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APPROPRIATE TECHNOLOGY FOR THE PRODUCTION OF OILS AND FATS

APPROPRIATE TECHNOLOGY FOR OILS AND FATS

~~Discussion Paper~~

Appropriate Technology
for Oils and Fats *

Issues and Considerations

Note prepared by the secretariat of UNIDO

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OILS AND FATS *

Contents

* Reference is invited to the background documents which are attached.

Summary

(i) Oils and fats production is an important agro-industrial activity and could be the basis of further industrialization in the developing countries.

(ii) The per capita consumption of oils and fats for food is about 5 kg in the developing countries as against 20 kg in the developed countries and emphasizes the urgent necessity to augment supplies to meet minimum nutritional requirements.

(iii) Varying scales and production technologies are employed in the processing of oilseeds and their products. Upgrading of the low levels of technology is necessary in the interests of efficiency and economy.

(iv) The industry lends itself to decentralization. It contributes significantly to the economies of the developing countries in making available an important article of food, providing employment opportunities and earning foreign exchange by the export of processed oils and by-products.

(v) Intergovernmental institutional arrangements have been established for groundnut, olive oil, and coconut industries. These need to be strengthened.

(vi) UNIDO organized the first consultation meeting in vegetable oils and fats industry in December 1977. A number of areas have been identified for international co-operation.

(vii) The objectives in the search for alternative technologies and decentralization of the industry are efficient utilization of indigenous resources including the by-products, increase in per capita consumption of oils and fats, greater dispersal of the industry and strengthening of national technological capability.

(viii) The alternative methods of processing oilseeds and their products from village level to mechanized , power operated techniques to sophisticated technologies have been indicated.

(ix) The peculiar technological requirements of cotton-seed, coconut and oil palm and soyabean industries have been discussed. The stabilization of rice bran has been a subject of Research and Development. Emphasis has been placed on the utilization of oil seed cake/meal as a source of protein and the development of the feed industry.

(x) Some points for consideration have been identified as (a) planned production and utilization of oil seed raw materials, (b) the structure of the industry including decentralization, (c) the markets for oils and fats and their by-products,(d) mechanical expression, (e) solvent extraction, (f) pre-pressing and solvent extraction, (g) refining, (h) factory management, (i) the linkage of the oils and fats industry with other sectors of processing, and (j) pre-investment considerations.

(xi) The policy implications should take into account production, processing and marketing constraints.

(xii) The government regulatory and fiscal policy would be in measures such as:reservation of capacity for the decentralized sector, incentives for development of specific industrial activities, price control, credit and marketing facilities; strengthening national technological capability including the indigenous production of equipment and machinery and, within the organizational structure of the government, to bring about effective co-ordination of the development activities generally dispersed in different departments and institutes.

(xii) The role of international co-operation would be in support of specific research projects of interest to developing countries, such as cottonseed, coconut, oil palm, rice bran etc. - International agencies could support national and regional R and D activities by providing both technical and financial assistance. Other areas of co-operation among developing countries could assist in the exchange of experiences, especially in the strategies for decentralization of the industry. The production of spare parts for machinery,/and equipment to start with and the manufacture of machinery for the oils and fats industry would be an important area of international co-operation.

Introduction

1) In most developing countries oils and fats industry is an important agro-industrial activity. It could be the basis for further industrialization. Primary processing of the oil seed or kernel into crude oil exists in almost all the countries. Secondary processing is less developed although facilities are being built to varying degrees in different countries. Soap making is widely prevalent and the technology base is simple. The production of margarine, washing powder and detergents have made limited progress because of the unsophisticated nature of the internal markets.

2) The per capita consumption of oils and fats for food is reported to be 4.4 kg for Asian region, 8 kg for Latin America, 7.4 kg in the Near East and 5.1 kg in Africa, as against an average 20 kg in the developed countries.

3) The oil palm industry as it is being developed in Malaysia and Ivory Coast serves the social aspects of industrialization in providing shelter and employment. Similarly the processing of coconut and its by-products provides extensive employment opportunities. Cotton seed processing and the by-products utilization also differ from other oil seeds.

4) In the oil extraction technology from oil seeds, broadly two methods are recognised - (i) mechanical expression, by the use of hydraulic press or screw press and (ii) the solvent extraction process. Different scales of processing and technologies are in use not only for extraction of oil but also for refining oils and the utilization of the by-products. According to the UNIDO study[1/] the share in the processing technologies of the developing countries as a whole, in village scale is 8-10%, in small scale expellers 45-55%, in the medium to large scale expellers 25-30%, and in solvent extraction 12-18%.

5) In the oils and fats industry there are different levels of technology which have been applied to varying degrees in the developing countries. The organizational problems such as making the raw material available through proper transport and distribution system and other supporting facilities require consideration. The oil milling industry lends itself to

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1/ Draft World-wide Study on the Vegetable Oils and Fats Industry: 1975-2000, UNIDO/icis.46.

decentralized processing without sacrificing the processing efficiency and the quality of the products. The socio-economic benefits could be immense when appropriate technologies are adopted.

6) Oil seed processing contributes significantly to the economies of the developing countries. Notable examples are coconut and its by-products (nearly 1/3 of the population of the Philippines and to a larger extent of some of the Pacific island countries are dependent on this industry). Oil palm plays an important role in the economies of Malaysia, Ivory Coast and a few others.

7) Institutional arrangements in the form of inter-governmental bodies have been established, namely the African Groundnut Council, the Olive Oil Council and the Asian and Pacific Coconut Community which promote the development of these industries.

8) Multinationals operate in a number of developing countries and are engaged in operations involving extraction and refining of vegetable oils and production of shortening, soap and synthetic detergents.

