

# Animal fat-Processing and Its Quality Control

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## Abstract

Animals are slaughtered to produce their by-products which can be well utilized for various applications in day to day human life, thus, contributing to the value of animals. Removal of fat from various parts of the animal body can be done by various methods, mainly dry rendering and wet rendering. The most advantageous technique is low temperature rendering which results in highest yield of fat. Further processing of fat is done before their utilization in food to meet today's special and general usage demand. Thus, the treatment involves series of purifying steps such as settling and degumming, neutralization, bleaching and lastly deodorization followed by modification into more usable products and finally packaging. The quality of fat control is as important as purification of fat in order to increase its utilization among the consumers and increasing the value of the animal by-products. The various analytical methods used for quality control of fat such as estimation of iodine value, peroxide value, saponification value have been described here briefly.

**Keywords:** Animal fat; Purification; Rendering; Quality control; Animal by-products

## Introduction

When animals are slaughtered to produce meat for human consumption, approximately 50% of the animal is turned into animal byproducts. The by-products are further processed and used for variety of applications, thus, adding value to the animals. Traditional uses for the protein rich solids include use in foods, pet foods, livestock feeds, and fertilizers. Fats have been transformed into soaps and oleochemicals (fatty acid derivatives) in addition to being used in food, pet foods and feed applications. The need for new outlets of products has also been realized due to commonly encountered zoonotic diseases. The new outlets include using protein meals and animal fats as energy sources in combustion units for the generation of steam or renewable electricity. Nonetheless, animal by-products contain high levels of water and have a very suitable biological and microbiological composition which, if not stabilized, can lead to decomposition and environmental pollution. The most conventional way of stabilizing raw material is to process the raw material with heat. This serves to both evaporate the water content and sterilize at the same time: this process is known as "Rendering".

## Animal Fat

Animal fats are rendered tissue fats that can be obtained from a variety of animals. Basically, these are the by-products of the meat packing industry, made available as a result of the preparation of meat either for sale as meat percent or from the manufacture of meat product.

## Types of animal fat

**Tallow:** It is hard fat rendered from the fatty tissues of cattle that is removed during processing of beef.

There are two types of tallow:

- Edible tallow:** The *Codex Alimentarius* recognizes standard for this as rendered from certain organs of healthy bovine animals. It is also known as *dripping*.
- Oleo-stock:** It is high grade tallow that is obtained by low temperature wet rendering of the fresh internal fat from beef

carcass. It has light yellow color, mild pleasant flavor and free fatty acid content is less than 0.2% [1]. Oleo-stock is also known by the synonym *premier jus*.

**Lard:** It is defined as the fat rendered from clean, sound edible tissues of hogs in good health at the time of slaughter. Its production is limited to certain killing and cutting fats from the hog.

Depot fats such as those surrounding the kidney portion are examples of killing fats, since they are removed during the slaughtering operation. Cutting fats are those fats which are obtained when the hog is cut into its various wholesale or retail cuts.

**Caul fat:** It is the fatty membrane which surrounds internal organs of some animals, such as cow, sheep, and pigs also known as the greater omentum. It is often used as a natural casing. It is also known as *Lace Fat*.

**Leaf fat:** It is the fat lining the abdomen and kidneys of hog that used to make the lard.

**Rendered pork fat:** It is the fat other than the lard, rendered from clean, sound carcasses or edible organs from hogs in good health at the time of slaughter, with certain parts of the animal specifically excluded. It includes bacon skins, fleshed skins, cheek meat trimmings, sweet pickle fats and fats obtained from skimming the rendered tanks.

**Inedible tallow and greases:** These are the main inedible animal fats which are produced in many grades. Inedible tallow and greases produced by meat packing meat industry may contain either hog or beef fat. These are described in terms of their hardness.

Fat with titer of 40 or greater than 40 are called as inedible tallow and those with titers less than 40 are called as greases. Titer is the measure

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of the temperature developed as a result of the heat of crystallization during cooling of melted fatty acids from the fat.

**Chicken fat:** It is the fat obtained (usually as a by-product) from chicken rendering and processing. It is high in linoleic acids, the beneficial omega-6 fatty acid. Linoleic acid levels are between 17.8-22.9%. It is used in the production of pet foods and bio-diesel. Chicken fat is one of the two types of animal fat referred as *schmaltz*, the other being goose fat.

