Finished Oil Handling and Storage in Europe

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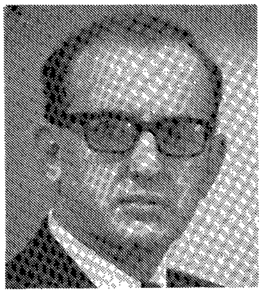

ABSTRACT

Quality characteristics of newly deodorized oils are covered. During handling and storage, the quality of the deodorized oil deteriorates. How to protect the achieved quality against oxidative deterioration and different types of contamination is discussed. The effects of temperature, oxygen, heavy metals, and antioxidants are also described.

INTRODUCTION

The last process in which the properties of oil markedly change is deodorization. If the conditions of the preceding processing technique and quality of raw material have been satisfactory, the result is a tasteless, odorless, and light-colored oil, free from hydroperoxides and contamination, with quality properties approximately those shown in Table I.

The methods for handling and storage of this product must be directed towards protection of the achieved quality. The fat must be protected against oxidative deterioration, contamination by water and dirt, contamination by other unwanted fats, absorption of foreign odor and taste, thermal decomposition, microbiological contamination, hydrolysis, and contamination from the packaging materials. With this objective in mind, the principles valid for handling and storage are quite general for all fats intended for human consumption, e.g., salad oils, cooking oils, frying oils, oils for margarine production, oils for shortening production, and chocolate fats.

The actual processing section is depicted in Figure 1. Using this processing diagram as a background and taking into consideration the stated possibilities of quality deterioration, I would like to discuss handling and storage of finished oils.

PROTECTION AGAINST OXIDATIVE DETERIORATION

Oxidative deterioration—whose different steps are forming of hydroperoxides, decomposition of hydroperoxides into carbonyls, dimerization, and polymerization—is increased by: increase of temperature; increase of oxygen pressure; increased concentration of oxidation products (peroxides and aldehydes), metals catalyzing oxidation,

TABLE I

Quality Characteristics of Newly Deodorized Oils (Sweden)

Type of oil	Water (%)	FFA[a] (%)	Lovibond color Yellow	Lovibond color Red	PV[a] (meq/kg)	AV[a]	Phosphorus (ppm)	Iron (ppm)	Copper (ppm)
Coconut	0.04	0.01	4.0	0.7	0.0	0.5	0.9	0.37	0.003
Rapeseed	0.04	0.03	7.0	1.0	0.0	0.5	1.5	0.04	0.002
Soybean	0.04	0.03	6.0	0.8	0.0	1.5	1.1	0.04	0.003
Sunflower	0.04	0.03	6.5	1.1	0.0	4.0	1.4	0.08	0.002
Palm	0.04	0.03	17.0	0.5	0.0	3.0	1.5	0.07	0.002
Hydrogenated rapeseed	0.04	0.03	6.0	0.5	0.0	0.7	1.0	0.06	0.003
Hydrogenated fish	0.04	0.03	6.0	0.9	0.0	0.7	1.0	0.07	0.003

[a]FFA = free fatty acids; PV = peroxide value; AV = anisidine value.

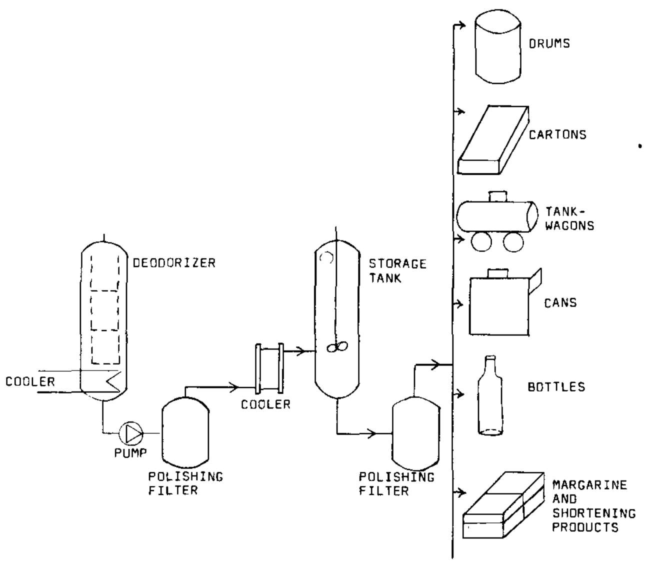

FIG. 1. Processing diagram for handling and storage of finished oil.

