, the airated effluents, introducing them in the anaerobic fermentors, to attend several variables such as, control of aggressive odors, temperature, ascencional velocity and the introduction of cellular material. At a certain hight, the anaerobic fermentor (5) forms a layer of microorganisms because the ascendional velocity of the fluid is inferior to the sedimentation of the cellular material.

One "L" shaped tube, that may rotate from the exterior, aspires from the zone of larger microorganisms concentration by means of a high pressure pump (8) and impels them through the liquid cyclones (9). The underflow of liquid cyclones is provided of specially closed deposits which decharge by means of a valve.

In this deposits, due to the centrifugal force developed, the microorganisms are concentrated in a paste of elevated solids content. From time to time,this valve is open, and due to the pressure existent in the cyclone system this paste is impelled to the silo(16), for chemical treatment and further sedimentation.

The overflow of the liquid cyclones is sent back to the aerobic fermentor (6).

C. **Tertiary Treatment** (plate VII)

Part of the overflow coming out of the aerobic fermentor (6) passes through a heat exchanger (10) of the shell and tube type, due to the convenience of obtaining a proper temperature in the terciary effluents.

We shall not comment on the flow-sheet of the terciary treatment due to its similarity to the previous one, as shown in the plate VII. As it is clear, the anaerobic fermentors act also as decanters, so its overflow is relatively free of suspended waters. This way it may pass a back flush type sand filter, followed by a sub-micron one.

D. **Polishing** (plate VIII)

We may consider here two solutions, which are the use of UF followed by RO or simply RO.

In the first case, the sand filtration and sub-micron filtration is followed by UF. Its permeate may be used as an effluent, if accepted by the authorities, or goes to the RO treatment, which yields a very low BOD_5 effluent.

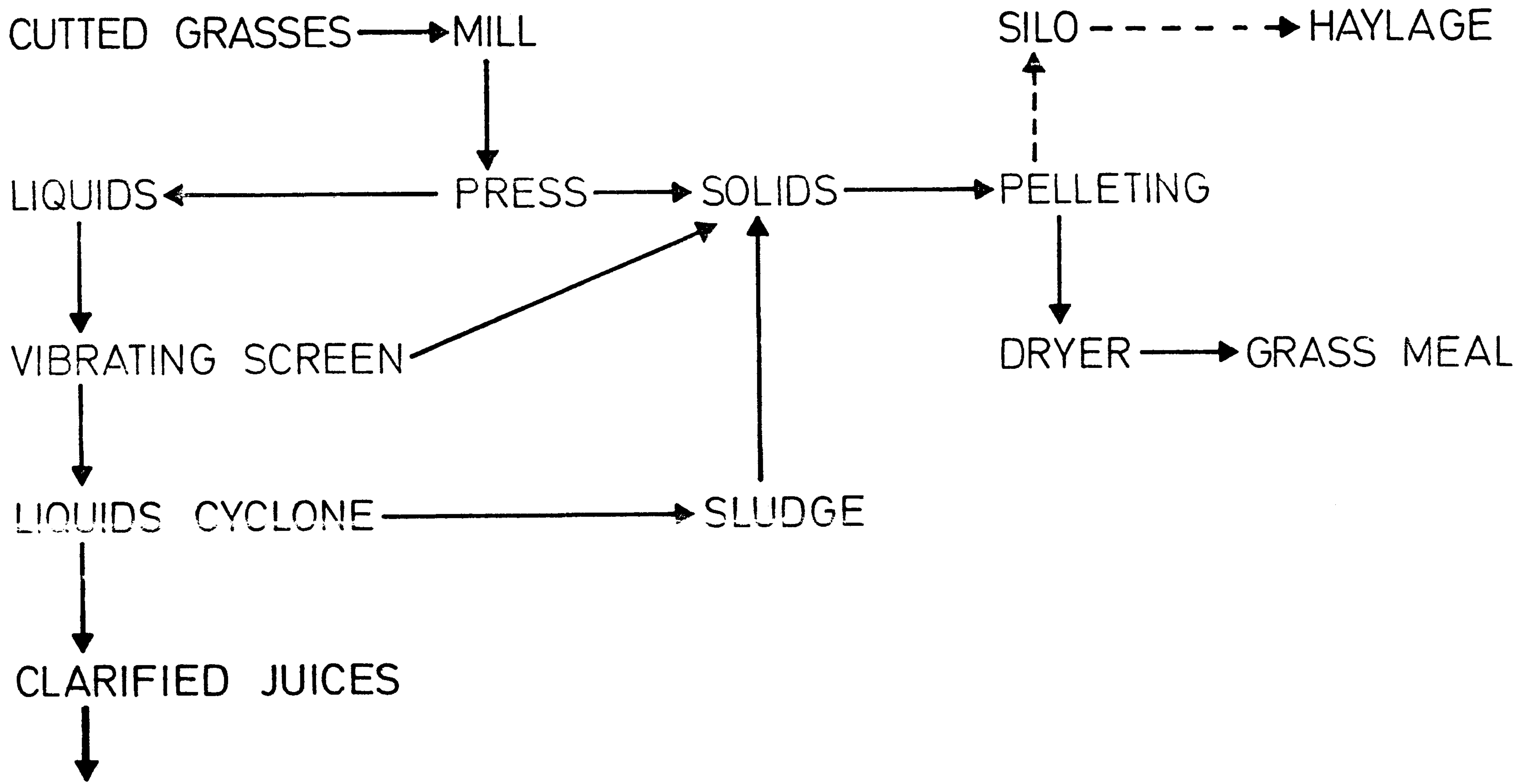
The back-flush of the sand filter, the UF concentrate which contains enzymes that will contribute to speed the operation, and the RO concentrate will be sent back to the anaerobic fermentor (5) of the secondary treatment. In the second case, the UF is suppressed and the effluents will be treated only by RO. Starting with a BOD_5 of 20,000 ppm, we expect to reduce it by fermentative processes in 84%, which means 3,200 ppm. As RO lowers this value in 97% the final effluent is expected to have 96 ppm, which means a reduction over the initial value of 99, 52% and a figure that many of the different authorities will accept.

In some cases, due to the presence of phenolic compounds, it might be required to introduce an active carbon treatment before the RO. We think that the ways we pointed out in this progress report may encourage pursuance of the investigations of this matter, which if successful, will provide food and energy to the needy developing nations of the wet tropics.

Thank you.

Note – This paper is based on papers No. 285 and 33, presented at the *Thirty-Sixth Annual Meeting of the Institute of Food Technologists*, Anaheim, California on June 6 and 7 1976.

PLATE - I



CUTTED GRASSES
MILL
LIQUIDS
PRESS
SOLIDS
PELLETING
SILO
HAYLAGE
VIBRATING SCREEN
DRYER
GRASS MEAL
LIQUIDS CYCLONE
SLUDGE
CLARIFIED JUICES

PLATE - II

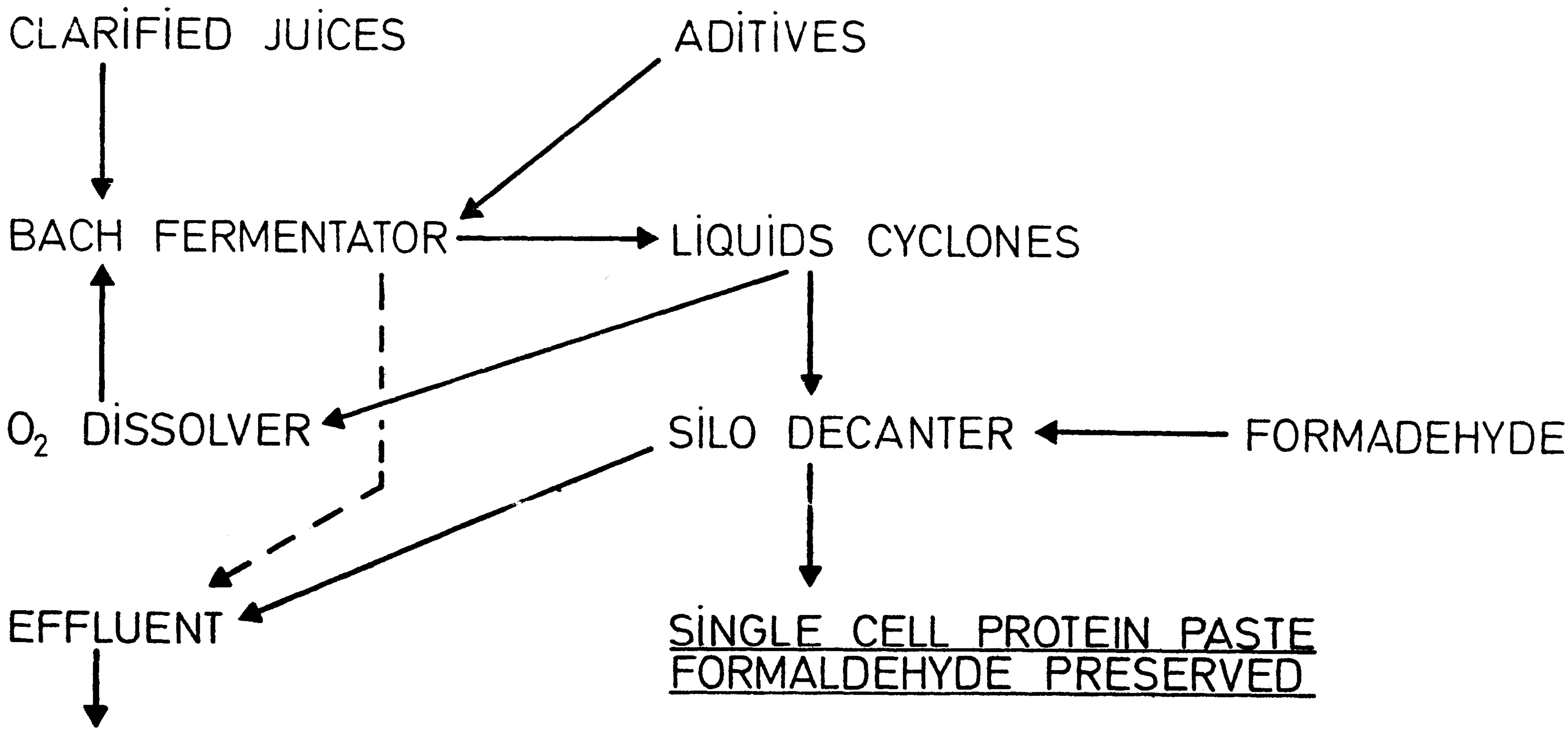
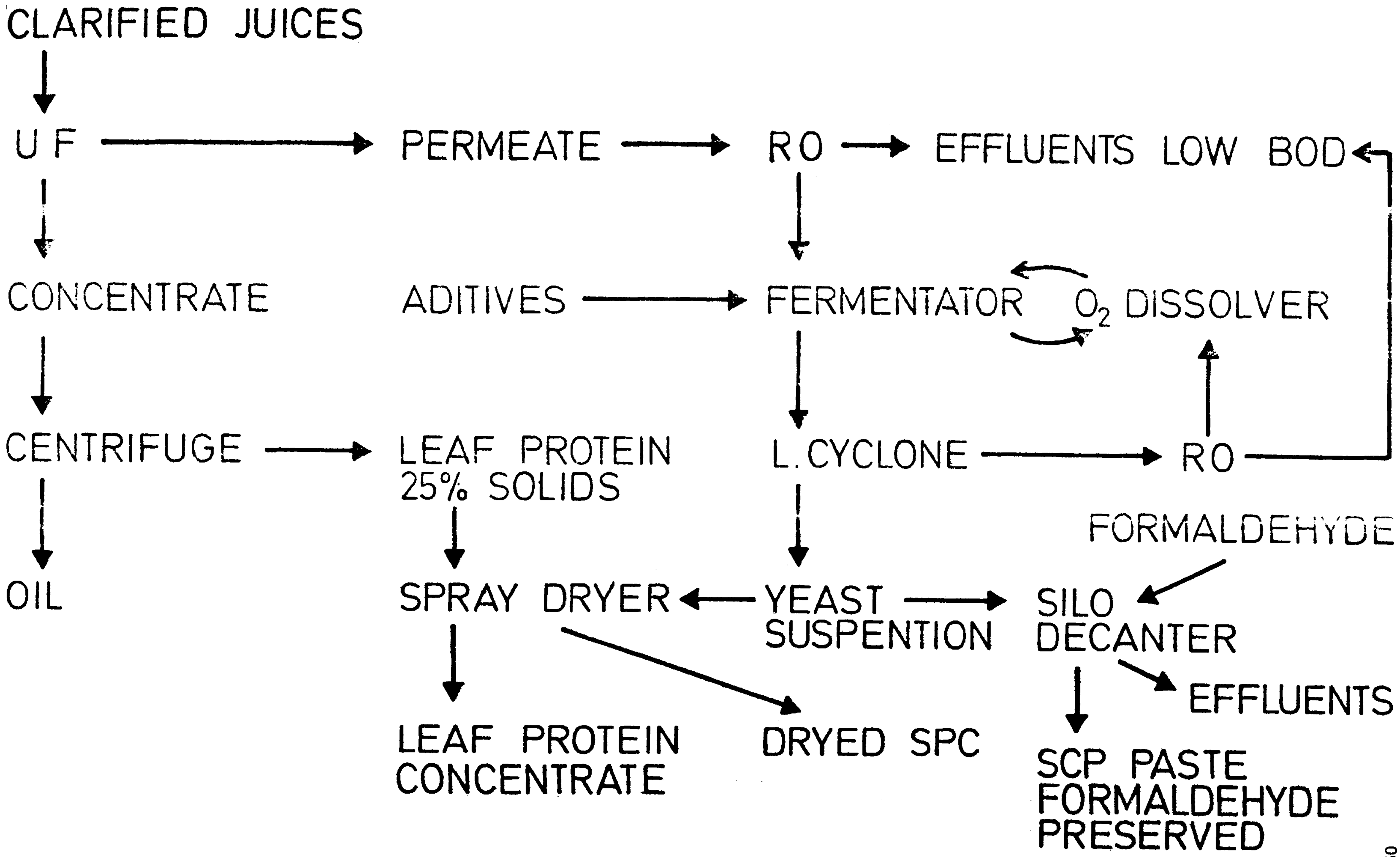
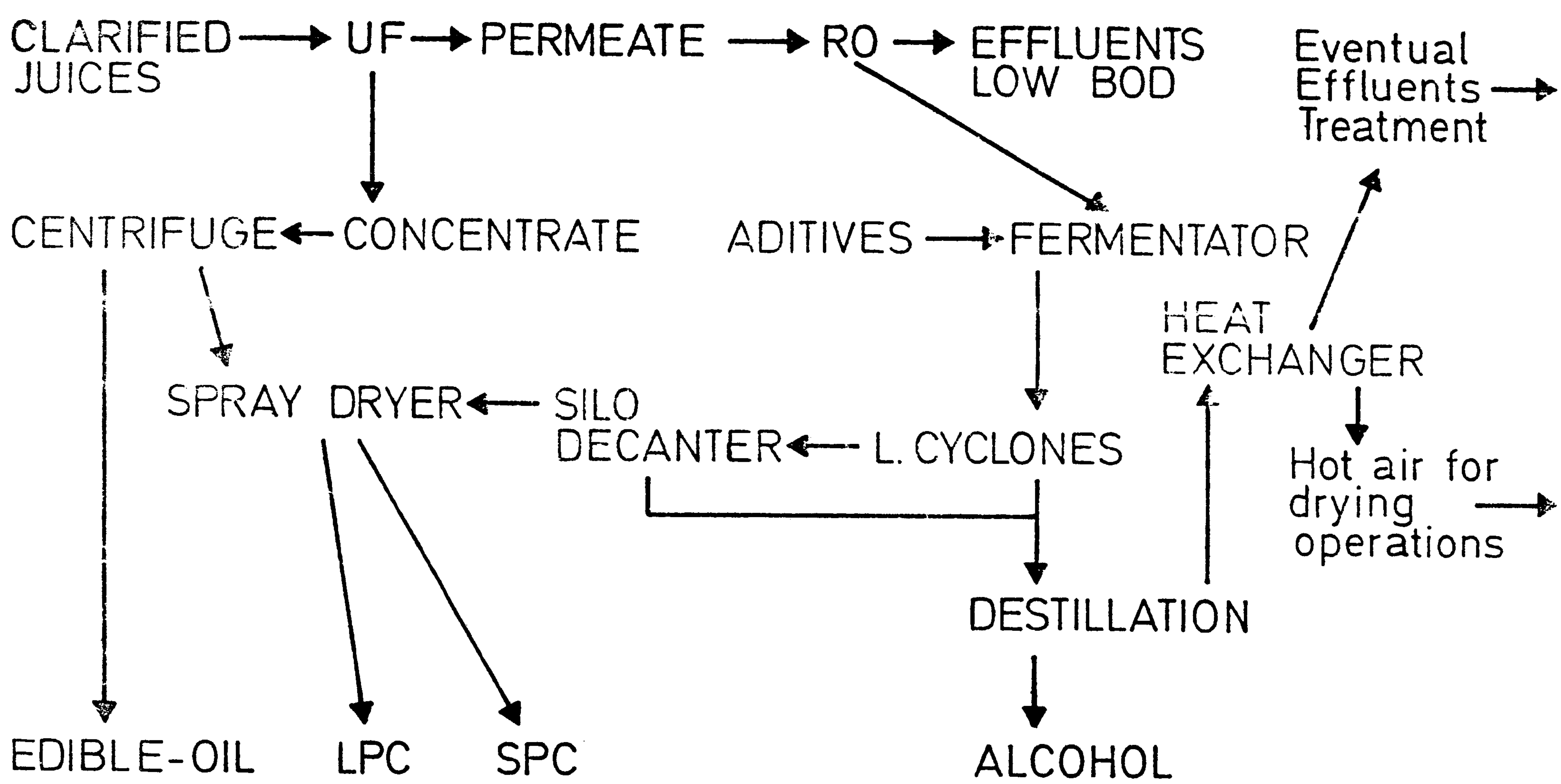

CLARIFIED JUICES
ADITIVES
BACH FERMENTATOR
LIQUIDS CYCLONES
O2 DISSOLVER
SILO DECANTER
FORMADEHYDE
EFFLUENT
SINGLE CELL PROTEIN PASTE
FORMALDEHYDE PRESERVED

