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Expert group meeting on pre-investment considerations and technical and economic production criteria in the oilseed processing industry
Vienna, Austria 16 - 20 October 1972

CASTOR OIL PRODUCTION AND PROCESSING 1/

by

H. Janson
Managing Director
Deutsche Rizinus-Oelfabrik Boley & Co.
Krefeld-Uerdingen, Federal Republic of Germany

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The Castor plants, one to ten meter high, grow wild in most tropical and sub-tropical areas of all continents. They are cultivated in but a few countries, the most prominent being Brazil, India and China, followed by Thailand and Tanzania. In all, less than a dozen countries produce, each, more than 10.000 tons of Castor beans, per year.

Total world crops vary between 750.000 and 900.000 tons, yearly, Brazil accounting for almost 50 %. Cultivation does not require any particular soil nor growers' skill. An annual rate of rain of 500/800 mm is favourable, most of it to fall during the 4 months following planting. A yield of 1000/1500 kilos of de-hulled Castor beans per hectare is considered satisfactory. Cultivation, harvesting and de-hulling methods vary, but only for de-hulling, mechanical devices should definitely be available.

The Castor bean is poisonous by its toxic protein-ricin. The oil, of which the bean contains from 45 % to 55%, is free from toxic ingredients. The residue, Castor meal, is still slightly poisonous but much less than Castor beans are; on the other hand, the effects of an allergen which is also evident in Castor, are much stronger in Castor meal than in Castor beans.

Castor oil derives its very particular characteristics from its nearly 90 % ricinoleic acid with 18 carbon atoms, a double bond in the 9th and 10th position and one hydroxyl group adjacent to the 12th carbon atom. This non-drying oil has the highest viscosity and density of all oils; it is miscible with alcohol, remarkably cold- and heat-resistant and compatible by softening with numerous natural and synthetic resins, polymers and waxes, having also formidable wetting and dispersing properties.

Centers of Castor bean processing are, apart from Brazil and India, mainly those consumer countries with a largely developed chemical industry as major customers, such as the USA, the UK, the Common Market and Japan.

Castor meal is exclusively used as a fertilizer, mainly for horticulture and viniculture. It is more appreciated for its 85/87 % of organic matters than for its relatively insignificant nutricious substances (5 - 6% N, 2.5% P_2O_5, each 1% K_2O and CaO, plus traces of other elements).

Castor bean processing starts by cleaning and preparing the beans for subsequent crushing. The crude oil is then gained by pressing and solvent extraction. For Castor beans, being too oil-rich and soft for crush by automatic screw presses, hydraulic installations, preferably automatic operated, are recommended. The remaining cake contains 12% of oil, which is then solvent extracted. Vertically operating extractors of modern design are offered by a Belgian firm, de Smet of Antwerp, and other manufacturers. As a solvent, hexane yields the best results on account of its low content of aromatics. Refining of Castor oil includes de-acidification, bleaching and cleaning, the equipment for which is not entirely identical with that for refining other - edible - vegetable oils.

The assessment of raw material regularly available for crush is imperative for general plant economics as 25.000 to 30.000 tons of seed p.a. are required to operate even a modest plant, whilst the more efficient unit would consume, annually, 60.000 tons of Castor beans, working on a 300 tons per day lay-out. For both, technical and health reasons, Castor should not be processed together with other oil-seeds in the same plant, as the equipment required for Castor varies from that to be economically employed for other raw materials, and as Castor is not only poisonous but also problematic for its allergic effects.

Castor oil processing does not require much manpower but a relatively high capital investment.

Being mainly absorbed by chemical industries - only abt. 1% is used for medicinal, pharmaceutical and cosmetic purposes - Castor oil has its markets wherever these industries are concentrated. A home market for at least 30% of its oil production seem to be necessary to justify the erection of a Castor bean pressing plant.

The world market for Castor oil can be considered more or less saturated as supply and demand are normally balanced. Uncertainties are evident in the supply position on account of the important share born by only one country, Brazil, with 50% of the world's Castor seed production, all of which is processed indigenously, and the Brazilian oil weighing heavily on all markets, - as well as in the demand situation the future of which is rather unpredictable.

Derivates, such as dehydrated, hydrogenated, sulphorated and thermally decomposed Castor oils are in competition with synthetic products of mainly petro-chemical origins, of which a polyamide, NYLON 12, just now threatens the future of Castor oil-based NYLON 11, used mainly for the production of plastics and fibres known under the French trade name RILSAN.

Castor oil consumption has steadily increased, worldwide, until 1970. Since then, a decline is evident, mainly on account of NYLON 11 being replaced by NYLON 12 and Sebacic acid, another Castor oil derivate being successfully rivalled by other products of petro-chemical origin.

Yet, Castor oil and its derivates are still considered irreplaceable in various branches of chemical and allied industries. The outstanding characteristics of this raw material may preserve its importance for some time to come.

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Chapter 1

(1) CASTOR, as referred to in this paper, is the seed of the plant RICINUS COMMUNIS, the only species of the monotypic genus RICINUS, of the euphorbiacese family.

This plant grows wild in most tropical and subtropical areas where sometimes it is just considered a troublesome weed, sometimes a shadow-giving agent for more sensitive low-growing cash crops, such as pineapple, sisal etc., and is only in some countries planted commercially.

It is 1 to 10 meters high, perennial with, however, fatal reactions to frost, which make it behave as an annual in regions with occasional temperatures below 0^{o} C.

Whilst most wild-growing plants have a bushy appearance with an erect stem and numerous branches starting from just above the surface, some of the cultivated types branch only at the upper part of the stem, thus behaving more tree-like.

The tissue of the stem is rather wide-mashed and, at least in its first years, not very resistant. The stem becomes hollow with age.

The most characteristic signs of Castor plants are their palmately loped, large leaf-blades with different shapes and colours ranging from dark- to reddish-green, according to variety.

Inflorescence bears female flowers at the top and male flowers at the bottom, of upto 2 feet length, flowering starting from the base upwards.

Castor is regarded as a highly cross-pollinated crop, and open pollination may cause differences in size and degree of maturity of pods and seeds formed

formed on the same plant.

Therefore, different varieties should be grown isolated at a distance of at least 30 meters.

Where and how Castor started first to grow, is unknown. It is supposed to originate in Africa from where it has spread to the Middle East as a wild-growing plant. Oil lamps having been lit in pharaonic Egypt by Castor oil, are an indication that Castor was cultivated as early as 6.000 years ago.

Whilst being known in India and China in the first millennium A.C., it was supposedly introduced to the Americas by colonists in the footsteps of Columbus.

Nowadays, there is more Castor grown in South America than anywhere else, Brazil producing - with 300.000 to 400.000 tons annually - almost half of the world's Castor seed crop. Other South American Castor producing countries, though on a much smaller scale, are Ecuador, Paraguay and Argentina; whereas other Latin American countries such as the Central American Republics, seem to have not yet realized the importance of this easily grown and relatively frugal plant, with the exception of Nicaragua, where an extended feasibility study for the production and marketing of Castor beans is just now under way.

North America, with the United States still having grown some 40.000 tons in 1968, but less than 10.000 tons in 1970, and Mexico with a regular output of almost 10.000 tons per year, adds only insignificantly to the total world crop of something considerably below 1.000.000 tons, i.e. varying from 750.000 to 900.000 tons per year.

Europe has a little production of between 10.000 and 20.000 tons in the Southern Balkans (Roumania, Jugoslavia).

Much more important for the production of Castor seed is the Asian Continent with abt. 100.000 tons produced in India, 40.000 tons in Thailand, adding up, with crops of largely alternating size in other countries - mainly China - to abt. 250.000 tons, annually.

Apart from this, the USSR are supposed to produce some 75.000 tons per year, mainly in their Asian territories.

A vast source of supply is Africa, largely still untapped. The Sudan, Tansania, South Africa, Kenya, Uganda, Angola, Mozambique, Malagasi Republic - in this order - contribute to a total of around 75.000 tons.

Favourable climatic conditions for the growing of Castor plants prevail in countries with a good supply of water in their early vegetative phase, until a vigorous root-system has developed.

Experts consider the most favourable rate of annual rains amounting to 500/800 mm, most of it to fall just before and during the first 4 months after planting. Afterwards, the Castor plant is very drought resistant, actually getting along without any additional water at all. Being basically a long-day plant, Castor is adaptable to a wide range in day-length, losing some yield with diminishing day-light.

Rather high temperatures are favourable, and any altitude from sea-level to 1.500 m is suitable.