**Blubber:** It is a thick layer of vascularized fat found under the skins of *pinnipeds*, *cetaceans* and *sirenians*.

### Recovery of fat

Fats are produced by a variety of processes, generally referred to as rendering. Fatty tissues from both beef and pork are composed of essentially three components, viz. water, protein and fat. It is the purpose of any rendering system to obtain as complete a separation as feasible of these materials. In most cases, the fatty tissues are cooked and the fat is released by temperature and cell rupture. In alternative process, the temperature is kept low and the fat is released principally through mechanical rupture of the cells [2].

Thus, the term "rendering of fat" is the thermal processing operation that breaks down the cellular structures to release triacylglycerols from animal by-products and underutilized fish species.

The fat can be obtained from any of the following three methods:

- a. Dry rendering
- b. Wet rendering
- c. Low-temperature wet rendering

*Lard and Tallow are obtained mainly by dry and wet rendering* [1].

**Dry renderer:** A dry renderer is made up of horizontal stem jacket with raw material or charge load of 8-10 quintals. Two or three stirrers keep the raw material continuously under motion for uniform heat distribution to avoid charring. The steam remains in the outer jacket and does not come in direct contact with raw material or charge which is cooked at 75psi for 3-4 hrs in its own moisture. There is no loss of nutrients in this. The resultant material called "*cracklings*" is taken out. The cracklings should be gritty, fibrous and non-slippery. It still contains lot of fat, thus, fat is removed to 5% in order to economize the labor and to increase the keeping quality of material. Removal of fat is done from cracklings inside the centrifugal expeller and fat settling tank.

Long bones from settling tank are sent to digester. Dried and nearly fat free cracklings are ground to recover meat meal. A cyclone and sacking unit allows direct filling of bags.

Lard and almost all of the inedible tallow is produced by dry rendering.

#### Advantages:

- a. Yield is nearly 20% higher
- b. Saving on labor and stem is there.

**Wet renderer:** This is generally vertical type equipment in which steam directly comes in direct contact with raw material or charge. The material is cooked at 40psi for 4-8 hrs. After processing, the tankage or slush is allowed to settle for 2 hrs. These greasy or fatty material which floats on top is removed first, followed by water and finally by

the tankage with digested meat and bones. The bones are sent to bone digester. Lard produced by wet rendering process is *Prime Steam Lard*.

#### Advantages:

1. Recovery of fat is better.

**Bone digester:** Long bones are crushed and processed in steam at 60psi for 2 hrs. The steam separates most of the protein and fat. After extractions of fat and gelatin, the digested bones are chalky and soft and can be easily grounded to bone meal which has about 32.5% calcium and 15% phosphorous.

**Low temperature wet rendering:** This system uses heating, separation and cooling on a continuous basis and is regarded as an ideal purpose. The process involves mincing of the material, melting by live steam injection at 90 degrees, continuous separation of solids from liquid fats in a decanter centrifuge; further heating; centrifugation to remove the fines and cooling in plate heat exchanger to below solidification point.

### Characteristics of fat

Fats and oils comprise one of the three major classes of foods, the others being carbohydrates and proteins. Chemically, they may be defined as esters of three carbon carboxylic trihydroxy alcohol, glycerol (propan-1,2,3-triol), and various monocarboxylic acids known as fatty acids. Since glycerol is a trihydroxy alcohol, monoacid, diacid and triacid esters are known.

**Lard:** It contains considerable proportions of palmitic acid, stearic acid, oleic acid and linoleic acid. There are small amounts of palmitoleic acid and traces of linoleic acid, arachidonic acid and myristic acid.

**Tallow:** It typically contains 9 or 10 predominant fatty acids, although approximately 180-200 individual fatty acids, mostly in small or trace quantities are also known to be present [1]. It also contains approximately 6% of trans-oleic acid formed by the action of rumen bacteria on vegetable oils found in food that is ingested by the bovine or ovine animal.

### Processing of fat

The treatment involves series of purifying steps followed by modification into more usable products and finally packaging.

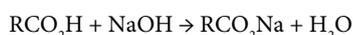
The major steps are described below:

**Settling and degumming:** These are utilized to remove animal or plant proteins, carbohydrates residues, phosphatides and water. Settling involves storing heated fats quiescently in tanks with conical bottoms. The presence of phospholipids will cause the formation of water-in-oil emulsion in fats and oils. These emulsions will make the oil cloudy and the water can present a hazard when the oils are heated to temperature above 100 degrees (spattering and foaming). Degumming is a process that removes phospholipids by the addition of water at 1-3% at 60-80 degrees for 30-60 mts. Small amount of acid is added often to the water to increase the hydrogen of the phospholipids in it.

