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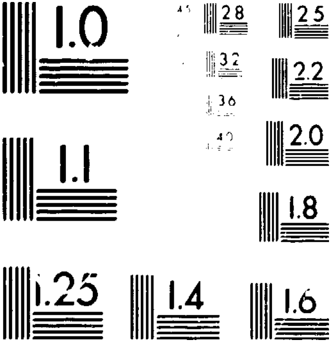

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NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL 1010a

(ANSI and ISO TEST CHART No. 2)

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.427/1
18 July 1984

ORIGINAL: ENGLISH

Second Consultation on the Food-Processing Industry with special emphasis on Vegetable Oils and Fats

Copenhagen, Denmark, 15-19 October 1984

DOWNSTREAM PROCESSING ACTIVITIES IN THE VEGETABLE OILS AND FATS INDUSTRY *

Information paper

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V.84-88512

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Annexes

Summary

1. A downstream-processing activity in developing countries is, in principle, especially attractive as a broad potential to improve efficiency of agriculture, industrial activities, nutritional status, purchasing power and standard of living. Beyond these national/regional options, activities of this kind play a major role in covering food requirements in edible fats and proteins for a growing world population.

2. The basis for any technology in this area is a sufficient and reliable supply of raw material. A careful selection of oil bearing seed and fruits well adapted to local conditions and well guided farming activity in the growth area must lead to high yields and correspondingly to reasonable low production costs for these commodities. Close links between farmers and processing plants (oilmills/extraction plants primarily) are crucial in guaranteeing a reliable supply and best utilisation of the plants. A well organized storage and transport system and sufficient energy supply are other prerequisites for a successful operation.

3. A broad, diversified food industry should be built up in parallel with the processing of vegetable oils which can play a central role in this context. Local eating habits and other marketing aspects must be considered in developing this industry.

4. Meal and cake, rich in protein, are important by-products of oil extraction from seeds, they can be essential to improve meat and milk production. In the longer term, big quantities of vegetable protein should be directly consumed, avoiding the costly roundabout way via the animal, but this concept requires further efforts in research and marketing world-wide.

5. Minor quality fats and "acid" oils can form the basis for a diversified soap and oleochemical industry; international co-operation plays a major part in this technology and is certainly needed by developing countries. Surpluses of highly priced raw materials should be exported and cheaper oils can then be bought as edible oils or for industrial use, however, fat-splitting and other oleochemical processes require sophisticated expensive plants, and world-wide overcapacities have to be considered before any investments are made.

6. Consultants, contacts concerning know-how, and further joint ventures might help to solve agricultural, processing and marketing problems. International institutions such as UNIDO can help to keep an ongoing dialogue between experts, to bring international partners together, and to support special projects.

Introduction

7. The term "downstream processing" should comprise all aspects of technology in its broadest sense, beginning in this case with the growing of oil-bearing plants and trees, propagation and cultivating under suitable agricultural conditions, processing the raw material into semi-finished and finished products; making best use of by-products and thereby taking marketing aspects into consideration.

8. Downstream processing activities in vegetable oils are of special interest as they constitute an important, often crucial technology to make best use of the farmland, to feed the people and ultimately to increase the standard of living and the total productivity of the country. There are some good examples of such development in a few developing countries especially in Asia, but there are other countries where much has yet to be done or where a new start has to be made.

9. If the world population is going to double, vegetable oils (and proteins) will play an essential role, as the increase in their production was about twice as high as average population growth over the last few decades.

1. Explanatory notes

10. Downstram processing of vegetable oils has some general aspects which in contrast to many other straight-forward technologies deserve special attention:

1.1. Vegetable oils as raw materials

11. Vegetable oils[1/] (and proteins) are replenishable raw materials not only as food for man and feed for animals, but also for industrial use. No other

---

1/ There is no basic difference between oils and fats, e.g. it depends on the temperature if consistent coconut fat is a liquid oil in tropical climates; all natural oils become 100% solid at minus 40°C.

food component is as rich in energy (9 kcal/g for fat in comparison with 4 kcal/g for protein and carbohydrates). Moreover, this energy is relatively cheap. Almost one third of all edible fat produced is available on the world market, the major part being consumed in the countries of origin.

1.2. Agricultural aspects

12. The discussion about replenishable resources had led to an evaluation of different types of bio masses in comparison with mineral oil:

	mineral oil	lignin	cellulose	starch	sugars	fats + oils
density of energy	+++	++	+	+	+	+
reactivity	++	+	++	++	++	+++
production of well defined compounds	++	-	++	++	+++	+++
multiple application of structural elements	+++	-	-	-	-	++
vicinity to end producer	++	-	-	-	-	++
possibility of homogeneous reactions	+++	-	-	+	++	+++

Source: Battelle

13. The conclusions could be that fats and oils are the best source of raw material to produce various chemicals if this can be justified from an economic point of view. As regards the well-known special issue of fuel for diesel engines, it should be considered that 50% of the total production of edible oils and fats could only replace 1% of the mineral oil demand (3000 mio tons).

14. Good prospects are offered by growing vegetable oil plants which may even yield double crops, as with soybeans in the USA and in Brazil. Other interesting examples are the growing of rapeseed in a sequence with other grains, increasing the nitrogen content of the soil due to the activity of root bacteria or the growing of palm trees instead of rubber trees; the

result would be a much earlier first return of capital employed in the plantations. Limitations to such an agricultural programme are primarily climatic conditions, but the quality of the soil, the structure of agriculture, the availability of fertilizers, labour and machines also have to be considered. Yields per hectare are high: 350 kg soybean oil (+ protein); 600 kg sunflower oil (+ protein), and up to 6000 kg palm oil.

