Consortium for Educational Communication

Module

on

Margarine

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Text

1. **HISTORY OF MARGARINE:**

Margarine has been produced for over 100 years. During the 1860's large sections of the European population migrated from country to town and changed from rural to urban occupations. At the same time, there was a rapid increase in population in Europe and a general recession in agriculture leading to a shortage of butter, especially for the growing urban population. As a consequence, the price rose beyond the reach of many poor people. The situation in France was so bad that the government of the day offered a prize for the best proposal for a butter substitute, which would be cheaper and would also keep better. The prize was won by the French chemist, Hippolyte MeÁge MourieÁs who patented his product in France and in Britain in 1869. MeAge-MourieAs tried to emulsify milk with so-called olio-margarine, a fraction of beef tallow. He followed this idea because he was convinced that milk fat was built from the storage fat of the cattle, even if they were not fed. Therefore, his basic idea was to leave out the intermediate step via udder and milk and produce milk fat directly from tallow. In the year 1867, MeAge-MourieAs succeeded in producing a product that was considered acceptable. On July 15, 1869, he asked for approval of a patent that was granted on October 2 of the same year. The product was described as mixed glycerol esters of oleic and margaric acids and was therefore called oleo-margarine. Margaric acid was thought to be heptadecanoic acid (17:0) though it was actually a eutectic mixture of palmitic (16:0) and stearic (18:0) acids.

The patented process starts with the slow cooling of melted beef tallow. The recipe read as follows, "The stearin fraction melting above 30°C is separated and the oil that accounts for two thirds of the beef tallow is amalgamated with the same amount of skim milk and 0.1-0.2% of freshly cut cow udder. The emulsion is shock-cooled with ice water and kneaded to achieve plasticity."

The name used for the new product "margarine" is derived from the Greek word for pearl "margarites," describing the pearly gloom of the beef tallow fraction used. At the beginning of the German-French war, a margarine factory was erected very quickly in Passy not far from Paris, but soon after had to be closed following the complete defeat of the French army. The patent for margarine making was then bought by the two Dutch butter dealers, Simon van den Bergh and Anton Jurgens. Those two in particular ensured that production locations were set up all over Europe in the following years and that margarine gained great distribution. In many European states, the launch of margarine was not appreciated by the butter producers, the wealthy landed aristocracy who did whatever they could to close off their home markets from the imitation product.

At the beginning of 1886**,** the imperial government became active and proposed a law concerning the traffic in the so-called artificial butter. One of the main aims was to make margarine easily distinguishable from butter. First, plans to color margarine blue were rejected by the social democrats who feared that the difference between children of rich butter-eaters and those of poor margarine-eaters would become apparent in the school yards. Other discriminating restrictions such as the limitation to special packaging formats (cubes and truncated cones) remained in place in Germany until the end of 1985. After the first detailed scientific discussion of margarine by Soxhlet in 1895, another famous chemist, Volhard, spoke about margarine in 1896 in a speech delivered to the annual meeting of the Society of Natural Science of Halle. He explained its composition and ingredients and tried to explain that it was not a imitation of butter but a product of its own. He said, "Margarine has nothing to do with the falsification of butter." Margarine making obviously had already reached a high standard, because he continued: "In good margarine halls . . . you find a surprising degree of hygiene that impresses the visitor."

For a long time, margarine was considered as a cheap and inferior substitute for butter. In several countries regulations were passed that prohibited the addition of colouring matter so that white margarine would compare even less favourably with the more familiar yellow butter. Now the situation is different. These impediments have disappeared and margarine is widely accepted as having several advantages over butter. It is a more flexible product which can be varied for different markets and modified to meet new nutritional demands such as desirable levels of cholesterol, phytosterols, saturated or trans acids, and fat content, as well as the statutory levels of certain vitamins.

At present, excluding China, 9 million tons of margarine are being produced per year. Margarine therefore plays a significant role in nutrition. Margarine accounts for

25% of the fat intake of the northern hemisphere's population, approximately equal to the consumption of butter.

