Quality Control in Storage and Transport of Edible Oils

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ABSTRACT

Care for quality of edible fats and oils during transportation and storage is especially important for partially or fully refined products. This paper describes some examples of deterioration caused by a brass sampler, by improper reheating during voyage, by contamination in a pipeline, and by absorption of oxygen during various processing steps. Trade associations have published recommended procedures to minimize some of these problems. From these recommendations and many personal experiences, PORIM has drafted a "Code of Practice" bringing together elements of good design of physical facilities and of good operating practices. A copy of this code appears as an appendix to this paper.

INTRODUCTION

There is a rapid increase in the volume of edible oils being transported and stored in bulk. There is also a rapid increase in the proportion of oils that are being transported after partial or full refining treatment, and it is highly probable that both these trends will continue. It is in the interest of all the parties involved from grower to end user that any deterioration occurring during transport and storage operations should be minimized.

This paper describes some recent examples of deterioration. It then discusses some of the advisory material available from various sources, including the latest compilation by the Palm Oil Research Institute. Finally it raises some problem areas which require further study.

QUALITATIVE OBSERVATIONS

In the course of visits to ships and land installations during the last three years the following have been noted:

- Severely rusted ships' tanks
- Rusty land tanks and uncleanable pipework, brass thermometers and sampling instruments
- Ships' heating coils made of aluminum brass alloy (Yorcalbro)
- Land tanks about to be filled although they contain the rancid residues of previous cargoes.

The number of factual complaints being received suggest that most of more than 3 million tons of products arrive in acceptable condition, but much of it requires reprocessing before use. Some analytical results for deliveries arriving in good condition are shown in Table I. Some specific examples of deterioration are of interest.

Brass Sampling Tool

Pike (2) has demonstrated the effect on keeping properties of samples which were in contact with a brass sampling utensil for a short period. Samples were left in contact for 0-20 minutes and subsequently stored in closed glass vessels at 50 C for one day and five days. The analytical results are given in Table I. The loss in quality is rapid and marked. A serious aspect of this example is that the quality of the sample taken will be totally different from the bulk.

Pipeline Contamination

While investigating transport conditions for fully refined palm oil Kheiri took samples at various intervals direct from a pipeline at the port of discharge. Analytical results are shown in Table II. It may be noted that pumping continued for 8 minutes, representing 20 tons of oil or more, before the product flowing was within specification, but there was some indication of contamination for about a further 20 tons.

Reheating During Voyage

Samples of crude palm oil were drawn from a ship's tank every second day throughout the voyage from Malaysia to England (Reed). The samples were placed in deep freeze and all analyzed after the voyage (Table III). There was no increase in the free fatty acid content of the load, and in fact anisidine values also showed only an insignificant change. The peroxide value remained rather stable until heating started on day 18, and then showed significant increases. The heating rate was well within that recommended by the IASC and other bodies (maximum 5 C per 24 hours). It is postulated that the oxidative damage was due to local overheating at the coil surface, because of a lack of mixing and/or the use of high steam pressures giving a high coil surface temperature.

Dissolved Oxygen Content of Palm Oil

It is self-evident that oxygen must be present before an oil can begin to oxidize. The deodorizer step at the end of the refining process reduces the dissolved oxygen to a very low level. Law measured dissolved oxygen content of palm olein

TABLE II

Pipeline Contamination of Refined Palm Oil

Time after start	Impurities (%)	Moisture (%)	Color Lovibond red (5¼" cell)
5 seconds	0.017	0.834	20
25 seconds	0.012	0.933	24.6
8 minutes	0.003	0.055	3.0
14 minutes	–	0.042	2.6
30 minutes	–	0.034	2.4

TABLE I

Effect of Using a Brass Sampler on Crude Palm Oil Quality

Contact time at 50 C (minutes)	Copper (ppm)	Anisidine value		Carotene (ppm)		Tocopherols (ppm)	
		1 day	5 days	1 day	5 days	1 day	5 days
0	0.12	4.6	5.8	656	593	665	668
5	0.23	8.5	11.1	528	170	169	39
10	0.60	10.3	14.8	498	64	78	N.F.
15	0.83	10.6	15.7	454	64	45	N.F.
20	1.43	12.8	20.0	468	70	51	N.F.