The soil can be very poor indeed, whilst a very fertile soil may even render a lower yield in seed. To avoid excessive acid and/or saline conditions, the soils should be well-drained.

According to the very many places where wild-growing Castor can be found, the plant is really modest in its choice of environment.

Wild Castor renders rather small-sized beans which can be, however, of first class commercial value, as their oil content may still be well over 45 %.

A large portion of the important Brazilian output - perhaps some 50 % - are gathered from wild growing Castor thus representing at least one quarter of the world's production, taking into account that in many other areas as well, beans are collected from wild-growing Castor plants.

It is rather difficult to make a more accurate assessment as to the percentage of wild-growing Castor, but the one given above is more likely to be on the low side.

Commercial farming of Castor knows both, Hybrid and Inbred varieties of seed, most of which have been developed in the United States. A high oil content of the beans, their yield and a low-growing type of plant - for easier harvesting - have been aimed at.

Well-known names of successful Hybrids are Baker's 22, 44, 55 and 66; McNair's 101, 202, and 303; whilst Cimarron most probably is the best-known Inbred variety. Hale, an intermediate flowering dwarf-internode variety, grows to a height of of 100-150 cm under irrigation and yields over 50% of oil.

Castor production under irrigation is not recommended in most areas, for economic reasons. This may, however, not refer to farms with established irrigation facilities, profiting from planting Castor to shadow other plants, or as an auxiliary crop on patches of soil, otherwise useless, though within the range of irrigation systems.

Cultivation of Castor doesn't require any particular skill. Castor can be sown by hand or mechanically, on land prepared as for corn. Ploughing is only necessary in cases where primary roots are unlikely to develop otherwise.

The treatment of seed with a disinfectant, before planting, is advisable to prevent the damping-off of the seedlings.

Planting rows should be a good meter apart and leave 35 to 40 cm space between plants, in a row.

It should be emphasized again that Castor growing is advisable as a supplementary crop for most types of private farms, whilst it renders satisfactory results as a main crop only after extensive studies have been made of soil and seed with regard to yield and oil content to be expected.

In general, a yield of 1.000 to 1.500 kilos per hectare is considered satisfactory; Brazil supposedly achieves an average of little less than 1.000 kilos per hectare for the totality of uncultivated crops, since 1966.

Reports of a new variety developed in Brazil, IAC Campinas, indicate the yield with 5.000 to 6.000

kilos per hectare of beans with 50/52 % analytic oil content.

Cultivation methods for Castor vary, and so does harvesting. Machines do exist for both procedures, though their economical use can still be doubted, the more as the quality of seed may suffer from mechanical harvesting.

It is also to be noted that most varieties do not mature at the same time, so that 2 - 3 pickings are necessary to obtain maximum yields. In these cases, of course, the use of mechanical harvesting is totally inopportune.

A well-known, cheap and practical harvesting method is the use of tin-cans with a V-shaped notch cut in the side, by which the dry fruit are made to fall into the cup.

In some Brazilian growing areas, such as the Mato Grosso, the stem of the Castor plant is severed about 10 cm above the ground, after harvesting, to encourage 6 - 7 new stems to sprout from the old stalk in the following year.

Most other cultivation methods involve the removal of the old plant and for new sowing every year. -

(2) THE FRUIT of the Castor plant is of globular appearance, with more or less soft spines, green or reddish-green, before maturity. The Castor fruit resembles the fruit of the Chestnut tree in all but its size, the former being much smaller than the latter.

In maturing, the outer hull of the fruit shrinks into a dry, brown capsule which may finally split and shed the seed, three of which are located in each fruit.

Each separate seed is wrapped in a rather hard shell, or hull.

Fully dried, un-dehulled seed needs treatment by which the bean located in the interior of the hull is to be separated from its wrapping. This process, very often referred to as "decortication", is more correctly called "hulling" or "dehulling", as the seed is already "decorticated" when freed from its outer hull, mostly taken care of by time and sun, only.

Efficient hulling of the beans is of utmost importance as the crushing process, later on, requires undamaged beans and as little extraneous matter, such as dirt or debriss of hull, as possible.

Hulling can be done by hand, but this certainly requires a lot of very cheap labour with more spare-time available than to be expected anywhere, nowadays.

Therefore, mechanical hullers should be available. Those are on the market with a capacity of 2 - 10 tons per hour, the costs of the machines varying from $ 1.000.-- to 4.000.--, depending on their working system and capacity. Small hullers which can easily be transported from one harvesting center to the other, have been developed in France, South Africa and elsewhere.-

(3) THE ACTUAL CASTOR BEAN, being finally freed from its outer and inner hull, represents itself as a rather beautiful looking, oval-shaped bean, from a little larger to double in size of a coffee bean, covered with a glossy, maroon-coloured coat with black spreckles, the base colour sometimes

ranging to almost white or almost red. This coat is brittle and breaks very easily thus reducing the quality of the bean and, in turn, that of its oil, the acidity of which increases, when the protective coat is damaged.

Inside, the flesh of the Castor bean consists of a white substance which can be squashed betweem two fingers.

The Castor bean is definitely poisonous, containing a toxic protein-ricin. Also, it contains an allergen, CBA, the effects of which, as a toxin, are still widely disputed. Unbroken beans are definitely harmless, as long as they are hot used for alimentation or as animal feed.

The effect of the ricin derives from the dissolution of erythrocytes, and is stronger than hydrocyanic acid (1 Kilo of ricin is likely to kill 3.6 million people, 1 Kilo of hydrocyanic acid only 1.600).

The oil, after pressing and/or extracting, is definitely free from any toxic ingredients, which remain in the residue, the Castor meal, where they are most unlikely, however, to inflict irritations to humans or to animals, unless consumed in large quantities which is unlikely to happen.

The allergen, on the other hand, may become troublesome as it can enter, with the dust of the residue, into respiratory tracts and irritate them rather severely.

Castor beans weigh between 0.1 and 1.3 grams of which 25 - 40 % fall to the skin.

The average content, including skin, is:

oil 45 - 55 %

water	4 - 8 %
soluble carbohydrate	5 - 12 %
fibre	15 - 18 %
proteins	14 - 21 %
ash	2 - 3 %

The oil is mostly found in the white substance of the bean, whilst the skin contains only 20-30 % of oil.

Practically, and economically, the Castor bean can be divided into oil, water and residue or meal, the latter representing abt. 50/55 % of the bean's weight, depending on the presence of remainders.

Castor beans are, normally, not classified by standards, these existing only in India, whilst they are marketed on a world-wide scale according to trading terms specified in the proforma contract No. 15 of the Federation of Oils, Seeds and Fats Associations (FOSFA), this contract having replaced, in 1971, the contract No. 69 of the Incorporated Oil Seed Association (IOSA), which have since been merged with other fat and oil quality control associations, all of them residing in London.

This contrat form describes in detail the methods of how Castor seed is to be traded and how impurities are to be defined and reckoned. As a quality description, reference to the origin of growth, such as "TUK" (Tanzania, Uganda, Kenya), combined with the term "fair average quality" suffices.

Indian standard specifications differentiate 6 grades, 3 "bold" and 3 "small", according to the size of the beans, counted in numbers of beans to the gram.

Supply and demand have been, in the average, somehow balanced. However, with more important crops varying subject to economic and climatic influences, a lack of supply is more likely than a production which does not meet its demand, the more as Castor seed can easily be stored, also in the open (with coverage against rain and sun), without its quality being affected, and thus its commercial value.

Of the major producing countries, which have already been listed above, Brazil and India have no bearing on the annual supply and demand position, as far as beans are concerned.

Although Brazil accounts for almost 50 % of the world's production of Castor seed, the beans are not made available to the world market, as legislation practically banned exports of Castor seed, ever since 1959. Similar legislation prevents exports of Castor seed from India.

The Soviet Union, with their 60.000 to 80.000 tons of Castor beans produced, annually, have also not been found, yet, amongst the exporting countries; the more as the USSR are known as buyers of additional quantities of oil, mainly from India.

Therefore, Castor seed exports amount to abt. 150.000 tons, annually, only, which represent some 20 % of the world's production.

The most important market for exportable Castor seed is Mainland China which sold 80.000 tons in 1967, but as little as 26.000 tons in 1968. Also in very recent years, China have put very little seed on the market which, in addition, is usually left completely in the dark as far as crop position, estimates, availabilities and trading intentions are concerned.

Therefore, countries importing and processing Castor seed and lacking a secured source of supply, tend to look appreciatively to the development of new growing areas where they are likely to offer encouragement by means of purchasing guarantees at a very early date of cultivation, at full world market values, these tending to be ever more above the level of $ 100 per ton FOB, for pure seed.