1.3. Nutritional aspects

15. It is well known that undernourishment is primarily connected with lack of purchasing power. The total food production of the world covers the needs to over 105%, but only 85% in the developing countries. In all developing countries there are options to grow one or other plant as long as it is well adapted to climatic and other conditions. The gap between the energy content of food intake based on fats and oils in developing countries versus highly industrialized countries ranges from less than 10 to more than 40 energy-% (hidden fat in e.g. meat and cheese included). Fat makes food richer in concentrated energy and therefore helps to avoid the negative effects of too bulky food as is consumed at present in most of the developing countries.

16. The aspect of malnutrition plays a rather important role, too, especially as far as vitamin A is concerned, and to a lesser degree vitamins D, E, K and linoleic acid (sometimes still called vitamin F). In large parts of Africa, South America and East Asia children often have insufficient quantities of vitamin A or carotene (provitamin A), as meat and fresh green vegetable are not available or are too costly (Xerophthalmia/blindness). Edible fat is the ideal carrier for all these fat-soluble vitamins. Red palm oil is a natural source of carotene, and vitamin E and F are contained in relatively high amounts in most of the vegetable oils.

1.4. Possible chemical modification

17. Oils of minor quality and especially the cake and meal of oilseeds are of greatest importance as feedstuff in increasing the efficiency of animal husbandry especially for meat and milk production. In the long run, oilseed protein for human consumption must become an important food component for the needs of the growing world population; the production of protein via the animal is 4 to 7 times less effective than the direct isolation of protein from vegetable sources.

18. Generally speaking, edible fats and oils consist of glycerin and a whole range of fatty acids, which differ in chain length and grade of saturation/unsaturation, which can find chemical usage. Technology and application of saturated fatty acids of different chain length is well developed in contrast to many options which are still not tackled in the area of modification of unsaturated fatty acids.

19. Free fatty acids as by-products of oil-processing can only cover a small percentage of requirements but the splitting of neutral fat to obtain free fatty acids is commercially only attractive in the case of either cheap (tallow) or very rare (medium chain fatty acids, e.g. in coconut oil) raw materials; it is otherwise much more lucrative to export neutral oil and import crude or even distilled fatty acids.

20. Major food products and the whole range of soaps require blending of more than one fatty acid to obtain good quality products. This has to be considered as far as possible in the production of oilseeds and fruits, or it might be necessary to buy other raw materials on the world market of oils and fatty acids.

21. Products called oleochemicals are to a large extent competing with products of the petrochemical industry world-wide. Development of industries in the area of oleochemicals, starting from fat and fatty acids, need careful investigation, and the result will be strongly influenced by requirements of other well developed industries such as textiles, paper, leather, chemicals, cosmetics, etc. in the region, as it would be a special taks to find clients and co-operation abroad.

Overall picture of oils and fats

(use)	(mio tons)
edible and animal feeding	52
soap	4
oleochemicals	3
other industrial uses, e.g. paints, linoleum	2

For comparison: petrochemicals are produced in the order of 150 mio tons.

1.5. Availability of equipment

22. Most of the equipment to start a downstream processing activity centered around edible fats can be purchased from specialised producers all over the world. The selection of the sequence of operations is nevertheless crucial in the first phase of oil milling and fat processing, and the choice of technologies to follow must be in correspondence. It might be desirable to seek advice and co-operation with experienced companies which have already demonstrated their ability to successfully start such activities in developing countries.

1.6. Fuel for diesel engines?

23. The issue of using vegetable oils as fuel for diesel engines may be of interest to farmers, or even to local governments with an interest in saving foreign currency (Brazil). This approach can nevertheless scarcely be justified. Malnutrition could spread in the world if a relatively high quantity of edible oil were to be burnt in combustion engines (remember 3000 mio tons of mineral oil consumption versus 60 mio tons of edible oil production world-wide). Economically, orientated on the world market prices, there is still a considerable gap which will not be bridged by reduced transport costs etc. in the near future.

2. Possible types of downstream processing activities based on vegetable oil crops, and fields of application of products obtained in the processing phase

24. Downstream processing activities comprise all fields of application from the relevant agricultural production of a country to the whole spectrum of semi-finished or end products which can be obtained either as products of the main stream, as by-products or derivatives. The downstream processing operation asks for a complete sequence of interrelated technological steps within a country. It offers different ways to choose the final product. In general, the product with the higher value on the world market should be the target, but alternatives must be investigated in case of other priorities due to local circumstances in a given country. It may be necessary to import special raw materials, semi-finished products or processing aids, if they play a key role in a broad concept.

25. Major potential options to start or develop downstream processing activities based on vegetable oil crops shall be listed in this chapter before a critical evaluation is made (cf.3).

2.1. Agricultural activities

(a) Growing of oilseeds and trees with fruits of high fat content. Alternative: the first seeds or plants are imported to start the agricultural activity. Depending on climate etc. the following seeds are of interest: soybean, rapeseed, sunflower, cottonseed, sesame seed, linseed, safflower seed, groundnuts, coconuts, palm kernels. Other which are of minor importance but of relatively high market value per ton such as sal (India), babassu (Brazil), jojoba (desert plant), illipe and shea butter deserve special attention. Finally, oil from the germs of corn oil, oil of grapeseed, and ricebran oil also deserve interest. Fruits of major importance are olives and palm fruits.

