Why refine vegetable oils?

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The vegetable oil refining industry offers clear, pale coloured, and odourless vegetable oils free of fatty acids by the process of refining. This happened in India about 40 years ago and has now become so widespread that it is very hard to buy unrefined edible oils free of adulteration.

Oil chemistry

As extracted, vegetable oils contain at least six ingredients that are probably intended by nature partly to preserve the oils and partly to ensure the oils do not cause any harm to the user.

Oils are primarily triglycerides with a terminal ester group with varying degrees of unsaturation. The ester group allows the oxidation of the fatty chain to carbon dioxide and generates energy for life. The unsaturation maintains it in liquid state at body temperature. The tendency of fats to deposit as reserve for rainy day has, however, become a problem for consumers.

As extracted, oils contain following 'impurities': a small portion of protein that comes from the oilseed; some water; some agricultural residues like leaves, fibres and some seed covers. Some part of the oil – about 0.5-1% – gets hydrolysed to free fatty acids (FFAs) and glycerine due to the enzymes present in the oilseed. These cause problems of odour (rancidity) and acidity to consumers. Some part of the seed germ also contaminates the oil.

In some oils, hydroxy fatty acids, such as ricinoleic acid, are also present. Common oils containing ricinoleic acid are castor oil and cashew oil, whereas gossypol is mostly present in cottonseed oil, a minor oil in the country. Adulterators are known to mix about 10% castor oil in edible oils whenever prices are attractive without any reported adverse effect to consumers.

The refining process

Theoretically, FFAs are the only components that need to be removed from the vegetable oil, but what happens in the refining process is that the oil is stripped of many of its protective features.

The refining process followed is broadly as follows:

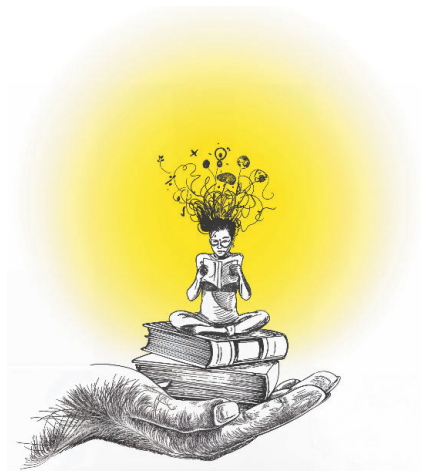
- Removal of phospholipids by contacting with water;
- Removal of FFAs first by alkali contact, followed by steam stripping;
- Removal of colouring components by treatment with clays and activated carbon; and
- Removal of waxes by wintering (i.e., chilling the oil to crystallize waxes, followed by filtration).

What is not acceptable is that the vegetable oil industry makes no efforts to replenish the refined oil with what it has removed unnecessarily!

Why does the oil industry remove all these substances?