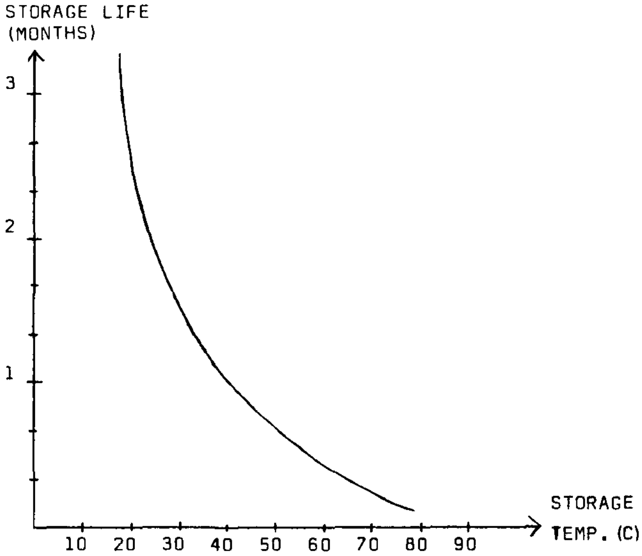

FIG. 2. Storage life (months) vs. storage temperature (C) for a salad oil.

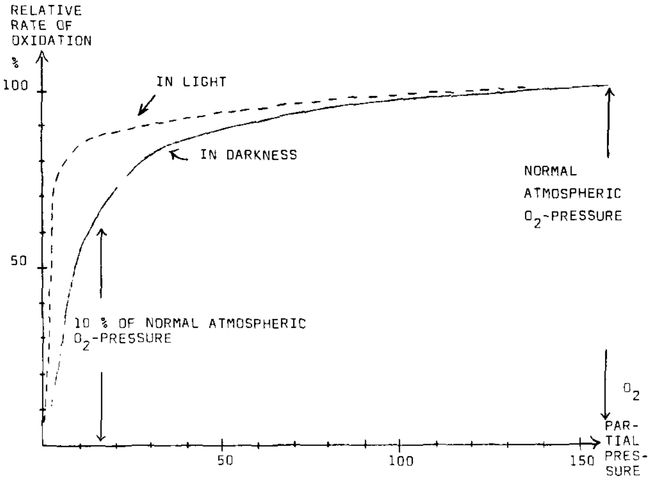

FIG. 3. Relative rate of oxidation for sunflower oil in darkness and light at different oxygen partial pressures.

lipoxydases, and hematin compounds; decreased concentration of antioxidants, natural and added synergists, and metal deactivators; and increased intensity of UV and visible light or any ionizing radiation.

The temperature should be kept as low as possible during handling. Before the deodorizing vacuum is released, the oil is usually cooled to 50-70 C. After polishing filtration, the oil can be further cooled. The speed of oxidation is doubled by each 15 C increase in temperature within the 20-60 C interval. Consequently, at a temperature of 20 C, the product can be stored 4 times as long as when stored at 50 C (Fig. 2).

A storage temperature of 5-10 C above the clear melting point is recommended for keeping the product in a liquid state. A substantial decrease in speed of oxidation will occur when cooling the fat into a solid state.

Oxygen contact can be reduced by keeping the entire handling process under vacuum or a protective gas. In finished oil processing, the fat is preferably protected by inert gases in the storage tanks and/or transport containers but also in consumer packages, e.g., cans and bottles (1).