(b) Generally, the growth of the seed plants and trees takes place on farms and plantations. In many cases double cropping will be possible and even beneficial to the soil.

(c) Harvesting: All the seeds mentioned above produced by plants can be harvested by machine which is not only effective but also helps to avoid damage to the seeds and admixture of foreign materials. The trees may be picked by hand and indeed palms are now grown with shorter trunks which makes harvesting easier.

2.2. Storage, transport and processing of fats

All these can be crucial for the whole operation.

2.2.1. Olives and palm fruits have to be processed as quickly as possible as the neutral fats (the triglycerides) are split due to enzymatic action. Capacity of the processing plant and harvest area of the fruits have to be well adapted. Decentralized processing in a number of plants will be the result.

2.2.2. Seeds can survive a relatively long storage period (some months) before considerable losses in fat quantity and quality occur, provided they are mature and dry when harvested or are dried with suitable equipment (or in the sun). Splitting or other damage to the seeds will increase enzymatic activity which again leads to losses.

2.2.3. Storage must be possible at different processing stages, e.g. in limited quantities at the farm, at collecting points and in the region, and finally at the processing plant. Great care must be taken during storage to avoid mould infection etc. Investments can be high. The storage capacity must be well adapted throughout the processing operation. Storage must be considered of utmost importance as this can have an influence on the financial, transport, energy, labour, hygienic and environmental aspects.

Processing of seeds and fruits

The processing of seeds and fruits is entirely different, the latter is easier to achieve.

2.2.4. To obtain oil from the seed there is the choice between pressing and extraction. Pressing needs less sophisticated equipment with the exception of the high-pressure continuous expeller press itself: the method is flexible. Energy supply is needed primarily or exclusively in form of electricity. Nevertheless, pressing is applied in industrialized countries only for oilseeds with more than 20% fat content, and those are usually only prepressed to a fat level of ca. 20%, and then also extracted.

Pressing - with or without conditioning (to obtain more fat and to destroy enzymes)
output: crude oil and cake (the latter as animal feed)

Extraction - with or without dehulling of the seeds. By dehulling, a high protein meal is obtained; such feed component shortens the time for meat production (e.g. broilers) considerably and therefore pays.
output: crude oil and meal (the latter as animal feed); in so far they cannot be used as a source of dietary fibre - hulls and husks (to be burnt in boilers).

Full fat meat - production could in special cases be of interest. Meal with full fat content, e.g. from soybeans, can be used as animal feed or as an additive to food as long as a somewhat beany or bitter taste is accepted by the consumer (processed e.g. in extruder - cooker).

Special processing plants are needed to obtain oil from oil fruits:

output: olive oil and palm oil
residues of olives (as animal feed),
residues of palm fruits (to be burnt in boilers of the processing plant).

Modification of fat

There is more liquid oil in the world than consistent fat; the latter is needed for many food products and for most technical applications (an exception is palm oil as its high melting solid fraction, the palm stearin, is less valuable than the oil, i.e. the liquid fraction).

2.2.5. Hydrogenation of fats (and fatty acids) with hydrogen produced either with the help of an electrolyser or in a catalytic process:

output: a practically endless range of more or less consistent fats, tailored to the needs of the edible fat and other food industries; minor quality products for technical use (soap and oleochemicals).

2.2.6. Fractionation of fats either "dry" or in solvents (complicated, hign investments, etc.):

output: fat fractions of which one or both are more valuable than the starting materials for edible fat products and other industries; cocoa butter substitutes of different qualities.

This process is mostly used to get upgraded products from tallow or palm oil as these fats are relatively easy to fractionate.

2.2.7. Interesterification (and re-esterification): The re-esterification of oils and fats (olive oil) with a high content of free fatty acids is possible but forbidden in Mediterranean and some other countries. Re-esterification might be of special interest to neutralise the free fatty acids in e.g. ricebran oil (as long as it is not too oxidised due to prolonged storage).

Interesterification is as important as hydrogenation to modify oils and fats as such or as blends: only the distribution of fatty acids over the glyceride molecules is changed but not the fatty acids themselves. The results are fats with a higher value.

output: fats tailored to the special needs of the edible fat and food industries

Interesterification can be regarded as a desirable but not always necessary supplement, or as an alternative to hydrogenation and fractionation. In addition, it is the method of choice to make high melting products like tallow or palm stearin palatible by interesterification with oils and/or "laurics".

2.2.8. Refining of oils and fats: The result is a bland fat; environmental chemicals like pesticides, aflatoxins and trace metals are also removed. The refining process comprises a number of steps: desliming, neutralisation, bleaching and deodorisation.

output: refined oils and fats for the food industry;

by-products at different stages are: crude phosphatides for different industries like margarine, chocolate, instant products, pharmaceuticals, cosmetics, and soapstock as raw material for fatty acid production or animal feeding,

bleaching earth (spent earth ultimately for animal feeding with up to 50% fat content),

deodoriser condensates (as potential source of tocopherols = vitamin E, via molecular distillation, or as a source of perfume components).

Modern physical refining can simplify the process depending on the raw material used (cf. 3 below).

2.3. Edible fat products

2.3.1. Fats for industrial use (refined)

as bulk products (transported in lorries, tanks, etc.):

oils and fats (100%),

blends of oils and fats,

hydrogenated fats and fat blends of different dilatation/melting points,

interesterifed fat blends of specific characteristcs,

pumpable shortenings (semi-liquid).

as packed products (in tins, boxes, etc.)

same as under "bulk", plus

plasticised, softened fats,

plasticised, softened fats whipped with gas,

mayonnaise for fast-food and other restaurants.