9) Among the processed products, refined oils are produced for frying and cooking purposes. Margarine is hydrogenated vegetable oil and is a substitute for butter. Soap production starts at low-levels of technology. Oil seed cakes and meals along with other indigenous raw materials are used in the manufacture of compound animal feeding stuffs or balanced rations. Each one of these activities could be a small or medium scale industry or all these activities could be combined in an integrated complex. In view of the scarcity of oils and fats for soap production in some of the developing countries, production of synthetic detergents has been established. This is particularly evident in countries where the multinationals are operating.

10) In the system of consultations established by UNIDO the first consultation meeting on the vegetable oils and fats industry was organized in December 1977 in Innsbruck. The deliberations have focussed attention on issues for international co-operation.

Objectives

11) The search for alternative technologies and decentralization of the industry are the guiding principles. The social and economic benefits of such industrialization should be widely shared by the people especially in the rural areas. In order to achieve these aims, the following objectives are set forth:

(a) efficient utilization of indigenous resources of oil-bearing materials for production of oils and fats and maximum utilization of the by-products;

(b) to increase the per capita consumption of oils and fats to meet minimum nutritional requirements ;

(c) fuller utilization of installed capacity for oil extraction, refining, processing, etc.

(d) utilization of oil seed cake/meal as a source of protein and development of animal feed industry ;

(e) greater disperal of the growth of the industry to under-developed and rural areas and generation of employment opportunities ;

(f) establishment or strengthening of national technological institutes for selection, development, application and transfer of technology, extension service and information dissemination and also development of design and engineering capability to manufacture equipment and machinery required for the industry.

Review of alternative technologies

12) The oils and fats industry presents an interesting study of widely varying plant size and production capacities. Investment and entrepreneurial requirements would vary from small-scale simple oilseed crushing units to integrated complexes such as in oil palm, coconut, cotton-seed and soybean processing industries. By and large, the low-scale technology employed in most developing countries is wasteful. Considerable improvements could be brought about in oil extraction, refining, margarine

production etc., and also in the utilization of by-products,such as the oilseed cake or meal. The employment potential is quite large and the industry lends itself to increased decentralization. Admittedly oil palm processing should be within the oil palm cultivation area for technical reasons due to quick deterioration of the fresh fruit bunches. Even other oil seeds could conveniently be processed nearer the souice of production of the raw material. However, when industry is export-oriented or is required to meet large demand for concentrated urban population, establishment of integrated complexes on grounds of the availability of markets or export facilities would seem to be justified. Marketing and distribution in the case of edible oils also presents an interesting picture. In most developing countries the patterns of consumption vary and hence the packaging, transport and distribution techniques. A few developing countries in the world are exporters such as Malaysia for the palm oil, and the Philippines for coconut oil and Brazil for soybean oil. Most other countries are either self-sufficient or importers of oils and fats. In countries where the supply is short of demand the prices are invariably higher than the world market prices. Government intervention in importing the oils and fats helps only to meet the demand to some extent but consumer prices tend to remain high. Foreign exchange constraint is an important consideration in allowing the import of oils and fats.

13) As a part of the preparations for the organization of the first consultation meeting on the vegetable oils and fats industry in December 1977, UNIDO commissioned a World Wide Study on the Vegetable Oils and Fats Industry 1975 - 2000 (UNIDO/ICIS 46). The study has examined the patterns of production, trade and prices of oil seeds, Vanaspati (hydrogenated vegetable oils) and soap making. Particular reference has been drawn to the under-utilization of capacity. The main variables which influence the development of the industry have been indicated. The future trend of growth and expansion of the industry has also been postulated. The problems and constraints which tend to limit the efficiency and expansion of the industry have been discussed. The point has been made that policies and strategies have to be developed and effected to overcome a number of constraints to maximize production.

14) In a separate section of the report, the technology of oilseed processing methods, substitutability between vegetable oils and related

matters have been discussed. In view of the usefulness of this analysis the relevant material pertaining to alternative methods of processing is reproduced in Annex-1. The end uses of oilseeds is shown in Annex-2.

15) The village level processing methods have their own limitations. Hand-operated processing methods have the disadvantage of inefficiency and wasteful use of resources. By-products are not used to the best advantage, while these processes could and should be upgraded. In the context of examining appropriate technology, in the sense that a technology that would bring maximum socio-economic benefits to the majority of the population, it would seem necessary to concentrate on mechanized technologies, and search for alternatives that could meet the objectives. It would seem necessary to replace the village ghani technique of oil extraction. In this method the oil extraction efficiency is admittedly poor when processing oil seeds such as groundnut, sesame, rape/mustard. The residual oil content in the oil cake up to 18% or more in this type of processing, is wasted. Even if the cake is used as a feed stuff for the cattle such a high percentage of oil is not required by the animal. Therefore wherever feasible the upgrading of technology would be replacement by mechanical screw presses which ensure a higher rate of recovery. Along with such technological improvements due attention should be paid to the transport, storage and handling of the oil-bearing materials. With groundnuts for instance, after harvest if they are not properly dried and should breakages occur in the seed, they become susceptible to bacterial attack and a toxicityknown as aflatoxin develops. This reduces the value of the oilcake or meal. It is possible to collect oilcakes from small scale oil milling units and extract the oil in the solvent extraction plants which are centrally located. There is a wide choice of technology in the solvent extraction plants;on the same analogy it should be possible to collect the crude oil from small oil milling units and refine the oil to produce refined cooking oils, hydrogenated oils (vanaspati) or bakery fats.

16) In commercial processing, attention should be paid to the handling and storage of oil seeds to avoid damage and to minimize the natural deteriorative factors which lead to increases in free fatty acid content and the development of objectionable odours, flavours and colours in the extracted oil as well as reducing the value of the residual oil cake or meal. Therefore the successful storage of oil seeds should take into account critical moisture levels above which the proliferation of fungi and bacteria and the activity of the enzymes lead to rapid deterioration.