PLATE - III



CLARIFIED JUICES
U F
PERMEATE
RO
EFFLUENTS LOW BOD
CONCENTRATE
ADITIVES
FERMENTATOR
O2 DISSOLVER
CENTRIFUGE
LEAF PROTEIN
25% SOLIDS
L. CYCLONE
RO
FORMALDEHYDE
OIL
SPRAY DRYER
YEAST
SUSPENTION
SILO
DECANTER
EFFLUENTS
LEAF PROTEIN
CONCENTRATE
DRYED SPC
SCP PASTE
FORMALDEHYDE
PRESERVED

PLATE IV



CLARIFIED JUICES
UF
PERMEATE
RO
EFFLUENTS LOW BOD
Eventual Effluents Treatment
CENTRIFUGE
CONCENTRATE
ADITIVES
FERMENTATOR
HEAT EXCHANGER
SPRAY DRYER
SILO
DECANTER
L. CYCLONES
Hot air for drying operations
DESTILLATION
EDIBLE-OIL
LPC
SPC
ALCOHOL

PLATE V

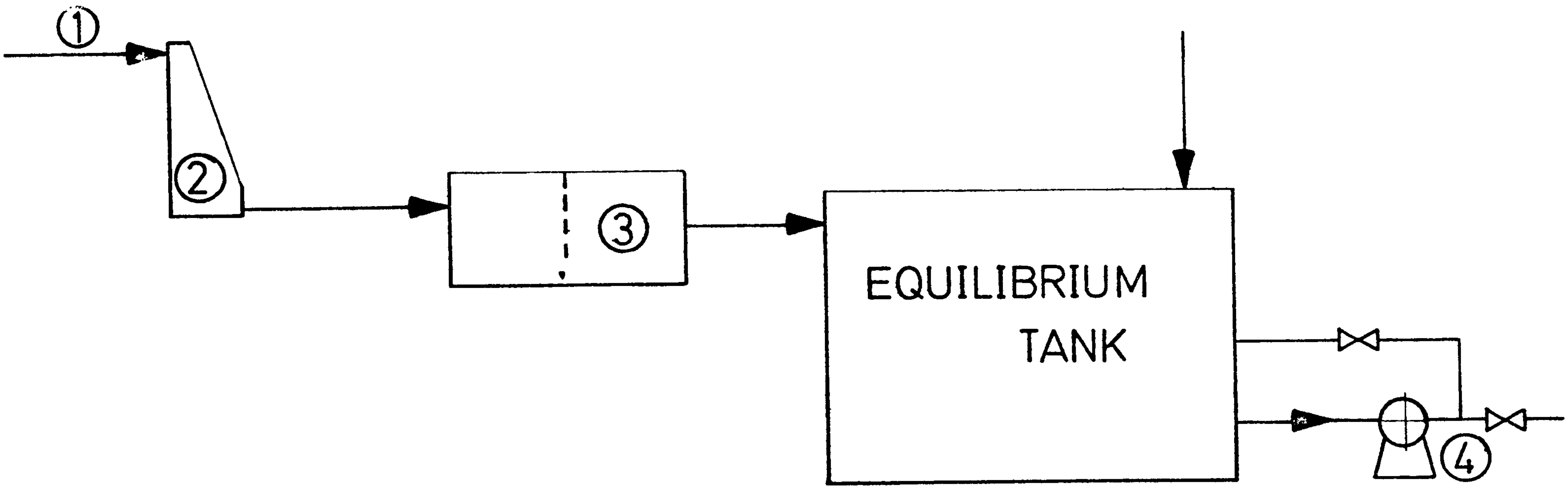


PLATE VI

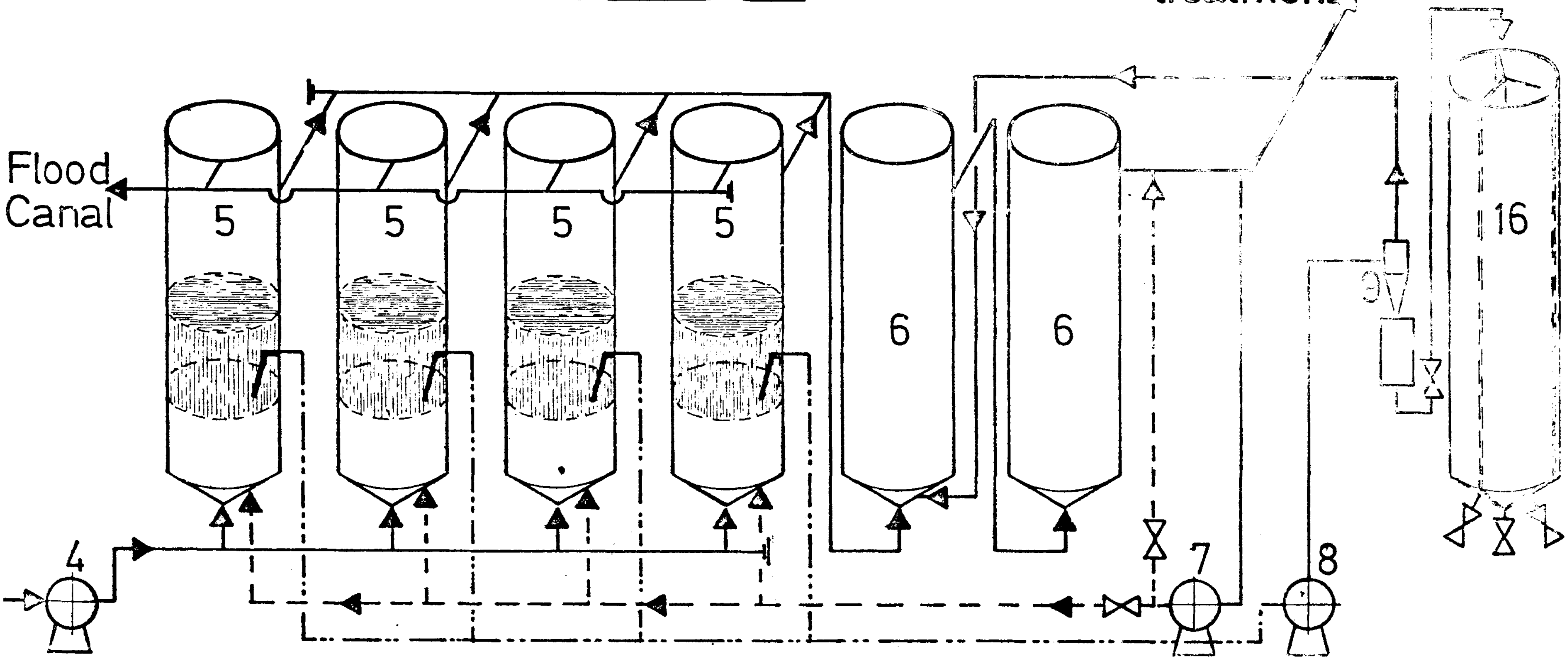


PLATE VII

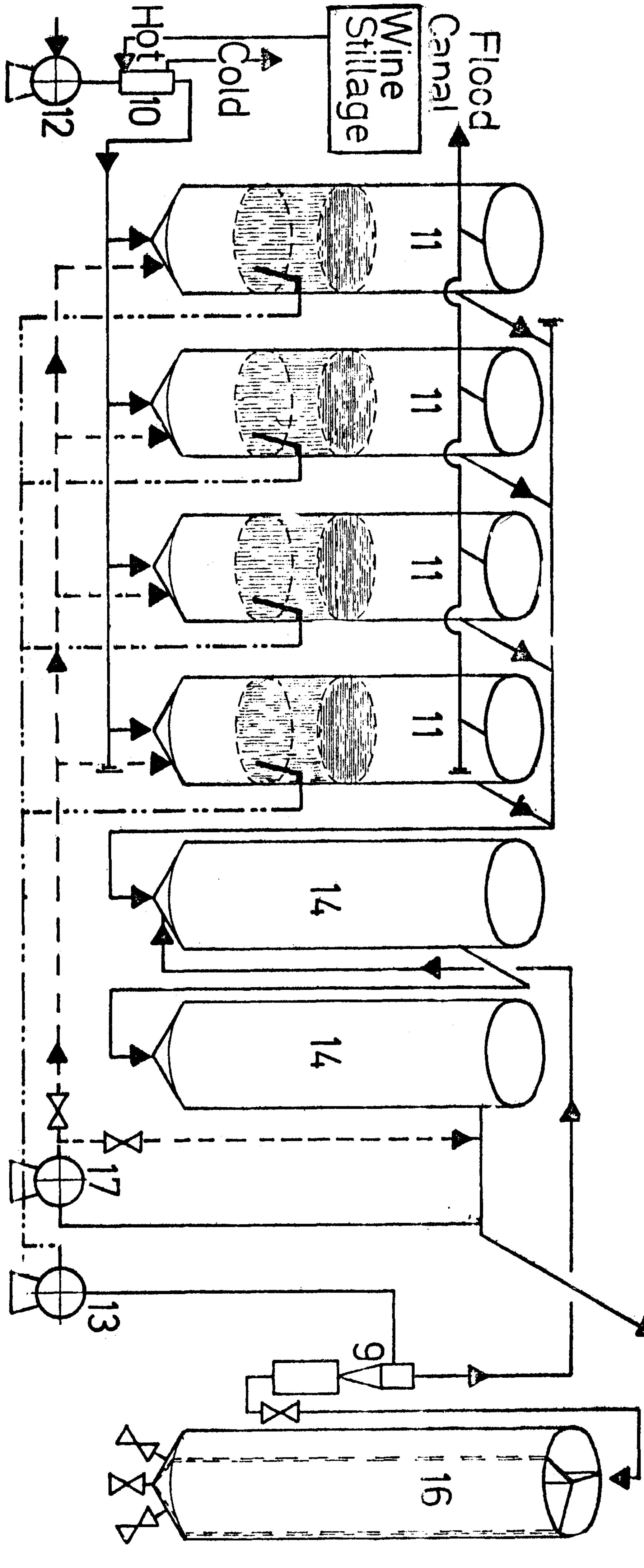

Flood Canal
Wine Stillage
Cold
Hot
10
12
11
11
11
11
14
14
17
13
9
16
To the filtration

PLATE VIII

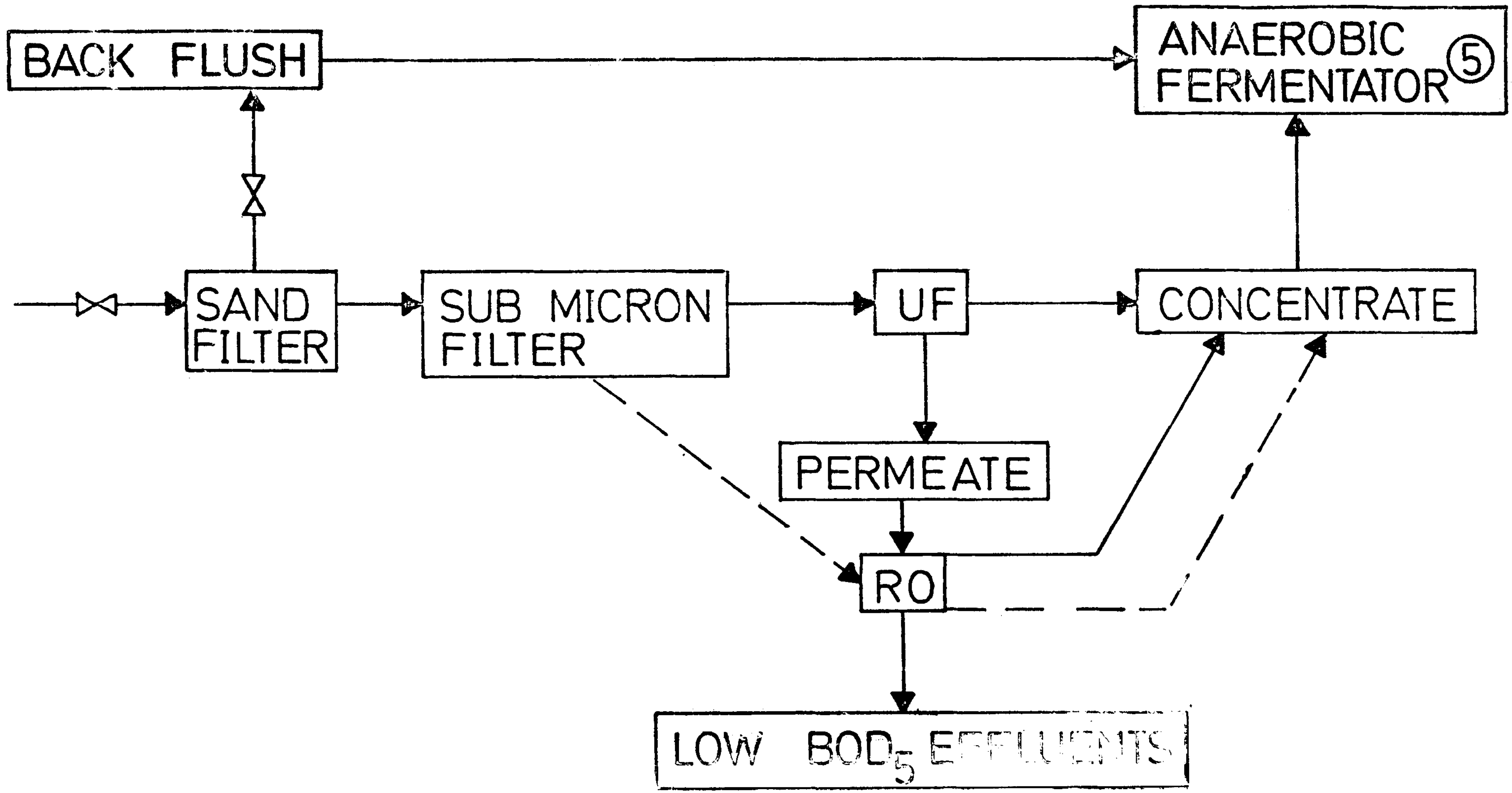

BACK FLUSH
ANAEROBIC FERMENTATOR ⑤
SAND FILTER
SUB MICRON FILTER
UF
CONCENTRATE
PERMEATE
RO
LOW BOD5 EFFLUENTS

PLATE IX

BOD_5 REDUCTION

		REDUCTION	BOD_5
STARTING EFFLUENTS		-	20.000 ppm.
AFTER THE:			
A-Secondary Treatment		60%	8.000 ppm.
B-Terciary	"	60% + 60% = 84%	3.200 ppm.
C-UF	"	84% + 35% = 89'6%	2.080 ppm.
D-UF-RO	"	89'6% + 97% = 99'7%	62,4 ppm.
E-ONLY-RO	"	84% + 97% 99'52%	96 ppm.

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Recovery & Utilization of Residues from Brewing & Other Fermentation Processes

by R.M. Gray

RECOVERY AND UTILISATION OF RESIDUES FROM BREWING AND OTHER FERMENTATION PROCESSES

BY: R.M. GRAY,

It is a feature of many fermentation processes that the final product represents a relatively small proportion of the total quantity of raw materials, including water, used in the process, resulting in considerable quantities of residual material. This generally takes the form of a liquid, containing a relatively small proportion of solids in solution or in suspension, consisting generally of a mixture of carbohydrates and protein. In addition, many such processes give rise to solid residues. In the brewing of beer, for instance, the latter is the main type of residue, being the spent grains from which the original mash is produced prior to fermentation. Liquid effluent, in this case, tends to be limited to drainings, washings, and pressings from the spent grains, although these can amount to substantial quantities. Processes for the production of potable alcohol in its various forms from cereals and other materials, tend to give rise not only to the cereal residue but to the dilute wash from which the alcohol has been distilled and which may contain a significant amount of recoverable solids. For many years now, the industries concerned with such processes have paid attention to the recovery of useful materials. The driving force behind this in the initial stages, at any rate, has been mainly environmental considerations, and in recent years, in most parts of the world, pressures to eliminate effluents which pollute water-courses have increased substantially and there has been an increasing emphasis on the study of ways and means of reducing the polluting effect of such effluents. It has, however, become very clear that, in some cases, where the effluents contain a significant proportion of protein, the recovery of the solid material present can be an economically viable proposition in itself, and even in times of rapid escalation of fuel costs the very high price realisable for animal feed materials, with reasonable protein contents, has enabled such processes to remain attractive and, indeed, become even more so.

In this paper, five such recovery processes are described with a view to presenting a reasonable overall picture of what can be done in this field to reduce the polluting effect of effluent streams, while in many cases, at the same time, recovering useful protein bearing materials. These are:- Waste Brewers' Yeast, Brewers' Grain Pressings/Waste Beer, Spent Molasses Washes, Distillers' Dark Grains, Distillers' Dried Solubles.

1. Waste Brewers' Yeast

In the production of beer, yeast is produced in the fermentation process in considerably greater quantity than that required to maintain the process, and therefore, considerable quantities have to be removed from the system. The waste yeast constitutes a difficult effluent if it is discharged to a sewer or effluent treatment plant because of its very high B.O.D. value. It is also rich in protein and vitamins, and these two factors combine to make it very suitable for recovery and utilisation. The yeast is discharged from the process in the form of a slurry at about 16% total solids. This slurry also contains alcohol at a concentration between 2 and 2.5% which can be recovered separately. The recovery process is made a little more complicated by virtue of the presence of viable yeast cells and CO_2 in the waste yeast discharge, and a process which has been adopted in Germany is illustrated in Fig.1.

The yeast bearing effluent is transported by road tanker from a number of breweries to a central processing plant. After initial storage, it is sieved to remove large particles and any foreign materials. After further storage, it is heated in a plate heat exchanger to 75°C by hot water, in order to kill off yeast cells and to inactivate the enzymes present in the cells. The plate heat exchanger is chosen to give gentle heating with a low temperature difference across the heating surface. This is important if fouling by yeast particles is to be avoided. Still at 75°C, the yeast is then stirred in a specially designed tank where CO_2 and other volatile materials are allowed to escape. This partial de-gassing stage enables subsequent concentration to be carried out in a plate evaporator without foaming. This low heat contact time evaporator concentrates the material, under vacuum, to 30% total solids and the gentle heat treatment thus imparted ensures that any degradation of the nutritive value of the yeast is minimised. The concentrate from the evaporator is then fed via a buffer tank to a roller dryer where it is dried to a final moisture content of between 8 and 10%; the product is then bagged for dispatch.