2.3.2. Products for in-home use

salad and cooking oil (in tins and bottles),

white cooking fat

yellow fat (carotene or red palm oil concentrate added, often flavoured, e.g. vanaspati),

margarine (in general about 80% fat content, yellow, flavoured, adapted to the functional and nutritional requirements by selecting special fat blends and additives),

special margarines for artisan bakers,

mayonnaise with 10 to 80% fat content, as a rule with 5 to 10% egg yolk or preferably lecithin-based replacers.

These consistent and semi-liquid products are in general packed in wrappers, tubs, tins and tubes (mayonnaise).

Food products with less than 50% fat content

It depends on local eating habits, legislation and standard of living as to what extent edible fat will be used in a broad range of food products.

2.3.3. Industrially fabricated products

baked goods: 1 to 2% fat in bread to improve quality,
10 to 30% fat in the majority of baked goods,
up to 50% fat in puff-pastry

ice cream: up to 30% fat

filled cheese: vegetable fat replacing milk fat
up to 50% fat (calculated on dry matter)

all-vegetable cheese made of vegetable protein and fat (up to 50%)

canned fish: up to 30% fat

ready-made meals and quick-frozen meals

soups - canned and dried

baby food - including reformed milk

reformed meat products and sausages

snacks and potato chips

dressings and sauces (up to 30% fat)

2.4. Edible fat in animal feedstuff

26. Vegetable or animal fat can be used to enrich compound animal feed and calf-milk replacer as well as pet-food. This is an industry in itself and special know-how is needed. The total consumption of oils, fats and fatty acids for this purpose is in general much higher than for technical use. In addition to fish oil (hydrogenated), low grades of tallow and lard, and lower grade quality vegetable oils are used in a number of feedstuffs, especially prepared for this purpose and with high nutritional value.

2.5. Meal and cake as raw materials for other industries

27. Depending on the seed processed, meal and cake are often the larger but the less valuable co-product of the oil milling operation. The essential component of meal and cake obtained is protein. The amino acid pattern of the protein is decisive for the nutritional value of these co-products which are in general blended and applied with other components in the food or feedstuff industries, e.g. additives like vitamins, essential amino acids and trace metals can be added to increase the feeding value. On the other hand, there are sometimes minor components in the meal or cake which can limit the use in compound animal feed (e.g. glycosinolates in rapeseed meal). This is one of the reasons why vegetable protein for human consumption has been concentrated and isolated from soybean meal only. Other proteins such as rapeseed protein have equal or even better nutritional value, but difficulties in the processing due to the removal of undesirable substances and off-flavours have at least postponed their application. Research in this area should have high priority.

Meal and cake are in general essential as components of animal feed to start large-scale livestock production and to increase milk production.

2.5.1. Toasting of meal as part of the oil milling operation destoys substances which can hamper digestion by the animal.

2.5.2. Products for animal feeding

cake - (pressed with up to 1000 bar) is cracked to smaller pieces and transported in sacks or in bulk and used for feeding or blended with other components;

meal - after careful removal of residues of hexane is transported in bags or in bulk; the meal is sometimes pelleted to facilitate storage and transport to the farmers or the factories producing compound feedstuffs.

2.5.3. Vegetable protein for human consumption: At present experience is limited to products made from soybean meal. The protein yield per hectare is about 5 times higher when growing soybeans than when raising cattle or other livestock. The "Protein Efficiency Ratio" (PER) of soya protein can be as high as 90% of the PER of casein.

Urease and trypsin inhibitors as well as other undesirable flavour components can be removed by suitable processing. Soya protein products have interesting functional properties such as good solubility, emulsifying properties and water-binding capacity, and they can therefore be used as ingredients in many food products. But the special soya protein products for human consumption deserve greatest interest:

De-fatted soybean meal (50% protein): limited percentages e.g. in bread; various types of soybean "milk".

Texturised soybean meal: extruded like spaghetti has the "cooked soybean off-flavour" but is superior to the de-fatted meal.

Protein concentrates: produced by extraction of meal with water/alcohol mixtures; protein content 60 to 70%; added in rather high percentages to meat products (20 to 30% as meat extender) and fish products, sauces and baked goods.

Texturised concentrates: even broader application, e.g. in quick-frozen products, soups, ragouts, etc.

Protein isolates: produced by extracting the meal with water and precipitation of the protein at pH 4.8 (isoelectric point); protein content: up to 90%, PER-value: 70%; primarily used as additives in many food products.

Texturised isolates: protein is first dissolved in alkaline media and then precipitated with acids; it may be spun to simulate meat fibre.

2.6. Soaps

28. The oldest industrial product made from fat or fatty acids and still the most important one - certainly for developing countries - is soap. Not only laundry and toilet soap bars, or soft soap, but soap as an active component (surfactant) in detergents might be of interest for some developing countries. Soaps have to be manufactured from saturated or almost saturated fatty acids to avoid oxidative deterioration, cracking and destruction of perfume.

29. Starting materials are in general "laurics" like coconut and palm kernel fatty acids, and tallow. The latter can be substituted by hydrogenated vegetable oils or hydrogenated unsaturated fatty acids of minor quality. Depending on habits ("washing profiles") and purchasing power, a number of different types of soap could be produced:

soap products as semi-finished products;
toilet soap bars, floating soap, marbelized soap, transparent soap, antibacterial soap, etc.;
soap detergent bars (e.g. with fatty acid derivatives - nonionics - to avoid calcium- (lime) soap formation);
soap as active component in heavy duty and other detergents;
soap as additive in cosmetics;
metal soaps used in many industries as catalysts, anti-statics stabilizers, etc.