Water and materials associated with water are denser than melted fat and settle into the cone, where they are drawn off, thus, coalesced "gum" formed by phospholipid and water is removed. Another technique involves heating at 200 degrees in the presence of adsorbents and then filtering.

**Neutralization/refining with alkali:** It refers to the removal of non-glyceride fatty materials by washing the oils with strong alkaline water

solutions (sodium hydroxide). The major impurities in most crude oils are the free fatty acids. Free fatty acids results from the lipolysis during or prior to rendering. Caustic soda solutions are added to the heated fat and stirred vigorously. After a short period, the mixture is allowed to settle.



The oil can be separated from the soap by gravity-that is, if we allow the mixture of oil and soap solution to stand, the oils (specific gravity-0.9) will rise to the top, and the soap and water (specific gravity-1.1) will sink to the bottom. The settlings, called "foots" are collected and sold as "soap stock". In continuous processes appropriate proportions of caustic soda solution and oil are continuously blended at 20-32 degrees, passed into a heat exchanger which rapidly rises the temperature to 55-70 degrees to break the emulsion, centrifuged to separate the foots, washed with water, and separated again by centrifugation. In addition to removing free fatty acids, refining also removes phosphatides, some solid matter, and some of the colored material. These substances are removed mainly by occlusion with soaps.

#### Advantages:

1. It reduces the loss of oil due to saponification.
2. Short time of reaction occurs in modern continuous centrifugal processes.

#### Disadvantages:

1. If this refining is allowed to occur by standing, the time taken is lengthy.

Certain methods of refining remove the free fatty acids by steam distillation under vacuum. This is known as *physical refining* and is the same process as deodorizing.

**Bleaching:** It is a very important step in oil and fat processing. Crude oils often contain pigments that produce undesirable colors (carotenoids, gossypol, etc.) or promote lipid oxidation (chlorophyll). In early days the process was thought to remove only colored pigments, but more modern schools of thought consider the process to be much more than this. Bleaching reduces the color of fat or oil and it is achieved by adsorbing the colorants on bleaching earth and/or charcoal or by chemical reactions involving their oxidation or reduction [3]. Chemical methods of bleaching are seldom applied to edible fats. In addition to decolorization, bleaching clay also absorbs suspended matter, soaps, phosphatides, water and nickel, if the treatment occurs after hydrogenation. The process would be better termed as "*Adsorptive cleansing*".

The most important adsorbent used in bleaching fats and oils is bleaching earth or clay. Natural bleaching earth consists mainly of hydrated aluminium silicates. These adsorbents are known as *fuller's earth* from their use in the "fulling" or scouring of wool. Bleaching clay (bentonite) contains not less than 85% of the mineral montmorillonite  $\text{Al}_4\text{Si}_8\text{O}_{20}(\text{OH})_4 \cdot n\text{H}_2\text{O}$ . Natural clay is bentonite in which some of the Al has been naturally replaced by H. These are still used in the petroleum industry but have mainly been replaced in the oil and fat business by acid-activated earth. Activated clay, produced by treating natural clay with mineral acid, has even more Al replaced with H and thus, it contains a higher percentage of hydrated silica and an increased adsorptive capacity.

The clay is added at a temperature lower than optimum so that increased residence time is achieved allowing the water which is slowly

released from the clay to form a protective vapor layer over the fat. Bleaching performance is governed by organic impurities in the oil and the oxidative state of the oil. Bleaching clay more effectively removes the green color (chlorophyll) than red colors (carotenes or xanthophylls). Carotenoid pigments fade due to heat bleaching, but heat may also induce red color formation by oxidation of tocopherol to chroman-5,6-quinones. Charcoal may be used in conjunction with clay when removal of red color is difficult. The efficiency of the bleaching process is determined by measuring the reduction in the color measurements in a "lovibond Comparitor" or a spectrophotometer.

*Most high quality lards generally do not require bleaching, but tallow may be bleached to remove the color bodies.*

**Deodorization:** It is an important oil refining step because of consumer demand for fats and shortenings that have a very bland or practically non-existent flavor. Neutral fats and hydrogenated contain substances contributing to undesirable flavor and odor and these substances must be removed. This is achieved by a technique known as steam distillation under reduced pressure which is designed to remove unacceptable odors and flavors from oils and fats.