Main processing countries are certainly Brasil, India and USSR, crushing their entire respective crops.

Besides these, processing of Castor seed takes place where-ever there is a strong demand for oil and meal, i.e. the most industrialized areas of the world, except for the USA.

The USA are refraining, to a large extent, from Castor seed crushing, in favour of imports of oil from Brazil, amounting to 40.000/60.000 tons annually, against an insignificant crush of domestic production which is likely to cease entirely.

On the other hand, strong Castor seed crushing industries are situated in Western Europe and in Japan, the leading import center being the Common Market. Its Castor seed crushing mills, situated in the Federal Republic of Germany (1 mill), France (1) and Italy (2) consume around 70.000 tons of Castor seed, annually, thus producing over 30.000 tons of Castor oil, which amounts to abt. one third of the E.E.C. Castor oil consumption.

With the entrance of Great Britain into the

Common Market, the European crushing volume will be increased by some 15.000 to 25.000 tons, to a total of little less than 100.000 tons of Castor beans for the production of nearly 50.000 tons of Castor oil. With varying figures from one year to the other, this amounts to almost half of Europe's Castor oil requirements.

The requirements of Japan are approximately 50.000 tons of Castor beans, and they account for the total consumption of Castor oil in that country. Comparatively, the Castor oil production in the United States, with 12.000 tons each in 1968 and 1969 or, 20 % of the country's requirements has already been rather insignificant and may cease altogether.

150.000 tons of world Castor bean exports, annually, create some transportation problems different from those known in the trade of grain and other oilseeds. Contrary to the large bulk shipments of the latter products, Castor beans have to be packed in bags, due to the sensibility of the bean's shell, which would suffer severe damages if shipped in bulk. However, those problems are far less important than those involved in the shipment of either Castor oil or Castor meal, as shall be demonstrated below.

Upto the present, mainly jute- or sisal-bags have been utilized, containing between 50 and 100 kilos each. There is a tendency to change over to non-ventilating plastic bags, in order to help port authorities avoid allergic irritations amongst particularly sensitive stevedores, in ports of destination.

(4) CASTOR OIL, when refined, is an almost colourless, slightly yellowish oil with the following characteristics:

density (20° C.)	0.955 / 0.968 g/ml
refractive index n_D^{20}	1.476 - 1.4795
saponification index	175 / 187
iodine value	82 / 88
unsaponificable matter	0.3 - 0.7 %
hydroxyl value	minimum 160
viscosity (20° C.)	9.5 - 11.0 poise
miscibility	completely in alcohol and glacial acetic acid - with hydrocarbon at normal temperatures in limited quantities, only.

Following more recent research with gascnromatographic methods, the undermentioned composition of fatty acids in Castor oil is derived from analysis of the methyl-ester of Castor oil fatty acid:

palmitic acid	0.9 - 1.2
stearic acid	0.7 - 1.2
oleic acid	3.2 - 3.3
linoleic acid	3.4 - 3.7
linolenic acid	0.2
ricinoleic acid	89 - 89.4
dihydroxy-stearic acid	1.3 - 1.4

The structure of the glycerides of Castor oil has been ascertained with appr. 68 % triricinolein, 28 % diricinolein, 3 % monoricinolein and 1 % with ricinoleic acid.

These typical analytic values for Castor oil may vary, according to the origin of Castor beans, and they depend, of course, on the analytic methods utilized.

Castor oil is the triglyceride ester of the fatty acids. The very particular characteristics derive from the nearly 90 % ricinoleic acid available in this oil.

Ricinoleic acid is a fatty acid with 18 carbon atoms, one double bond in the 9th and 10th position and one hydroxyl group adjacent to the 12th carbon atom. It is also a 12 hydroxy oleic acid.

We do not know any other natural oil containing a similarly high content of hydroxy fatty acid. This characteristic composition of glycerides distinguishes Castor oil from all other vegetable oils and fats and is responsible for its remarkable physical and chemical properties: the non-drying Castor oil has the highest viscosity (which changes only slightly at different temperatures) of all vegetable oils.

Castor oil has the highest density of all oils; unlike all other vegetable oils, it is miscible with alcohol, in every concentration, but only miscible within limits with aliphatic petroleum solvents.

Its remarkable cold resistance (the pour point is at 16° C. below zero), the equally remarkable heat resistance, as well as the capability to burn almost without residues, give it the property of a lubricant.

Castor oil, due to its polar hydroxyl groups, is compatible with numerous natural and synthetic resins, polymers and waxes. As a plasticizer, it has formidable wetting and dispersing properties for pigments, filling agents and colouring matter.

Numerous possible reactions which can be conducted with the reactive centers of Castor oil, i.e. the hydroxyl groups, the double bonds and ester unions, will be mentioned further below.

The purging effect is well-known. There will be reference to pharmaceutical Castor oil in Chapter V.

Castor oil is marketed in 2 main qualities, technical oil and pharmaceutical oil.

Whilst the latter quality is defined in the BP and similar medical specifications, technical Castor oil can be divided into "first" and "second" or "third" (or "commercial") qualities. Only the "first" quality refers to Castor oil obtained by pressing of the seed, containing no extraction oil, and normally defined by the British Standard Specifications (BSS), reading as follows:

quote -

> This British Standard applies to Castor oil "first" quality. The oil shall be the product obtained by expression from Castor seeds, and shall be free from admixture with other oils or fats.

Colour (when measured through a one-inch cell of Lovibond Colour Scale)	- max.	2,2 yellow
	max.	0,3 red
Relative Density	- not lower than	0.958
	not higher than	0.969
Refractive Index at 20° C.	- not less than	1,477
	not great.than	1.481
Iodine value	- not less than	82
	not great.than	90

Saponification value - not less than 177
not great. than 187

Critical solution temperature of oil in ethanol shall be below 0° C.

Unsaponification matter max. one percent

Acetyl value not less than 140

Acidity: "The oil shall be free from mineral and added extraneous organic acids. Unless otherwise agreed between the purchaser and the vendor, the acid values shall not be greater than 4.o; this is equivalent to 2.o per cent by mass of free fatty acids, calculated as oleic acid."

Note: "In certain seasons, compliance with the above limits of acidity may not be generally possible and in such instance the limits should be subject to agreement between the purchaser and the vendor." unquote -

Brazilian Castor oil is mostly sold according to specification "No. I" which is less rigid and may contain extracted oil.

First pressing oils of German, French and Italian and, of course, also British production distinguish themselves by outstandingly high quality standards, being almost colourless and of particularly low acidity.

Commercial grades, as offered under this denomination from Brazilian, Chinese and other origins, are in much less demand and can be used for only a limited variety of processing activities.

Castor oil derivates such as dehydrated Castor oil, hydrogenated Castor oil and Castor Oil fatty acids, will be referred to in Chapter V.

(5) CASTOR MEAL, representing the residue of Castor seed with 50/55 % of its weight, after the extraction of the oil (as for the production process see Chapter II), is mostly traded as either a coarsely ground substance or granulated into pellets.

The former appearance is arrived at, after desolventising, without further treatment, whilst the pellets are produced by pressure pressing of the "coarse grinding".

There is also meal of "fine grinding", achieved by the additional grinding of the coarse material, sometimes required for industrial utilization, such as the production of mixed fertilizers.

However, the "fine grinding" develops the largest degree of dust and is thus rather dangerous in production, transportation and processing.

Castor meal, in its dry substance, consists of:

Nitrogen	appr.	5.5 - 6.0 %
P_2O_5		2.5 %
K_2O		1.0 - 1.5 %
CaO		1.0 %
MgO		0.5 - 0.7 %
Cu		27 ppm
Mn		55 ppm
B		23 ppm
Organic matter	appr.	85 - 87 %

In its original consistence, Castor meal analysis usually records appr. 10% of H_2O and a maximum of 1% of oil, the percentage of the above listed ingredients thus reducing accordingly.

Castor meal is poisonous, having both toxic and allergic properties.

The International BIO-Research Inc. of St. Louis

(USA) have conducted, in their branch laboratory of Hannover (Germany), respective tests in 1966 with rats and guinea pigs, resulting in two perceptions: firstly, that Castor meal takes affect, in toxic doses, acutely or sub-acutely, though less fatal than Castor beans. Secondly, that none of the animals, after having been kept under the influence of Castor meal dust for over three weeks in an inhalation chamber, showed any allergic affects but behaved completely normal.