2.7. Technical uses of (neutral) oils and fats

30. There are technical uses for oils and fats (triglycerides) after some modification. Especially important are drying oils, namely different kinds of linseed oil, perilla- and hempseed oil with more than 35% conjugated unsaturated fatty acids.

31. Such products are:

paints and varnishes made from drying oil after thermal and/or oxidative polymerisation;

linoleum as floor covering made from highly oxidised and polymerised linseed oil; further

drying oils as components for oil cloth and rubber-like materials (factices);

other oils and fats are used for finishing of leather, or as lubricating oils and greases (e.g. castor and rapeseed oil).

32. In addition, oils are used as:

additives in cosmetics and pharmaceutical products, as spreading agents for insecticides and fungicides, and for dust control. Finally, oils and fats have always been used for burning and illumination.

2.8. Oleochemicals (see Flow Sheet in Annex I)

33. The attraction of natural fatty acids over synthetic products is often the specific location of double bonds and functional groups, but the majority of oleochemicals is made from saturated fatty acids.

34. It is impossible to list all opportunities in this area, as there are too many products and applications. The industry is "mature", but derivatives of basic oleochmeicals might find more customers. In contrast to petrochemistry, oleochemicals already start from molecules which have been synthesised by nature. Nevertheless, competition with petrochemical products will remain fierce.

35. Starting materials for oleochemicals are in general saturated fatty oils from sources which enable a low price, like tallow of low quality, soapstock or low quality vegetable fats.

2.8.1. Basic oleochemicals: could be produced in well developed countries.

- Fatty acids:
  Crude fatty acids made by splitting of neutral fats or soapstock (by-product of refining). Unsaturated fats or fatty acids have to be hydrogenated for most uses in soap and oleochemistry. Crude acids can be purified and fractionated by distillation or alternatively by wet fractionation (Lanza/Henkel process).

- Fatty alcohols made from fatty acids or fatty acid methyl esters, and primarily used as intermediates (hydrogenation at 250 bar/300°C).

- Fatty acid methyl esters made by alcoholysis of fats (80°C/normal pressure) and primarily used as intermediates or hydrogenated to fatty alcohols. They have a viscosity which is only twice as high as Diesel fuel and they are therefore more suitable to replace the latter than neutral refined oils. The viscosity of vegetable oils is ten to twenty times higher than that of Diesel oil which requires a special sophisticated adaption of the engines.

- Fatty amines
  made from fatty alcohols; direct use in road building, anti-caking, printing inks, etc., but the greater part is used for derivatives like quaternary ammonium components, cationic surfactants and desinfectants.

- Glycerin
  as valuable by-product from fat splitting and soap manufacture, applied e.g. in cosmetics and pharmaceutical products, and in form of monoglycerides (emulsifiers) in food and other industries.

2.9. Derivatives of basic oleochemicals

36. There is only room here and on the Flow Sheet to mention some derivatives of the basic products mentioned earlier. The majority requires rather sophisticated plants and processes.

Fatty acids: soap, fatty alcohol alkanolamides, fatty acid chlorides, metal soaps, candles.

Fatty alcohols: fatty alcohol sulphonates, fatty alcohol ethoxylates and other surfactants, polyglycol ethers, polyacrylmethacrylates.

Fatty acid methyl esters: alkanolamides, alpha-sulphofatty acid methylesters.

Fatty amines: quaternary ammonium compounds (disinfectants and surfactants).

Glycerin: Alkyd resins

37. Components of this product range find application as surfactants, plasticiser, stabiliser, emulsifier etc. It will certainly require intensive market research to find out which industries take an interest in which product in the region concerned, and if it really pays to invest money in this advanced technology.

3. Basic and general technological differences in various kinds of downstream processing activities in the vegetable oil field

38. There are a number of options to discuss first some basic differences in such downstream activities:

3.1. The whole operation has to start from scratch, and
3.1.1. (almost) exclusively with locally produced raw materials, or
3.1.2. with considerable quantities of imported raw materials.

3.2. Major operations in the area of vegetable oil technology exist already

3.2.1. Gaps would be closed. By-products have to find better use. Some modernisation is to be planned to save energy and other costs.

3.2.2. Existing technology should be extended to produce more sophisticated products.

39. Starting from one of the situations already mentioned, a step-wise build-up of these processing activities could take place. There are a number of very important and sometimes entirely different solutions which have to be investigated, depending on the situation in the country.

ad 3.1.1.

40. To start such an activity from scratch one has to decide on the raw materials which should become the basis of the whole operation. Agricultural conditions, especially climatic ones, are crucial. In the case of perennial plants such as olive or palm trees, a time span of some years is needed before the first crop can be expected. On the other hand, for almost all seeds the planning of the investment in factories, including silos, has to be the first stage. If possible, two or more kinds of seeds should be grown which are harvested successively; this offers the chance to keep the processing plants running continously almost the whole year and/or to reduce storage

facilities. In addition, it must be kept in mind that extraction plants should run continously primarily to avoid explosions or varying qualities. The farmers, in one way or other, must have a formal or informal guarantee for selling their products at reasonable prices to the collecting points and finally to the factories.