Steam distillation is often used in the organic chemistry laboratory to distill relatively nonvolatile materials without decomposition. The same principles are used in deodorizing. Triglycerides have extremely low vapor pressures and are therefore non-volatile whereas aldehydes, ketones, alcohols and free fatty acids, which contribute to the flavors and odor of fats, are removed by steam distillation. Deodorization may be carried out in batch vessels with capacities of up to twenty or thirty tones or by a semi-continuous or continuous process.

The process is carried out by injecting high pressure steam into the fat at temperatures between 180-250°C with a vacuum of about 1kPa and allowing it to cascade over-stream moving in a countercurrent direction [4]. This has the effect of removing odoriferous volatile compounds leaving the fat almost tasteless.

**Fractionation:** Fractionation refers to the partial crystallization of a fat or oil at a specific temperature. The fat is held at the crystallization temperature for a period of time to allow equilibrium or near equilibrium to occur between crystallizing and non-crystallizing triacylglycerols. Once partial crystallization is complete, the actual fractionation is accomplished by effecting the liquid-solid separation. The different melting points of the mixed triacylglycerols in a fat, such as tallow, provide the basis for fractionation processes. Thus, tallow can be fractionated to yield several fractions with vastly different melting ranges.

The *major objective* of fractionation is to optimize separation of the liquid (olein) and solid (stearin) fractions. An effective early method of separating olein and stearin phases is known as *winterization*. Technically called as *dry fractionation*, mechanical pressing of a partially crystallized fat is the oldest method for fractionating tallow. Tallow is slowly cooled in small shallow tanks to a temperature over 30degrees. The fat is kept at this temperature for 3-4 days during which time crystals are formed. This process retards nucleation and allows the growth of large crystals which is necessary for the subsequent filtering of the crystals from the oil. Plate type presses with canvas cloths are used in this process. Yields of 55% olein have been reported for this process for fats which yield 75% by aqueous fractionation technique.

A modern version of the dry fractionation method referred to as *tritiaux fractionation* is based on the directed crystallization of a suitable fat followed by filtration [5]. A continuous vacuum filter

equipped with a stainless steel perforated belts as a filtration support is used. Yields of 70% olein is achieved by this method in comparison to 80% by aqueous fractionation at the same temperature [5].

*Solvent fractionation* is another type of fractionation and involves the use of large quantities of solvents such as acetone to dissolve the fat completely. The solution of fat and solvent is then brought to the sterilization temperature and held to allow partial crystallization of higher melting triacylglycerols. The solvents serve to reduce the viscosity of the liquid phase, thus, facilitating the filtering of the liquid solutions from the solid crystals [6,7].

In *detergent (aqueous) fractionation*, liquid solid separation is accomplished by adding an aqueous solution a surfactant and an electrolyte to a partially crystallized oil, which preferentially wets the crystal into the aqueous solution [8]. It has the disadvantages of emulsified olein product formation and residual electrolyte and surfactant in the fractions obtained. Residual surfactants can be easily removed from the olein and stearin fractions by hot water washing. Water washing also removes any electrolytes present.

**Hydrogenation:** The physical requirements of many fats used in foods are grossly different those of natural fats or oils. Hydrogenation, the direct addition of hydrogen to double bonds of fatty acids, is used to modify vast quantities of fats and oils. This process alters molecular configuration and changes the geometry, number and location of double bonds. These changes, in turn, alter the physical and chemical properties of fat.

*Thus, hydrogenation is usually carried out before bleaching.*

The hydrogenation reaction requires a *catalyst* to speed up the reaction, *hydrogen gas* to provide the substrate, *temperature control* to initially heat up the oil to make it liquid and then cool the oil once the exothermic reaction is started, and *agitation* to mix the catalyst and substrates [9]. Agitation aids solution of hydrogen in the hot oil, aids movement of unmodified oil to the catalyst surface, and aids movement of converted oil away from the catalyst. The oil used in hydrogenation must first be refined since the contaminants will reduce the effectiveness of or "poison" the catalysts. Hydrogenation is done as a batch or continuous process at temperature ranging from 250degrees to 300 degrees. Reduced nickel is the most common catalyst that is added at 0.001-0.002%. The nickel is incorporated onto a porous support to provide a catalyst with high surface area that can be recovered by filtration. Continuous mixing is a critical parameter since mass transfer of the reactants limits the reaction. The reaction takes 4- 60 min during which progress is monitored by change in refractive index. Upon completion, catalysts are removed by filtration so that they can be used in other reaction.