These results confirm the experience gained by experts according to which Castor meal is less poisonous than Castor seed, although none of the poisonous properties remain in the oil. Actually, Castor meal can hardly cause accidents, by its toxic properties, in small doses. On the other hand, the allergen, though apparently ineffective to animals, causes irritations of different degrees and in a variety of symptoms to human beings. This phenomenon still remains rather unexplored though, contrary to wide-spread opinion amongst laymen, it seems to be the result of fear and human imagination that causes most of the troubles encountered. More recent research, conducted by medical circles arrives, however, at different results; according to it, the influence of the allergen carried by Castor dust from both beans and meal, is most alarming and calls for preventive actions, where-ever these materials are being handled.

The economic consequences of these particularities in Castor meal will be dealt with later (see specially Chapter IV).

Chapter II

(1) NTRODUCTION: Oil seed processing has been the business, ever since industrialization in its earliest stages, of crushing mills, the name already indicating the procedure and the kind of machinery in use: the seed is pressed to yield its oil.

In order to serve its purposes, the modern crushing industry, however, distinguishes various pressing methods which depend only partially on pressing installations, as the inability to obtain, from the seed, its entire oil content by crushing, would render this industry uneconomical unless alternative or additional devices are utilized.

Therefore, efficiency depends largely on the knowledge of which crushing process - "cold"-pressing, hydraulic pressing, screw-pressing - and which solvent extraction - extracting directly from the oil seed or from a pre-pressed "cake" - is best to be employed in order to achieve the individual oil mill's ultimate economical goal to either process many different oil seeds in the same installation, or restrict its activities to those oil seeds which fit a certain technical conception for the purpose of the largest crushing volume, or suit the processing of a certain, particular oil fruit.

Quite certainly, the characteristics of Castor beans require special consideration and hardly tend themselves to any combination of the above economical conceptions without endangering the efficiency of the operation.

First of all, it is to be taken into account that Castor beans have a higher oil content and are softer than most other oil seeds.

They present themselves, furthermore, with a very brittle shell which breaks easily when mechanically strained. The shell, in itself, is hard and sharp-edged, thus causing considerable wear and tear of the conveying equipment, particularly when pneumatically handled. De-shelled, skinned beans are already smeary and particularly soft, without being heated. Only the moisture with 5 - 7 % hardly deviates from other comparable oil seeds.

As far as storage is concerned, the most protective for Castor seed is the storage of bagged beans in dry warehouses. Also, bulk keeping in silos is possible, though with some complications. Already the transport via normal conveying equipment, such as conveying belts and elevators, and the pourring of the beans into the silos cause breakage of appr. 7 % of the seed. Tests with pneumatic equipment have resulted in a breakage of upto 30 %. Beans with such a high breakage would, however, acidify and rot, during extended storage. Covering the silos with Nitrogen gas would be both problematic and expensive.

(2) THE CLEANING AND PREPARATION PROCESS requires a vibrating sieve with different perforated steel plates through which the beans are led in order to separate larger foreign matters such as stones, wood, other fruit like harder nuts as well as metallic particles. Both seed as well as foreign matters smaller than Castor beans, also small stones and sand, remain with the seed. (if an expeller type of machinery would be used, however, the smallest particles would also have to be eliminated, as this kind of device is operated mechanically more sophisticated, to avoid failure of the more intricate

parts of the machinery).

Afterwards, the seed runs through a sifter with cyclone, in which all matters specifically lighter than Castor beans are eliminated, particularly broken shells, deaf beans and jute or sisal tissue from the bags.

Quite a problem is constituted by metallic particles not larger than Castor beans. These cannot even be eliminated by the most efficient magnets over which the seed is ordinarily run, and they cause big complications during the cake preparation as sparks are emitted in the roller mills and this again may cause dust explosions.

(3) THE PRESSING PROCESS is equally intricate, as neither the "cold" process nor the utilization of automatic screw-presses offer alternatives to the use of hydraulic presses. The first, because the viscosity of Castor Oil with 1.000 c.p. at 20^{0} C. does not permit "cold" pressing to work efficiently, even if energy is wasted.

The second, automatic screw-presses, though applicable for the pressing of Castor seed, require an expensive conditioning of the seed, such as reducing it to smaller pieces, steam-treating and drying.

Furthremore, seed temperatures during the process of upto 120^{0} C., which cause a considerable deterioration of the oil quality, have to be tolerated.

The screw-presses working, with Castor seed, only in a pre-press operation, leave the cake with a residual oil content of 12 % which would have to be solvent extracted.

Compared to hydraulic presses, screw-presses re-

require double the amount of energy and are worn-out very quickly when operated for Castor seed.

The crude oil flowing from screw-presses contains so much sediment that it requires pre-filtration before entering into the refinery. Against screw-presses, for crushing Castor beans, stands also the requirement of a larger workshop and store of spare-parts for impending repairs, the frequency of which is rather intolerable.

The seed is to be warmed-up to appr. 60° C., this temperature to be apparent at the outside of the beans. The center of the beans should be relatively cooler on account of the poor heat conductivity of oil seeds, in general.

The warming/drying process of the seed is effected in a multi-floor dryer. The seed runs, by means of a metal sieve-belt, through the different floors of the drying machine which is heated with hot air at 120° C. The air serving rather for heating than for drying, is to be led, by means of ventilators, under pressure of 50 lbs/in^2 via 154 ° C. heaters through the seed until the surrounding air is almost saturated with moisture. Only then, it is to be removed from the warming case.

The drying effect achieved with this kind of warming-system does not exceed 1 - 2 %. Besides the aforementioned, there is another one worthwhile considering: the dielectric capacity process, where high frequency is produced in a tube-generator upon the steel-plates of a condensor between which the seed is led for heating. It is operated at voltages of upto 15.000 V.

With such an installation, the efficiency reach-

reaches 30/50 %. The appreciable advantage of such an inst llation depends upc . a more regula penetration of the entire bean, with warmth, thus improving enormously the crushing-suitability. However, this process, in most cases, must be discarded as being far too expensive.

From the warmin device, the seed is delivered into a smaller silo, where it is kept under heated air, and from where it can be withdrawn to the crushing presses, according to requirements. The higher the temperature, the better is the performance of the crushing press, the capacity of which, however, is limited by the importance given to the quality of the oil.

An additional pre-conditioning of the seed, as it is usually required for other oilseeds, is not necessary, as far as Castor is concerned.

For the following crushing process, hydraulic presses are employed. They mainly consist of 480 mm diameter "strainers", operating in three pressure stages of 50, 120 and 320 atmospheres.

The crude oil leaving these presses, contains very little sediment, so that it may be led directly into the refinery, without previous filtration; the cake contains appr. 12 % fat.

As an alternative to the above mentioned process, automatic screw presses have already been mentioned, as well as their disadvantages. However, they can definitely be employed for the crushing of Castor, but it must be remembered that they require a rather extensive system of pre-conditioning of the seed.

As these presses, for Castor, can only be operated at their input stage, they achieve also not less than 12 % oil content in the cake, this having to be extracted, as well.

Consequently, it is the hydraulic press which - at least for Castor - can still be considered the more economical crushing device, being particularly protective for the installation as well as for the oil.

The seed temperature must be kept at a steady 60° C., during the crushing, as already an increase of a few degrees could cause, under unfavourable conditions, a deterioration of the oil-quality, as far as its colour is concerned.

Also, the crude oil must be refined, instantly, after leaving the press or, at least, its humidity must be reduced. Even 24 hours of keeping crude oil in its humid state, are likely to double the acid value and deteriorate the colour value. It has already been demonstrated with the example of automatic screw presses, as to how the temperature may influence the colour of the oil.

For further comparison, the Lovibond Colour Scale indicates 1.5 red, 5 yellow, for crude oil from hydraulic presses; and 2.8 red, 50 yellow, for the same, when automatic screw presses are employed.

(4) A REFINERY for Castor oil requires equipment for de-acidifying, bleaching and cleaning.

On account of its high specific gravity of 0.96 (at 20° C.), its high viscosity of 1.000 c.p. (20° C) and its extreme tendency to emulsify in contact with bases, Castor oil requires considerably different provisions for refining than is the case with all other oils.

The kettle system has proved reliable. The press-oil is directly pumped from the press into the refinery (boiler) which should have abt. 10-50 cm^3 content, and be equipped with a stirring device and heating pipes.

The kettle should further be equipped with nozzles for bases, salt water and hot water, and with light- and control-windows, as well as with a thermostat for the regulation of the oil temperature.

The oil is heated under constant stirring. In the meantime, the kettle is kept under vacuum to remove the humidity from the oil.