41. Traditional agricultural activities have to be changed round the factories if necessary to get a highly efficient raw material supply.

42. Only part of the desired downstream operation will be sensible in those decentralised places, but the capacity can be well adapted and - if only one raw material has to be handled - the plants can be simpler in their construction and equipment. Less bulky keepable intermediates can afterwards be transported much more easily to a central point where the final steps of the downstream activity will take place.

43. In addition to sharing of energy supply systems and training stations, some cross-fertilisation of this activity with other industries, clients and suppliers will be desirable or even essential for the success, as chemicals, catalysts, engineering services etc. are needed.

ad 3.1.2.

44. The capacity of the processing plants can be used better and the range of intermediate and final products can be broader if imported raw materials supplement the locally produced vegetable oil. Centrally located processing plants or those which process the intermediates collected from the country should be located in a harbour area with a deep channel and suitable unloading facilities; only in exceptional cases a railway connection would be acceptable. The proper choice of the location is of great importance, as machinery, spare parts etc. must come in, and possibly fuel or coal to produce steam and electricity.

45. It can be imagined, nevertheless, that only the first steps of the whole activity would be located in a harbour area and the final part in another industrial centre of the country to have the full benefit of cross-fertilisation. And once again:
Modern plants must often operate continously either for safety reasons (e.g. extraction plants) or to be competitive cost-wise.

ad 3.2.1.

46. In cases where there are already some industrial activities in the field of vegetable oil technology in the country, it has first to be investigated if they should become part of a new downstream activity at all. The answer will primarily depend on their location and flexibility to process different raw materials. Furthermore, it should be ensured that those factories fit in the total plan for a new downstream activity to avoid bottlenecks in production steps.

47. The enlargement of existing plants, e.g. by combining modern continous with older batch operations, can be another point of discussion.

48. Special investigations are needed to make best use of by-products, e.g. cake and meal or soapstock.

ad 3.2.2.

49. On the assumption that basic steps of a downstream activity are already well developed, intensive market research seems advisable before investments in a range of other new products are made. This task might be rather easy as far as food products, soap and animal feed are concerned, but it will be much more difficult in the case of oleochemicals. The majority of those products is competing with petrochemicals on the world market, and there is already some overcapacity under the present conditions. It will depend on the stage of development of other industries in the country or the region if oleochemicals can be regularly sold at reasonable prices. Export opportunities ask for the service of salesmen experienced in the broad range of application of oleochemicals, and for reliable clients as well, as otherwise rather sophisticated processing plants could stay idle. Joint ventures could be an optimum solution.

3.3. There are general technological differences in various kinds of downstream activites which will be elaborated in two respects:

3.3.1. Activities primarily orientated on the composition of the raw materials, and

3.3.2. Confrontation of rather simple technologies with modern and elegant ones.

ad 3.3.1.

50. The kind of material(s) will determine at first what methods of extraction will be applied:

51. Mechanical extraction of oil (in open or closed batch process, or in continuously operating expellers), a process which has been used primarily for oil seed with a high fat content, like copra (more than 60%), palm kernel (45 to 50%), sunflower seed kernels (40 to 60%), safflower seed (25 to 35%), groundnuts (25 to 35%), rapeseed (40%), linseed etc. But in modern extraction plants most of these seeds are first prepressed to reduce the fat content to about 20%, and afterwards the residual fat is extracted with solvents (hexane).

52. If sufficient high pressure (about 1000 bar) is applied, the fat content can be reduced directly to 4 to 5% by pressing only, but it is more economic (in industrialized countries) to extract with solvents as only 1% is then left in the meal.

53. Higher fat contents in the oil meal are often not well paid for by the animal feed industry.

54. Solvent extraction is certainly especially attractive when soybeans or cotton seed can be directly extracted with hexane after cleaning, dehulling and flaking but without any pre-pressing. High safety requirements, continuous operation, a well defined solvent, etc., are needed. Solvent residues in the meal have to be carefully removed (primarily for safety reasons). Losses of up to 0,2% solvent calculated on seed throughput are unavoidable in practice.

55. Recovery of oil from pulps of olives or palm fruits with about 35% fat is in principle much easier. Originally, batch processes were used but to-day continuous processes and centrifuges solve the problem. Modern plants for palm oil extraction also have the necessary heavy machinery to crack and press the palm kernels (from the same fruit).

56. Not only the extraction but the following steps of downstream activity also will depend to a large extent on the type of raw material:

57. Refined oils from coconuts or palm kernels can be used for almost all food products as mentioned under 2. above. In adddition, these fats (if they are of minor quality) can be used without any modification other than bleaching, for the production of soaps or fatty acids because they consist primarily of saturated fatty acids of medium chain length. These fatty acids are stable and have a broad spectrum of potential applications.

58. The other refined seed oils are used as cooking/salad oils and as components in cooking fats and margarines, but the bigger part must be partly hydrogenated to fulfil the role of a hardstock in the latter products. Refined oils can be used as such in many other food products (canned fish, dressings), but only hydrogenated fatty acids of these oils could be used in soap and oleochemicals, industries which would anyway prefer animal fats for price and chemical reasons (narrower spectrum of fatty acids). The effort for fractionated distillation of fatty acids of those oils will often be considerably higher.

59. Palm oil is an interesting exception as it can be fractionated into stearin and olein. The latter can be used (after a special refining procedure) like a refined seed oil, but the stearin has fatty acid broadly similar to that of tallow. Stearin is used as edible fats. The stearin fatty acids are suitable for soap making and oleochemicals.