In the evaporator, the alcohol present in the original waste material is distilled off with the water and the condensate from the 2nd effect of the evaporator and the condenser contains some 5% alcohol. This is taken to a rectification column in which the alcohol concentration is increased to a level suitable for sale.

The approximate composition of the solids in the yeast product is shown in Table 1, and Table 2 indicates the vitamin content of the yeast as it leaves the fermenting vessel. The recovery process detailed, utilising low temperature operation and gentle heating wherever possible, ensures that the minimum degradation of these vitamins occurs, rendering the product of excellent nutritive value.

2. Brewers' Grain Pressings/Waste Beer

The spent grains from breweries are often sold in the wet condition to farmers for cattle feeding, but in many cases are now dried to facilitate storage and to enable blending into other compound feed materials. Before drying it is normal to remove as much water as possible by pressing the grains and the resulting liquid generally contains some 2% total solids, including a significant quantity of recoverable protein. In addition there are a number of other effluent streams from a typical brewery, consisting of tank washings etc., and in some cases, a considerable quantity of waste beer arising from bottle breakage, spillage etc. associated with filling lines. Such an effluent is very high in B.O.D. and can, of course, contain significant quantities of alcohol. A recovery installation has been installed in the United States designed to recover alcohol from such a stream and at the same time concentrate the spent grain pressings to provide a concentrate suitable for drying together with the spent grains themselves, to provide a protein enriched dried product. The process for the treatment of these effluents is illustrated in Fig.2. The alcoholic effluent stream is initially treated separately. Since it can also contain significant quantities of CO_2, it is first of all subjected to a degassing operation by heating, first in a plate heat exchanger, and then in a tubular heat exchanger and flashing at atmospheric pressure. The degassed effluent material is then fed to a stripping evaporator which is of the falling film type with recirculation. The vapour/liquid separator on this unit is fitted with a suitable packing in order to provide some rectification of the alcohol/water vapour mixture. This alcohol enriched vapour is taken away from the plant for rectification. The partly concentrated and de-alcoholised effluent is then cooled by giving up some of its heat to the incoming material and combined with the remainder of the effluent, consisting mainly of spent grain pressings.

This then constitutes the feed to another evaporator system, operated on the reverse feed principle so that the viscosity of the concentrated product is kept to a minimum by arranging for it to be produced on the effect operating at the highest temperature. This is a multiple effect evaporator with effects other than the first, operated on the falling film principle as these require to handle the more dilute product. The first effect consists of a two-stage forced circulation evaporator arranged with the two stages operating in series on the liquor side. This ensures that the most viscous concentrated product is only present in the final stage, makes the most effective use of the heating surface area and gives economy in the use of power for pumping. The concentrated effluent may be dried separately or in admixture with the spent grains to provide a valuable ingredient for compounded animal feeds.

3. Spent Molasses Washes

Many fermentation processes use molasses as the basic material upon which the fermentation is carried out. The processes vary widely and may involve the production of alcohol, yeast or citric acid. The molasses itself can be either from cane or beet sugar. The result of this is that the residues from such processes tend to be rather variable but nevertheless exhibit similar properties, as is consistent with the similarity of their origin. The spent fermentation wash is generally discharged from the process at about 7% total solids and once again concentration is required in order to reduce the bulk of the material and to bring it into a form suitable for utilisation. The major incentive to treat such molasses spent washes continues to be the environmental problem, as, to date, few satisfactory uses have been established for the concentrate, and it is difficult to dispose of it at a price commensurate with the cost of producing it. The basic process involved is one of evaporation, but due to the high mineral content of this material, and in particular to its calcium content, careful attention is needed to the design and selection of evaporators to deal with it. Scaling of the heat transfer surfaces in such plant is always likely to be a problem, particularly where the molasses originates from cane sugar. Traditionally, evaporators to deal with calcium bearing materials have been of the forced circulation type and there are a number of installations in operation in several countries of the world where scaling is kept to a minimum by the use of forced circulation. However such plant tends to be expensive both in first cost, and in operating cost due to the high energy use for pumping, and there has been considerable incentive to develop evaporation systems for this material, utilising film evaporators. One such installation in the U.S.A., concentrates the spent wash to 25% total solids in a recirculatory falling film evaporator with the remaining concentration to 70% total solids carried out in the more traditional forced circulation type. In this particular case the film evaporator is operated on the mechanical vapour recompression cycle giving great economy in the use of energy. The scaling of the heat transfer surfaces is kept under control by the low temperature differences across them, and by regular acid washing of the evaporator.

A typical analysis of the total solids content of spent molasses wash is given in Table 3. The high mineral content of this material renders it rather unsatisfactory for use as an animal feed, and quite unacceptable to pigs, but it does find some limited use in some countries, mixed with wheat chaff and other cereal residues as a feed for dairy cattle. The concentrate may also be incinerated to produce a dry mineral material which is useful as a fertiliser, and various other minor uses have been reported such as use as a binder in the pelletising of compounded animal feeds. There is however much of this material available and the concentration and recovery of it is at present restricted by the absence of a good outlet for the product at a price which makes its recovery economically viable.

4. Whisky Distillery Effluents

The recovery and sale of by-products from the effluent from whisky distilleries is probably one of the best established processes of this type with major units in operation in Scotland, U.S.A., Canada, Spain and Japan. The important effluents from whisky distilleries, once again, come in two streams, one solid and one liquid. The exact nature of these varies depending upon the distilling process used and whether the product is a malt whisky or a grain whisky, and sometimes these streams are not separated until the recovery process begins. Nearly always however, in the course of recovery of materials from the effluents, the solids and liquid streams are treated separately. The processes described refer to the effluents from malt whisky production but they do apply with only minor variations to the effluents from grain distilleries. The recovery plants installed in Scotland generally produce one of two possible products. The first, called Distillers' Dark Grains, is a dried mixture of all the effluent, while the second, called Distillers' Dried Solubles, is only the dried solids contained in the liquid stream. When the latter is produced, the solid material is disposed of separately, generally in the wet condition, for animal feeding.

(a) Distillers' Dark Grains

A typical process for the manufacture of this by-product is illustrated in Fig.3. In many cases plants are set up to serve a number of small distilleries and in these circumstances the liquid effluent, known as pot ale, is delivered by road tanker, screened and passed into storage. It is immediately heated to a sufficiently high temperature to prevent bacterial action leading to secondary fermentation, resulting in the presence of volatile materials which would subsequently contaminate the condensate from the evaporation stage and produce a high B.O.D. effluent. From this hot storage, the pot ale is then taken to an evaporator where it is concentrated from about 4% total solids to some 40-50% total solids. The concentrate is held in an intermediate storage tank. Meanwhile, the solid grain effluent, known as draff, is also delivered by road and stored in the wet condition in a hopper. It is then continuously transported to a screw type press where its moisture content is reduced from about 78% to 65% before being fed, in this instance, to the first of two dryers in series. The partially dried product from the first dryer is then mixed with syrup from the intermediate storage tank before drying is completed in the second dryer. The product is then passed to a pelletising plant and from there to bulk storage or bagging facilities ready for dispatch.

(b) Distillers' Dried Solubles

The manufacture of this by-product is illustrated in Fig.4. and the process is similar to that already described for Distillers' Dark Grains except that there is no solids processing line. The pot ale is treated in exactly the same way, but the syrup has to be mixed with lime prior to drying, in order to produce a product which is not too hygroscopic. In this process, spray drying is often used, as the dryer does not have to handle solid particulate material. Distillers' Dried Solubles is seldom dispatched in bulk due to its hygroscopic nature and is generally bagged for sale.

Distillers' Dark Grains forms a readily saleable and useful ingredient for compounded animal feeds and is capable of storage over extended periods. Distillers' Dried Solubles, on the other hand, has found particular application to the feeding of poultry, but requires more careful storage. Typical analyses of these products are given in Table 4.

Economic Considerations

All the processes described in this paper involve the removal of water from relatively dilute liquid effluents, or very wet solid ones, and as the removal of water by thermal means involves the use of large quantities of energy, the economics of such processes tend to be very much affected by the efficiency of the means of water removal adopted. Obviously, wherever possible, mechanical dewatering methods should be used, and examples of this have been quoted in the pressing of brewers' spent grains, and distillers' wet draff, prior to drying by thermal means. Other mechanical processes not described include centrifugation of certain whisky distillery effluents to separate solids from the liquid effluent and partially dewater them before further processing. Membrane processes offer interesting possibilities either in the modification of the effluents prior to processing by more estabiished means, or in carrying out preconcentration duties. However, current uncertainties with regard to membrane life coupled with the variable nature of the effluent products considered, render commercial developments in this field very slow.

The greatest contribution which has been made over the years to improving the economy of such processes by reducing the energy consumption, has been made in the field of water removal by thermal means and particularly in the area of evaporation. There are many suppliers of evaporation equipment and many types of plant available and careful selection of the right equipment can ensure that the recovery of such residues as have been described can be carried out most economically and effectively. The processes shown in Figs. 1-4 deliberately indicate different types of evaporator to give some indication of the selection of equipment which is available. The brewers' yeast plant in Fig.1 illustrates a plate evaporator selected for its hygienic construction and low residence time but the plant illustrated is only a double effect unit and requires approximately 0.55 kg of steam for every kg of water evaporated. The brewery effluent plant in Fig.2 illustrates a quadruple effect evaporator which will require only about 0.3 kg of steam for every kg of water evaporated and the design of which is specially tailored to the product being handled. In Fig.4 a relatively simple triple effect evaporator of the falling film type is shown. This would have a lower capital cost than the quadruple effect unit of Fig.2 and would be appropriate to units operating on smaller duties. It would, of course, be rather less economical to operate, requiring about 0.4 kg of steam per kg of water evaporated. Fig.3 illustrates the use, in a plant for making distillers' dark grains, of a mechanical vapour recompression evaporator in which the vapour produced is mechanically compressed to act as the heating medium. In such a plant the energy is supplied as mechanical energy through the drive to the compressor, which may be an electric motor. This is a very efficient cycle and the energy required is equivalent to that in about 0.04 kg of steam per kg of water evaporated. Reference has already been made to the selection of an evaporator of this type for preconcentration of molasses spent wash and such systems have been applied fairly widely in the concentration of whisky distillery effluents.

The importance of selecting an evaporator which operates economically is illustrated by the Distillers' Dark Grains process in which for every ton of final recovered product, ten tons of water have to be removed from the original effluents of which 8.5 tons are removed in the evaporator. Although the evaporator removes the greater part of the water which has to be removed in these processes, the economy of operation of the dryer is also important. This is because dryers are generally much less economical to operate than evaporators requiring the energy equivalent of 1.2 to 1.5 kg of steam for every kg of water evaporated. This means that the energy used in the dryer is often as much as that used in the evaporator, and so there is continuing interest in improving the efficiency of this part of the operation. When attention is paid to these factors then it is possible to make recovery processes from the residues that have been described look much more attractive in economic terms than might otherwise be the case, although the picture remains heavily influenced by the price for which the product can be sold and by the cost of alternative methods of disposal of the residues themselves.

In the June 1972 edition of International Brewing and Distilling, Wysocki gave details of the economics of the recovery process for yeast, alcohol and water, described earlier in this paper, indicating that an excellent return on the necessary capital investment can be achieved. Table 5 illustrates the economics of the production of distillers' dark grains, once again indicating that a quite satisfactory return on capital can be achieved. As has already been indicated however the market for concentrated molasses spent wash is poor and there is little incentive at present to industry to install recovery equipment at considerable expense unless severe pressure is mounted for anti-pollution reasons.

Conclusions

It is clear that the beverage and fermentation industries have already paid considerable attention to the recovery of useful by-products from their waste materials. A considerable number of installations have proved that in favourable circumstances such operations can be economically attractive in addition to providing a marked improvement in the quality of discharges from the factories concerned to water-courses or public treatment facilities. There are however problems which remain unsolved. The basic one is that the effluents from these industries do not always contain substances which are sufficiently desirable or in sufficiently short supply to reflect properly the cost of recovering them. There is little that industry itself can do to solve this problem and it is unlikely that such residues will find much utilisation unless pressure is brought to bear upon the industries concerned to treat their residues for other reasons. This would only be economic where by doing so industry avoids substantial processing charges from local authorities or other statutory bodies. In the main, processes for the recovery of useful materials from residues from the beverage and fermentation industries involve using large quantities of energy and the economic viability of them will continue to be improved as further attention is paid to reducing the energy requirements of evaporators and dryers and in particular if developments in the field of membrane processes result in more effective removal of water by mechanical means.

*****

TABLE 1

Approximate composition of the total solids of brewers' yeast:-

Ash	8%
Carbohydrate	43%
Protein (Nx 6.25)	47%
Fat	2%

TABLE 2

Vitamin content of a bottom fermented brewers' yeast referred to yeast total solids:-

Thiamin (B_1)	150	/mg
Riboflavin (B_2)	50	"
Niacin (nicotine acid amide)	500	"
Pantothenic acid (B_3)	120	"
Pyridoxin (B_6)	30	"
Biotin (H)	1.1	"
Folic acid	45	"

TABLE 3 TYPICAL ANALYSIS FOR SPENT MOLASSES WASH

Composition from cane molasses

Soluble Solids 7.2% w/w

Insoluble Solids 0.3% w/w

Inorganic content of solids (dry basis):

	% w/w	
Mg	1.8	
Na	0.4	
K	7.0	
Ca	1.8	
Fe	0.6	
Cu	0.005	
Zn	0.001	
SO_4	6.7	
Cl	3.8	
PO_4	0.4	22.5

Organics:

Total sugars and amino acids	22.0	
Ethanol (partially combined as ethyl acetate)	0.03	
Unknowns including carbohydrates, organic acids such as acetic, propionic	55.5	100

TABLE 4 TYPICAL ANALYSES FOR DARK GRAINS AND DRIED DISTILLERS' SOLUBLES

	Dark Grains ex Malt	Dark Grains ex Grain	D.D.S. ex Malt	D.D.S. ex Grain
		Per cent		
Moisture	10	10	5	5
Protein	22	25	26	27
Fat	5	7	1	8
Fibre	11	7	1	4
Ash	5	4	17	8
Carbohydrate (by difference)	47	47	50	48
		Milligrammes/gramme		
Amino acids				
Lysine	9.3	4.0	11.9	9.0
Methionine	3.1	4.8	3.7	5.4
Arginine	-	-	4.5	11.8
Cystine	2.1	3.1	0.8	0.8
Histidine	-	-	4.3	6.3
Phenylalanine	-	-	7.0	23.6
Tryptophan	-	0.9	0.7	1.1
		Microgrammes/gramme		
B-vitamins				
Aneurin	2.2	-	1.5	3.5
Niacin	165	55	510	76
Pantonthenic acid	34	9.7	67	11
Riboflavin	11.2	7.5	21	12
Choline	5600	2700	2000	3100
Pyridoxin	4.6	-	19	1
Biotin	0.22	-	0.7	0.3
Inositol	2250	-	10000	7200

TABLE 5 ECONOMICS OF SOLIDS RECOVERY FROM MALT WHISKY DISTILLERY WASTES, BASED ON A SPECIMEN EXAMPLE

	Dark Grains	D.D.S.
Net capital investment on plant etc.	£1,650,000	£1,400,000
Production	15,000 ton/annum	7000 ton/annum
Product price	£90 per ton	£110 per ton
Income	£1,350,000	£770,000
Cost of production:-	£	£
Depreciation @ 10% per annum	165,000	140,000
Raw materials: pot ale - zero value	-	-
wet draff @ £12 per ton	384,000	-
lime @ £30 per ton	-	45,000
Utilities: Oil @ 20p per gallon	110,000	33,000
Power @ 1.6p per kWh	73,000	50,000
Transport of wet draff*	15,000	-
Salaries and overheads	50,000	50,000
Maintenance	25,000	25,000
Total cost of production	£822,000	£343,000
Profit	£528,000	£427,000
% of investment	32%	30.5%

*The pot ale has to be transported in any case if alternative disposal methods are adopted and therefore no additional charge is included here.

