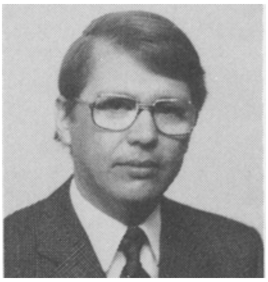
SESSION II – PROCESSING VEGETABLE OIL-BEARING MATERIALS

Characteristics and Composition of Vegetable Oil-bearing Materials



A. LANGSTRAAT, Development Manager, Van den Bergh & Jurgens B.V. (Unilever), Rotterdam, The Netherlands

ABSTRACT

A survey of the commercially most important oil-bearing fruits and seeds is presented. Their place in the nutrition of the world's population is sketched, both as a source of fat and as a potential source of protein. Origin and occurrence of a number of oil fruits and seeds are treated, and their relative importance is discussed. Characteristics of the vegetable oils are described in the light of their fatty acid compositions. Nutritional aspects of polyunsaturated fatty acids are discussed briefly, as well as the anti-nutritional properties of erucic acid. Oilseed proteins are discussed from the point of view of their growing importance as a source of food for man, and compositions of their essential amino acids are discussed in relation to their nutritive value.

INTRODUCTION

There are many angles from which one can approach the subject of vegetable oil-bearing materials, and, in doing so, one is confronted with matters that have a direct bearing on the well-being of the people inhabiting this world. For instance, oil-bearing materials have an immediate relevance to the nutrition of the world's population. The economy of developing and developed countries depends to a greater or lesser extent on their cultivation and export. The oil-bearing materials and their products, food and animal feedstuffs, are traded internationally. Millions of tons of these products are shipped around the globe annually. They are the subject of agricultural policies of nations and international organizations. The science of agronomy and research in plant breeding attempt to achieve their improvement. Finally, and that is what this World Conference is about, they form the basis of a technology and an industry which produces the main products: vegetable oils and protein-containing meals from the oil-bearing fruits and seeds. The oils are the raw materials for the finished products industry of margarines, shortenings, table oils, bakery margarines and fats, cooking and frying oils and fats, etc., while the by-product meals are mainly used as animal feedstuffs, although in the past decade protein products for human consumption are being made from them and the importance of this application is growing.

Total world production of edible oils and fats of vegetable origin has grown exponentially over the past 20 years and has now reached 30 million tons per year, i.e., approximately two-thirds of the total world visible fat supply (Fig. 1). If we could distribute this amount of visible vegetable fat evenly to the total world population, it would mean a daily ration of 22 g of vegetable fat or the equivalent of ca. 200 calories for each human being. Of course, one of the major problems we face is that the present distribution is very uneven indeed (Fig. 2).

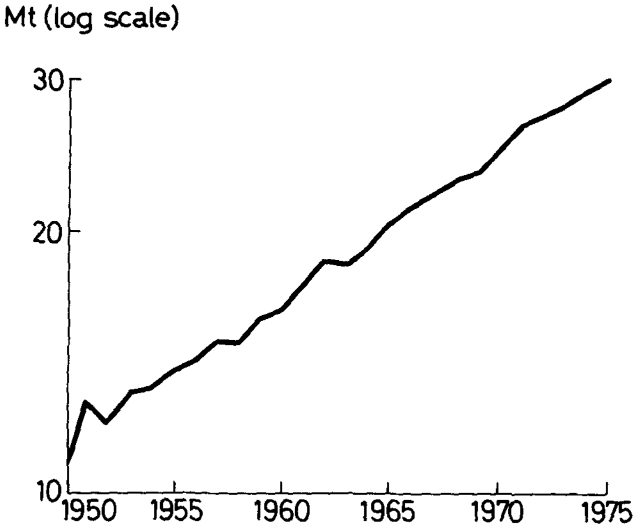


FIG. 1. World production of vegetable oils in million tons (Mt).