During this phase, Fuller's earth is sucked into the oil, via the vacuum, before the latter is released and the oil passed through the filters.

Oil cannot be treated a second time with Fuller's earth, without risking a deterioration of the colour beyond the attempted result.

For bleaching and drying of Castor oil, a continuous process can be als employed, for which a vacuum dryer and a mixer with dosage device for Fuller's earth are required.

Normal press-oil is de-acidified by means of bases. The oil is to be heated under stirring, then the base sprayed slowly through nozzles on the oil.

After some time, and when the stirring is then stopped, the mixture has reacted into separating the heavier soapstock from the clean oil. The soapstock settles at the bottom of the boiler and can be withdrawn.

Soap residues in the neutralized oil are washed-out under constant stirring and adding of hot water. Stirring too fast, or operating under too low temperatures of water and oil, lead to partial or complete emulsification of the oil. This emulsion can only be separated in a drying process requiring much time and energy, and deteriorating the quality of the oil.

The oil is washed until the water leaving the kettle, appears to be as clear as when added to the oil.

Further de-acidification is necessary for the production of pharmaceutical Castor oil as well as for the improvement of colour- and acid-values of extraction oil.

During the miscella phase (see below: extraction) it has not produced favourable results. The aforementioned refining kettles are used for de-acidification of these two oil qualities, as well.

The soapstock, to which is added highly acid pit-oil, is collected in a pointed, acid-resistant and isolated container. Sulfuric acid (78%) is added for neutralization. The container is equipped at the cone with a direct steam intake through which steam is blown with 50 lbs/in^2 and 154° C. into the soapstock.

In order to avoid foaming before boiling, the steamflow is automatically reduced whenever the content rises.

Once the boiling point is reached, the material doesn't rise any more.

Boiling takes 4 - 5 hours and results in splitting the soapstock into refining fatty acid + neutral oil and acid waste-water. The waste-water is drawn-off, neutralized and abandoned whilst the acid oil is dried, bleached and filtered like the other oils.

All qualities of oil are to be filtered with the same pressure and the same temperature. The filter is inter-woven metal-structure with refined steel sieves and filter frame. The capacity of the filters should be 300 - 350 litres of refined oil per m^2 p.h, according to the degree of dirt in the sieves.

The above mentioned capacity can only be maintained as long as the filters don't cool-off but remain continuously under operation.

As soon as the filter is left cold for half or even full days, the surface of the filter tends to resinification and the capacity is thus reduced considerably.

Therefore, it is imperative to employ a refinery perpetually.

The filter is to be cleaned every 45 minutes, in order to secure economical filtration. For this purpose, the pumps are stopped. These are mono- or eccentric screw pumps which secure a steady admission of the oil. The filter is blown dry with air or steam. After abt. 5-7 minutes blowing time, the filter cake or Fuller's earth residue is dry enough - though still containing 25 % fa - to fall from the filter frame by vibration.

Since the pumps are exposed, by the dirt contained in the oil, to a high degree of wear, and since the oil steam-exhausted from the filter vessel has to be once more dried, it is recommended to instal pressure vessels, in relation to the filter capacity, between kettle and filter, and to blow the oil with compressed air through the filter.

After filtration, the oils are ready for sale, except for pharmaceutical oil which, after cooling, has to be filter-polished by means of a multi-ply paper filter.

(5) SOLVENT EXTRACTION, as hereunder mentioned, concerns the extraction of oil from Castor cake and not from Castor seed, directly.

100% solvent extraction of the latter has been tried again and again, but so far not yielded satisfactory results; in as far as the necessary shelling of beans create numerous hitherto unsolved problems, experts are convinced that the solvent extraction of Castor beans could - even if ever possible - not yield oil of similar good quality as hydraulic pressed can.

The remainder of oil in the cake, at abt. 6 - 7 % humidity, is abt. 12 % and can be reduced, by solvent extraction, to 0.7 - 0.9 % oil content in the remaining Castor meal.

In this connection, the humidity of the cake - depending on the origin of the respective seed - is of great importance. The lower the humidity in the cake, the better the extraction. However, the humidity should not go below 5 %.

The warm press-cake reaches, after running through some cracking rolls and flakers, the extraction without further heating and drying.

It is to be supposed that the general system of solvent extraction is well-known. There are various types of vertically operating extractors of which the method "de Smet" can be considered most up to date (for further reference see: de Smet Extraction Engineerings, Antwerp, Belgium).

As for the solvent, ultimate results can be achieved with hexane (0.01 % aromatics) dissolving less non-fatty components which render, in their dissolved state, the crude oils darker and make refining more difficult.

Due to the presence of 1.5 % aromatics, ESSO-solvent dissolves more non-fatty components than hexane.

Ethyl-alcohol, though also dissolving non-fatty components such as phosphatides, saponines and pigments from the cake, has the agreeable property to settle, under room temperature, in two different layers: one containing oil with only traces of alcohol, the other alcohol with the above mentioned impurities which are thus withdrawn from the oil. Like this, a relatively light and clean oil reaches the refinery.

The solvent extraction plant is the most dangerous part of the oil mill. Its installation has to be absolutely explosion-proof, i.e. all switches, motors etc. have to be mounted and equipped under safeguard of the respective security measures decreed by the local authorities.

It is the mixture of volatile solvent with air which causes the danger of explosions, the concentration of the gas-air-mixture being highly sensitive to sparks and other abruptly appearing contacts with extreme temperatures.

Security measures, in most plants, include strict instructions not to admit into the extraction plant persons carrying metal implements likely to strike sparks when falling to the floor or hitting other hard materials.

Chapter III

(1) GENERAL PLANT ECONOMICS require - as far as Ca-
stor seed processing is concerned - an assessment
of raw materials available for crush as the deci-
sive factor technically and economically not only
to determine the capacity of the plant but, more-
over, of the entire scheme.

Regarding, at this stage, solely the technical
aspects, it is generally assumed that 25.000 to
30.000 tons of Castor seed must be available, annu-
ally, to operate a Castor plant.

This refers to smaller plants, as they are still
operated, today, without automation of the hydrau-
lic crushing installations.

For a modern conception, the former type of
crushing plant must already be considered outdated.

Therefore, for a plant really to meet tomor-
row's competition by exploiting all achievements
of modern technology, the outlay of the crushing
installation should be based on a requirement of
abt. 60.000 tons annually, of beans or, 300 tons
per day.

It is this quantity which corresponds ideally
with the number of attendants required for the pro-
cess of hydraulic crushing directly followed by
solvent extraction.

The acquisition of smaller units for a lower
daily crushing volume would also be disadvanta-
geous if provisions were made for additional units
to increase, in stages, the capacity later on.

Each unit would then require individual su-
pervision and thus cause a disproportionate in-
crease of manpower to be employed.

If a regular supply of seed is secured but the quantities do not suffice to operate the plant continuously, production would have to be stopped during one or even two thirds of the day, thus working on one or two shifts of 8 hours each, only.

This would create complications with the proper timing of the various phases of the working cycle which requires the simultaneous operation of the pressing, refining and solvent extraction plants.

Otherwise, power and steam would have to be supplied all the same for continuous 24 hours per day, notwithstanding the actual time the plant is operated, as an interruption of the power and steam supply would have most unfavourable effects on the filtration and de-acidification process and ultimately, on the quality of the oil.

Whilst the ideal outlay of the plant thus depends on the initiators' skill to match the supposed capacity of the plant with the expected supply of raw material - not speaking of other criteria, such as the marketing of oil and meal - it must always be remembered that only fully automatic hydraulic crushing installations satisfy the requirements of modern technology.

Such a Castor plant to be operated in a continuous and well-tuned flow of production in its various stages - the requirement of absolute continuity in filtration calls again for attention - with complete co-ordination of machinery and manpower, could be imagined to have the following layout: The seed which has to be di-electrically pre-heated - with penetration of moderate heat deep into the inner bean - is fed into fully auto-

automatic hydraulic presses of 300 tons daily capacity to be accomplished in three shifts of 8 hours each.

The cake is to be run over grooved and roller mills into the extractor which is to be operated with hexane or ethyl-alcohol as a solvent, the extraction plant including vacuum distillation and de-solventiser toaster to dry the meal.

The oil then enters the refinery where it is to be operated in a kettle process, as previously demonstrated.

The importance of a well-designed power and water supply system must not be under-estimated.

A crush of 300 tons of beans per day requires abt. 9 tons of steam per hour at approx. 150° C. Refinery and extraction plant consume most of this steam.

At the same time, 600/700 kw^h of power are needed. Since a turbine power plant with a 9 ton boiler may easily generate 700 kw^h, such an acquisition is advisable.