FIGURE 1 Process for recovery of waste brewers' yeast

1. Feed storage tanks
2. Screen
3. Plate heat exchanger
4. Stirred de-gassing vessel
5. Plate evaporator
6. Alcohol rectification column
7. Roller dryer
8. Product storage and packaging

FIGURE 2 Process for solids recovery from brewery effluent

A. Alcoholic feed stream
B. Non-alcoholic effluent
1. De-gassing stage
2. Alcohol stripping and partial rectification
3. Multiple effect evaporator

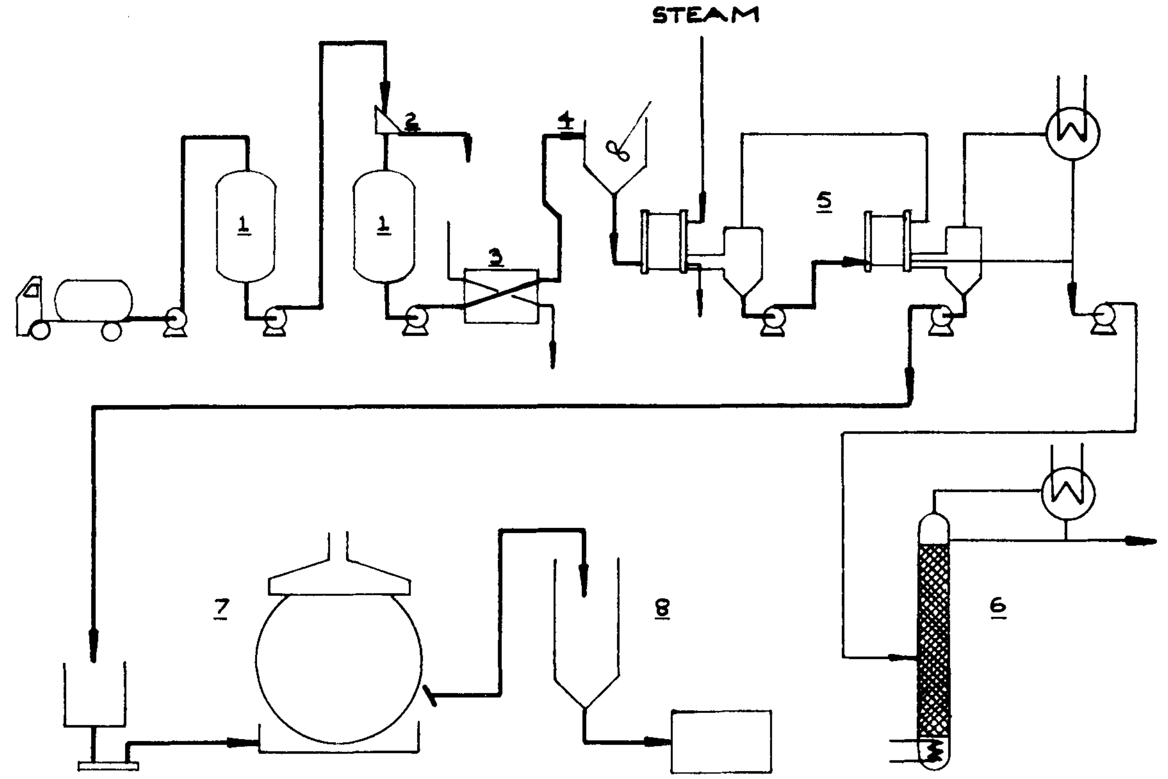

FIG 1

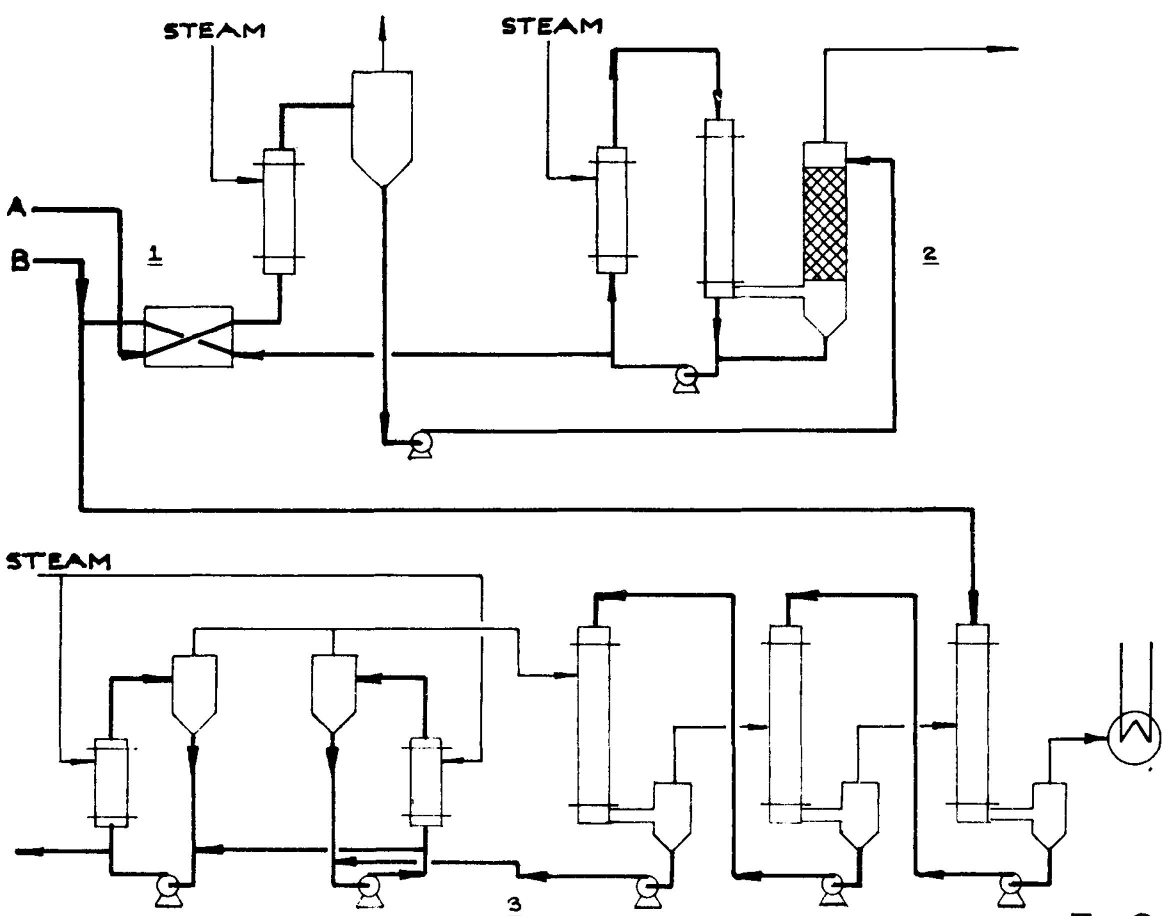

FIG 2

FIGURE 3 Process for the manufacture of Distillers' Dark Grains

1. Screen
2. 'Pot Ale' feed storage tanks
3. Plate heat exchanger
4. Mechanical recompression evaporator
5. 'Wet draff' storage
6. Screw press
7. Two 'Rotadisc' dryers
8. Pelletising & product dispatch

FIGURE 4 Process for the manufacture of Distillers' Dried Solubles

1. Screen
2. 'Pot Ale' feed storage tanks
3. Plate heat exchanger
4. Multiple effect evaporator
5. Lime addition and mixing
6. Spray dryer
7. Product bagging and dispatch

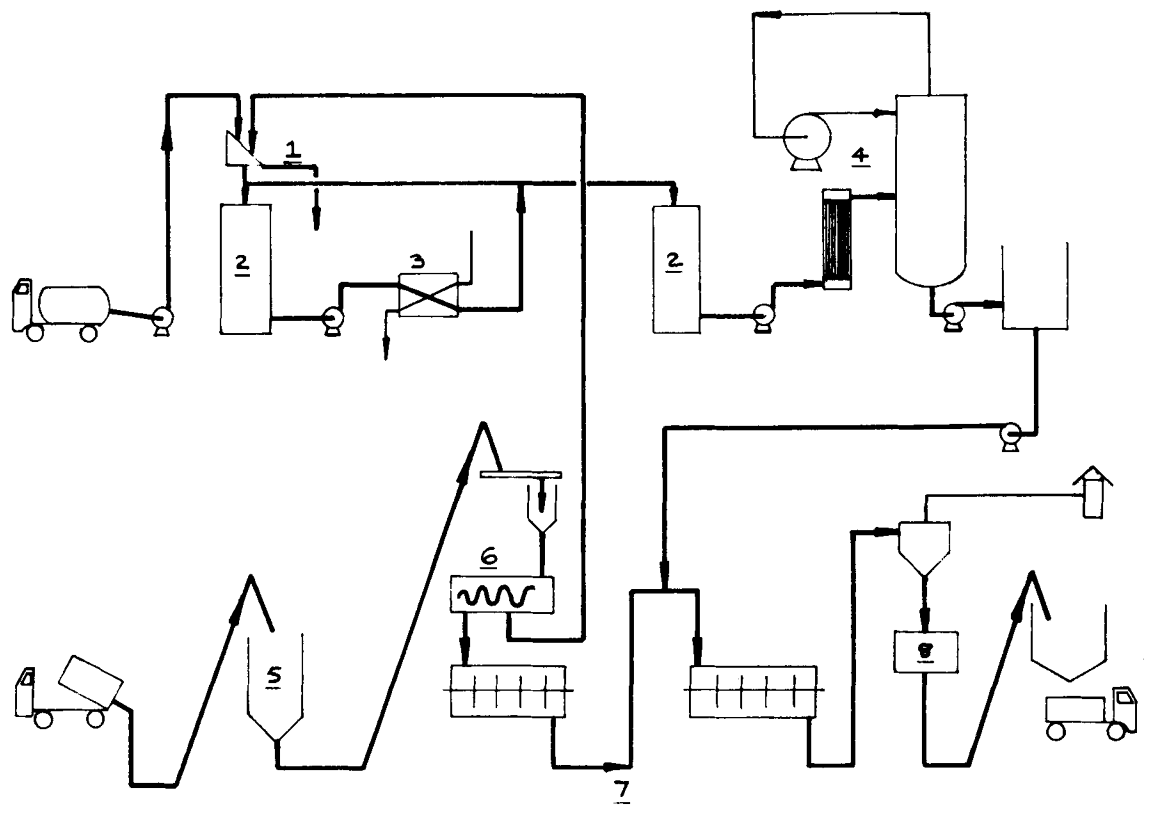

Fig 3

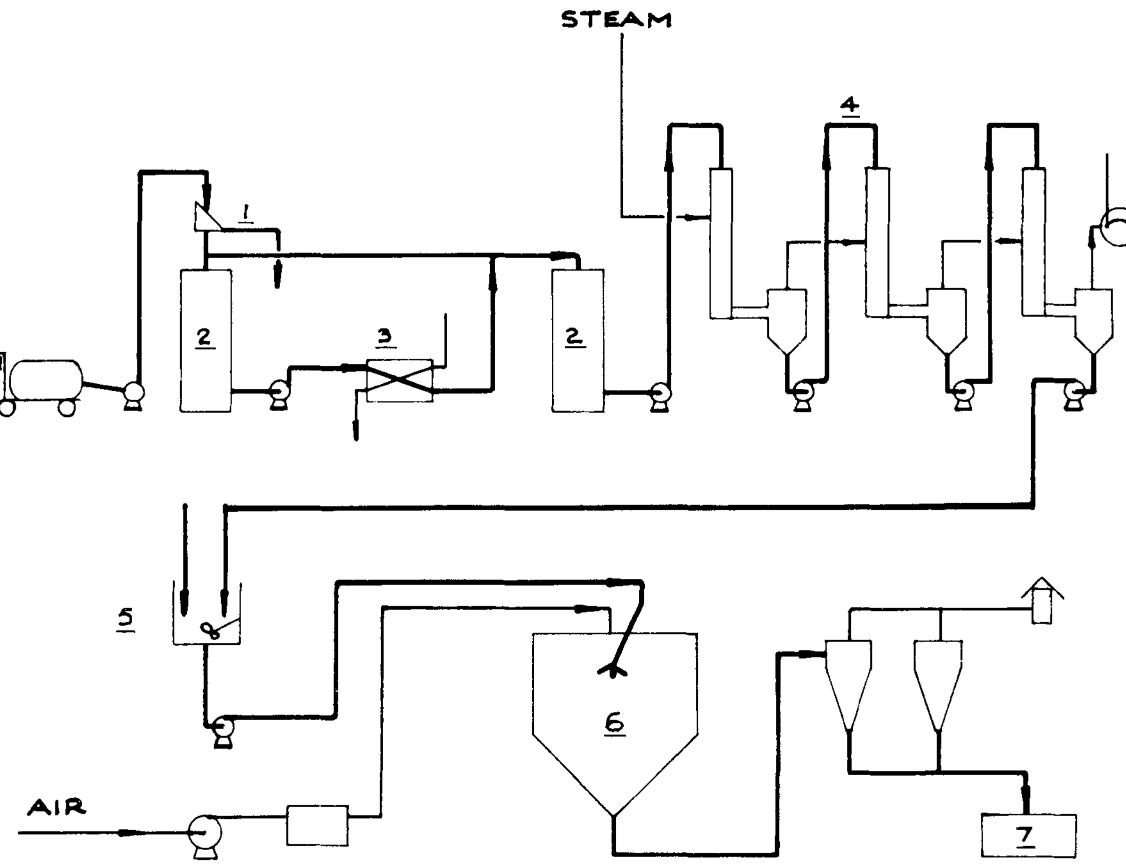

Fig 4

A Review on the Utilization of Agricultural Wastes in Central America

by S. de Cabrera, C. Rolz, J.F. Menchù, J. Valladares, R. Garcia & F. Aguirre

A Review on the Utilization of Agricultural Wastes in Central America

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1. INTRODUCTION

The topic under discussion these days, use of residues and wastes, is looked at from two points of view, depending upon whether the observer is looking out from a developed country or a developing country. In the developed countries, there is much concern for the disposal of the massive quantities of wastes and residues which accumulate in the highly mechanized industry and agriculture, residues which if not handled adequately would have a profoundly detrimental impact on the environment. In the developing countries the emphasis has been placed on a increased utilization of the resources present, and it happens that wastes and residues from part of these resources. It is important to point out here that the position adopted by some institutions and international agencies has been, to a great degree, that of the developed nations, or in other words environmental protection. And, when, by chance, a useful product results from the manipulation of the wastes, this is to be exported to the developing countries.

It is our opinion that the utilization of wastes and residues is important. However, optimal utilization of resources is the most important goal - be they space, energy, water or human resources. Optimal utilization of resources is imperative for developed as well as developing countries. Differences among the regions of the world demand that whatever processes developed, this must be done in light of local needs and resources.

ICAITI has been working on different aspects since 1969, mainly on cellulosic wastes and other wastes from the agroindustry, principally from coffee and sugar cane processing. See Tables 1 and 2 for description and quantification of the wastes.

Agriwastes for pulp and paper

The economics of the Central American countries have been affected profoundly in the past and will continue to be affected in the future by the imports of pulp, paper, and like products. As an example we can cite the importation in 1974 of $CA166 million of these products.

The possibilities of developing a pulp and paper industry based on wood are remote, due principally to the lack of financial resources, infrastructure and technology. In light of this discouraging panorama, efforts have been made to evaluate certain types of wastes from the agroindustry, considering that their transformation into finished products present less complex problems than those from the use of forests. An evident example is sugar cane bagasse, whose industrialization has contributed toward resolving this problem in many developing countries. Nevertheless our research efforts have been centered on other types of wastes, since we felt that the technology for sugar cane bagasse has been amply developed and to the contrary, the technology necessary to process other types of wastes is unknown. Such is the case of lemon grass bagasse (Cymbopogon citratus,flaxuosus y nardus) a byproduct of the essential oils industry, and for which, at laboratory level, it was found that processed correctly, excellent quality corrugated cardboard could be produced. Likewise, it was shown in the laboratory that cotton linters mixed with imported pulp constitute an excellent raw material for producing high quality bleached paper.

Nevertheless, these isolated efforts to use local wastes for producing paper have been restricted due to the lack of resources and large capacity installations.

Coffee byproducts

Pulp

Pulp is the most volumenous waste from coffee processing, representing 40% by weight of the fresh fruit. Expressed in another way, the American countries which produce washed coffee (that is, except Brazil) produce around 3 000 000 metric tons yearly.

The pulp is usually used as ground cover or it is incorporated in the soil in the coffee plantations. Nevertheless, given the difficulties encountered in handling great amounts of solids, particularly now that there is a tendency towards the establishment of large central processing plants, in large plantations or by coffee cooperatives, the transport and distribution of the material becomes costly. Due to the reasons above, a large proportion of the pulp contaminates rivers and causes problems where it is inadecuately stored.

Pulp which has been dried and detoxified through fermentation can constitute a valuable feed; however this entails an elevated inversion which, until now, makes its use unattractive, but more research is needed on the subject. The pulp mixed with manure and fermented anaerobiolically has shown to be a good substrate for producing methane gas and organic fertilizers. Now, efforts are being made towards continuous production of the gas. An ideal application of the above system would be in cooperatives of small coffee farmers who are also produce hens and swine. In this case, the gas can be used to heat the hatchery and to dry the washed coffee, one of the most expensive steps in the production of green coffee. In this way, both coffee and animal production would be made more efficient, and at the same time there would be a savings in energy sources and chemical fertilizers which are imported.

Mucilage

Mucilage is a byproduct from coffee which at present, is wasted in Central America, since it is eliminated from the outside of the bean by biodegradation in the wet fermentation process.

For many years machines of proven efficiency have been available to eliminate mechanically mucilage from the coffee fruit, which would make possible its utilization as a byproduct. In order to have an idea of the real magnitude of this waste, it can be estimated that, if the production of the coffee fruit in Central America is around 2.7 million metric tons, then the processing plants will have around 540 000 metric tons of fresh mucilage, which represents around 108 000 metric tons of crude dry product. Mucilage is a material rich in pectins; research is needed to determine if the pectins are of the quality which can be used in food and if they can be recuperated economically. The answer to these questions might open the door to a new industry of great importance for the region. According to the present prices for commercial pectins, it would be an industry as important economically as the exportation of the coffee bean.

Another possibility is to use mucilage as substrate for the production of single cell protein. At present ICAITI is carrying out work on the physico-chemical characterization of mucilage, as well as screening of microorganisms able to grow on this product. Laboratory results are available on the vigorous growth of some fungal cultures on media prepared with diluted mucilage; but more research is necessary to overcome problems due to the high viscosity of the medium and its resistance towards oxygen transfer, which limits the yield of cell mass in the industrial scale fermentation process.

Coffee Waste Waters

The filamentous fungi show good perspectives for the treatment of wastes which contain carbohydrates, and the resulting product can be used as an animal feed, since some species of fungi have levels of nucleic acids is up to three times less than in yeasts and bacteria. In addition, the enzymatic capacity of the fungi permit them to grow more efficiently in complex media, and present the possibility of growing actively in mixed cultures. On the other hand their mycelial structure permits recuperation through a simple filtration, instead of a costly centrifuging operation, which is necessary for recuperating yeasts and bacteria.

ICAITI carried out a research project to evaluate the conversion of organic wastes from coffee processing plants into single cell protein, to be used as an animal feed supplement. A species of fungi capable of growing in a low cost, non-aseptic, continuous process was used, with the idea of producing protein and, at the same time, reducing the contamination of the waste waters due to the high biochemical oxygen demand (BOD). The first trials were done at the laboratory, and later a pilot plant was built in a coffee fruit processing plant in El Salvador. These pilot plant runs gave promising results, achieving a 85% reduction in COD, and an effluent with 6 to 7 g of solids per liter with a protein content of 50%, produced by yeasts and fungi. Nevertheless, more research is needed to optimize the process and to evaluate biologically the product which is recuperated.

Tropical Fruit Wastes

The continuous production of vinegar would be an attractive means of utilizing tropical fruit which does not meet the requirements for exports, and the fruit wastes from local markets. Nevertheless, further research is required to achieve continuous production of wine and vinegar from tropical fruits. Studies carried out in ICAITI showed that good quality vinegar can be obtained from tropical fruit wastes as a batch process, although the production trials on a continuous basis were not successful.