N.F. = not found.

TABLE III

Quality Changes of Crude Palm Oil During Voyage

Day	Peroxide value (Meq/kg)	FFA (% palmitic)	Temperature at time of sampling (C)
1	4.3	3.16	42
3	4.8	–	40
5	5.2	–	38
7	5.2	–	37
9	5.6	3.16	40
11	5.1	–	38
13	5.6	–	38
15	5.7	3.16	38
17	5.6	–	37
19	6.6	–	40
21	7.8	–	44
22	8.8	3.17	46
23	7.8	–	48
24	8.5	–	50
25	9.8	3.23	52

TABLE IV

Dissolved Oxygen in Palm Olein During Processing (in ppm)

Step		Mean (12 values)	Range
1	Crude olein, storage tank	14.9	11.7-20.4
2	Degummed, bleached from bleacher	8.1	4.5-17.7
3	Degummed, bleached from holding tank	25.6	18.1-33.0
4	Degummed, bleached after deaeration	11.9	0.3-30.6
5	From deodorizer	7.8	3.9-12.6
6	After polishing filter	6.5	4.2- 9.6
7	In bulk storage tank[a]	31.0	30.0-32.4

[a]4 results only.

at various steps in the refining process and also the rate of diffusion during storage. Readings were taken on 12 separate days (see Table IV). As would be expected, the oxygen content is reduced by steps 2, 4 and 5, which employ vacuum, while the filling of the holding tank (step 3) and the storage tank (step 7) involved splashing the stream of oil from the top of the tank and resulted in a substantial increase in oxygen level. The saturation level for palm olein at 60 C is about 36 ppm oxygen.

ADVISORY MATERIAL

Various trade associations have published recommended procedures covering surveying, sampling and testing of cargoes of edible oils and in addition some aspects of operation and design. The following list is not comprehensive:

- The International Association of Seed Crushers produces a handbook, updated in 1980, which deals in detail with sampling and analytical procedures. It also gives heating instructions for bulk shipments and recommendations on the information to be supplied in surveyors' reports.
- The National Institute of Oilseed Products trading rules contain advice on sampling, analysis and specifications.
- The National Soybean Processors Association has developed a standard for inspection, sampling and measuring procedures of soybean oil.
- The Malaysian Palm Oil Producers Association prepared a guide book for surveying of crude palm oil, which was subsequently updated by the Malaysian Oil Palm Growers Council.
- The Palm Oil Refiners Association of Malaysia, in association with FOSFA (Federation of Oilseeds and Fats Association) and the Palm Oil Research Institute has recently published a guide (1983) on storage, transportation, sampling and survey of processed palm oil products.

Examination of these documents shows that there is a great deal of common ground. It is appropriate that they deal mainly with operations necessary to fulfill the contractual obligations involved in the trade of specific commodities. It was felt that there was in addition a need for a coordination document that would bring together both the elements of good design of the physical provisions and of good practice in operating the facilities. Such a document would be of particular value in a growing trade whenever new installations are being planned or operated. The Institute has therefore drafted a "Recommended Practice." It has been circulated to individual companies and to trade associations internationally for comment and amplification. At the time of writing a fourth draft has been submitted for endorsement by any parties interested. It forms the appendix to this paper.

The development of the Recommendations has benefited by the many comments that have been received, based on first hand experience. It has also become clear that, within the general guidelines of such a code, there need to be variations dictated by local circumstances, and also that there are some aspects where current knowledge is insufficient. Some of these points of interest will now be discussed.