Finally, appr. 100 cbm of fresh, clean and rather cold water, possible to be drawn from a well, must be available.

This water serves mainly for cooling purposes in the solvent extraction plant.

(2) THE INDEPENDENT CASTOR PLANT should certainly be favoured against an oilmill crushing all kinds of vegetable oilseeds, as a unit processing Castor beans requires installations and accessories which are not suitable - or at least absolutely uneconomic - for other oilseeds.

Also, there is, for Castor, no need for pre-conditioning or deodorising, as required for the production of other oils.

Quite certainly, most other seeds cannot be economically crushed in hydraulic presses; the advantage of fully automatic screw presses being obvious and undisputed.

Furthermore, the use of hydraulic presses for other oilseeds mostly rendering edible oils would require additional equipment such as a pre-filtration unit and a pre-demucilage installation for the crude oil, whilst de-acidification of such edible oils calls for centrifugal installations, which do not suit Castor oil.

Generally speaking, it could be emphasized that the choice should be for screw presses if oilseeds with a lower oil content - soya, linseed - are processed; for hydraulic presses when the crush of oilseeds with high oil content - Castor - is intended.

Furthermore, there are two more reasons for keeping a Castor seed crushing mill apart from similar installations which process oilseeds yielding edible oils: security and health.

It cannot be imagined that the authorities anywhere in the world are likely to close their eyes to the danger involved wherever Castor seed is stored together with other oilseeds destined for alimentary purposes or, if the same conveying equipment is used for their transport.

A Castor plant as described above requires the number and qualitfication of workers as listed below:

<u>per shift</u> - generating plant: 1 superintendant
pre-conditioning: 1 labourer

automatic presses:	1 labourer (trainee)
refinery:	1 labourer (trainee)
extraction plant:	1 labourer (trainee)
	1 superintendant (who should be qualified as a mechanic)
	1 additional hand to assist the superintendant.

Furthermore, the day-shift requires

a team of 4 mechanics under 1 foreman,
another of 2 electricians under 1 foreman,
a team of 15/20 hands under 1 superintendant for transport and storage,
1 bricklayer, 1 painter, 1 hand for cleaning jobs, 1 technician.

This list does not account for managerial staff and clerks to be employed in the commercial departments of the company.

Sufficient importance has to be given to the allergic properties of Castor seed and Castor meal - these being much more dangerous than the toxic factor - and their influence on plant attendants.

First of all, the individual human physique reacting differently to allergic influences, persons should be selected as plant attendants who prove less sensitive than average.

Secondly, an exhaust system for dust absorption should be installed in those parts of the plant where seed and meal are stored, moved or treated.

Also the location of the plant is to be taken into account, as far as third persons can be aller-

allergically contaminated by fumes discharged from the plant.

Caution, in this respect, certainly rules the choice of seed- and meal-storage and -transport, as described in Chapter II.

No such caution is necessary for the storage of oil, this having neither allergic nor toxic properties and requiring only heatable steel tanks to maintain the fluidity of the oil when it has to be discharged and filled into tankcars and drums.

The plant should possibly be located near a waterway with approach to the open sea, for either raw material supply or export of oil and meal. Residential areas must be avoided for danger of explosion always existing in solvent extraction plants and on account of allergic contamination.

Apart from these rather general remarks, an individual feasibility study must, under all circumstances, be available by expert marketing and agricultural consultants before serious industrial planning can take place, and the most suitable processing technology be selected.

(3) THE INFLUENCE OF CASTOR OIL MARKETING ON INDUSTRIAL PLANNING is certainly not to be underestimated. International Castor oil trading, with the peculiarity of Brazil's outstanding position, is important enough a factor to be thoroughly taken into account before launching the venture of a Castor seed crushing mill.

Before evaluating, however, all those considerations, hopes, guesses and facts which accumulate in result of any thoroughly conducted examination of the market chances for the merchandise intended to be produced, it is inevitable to give some very serious thoughts, once more, to the question whether, in every individual case concerned, the regular supply of sufficient seed is secured and what could, for instance, be done in case of a failure of the very crop on which the mill totally depends for its annual crush.

It has been demonstrated earlier in this Chapter (see above) that the plant can be considered sufficiently supplied if there are some 25.000/30.000 tons annually available for crushing, provided the initiators have decided for the more orthodox than the technically advanced version.

The management of the plant has to make sure, moreover, that this quantity, which in most instances will be derived from one single crop and be thus available in the course of 2 months at most, can be financed and stored for crush in later months - unless their agricultural counterparts are satisfied that they cannot dispose of their crop immediately upon being harvested but only by instalments, thus involving the necessity of storage at their end.

There remains a third possibility: that of letting the plant operate for only a few months a year - at least on Castor. The hazards involved have been equally demonstrated in this Chapter.

(4) THE WORLD MARKET SITUATION for a commodity is generally governed by demand and supply. Whoever wants to promote supply should, therefore, gain the necessary knowledge of the demand-structure for this commodity. For Castor oil, the pattern of consumption in different industrial countries differs so widely, that generalization is as difficult as

it is dangerous.

Whilst it appears that in the USA and in certain European markets, paints and varnishes, plastics and resins account for more than 50 % of Castor oil consumption, the UK seems to consume only 20 % of its requirements as unmodified Castor oil, the rest appearing in the form of sebacic acid, hydrogenated Castor oil or -fatty acid, dehydrated Castor oil or -fatty acids, blown Castor oil, sulphonated Castor oil etc., before entering the various stages of further processing.

Of the above mentioned 20 % of Castor oil unmodified for marketing, less than 10 % account for cosmetics, pharmaceutical and medicinal use, this fact definitely discarding the - false - common opinion that Castor oil is mainly destined to be swallowed.

As a matter of fact, the quantities needed to meet the demand for medicinal, pharmaceutical and cosmetic purposes are far too negligible to justify the erection of a Castor oil plant.

It is generally assumed that a plant producing raw materials mainly destined for serving chemical industries - and Castor oil can be so classified - should be able to base on a home market for at least 30 % of its production. This would provide, of course, for a sophisticated structure of domestic industries generally not available in countries interested in Castor oil production, on account of their climatic and other conditions, rendering them well disposed for, at least, Castor seed production.

Unfortunately, the major reason for failure of Castor seed processing plants in other than highly industrialized countries has always been the lack of sufficient knowledge of consumer habits which are difficult to be analysed and followed, unlees they can be studied in the actual neighbourhood and thus lead to an easy adjustment of the Castor oil producer's marketing strategies.

It doesn't seem to suffice replacing a home market with all its merits by governmental support programs destined to foster the export of the oil, since this does not help to keep the producer of the oil sufficiently in touch with his consumer.

On the other hand, support programs have to be paid for by someone who is certainly not identical with the importer in other consumer markets. More likely, it is the local agriculture which has to foot the bill when, for instance, the oilseed crushing industry of a country is to be protected by a ban, or a levy, on the exports of seed.

Lacking competition on the raw material acquisition front, the crushers who have enough trouble to place their oil on saturated and anonymous world markets, tend to obtain relief by simply underpaying their suppliers, the seed growers.

If a certain home market capacity is necessary for Castor oil, it is not less desirable for Castor meal, this being used as fertilizer, only.

Most agricultures, however, suffer - above all - from insufficient N.P.K. for field manuring, and will certainly prefer a synthetic fertilizer, such as sulphate of ammonia, to Castor meal, with its 5 - 6 % of Nitrogen being worth abt. $ 1.-- per unit, compared to $ 0.20 per unit in sulphate of ammonia.

The high market value of Castor meal originates from its appreciation as an organic fertilizer for sophisticated agricultural ventures, such as lawns, flowers, prime vegetables, fruits and vineyards.

Its disposal on a market with a restricted number of consumers who are likely to pay more for Castor meal than the value of Nitrogen therein contained is certainly a factor not to be under-estimated, the more as overseas transportation, transshipment and discharging of Castor meal create a number of problems originating from the allergic affects, particularly of Castor meal dust which - as most port authorities claim already - is insufferable for stevedores and other humans likely to be contaminated.

In a rather saturated world market, profitability of Castor oil exports also depends on the producer's technical ability and economic readiness to offer such high qualities of Castor oil as permit an effective competition by fetching those prices which are normally quoted for oil which has not suffered in colour and acidity by overseas transport and transshipment.