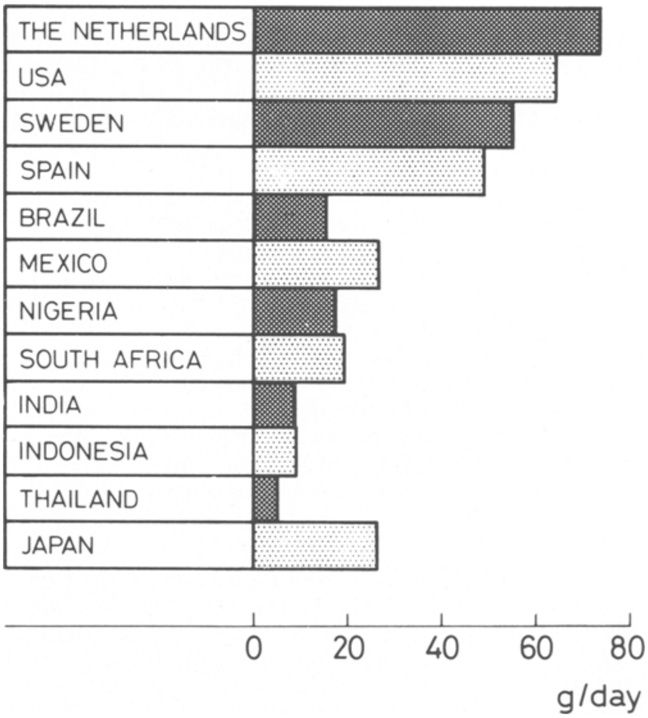


FIG. 2. Per capita consumption of visible fats in several countries.

ORIGIN AND OCCURRENCE

For many centuries, most oil-bearing fruits and seeds

TABLE I

Approximate Production (1974) of Commercially Important Oil-Bearing Fruits, Nuts, and Seeds[a]

		Crop	Expressed as oil
		(Mt/(10^6)	
Fruits and nuts (from trees)	Coconut (as copra)	3.6	2.4
	Palm fruit	-	2.7
	Palmkernel	1.4	0.5
	Olive	7.7	1.5
	Babassu	-	0.1
Beans, seeds, and nuts (from plants)	Soybean	57.3	9.2
	Sunflowerseed	11.1	3.8
	Groundnut	17.9	3.0
	Cottonseed	25.6	2.9
	Rapeseed	7.3	2.3
	Sesame seed	2.0	0.8
	Maize	312	0.4
	Safflowerseed	1.0	0.3

[a]Mt = million tons.

have been grown in countries all over the world and used locally for food and with great ingenuity for many other purposes as well. More than 100 varieties of plants are known to have oil-bearing seeds, but only about a dozen are significant commercially. They are listed, together with their approximate yearly production figures on the basis of 1974 statistics, in Table I. In general, the oil fruit bearing trees are more confined to a certain climate than the oil-bearing plants. The difference between trees and plants is therefore more than just a matter of botanical classification. It also represents the separation between oil-bearing crops that must be harvested essentially manually, requiring much labor, and the oil-bearing crops that can be sown and harvested mechanically, requiring high investments. At present, the situation is such that the oil crops requiring of necessity much labor are mainly in tropical and subtropical areas, where relatively inexpensive labor is still abundantly available. On the oilseed side the picture is more diverse, although in many industrial countries a high degree of mechanization is prevalent.

Coconut

The coconut palm *(Cocos nucifera)* is typical of a tropical climate. No picture of the tropics is complete without a palm tree. Coconut palms are traditionally found in coastal regions in Asia and in the Pacific islands. A popular theory holds that the coconut palm has spread because coconuts, fallen into the water, were carried by sea currents and washed ashore elsewhere, where they germinated. The trees start to bear fruit after 5 or 6 years, and they can continue to do so for as much as 60 years, reaching heights of 25-30 m. The nuts ripen in 9-12 months and can be harvested all year round, so that labor can be spread evenly over the year. To make harvesting easier, new dwarf varieties have been developed for plantations. The ripe coconuts are husked, i.e., the fibrous shell is removed; then the shell is split, and the meat is dried to obtain copra, the oil-containing material. Many other products are made from the coconut, and it has always been an important source of income for the local population. The Philippines is the most important producing and exporting country, followed by Indonesia, India, Sri Lanka, Malaysia, and Oceania.

Oil Palm

The oil palm (*Elaeis guineensis*) is found in the tropical rain forest of West and Central Africa and in Asia. The oil palm most probably originates from Africa. It was carried with Portuguese slave ships to Brazil in the 16th century. In the 19th century four palm trees were sent from the Hortus Botanicus in Amsterdam, via Mauritius, to the botanical garden at Bogor on Java for ornamental purposes. There is also a report of palm trees being sent for the same reason from Kew Gardens in London to Kuala Lumpur. It took more than 50 years before the commercial value was realized and exploited in Asia. The first palm plantation was established in Malaysia in 1917. In recent years the area of palm oil plantations in Malaysia has grown at the expense of the less remunerative rubber plantations. Oil palms start to bear fruit after 4 or 5 years and reach their full yield after 15 years. They bear fruit for ca. 25 years. The fruit bunch contains ca. 1,000 fruitlets, each fruitlet containing two or three kernels. The palm oil from the fruit is pressed locally, but the palmkernels are generally exported as such.