17) The oil extraction and refining techniques are explained in Annex-1. It would however be useful to examine the processing of some specific oilseeds or oil bearing material which call for special pre-treatment and processing techniques. The method of oilseed processing either by mechanical expression or solvent extraction process is by and large the same in the case of most oilseeds such as groundnut, sesame, rape or mustard, soybean etc. However there are some oilseeds or oil bearing materials in which there is a variation of processing technology. It is for this reason that in the following paragraphs the processing technologies of selected oilbearing materials such as: (i) cottonseed, (ii) coconut, (iii) oil palm & (iv) rice bran and (v) soy bean have been examined to illustrate the peculiar characteristics of such technologies.

18) In cottonseed processing, the oil is extracted to some extent by using the primitive techniques and without delinting or decorticating the seed which results in poor yields of oil and cake. An efficient cotton-seed crushing unit would provide suitable storage facilities for the seed and at the first stage clean the seed to remove stalk, leaf, etc. and then subject it to delinting which results in first and second cut linters with specific uses as raw materials for specialized type of paper making and cellulose acetate production. The seed is then subjected to decortication which separates the hulls from the meats. The meats are cooked and subjected to either mechanical expression or solvent extraction or a combination of the two. Under these circumstances the yield of oil is higher and the quality better. The hulls have an economic value as roughage in animal feeds. The cottonseed cake or meal is of a better quality and is an important raw material for the manufacture of compound animal feeds. Even in the context of decentralization of the industry the point to be emphasised is that there should be no compromise on the efficiency of processing the cottonseed and its by-products as explained here. Perhaps the adaptation of technology should be examined to permit processing in the small and medium scale sectors.

19) Another interesting example would be the processing of coconut products. As practised at present, the primary processing of coconut into copra and the further stages of conversion into oil and cake, refining the oil, etc. as also the utilization of by-products of oil cake or meal, coir, shell, etc. call for considerable technological improvements. The improvements in copra production will prevent its deterioration by fungal attack and will improve the quality and quantity of oil and cake. The

coconut oil is unique in its physical and chemical properties and has therefore a number of food and industrial uses. In food use it is an excellent raw material for production of margarine and its industrial uses are for the production of special types of detergents. The coir industry is an ideal rural industry with immense employment potential. The shell has important uses such as the production of charcoal and activated carbon. In the decentralization of the coconut products processing industries, efficiency in processing is to be maintained at all levels.

20) The oil palm processing techniques widely vary in different countries in Africa, Asia and Latin America. The primitive method of processing has been referred to in Annex-1. Malaysia and Ivory Coast have emerged as large scale producers and exporters of palm oil. The rationale in establishing the oil palm industry is that it can grow in 10-15^{o} north or south of the equator and only countries which are situated in this latitude have the advantage of having the oil palm industry. In some countries the industry is being promoted as a replacement of the unproductive or underproductive rubber or coconut plantations. But recent developments in Malaysia and Papua New Guinea have been on a systematic basis of opening up the jungle and planting oil palm trees of high yielding varieties. The projects as envisaged and implemented in Malaysia and Ivory Coast are integrated agro-industrial complexes. As has been referred to earlier, for technical reasons, the processing has to be integrated with the production of fresh fruit bunches. Nevertheless, the new projects in the public sector in Malaysia have been serving the purpose of settlement of landless people, employment generation and substantial earnings of foreign exchange by the export of oil and processed products. Lately the palm kernels are also being processed into palm kernel oil. The crude palm oil is gradually being replaced by fractionated and refined products for exports. Therefore in the oil palm industry although decentralization can not be applied strictly, the integrated operations do serve the socio-economic objectives. In the worldwide study on the vegetable oils and fats industry, commissioned by UNIDO the oil palm processing technology as existing in Malaysia, Zaire, Nigeria, and Ivory Coast has been discussed in paragraphs 250 to 253. The different scales of operations and the organizational structure of the industry has also been described.

21) It would perhaps be interesting to refer to another oil bearing

material with different technical problems. Rice bran is a by-product of rice milling and the brown rice when polished yeilds 7-8% of rice bran. Depending on the pre-treatment of paddy such as parboiling, the yield of bran, and its oil content (18-22%) might vary. Immediately after the bran is separated from the grain, due to enzymatic action, lipolysis starts and the quality of the bran in terms of its oil content will decrease. It is technically feasible to stabilize the rice bran to increase its keeping quality. However the existing pattern of rice mills which are small in capacity and scattered in the rural areas present a problem of collection and transport. Therefore the development of low-cost rice bran stabilization units of small capacity which could preferably use rice husk as a source of energy is being investigated. Should there be a breakthrough in technology to develop a suitable stabilization unit, substantial amounts of rice bran oil could be extracted, refined and used as an edible oil in the rice producing countries. Admittedly an attempt is being made to develop a technology for rice bran stabilization which would be suitable to the small-scale operations in the rural areas.

22) The oil seed processing picture will be incomplete without a reference to soybean processing.While its oil content is 18-20%, the yield of 70-75% of the cake or meal makes the latter a more important product. Additionally soybean protein has a better amino acid profile and is hence superior in quality as one of the ingredients for the production of feed-stuffs. In the Orient soybean has been traditionally used as a source of protein food in fermented products such as tofu. These techniques could be further strengthened for fuller utilization of the bean as a source of protein products.

23) While considering the oils and fats industry the utilization of the residual cake or meal needs particular attention. While it is a valuable source of protein and many attemps are being made to isolate the protein to be used for enrichment of the starchy diets, in most developing countries such usage has not been found to be economical. However, in most developing countries in addition to oilseed cake or meal, rice bran, maize, tapioca, and millets are usually available. Therefore the production of compound animal feed (balanced rations) could be taken up extensively in the decentralized sector. The feed industry is also the basis for the development of the dairy and meat industry (poultry and piggery). In

view of the low-level of technology involved, small-scale feed mills should be designed and developed for adoption in the rural areas, where the raw materials are available for processing.