Recommendation

From our experience, we should like to sugest that the processes be developed in the countries where they will be eventually used, in order to better meet the actual circumstances. This requires participation of local scientits and technicians and use of materials available locally, and trials on the waste as is it is available locally. Collaboration from international agencies is important, as is the transfer of ideas from areas which have faced similar situations. But our experience has found that the trasplant of entire plants or processes directly from developed countries to developing countries usually does not work satisfactory. Also the work of "experts" who come into a region for short to medium lengths of time to develop a complicated project, but who do not stay around to confront mechanical and technical problems which arise during functioning and are not present when severe economic, ecological, or cultural side effects might arise; has not suported the expectations normally built around the image of such an expert. To put these points more concisely, financing should be made available to work being carried out in developing areas by local people who understand the limitations and the environment and who will be responsable for the repercussions which the process might have. Advantage, should also be taken from expertise available, an the subject matter, from other developing areas. Foreign experts from developed countries can be expected to contribute in the very specialized aspects, which entail advanced technology not available locally.

TABLE 1

CLASSIFICATION OF AGRICULTURAL BYPRODUCTS*

Group	Predominant compound	Agricultural activity	Byproduct	Physical state	Use
I	High proportion of di and monosaccharides	Sugar cane growing and processing	Molasses	Liquid (~50°Brix)	Raw material in fermentation industries. Microbial protein production. Animal feed
		Pulp elaboration	Sulphite liquors	Liquid (~10°Brix)	Microbial protein production
		Cheesemaking	Whey	Liquid (~ 8°Brix)	Contaminant
II	Di and monosaccharides with some structural polysaccharides	Fresh fruit collection centers	Rejected or damaged fruit	Solid (~80% moisture)	Processing. Animal feed
		Rum making	Spent wash	Liquid (10-50 g/l COD)	Contaminant
		Fermentation industries	Waste waters	Liquid (concentration varies according to process)	Contaminant

TABLE 1

(continuation)

Group	Predominant compound	Agricultural activity	Byproduct	Physical state	Use
III	Mixture of soluble organic compounds including di and monosaccharides, protein, starch, pectin, acids, etc.	Fruit and vegetable processing	Waste waters from washing, peeling and blanching	Liquid (concentration varies according to raw material and process)	Contaminant
		Tuber and grain processing	Waste waters from washing and sorting	Liquid (1-7 g/l COD)1/	Contaminant
		Coffee processing	Washing and pulping waters	Liquid (10-60 g/l COD)	Contaminant
		Meat processing (beef, pork, poultry)	Water from washing and scalding	Liquid (variable)	Contaminant
IV	Complex mixtures of structural polysaccharides and other compounds such as protein, lipids, starch, etc.	Fruit and vegetable processing	Peels, insoluble solids from the pulp and seeds	Solid	Contaminant. Animal feed
		Beef and poultry production	Manure	Solid	Contaminant

TABLE 1

(continuation)

Group	Predominant compound	Agricultural activity	Byproduct	Physical state	Use
		Meat processing (beef, pork and poultry)	Suspended solids	Solid	Contaminant
		Beef slaughtering	Rumen	Mixture of liquid and solids (~ 1 : 1)	Contaminant
		Coffee processing	Pulp	Solid (~80% moisture)	Soil conditioner, organic fertilizer. Animal feed in proportions
		Alcohol and alcoholic beverage production	Residual solids	Solid (concentration varies according to raw material)	Contaminant
		Sugar cane processing	Filter muds	Solid (~80% moisture)	Contaminant

TABLE 1

(continuation)

Group	Predominant compound	Agricultural activity	Byproduct	Physical state	Use
V	Structural cellulose and lignin as plastifier in high proportion	Cereal growing	Straw and husks	Solid (~ 80% moisture)	Raw material for paper. Fuel
		Corn growing	Stalks and cobs	Solid (~80% moisture) (~10% moisture	Feed for ruminants
		Sugar cane growing	Stalks and leaves	Solid (~ 80% moisture)	Feed for ruminants
		Sugar cane processing	Bagasse	Solid (~50% moisture)	Raw material for paper. Fuel. Feed for ruminants
		Citronelia and lemon grass processing	Bagasse	Solid (~80% moisture)	Contaminant
		Rice processing	Husks	Solid (~10% moisture)	Fuel
		Coffee or cacao processing	Husks	Solid (~10% moisture)	Fuel

TABLE 1

(continuation)

Group	Predominant compound	Agricultural activity	Byproduct	Physical state	Use
		Cottonseed processing	Hulls	Solid (~10% moisture)	Fuel
		Wastes from the industrialization of the forests	Bark, sawdust, stumps	Solid (~80% moisture)	Fuel

1/ COD = Chemical Oxygen Demand

* Compiled and designed at ICAITI

TABLE 2

PRINCIPLE BYPRODUCTS OF SUGAR CANE AND WASHED COFFEE*
- Quantity produced in Latin America in 1972 -

	Total production	Residual bagasse (100: 5)3/	Filter mud (100:3)	Molasses (100:2.7)
SUGAR CANE				
Brazil	84 2/	420 000	252 000	226 800
Caribbean 1/	60	300 000	180 000	162 000
Mexico	34	170 000	102 000	91 800
Colombia	18	90 000	54 000	48 600
Central America and Panama	13	65 000	39 000	35 100
	Whole fruit	Pulp (100: 40) 4/	Mucilage (100: 20)	Parchment (100: 3.4)
WASHED COFFEE				
Colombia	3.4	1 360 000	680 000	115 600
Central America and Panama	2.25	900 000	450 000	76 500

TABLE 2

(continuation)

	Whole fruit	Pulp (100: 40) 4/	Mucilage (100: 20)	Parchment (100: 3.4)
Mexico	1.10	440 000	220 000	37 400
Caribbean	0.40	160 000	80 000	13 600
Venezuela	0.35	140 000	70 000	11 900

1/ Cuba, Dominican Republic and Puerto Rico
2/ Production in millions of metric tons, 1972 (FAO, 1973)
3/ Sugar cane production: byproduct in metric tons (Paturau, 1969)
4/ Coffee production (fruit or cherry): byproduct in metric tons (Rolz, 1973)
* Compiled and designed at ICAITI

Considerations Concerning Upgrading of Cellulosic Wastes & Carbohydrate Residues from Agriculture & Agro-Industries

by J.L. Baret

CONSIDERATIONS CONCERNING THE UPGRADING OF CELLULOSIC WASTES AND CARBOHYDRATE RESIDUES FROM AGRICULTURE AND AGRO INDUSTRIES

by

J.L. Baret

INTRODUCTION

1. TYPES OF CELLULOSIC WASTES AND CARBOHYDRATE RESIDUES FROM THE AGRO FOOD INDUSTRY
   - sulphite liquors
   - whey
   - molasses
   - forestry residues
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3. MEDIUM AND LONG TERM PERSPECTIVES

4. CONCLUSIONS

During the last few years, under the pressure of various policital and economic events, energy and resource management has become very important. In addition, increasing ecological problems have raised the question of the relationship between man and his environment.

These various phenomena have emphasised the problem of waste management, forcing a move towards a more efficient utilisation of our resources and, simultaneously, an improved protection of our environment.

In this context, the utilisation of cellulosic wastes and agricultural and agro industrial carbohydrate residues opens up very promising perspectives. These carbohydrates are key elements in the natural carbon cycle, their degradation leading to carbon dioxide and water. These compounds are recombined during photosynthesis.

CO_2 fixation is a process requiring an energy supply. The mechanisms of glucide formation from CO_2 are the same for a wide range of organisms (plants, algae, autotrophic bacteria). The main difference is the energy source which is used during CO_2 fixation. It can either be light (photosynthesis) or chemical energy released during the oxidation of a mineral compound.

The development of technologies using vegetable raw material or biomass covers two complementary approaches:

- utilisation of renewable carbon sources (non fossil carbon sources)
- bioconversion and utilisation of solar energy.

These two fundamental aspects emphasise the benefit that can be expected in the field of resources, energy and food by developing an efficient biotechnology.

Research and development of new technologies and industrial processes allowing the upgrading of wastes are included in this general approach.

We have more particularly considered the case of wastes with a high content of carbohydrates, either in a free form or in the form of natural polymers.

1. TYPES OF CELLULOSIC WASTES AND CARBOHYDRATE RESIDUES FROM THE AGRO FOOD INDUSTRY

From a chemical composition point of view, these wastes are characterised by a relatively large content of carbohydrates (generally pentoses or hexoses) or their natural polymers (cellulose, hemi-cellulose, starches $(C_5H_8O_4)_n$ and $(C_6H_{10}O_5)_m$).

These wastes are generally poorly used and they contribute to pollution of the environment, either in the form of solid wastes or as waste effluents. Among them can be noted:

- Sulphite liquors

These waste streams are obtained in large amounts when producing cellulose pulp by the chemical sulphite process. The production of 1 ton of pulp gives rise to about 8 to 10 tons of liquors. They contain about 10 to 14% of dissolved solids, mainly lignosulphonates (60-70%). They also contain important amounts of free sugars (hexoses and pentoses 20-30%), and various complex compounds. The concentration of free sugars in the liquors is in the range 2-4%. The production of 1 ton of cellulosic pulp leads to an average sugar loss of 200 kg. Various possibilities of upgrading these liquors have already been considered. Industrial processes of great interest are in operation, aimed at producing either feed yeasts or ethanol (1).

- Whey

Whey is the most important by-product of cheese manufacturing. This waste still contains 50% of dry milk extract. Its upgrading possibilities are presently limited in spite of various important and recent technological advances. It is often dried in order to obtain a whey powder which can be used in various food formulations.

The production cost of the whey powder is about 1 FF/kg. This is mainly due to the energy needed to dry this dilute solution (spray drying or roller drying).

The following tables include some basic data on whey.

- Molasses

These are important by-products obtained during the manufacture of sugar. They correspond to the concentrated mother liquor after crystallisation and removal of raw sugar. Molasses production is about 300 kg of molasses per ton of sugar or a potential sugar loss of 150 kg per ton produced. Various methods for recovering the residual sugar in the molasses have been proposed but generally are not economic.

Molasses have, however, important and interesting applications in the animal feed stuff and fermentation industries (yeasts, alcohol, organic acids, amino acids, pharmaceuticals). Developed countries are often molasse importers. At the level of developing countries, knowledge of the exported and self-consumed molasses quantities often shows very large amounts of surplus which are simply dumped.

Molasses should, however, be considered as an important raw material for a fermentation industry. An effort to develop and select industrial uses should be made, taking into account the various specific conditions of the country and potential markets.

Constituent	Percentage
Water	93
Total solids (dry extract)	7
- Lactose	4.5 - 5
- Proteines	0.7 - 0.9
- Ashes	0.6 - 0.8
- Fat	0.1 - 0.3
- Lactic acids	~ 0.2

Table 1 Average Composition of Whey

	France			Germany			Italy			Holland		
	F	LS	Lact	F	LS	Lact	F	LS	Lact	F	LS	Lact
1965	580	3306	150	375	2110	95	450	2565	115	220	1254	56,4
1970	730	4160	187	470	2680	120	400	2280	102	260	1482	67
1980	950	5414	243	620	3530	160	500	2850	128	350	1995	90

Source : Battelle

Table 2 Rough estimate of whey and potential lactose production in some European countries - thousands of tons.

F : cheese production

LS : whey

Lact : lactose

The evaluation is based on the following balance:
1 ton of milk gives 150 kg cheese and 850 kg whey. Lactose content of whey 4.5%.

Table 4 Average composition of molasses

Constituants	Sugar beet - molasses	Sugar cane - molasses
Water	16.5	20
Sugar	53	62 { sucrose 25-40; glucose, fructose } 12-35
Others than sugar	19	10
Inorganics	11.5	8
Total solids	78.85	77-84
Total nitrogen	0.2 - 2.8	0.4 - 1.5

(Indicative values - some variation can occur according to the origin of the molasses).

Average density : 1.5 t/m^3

Production :   300 kg molasse/t raw sugar.

Table 5 World molasse production in thousands of metric tons

	1970/71	1972/73	1974/75
North America	5916	5931	5886
South America	3123	3536	4071
West Europe	3008	3340	3750
East Europe	1219	1509	1614
Russia	3250	3000	2842
Africa	1344	1488	1618
Asia	4381	4988	5976
Oceania	580	633	692
World Total	22821	24425	26449

Ref. (2)

- Forestry residues

Cellulose is the most abundant constituant of the cells forming the tissues of plants. It acts as the protection system of these plant cells. It is, in fact, a natural polymer composed of chains of glucose units (β.1.4). Starch, a polysaccharide present in various plants acting as a reserve, is also composed of glucose chains (α.1.4). This difference in the nature of the glucose binding leads to very different mechanical, physico-chemical and bio-chemical properties. Cellulose is generally organised in fibres, in which crystalline zones are more or less combined with amorpheous zones. This has a very important influence on the characteristics of the fibres obtained from various sources.

Table 6 Typical composition of various woods

	Pine	Fir	Poplar	Beech
Ashes	0.5	1	1	1.1
Resins	3.2	2.8	2.3	1
Proteines	1.3	1.2	1.2	1.3
Pentosans	10.5	11.5	22	24
Hexosans	13	13.5	3	4.6
Pure cellulose	42	41	48	45
Lignin	29.5	29	22.5	23

Industrial utilisations of wood have been developed and represent a considerable economic activity (production of wood products, of cellulosic pulps, paper, carboard). At each step of the exploitation and transformation of wood, important amounts of wastes are produced.

In the United States, for instance, the following data have been published for 1973:

Table 7 Evaluation of wood and bark residues in the USA 1973 (dry weight) (10^6 tons)

	Total	Wood	Bark
Exploitation	130	110	20
Primary transformation	76	59	17
Secondary transformation	14	14	-
Total	220	183	37

Ref. (5)

Dry wood is generally composed of 40-45% cellulose, 20-30% hemicellulose, the remainder being mainly lignin. These residues are often left on the spot during forestry exploitation or very poorly disposed of by uncontrolled combustion.

- Agricultural wastes

Agriculture is a very large waste-producer; for instance, in plant culture only a very small part of the plant is used as food agricultural wastes are generally left on the spot, burned or turned into the soil. In certain cases these practices can be considered as a primary recycling method.

In the United States the amount of agricultural wastes is about 300-500 million tons (dry weight). The wastes are mainly residues from corn, soya bean, wheat and sorghum production (Table 8).

In European countries important amounts of agricultural wastes are also available. Table 9 shows quantities of residues obtained from straw, corn and sugar beet production.

In some cases, particularly in the areas of intensive agriculture, it should be possible to recover sufficient tonnages of wastes economically in order to feed a chemical industry of non fossil carbon sources.

In-depth techno-economic studies have been carried out during the last few years at Battelle-Geneva. Presently, selected promising lines are being studied at the level of technical feasibility in a pilot plant development project (hydrolysis of vegetable materials: straw, bagasse, wood wastes).

The "Energy Farming" concept has recently been studied, particularly in the United States. Possibilities of producing fuels and chemicals from annual plants have been investigated in preliminary studies (Fuels from Sugar Crops). In this context the selected species include sugar cane, sorghum and sugar beet. The main aspects cover culture systems and the production, collection, storage and transformation of these vegetable materials.

Table 10 gives some data concerning the yields of these various cultures.

Table 8 Agricultural Wastes from Major Crops in USA

	T/acre	T/ha	Total millions of tons Min.	Max.
- Corn	2-3	5-7.5	124	186
- Soy beans	1-2	2-5-5	56	112
- Wheat	1-2	2.5-5	54	108
- Sorghum	2-3	5-7.5	32	48
- Oats	1-2	2.5-5	14	28
- Cotton	1-2	2.5-5	12	24
- Barley	1-2	2.5-5	11	22
- Sugar beet	1-2	2.5-5	1.2	2.4
- Sugar cane	6-10	15-25	6.6	11

Ref. (4)

Table 9 Agricultural Wastes in Selected European Countries

Country	Cereal-straw	Corn by-products stalk + cob (dry weight)	Beet by-products (dry weight) Pulp/green part + beet tops
France	26,000,000 t yield 3-3.7 t/ha.	9,000,000 t yield 1,8 t/ha.	1,100,000/ 2,800,000
U.K.	26,000,000 t yield 3-3.5 t/ha.		375,000/ 1,200,000
Holland	1,350,00 t yield 3-5 t/ha.		110,000
Belgium	1,765,000 t yield 3.6-4.4 t/ha.		120,000
W. Germany	8,600,000 t		700,000/ 2,000,000
Italy	8,850,000 t yield 1.5-2.5 t/ha.	4,000,00 t	
Spain	11,000,000 t Yield 1-2 t/ha.	2,000,000 t	

Table 10 Possible Yields of Saccharine Plants in the USA

	Short t/acre	t/ha	t MS/ha
Sugar cane solid 27%			
Texas	38	85.2	23
Louisiana	27	60.5	16
Florida			
a) Mucksoil	42	94	25.4
b) Peat soil	35	78.4	21
c) Sandy soil	31	69.5	18.75
Puerto Rico	27 - 35	60.5 - 78.4	16.3 - 21
Sorghum solid 22.5%			
USA	17 - 27	46.5 - 66.7	10.5 - 15
Sugar beet solid 20%			
California	35	78	15.6
Texas	22	49	9.8
Minnesota	15	33.6	6.7

Source : Battelle

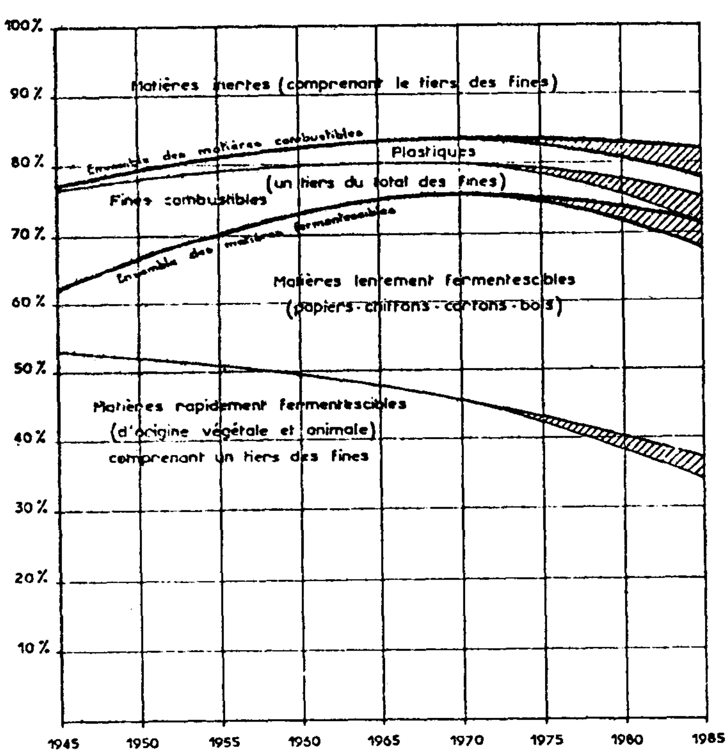
- Municipal solid wastes (MSW)

Table 11 Average Quantities of MSW in Various Countries

	kg/hab./an
France	290
W. Germany	200
Italy	200
Holland	270
Switzerland	150
UK	270
USA	1100

Ref. (6)

Fig. 1 Classification of MSW constituants and progressive evolution (7)



2. TECHNOLOGICAL ALTERNATIVES AND EXAMINATION OF VARIOUS PROCESSES

Available quantities of cellulosic wastes and carbohydrate residues from the agro food industries are considerable. These wastes can be considered as renewable resources, either chemical-wise (carbon source) or energy-wise. It also appears important that waste management considers the various ecological, economic and technological aspects related to the waste problem in order to obtain a better utilisation of these renewable resources, simultaneously aiming at an improved protection of the environment.