Olive

The olive tree (*Olea europea* L.) thrives best in a subtropical climate. It probably originates from Mesopotamia, and it has been cultivated for many centuries in the Southern European countries bordering the Mediterranean and in North Africa. The olive tree region stretches from there across Asia Minor, the Southern USSR, and Iran to the Punjab in India. The olive tree can become several hundred years old. It is probably the oldest culture tree in the world. In the book of Genesis we can read of Noah, who sent out a dove from the ark, and when it returned with an olive leaf he knew that the earth had fallen dry after the flood. In Greek mythology the greatest gift of the goddess Pallas Athene to the city of Athens was an olive tree.

Babassu

There is one tree today that is still in the position in which the oil palm was two centuries ago, namely, that it grows wild and despite its potential is not cultivated on a large scale for lack of infrastructure: roads and transport. This tree is the babassu palm *(Orbignya martiana)*, which occurs in Brazil in the Amazon territory. The babassu palm starts to bear fruit after 10 years and can become up to 200 years old. A fruit bunch contains on average 200 nuts. The nut has a very thick, hard shell and contains between three and seven seeds, which have a high oil content. Breaking the nuts used to be a major problem, but suitable equipment is now available.

Soybean

The soybean (*Glycina maxima*) grows best in warm, temperate areas with continental warm summers, such as the so-called cotton and maize belts in the USA and in China or in subtropical climates, e.g., in Brazil. The soybean originated in Manchuria, from where it spread to China and later to Japan. In these countries it has been an important part of the daily menu for centuries. From Japan, the soybean came to America in the 19th century. In 1908 the first soybeans came to Europe when a Japanese merchant sent a sample lot to London. In the USA, the soybean has become one of the most important crops. Despite the fact that the seed has a relatively low oil content, the soybean is now the most important oil-bearing crop in the world. Moreover, it has a great potential for further growth. A good example is the tremendous growth rate of the soybean crop in Brazil, where the soybean is again establishing itself as a "miracle crop."

Sunflower

The sunflower (*Helianthus annuus* L.) is an example of an oil-bearing plant that is extremely adaptable to different types of climate, occurring as it does in temperate, subtropical, and tropical countries. At present, large scale production is still mainly concentrated in countries in the temperate zones. The wild sunflower is believed to have originated in the southern part of the USA and Mexico, where it was found growing as a weed. In the 16th century—to be precise in 1569—the Spaniards brought the sunflower to Spain, where it was used as an ornamental plant and

TABLE II

Rise in Average Yield of Oil From Sunflowerseed in Russia

Year	Average yield (%)
1940	29
1965	44
1970	45
1971	46

from where it spread throughout Europe. In the 19th century its cultivation as an oilseed crop began in Russia and some East European countries and later in Argentina as well. In the USSR seed and oil yield were substantially improved (Table II). In post-war years, and more particularly in the 1960s, efforts have been made to establish sunflowers as an oilseed crop in other parts of the world. The Russian varieties, which were developed mainly for their performance under the climatic conditions of the Russian steppe, were also tested in countries with other types of climate. A number of experiments and commercial production in these new growing regions, for instance Mexico and Pakistan, made it clear that these varieties could be grown successfully under a wide range of conditions. Today, the sunflower is the second largest world source of vegetable oil. The oil is valued highly as a source of polyunsaturated fatty acids. Two-thirds of the world production still is in the USSR. Other important producing countries are Argentina, the USA, Romania, Turkey, Bulgaria, and Spain.

Groundnut

The groundnut (*Arachis hypogaea*) belongs to the same legumes family as the soybean (*Papilionaceous flowers)*. It is grown both in tropical regions in West Africa and Asia and in moderate climatic zones like the southern U.S. and China. The groundnut, or peanut, has an interesting history. It originated in South America. In the 16th century it was brought from Brazil by the Portuguese to West Africa. Incidentally, as mentioned before, the oil palm went in the opposite direction. Almost two centuries later, the groundnut was then taken from West Africa by the slave traders to North America, since it provided what little food there was on board the slave ships. Today it is still an important crop in West Africa and also in India, China, and the USA.