**Interesterification:** Interesterification, sometimes called 'ester interchange' or transesterification involves an interchange of an acyl groups among triacylglycerols [10]. Since triacylglycerides have three ester groups per molecule, many exchange possibilities exist. Interesterification is performed by acidolysis, alcoholysis, glycerolysis, and transesterification [11]. Transesterification is the most common method used to alter the properties of food lipids. It can be achieved with the aid of any of several catalytic agents, including metallic sodium and sodium methoxide. These latter compounds are classified as low-temperature catalysts and are used at a low level, i.e. 0.002-2.0% [12].

Random Interesterification has been most often applied to lard. Lard is a natural product of somewhat variable composition, which has typically about 2% saturated triacylglycerols ( $GS_3$ ), 27% disaturated

triacylglycerols ( $GS_2U$ ), 47% monosaturated triacylglycerols ( $GSU_2$ ) and 24% triunsaturated triacylglycerols ( $GU_3$ ). The  $GS_2U$  fraction is mostly composed of oleopalmitostearin (OPS), which plays a major role in consistency of lard from 10 to 38 degrees, over which range the solid content index changes from 26 to 2 [13]. Randomization decreases the proportion of palmitic acid in the 2-position of the triacylglycerols from about 64%-24% [14], thus producing a mixture of disaturated acylglycerols, which has a substantially lower melting point than the original OPS. Randomized lard crystallizes in the  $\beta'$ -2 form, which is characteristic of hydrogenated vegetable oil shortenings [10]. This modification of crystal habit of lard results in improved creaming power and ability to incorporate air and has made lard a highly regarded ingredient for quality shortenings based on meat fats [2].

Directed Interesterification produces lard with increased solid content at high temperatures, and thus results in an extended plastic range. Therefore, lard produced in this manner can be used as a shortening without any addition of fully saturated acylglycerols, whereas lard produced by randomization requires addition of stearin for high-temperature stability. The application of tallow as a shortening is not as widespread, although some meat fat shortenings may contain tallow in addition to interesterified lard [15].

Interesterification can also be performed by using lipases as catalysts [16].

## Quality control

The primary role of the laboratory is quality control. The analytical methods described below are used routinely to control the processing steps and to maintain the constant check on product quality.

**Free fatty acid:** Free fatty acid is expressed as percentage of free oleic acid of total sample weight. All fat contains some free carboxylic acids, but these are removed by the refining process. The level of these free fatty acids is measured continuously to check the refining efficiency. The fat is mixed with alcohol (in which the carboxylic acids are soluble but the fat is insoluble) and the alcohol layer removed and titrated with sodium hydroxide. Indicator used in this phenolphthalein. The amount of FFA in tallow is an indication of the degree of spoilage that has taken place. Generally the FFA content should not be more than 2%.

**Iodine number:** It indicates the degree of unsaturation i.e. the number of double bonds present in the length of the chain. The iodine value is low for animal fats and high for vegetable oils. The higher the iodine value, the lower becomes the melting point. In this manner, the presence of pig fats would be detected in tallow allegedly derived from beef sources. Lard-55-65; Rendered Pork fat-60-72; Premier Jus-36-47; Tallow-40-53

**Peroxide test:** This test is used to determine the rancidity of tallow. If the peroxide value is low, this normally suggests that the tallow has not become rancid and will have good stability. Fresh fats have a peroxide value of 1-2, whereas rancid fats have a peroxide value of 15-20. Rancidity is caused by *oxidation* and *hydrolysis*.

**Smoke point:** It is the temperature to which the fat may be heated before it begins to smoke. It has direct relationship with FFA. Tallow with FFA of 0.2% has smoke point of 225 degrees, Tallow with FFA of 1.0% has smoke point of 145degrees and tallow with FFA of 5.0% has smoke point of 120degrees. Lard has smoke point of 121-218degrees.

**Saponification value:** It represents the number of milligrams of *potassium hydroxide* or *sodium hydroxide* required to saponify 1g

of fat under the conditions specified. It is a measure of the average molecular weight (or chain length) of all the fatty acids present. As most of the mass of a fat/triester is in the 3 fatty acids, it allows for comparison of the average fatty acid chain length. The long chain fatty acids found in fats have low saponification value because they have a relatively fewer number of carboxylic functional groups per unit mass of the fat as compared to short chain fatty acids. Lard- 192-203 mg KOH/g of fat, Tallow-190-202mg KOH/g of fat.