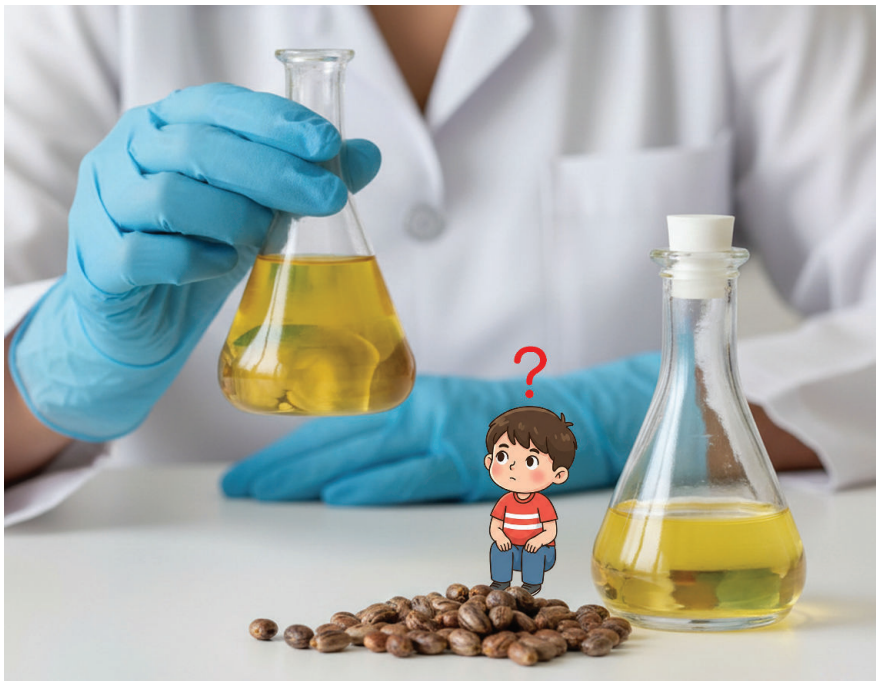
There are technological limitations that lead to removal of components other than the desired ones. While what is targeted for removal is only water, proteins, colour and FFAs, the phospholipids, which are important components of all living cell walls, also get removed.

Phospholipids are highly water-sensitive. They swell several times in contact with water, and being not completely oil-soluble, cause haze and turbidity in the oil. In contact with water, they acquire a gum-like texture, which makes processing difficult. Therefore,



these too get removed in a centrifuge (and carry with them about equal weight of the oil) even before the alkali touches the oil.

The first treatment for removal of FFAs is alkaline water extraction. This is a heterogeneous process. The alkali does not dissolve in the oily layer. The extracted fatty acids form soaps and start emulsifying the oil. This leads to more loss. Therefore, the treatment does not remove more than 50% of the FFAs present, while taking away another 1% of the oil. If the balance FFA is left behind it can give a disagreeable odour. Therefore, steam stripping (deodorizing or DO) with high pressure superheated steam is carried out in a falling film evaporator. The FFAs are not the only volatile materials. The other components to get evaporated are sterols and tocopherols (natural phenolic antioxidants for the vegetable oil; vitamin E being one of five). The mixture is condensed and the water insoluble oily layer is separated and sold off at about 20-25% of the price of oil. It contains about 80% fatty acids, 3-5% sterols and the balance is tocopherosl. Vitamin E content is about 3% of the total DO



distillate, which is about 1-1.5% of the oil processed.

The oil is now chilled, and the wax allowed to crystallize out (which would otherwise produce turbidity).

Wonder what happens to the ingredients removed? Many companies make money by separation and value addition to most of the materials discarded as waste by the vegetable oil refining industry.

Lecithins

As separated, the lecithins are sold for about Rs. 60 per kg. The composition is typically 10% water, 40% oil and 50% lecithin. Lecithins are then separated from the residual oil as acetone insoluble and fetch between Rs.150 and Rs. 200 per kg.

Phospholipids, such as lecithins, are excellent emulsifiers. The primary use is in the paint industry as a wetting and dispersing agent in oil-based paints. They are also used as emulsifiers in chocolate and sweets.

Lecithins are amphoteric phosphoric acid esters of glycerol diesters of fatty acids with other components such as ethanolamine, choline, inositol, etc. Further separation is possible by selective solvents and ion exchange.

Some of the lecithins are of high medicinal value, used for the treatment of liver cirrhosis. A dose of about 3 g per day may cost a patient up to Rs. 60 per day. The effective cost of lecithins works out to Rs. 20,000 per kg.

India produces about 8,000 tonnes of lecithins. Most of it is used in paints or is exported for value-addition elsewhere. We do import the active ingredient for pharmaceutical applications at a fabulous price.

Hydrogenated lecithin is a very important emulsifier for applications in food and cosmetic preparations. Products with very low iodine value (1-2 g iodine /100 g lecithin) are very expensive and find international markets at prices ranging from Rs 20,000 to Rs. 30,000 per kg.