2. INTRODUCTION:

Table margarine is made from appropriate oils and fats (soybean, rape/canola, cottonseed, palm, palm kernel, coconut) which may have been fractionated, blended, hydrogenated in varying degrees and/or interesterified. Fish oil (hydrogenated or not) may also be included. Other ingredients include surface-active agents, proteins, salt, and water along with preservatives, flavours and vitamins.

Margarine production involves three basic steps: emulsification of the oil and the aqueous phases, crystallisation of the fat phase and plastification of the crystallised emulsion. Water-in-oil emulsions are cooled in scraped-wall heat exchangers during which time fat crystallisation is initiated, a process known as nucleation, and during which the emulsion drop size is reduced. There follows a maturing stage in working units during which crystallization approaches equilibrium, though crystallisation may continue even after the product has been packed. The lipid in margarine is part solid (fat) and part liquid (oil) and the proportion of these two varies with temperature. The solid/liquid ratio at different temperatures is of paramount importance in relation to the physical nature of the product. Individual crystals are between one tenth and several micrometres (μm) in size and form clusters or aggregates of 10-30 μm. The aqueous phase is present in droplets, generally 2-4 μm in diameter, stabilised by a coating of fat crystals.

It is desirable that margarine taken from the refrigerator at 4°C should spread easily. For this, the proportion of solids should be 30-40% at this temperature and should not exceed the higher value. For the sample to 'stand up' at room temperature (and not collapse to an oily liquid) it should still have 10-20% solids at 10°C. Finally, so that it melts completely in the mouth and does not have a waxy mouth feel, the solid content should be less than three per cent at 35°C. These important parameters can be attained with many different fat blends. Formulations have to be changed slightly to make the product suitable for use in hot climates.

Fats usually crystallise in two different forms known as β' and β. Of these the β form is thermodynamically more stable and will therefore be formed in many fats and fat blends. But sometimes the fat remains in the β' form. For margarines and other spreads the β' form is preferred since the crystals are smaller, are able to entrap more liquid to give firm products with good texture and mouth feel and impart a high gloss to the product. β Crystals, on the other hand, start small but tend to agglomerate and can trap less liquid. It is therefore desirable to choose a blend of oils, which crystallise in the β' form.

Margarines and shortenings made from rapeseed/canola, sunflower and soybean oil after partial hydrogenation tend to develop β crystals. This can be inhibited or prevented by the incorporation of some cottonseed oil, hydrogenated palm oil, palm olein, tallow, modified lard, or hydrogenated fish oil: all of which stabilise crystals in the form. The canola, sunflower, and soybean oils all have high levels of C18 acids, while the remaining oils have appreciable levels of C16 acids (or other chain length) along with the C18 acids and thus, contain more triacylglycerols with acids of mixed chain length. There are many formulations for making margarines, and different recipes are used around the world depending on the oils most readily available in any particular locality. Practically all of them contained partially hydrogenated oils and therefore, had appreciable levels of trans acids. Attempts are now being made to reduce the levels of such acids on nutritional grounds.

Considerable progress has been made in European formulations and the average content of trans acids has fallen in recent years. Many preparations approach zero trans. However, it must be realised that it is not possible to make spreads without a proportion of solid triacylglycerols which must contain saturated and/or trans monoene acids. If the level of trans acids is to fall, then there must be some rise in the content of saturated acids. Nor is it sufficient merely to blend hardstock (material with a high proportion of solid triacylglycerols) with oils containing 'healthy' mono and polyunsaturated acids. The blended oils may have to be interesterified to get the appropriate distribution of fatty acids in the triacylglycerols.

It is not possible to list all the formulations used to make margarines and the following examples are merely indicative (in the following blends hydrogenated means partially hydrogenated):

- Blends of hydrogenated soybean oils with or without unhydrogenated soybean oil,
- Blends of canola oil, hydrogenated canola oil and hydrogenated palm oil or palm stearin,
- Blends of various hydrogenated cottonseed oils,
- Blends of edible tallow with vegetable oils (soybean, coconut),
- Blends of palm oil with hydrogenated palm oil and a liquid oil (rapeseed, sunflower, soybean, cottonseed, olive),
- Palm oil (60%), palm kernel oil (30%) and palm stearin (10%),
- Palm stearin (45%), palm kernel oil (40%) and liquid oil (15%).