24) The points that may be considered are:

(a) The planned production and utilization of oil seed raw materials for processing.

The basic question should be the relationship between agriculture and industry, post-harvest operations, infrastructural requirements, appropriate planning and the co-operation between planning authorities, department of agriculture or primary industry and the processing industry. It would seem necessary to establish a suitable co-ordination mechanism within the government to ensure that the plan objectives are implemented.

(b) The structure of the processing industry

The question to be considered is centralization or decentralization, the village and small scale industry and the problems caused by them, the pre-conditions and requirements of a modern large scale industry and its advantages and disadvantages and the posssible plant locations. In the specific context of decentralization the issue for consideration would be the extent of decentralization that could be brought about so that sight is not lost of the broader objectives of efficient extraction of oil and economic utilization of the by-products.

(c) The market for oils and cakes

The market-oriented production is to be stressed with regard to quantities and quality of the products in demand, domestic consumption habits such as the preference for a particular oil such as groundnut, rapeseed, sesame etc. the market price structure and its influence on the processing costs and technology. The packaging problem, tradenames and brands for edible oils and importance of local market for oil cakes and meals are other points for consideration.

(d) The mechanical pressing technology

The points for consideration in the adoption of mechanical expression technology are advantages and disadvantages, energy consumption, spare-part supplies, appropriate processing in view of the production of quality products, and the conditions under which pressing plants can be operated efficiently.

(e) The solvent extraction technology

Alternative scales and types of technology such as batch or continuous and capacities from 50 to 200 ton/day. Advantages and disadvantages, the solvent and the question of safety and security, solvent losses, appropriate processing operations. The extracted meal versus oil cakes and its utilization in the food and feed industry, the training of staff, appropriate plant attendance and process control requirements.

(f) The pre-pressing and solvent extraction technology

The conditions under which it should be applied such as in the high oil content oil bearing materials of copra (65%) and groundnut (45%). Pre-pressing plants in comparison with pressing plants, the economics of operation and of economy of scale, direct solvent extraction versus pre-pressing and solvent extraction, multi-purpose processing plants. The problem of processing oilseedcakes collected from different pressing plants in centrally located solvent extraction units.

(g) The vegetable oil refining technology

The various steps of vegetable oil refining, batch operations versus continuous operations in neutralization, bleaching and deodorization, the various refining processes, the appropriate equipment, the refining losses, the soap stock and its utilization, the waste water, bulk storage of refined oils, bottling, bottle and can production untis, the process control requirements.

(h) The impact that appropriate vegetable oil industrialization has on a country's social structure and overall industrial development.

The relationship between the vegetable oil industry and the (a) feedstuff industry, (b) the soap industry and (c) the food industry. The creation of employment as a primary and secondary result. Labour intensive factories versus mechanized processing plants. The training of staff and other educational aspects. The local manufacture of spare-parts and equipment.

(i) Pre-investment considerations and the creation of the required pre-conditions for the setting-up of viable vegetable oil factories

The market-oriented approach. First step: the definition of the products in demand of the domestic market with regard to quantity, quality and price. Second step: the definition of the required raw materials. The import of raw materials, the elaboration and implementation of raw material production plans, the selection of raw material varieties.

Third step: the definition of the type of processing plant in detail that can produce the products in demand at permissible costs in appropriate quantities and quality from available raw materials. The importance of industrial planning. The time factor involved. The required establishment of related industries (feedstuff, soap, etc.) and the creation of additional markets for oilseed products, and the long-term planning requirements in this context.

III. Policy implications of alternative techniques

25) It would perhaps be useful to examine the constraints in production and processing in examining the policy implications of alternative techniques:

(i) Oil seed production constraints have been identified as inadequate services and factors of production such as land, particular forms of labour and capital. Technical constraints include the need for higher yielding disease-resistant varieties that are adopted. Improved storage facilities, extension services and the government priority for the sector are also important.

(ii) Processing constraints are irregularity and quality of supplies of seed for crushing, efficiency and availability of service infrastructure, skills and entrepreneurial ability of manpower, managerial skills and the adaptability of machinery to different types of seed.

(iii) The marketing constraints at domestic level are the demand for the product, the price to the producer and the marketing mechanism. Most fats and oils can be regarded as raw materials for the processing industry to be transferred into margarine, shortening, cooking oil and vanaspati.

The consumption of oil seed products is very largely determined by the level of income, which, in the majority of the developing countries adversely affects overall demand for these products. Increase in incomes and growth in the economy in general are pre-requisites for the expansion of domestic markets. The easing of constraints at the processing level however will help to ensure that costs and hence prices are kept at a level that allows maximum advantage to be taken from growth in domestic purchasing power.

It has been mentioned earlier that the low-level technology of village ghanies and chekkus could be modernized by the introduction of screw presses and the factory operations could be run efficiently in the decentralized sector. However in export-oriented industries such as in oil palm, coconut and soybean, the most modern and sophisticated technology needs to be adopted. Additionally the immense organizational and management requirement should be of a high order to be able to withstand competition not only in terms of price and quality but also in the ability to export the products to international markets. There is already evidence of the existence of such competence and advanced technology in Malaysia & the Ivory Coast for oil palm, in Brazil for soybean and in the Philippines for coconut products.

26) In the selection and adoption of appropriate techniques and processes, regulatory control by governmental agencies would be necessary. They could take the form of reservation of capacity for the decentralized sector, adequate provision of credit and marketing facilities.

27) The taxation measures could be used as an incentive for the development of the decentralized sector. There have been examples of incentives having been given for the development of cottonseed and ricebran processing and solvent extraction industries in their early stages of development.

28) Price control of oils and fats could be an effective incentive to the small-scale sector. It is justifiable on grounds of their being essential commodities.