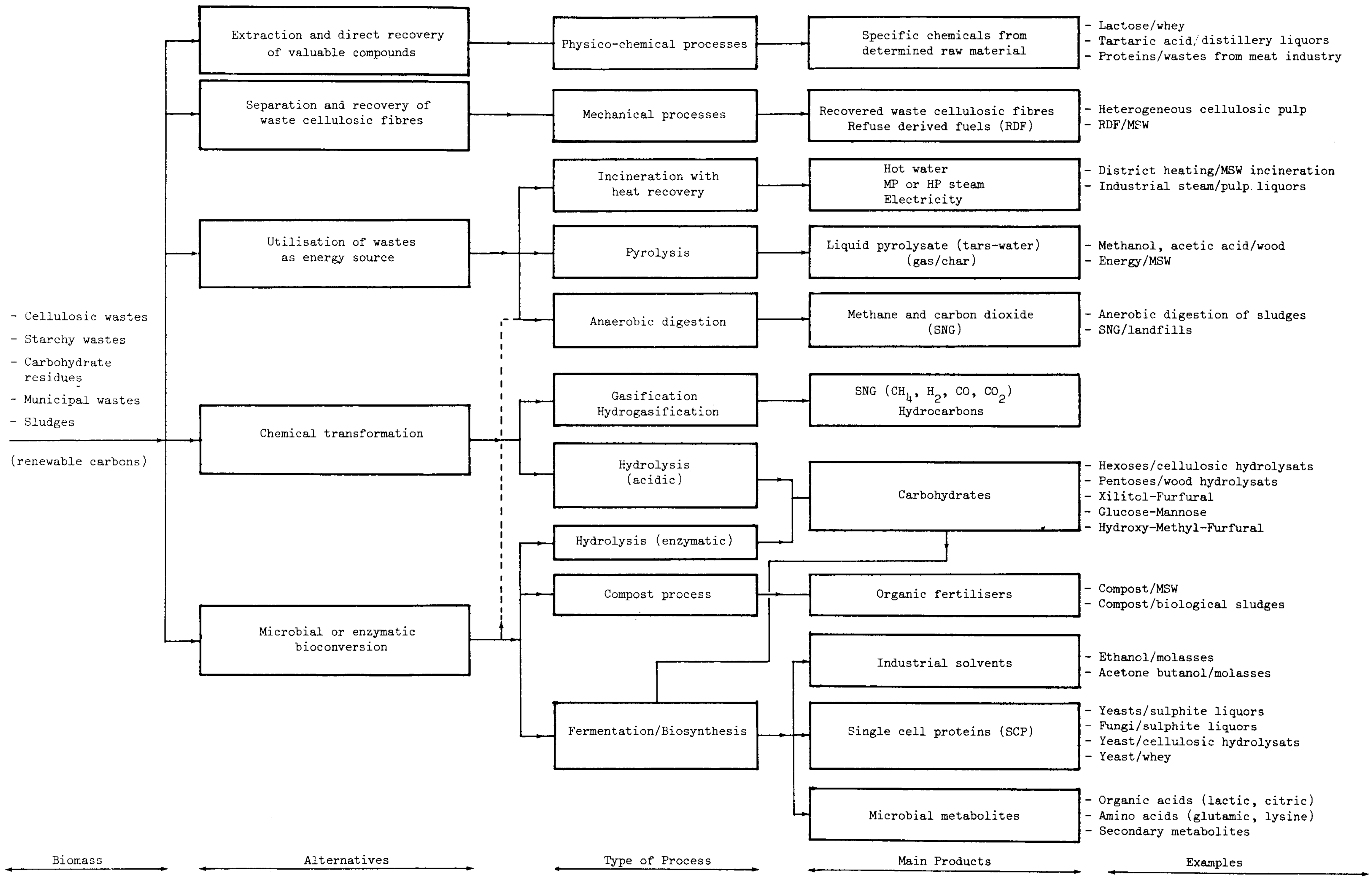
The system of waste recovery and recycling should be considered at various levels, including:

- nature and characteristics of the wastes
- technical feasibility of the processes
- economic feasibility
- markets for the recovered products.

In some cases an efficient technology is already available, allowing a satisfactory utilisation of the wastes. Assessment of specific solutions can be performed after a detailed study of the various aspects of the problem, taking into account the existing conditions in the considered area or country (socio-economic aspects, needs, infrastructures).

The following table summarises a group of technological alternatives for cellulosic waste utilisation as well as other carbohydrate residues from the agro food activities. It presents a certain number of possibilities based on available industrial technologies on the industrial scale or technologies under development.

The following examines the main aspects of the various alternatives.



TECHNOLOGICAL ALTERNATIVES FOR UPGRADING CELLULOSIC WASTES AND CARBOHYDRATES, RESIDUES FROM AGRICULTURAL AND FOOD INDUSTRIES

2.1 Extraction and Direct Recovery of Valuable Compounds from Wastes

Different examples show that wastes often constitute a source of raw materials which can be used industrially. It is sometimes interesting to recover selectively a valuable compound from the wastes. Reduction of pollution is, in this case, essentially linked to the concentration of the selected constituant in the wastes.

Various processes have been proposed in order to separate fats and proteins from the effluents of the specific industries (meat, milk, fisheries). In certain cases carbohydrates or other organic compounds can be recovered. For instance, lactose can be obtained from whey, which is the sole industrial source. Tartaric acid can be obtained either by fermentation or by direct extraction from distillery slops.

Recent work in the field of physico-chemical separation has greatly contributed to the development of extractive techniques (flotation, ion exchange, ultra filtration, reverse osmosis, electrodialysis). These new techniques can be of great interest in reducing the polluting levels of the effluents as well as recovery of valuable constituents.

2.2 Separation and Recovery of Cellulosic Fibres

Waste paper and, to a general extent, waste cellulosic fibres, have been considered for a long time as a secondary material. This situation has changed due to the increasing price of fresh cellulosic pulp. This trend, if it is confirmed, will be an important element for promoting the recovery and recycle of cellulosic fibres. However, various problems at the economic level (instability of waste paper prices, treatment costs) and at the technical level (elimination of contaminants, substitution of fresh pulp, classification of fibres) will have to be solved.

Presently, in various countries, waste paper is largely used in the paper and cardboard industry. The treatment of these fibres is far less polluting than the production of fresh fibres, and energy requirements are also less important. Heterogeneity of raw waste fibres is, however, an important problem in these processes.

Treatment technologies are generally adapted to a defined type of waste fibre. They have three main functions : pulping, classification, purification. De-inking is a complementary treatment aimed at increasing the brightness of the recovered pulp (two main techniques are used : de-inking by washing or by flotation). The units of recovered fibres are, however, dependent on the existence of a specialised collect system (selective collect, classification, storage).

Recently the recovery of cellulosic fibres from municipal solid wastes has begun to be realised. Two interesting installations can be noted:

- "Hydrasposal - Fibre claim", Black Clawson, Franklin, Ohio 150 t/d
- Cecchini Process, Rome, 1600 t/d.

Processes operating under dry conditions have also been proposed. In this case the separation of the cellulosic fraction is carried out either by ballistic separators or air classifiers. This cellulosic fraction can be used as raw material in subsequent recycling treatment or burned as a solid fuel (refuse derived fuels RDF). Among the recent processes, two can be mentioned:

- N.C.R.R. Process, New Orleans
- Union Electric, St. Louis.

2.3 Incineration with Energy Recovery

Combustion of cellulosic wastes releases a certain amount of heat which is a function of the composition of these wastes in terms of combustible, ash and water content. The heat value of cellulose is about 4000 kcal/kg. For municipal solid wastes this heat value greatly depends on the origin of the wastes. However, average figures are in the range 1000-3000 kcal/kg, giving a rough oil equivalent of wastes of about 0.1-0.3 t oil-equivalent.

In European countries and in Japan heat recovery from municipal solid waste incineration is a relatively common practice (Table 13). The technology used is based on incineration within furnaces equipped with reciprocating or rocking grates or rotating drums on which combustion in the solid phase takes place. The combustion chamber generally has a water-wall system.

Heat can be recovered through a system of heat exchangers placed in the hot gases flow region and in the radiation zone of the furnace. Boiler systems include an economiser, vaporisation bundle and superheater. The efficiency of the boiler system is about 60-70%, leading to vaporisation rates of 1.5 to 2.2 tons of steam per ton of waste. For a given unit, this vaporisation efficiency mainly depends on the heat value of the wastes.

The use of the recovered steam depends on the local possibilities offered by the energy market:

- utilisation as industrial steam
- production of domestic hot water
- district heating
- electricity generation.

Table 13 Heat Recovery from Municipal Solid Waste Incinerators in Various Countries

	Total Capacity t/day	Number of Units where Tons are known	t/day/unit	Population 1972-1973	Quantity of Waste Converted to steam per capita per day
Austria	1,320	2	660	7,490,000	0.388
Belgium	400	1	400	9,691,000	0.091
Canada	2,800	3	933	22,047,000	0.254
Denmark	5,670	36	158	5,100,000	2.446
Finland	384	1	384	4,630,000	0.182
France	11,708	28	418	51,915,000	0.496
Germany	26,908	31	868	78,720,000	0.752
Holland	8,892	8	1111	13,370,000	1.463
Italy	7,747	22	352	54,350,000	0.314
Japan	27,198	43	633	107,332,000	0.557
Norway	312	1	312	3.930,000	0.175
Russia	400	1	400	250,900,000	0.004
Spain	960	2	480	34,490,000	0.061
Sweden	5,090	21	242	8,143,000	1.375
Switzerland	5,170	21	246	6,420,000	1.712
U.K.	5,921	9	658	55,788,000	0.212
U.S.A.	6,540	9	727	205,000,000	0.062

Table 18 Some European Energy Recovery Plants from MSW

Location	Year plant started	Capacity (t/day)	Comments
W. Germany			
. Stuttgart	1965	1450	Combines refuse and sewage sludge
. Manheim	1965	450	Combines refuse and sewage sludge
. Essen-Karnap	1960	480	
. Dusseldorf	1965	1200	Unit type "Dusseldorf system"
. Hamburg	1973	900	
. Munich-North I	1964	1300	
. Munich-North II	1966	1100	Combined firing with fossil fuels
. Munich-South V	1969		
. Munich-South IV	1971	2100	
. Frankfurt	1966	1200	District heating and power generation
France			
. Paris St. Ouen	1954	1200	
. Paris-Issy	1965	1800	First "Martin" unit in France
. Paris-Ivry	1969	2600	"Martin" furnace electricity generation
. Nancy	1975	360	District heating
. Grenoble	1972	300	District heating
Holland			
. Rotterdam-Botlek	1972	1900	
. Rotterdam-Roteb	1964	1600	
Denmark			
. Kolding	1970	140	District heating
Sweden			
. Sundyberg	1967	120	Small unit, heats housing projects
. Stockholm-Högdalen	1966	720	"Dusseldorf system"
Switzerland			
. Zurich-Hagenholz	1969	1000	
. Lausanne	1958	200	"Von Roll" furnace
. Geneva	1966	400	"Von Roll" furnace electricity production

 Source : Battelle

Table 14 summarises various examples in Europe.

2.4 Pyrolysis of Cellulosic Wastes

Pyrolysis is defined as the chemical transformation of molecules under the action of heat. It can also be thought of as a destructive distillation in the absence of oxidants.

This process has been traditional for a long time and has constituted the basic technique in wood and coal chemistry.

Through this process single organic molecules can be obtained from various and complex raw organic materials, for instance:

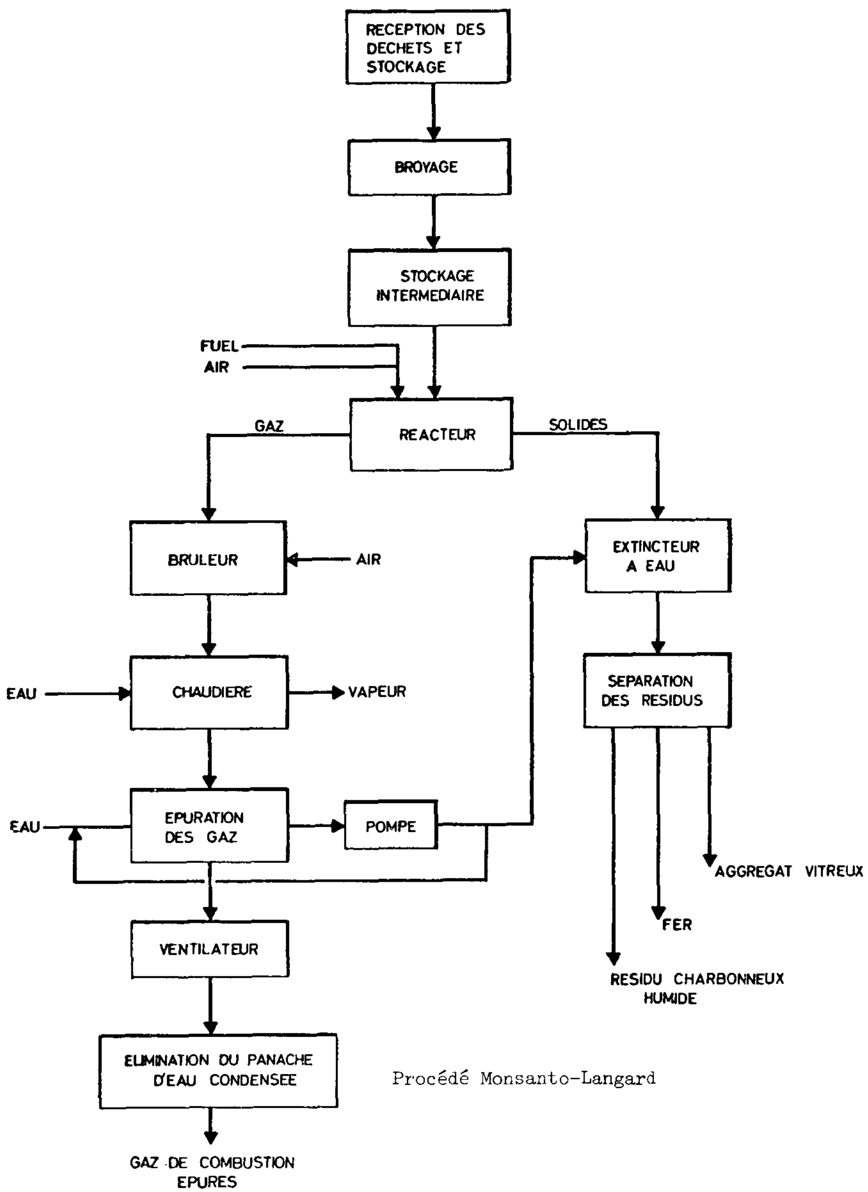
- production of methanol, acetic acid, turpentine and charcoal from wood
- production of cresols, quinoleic bases, tars from coal.

Various trials have been carried out in order to apply this technique to solid waste treatment. Main problem parameters to be solved are:

- operating conditions (temperature, heat transfer rate)
- characteristics of the feed (composition, heat value).

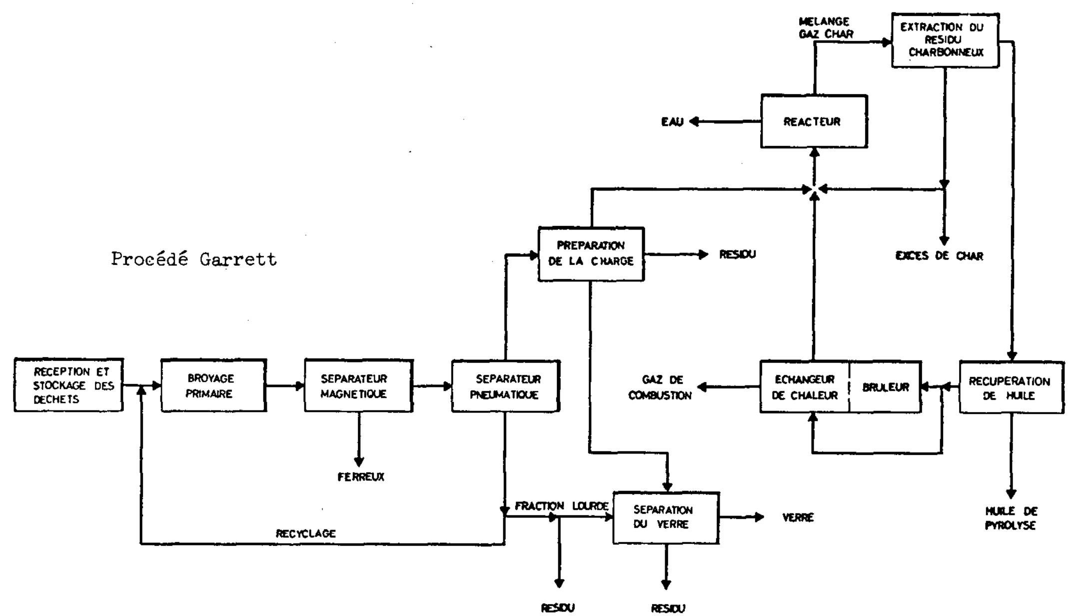
Production of specific products could be favoured to a certain extent by using different conditions, for example presence of steam, limited amounts of oxygen (gasification) or also presence of hydrogen (hydrogasification).