AREAS OF POSSIBLE IMPROVEMENT

Tank Coatings

The food industry's primary objective in using a coated

TABLE V

Quality of RBD Palm Oil in Transport

	I To Karachi (21 days)				II To Auckland (16 days)		III To Rotterdam		
Factor	Refinery	Ships tank loading	Ships tank arriving	Shore tank after discharged	Loading sample	Arrived	Ships tank loading	Ships tank Liverpool (27 days)	Ships tank Hamburg (via Rotterdam)
Moisture	0.03	0.04	0.03	0.05	–	0.03	–	–	–
Impurities	0.002	0.002	0.003	0.02	–	–	–	–	–
Color red	1.6	1.7	2.3	2.4	1.0	1.0	–	–	–
FFA	0.05	0.06	0.17	0.19	0.03	0.04	0.06	0.12	0.17
PV	0.8	0.7	1.0	1.0	0.60	0.60	1.4	4.0	4.4
AV	2.2	2.5	2.3	2.7	–	–	–	–	–
Tocopherol (ppm)	–	–	–	–	–	–	281	261	246

Load I - There was a moderate increase in free fatty acid content. In other aspects the condition was satisfactory.
Load II - The oil arrived in perfect condition.
Load III - Loss of quality was moderate to Liverpool. Further changes occurred during transfer at Rotterdam and subsequently, but condition on delivery was acceptable.

tank is to protect the food product from contamination, whereas the shipowner is anxious to protect his tank from possibly corrosive cargoes and to maintain flexibility of tank usage. A coating that may be optimal for foods may be incompatible with some of the other bulk cargoes to be carried. Its use would restrict the cargoes and increase transport costs. There is a need to compromise, but decisions are not easy, partly because authoritative rulings on suitability of coatings for food use are not generally available. The only official scheme seems to be formal approval by the U.S. Food and Drug Administration.

Preparation of tanks and application and curing of tank coatings is a skilled, specialized job. In any case tank coatings usually have limitations on their resistance to elevated temperatures, to pH etc., which may be exceeded, leading to damage. Coatings are all more or less sensitive to abrasion during cleaning.

Tank and Pipeline Design

Many shore installations are on the seashore or on reclaimed land with limited load-carrying capacity. Tall, narrow tanks are not feasible in such positions. Lagging of storage tanks not only saves energy, but reduces convection currents due to diurnal temperature changes, and as a result slows down mixing of oxygen and oxidation. On the other hand tanks designated for long-term storage may be better unlagged, since the temperature will fall more quickly.

Tank-filling inlets of various types are proposed:

- Inlet at bottom
- Pipe in from the top but reaching to bottom (with syphon breaker if necessary)
- Pipe in from the top connected by a swivel arm to an outlet that floats on the surface and discharges just below. This design reduces turbulence during filling.

Previous Cargoes

There is a widespread call for the obligatory declaration of the three of five previous cargoes in a ship's tank intended for edible oil. The consequences to a large food manufacturer of using contaminated material could be disastrous, and consequently the risks must be minimized. Such risks are obviously increased if a cargo has to be trans-shipped.

Heating

The recommended maximum rate of temperature increase of 5 C in 24 hours is appropriate for large unstirred tanks, and helps to prevent local overheating. If, however, a tank is fitted with an effective agitator, much higher heating rates can be attained without risks of overheating (e.g., 25 C/24 hours).

Collection of the First Runnings at Discharge

While some operators do not regard this as feasible due to cost and practicality, others do it as a matter of normal routine.

Inert Gas Protection

Combustion gases are not pure enough for inert gas protection. It is necessary to use commercially pure nitrogen or carbon dioxide. However, in general nitrogen blanketing is regarded as uneconomic. Sparging with nitrogen under pressure into the oil stream during pumping may be a practical alternative. It has proved very successful for protection of fully refined oils in road tankers over long journeys. The cost of sparging is limited and can be forecast, whereas the cost of blanketing is much higher and indefinite, since it depends partly on the leaks in the system.

Temperature for Transport and Pumping

Some of the figures given in the code are taken from IASC instructions. There is a need today for data on a wider range of products, and the table has been amplified with advice from NIOP. As a general guide, a figure of 5 C to 10 C above the melting point for fats, and 5 C to 10 C above the titer point for fatty acids is proposed for pumping.

Contamination with Water

The presence of water in a cargo causes deterioration by hydrolysis. Residual free water tests should be made each time oil is transferred. Pipelines and manifolds should always be thoroughly drained after washing. Dedicated pipelines and pumps are much to be preferred on ships.