29) Technological institutions should undertake design and engineering activities to develop prototype equipment suited to small and medium scale operations. Such institutions would also have to conduct training programmes, provide extension services and diseminate information.

30) Within the organizational structure of the government, co-ordination of the work dispersed in different departments, R and D institutes manufacturers' associations and the establishment of suitable linkages would go a long way in the determination of alternative technologies for the decentralization of the oils and fats industry.

V. Technological Programme of Action

31) Research in technological aspects of storage and processing of a variety of oil seeds and their by-products would be necessary. This is particularly true of oil palm where the traditional techniques have

to be upgraded. In coconut the wet processing of coconut is already a subject of such research. In cottonseed more efficient processing of the seed and utilization of the by-productsof linters, hulls and oil seed cakes or meal merits consideration. In the case of rice bran its stabilization to facilitate production of rice bran oil of edible quality has been initiated. Soyabean processing and its utilization as a source of protein food needs further study and research. Similar research in technological aspects of other oilseeds such as in rapeseed has to be considered.

32) In most developing countries it would be necessary to support research and development activities through the existing national research institutes.

33) The co-operation of the developed countries and their aid agencies could be in one or more of the following areas:

(i) In some developed countries extensive Research and Development work is being carried out in support of the development problems of the developing countries. Such activities could be made more specific both for individual countries and groups of countries on a subregional basis in the resolution of identified problems.

(ii) Developed countries and international agencies could support national Research and Design engineering activities by providing both technical and financial assistance.

(iii) The technical assistance programmes of some of the developed countries such as in carrying out feasibility studies, processing technology, storage, the setting up of laboratories and quality control may be oriented towards decentralized development of the industry.

(iv) International aid agencies might provide capital funds for the development of oils and fats industry using more appropriate technology.

(v) International co-operation could assist the national institutions in the collection, analysis and dissemination of information on the alternative technologies, and new developments; and promote exchange of experiences pertaining/to the processing of a variety of oil bearing materials and their by-products.

(vi) Training is yet another important area of co-operation.

34) Technical co-operation among developing countries would also be valuable especially in the context of search for alternative technologies and decentralization of the industry.

35) Under the system of consultations introduced by UNIDO the search for alternative technologies and their socio-economic advantages could be examined for future international co-operation.

36) Co-operation between developed and developing countries with a view to the establishment of plants for the manufacture of necessary equipment and machinery for the oils and fats industry merits consideration.

The following background documents on this subject are being circulated:

Appropriate Technology for Production and Processing of Oils and Fats	ID/WG.282/36
Problems of Raw Materials Acquisition in Ghana	ID/WG.282/76
Draft World-Wide Study on the Vegetable Oils and Fats Industry, 1975-2000	UNIDO/ICIS.46
Guidelines for the Establishment and Operation of Vegetable Oil Factories	ID/196

ANNEX I [1/]

I. OILSEED PROCESSING METHODS

Farm/village processing methods

The extraction of oil from oilseeds is principally the same whether the process is carried out at the village level or industrially. Before oil extraction can start, the oil-bearing material, with few exceptions, is dried, cleaned, broken into small particles and heater or "cooked". Palm fruit is treated differently, as it is either allowed to "ferment", to facilitate the removal of the individual fruits from the bunch, or boiled in water prior to extraction, both to facilitate the removal of the fruits and to inactivate the lipolytic enzymes. The pressing of palm fruit is commonly done by simple, traditional methods, that is, stamping with the foot or squeezing in the hand followed by water displacement. Alternatively, hand-operated, or small mechanically-driven hydraulic pressed may be used, when yields of about 70 per cent of the total oil in the mesocarp can be obtained.

The majority of oilseeds or oil-bearing materials such as copra, are dried by spreading on the ground, and are left in the sun for some time. In the case of fresh coconut kernel, which has a moisture content of about 50 per cent, small, cheap, locally-made dryers are used to assist moisture reduction. In addition to speeding up the drying process, these simple copra dryers generally produce a good quality copra.

For the removal of vegetable debris, dirt, and other foreign matter, some form of sieve or screen is employed. The screens are usually made of wire mesh, wire cloth or perforated metal, and are shaken by hand to remove sand and earth. Larger pieces of foreign matter such as stones and vegetable stalks are removed by hand.

Size reduction of oilseeds is also necessary prior to extraction since it facilitates the removal of the oil. At the village level the method which is most commonly used is grinding in a wooden mortar with a pestle, generally also made of wood. Where animals are being used to operate a water wheel or press, oilseeds such as groundnut kernels are strewn in the animals's tracks and reduced in size by trampling.

Extraction of the oil from the pre-treated oilseeds is done under pressure, and one of the simplest systems that has evolved is the weighted pestle rotating inside a stone or wooden mortar where the pressure is exerted between the mortar wall and the pestle. This type of rural extraction equipment is widely used in Asian and African countries; a typical example is the Indian chekku. The capacity per charge is 16-17 kg depending on the oilseed, and the time taken to process a charge is about 45 minutes to 1 hour for copra, and up to 1½ hours for sesame seed. Daily capacity is about 100 kg and the oil content of the residual cake from improved animal driven chekkus ranges from 11-13 per cent.

The efficiency of this type of animal-powered press has been improved by adopting a motorized version, which increases the throughput, and also extracts a further 4-5 per cent of oil.

In many coconut producing countries, fresh undried coconut meat is processed for oil at the farm level. Fresh grated coconut meat is pressed by hand, then mixed with water and pressed a second time. The mixture of oil and water resulting from the hand pressing procedure is transferred to a pan and boiled, when the oil and water separate. The oil is skimmed off the surface of the water, while

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1/ An extract from the Draft World-Wide Study on the Vegetable Oils and Fats Industry: 1975-2000 (UNIDO/ICIS.46).

the residue on the press is used as a human food material in a variety of dishes. An example of this method is the klentik method practised in Indonesia.