Various projects related to these possibilities are presently exploited or developed in the world, as numerous waste materials can be considered as potential feed (tyres, municipal solid wastes, vegetable and agricultural wastes, plastic wastes).



Procédé Monsanto-Langard

Procédé Garrett



Procédé Ardco-Torrax

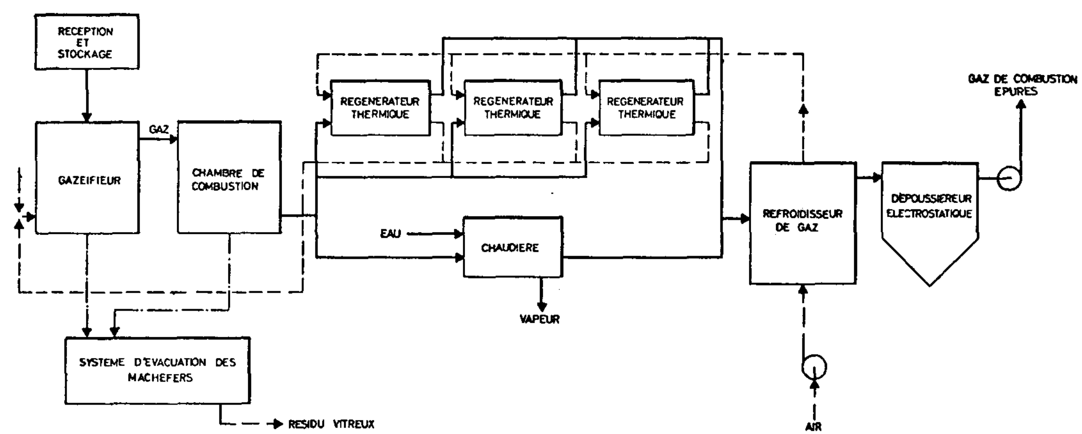


Tableau 15 Diagrammes schématiques de divers procédés de pyrolyse

Four broad classifications of products are obtained from pyrolysis:

- a solid fraction (char)
- a liquid aqueous mixture
- an organic fraction (oil and tars)
- a fraction of non-condensed gases.

The relative proportions of these different fractions depend greatly on the characteristics of the raw material as well as on the operating conditions.

In principle, the liquid organic fraction could be considered as a potential source of synthetic oil.

The potential advantages of pyrolysis include:

- self-maintained process with consumption of part of the combustible obtained
- production of storable liquid or gaseous compounds.

Since 1968, most of the studies concerning pyrolysis have been carried out in the United States (Municipal Solid Wastes) and in Japan (Plastic Wastes).

Table 15 gives the flow diagram for three of the main pyrolysis processes.

Investment for standard pyrolysis units represents about 65% of the investment required for an equivalent incineration unit.
In the latter case the average estimate of the investment would be $1.5\ 10^6$ FF per t.hour capacity for an incineration unit with heat recovery.

Among the recently developed processes can be noted:

- Monsanto Landgard process

The demonstration unit erected at Baltimore treats 1000 t/day of municipal solid wastes (average heat value 2500 kcal/kg). The objective of this project is to demonstrate the technical and economic feasability of the pyrolysis-gasification process with energy recovery. The feed is prepared by grinding, and metals are recovered. The pyrolysis reactor is of the rotary kiln type and is heated by the heat released during partial combustion of the wastes; a secondary heat source is necessary (fuel : 27 l/t of wastes). The boiler system allows the production of 100 t/h of steam (7-18.5 kg/cm^2) which gives an efficiency of about 2.5 t per t waste. The project cost is about 16.10^6 \$ (13).

- Garrett process

An industrial unit based on this process has been built in San Diego in order to obtain the information allowing the optimisation of the large scale commercial units.

The unit has been designed to treat 200 t/day of MSW (average heat value 2300 kcal/kg). Simultaneous addition of different waste tyres is possible. The feed is prepared prior to being introduced into a vertical tubular reactor. The thermal energy necessary to sustain the reaction is supplied by recycling part of the hot chars produced in the reactor.

It is possible to obtain about 180 kg of synthetic oil (heat value 5800 kcal/kg) per ton of waste. The overall energy efficiency of the system is about 40%. The project cost is approximately 9.10^6 \$ (12).

- Andco Torrax process

This is a high temperature pyrolysis-gasification process, developed for MSW from the technology used in the Steel industry.

Raw wastes are directly gasified at about 1600°C. The resulting gases are then burned in a secondary combustion chamber (1200°C). The heat of the high temperature gases is recovered in a conventional boiler. A 75 t/day unit is presently running in Buffalo (USA) (14).

2.5 Hydrolysis of Cellulosic Wastes

Hydrolysis consists of transforming cellulose as well as the other glucidic polymers in order to form sugars. This method generally leaves a non attacked residue - lignin. The chemical reaction is simply expressed by the reaction:

$$(C_6H_{10}O_5)_n + H_2O \longrightarrow n\ C_6H_{12}O_6$$

In practice the hydrolysis reaction has to be carried out in relatively severe conditions due to the high resistance offered by the cellulosic fibres to physico-chemical or biochemical attack.

Most of the processes which have been employed are derived from two basic methods using acidic solutions:

- Scholler process : Action of dilute acidic solutions (~ 1%) under pressure and high temperature (120-180°C) (Fig. 2) Derived process : Madison process.

- Bergius process : Action of concentrated acids at ambient temperature and pressure. Derived processes : Hereng and Rheinau processes (figs. 3 and 4).

The principal advantages of the processes using concentrated acids are mainly the yields of reducing sugars and the energy balances of the units. For instance, the Bergius-Rheinau process uses a preliminary prehydrolysis of the wood with 35% hydrochloric acid, followed by hydrolysis with 41% hydrochloric acid. The acid consumption is about 6 kg (HCl 100%) per 100 kg dry wood, the total sugar yield being 63 kg (same base) (15).

Cellulosic waste hydrolysis is a key step related to the chemical, biochemical or microbiological utilisation of these wastes. Various research and development projects are presently being carried out aimed at obtaining economic conditions for this fundamental step. Alternative technologies to the acidic processes are also being investigated and techniques based on enzymatic hydrolysis of cellulose have been proposed by:

- "Louisiana State University" which has worked on a method of direct conversion of cellulosic wastes to single cell proteins. This process is based on a mixed culture of cellulomonas bacteria with another microorganism - alcaligenes faecalis. (This latter can be replaced by a yeast). Cellulose degradation is due to the cellulolytic activity of the cellulomonas (17).

- "US Army Natick Laboratories" have developed an enzymatic method for hydrolysing cellulose fibres in order to obtain glucose solutions. Cellulose degradation occurs under the action of (C_1 - C_x) enzymatic complexes released by a fungi (Trichoderma Viricle) (16).

  These research studies are being carried out in depth and the long term results will almost certainly be exploitable industrially.

However, other research teams have preferred to concentrate their attention on the improvement of the acidic processes. This direction should give short term results capable of being applied quickly at the industrial scale. This is particularly so in the case of

Fig. 2 Simplified flow diagram of wood hydrolysis plant dilute sulphuric acid process

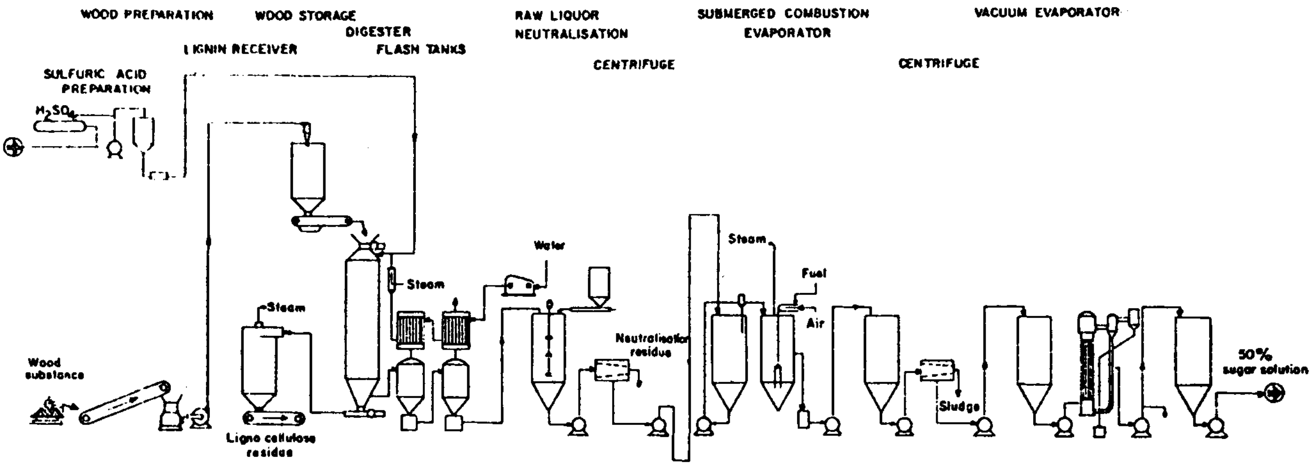


Fig. 3 Flow sheet of Bergius-Rheinau process

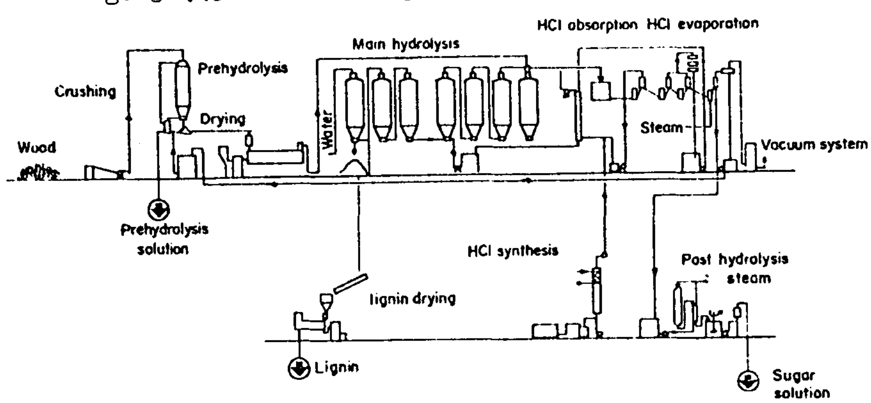
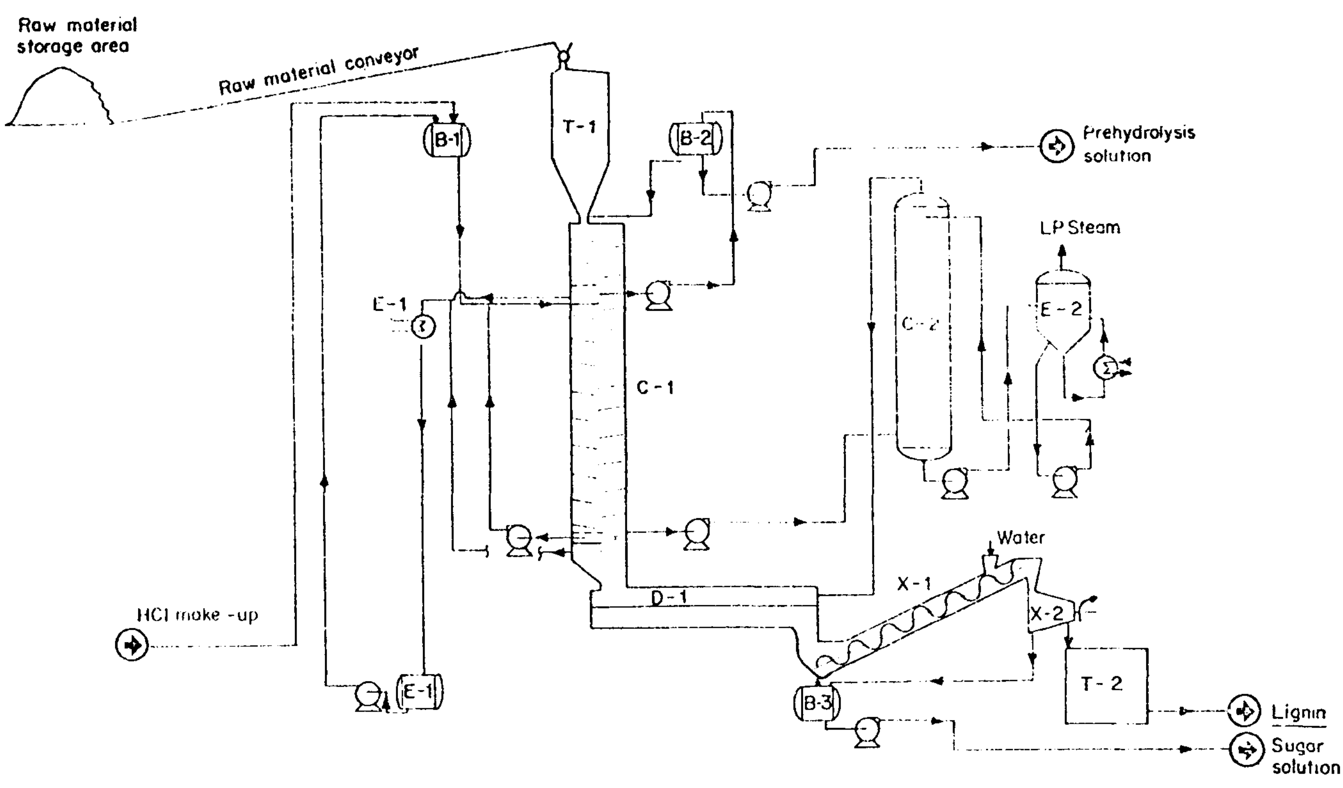


Fig. 4 Simplified flow diagram of HCl gas process

B-1 Hydrochloric acid tank
C-1 Barometric condensor
T-1 Raw material feeder
C-1 Saccharification column
B-2 Pentose solution tank
D-1 Dryer
C-2 Hcl dehydrating column
X-1 Sugar extracting device
B-3 Fermentable sugar solution tank
E-2 Dehydrating agent regenerator
X-2 Lignin recovery centrifuge
T-2 Lignin receiver



Battelle-Geneva where we are working on the development, at the pilot scale, of a hydrolysis process for vegetable wastes using concentrated hydrochloric acid (cf separate document "Non Fossil Carbon Sources").

2.6 General Aspects concerning Waste Bioconversion

Numerous methods using microorganisms have been used by man for centuries. Most civilisations empirically learned to use microorganisms without even knowing of their existance. These applications were essentially aimed at transforming natural food products, for example:

- Soy sauces from fermented beans in Japan and China
- Yoghourts in Central Europe and Arabian countries (Laban)
- wines and other beverages from fermented fruits
- Ensilage of vegetables for animal feeding.

These traditional utilisations are still the best means of storing perishable products. They have had a deep impact on the eating habits of different people.

Since the discovery of microorganisms by Pasteur, man has been trying to improve the empirical and traditional methods by using them more efficiently in industrial processes. Fundamental knowledge of their behaviour in the fields of genetics and biochemistry, and the development of biotechnology have greatly contributed to the progress of industrial microbiology during the last 20 years. Specific industrial processes adapted to living systems are already available and research and development activities are very high in this field. These processes utilise the high potentialities of certain microbes under controlled conditions and for defined objectives. They operate either with microorganisms or in pure or symbiotic cultures, or with specific enzymes obtained from defined microorganisms.

Practical applications of microorganisms are part of industrial reality. In the future, new applications may be developed, particularly in the following fields:

- bioconversion and storage of solar energy
- biological nitrogen fixation
- unconventional protein sources
- food or pharmaceutical industries.

Microbiological transformation of wastes is also a field of great interest. Possibilities allow the realisation of two simultaneous objectives:

- reduction of the pollution related to solid or liquid wastes
- production of metabolites or cell populations.

2.7 Production of Single Cell Proteins

Protein production is an essential objective for supplying food to meet human and animal needs. In the future protein demand will remain high. The production of single cell proteins appears to be very promising as a means of overcoming, at least partially, the increasing world protein shortage.

Production of microorganisms with high protein content can be realised industrially. Conditions of production are easier to control than conventional agricultural production; they are also independent of geographic and climatic variations.

The microorganism growth rate is far greater than animal or plant growth rate. A precise selection of species and strains can be rigourously carried out in order to obtain high productivities on the available substrates, taking into account the different nutritional and biological constraints. Microorganisms which can be used are widely different (yeasts, bacteria, algae, fungi). Yeasts of the Saccharomyces type have, for example, important industrial applications in the food industry (bread, wine, beer). Other species are also presently produced as food or feed yeasts, their nutritional interest being related to their high protein and vitamin content.

During the last few years the petrochemical substrates (gas oil, n- paraffins, methanol, ethanol) have been extensively studied in the research and development programmes of various companies. Some of the developed processes have now reached the level of the industrial unit, particularly in Europe (Table 16).

Various other possibilities offered by the systems of microorganisms/ substrates have also been considered or exploited. Production of single cell proteins from liquid effluents appears to be an interesting possibility in specific cases. This approach allows us to obtain from various complex soluble pollutants a homogeneous solid biomass which can be easily separated from the liquid. This biomass is composed of the microorganism population which has been able to assimilate the organic matter of the actual effluent. Pollution can be reduced from 50 to 90% with simultaneous recovery of a high protein biomass.

These processes can be considered as typical methods of profitable utilisation of waste. In certain cases, pollution reduction can be very high and simultaneous production of high value nutritional products can be realised. Yeasts have been obtained from various waste effluents, and recently fungi production has also been developed (Table 17).

Table 16 Single Cell Protein Production from Petrochemical Substrates

Producer	Organism	Substrate	Unit Size
British Petroleum Co. Grangemouth, Scotland	C. Lipolytica (yeast)	n paraffins	4,000 t/y
Société Française des Pétroles BP, Lavera, France.	C. Lipolytica (yeast)	gas oil	16,000 t/y
I.C.I., Billingham, U.K.	M. Methylotrophus (bacteria)	methanol	1,000 t/y
Liquichimica, Saline, Italy.	-	n paraffins	1,000,000 t/y
Ital proteins (BP ANIC), Sarroch, Italy.	C. Lipolytica	n paraffins	100,000 t/y

Table 17 Processes for the production of unicellular proteins from wastes

Type of Waste	Process	Organism
Waste from starch industry	Symba	Mixed culture Endomycopsis fibuliger C. Utilis
Sulphite liquor	Pekilo	Paecilomyces varioti
Sulphite liquor	Lefrançois	C. Utilis or other yeasts
Whey	Bel	Kluyveromyces Fragilis
Cane or beet slops	Lefrançois	C. Utilis or other yeasts

The following data give mass and energy balances concerning two processes for the upgrading of sulphite liquors (Table 18).