Information

Many of the people involved in the transport chain are responsible for handling many different types of cargo and are not sufficiently knowledgeable about edible oils. Information packages are required for their specific needs.

REFERENCES

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APPENDIX

Recommended Practice for Storage and Transport of Edible Oils and Fats

1. INTRODUCTION

The volumes of edible oils and fats being traded in bulk are increasing every year. The products may be shipped in the crude, partially processed or refined form and the tendency is towards shipping more refined oils.

It is in the interest of all the parties in this trade that any changes in quality taking place during storage and transport should be as small as possible. Presently, the facilities and techniques available are variable, and in some instances, not satisfactory. This document is an attempt to define a basis for sound practice in the design and operation of the facilities.

The recommendations have been put together by using existing documentation from trade associations and in consultation with them and with a number of prominent practitioners. We acknowledge their help with gratitude. It may be mentioned that all the features described are in use somewhere and are regarded as practical and economical by the users.

2. STORAGE INSTALLATIONS AND TRANSPORT

2.1 Tanks

2.1.1. *Storage Tanks.* The most suitable shape is the vertical, circular cross-section tank with self-supporting fixed roof, preferably convex in shape. Where possible, tall, narrow tanks are preferred, to minimize exposed surface areas. Tank bottoms should be conical or sloped to be self-draining.

2.1.2. *Capacity.* For each installation, the storage capacity needs to be related to the expected storage period, the rate of turnover and the number of different products to be handled. The following sizes are generally found to be satisfactory.

For refineries or end users, the capacities of storage tanks should be small, and it is desirable to have a number of tanks ranging from 200-1,000 tons.

For export and import tank farms, suitable capacities for the various products are:

- Crude liquid oils, 1,000-5,000 tons.
- Crude non-liquid oils and refined oils, 500-2,000 tons.
- High melting fats such as palm stearin, tallow, hydrogenated oils, 500-1,000 tons.
- Fatty acid distillates or acid oil generally 500 tons or larger where turnover is large.

2.1.3. *Ship's Tanks.* Ship's tanks of mild steel must be coated with a suitable inert, food-grade coating. It is preferable to construct a number of smaller tanks with capacities ranging from 200-1,000 tons.

2.1.4. *Materials.* a) Copper, brass or bronze should be absolutely avoided for use in any part of the storage installation and means of transport that has contact with the oils, such as piping, pipe connections, valves, heating coils, temperature gauges for oil, strainers, pumps, etc. or in sampling apparatus. Gauges containing mercury should not be used.

b) Any other material used for the construction of tanks should be inert to oils and fats.

c) Mild steel is acceptable for oil products but the tank wall, floor and roof should preferably be coated with inert material of food grade. A number of different products are available, and specific assurance as to suitability for contact with foodstuffs should be obtained from the manufacturers. Before applying the coating, the surface must be sand blasted to bright metal (Swedish Standard SA3). There is usually a temperature limitation to the coating, which must be observed, and cleaning with live steam is not recommended.

d) Mild steel is not suitable for acid oil or fatty acid. Fiberglass or 316 stainless steel can be used; for many grades of product aluminum is also satisfactory.

2.1.5. *Heating Installation–Tanks.* All tanks for solid or semi-solid products should be installed with heating facilities in order to obtain homogenous products when they are transferred or unloaded. Heating coils should be of mild steel for mild steel tanks and of stainless steel for coated and stainless steel tankage. The following means are suitable.

a) *Bare Hot Water Pipes.* Heating by hot water (controlled at 80 C) circulated through coils is the best procedure, because it is least likely to cause local overheating.

b) *Bare Steam Pipes.* Heating by steam with pressure up to 1.5 kg/cm^2 (temperatures of 127 C). The heating coils are normally mild steel 5 cm (2″) bare pipes and should rest on supporting legs about 7.5 cm (3″) above the base of the tank. Some operators prefer supporting legs 6″ to 12″ high. Vertical hairpin coils or side heating coils installed on the tank walls also should be provided. Where no provision exists for mixing the oil, a maximum heating rate of 5 C/24 hr should be maintained to avoid local overheating at the coil surface. Where mixing is provided, see section (c) below, a higher heating rate is permissible. As a guide a coil area of about 0.1 m^2 per ton of tank capacity is required if the fat has to be melted, but 0.05 m^2/ton suffices for heating-up purposes. For lagged tanks a smaller coil area is adequate. The total coil length is normally divided into two or more separate coils, of a length to avoid excessive accumulation of steam condensate.