Hand-operated hydraulic presses are still used in the rural areas of many developing countries, particularly Nigeria, where they are used to extract the mesocarp oil from palm fruit. However, mechanical hydraulic presses fitted with metal cages, which are more efficient and do not require the use of press cloth, are gradually replacing hand-operated units in many developing countries.

These general methods of village-level processing are universal but local modifications to the basic principle are often found. Some of the more locally important village processing methods are discussed in greater detail in the final section of this chapter. However, irrespective of the precise method used, village processing is very limited in its absolute level of output and tends to be a comparatively inefficient extraction process, leaving a high proportion of oil in the residue.

Commercial processing methods

Post-harvest handling, storage and preparation of oilseeds

After harvesting, oilseeds require to be handled and stored in such a manner as to avoid damage and to minimize the natural deteriorative factors which lead to increases in free fatty acid contents and the development of objectionable odours, flavours and colours in the extracted oil, as well as reducing the value of the residual oilcake or meal.

Oilseed materials can be handled by most conventional handling conveyors. Free-flowing seeds such as soyabeans, sunflower seed, safflower seed, shelled groundnuts, sesame seed, delinted cottonseed and rapeseed, lend themselves to being handled in much the same way as corn and wheat grain. Quite different conveyors, however, are needed for the bulkier and less free-flowing oilseeds, such as undelinted cottonseed, copra and palm kernels.

The successful storage of oilseeds, prior to processing, is dependent on the observation of certain conditions. Attention must be paid to critical moisture levels, above which the proliferation of fungi and bacteria and the activity of enzymes lead to rapid deterioration.

Prior to processing, the oilseeds are prepared in a number of ways. Firstly, the seeds must be cleaned to remove foreign material. Sticks, stems, leaves and similar trash are usually removed by means of revolving screens or reels. Alternatively, a pneumatic system can be employed, where the light material is pulled through and the heavy material, usually the oilseed, is gravitated out.

Wherever practicable, oilseeds are preferably decorticated before they are extracted. The first step in the dehulling is the cracking of the seeds' hulls with machines. The two principal types of machine used for this process are bar hullers and disc hullers.

When decorticated, different seeds vary considerably in the readiness with which they fall out of the split hulls. For example, groundnuts are loose in the shell and separate readily while cottonseed kernels or "meats" are more adherent to the hull. Generally, therefore oilseed hulls are customarily passed through a hull beater to detach small meat particles after the first separation of hulls and meat by screening. The separation systems used usually consist of various combinations of vibrating screens and pneumatic lifts. It is necessary not only to separate the hulls from the meats, but also to separate and recycle a certain proportion of uncut seeds which escape the action of the huller. Some oilseeds such as rapeseed and sesame are usually processed without decortication.

The next step immediately prior to oil extraction is the reduction of the seed to small particles. Hammer mills, attrition mills, and other devices are sometimes used for the preliminary process when large oilseeds such as copra and palm kernels are being processed, but for the final process it is common practice to use milling rolls which subject the seed particles to progressively increasing pressure and form them into thin flakes. The flakes thus formed are more satisfactory for hydraulic pressing than the irregularly shaped particles obtained by grinding. Flaking rolls are essential for preparing oilseeds for continuous solvent extraction since no other form of mill is capable of forming particles which are thin enough to extract readily yet large enough and coherent enough to form a mass through which the solvent will pass easily.

If oil is extracted by mechanical expression, the oilseeds yield their oil more readily after cooking. Cooking coagulates the proteins in the seed causing coalescence of the fine oil droplets and making the seed permeable to the flow of oil. The affinity of oil for the solid surfaces of the seed is also decreased, and the increased fluidity of oil at elevated temperatures assists its outflow. Important secondary effects of cooking are drying of the seeds to give the seed mass the proper plasticity for efficient pressing, insolubilization of phosphatide, destruction of fungi and bacteria, and, in the case of cottonseed, detoxification of gossypol, in rapeseed inactivation of the enzyme myrosinase, and, in soyabeans, inactivation of anti-nutritive factors. The moisture content of the seed is controlled during the cooking operation as very dry seeds cannot be efficiently freed of their oil. The optimum moisture content of cooked seeds varies widely according to the variety of the seed and the method used for expression.

Extraction of oil

The oldest method of oil extraction comprises the application of pressure to batches of oil bearing material confined in bags, cloths or cages. Levers, wedges, and screws have been used as a means of applying pressure in early types of presses, but modern presses are almost invariably activated by a hydraulic system. Batch presses are divided into two main classes: the open type requiring the oily material to be confined in press cloths, and the closed type, which is equipped with a form of cage to confine the oily material. Some oilseeds of high oil content, such as copra, are difficult to express satisfactorily in batch equipment by a single pressing, and are preferably processed in continuous screw presses or expellers. With a given lot of seed, cooked and ready for pressing, the oil yield will depend upon the rate at which pressure is applied, maximum pressure attained, the time allowed for oil drainage at full pressure, and the temperature or viscosity of the oil.

Continuous expellers or screw presses have now almost completely replaced hydraulic presses for the mechanical extraction of oilseed. Expellers may be high-pressure machines designed to effect oil recovery in one step and may be modified to process a particular oilseed. Special low-pressure expellers are often used for pre-pressing prior to solvent extraction, although high pressure presses may also be used, operated at low pressure and increased capacity. In areas where various oilseeds are handled by the same equipment it is common practice to press the seeds in two or three stages at increasingly higher pressures in each stage. Continuous presses require less labour than hydraulic systems and eliminate the need for press cloth. They are adaptable to a wide variety of materials, and in most cases produce a higher yield of oil. However, their power requirements are relatively high, fairly skilled labour is needed for their operation and maintenance, and they are not well adapted to intermittent operation.