For hot climates a harder formulation is required as in the last two examples from Malaysia.

Margarine is expected to have a shelf-life of about 12 weeks. With good ingredients and absence of pro-oxidants (copper), oxidative deterioration is not likely to be a problem but care must be taken to avoid microbiological contamination in the aqueous phase. This is avoided by hygienic practices during manufacture, the addition of some salt (8-10 per cent in the aqueous phase, corresponding to a little over 1 per cent in the margarine), control of pH of any cultured milk that may be used, and careful attention to droplet size in the emulsion.

Margarines are now available with added phytosterols which, it is claimed, are able to reduce blood cholesterol levels. The phytosterols are obtained from tall oil and added as hydrogenated sterol esters or from soybean oil and added as unsaturated sterol esters to margarines at around the eight per cent level. Margarine is a suitable vehicle for phytosterol addition because it is a food used widely and regularly but unlikely to be over-consumed. Intake of phytosterols is normally 200-400 mg/day, though higher for vegetarians, and the intake of 1.6-3.3 g/day, recommended by those offering this special margarine, is markedly higher. Normally about 50 per cent of ingested cholesterol is absorbed but with an adequate supply of phytosterols, which are absorbed only at the five per cent level, absorption of cholesterol falls to about 20 per cent.

3. STRUCTURE OF MARGARINE:

Margarine is an emulsion of the type water in oil, consisting of 80% fats and oils, and 20% of an aqueous phase, which like the oil phase contains soluble ingredients. About 20% (minimal 12%) of the triglycerides of the fat blend are solid at room temperature, the remainder is liquid. During processing, a phase-inversion takes place in the emulsion so that, in margarine, water is the dispersant; oils and fats constitute the continuous phase. That means that water is dispersed in droplets in a continuous oil matrix. The oil phase of a margarine as well as the structure of processed shortening is not homogeneous, but consists of a network of fat crystals and of agglomerates of fat crystals with liquid oil distributed in between. Margarine draws its mechanical stability from the crystal network as well as from the stability of the emulsion. The bonds of the finely dispersed water droplets contribute to the stabilization of the emulsion; the surface of these droplets can constitute up to 750 m^2 kg of margarine. The disadvantage of this fine water droplet distribution is the very slow release of flavors and salt during its melting in the mouth. Water droplets with a size <5 pm are the objective; such droplets are smaller than bacteria so that any bacteria (should they be present or brought in during open shelf life) cannot multiply. Therefore, provided storage conditions are adequate, the emulsion is microbiologically relatively stable.

To achieve a certain consistency, the crystal networks built often have to be destroyed intentionally by overworking. By agglomeration of crystals (secondary bond), stability is regained. Crystal growth continues after the product has been processed and wrapped or filled into tubs; the margarine matures and stiffens up.

4. COMPOSITION OF MARGARINE:

Margarine contains 80% oil, with 40% in the half-fat margarines or minarines that were first introduced in 1964. In some countries, this amount can be chosen deliberately. The oil phase contains the fat-soluble ingredients. These are usually fat soluble flavors, vitamins as well as emulsifiers and carotenes. The aqueous phase holds the water-soluble ingredients, which are generally water-soluble flavors, salt, milk or milk solids, and in special cases, preservatives. Margarines with lower-fat content also contain stabilizers, e.g., gelatin, and ingredients to increase the dry matter content, e.g., milk powder. According to the local taste in the different countries or following special legislation, the amount of individual ingredients may exceed. In some countries, vitamins, for example, are added in much higher amounts than shown to fight malnutrition, because margarine is the only source of fat-soluble vitamins in the diet. In some countries, the use of hardened fats is or was not allowed until recently. In others, the use of flavors and coloring agents is forbidden. For countries in which the trade keeps margarine in the cool cabinet, the fat composition can be slightly softer. For tropical countries, the content of consistent fats must be considerably higher.