**Refractive index:** It indicates the purity and identity of substance. Lard-1.448-1.460, Rendered Pork Fat-1.448-1.461, Premier Jus-1.448-1.460, Tallow- 1.448-1.460

**Melting point:** The melting point of a solid is the temperature at which it changes state from solid to liquid. At the melting point the solid and liquid phase exists in equilibrium. Back Fat: 30-40 degrees, Leaf Fat: 43-48 degrees, Mixed fat: 36-45 degree.

**Moisture, impurities and unsaponifiable (MIU):** Pure fat is virtually free of moisture. Water in tallow is undesirable as it acts a medium for the growth of fat-splitting bacteria and the action of fat-splitting enzymes. Level around 0.2% is desirable. If Polyethylene (oil-soluble impurity) is present in the fat to be used for the manufacture of soap, then it is seen as black specks in the soap in the settling and filtration process. Unsaponifiable matter is the material in tallow that cannot be converted into soap by the use of an alkali. Small quantities occur naturally in a fat. Cholesterol is naturally occurring unsaponifiable fat. Lard-10 g/kg, Rendered Pork fat-12 g/kg Premier Jus-10 g/kg, Tallow-12 g/kg

## Conclusion

Lipids play an important role in food quality by contributing to attributes such as texture, flavor, nutrition and caloric density. As knowledge of the nutritional importance of lipids continue to evolve, manufacturers will need to modify the physical and chemical properties of lipids in order to produce healthy foods with high consumer acceptability. This means that food will likely be produced to contain less of the nutritionally detrimental lipids (e.g., lower in total fat, saturated fat and *Trans fatty acids*). However, to accomplish these goals, researchers will need to have a strong understanding of how lipids impact texture and flavor. Food will also be produced to contain nutritionally beneficial lipids such as omega-3 fatty acids and phytosterols. A thorough knowledge of the physical properties and

chemical stability of lipids will be required to produce functional foods with bioactive lipids since these compounds can be chemically unstable or difficult to physically incorporate into foods.

## References

1. Sonntag NO (1979) Composition and Characteristics of individual fats and oils. In: Bailey's Industrial Oil and Fat products. (4<sup>th</sup> edition), John Wiley, New York, USA.
2. Dugan LR (1987) Meat animal by-products and their utilization. Part 1, Meat fats. In: The science of meat and meat products. Food and Nutrition Press, Westport, Conn.
3. Young V (1980) Processing of oils and fats. In: Fats and Oils: Chemistry and technology, p.135. Applied Science, London.
4. Mattil KF (1964) Deodorization. In: Bailey's Industrial Oil and Fat products. (3<sup>rd</sup> edition), John Wiley, New York, USA.
5. Tirtiaux A (1983) Tirtiaux fractionation: Industrial applications. Journal of American Oil Chemists Society. 60: 473.
6. Luddy FE, Hampson JW, Herb SF, Rothbart HL (1973) Development of edible tallow fractions for specialty fat uses. J Am Oil Chem Soc 50: 240-244.
7. Luddy FE, Hampson JW, Herb SF, Rothbart HL (1977) Physico-chemically designed fat composition from tallow. US patent 4049839.
8. Glassener DA, Grulke EA, Gray JI (1984) Detergent fractionation of tallow. Journal of American Oil Chemists Society 61: 1919-1924.
9. Johnson LA (2002) Recovery, Refining, Converting and Stabilizing Edible Fats and Oils. In: Food Lipids, Chemistry, Nutrition and Biotechnology, Marcel Dekker Inc., New York, USA, p.223-274.
10. Dugan LR (1976) Lipids. In: Principles of food science. Part 1 Food Chemistry. Marcel Dekker, New York, USA.
11. Rousseau D, Marangoni AG (2002) Chemical Interesterification of Food Lipids: Theory and Practice. In: Food Lipids, Chemistry, Nutrition and Biotechnology, Marcel Dekker, New York, USA.
12. Bhati A, Hamilton RJ, Steven DA (1980) Prospects and Retrospects of glyceride-synthesis. In: Fats and Oils: Chemistry and Technology. Applied Science, London.
13. Lutton ES, Mallery MF, Burgers J (1962) Interesterification of lard. Journal of American Oil Chemists Society 39: 233-235.
14. Sreenivasan B (1978) Interesterification of fats. Journal of American Oil Chemists Society 55: 796-805.
15. Wiess TJ (1983) Food oils and their uses. (2<sup>nd</sup> edition), AVI Publishing Company, Westport.
16. Willis WM, Marangoni AG (2002) Enzymatic Interesterification. In: Food Lipids, Chemistry, Nutrition and Biotechnology, Marcel Dekker Inc., New York, USA.