The pressure necessary to force the oil out of the cooked flakes is obtained by means of a continuously rotating wormshaft and worms, fitted with a choke mechanism at the cake discharge orifice to control cake thickness. The main wormshaft and worms are designed to exert a pressure of 5-15 tons per square inch (79 to 2,370 kg/cm^2) on the seed being processed and to convey it through and out of the pressure chamber. Different wormshafts may be employed, depending upon the material to be processed and whether or not expression is to be complete or merely a pre-pressing operation preliminary to later solvent extraction. With adequate preparation and cooking of the oil bearing material, the capacity of an expeller is a function of the shaft arrangement and speed. For example, the meats from 25-100 tons of cottonseed per day can be expressed leaving cakes containing 3-9 per cent oil.

For the pre-pressing of oilseeds prior to solvent extraction, although high pressure expellers may be operated at low pressure and increased capacity, specially designed machines are more satisfactory and are normally used in new installations. As most of the oil is removed by pre-pressing, only a minimum size of solvent plant is required. Low pressure expelling also produces a meal of high protein quality. Cakes pre-pressed for subsequent solvent extraction generally have an oil content of 15-18 per cent.

The processing of palm fruit involves procedures distinct from normal oilseed processing. After cutting, the average acidity of the oil in the fruit rises very rapidly, especially in the injured exterior fruits which will particularly undergo enzymatic hydrolysis. This increase in acidity can be stopped only by sterilization. The quality of the palm oil is therefore conditioned largely by the maturity of the bunches and by the speed with which they are processed after cutting. The first operation in the process consists of cooking the bunches for 60-90 minutes in steam sterilizers under 3 kg/cm^2 pressure at 140°C. This stops the development of acidity and aids the removal of fruits from the stem as well as loosening the palm kernels in the nuts. Sterilizer capacity can vary from 6-20 tons of bunches per hour and two or three sterilizers ensure continuous feed for the extractors. After cooking, the bunches are fed into a picker, the fruits are detached and conveyed to a vibrating strainer and washed with boiling water before being fed to digesters. The digesters operate by vigorously mashing the fruit to detach the pulp from the nut and break down the oil-bearing cells. The oil is separated from the digested mash usually by the use of expellers or sometimes by hydraulic presses or a battery of large centrifuges. The palm oil obtained, mixed with about 65 per cent water, vegetable debris and sand, is heated to 100°C in a preparation tank and passed through a straining circuit equipped with a sand cyclone to remove high density foreign matter. The remaining palm oil and water are then separated by centrifuging followed by re-clarification of the palm oil in a second centrifuge or a decantation vat. The oil is then dried, preferably under vacuum, to less that 1 per cent moisture and pumped into holding tanks.

Solvent extraction constitutes the most efficient method of recovery from oil-bearing material, particularly for those oilseeds or other materials low in oil content. A figure of 3 per cent is about the minimum oil content to which cake can be reduced by mechanical expression. Consequently, as the oil content of the seed decreases, the amount of oil unrecoverable by mechanical expression increases in relation to the total amount present. Also, since minimum heat treatment is involved, the oil produced by solvent extraction is of maximum quality and the meal contains proteins subjected to a minimum amount of damage due to the effects of heat. However, solvent extraction equipment is relatively expensive compared with other extraction systems, and in using inflammable solvents there is a safety factor involved. Also, low oil-content meal tends to be dusty, and in the case of the extraction of raw cottonseed flakes and uncooked soyabean meal, the relatively mild processing may not inactivate the toxic or anti-nutritional materials present and further treatment of the oilcake may be required. Low oil content seeds such as soyabeans are solvent extracted most easily, while optimum solvent extraction efficiencies of high oil-content seeds are not readily achieved without a preliminary pre-pressing operation as they tend to disintegrate more readily, producing troublesome finely divided material. However, some recent types of solvent extraction plants have provision for directly handling high oil-content seeds.

The most common solvents used are light paraffinic petroleum fractions and the hexane fraction (boiling point 146^{o}-156^{o}F, 63.3^{o}-68.9^{o}C) is the most widely used and preferred for oilseed extraction although the heptane fraction (194^{o}-210^{o}F, 90^{o}-100^{o}C) is also used. Because of the potential fire and explosion hazard involved when hydrocarbon solvents are used for extraction, non-flammable solvents like trichloroethylene (boiling point 188^{o}F, 86.7^{o}C) are sometimes employed in their place. However, trichloroethylene requires to be carefully handled because of its toxicity, corrosion is a serious problem, and its relatively high cost is not counterbalanced by proportionately lower solvent losses.

Solvent extraction procedures provide the means of bringing the oilseed and solvent together in a counter-current flow in order that the seed is extracted with solvent of progressively decreasing oil content as it passes through the system. Conversely, as the solvent is brought into contact with seeds of progressively increasing oil content, it is finally discharged with the highest possible oil content, minimizing the cost of solvent recovery. This principle of mixing the solvent and oil in continuously moving counter-current streams is the basis of continuous counter-current extraction. Although batch counter-current extraction may theoretically be brought to an efficiency approaching that of continuous counter-current extraction by sufficiently increasing the number of extractors, the system becomes increasingly cumbersome. In practice, therefore, solvent extraction is carried out on a large scale only in continuous systems which are entirely automatic in operation, achieving the highest economy of power, labour and materials.

There are a variety of different designs of equipment for continuous extraction. Percolation extractors are the most widely accepted as there are a number of advantages in their use. The principal advantage is that the system yields a very clean miscella with a minimum content of fines. It is also more adaptable to large throughput in a limited space.