4.1 Fat blend:

The choice of the fat blend of the margarine follows three criteria, namely, the achievement of certain physical properties, the presence of claims or declaration on the pack and nutritional physiological considerations. Considering those criteria, a fat blend can vary within relatively wide limits, because oils and fats are themselves refined to be mainly neutral in taste and have equal or at least similar physical properties and chemical composition. Bearing in mind the above criteria, the fat blend composition can be optimized to give the lowest cost. The blend composition for margarine has changed dramatically over the last century of its development in the market. At present, animal fat has almost completely disappeared, and vegetable oils and fats are dominant in almost all countries. The fat blends are composed in such a way as to yield a certain consistency at a given temperature; the solids content at that temperature is the measure.

4.2 Emulsifiers:

Emulsifiers stabilize the emulsion. After the introduction of the process of cooling in scraped surface heat exchangers, they are less important for margarine production than before when the churn-drum process was used. However, they are still one of the most important ingredients. The main emulsifiers used are lecithin and monodiglycerides.

4.2.1 Lecithin: Lecithin replaces the egg yolk that was the only emulsifier in margarine in the old days. For that use, it was necessary to produce specially purified lecithins. By using the alcohol fractionation process, it is possible to achieve a ratio of choline-lecithin:cephaline of >5:1. Such lecithin fractions work as antispattering agents when margarine is used for frying. In additon, workability in puff pastry margarines is improved.

4.2.2 *Monodiglycerides:* Monoglycerides and monodiglycerides are naturally associated with oils and fats. They can be produced by the reaction of fats and oils with glycerol. Their surface-active properties that stabilize the emulsion are due to the hydrophilic properties of the glycerol-OH residue and the lipophilic properties of the fatty acid chains of the ester. In addition to their ability to influence consistency by stabilizing the emulsion, there is a second effect. Monodiglycerides have a melting point that lies 10-20°C above the melting point of fats and oils that are composed of the same fatty acids. Therefore, during cooling, they crystallize early on in their position around the water droplets between the water and the oil or fat phase. This creates additional stability. Monodiglycerides crystallize in the same different crystal modifications as do fats. Because they are part of the natural metabolic chain during digestion of triglycerides, there is no limitation on daily intake. The suitability of the emulsifiers for certain types of emulsions can be described by the HLB-value (hydrophilic lipophilic balance). For each type of emulsion, a certain HLB-value is necessary.

4.3 Milk Components:

In some countries, milk components are prescribed as ingredients. Most margarines contain milk solids. On the one hand, this can be understood historically from the attempt to imitate butter. During shallow frying, a sediment is built that is responsible for the browning (Maillard reaction; protein lactose interaction). Most consumers want this property. In addition, the finely dispersed proteins and lactose bind boiling nuclei when the water is evaporated from the melted emulsion. This decreases spattering. In addition, all milk components that have passed a souring step carry flavors, traces of butyric acid, ketones, lactones as well as diacetyl and its precursors. These substances work as flavors on the one hand, and at the same time, they mask off-flavors that arise during long storage of the margarine. Milk proteins also reduce the tendency of the fat to oxidize during frying.

4.3 Acids:

Acids have to fulfill several tasks. On the one hand, they lower the pH value, improving bacteriological stability. In addition, they create a better, fresh taste. The use of lactic acid gives a peaked, fresh taste. Citric acid is a milder acid with the additional benefit of binding metals such as iron in a complex, which tremendously reduces the sensitivity of the oil to autoxidation.

4.4 Salt:

Salt has two functions. One is to decrease the microbiological sensitivity; the other is to act as a flavor. Sodium chloride is the commonly added salt; however, potassium chloride can be used in sodium-free margarines. Salt content differs greatly from country to country. The other role for salt results from its bacteriostatic behavior. In margarines with salt contents >2% product weight, this value is reached in the aqueous phase because the water content of margarine is 20% at maximum. In addition to these properties, salt levels ~ 0.2% work as an antispattering agent during shallow frying.

4.5 Flavors:

The flavor cocktails used in margarine making work as flavors and flavor enhancers; they also mask off-flavors. The flavors used depend on the geographical region, i.e., the local taste, and can range from bland to over-buttery to cheesy. If butter is normally slightly rancid in the respective country, this can also be reflected by the flavor notes used. Dosage also is done according to local preference. Many synthetic butter flavors are also added in margarine. They are usually based on mixtures of compounds that have been identified as contributing to flavor of butter, such as lactones, butyric fatty-acid esters, ketones, and aldehydes.