Cottonseed

Cottonseed (*Gossypium*) is a by-product of cotton production and as such is dependent on the supply and demand situation of cotton. It is still a major crop, despite the increased use of synthetic fibers. Cotton is one of the oldest culture crops. There were cotton fields in India 4,000 years ago. When Columbus discovered America, he found the cotton plant already there. The use of the oil from cottonseed dates from much more recent times. Harvesting cotton used to be very labor intensive, and this provided an impetus for the slave trade in the 18th century. The most important cotton growing areas are in the USSR, China, USA, India, Pakistan, Brazil, Turkey, Egypt, and Sudan. In some of these countries, the full potential of the cottonseed as a source of edible oil is not yet exploited.

Rapeseed

Rapeseed (*Brassica oleifeira*) has two principal varieties: *B. napus*, the so-called Argentine variety, and *B. campestris*, the so-called Polish variety or turnip rape. Winter and summer types of rape and turnip rape occur. Canada's crop is mainly of the summer turnip rape type, while in Europe the winter rape type is predominantly grown. Rapeseed is traditionally the most important oilseed crop of Western Europe. France, Germany, and Sweden are the main producing countries. Since the Second World War, cultivation has been established more permanently, among others as a result of the EEC agricultural policy. In Canada, today one of the most important rapeseed producing countries in the world next to India and China, production was also initiated in the Second World War as a source of domestic fat supply. From a nutritional point of view, rapeseed poses the following problems: (a) the high erucic acid content of the oil may be physiologically harmful; and (b) the glucosinolates in the meal hydrolyze enzymatically to toxic substances: isothiocyanates, oxazolidinethione, and nitriles.

Recent rapeseed history provides an example of how systematic research and development in cooperation between various public and private institutions can lead to a clear definition of the problems and provide solutions. New varieties of rapeseed have been developed and released for commercial application. A gradual changeover to low erucic or even zero erucic rapeseed varieties is now taking place. In the beginning, yields of oil and protein of the new low erucic varieties were lower, but intensive research in Canada made it possible to overcome most of the difficulties, so that in 1974 low erucic rapeseed varieties accounted for 94% of the Canadian crop. In Germany the changeover to low erucic varieties coincided with unfavorable weather conditions, and yields were on average 20% lower in 1974-1975. Also in France and Sweden a changeover to low erucic acid varieties is in progress. Most recent varieties are the so-called "zero-zero" types, which are both low in erucic acid and in glucosinolates.

TABLE III

Oil Content of a Number of Oil-bearing Materials

Number	Oil-bearing material	Oil content (%)
1	Copra	65-68
2	Babassu	60-65
3	Sesame	50-55
4	Palmfruit	45-50
5	Palmkernel	45-50
6	Groundnut	45-50
7	Rapeseed	40-45
8	Sunflowerseed	35-45
9	Safflowerseed	30-35
10	Olive	25-30
11	Cottonseed	18-20
12	Soybean	18-20

CHARACTERIZATION AND COMPOSITION OF VEGETABLE OILS

The oil content of vegetable oil bearing materials varies between 15 and 70% of the total weight of the seed or fruit meat. Oil contents of twelve major oil-bearing materials are shown in Table III.

Chemically speaking, oils and fats are triglycerides, i.e., esters of glycerol and fatty acids. Since they all share the glycerol part, the different properties of the oils and fats are to a large extent determined by their fatty acids. Three aspects must be mentioned here: chain length, the number and position of double bonds in the chain, and the position of the fatty acids with regard to the glycerol.

Neglecting minor quantities of higher and lower fatty acids, we may for practical purposes say that for vegetable oils the carbon chain length varies between 12 and 22 carbon atoms (only even numbers occur) with up to three double bonds (Table IV). The most important saturated fatty acids are lauric acid (C12), myristic acid (C14), palmitic acid (C16), stearic acid (C18), arachidic acid (C20), and behenic acid (C22). The most important monounsaturated fatty acids are oleic acid (C18:1) and erucic acid (C22:1). Of the di-unsaturated fatty acids, linoleic acid (C18:2) is particularly important. Finally, of the triunsaturated acids, linolenic acid (C18:3) should be mentioned.