c) *Mixing.* When the product is being kept liquid, local overheating is avoided if mixing facilities are provided, preferably by side entry agitators. Alternatively oil may be recirculated by pumping from the bottom and returning from the top through a line reaching below the oil surface. Aeration must be avoided. Mixing also reduces sampling problems.

2.1.6. *Heating Installation–Road and Rail Tankers.* For solid or semi-solid fats tankers should be fitted with stainless steel or mild steel steam coils which can be coupled to a source of hot water or low pressure steam (steam pressure up to 1.5 kgm/cm^2). In temperate and cold climates tankers should be insulated.

2.1.7. *Tank Insulation.* Storage tanks should be insulated, particularly in temperate and cold climates. Insulation is usually fitted externally to the wall of the tank and must be designed to avoid the absorption of oil or water. Insulation has been proved of benefit even in tropical climates. Oil quality is preserved and energy is saved.

2.1.8. *Control of Temperature.* All ships and storage tanks with heating installation should be equipped with temperature sensors and automatic control devices to prevent overheating of oil in the tank. Thermometers must be carefully sited and away from heating coils. It is useful to have automatic recording type thermometers to provide records of temperature control. The recorder should be installed in a conspicuous location such as supervisor's office or the ship's bridge.

2.1.9. *Protection from Aeration.* Pipeline connections should be designed so that admixture of air is avoided. Filling and emptying should be done from the bottom of the tank to avoid aeration.

2.1.10. *Inert Gas Protection.* Ships and storage tanks for high quality products or for long storage should have facilities for sparging and blanketing with inert gas.

2.2. Pipelines

At a storage installation a sufficient number of separate pipelines should be provided to avoid cross contamination of different products.

At a ship loading pipelines should reach the bottom of ship tanks; there should be a proper drain-out pipeline at the base of each tank so that it can be completely drained.

2.2.1. *Materials.* Mild steel is acceptable for all crude and semi-refined oils and fats; for refined products and distilled fatty acids 316 stainless steel should be used.

2.2.2. *Cleaning.* A pipeline pigging system should be provided.

2.2.3. *Flexible Hoses.* All flexible hoses used to connect pipelines during loading and unloading must be of inert material and have both internal and external reinforcing wire to prevent them from either bursting under pressure or collapsing under vacuum.

2.2.4. *Insulation and Heating.* In temperate and cold climates pipelines should be lagged and also provided with heating, for example by steam tracing lines, or electrical heating tape. Heating must be shut off when lines are empty.

3. OPERATIONS

3.1. Loading and Unloading

3.1.1. *Heat up.* Solid and semi-solid products in refinery storage tanks, shore tanks and ship tanks should be heated up slowly so that they are liquid and completely homogenous before transfer. Heating up should start at a time calculated to give the required pumping temperature without ever exceeding the maximum rate of 5 C/24 hr. If a steam is used, the steam pressure should not exceed 1.5 kg/cm^2 to

TABLE I

Unloading Temperature

Products	Minimum (C)	Maximum (C)
Palm oil (processed or crude)	50	55
Palm stearin[a] (processed or crude)	50-60[a]	65-70[a]
Palm olein (processed or crude)	30	35
Palm oil mid-fraction	40	45
Palm kernel and coconut oil	30	35
Palm kernel olein	30	35
Palm kernel stearin	40	45
Tallow	55	60
Groundnut and cottonseed oil	20	25
Other liquid oils	15	25
Palm acid oil and palm fatty acid distillate	55	70
Specified fatty acids	5-10 C above titer point	

[a]The lower temperatures apply to soft grades, while the higher temperatures are necessary for hard grades. The temperatures apply to both crude and processed oils in each grade.