If it can be assumed, after studying reliable international statistics such as the Foreign Agriculture Circular regularly published by The Foreign Agricultural Service of the US Department of Agriculture on World Exports of Oilseeds, Fats and Oils, that the supply and demand position in existing markets for Castor oil can at least be called balanced by presently available Castor seed crush-

crushing capacities, the assessment of future Castor oil consumption definitely merits consideration, as all industrial planning should be guided, after all, by sound economic aspects, only.

In this respect, experts' opinions do differ much more than is desirable.

It is known, for instance, that France has been producing a synthetic fibre, RILSAN, from Castor oil, accounting for 75 % of the oil consumed in that country, in 1969.

In 1970, the requirements for Castor oil of this one industry once more rose by 9.000 tons to 45.000 tons (out of 75.000 tons total imported by the Common Market countries besides their own production in that year of some 30.000 tons), and as late as in the fall of this year, RILSAN production, for 1971, was estimated to push raw material requirements upto 60.000 tons of Castor oil. However, it became evident in spring, 1971, that the depression from which the synthetic fibre industries had started to suffer, world-wide, made it necessary to reduce the RILSAN production sharply. From January to September, 1971, not even 20.000 tons of Castor oil were actually absorbed by this consumer.

The very large proportion of Castor oil used as a drying oil for making paints and plastics, also calls for attention.

Certain characteristics of Castor oil which have been mentioned in Chapter I have not yet been matched by synthetic products. Future development of Castor oil consumption will depend, however, to a very large extent on the chemical industries' research and its results in this respect.

It is, therefore, much easier to assess the chances of Castor <u>seed</u> production with its investments likely to be depreciated within a few years, than to ascertain reliable planning for the full exploitation of plant equipment which, by their very nature of being most sophisticated investment goods claiming long-term depreciation, should be secured by more reliable prospects than those that the future consumption of Castor oil can presently offer.

<u>Chapter IV</u>

(1) COMMON USE OF <u>CASTOR MEAL</u> has always been in the past, and still is, that of manuring, particularly in demand for gardening, and wherever people ask for an organic fertilizer.

As shown in Chapter I, Castor meal is not particularly rich in nutrious substances, containing relatively little N.P.K.

Being very effective, however, for certain cultivations such as lawns, flowers, prime vegetables and grapes, Castor meal has its regular consumers who absorb the annual production.

This refers to Europe and Japan. No accurate details are available from Brazil and India, where Castor meal seems to serve also for field manuring, possibly mixed with synthetic fertilizers.

There is some negligible export of Castor meal, from Brazil to Europe, which has hardly any chances to expand although import duty on Castor meal is neither charged by the Common Market nor in UK.

As shipment is difficult on account of the notorious allergic hazards, and as the bulkiness of the merchandise makes it rather expensive, an impetus for export is lacking on he shippers' side. As the European market is more or less staggering on account of competition arising from chicken refuse and other organic residues of newly created industries, the import into consumer countries is not very much attractive.

The advantages of Castor meal on the fertiliser market are still prevailing over the one alternative, detoxification, because the fertilizer prices are, though low, relatively stable.

Castor meal is not a money-maker but a constant calculation factor which permits the manufacturer to escape the two-front combat, the dread of the average oil seed crushers who normally have two seperate hazards to cope with, ups and downs of oil-prices and of cake- and meal-prices.

(2) ALTERNATIVE USES OF CASTOR MEAL can be seen, generally, in the extraction of its pure protein, Castor meal containing 30/36 % of protein, - or in its use as a feeding stuff after detoxification.

This second alternative has attracted some attention, now and then, in recent decades; less because of an imminent shortage of protein-containing feed stuff - the production of soyabean meal rising continuously - but for various detoxification methods which have been developed and published, in due course.

As a matter of fact, some of these methods are neither complicated nor uncertain, as far as their positive results are concerned. However, even if detoxification were imperative, for reason of a necessary disposal of the meal rather than for commercial considerations - there would have been created some serious problems if Castor meal had not found its merits as a fertilizer - the availability of a non-toxic, non-allergic Castor meal on the fodder market would be far from making it a paying proposition.

Recent studies have been extensively made and completed by Prof. Ferrando of the Ecole Vétérinaire d'Alfort of Paris/FRANCE.

Their results have confirmed the sceptic views always kept by Castor crushers: though the elimination of the ricin would be relatively simple, the meal would not only be refused by farmers instinctively but would actually remain dangerous as an animal feed because of its containing debris of the bean shell which is extremely abrasive and provokes cuts and bruises in the tissue of the animals' digestive apparatus.

Consequently, it would be necessary to peel the beans before crushing.

The impracticability of this process - which is technically possible - has been demonstrated in respect to the question of a 100 % solvent extraction of Castor beans (see above Chapter II/5). For the sake of rendering Castor meal harmless, after detoxification, it would involve an inadequately high expenditure.

Equally exorbitant have proved to be the costs of processing Castor meal with the aim of obtaining Furfural, an aldehyde usually derived from the furfure of oats. The alcohol of Furfural is in good demand by manufacturers of Furan-resins which are used in the iron- and metal-foundry business, to prepare casting moulds.

Unfortunately, the yield of Furfural is far too low compared to that from furfure of oats, in order to justify this process which had attracted Castor seed crushers some years ago.

There remains the extraction of pure protein. It is achieved by treatment of the meal with a solution of Sodium-Chloride and its precipitation with hydrochloric acid.

However, proteins of other origins are not only cheaper but also of better quality, as regularly made efforts have revealed, both, in feeding tests as well as in industrial exploitation.

Chapter V

(1) PHARMACEUTICAL CASTOR OIL has been already referred to in other connections.

For every layman Castor oil is, first of all, a laxative, its taste and its purging effects having marked moments of anxiety for generations of constipated human beings.

Today, Castor oil has been more or less replaced by more elaborate products, listed as specialities by the pharmaceutical industry for the intestinal relief of mankind.

This may also refer to another application of Castor oil in the medical field, i.e. in dermatology, where it was used to eliminate warts and to soothe the skin against itch.

More important, nowadays, is the use of Castor oil in the cosmetic industry, serving as softener for nail polishes, lipsticks, in creams and lotions.

Both, medicinal use and cosmetic industries accounted (in U.K., 1969) for 7 % of the consumption of unmodified Castor oil which, in turn, made only 18 % of the total consumption, the rest being modified Castor oils.

This means, that little more than 1 % of the Castor oil (in U.K., 1969) actually served for medicinal, pharmaceutical or cosmetical purposes.

(2) UNMODIFIED CASTOR OIL, or its chemical characteristics, after refining, as well as its analytic value and its trade descriptions, have been acknowledged in Chapter I above.

First pressing Castor oil is mainly used for

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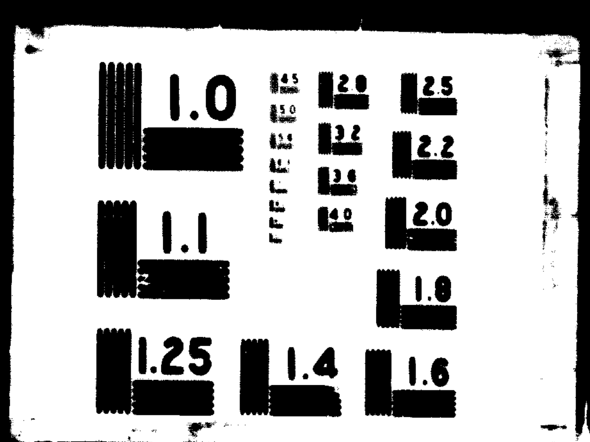

surface coating, i.e. in the manufacture of alkyd resins which represent vehicles for highly efficient oven-baked varnishes and enamel finishes, as they are used, for instance, in the automobile industry, for the coating of household utensils, refrigerators, etc.

For some of its properties, such as liquidity and solubility, and for being an excellent emulsifier and wetting agent, Castor oil is also used in the manufacture of household and industrial disinfectants and of products used in pest-control.

Whilst few techniques seem to have been developed, in recent years, to match Castor oil in the surface coating and the disinfectant field, none seem to have succeeded in replacing it, not even in 1967/1968 when Castor oil topped the $ 500.-- per ton CIF mark, due to an unusually bad crop year in Brazil.

It has been mentioned that Tall oil has replaced Castor oil to some extent, in those years, but lower prices for Castor oil witnessed more recently - $ 200 / $ 350 per ton CIF - seem to have stemmed this tendency just when the urge to find formulae favouring synthetic compounds or derivatives of cheaper oil as a basis for products of similar characteristics as the yet unrivaled Castor oil, became threatening.