TABLE IV

Main Fatty Acids of Vegetable Oils

	Chain length	Common name	Systematic name
Saturated	12	Lauric	Dodecanoic
	14	Myristic	Tetradecanoic
	16	Palmitic	Hexadecanoic
	18	Stearic	Octadecanoic
	20	Arachidic	Eicosanoic
	22	Behenic	Docosanoic
Mono-unsaturated	18	Oleic	*cis*-9-Octadecenoic
	22	Erucic	*cis*-13-Docosenoic
Di-unsaturated	18	Linoleic	*cis,cis*-9,12-Octadecadienoic
Tri-unsaturated	18	Linolenic	*cis,cis,cis*-6,9,12-Octadecatrienoic

TABLE V

Main Vegetable Oil Categories

Principal fatty acid	Oil
Lauric	Coconut Palmkernel Babassu
Palmitic	Palm
Oleic	Olive Groundnut
Linoleic (medium)	Soybean Cottonseed Sesame Maize
Linoleic (high)	Sunflowerseed Safflowerseed
Erucic	Rapeseed

Cis and *trans* configurations of unsaturated fatty acid chains have different physical and physiological properties. It also matters to which carbon atom of the glycerol the fatty acid is linked, and also whether the three fatty acid chains are partly or wholly the same or different and whether there is symmetry or not. Consequently, the best characterization of vetetable oils is according to the typical fatty acid composition.

In the past 20 years, special attention has been paid to the so-called essential fatty acids of the polyunsaturated type, of which the most important one in vegetable oils is linoleic acid. These fatty acids are essential in the sense that they are needed in the human body and cannot be synthesized in the cells or fibers in sufficient quantities. The essential fatty acids lower the blood lipids, especially the blood cholesterol-level, and so help to lower one of the risk factors involved in atherosclerosis.

The oils and fats of vegetable origin are conveniently subdivided into six groups in Table V.

Laurics

The laurics are oils characterized by a high amount of C12 saturated fatty acids, i.e., more than 40% and a relatively low unsaturation. Coconut oil has the highest lauric acid content of the three oils in this group and the lowest melting point: 24 C as compared with 26 C for babassu oil and 28 C for palmkernel oil. In the tropical countries of origin it is a liquid oil; in temperate climates it is a solid fat. Coconut oil contains ca. 8-10% unsaturated acids, mostly oleic acid. Palmkernel oil contains ca. 17% unsaturated fatty acids, also mostly oleic acid. As a result of the high content of a single, medium mol wt fatty acid, the lauric oils exhibit a low melting point combined with an extremely steep dilatation line, yielding a quick melting behavior with an impression of coolness on the palate when they are applied as a component of table margarines. They also improve the creaming and cake-making properties in bakery products. As a result of their natural low unsaturation, lauric oils are very resistant to the development of reversion flavors or rancidity. However, free fatty acids from the lauric oils are very noticeable even in low concentrations, as they are sufficiently volatile and soluble to contribute a definite odor and flavor.

Palm Oil

Palm oil is characterized by its high palmitic acid content (saturated C16), which varies between 35 and 45%. This aspect, combined with a rather low unsaturation (50% saturated, 50% unsaturated) results in an elevated melting point and a relatively flat dilatation line. Palm oils of Asiatic origin (Malaysia, Sumatra) have a somewhat higher melting point than those of African origin. Palm oils contain high amounts of carotenes and are therefore deep orange-red in color. Palm fruits experience strong enzymatic action during harvesting and subsequent handling by which fatty acids are formed. The fruit is therefore sterilized on plantations as soon as possible after harvesting. The palm oil quality, especially the free fatty acid content, is highly dependent on this treatment. Because of its specific fatty acid composition, palm oil is a good starting material for fractionation to produce special products, e.g., for the confectionery industry.

Oils High in Oleic Acid

Olive oil is a very stable oil of excellent quality which is widely used as a table and cooking oil, especially in the countries where the olives are cultivated. It is generally too expensive for use in margarines. Ten to twelve percent of the fatty acids are saturated, largely palmitic acid, and 88-90% are unsaturated, largely oleic acid.

Groundnut oil is differentiated into two main varieties according to origin. The fatty acid composition of both varieties shows 17-20% saturated and 80-83% unsaturated acids. The saturated part consists mainly of palmitic acid, but significant amounts of stearic, arachidic, and higher fatty acids are also present. In West African oils, the unsaturated acids are ca. 60% oleic and 20% linoleic; in oils from other sources, the composition is closer to 40% oleic and 40% linoleic acid. Groundnut oil, particularly the African variety, has good keeping properties and is excellent for use in deep-frying. Because of its characteristic odor and flavor, it is highly appreciated as a salad oil.