TABLE II

Temperature During Storage and Shipping

Products	Minimum (C)	Maximum (C)
Palm oil	32	40
Palm olein	25	30
Palm stearin	40	45
Palm mid-fraction	35	40
Tallow	44	49
Palm kernel/coconut oil	27	32
Palm kernel olein	25	30
Palm kernel stearin	35	40
Liquid vegetable oils	Ambient	
Palm acid oil and palm fatty acid distillate	52	55

prevent localized over-heating.

3.1.2. *Temperatures.* The various oil products should be heated up to the temperature shown in Table I before transfer.

3.1.3. *Temperatures During Storage and Transport.* To prevent excessive crystallization during short-term storage and shipping, oil in bulk tanks should be maintained within the temperature ranges given in Table II.

The temperatures are chosen to minimize damage to the oil. Some crystallization will occur, but not so much as to require excessively long heating before delivery. Thus palm oil stored at 32-40 C will require about three days heating at 5 C/day to bring it to discharge temperature. Long term storage of all oils should be at ambient temperature, and heating should be completely turned off.

3.1.4. *Loading and Unloading Sequence.* Where a number of products are unloaded through a common pipeline system the system must be cleared between different products or grades. The order of loading or discharge must be carefully chosen to minimize the consequence of contamination. The following principles should be observed:

- Fully refined oils before partly refined.
- Partly refined oils before crude oils.
- Edible oils before technical grades.
- Fatty acids or acid oils should be pumped last.
- Special care should be taken to prevent contamination between lauric and non-lauric oils.

3.1.5. If possible the first 3-5 tons of each grade should be collected in separate tanks for quality checks.

3.1.6. When empty, tanks and pipelines and pumps should be drained and all heating turned off.

3.2. Cleaning

Pipelines and valves should be immediately cleared after each pumping for which pigging systems are recommended. After clearing and/or emptying, pipelines and tanks should be cleaned when no longer used for the same grade or product or if inspection shows the presence of residues. Where tanks have been used for non-edible materials, the greatest care must be taken in cleaning and inspection that all residues have been totally removed.

Land tanks and pipelines should be constructed to drain by gravity, and suitable drainage cocks, etc., should be provided. This is especially important where pipeline pigging facilities are not available. All common user pipelines and valves should be immediately cleared and cleaned after every pumping. If steam or water is used for cleaning, the system must be drained and completely dried before oil is handled.

Ease of cleaning of mild steel tanks is greatly facilitated and costs of cleaning reduced by a suitable inert food-grade coating.

3.3. Maintenance

Regular maintenance checks should be made. They should include functioning of steam pressure regulation valves; all steam supply valves and steam traps for leakage; thermometers, recording thermometers, weighing equipment and any gauge meters for function and accuracy; all oil pumps for leakage; condition of tank coatings; hoses (internal and external), and condition of tanks and ancillary equipment.

3.4. Others

3.4.1. There should be a suitable marking or identification system for the pipelines and storage tanks.

3.4.2. The condition such as cleanliness of storage tanks, road tanker, ship's tank and pipelines should be inspected by suitably qualified personnel for every loading or unloading of oil and written reports provided.

3.4.3. All openings of tankers, storage tanks, etc., such as manholes, inlets, outlets, draining out points, etc., should be made such that they can be locked and/or effectively sealed.

3.4.4. Before heat up of oil, the heating coils should be covered completely.

3.4.5. Temperature of loading or unloading should refer to the average of top, middle and bottom temperature readings. Bottom readings should be taken 12" away from the heating coils.

3.4.6. Where there are doubts about cleanliness of pipes/manifolds before discharge of oil from ship tank to shore tank, then if possible, first runnings (3-10 tons) from the delivery line should be drawn into a separate container for inspection. Tank sediments also should be kept separate from the bulk.

3.4.7. Records of the ship's heating log should be provided to the buyer.

3.4.8. Ship loading samples properly marked and sealed should be delivered to the buyer.

3.4.9. The three previous cargoes carried in a ship's tank should be declared to and approved by the charterer of the tank before an edible oil cargo is loaded. This provision should be part of all shipping contracts.