The effect of variations in the oxygen partial pressure on the rate of oxidation has been studied by several people (2,3). Paul and co-workers (4) have demonstrated the influence on the relative speed of oxidation of different oxygen partial pressures on some edible oils. We can observe in Figure 3 that a reduction of pressure to 10% of the normal atmospheric pressure only reduces the rate of oxidation to 67%. The oil phase can contain as much as 10% of air by volume.

If an effective protection against oxidation is to be achieved by means of lowering the oxygen partial pressure, the air in the oil and headspace should consequently be removed by vacuum and then replaced by a protective gas. Great care must be taken both as regards the choice of the protection gas and the way of application.

Heavy metals, particularly those possessing two or more valency states, generally increase the rate of oxidation. Of all metal, copper is the most potent catalyzing one. A concentration high enough to produce a noticeable oxidative effect lies in the proximity of analytical detection limit, i.e., at 0.005 ppm. The corresponding content for iron is 0.03 ppm.

To provide the reader with a fair idea of the oxidation-catalytic power of various metals, the contents of metal ions required to decrease by 50% the keeping time of lard at 98 C are listed: 0.05 ppm copper, 0.6 ppm manganese, 0.6 ppm iron, 1.2 ppm chromium, 2.2 ppm nickel, 3.0 ppm vanadium, 19.6 ppm zinc, and 50.0 ppm aluminum (5).

This comparison stresses the importance of not using, in particular, copper and copper alloys as construction materials. Nor should iron be used if the highest possible

TABLE II

Comparison between Epoxy and Polyurethane Lacquering of Tanks for Deodorized Oil

Type of lacquer	Method of application	Number of layers	Stands max. temp. (C)	Remarks	Total cost ($\$/m^2$)
Epoxy (2 components)	Spray-painting	2 thick layers	70	Does not stand fatty acids	10
Polyurethane (1 component)	Spray-painting	5-6 thin layers	90	Stands fatty acids well	20

TABLE III

Permitted Additions of Antioxidants (Natural or Synthetic) and Synergists to Fats and Oils in some European Countries[a]

Additive	Permitted additions (mg/kg)				
	Denmark	France	Italy[b]	The Netherlands[c]	Sweden[d]
Tocopherol	1,000	-	300	-	200
Guaiac resin	-	-	-	-	-
Lecithin	+	-	-	-	-
Tartaric acid	-	-	-	-	-
Citric acid	+	-	-	+	+
Ascorbyl palmitate	80	300	3,000	-	500
Ascorbic acid	200	300	-	-	200
Butylated hydroxyanisole	100	100[e]	300	100[g]	100
Butylated hydroxytoluene	(100, combined)	100[e]	300	100[g]	100
Gallates	100	100[e,f]	100[f]	100[f,g]	100[f]

[a]-May not be added; + may be added (no limit).

[b]Not olive oil.

[c]Fats and oils (not cocoa butter nor margarine).

[d]Animal and vegetable fats and mixtures of these.

[e]Fats solely for food industry in amounts of >5 kg units.

[f]Propyl, octyl, and dodecyl gallates.

[g]Fats and oils (not in cocoa butter nor in fats and oils for use in margarine and bread).

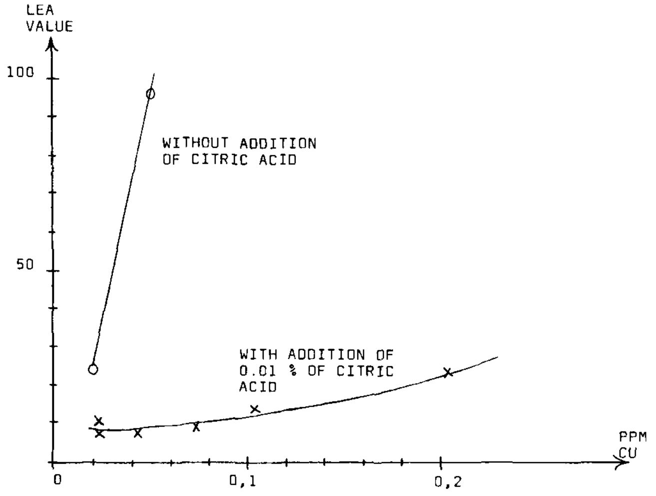

FIG. 4. Effect of copper content and citric acid addition on oxidative stability, measured as Lea-value after 8 hr at active oxygen method conditions.

stability is desired. The best but most expensive material is stainless steel.