60. It should be mentioned once again that cake and meal of practically all seeds can be used as animal feed, but there are great differences in quality. The essential component is the protein, and the nutritional value depends on the spectrum of amino acids. Real experience with vegetable protein for human consumption is only available with soybean protein. As far as other cakes and meals are concerned, the protein concentration is either too low or the isolation and purification is still too difficult and costly (e.g. in the case of rapeseed).

61. Some other special seeds have to be mentioned here, as they offer chances for activities which are clearly directed to one or only a few products, or are collected and processed in only small quantities.

cocoa beans	- for cocao butter, chocolate, etc.
linseed oil	- for different industrial uses (see under 2.)

babassu seed	-	fat similar to coconut oil (Brazil)
illipe and shea butter	-	for use in special food products (Borneo)
oil from grapeseeds	-	for food use
sesame oil	-	for food use (Burma, Turkey, China)
corn oil	-	for salad oil (by-product from corn)
teaseed oil	-	(China)
ricebran oil	-	difficult to process, high in free fatty acids
sal fat	-	used as substitute for cocoa butter (India, Nepal)
jojoba fat	-	used as substitute for sperm oil (Mexico)

ad 3.3.2.

62. It might be realistic to differentiate between the option to use either simple and cheap installations or a more sophisticated technology, especially if limitations in financing, qualified personnel or energy supply have to be considered. Some examples are given below:

Extraction of fat

63. Pressing is much easier to control than solvent extraction. The investment, safety and energy requirements in solvent extraction are high and the technology of such plants with solvent recovery etc. is much more complex than for high-pressure pressing. In addition, extraction plants are often less flexible, and they must operate in 3 or 4 shifts as mentioned before to avoid explosions.

Refining of oil

64. Many raw materials require all steps of classical refining, but the alternative of physical refining - especially for palm oil - will pay if the necessary stainless steel equipment and high-temperature steam are available to combine distillative neutralisation and deodorisation in one operation (at about 240^{o}C).

Soap making

65. The simplest and oldest process would be the so-called semi-boiled and cold method to produce soap in kettles or crutches (4 hours). There are, on the other hand, a number of continuous and more or less automatically controlled processes available. Other alternatives exist for drying of the "neat" soap in frames or spray-drying, and finally many different machines for finishing the soap are available.

Fat splitting

66. This can either be done batchwise at normal pressure (Twitchell) with rather long residence time, or semi-continuously. The equipment is cheap in the first case, the process is energy-intensive, and some discolouration of the fatty acids will occur. Alternatives are medium-pressure (30 bar/230^{o}C) splitting in autoclaves with metal catalysts, or the high-pressure splitting in specially constructed towers (25 m high) with complicated and expensive equipment for heat recovery etc. High quality of fattty acids and glycerol on the one hand, and low energy costs on the other hand, might make this latter process in general more attractive.

Hydrogenation

67. The way in which hydrogen should be produced will depend on the throughput of the hydrogenation plant, environmental factors and electricity supply, to mention only the most important factors (i.e. either by electrolysis or in a rather complex plant for a catalytic process with a number of steps to purify the gas).

68. There are certainly a number of other examples of that kind in fat and oleochemical technology, and there will often be some trade-off between quality requirements and processing costs, but generally speaking investments must not always be made in most modern techniques if local conditions speak in favour of a simpler solution which is sometimes even more flexible.

4. Economic and technical conditions indispensable for broadening downstream processing activites

69. Only a few aspects can be mentioned here. Agricultural raw material supply deserves first priority. The developing countries should be a position to grow oil seed or palm trees at prices which are more or less competitive on the world market. This aspect, to be competitive without direct or indirect subsidies, is at least as important for further technological steps such as extraction, production of compound feedstuff, oil refining etc. The relatively high investment in technical installations should yield profits high enough to cover full costs (including depreciation or replacement value).

70. In case of mono-cultures of high priced oil like "laurics" (coconut-, palm kernel- and babassu-oil) or groundnut oil, part of the production can be sold

on the world market to buy much cheaper oils such as soybean oil or rapeseed, which fulfil the requirements of many products.

71. It is often the very diversified structure of the farmland which makes the necessary raw material supply so difficult in many African and other developing countries. The raw material supply is therefore not reliable and distances between growing areas and processing plants are too great.

72. Infrastructure under those conditions deserves special attention. The storage stystem at the farm, the regional collecting points and the processing plant itself should be well adapted to the capacity of the extraction plant or oilmill, and the transport system should function without any problem. Therefore this must be carefully planned.

73. Energy supply is frequently another limiting factor. Processing plants need a continuous energy supply at a price as low as possible, as demand is relatively high and interruptions become very costly for a number of reasons. About 2 tons of steam (20 bar) and 200 kWh are needed to produce 1 ton of refined deodorised oil from seed.

74. A downstream activity ending in sophisticated products such as refined vegetable protein or oleochemicals and their derivatives should be backed by scientific service institutions and would certainly benefit from other well developed industries. The palm oil research centre in Malaysia and fat institutes in India are examples greatly contributing to the success of the total activity in those countries.

75. Factories can be planned and installed by a number of companies with world-wide experience. Maintenance, repairs and further development adapted to local conditions will nevertheless require well-trained personnel which is not available everywhere. Technical and commercial managers need special education and training e.g. in institutions outside the country. Finally, a step-by-step approach during the build-up of this industry is necessary.