Castor oil second, or third pressing - the division between them being somewhat arbitrary, the denomination "commercial grade" applying as well, and all confirming quite definitely that "first" pressed oil has been mixed with extraction oil, if it is not just that - have a limited use in similar fields, where-ever their lower prices appease the technicians' conscience, but they are largely serving as raw materials for the production of derivatives,

The breakdown of 1969 figures for U.K., as compiled by the International Trade Center of Geneva, in November 1970, reveal that of 28.000 tons of Castor oil consumed in that country, 5.000 tons were marketed as unmodified, 1.750 tons of which were for surface coating, 1.600 tons for disinfectants, 1.000 tons for lubricants.

More than 23.000 tons, on the other hand, were listed as derivatives which, in due course, would have served similar purposes as the unmodified oil, just as this or that particular industry may have preferred their raw materials more or less semiprocessed.

This fact renders statistical figures which are, therefore, more likely confusing than enlightening, rather immaterial.

(3) CASTOR OIL PROCESSING, though mainly a task for the chemical industries who are customers to the crushing mills, has been added to a certain degree, to the activities of the latter.

By tradition, the European Castor seed crushers produce not only unmodified Castor oil in pharmaceutical, first pressing and - mostly modified - extraction quality, but also those derivatives not requiring techniques which would be absolutely uncommon in oil mills, such as blown and dehydrated Castor oil.

" B l o w n " is the description for a Castor oil which has been thickened by air-oxidation.

It retains its fluidity at a lower temperature than unmodified Castor oil and is preferred as a basic ingredient for hydraulic oils.

D e h y d r a t e d Castor oil is a drying oil, contrary to unmodified Castor oil which is non-drying.

Dehydration of Castor oil is achieved by reacting the hydroxyl group of the ricinoleic acid with an adjacent hydrogen atom and separation of water, producing unsaturated fatty acids with 2 double bonds of the 9.12 and 9.11 linoleic acid types.

This process is nowadays practiced to a large extent by employing acid catalysts under vacuum at high temperatures.

An oil with 25 % conjugated fatty acids is so obtainable.

Dehydrated Castor oil being very pale and odourless, is most suited for the production of alkyd resins, epoxy resins, styrenated and acrylized alkyd resins as well as for utilization in combination with other drying oils and resins.

It constitutes films of outstanding flexibility and gloss, is fast drying and possesses good metal adhesion properties.

The same can be attributed to d e h y d r a t e d C a s t o r o i l f a t t y a c i d s, which are also favoured by the surface coating industry.

They are obtained by decomposition processes in which very few manufacturers are specialized.

Alternatively to dehydrated Castor oil which is normally of low, i.e. 2 - 3 poise, viscosity, there is also produced and offered a s t a n d o i l of dehydrated Castor oil, polymerized to 30 poise and higher viscosities.

Other derivatives of Castor oil requiring more extensive installations, are usually manufactured by subsequent industries, using Castor oil first pressing as well as commercial grades, for some of these processes hereafter described depend on the chemical components of Castor oil more than on the total scope of applications available in first pressing Castor oil, only.

S u l f o n a t e d C a s t o r o i l is used by a wide range of industries as a finish.

Sulfonation - or sulfating, being a more up-to-date denomination - refers to the treatment of oils with concentrated sulfuric acid, oleum and chlorosulfuric acid, in order to obtain esters of sulfuric acid and sulfonic acid.

Esterification of the hydroxyl groups of Castor oil results in several useful products, the most well-known of which is Turkey Red oil, a sulfonated - or sulfated - Castor oil of medium degree sulfation.

Concentrated sulfuric acid acts on Castor oil, the unreactive sulfuric acid is washed-out and neutralized with soda-lye.

Turkey Red oil has been, for a long time, unrivaled as a medium to impregnate cotton making it receptive for dye-stuffs.

Sulfated as well as the more recently developed highly sulfated Castor oils, are frequently utilized in dye-works, textile finishing, textile processing and leather industries. They are also used for wetting and emulsifying agents in the paint industry.

These oils are soluble in water, they possess the properties of soaps without being as sensitive to hard water as these.

Sulfated oils can be considered the ancestors of synthetic wetting agents and detergents, this explanation implying that the former are now in the course of being supplanted by the latter which are mainly produced from petro-chemical materials.

H y d r o g e n a t i o n is another way of modification of Castor oil.

Catalytic hydrogenation of fats, i.e. the addition of hydrogen to unsaturated fatty acids which are transformed into saturated fatty acids by the splitting of their double bonds, refers to this term.

When Castor oil is hydrogenated, the double bond of the ricinoleic acid is saturated, developping into hydroxy-stearic acid.

The typical features and the usefulness of hydrogenated Castor oil depend on its hydroxyl groups which must be protected to the extent that they remain evident after full hy-drogenation.

This type of modified Castor oil is, with a high hydroxyl value and a low iodine value, of brittle hard, taste- and odourless nature, melting at a temperature of 86^{o} C.

In its solid form, it is mostly supplied in flakes with a flat, waxe-like gloss. The melted product is clear, transparent and almost colourless.

Hydrogenated Castor oil is compatible with all natural and petro-chemical waxes, increasing their melting point and decreasing their melting range.

The acid of hydrogenated Castor oil, 12 h y - d r o x y s t e a r i c a c i d, is also success-

successfully marketed.

Both products are used in the surface coating industry, in lubrication greases and various polishes and dressings.

Their main use is in greases, the resistance of which to extreme temperatures, both heat and cold, is decisively increased when containing hydrogenated Castor oil.

Even more important, at least in respect of the quantities it absorbs of hydrogenated Castor oil, is the surface coating industry who appreciate it as a pigment dispersing or anti-settling agent in paints, to improve brushing qualities and to reduce the sagging of thick coats. Also, hydrogenated Castor oil affords good non-yellowing properties for stoving finishes and enamels which are subject to high temperatures.

12 hydroxy-stearic acid is used for similar applications.

Some of the most sophisticated derivatives of Castor oil are, by all means, those polyamides which are produced in France nder the trade mark RILSAN.

They are attained by t h e r m a l d e c o m p o s i t i o n of Castor oil which is heated to 500 / 600^{o} C. into oenenithol (a hept-aldehyde) and undecylenic acid.

This reaction leads, via the undecylenic acid, in several stages to 11-aminoundecylic acid which is then transformed by poly-condensation, into polyamide 11 (or NYLON 11) which, under the name of RILSAN, has met a large scope of application.

It is humidity-, chemicals-, and corosion - resistant and used as a plastic for high precision parts, insulating material in the electronic industry and for metal-protective coating.

Most of its fame it has achieved as a textile fibre.

Its heat-resistance reaches from 40° C. below to 130° C. above zero.

Recently (compare Chapter III/4 above) RILSAN is under heavy competition from a polyamide of petrochemical origin which is known as NYLON 12.

It is obtained from butadien which is available as a residue in petroleum refineries and can be transformed by polymerisation and condensation by gradual process.

Finally, there is s e b a c i c a c i d to be mentioned as a derivative of Castor oil, although it is understood that all former major uses for it are on the decline, or have already ceased, consumers outside the UK hardly being traceable any longer.

Reasons for this development appear particularly complex and hard to analyse.

Sebacic acid can be used for the production of the polyamid NYLON 610. Its esters are excellent plasticizers for vinylic resins and gained reputation as lubricants for jet-aircraft.

Sebacic acid and iso-octanol which is used in perfumery as a defoaming agent and as a high boiling solvent, result from the decomposition of the chain of carbon-atoms of the ricinoleic acid in reaction with alkalis at 270° C., the fracture taking place between the 10th and 11th carbon atoms.

(4) TO DRAW A CONCLUSION, the importance of Castor oil as a raw material for the chemical industry, is not easily assessed.

Until 1970, consumption of Castor oil has steadily increased, world-wide.

Adding up Castor seed exports, in terms of oil, and Castor oil exports for the period from 1964 to 1969, these figures rise from 205.300 in 1964, to 267.850 in 1969, this leaving unconsidered the home consumption in Brazil, India and some minor important seed growing countries.

Whilst for 1970 a decline in Castor oil exports is statistically evident but may not bear much significance, the sharply reduced consumption of Castor oil in France, for the production of RILSAN, should leave its marks on world totals, at least as from 1971 onwards.

Still, there is no evidence of a replacement of Castor oil by other materials, elsewhere, with the exception of sebacic acid consumption.

Whether or not new fields of application for Castor oil may still be undetected, remains to be seen.

For the time being, quite certainly, Castor oil is to be judged as a raw material of outstanding value to various branches of the chemical and allied industries, and it is most likely that this situation will prevail for still some time to come.

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