Sterols or steroid alcohols

The DO distillate contains up to 80% fatty acids. For ease of separation, FFAs from the deodorizer are converted to methyl esters. The esters are cooled to crystallize sterols, which are removed as flaky solids by filtration. The methyl esters are now lower boiling than the tocopherols and hence these are fractionated and sold as biodiesel. They typically fetch about Rs. 80 per kg – about the same price as the oil. The residue left behind is tocopherol.

Sterols of plants are called phytosterols and sterols of animals are called zoosterols. The most important zoosterols are cholesterol and some steroid hormones; the most important phytosterols are campesterol, sitosterol, and stigma sterol.

Sterols play essential roles in the physiology of eukaryotic organisms. For example, cholesterol forms part of the cellular membrane where its presence decreases the cell membrane's fluidity and serves as secondary messenger in developmental signalling.

Plant sterols are also known to block cholesterol absorption sites in the human intestine, thus helping to reduce cholesterol in humans. In humans, sterols provide important signals and metabolic communications, e.g., circadian rhythms, blood clotting.

Phytosterols are white powders with mild, characteristic odour, insoluble in water and soluble in alcohols. They have many applications as food additives, and in medicine and cosmetics.

Tocopherol is a highly substituted phenol, with 2 to 3 methyl groups and a long regularly branched alkyl chain in *meta* position. This chain is meant to provide the oil solubility to the molecule, and lower melting point. Importantly, tocopherols serve as antioxidants, preserving the oil from degradation.

Natural oils have unsaturation ranging from 1 to 3 double bonds along the chain. These are susceptible to air oxidation and produce oxygenated products such as hydroxyls, ketones, and carboxylic acids. These can be bad for health, taste and odours.

In oil refining, the naturally provided antioxidant (tocopherol) is removed and at times replaced by a synthetic one. Most commonly used substance is *tert*-butylcatechol. This adds to the cost of the vegetable oil, and, unlike tocopherols, has no anti-aging properties.

Waxes

All vegetation is covered with a thin layer of wax to prevent evaporation of water. Nature does not synthesize a plain hydrocarbon, probably because it would biodegrade with difficulty. Instead, it synthesizes esters of long chain fatty acids and fatty alcohols. The fatty acid generally is palmitic acid, and the fatty alcohol is a mixture of C20-40 carbon chains. The two components get easily separated by saponification, and the fatty alcohol is extracted with diethyl ether or petroleum fractions. These alcohol mixtures are termed as Policosanols.

Wikipedia write about plant waxes as follows:

"Policosanol is a mixture of a few fatty alcohols derived from the waxes of such plants as sugarcane and yams, as well as beeswax. The most prevalent alcohol in policosanol is octacosanol, followed by triacontanol. There is a much lower concentration of several other fatty alcohols: behenyl alcohol, lignoceryl alcohol, ceryl alcohol, 1-heptacosanol, 1-nonacosanol, 1-dotriacontanol, and geddyl alcohol.

"Policosanol is touted as a natural way to treat high cholesterol levels. Published studies have come to conflicting conclusions regarding the efficacy of policosanol in lowering LDL (i.e., "bad cholesterol") or raising HDL (i.e., "good cholesterol"). Many studies that have found positive effects of policosanol have come from one group in Cuba, whose research has been funded by Dalmer Laboratories. This company was created by the National Centre for Scientific Research in Havana, Cuba specifically to market policosanol. Cuba produces sugarcane, one of the sources of policosanol. A German study, however, failed to find evidence of cholesterol-lowering effects. In this study, 143 participants with hypercholesterolemia or combined hyperlipidaemia were randomly assigned to groups given policosanol at doses of 10, 20, 40 or 80 milligrams daily or placebo. After 12 weeks, the researchers found no statistically or clinically significant effect on LDL-C, HDL-C, total cholesterol, triglycerides, or lipoproteins. In other words, they found policosanols to be of no clinical value."