Oils with Medium Essential Fatty Acids Content

Characteristic of soybean oil is its high content of phosphatides (up to 2.5%) which are separated from the oil before refining and made into the valuable by-product lecithin. Of the soybean oil fatty acids, 12-15% are saturated, mostly palmitic; 85-88% are unsaturated, of which 25-30% are oleic, 50-55% linoleic acid, and 5-10% linolenic acid. The relatively high linolenic acid content is held responsible for the characteristic flavor change of the oil, which tends to restrict the application of the liquid oil in margarines and also in cooking oils. To improve its taste stability, the oil may be partially hardened to reduce the linolenic acid. This, however, also reduces the linoleic acid

TABLE VI

Protein Contents of Various Oilseed Meals

Oilseed meal	Protein content (%)
Soybean	45-50
Cottonseed	40-45
Groundnut	50-55
Sunflowerseed	45-50
Rapeseed	35-40

content of the oil. The value of soybean oil as a source of linoleic acid in fatty foods is therefore somewhat limited. New specific hardening catalysts can improve this situation.

Cottonseed oil requires a rather drastic refining treatment to remove the strong flavor and dark color which are characteristic of the crude oil. The fatty acids are ca. 25% saturated and 75% unsaturated. The saturated part is nearly all palmitic acid; in the unsaturated part, the linoleic acid content is ca. 45%, and the remainder is nearly all oleic acid.

Sesame oil contains strong antioxidants in the form of sesamol and tocopherol and is therefore an oil particularly resistant to oxidative rancidity. The antioxidant sesamol, a phenolic substance, gives a strong red color in the Bauduin test with furfuraldehyde; in some countries, the use of 2-10% sesame oil is compulsory as indicator substance of margarine blends. Total saturated acids, with palmitic and stearic acid as main components, amount to 13-17%; the unsaturated part comprises 35-45% oleic and 35-45% linoleic acid.

Corn oil or maize oil is a by-product of corn starch production. It is mainly produced in the USA. Its principal use is as cooking and salad oils, and generally it is too expensive for margarine outside producing countries. In fatty acid composition, corn oil is very similar to sesame oil, although slightly higher in linoleic acid. Due to its relatively high tocopherol content, it is quite stable to oxidative deterioration, despite its high degree of unsaturation.

Oils High in Essential Fatty Acids

Sunflowerseed oil is the most important supplier of essential fatty acids because of the large quantities produced and the high level of linoleic acid in the oil, which is rarely below 60% and can be as high as 72%. The amount of linoleic acid in sunflowerseed oil is dependent on the temperatures to which the plant is exposed during growth. Generally, high yields in linoleic acid are achieved under low temperature conditions. The linoleic acid content of the seeds in the center of the flowerhead is also higher than that towards the periphery. The keeping properties of the oil are good.

Safflowerseed oil is very high in linoleic acid, i.e., 75%. The rest is mainly oleic acid. The oil is derived from the seeds of the safflower (*Carthamus tinctorius* L.), a thistle-like plant which is at present grown only in small quantities as an oilseed crop, but the safflower is likely to become more important now that the demand for oils high in linoleic acid is increasing.

Oils High in Erucic Acid

Apart from the high linolenic acid content, comparable to that of soybean oil, the traditional rapeseed oil was characterized by high erucic acid content; oils from *B. napus* contained from 40-50% and oils from *B. campestris* from 25-35%. Because of possible physiopathological harmfulness of high quantities of erucic acid in the human diet, new rapeseed varieties have been developed in recent years and are now commercially available. They contain less than 5% erucic acid; instead of erucic acid, oleic acid is formed. In composition, this low erucic acid rapeseed oil is inbetween groundnut oil and soybean oil.