	Pekilo Process (8)	Lefrançois Process (9)
Microorganisms	Paecilomyces	Candida
Utilities:		
Electricity	1300-1600 kWh/t	1100-1050 kWh/t
Steam	5.5 Gcal/t	4 Gcal/t
Water	600 m^3/t	600 m^3/t
Gas		0.7 Nm^3/t
Additives	NH_3 100 kg/t KCl 15 kg/t P_2O_5 40 kg/t	100-110 kg/t K_2O 25 kg/t P_2O_5 45-50 kg/t
% proteins dry weight	55-60	50

2.8 Energy and Chemicals Production

The bioconversion systems used to convert waste to energy or to chemicals may be classified as anaerobic digestion and fermentation. The anaerobic digestion system (or bio-gas production system) produces, under proper environmental conditions, fuel gas (methane) as a mixture with CO_2. The reactions occuring in such a process are determined by a complex symbiotic system of various strictly anaerobic microorganisms (Methanogenic bacteria, acid forming bacteria, mesophilic or thermophylic bacteria).

The fermentation systems are generally based on a defined culture of microorganism population, selected with respect to a specific metabolism leading to specific microbial primary metabolites (alcohols).

Among the more significant examples are:

- Ethanol	S. Cerevisiae
- Butanol/acetone	Clostridium acetobutylicum
- Glycerol	S. Cerevisiae (by-passing the alcoholic fermentation)
- Butane 2-3 diol	Bacillus Polymyxa

2.8.1 Anaerobic digestion systems

This process can be applied to a wide range of organic matter. The anaerobic digestion of these organic matters to produce methane consists of three consecutive steps: solubilisation of the organic matters; acidification in which the bacteria reduces the soluble organic materials to organic acids (formates, acetates, propionates); and in the final stage methanation where organic acids are reduced to methane under the action of methanogenic bacteria. They are probably very specialised microorganisms which are only able to use single molecules (H_2, CO_2, formate and acetate) to produce methane.

The various microorganisms interacting in the various complex reactions may be classified as:

- acidic bacteria
- methanogenic bacteria

They are considerably different at the level of physiology, nutritional and energy needs, kinectics and adaptability to environmental conditions. The conception of two-stage digesters may be an interesting solution for these systems to improve their efficiency.

Critical parameters affecting the anaerobic digestion are pH, retention time and temperature. In addition, the bacteria involved in the process are very sensitive to toxics. Anaerobic digestion is currently carried out at a pH around neutrality. Temperature has favourable effects on the reaction rates and some benefits can be expected in running the digestors under thermophylic conditions (55-60°C) rather than under mesophilic conditions (31-37°C).

The gas produced is generally a mixture containing 50 to 60% methane. This gas can be purified in order to eliminate contaminants such as CO_2 or H_2S.

Study of the optimum conditions for the various systems considered could be done in order to select the most promising, taking into account economic considerations.

Anaerobic digestion is, moreover, a current method applied to the treatment of sludges obtained by purification of waste water through activated sludge processes.

The possibility of methane gas recovery from landfill has also been examined, mainly in the United States. The two configurations in which methane recovery programmes can be developed include:

- recovery systems for previously completed sanitary landfill
- recovery systems for partially completed portion of presently operating sanitary landfill.

Two processes are operating in the United States:

- The "NRG NuFuel Company" process recovers methane which is upgraded and marketed to natural gaz consumers

- the process of the "Los Angeles Department of Water and Power" utilises non-purified extracted methane to generate electricity.

2.8.2 Fermentation systems

Ethanol production through fermentation has been for a long time the only possibility of obtaining this basic chemical on an industrial scale. However, the synthetic process using ethylene to produce industrial ethyl alcohol is more attractive now in most cases. In the United States, for example, practically all industrial ethanol is currently obtained synthetically. This situation could change in the future.

It is technically feasible to produce ethanol through fermentation of various sources of fermentable sugars (mainly hexoses). The fermentation industry generally uses three main raw materials:

- Saccharine materials : molasses
- Starchy materials : corn and potatoes
- Cellulosic materials : waste sulphite liquors.

The production cost of ethanol through fermentation is largely dependent on the price of the raw material used. The following estimates have been published in a recent publication. Considering the production of ethanol from corn with a yield of 2.7 gallons (200^{o} proof) ethanol/bushel of corn (about 380 kg of ethanol/t dry material), the production cost of ethanol would be 80.9 cents/gallon (270 \$/t). If corn is available at 1.50 \$/bushel (70 \$/t dry material), the raw material cost would represent up to 70% of the production cost. If corn is available at 4 \$/bushel (190 \$/t dry material), ethanol should be produced at 173.8 cents/gallon (570 \$/t).

The production cost of ethanol from ethylene would be 52 cents/ gallon (170 \$/t) with ethylene available at 5 cents/lb (110 \$/t) and 93.8 cents/gallon (310 \$/t) when ethylene is available at 15 cents:lb (330 \$/t).

Fermentation processes may become competitive if ethylene prices increase. Taking into account the high impact of substrate cost on the production cost of ethanol through fermentation, particular attention must be paid to the best selection of the appropriate carbon source. A small variation in the substrate cost will give rise to an important variation in the production cost.

Systematic utilisation of both molasses and waste effluents from the sugar industry appears to be an interesting alternative, as demonstrated by the Brazilian national alcohol programme. During 1975 Brazil produced through fermentation 750,000 m^3 of ethanol. The national programme foresees the production in the early 80's of 3.10^6 m^3 of ethanol through systematic utilisation of waste sugar solutions.

This production will certainly be of strategic importance from the economic point of view as it will contribute in a marked way to the overall energy balance in Brazil.

Sugar solutions obtained through hydrolysis of cellulosic wastes also appear to be substrates of potential interest for the production of ethanol. Ethanol could be obtained by fermentation of cellulosic hydrolysats at a production cost inferior to 150 \$/t when cellulosic wastes or vegetable materials are available at 30 \$/t, with an operating cost of the hydrolysis unit between 20-30 \$/t.

This orientation can be an interesting alternative for the large scale production of ethanol. It is presently being studied both technically and economically within our laboratories.

2.9 Utilisation in a Biosynthesis Industry

The biosynthesis of different microbial metabolites through fermentation of agro industrial substrates consitutes a field of particular interest due to the possibility of obtaining sophisticated compounds destined for the fine chemistry, pharmaceutical or food industry.

The following classes of microbial metabolites can be obtained:

- Organic acids (lactic, citric)
- Amino acids (L glutamic acid, L lysin)
- Polysaccharides (dextrans)
- Antibiotics
- Enzymes.

Biosynthesis systems may be classified as:

- Direct biosynthesis through transformation of a substrate by a specific microorganism (L glutamic acid, L lysin, citric acid)

- Enzymatic bioconversion by specific action on a selected substrate (isomeration of glucose to fructose syrup)

- Multi-step biosynthesis in which the production of a required enzyme is first induced, followed by selective reaction to obtain a specific product (dextran).

Examples are very numerous, however applications of the amino acids in human or animal nutrition are of particular importance (Table 19).

Cereals generally have low lysin contents; on the other hand, high grade proteins (fish, meat, soya) are relatively poor in sulphur-amino acids (methionine, cystine). The amino acid content of proteins plays a determining role in the definition of the optimum composition of the feedstuff in industrial animal feeding. L lysine and methionine are generally the limiting amino acids in the association cereal, oil-cake. Their production at the industrial scale is thus of interest as their availability allows the upgrading of the nutritional value of protein mixtures.

L glutamic acid is industrially obtained by fermentation. It is reserved for human food where it acts as a flavour enhancer of certain foods.

Utilisation of agricultural and agro industrial substrates in a biosynthesis industry is, however, based on very specific techniques and specialised "know-how". The recent industrial realisations in the field of microbial metabolite production demonstrate the real interest in microbiological systems and the profit than man can expect from their efficient utilisation.

Table 19 Main Industrial Amino Acids

	Production Process	World Capacity X 1000 t	Foreseen Demand 1980 X 1000 t	Actual and Potential Uses
L glutamic acid	Fermentation	200	300-330	- Food additive - enhancer - Enhancer - Synthetic leather
L glycine	Chemical synthesis	12	12-15	Pharmaceutical applications
L lysine	Fermentation	16	60-70	- Feed additive - Cereal complementation
DL methionine	Chemical synthesis	92	100-140	- Feed additive - Oil-cake complementation
L tryptophane	Synthesis/separation	0.1-1	1-5	Cereal complementation

Ref. (10)

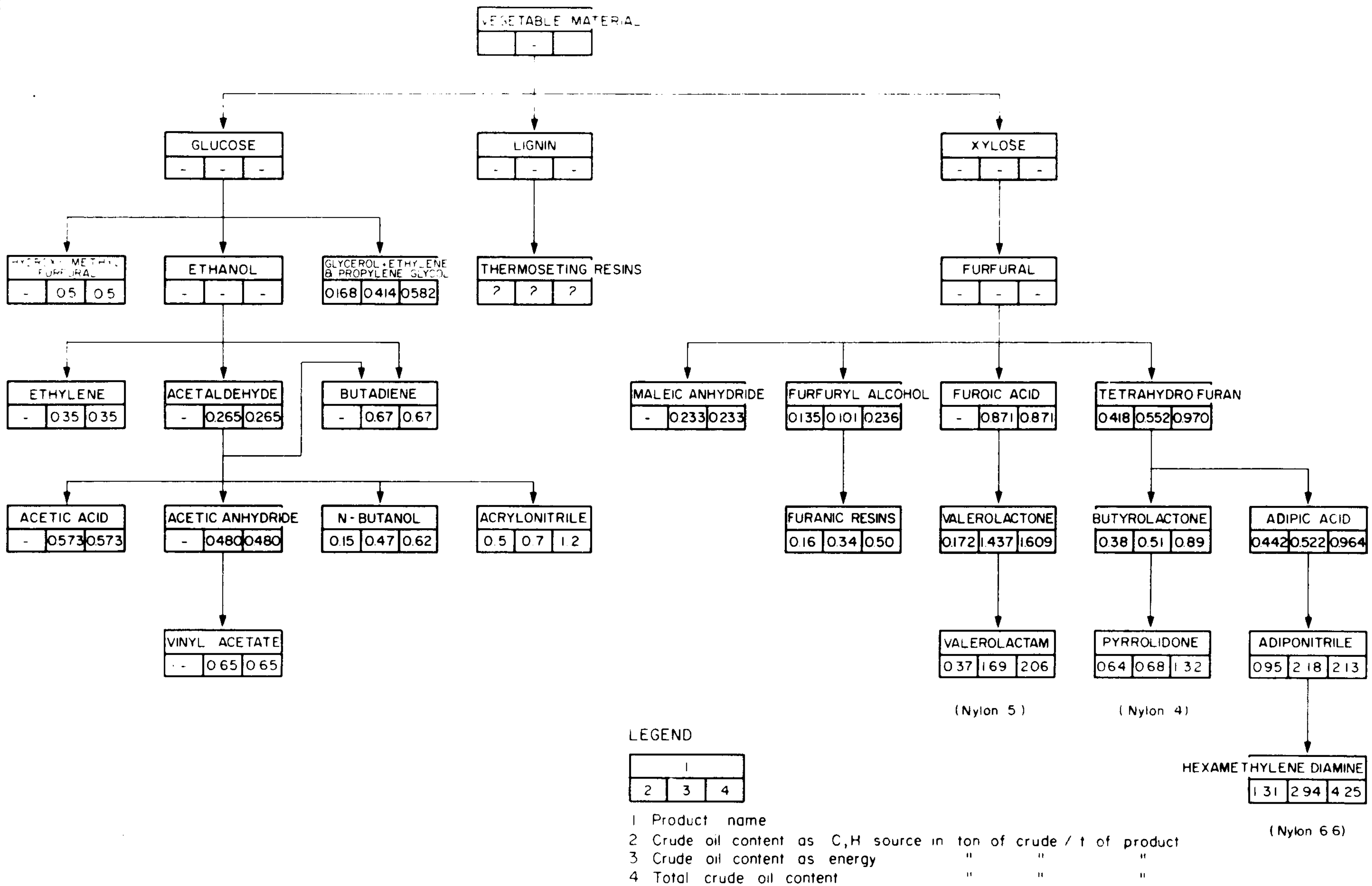


Fig 5 CRUDE OIL AND ENERGY CONTENTS OF THE MAIN NON FOSSIL CHEMICALS

Tableau 20

END USE PRODUCTS	PRODUCTION (IN TONS)	NON FOSSILE CHEMISTRY		PETROCHEMISTRY	(II) - (I)
		CONSUMPTION OF NON FOSSILE FEEDSTOCK (IN TONS)	CONSUMPTION OF CRUDE OIL (I) (IN TONS)	CONSUMPTION OF CRUDE OIL (II) (IN TONS)	
		ETHANOL			
ETHANOL	100,000	100,000	-	121,000	
ACETALDEHYDE	-	-	-	-	
ACETIC ACID	150,000*	120,000*	52,000	240,000	
ACETIC ANHYDRIDE	168,000	178,000	31,000	238,000	
BUTANOL-BUTYRALDEHYDE	130,000	220,000	80,000	264,000	
ACRYLONITRILE	130,000	143,000	52,000	396,000	
VINYL ACETATE	90,000	165,000	59,000	185,000	
BUTADIENE	120,000	330,000	36,000	456,000	
MISCELLANEOUS	300,000	330,000	100,000	600,000	
TOTAL (1)	......	1,580,000	460,000	2,500,000	2,040,000
		GLUCOSE			
GLYCEROL AND GLYCEROL ESTERS	100,000	285,000	60,000	150,000	
HMF AND MISCELLANEOUS	80,000	115,000	40,000	120,000	
TOTAL (2)	......	400,000	100,000	270,000	170,000
		FURFURAL			
ADIPIC ACID	300,000	340,000	147,000	800,000	
ADIPONITRILE	200,000	340,000	354,000	1,082,000	
MALEIC ANHYDRIDE	50,000	80,000	12,000	98,000	
MISCELLANEOUS	80,000	120,000	60,000	240,000	
TOTAL (3)	......	880,000	573,000	2,300,000	1,727,000
		LIGNIN			
LIGNIN-FORMOL RESIN	500,000	500,000	300,000	1,500,000	1,200,000
TOTAL (4)		500,000	300,000	1,500,000	
GRAND TOTAL (1,2,3,4)	......		1,433,000	6,570,000	5,137,000

3. MEDIUM AND LONG TERM PERSPECTIVES

The utilisation of cellulosic wastes and carbohydrates, residues from agriculture and the agro food industry presently remains limited. However, various examples have shown that efficient industrial processes can operate in order to upgrade some of these wastes in satisfactory economic conditions.

The general methods aimed at using these wastes include:

- direct utilisation of the wastes (scattering in the fields, compost)
- extraction of constituants from the wastes
- thermal, chemical or microbial transformation of the wastes.

Various technologies are available.

It appeared important to orientate our research and development programmes towards possible utilisation of the wastes after chemical transformation or bioconversion. Considering this line, the key step to be resolved is the hydrolysis of the cellulosic materials. It allows the production of cheap hexose and pentose solutions under profitable economic conditions. These sugar solutions can then be used either chemically or microbiologically.

Considering the different evolution of oil and vegetable material prices, an industry of the non fossil carbon source type could be established. However, there is only a small probability of substituting this chemistry for petrochemistry. It could allow the manufacture of certain intermediate chemicals, and act as a complementary solution for producing certain specific products.

Fig. 5 is a flowchart summarising the different pathways for a renewable carbon source chemistry. Table 20 gives a comparaison based on energy and materials consumption, between the petrochemical productions and the alternative "renewable carbon" chemistry.

In addition, the availability of cheap substrates (hexose and pentose solutions) could greatly contribute to the partial overcoming of the protein shortage. Single cell proteins can be obtained from sugar solutions and this method of production would appear to be an interesting alternative to the processes based on petrochemical substrates (paraffin, methanol, ethanol), not only in industrialised countries but also in certain developing countries which have no oil resources (11).

The availability of cheap substrate would also contribute to the development of a biosynthesis industry, allowing the production of a wide range of microbial metabolites. This orientation is, however, largely dependent on the successful development of microbiological systems.

Finally, we should consider the problem of biological sludge utilisation. These sludges are produced in large amounts during waste water treatment based on activated sludge processes. They are essentially composed of organic matter and are characterised by a high protein content. These sludges are presently difficult to upgrade and the cost of their elimination is always relatively important. This sludge has, however, a certain potential value although, in view of its heterogeneous nature, it would be inconceivable to use it in its original form.

In order to minimise biological sludge disposal problems, with simultaneous recovery of valuable compounds, we have started a research programme with the objective of transforming these sludges during the water purification process, to protozoa proteins. The method that we have chosen is partially based on the natural food chains. The complex microflora which have been obtained from polluants are digested by a selected species of bactivorous protozoa. These protozoa are considered as a potential source of high grade proteins and can be easily recovered from the purified water stream and then conditioned as S.C.P. This process, combining at the same time, depollution and nutrition, could constitute an important long term step in the general context of a "Non Waste Technology".

4. CONCLUSIONS

This general presentation was limited to the examination of various technological alternatives in the field of upgrading of cellulosic wastes and carbohydrate residues from agricultural and agro food industries.

Different industrial possibilities have been briefly described. They demonstrate the determination to profitably use certain waste materials in order to upgrade them, avoiding at the same time transfer of pollution.

These are possibilities which can be complementary but, in certain cases, numerous factors can considerably limit the applicability of a specific technology. It is important to consider each project in relation to the local conditions in order to define the solution which presents the best prospect at the technical, economical and environmental levels.

Recycling of wastes appears a long term necessity, allowing both environment protection and a high level of consumption. In this context the development of new technologies or the adaptation to waste disposal of existing technologies will be a determining aspect.

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