In spite of the controversy, which is probably politically motivated, the policosanols derived from sugarcane have become a product of commerce as nutraceuticals – a product group that is out of the purview of the regulations of the pharmaceutical sector. The current price for a purified policosanol is about Rs. 800-1,200 per kg. A purified component, triacontanol, is a plant growth regulator at about 1-10 ppm (mg/l) concentration, and increases the crop yield of several vegetables like tomato, brinjal and gourd. A 0.2% emulsion sells for about Rs. 200 per litre.

There is hardly any difference in the composition of sugarcane wax and waxes found in vegetable oils. In the stomach, it gets hydrolysed to fatty acid and policosanol, just like the vegetable oil, and is absorbed as fatty acid and fatty alcohol. The two components reach their destinations separately. There is no need to remove these waxes from the oils just because they cause turbidity at low temperature. Oil is used at room temperature or is heated for frying. In hot conditions, the wax is molten and is transparent. Then why is it removed?

Trans fatty acids in saturated fats

In the early 1950s there was an acute shortage of milk and milk products in India, and planners encouraged the technology of saturating vegetable oils using nickel catalyst and hydrogen. In the process, the polyunsaturated fatty acids pass through a series of hydrogenation steps. Once one double bond is hydrogenated, an isomerization of residual double bond leads to formation of trans isomers. These are more difficult to hydrogenate and therefore continue to be present as unsaturates.

Many vegetable oils are hydrogenated to about 80 Iodine Value, and most of this Iodine Value comes from the trans fatty acids.

Interestingly, the body does not absorb the fat we eat directly. It is first hydrolysed by Lipase enzyme into fatty acids and glycerine. Both separately travel to the site of deposition and are re-esterified and deposited.

The coronary blood vessels are the most common site for deposition of fats containing trans fatty acids. Over the last 75 years several million people worldwide have died of heart failure due to deposition of these trans fatty acids. A huge population has suffered a lot of avoidable disease because of this thoughtless act, which has probably killed more people than road accidents and the atom bomb put together. I wish such acts are not repeated without adequately understanding the after-effects.

Practical strategies to combat nutrient loss

I would strongly recommend to the younger generation to keep away from hydrogenated fats and refined

vegetable oils. Use just filtered vegetable oils to the extent possible; the best source could be a village *Ghani*, if you can find one still in operation.

The Khadi Village Industries Commission (KVIC) might be able to supply *Ghani* extracted vegetable oils. In all probability, it would cost more than refined vegetable oils because of the lower yield of extraction and higher transportation cost.

Another option is to consume lots of raw nuts such as coconut, groundnut, cashew, almond and soybean, and co-ground these with wheat for making *chapatti*.

Here are some other practical suggestions for better health:

- Select cold-pressed or virgin oils, such as olive, sunflower, sesame, or flaxseed, when possible, especially for raw or low-heat uses. These retain more antioxidants and phytonutrients.
- Use a blend of unrefined oils for flavour and antioxidants, and refined oils for high-heat cooking.
- Ensure adequate intake of omega-3 fatty acids (e.g., from flaxseed, walnuts, fish) to balance omega-6s common in seed oils.
- Keep oils cool, dark, and sealed to limit oxidation and prolong their functional life.
- Do not reuse oils repeatedly for frying, as heat accelerates oxidative damage and breakdown of fats.

Concluding remarks

Industrial refining of vegetable oils ensures safety, neutral flavour, and stability for diverse cooking needs. However, it also reduces valuable minor compounds also such as tocopherols, sterols, and polyphenols that may contribute to antioxidant effects and overall diet quality. Choosing unrefined or lightly processed oils, balancing dietary fats, and using appropriate oils for different cooking methods are practical, evidence-based ways to maximize nutritional benefits and leverage the virtues of plant-derived oils in human diets.

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