The final stage in obtaining the crude oil is to remove the solvent from the miscella. The most common method of removal is in a rising film evaporator, a series of long tubes contained in a vertical cylindrical shell which is heated by steam. The solvent to meal solids ratio in modern extractors is about 1.1:1.3. The concentration of oil in the miscella leaving the extractor is about 20-35 per cent depending on the oil content of the extracted seed material. The amount of solvent left in the meal after extraction in a percolation type extractor is about 30-35 per cent.

Crude oils from soyabeans and rapeseed contain about 2-3 per cent lecithin gums which are removed by a degumming process at the oil mill or extraction plant before the oils are shipped or placed into storage. If the gums are not removed they will cause trouble by settling out in storage tanks and will tend to produce large refining losses. If the removed gums are to be used for commercial lecithin production, they are dried as soon as possible. Generally only soyabean gums are used to produce lecithin as rapeseed lecithin is of low value because of its dark colour and unpleasant taste and odour, and its separated gums are usually fed back into the desolventizer-toaster where they help the meal powder to agglomerate more easily.

Filtration of crude oils

Suspended impurities in crude oil are removed using filter presses, leaf pressure filters, vacuum filters, or centrifuges. As filter presses are rather heavy in labour charges and usage of filter cloths, the leaf pressure filter has found application in the oil and fats industries, although plant and frame presses remain the usual equipment for filtering bleaching earth in most edible oil refineries. Continuous rotary drum filters (vacuum filters) are used in oil extraction plant and refineries, particularly for the filtration of crude oil, but have not found much application in edible fats factories. As fairly open weave cloths are used it is frequently necessary to give the oil a second filtration. High speed centrifugal separators have found wide application for a number of purposes in oil treatment plants and refineries and are particularly useful for clarification of oils containing fine suspended impurities.

Refining of crude oil

The removal of substances detrimental to the use of fats and oils for edible purposes is most frequently carried out in four operations: degumming, de-acidification, bleaching and deodorizing. Degumming and de-acidification are often combined in one operation. Traditionally, these have been carried out as batch procedures but modern plants employ continuous systems. Other refining systems employing steam refining and miscella refining are also sometimes used.

Alkali refining is the most common form of process used in the refining of crude oil. The free fatty acid content of crude oils and fats normally represents the largest amount of impurities to be removed and normally the process of neutralization (de-acidification) is carried out with solutions of sodium hydroxide (caustic soda), termed "lyes" and measured in term of their specific gravity expressed in degrees Baume. In order to reduce losses arising from emulsification of neutral oil in soap stock and from saponification of the neutral oil, weaker alkalis such as sodium carbonate, capable of reducing the free fatty acid content without saponifying the oil, are sometimes used either before or after a caustic soda refining stage. Weak alkalis used alone, however, do not decolourize or reduce the free fatty acid content of oils as effectively as caustic soda. Thus the technology of alkali refining is concerned with the proper choice of alkalis, amounts of alkalis and refining techniques, to produce the desired purification without excessive saponification of neutral oil and with methods for the efficient separation of refined oil and soap stock. (Soap stock is itself a useful raw material. Consisting chiefly of water, neutral oil, the sodium salts of fatty acids and free alkali, it can be used as a source of fatty acids for soap-making or for fatty acid distillation). After alkaline treatment the oil is preferably washed with soft water, as the calcium and magnesium salts from hard water can dissolve in the oil. Immediately after washing, the oil is dried under vacuum to avoid hydrolysis. As refining removes some of the oil's natural antioxidants, the storage of dried and refined oil before bleaching is kept as short as possible and the oil is protected by nitrogen in closed tanks to minimize oxidation.

After pre-treatment and neutralization there are natural pigments and sometimes coloured degradation products which remain in the oil and require to be removed by a special bleaching process which is usually carried out by heating the oil under vacuum with an adsorbent material onto which the pigments become adsorbed irreversibly. Usually a contact time of 10-15 minutes at 220-240°F (104°-115°C) is ample decolourizing time, and the extent to which a fat is bleached depends upon its future use. Besides decolourizing, adsorbents also remove traces of soap from alkali refined oil.

Deodorization, the final process in the refining of crude oil, removes substances which impart undesirable odour and taste to the fats. The concentration of volatile materials in oils is relatively low, generally around 0.1 per cent. Most oils and fats, either because of their natural flavour or because of changes arising during storage and processing, require a final deodorization to give them a bland or mild flavour which is considered essential for their successful use in the manufacture of edible fatty products such as cooking fats, shortenings, margarine and salad oils. In the case of some regions of the world where the flavour of the oil has traditionally been a culinary component, for example, rapeseed oil in India, complete blandness may not be necessary. The process of deodorization removes the undesirable flavour compounds by passing a current of dry steam through the neutralized fat under vacuum in deodorizers. The refining process destroys a considerable proportion of the natural antioxidants which occur in crude oils and consequently refined oils are often more prone to oxidation. Many refiners, therefore, add some ingredients to the oil in the deodorizer to increase its resistance to oxidation during the high temperature treatment and subsequent storage.

During storage, finished oils have to be protected against contamination from atmospheric adulterants, internal contamination by water and soaps, overheating and exposure to oxygen. Usually oils are stored in completely closed iron tanks provided with internal heating or cooling coils and an agitator to help heat transfer and avoid localized over-heating. Stainless steel storage tanks are used when it is desired to maintain the highest stability of the finished oil.

ANNEX II

The end uses of oilseeds

- Vegetable oils
  - Cooking/salad oils
  - Shortening
  - Margarine
  - Soap
  - Paints
  - Confectionery
  - Cosmetics
  - Lubrication
  - Industrial chemicals
- Oilmeal
  - Animal feeds
  - Protein flour
  - Beverages with high protein content
  - Meat extenders and substitutes
  - Texturized protein foods
- Hulls, shells, fibre etc.
  - Handicrafts
  - Fuel
  - Building materials
  - Matting
  - Pulp and paper
- Whole seed or nut
  - Confectionery
  - Subsistence food
  - Beverages

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