76. The technology of oils and fats in the narrow sense is rather capital- and energy-intensive, labour costs playing a minor role. This shows clearly that the stage of development of the country and the creditability will be crucial for a broadening or an extension of a downstream activity in this field. The

processing plants must be controlled regularly by an independent engineering service to reduce safety risks with this relatively complicated technology to a minimum.

77. Chemical and hygienic quality control can be crucial. Many products of this downstream activity - especially food - have health risks, other goods are bought by critical clients. Contracts will in general contain clauses concerning the quality standard.

78. The broadening of the vegetable fat activity requires a certain purchasing power and demand in the country. This could mean that food and compound feed industries should be developed in parallel with other enterprises within the country and the region as it would be risky to rely primarily on export activities which may possibly never by realised. In other words, a market for products of this downstream activity should be developed within the country or the region.

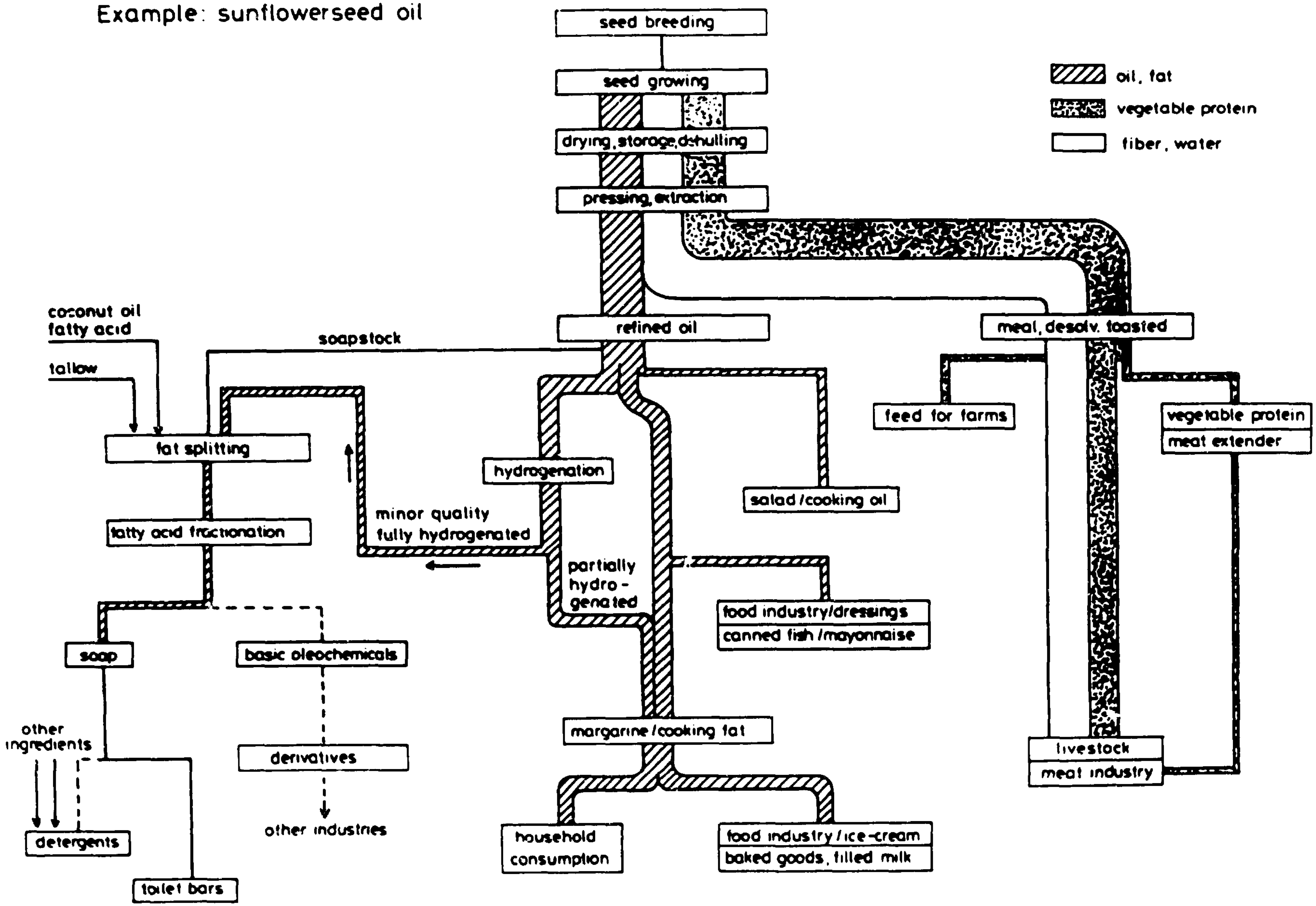
79. Profit margins for products of this downstream activity for vegetable oil and fat will not be exceptionally high. Crude fats and fatty acids as well as cake and meal are commodities produced in increasing quantities world-wide, and this trend could on a longer term stabilise prices. There is always a demand somewhere, and prices are fixed traditionally in a hard currency. The broad range of processed food containing more or less oil and fat will meet a regular, probably increasing demand in the country itself, but the products are often regarded as basic food which should be available at relatively low prices.

80. More sophisticated products such as fat fractions, vegetable proteins, pet-foods or oleochemicals can only be produced with great experience in manufacture and application. Moreover, a careful study of the potential market is needed. A marketing strategy and well trained salesmen will play an important role.

Annex I:

Simplified example of a possible downstream processing activity

Example: sunflowerseed oil



Annex II:

Important Oleochemic..s - Production and Application

(simplified overview)