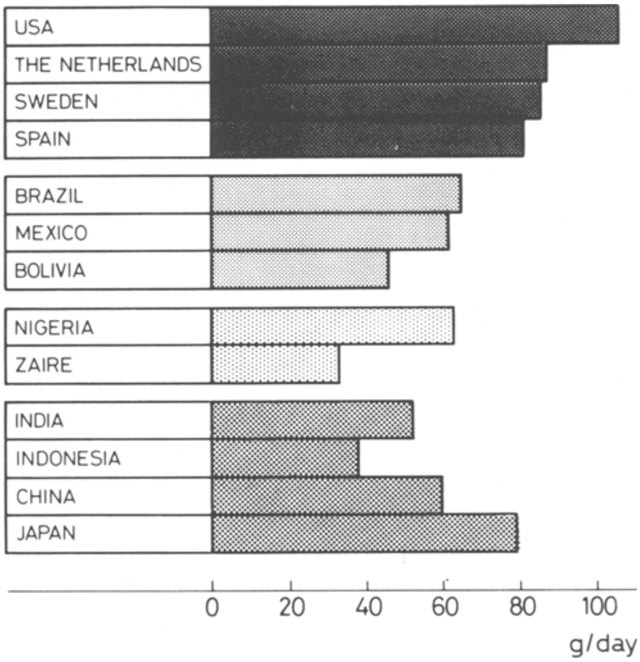


FIG. 3. Per capita consumption of protein in several countries.

PROTEIN CONTENT AND COMPOSITION

Traditionally the meals and cakes left after pressing, expelling, or extracting oil from the fruits or seeds have been used as animal feedstuffs. In fact, in some cases the animal feedstuff is the main product. The tremendous growth of the soybean crop in the U.S. was largely due to the increased demand for soybean meal as an animal feedstuff. The oil is a by-product in this case, although an important one. Oilseed meals and cakes are relatively high in protein content and as such form a vital contribution to the animal diet with one of the three main essential food components: fats, proteins, and carbohydrates (Table VI).

However, in the past decades there has been an increasing interest in developing vegetable proteins from oilseeds as an additional food source for man. One of the reasons is that an estimated 16% of the world's population suffers from insufficient protein supply. Adults need a minimum of 0.75-1 g of protein per kg body-weight per day. Children need twice as much and babies four times as much. The per capita daily protein consumption varies considerably from country to country (Fig. 3). The requirements are not always met. The Western world is fortunate in having an abundant supply of protein-rich food of animal origin: meat, fish, milk, cheese, and eggs. Other sources of proteins are cereals, legumes, and pulses, which are generally low in protein (Table VII), but they are consumed in large quantities. However, worldwide, only 30% of protein consumed comes from animal products, and 70% is derived from plants such as grains, starchy roots, pulses, oilseeds, nuts, vegetables, and fruits. World supply of proteins can be ranked according to source as given in Table VIII.

Animal protein foods enjoy great popularity. Their production is, however, rather inefficient with respect to nutrients and to the utilization of land. Plants can make all the amino acids they need from simple nitrogen compounds, e.g., nitrate, in the soil and carbon dioxide in the air. Animals cannot do so; they need a source of protein or amino acids in the diet. Therefore, they have to eat plants or other animals. The conversion of the amino acids in the diet is rather inefficient. Some 5-10 kg of vegetable protein is necessary for the production of 1 kg of animal protein. Therefore, the price of animal protein is high and it is beyond the reach of many low income populations. Because the world population is expected to increase from

TABLE VII

Protein Content of Some Cereals, Legumes, and Pulses

Source	Protein content (%)
Wheat	10-13
Maize	8-11
Rice	8-10
Peas	21-28
Beans	23-32

TABLE VIII

World Protein Supply

Source	Quantity (%)
Grains	49
Pulses, oilseeds, nuts	13
Meat and poultry	13
Dairy products	11
Roots	5
Vegetables and fruits	4
Fish	3
Eggs	2

ca. 4 billion people today to 6 billion by the year 2000, the acreage of available agricultural land per head of the population will decrease, and so the inefficiency of livestock raising will become an increasing burden. The relative efficiency of protein production in terms of utilization of land for the various protein sources is shown in Fig. 4. Good land is both valuable and scarce! So the motives behind the use of vegetable oilseed directly as food, rather than by the inefficient roundabout way of animal food, are obvious. Total world production of vegetable protein from oilseeds is almost equal in quantity to the total vegetable fat from oilseeds production, i.e., ca. 31 million tons per year.

A great deal of technological development has taken place in the past decade to convert vegetable proteins into suitable products for human consumption. The main emphasis of this work has been on soybean proteins, which is logical considering that soybean proteins constitute two-thirds of the total vegetable oilseed protein production. Besides, they have been used as human food for centuries. In Eastern Asia the soybean has served as an important part of the human diet for centuries, and in Japan it still constitutes ca. 12% of the protein diet. Unfortunately, it is not a crop indigenous to those countries in the world where the largest protein deficiencies occur. There may not be enough foreign currency available in these countries to import soy protein products, which have proved acceptable as a food in the Western world.