Surface treatment with a protective coating lacquer is a common method used to prevent contact between fat and metal. It is then important that the layer of lacquer is not damaged and flakes off. A comparison between two normal methods of lacquering, epoxy and polyurethane lacquers, is shown in Table II.

Keepability of a deodorized oil can be greatly improved by addition of antioxidants, synergists, and metal deactivators. The upper limit of such additives has been set in food legislation in various countries. Examples of such additives permitted in some European countries are shown in Table III. Because of the present intensive discussion on this subject, our attitude towards the use of such additives is generally hesitant.

Undoubtedly the most common metal deactivator is citric acid. It is usually added as an alcohol or a water solution in the cooling step of deodorization. The amount of added citric acid usually varies between 0.005 and 0.01%. Several examples of the properties of citric acid improving the stability are found in the literature. Jakubowski and Rudzka (6) have studied the effect of trace concentrations of iron and copper in rapeseed oil with and without addition of citric acid. Figure 4 illustrates the effect of copper content and citric acid addition on oxidative stability, measured as Lea-value after 8 hr at active oxygen method conditions.

As the handling and storage of finished oil are normally carried out in a closed system, light and ionizing radiation cannot normally affect the rate of oxidation. However, salad oils are usually drawn off into transparent glass bottles, and samples taken for laboratory tests and organoleptical evaluations are often poured into transparent jars.

Paul and co-workers (7) have studied the effect of wavelength and intensity of light on the oxidative deterioration of edible oils. The rate by which oxidation takes place is greatly affected by wavelength as well as intensity of light. A general changeover to brown-colored glass for bottling of edible fat can therefore be recommended.

AVOIDING CONTAMINATION BY WATER AND DIRT

Contamination by water usually occurs from leaking coolers and inadequate drying of rinsed tanks, pipes, and vessels. Water in amounts $> 0.05\text{-}0.15\%$ causes a turbid oil at temperatures < 20 C. Furthermore, as hydrolysis and microbiological contaminations are to be avoided, the fat must be protected from contamination by water.

Foreign particles in the finished product are usually caused by malfunctioning of the polishing filter after deodorization, precipitation of citric acid or citrates, and inadequate or incorrect cleaning of tanks. In most cases, a sufficient measure to prevent solid particles from passing into the finished product is to insert a polishing filter directly before the filling station.

AVOIDING CONTAMINATION BY OTHER UNWANTED FATS

Every fat has its own specific properties, and, depending on the field of application, the tolerance towards admixture of other fats varies to a great extent.

Fat products which are to be stored for a long period in an environment propitious to hydrolysis, e.g., mayonnaise, caviar, and some chocolate products, do not tolerate contamination by coconut, palmkernel, or other fats which as products of hydrolysis give short chain fatty acids of the length C4-C12. These fatty acids have very low taste threshold values (8).

Liquid oils, e.g., salad oils, which should keep clear in the refrigerator, do not tolerate contamination by fats having a higher melting point, e.g., hydrogenated fats (Table IV).

Fats which are absolutely free from contamination by other fats are sometimes required for religious and ethical reasons. For instance, one such demand can be a total absence of certain animal fats.

AVOIDING MICROBIOLOGICAL CONTAMINATION AND HYDROLYSIS

Newly deodorized oils do not contain living microorganisms. Such organisms can, however, be brought into the fat through unclean transport devices. Many microorganisms produce lipase enzymes. Among such microorganisms are many yeast and mold fungi and most of the bacteria. In the absence of lipase, no noticeable hydrolysis occurs.

Low content of water and good hygiene after deodorizing will ensure that no hydrolysis will occur.