It is possible that varieties of soybeans can be developed for production in the semitropical and tropical climates, but this may imply considerable sacrifices in yield per acre. Cottonseed and groundnut are much more favorable from this point of view; however, so far the protein meal of cottonseed and groundnuts is used in such a way that a minimum contribution to the human diet is made. The exception is the USA, where the groundnut is mainly consumed as human food. Cottonseed poses the additional problem of removing gossypol glands from the seeds, for which only one or two installations now exist. Gossypol is a complex phenolic substance, toxic to monogastric animals and man. The breeding of glandless varieties of cottonseed has been accomplished. As a third alternative, the sunflower might also be a good crop for these countries inasmuch as sunflowerseed meal is of rather good quality and the oil has a high value.

The disadvantage, from a nutritional point of view, of vegetable proteins as compared with animal proteins is that they do not have as favorable a balance of amino acids for animal and human requirements. In the body the food proteins are digested into amino acids. These amino acids

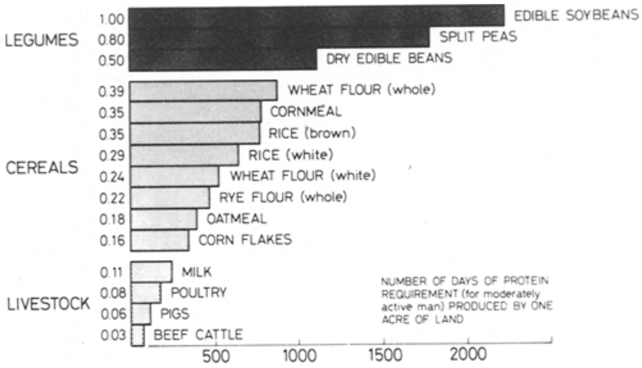


FIG. 4. Relative efficiency of protein production in terms of utilization of land for various protein sources.

TABLE IX

Limiting Amino Acids of Some Oilseed Proteins

Oilseed	Limiting amino acid
Soybean	Methionine
Sunflowerseed	Lysine
Groundnut	Methionine
Cottonseed	Isoleucine
Rapeseed	Isoleucine/methionine

are subsequently built up into body proteins. Some of the required amino acids for this synthesis can be made by the body itself, but there are a number of amino acids that must come from external sources, i.e., food. These are the so-called essential amino acids, of which there are eight, and which must be present in a certain ratio. The Food and Agriculture Organization (FAO) has set standards for the ideal amino acid composition of food proteins. Egg protein comes very close to these specifications.

Since proteins, in contrast to fats and carbohydrates, are not stored in the body and an excess is either secreted or metabolized, there is also the additional requirement that all these essential amino acids must be present in the same meal in the required concentrations. Compared to the FAO standards, each of the vegetable proteins has one or more limiting amino acids which restrict its utility in animal feed and human food if it is the sole source of protein in the diet. The limiting amino acids of some of the meals are given in Table IX. However, amino acids from different sources are complementary, and mixing of, for example, two vegetable protein sources with different limiting amino acids, may result in a more nutritious mixture than would each component by itself. For instance: soybean protein is high in lysine and low in methionine; sunflowerseed protein, on the other hand, is low in lysine and not deficient in methionine. A mixture which is not deficient in any amino acid can be made.

With respect to the position of vegetable oilseed protein today, a parallel can be drawn with the situation in the Western world 100 years ago with respect to fat. A century ago, margarine was invented, and a number of technological breakthroughs made it possible to make increasing use of vegetable oils and fats to meet the ever increasing demands of a rapidly growing urban industrial population for which traditional animal fats and butter supplies were no longer sufficient. Today, twice as much vegetable fat as animal fat is used for food. Almost a century later, we are in the same position with regard to oilseed proteins, and there can hardly be any doubt that in a few decades oilseed proteins will have become an important alternative protein source for the human diet.

THE FUTURE

It is to be expected that vegetable oil bearing materials will grow in relative importance in the next decades. Three reasons can be given: (a) the world population is increasing rapidly and the need for fats, oils, and proteins will rise accordingly; (b) the relatively inefficient production of animal protein as compared to vegetable protein will of necessity favor the latter, since the area of agricultural land cannot be expanded so quickly and the yield per acre of vegetable oil bearing crops is, on average, expected to increase substantially; and (c) with the growing recognition that linoleic acid should form a substantial part of the fat intake, the vegetable sources of linoleic acid, especially the sunflower, the safflower, and—provided the technological problems to improve the taste stability can be solved—the soybean, will be in greater demand.

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