TABLE IV

Tolerance of Corn Oil to Contamination by Some Hydrogenated Fats

Admixture in corn oil (%)	Hydrogenated rapeseed (40 C)	Hydrogenated soybean (40 C)	Hydrogenated fish (40 C)
0.0	clear	clear	clear
0.1	clear	clear	clear
0.2	clear	clear	clear
0.3	slightly cloudy	clear	clear
0.4	cloudy	clear	slightly cloudy
0.5	cloudy	clear	slightly cloudy
0.7	cloudy	clear	cloudy
0.8	cloudy	slightly cloudy	cloudy
1.0	cloudy	cloudy	cloudy

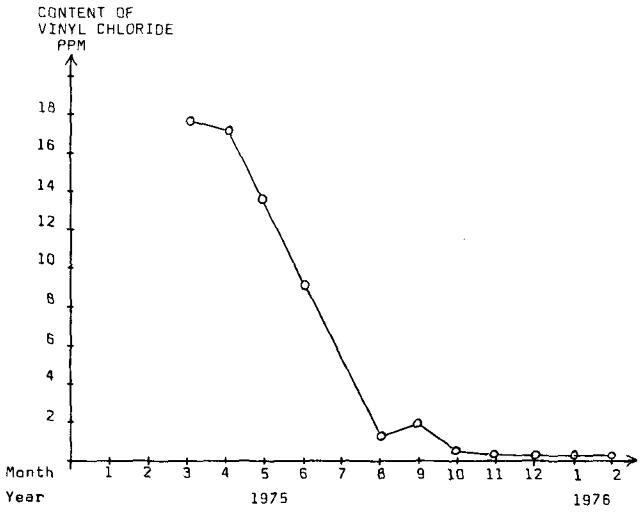

FIG. 5. Vinyl chloride in PVC foil for margarine packages (arrival control).

Contamination by vinyl chloride monomers (VC) emanating from polyvinyl chloride (PVC) packaging material caused a great commotion in some countries. Before the manufacturers of PVC became aware of the situation, comparatively high contents of VC were recorded in PVC foil.

The maximum content of vinyl chloride permitted in foodstuff in Sweden has been limited to 50 μg/kg. We have found that, in order not to exceed this upper limit, the foil must satisfy the demands listed in Table V in regard to the content of VC. The demands apply to packagings for margarine (12,13).

Thanks to purposeful and effective development work carried out by the manufacturers of PVC, the contents of VC in foil have in a short time been reduced to < 0.1 mg/kg (0.1 mg/kg = our detection limit). The progress as regards the content of vinyl chloride in PVC foil is shown in Figure 5.

TABLE V

Vinyl Chloride (VC) in Packaging Materials

Quantity of margarine (net weight, g)	Weight of foil (g)	Area of foil in contact with product (cm^2)	Maximum content of VC permitted in foil (mg/kg)
400.0	18.0	400.0	5.0
10.0	1.0	30.0	1.0

AVOIDING ABSORPTION OF FOREIGN ODOR AND TASTE

Oils and fats easily absorb odor and taste emanating from, for instance, solvents. A fact known to most people working with organoleptical tests is that a sample passing the chemical laboratory very often has absorbed flavors from solvents, thereby spoiling any meaningful taste evaluation. Therefore, great care should be taken when airing newly painted tanks and rooms where air circulation permits transmission of tastes of solvents to the fat.

AVOIDING THERMAL DECOMPOSITION

In normal handling and storage, there is no risk of thermal decomposition. If heating is necessary, it should be done with either hot water or low pressure steam—at < 1.5 kg/cm^2 (9). If lecithin has been added, sensitivity to heat is highly increased. In that case, temperatures > 70 C should be avoided.

AVOIDING CONTAMINATION FROM PACKAGING MATERIALS

Last, but not least, the product must be protected from contamination originating from the packaging material. Such contamination can be, e.g., copper and iron from packaging materials made of metal, paper, or plastic (10,11); and plasticizers, stabilizers, or other chemical substances from plastic packagings.

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