4.6 Preservatives:

Preservatives are rarely used in 80% fat margarines in countries with moderate climate, households equipped with refrigerators and well-developed logistic chains. In reduced-fat margarines, they are not necessary for production, but are needed to protect the product during open shelf life. Margarine preservatives fall into three categories: antimicrobial, antioxidant, and metal scavenger. Antioxidants are necessary for the oxidative stability of products formulated with meat. Vegetable oil margarines usually don't require antioxidants as the tocopherols present in them act as antioxidants. Scavengers such as ethylenediaminetetraacetic acid (EDTA), isopropyl citrate etc tie up or chelate trace metals that act as catalysts in oxidation. Some principally used preservatives in margarine are:

4.6.1 *Benzoic acid:* Benzoic acid is added in a concentration of ≤ 0.1%. It works as a preservative in the undissociated form only. A minimum acidity is necessary therefore to block dissociation and to dissolve the acid from its salts when benzoates are used. The dissociation constant is 6.46×10^2 which means that the pH that is reached applying lactic acid is already sufficient. However, the pH of common margarine is only a little lower than that needed to ensure the efficacy of benzoic acid. Above that, the distribution coefficient between the fat and water phase is very unfavorable. The working mechanism of benzoic acid is based on the inhibition of enzymes belonging to the acetic acid cycle. It also inhibits oxidative phosphorylation as well as the citric acid cycle and has a negative influence on cell walls.

4.6.2 Sorbic acid: Sorbic acid usually is allowed up to 0.12%, but the amount used is normally lower. Sorbic acid is 50% more effective than benzoic acid and is used mainly in reduced fat margarines. The distribution coefficient between the oil and water phase is favorable. In the human body, it decomposes into water and carbon dioxide. The working mechanism of sorbic acid is based on the inhibition of enzymes of the carbohydrate cycles and the citric acid cycles. Sorbic acid forms covalent bonds with SH-groups of the enzymes, thus inactivating them. In addition, it has negative influence on the cell walls.

4.7 Thickening Agents and Stabilizers:

In half-fat margarines or margarines with an even lower amount of fat, the emulsion on its own is no longer able to stabilize the product. Therefore, thickening agents or stabilizers, (for example, gelatin), are used to stabilize the water phase.

4.8 Colorants:

In Europe, margarines usually are not colored with artificial colors. Often, however, β-carotene is added; it dissolves in the oil to give a reddish color. In many countries, Bixin and Annatto are allowed in margarines.

4.9 Vitamins:

Vitamins are added to almost all household margarines. In some countries, the addition at the level that is usually present in butter is mandatory. Usually, fat-soluble vitamins A, D and E are used. In geographical regions with deficiencies in water-soluble vitamins, some B and C vitamin addition is also common. Margarines should not contain less than 15,000 international units (IUs) of Vitamin A per pound. Addition of vitamin D is optional, when added should be about 1500 IUs per pound of margarine.

4.10 Water:

Water usually stems from wells on the margarine factory sites or is taken from the municipal net. Water quality must be monitored constantly.

4.11 Air and Nitrogen:

Some margarines and fats are whipped with nitrogen or air to soften the products (so-called soft margarines). In most countries, the gas used for whipping has to be declared on the ingredients list.

4.12 Starch:

Until some years ago, in some European countries, starch had to be added to margarine to enable adulteration of butter with margarine to be detected. This legal requirement stems from the last century, because current modern analytical techniques allow easy detection of adulteration without the addition of marker substances such as starch or sesamol. Starch has no function at all in margarine. On the contrary, it negatively influences its spattering behavior.

5. PHYSICAL PROPERTIES:

Margarine is plastic, which means that its internal repulsive forces are not sufficient to bring it back to its original shape when it is deformed under outer pressure. Because the inner structure of margarine can be softened under mechanical influence (e.g., kneading), the structural bonds are then destroyed so that only the molecular bonds between the crystals stay in place. Hardness and flow limit of margarine are closely connected.

Heart health margarines with a guaranteed high amount of polyunsaturated fatty acids are much softer that other margarines due to their fatty acid composition. Hardness of margarine is determined by many factors. If it crystallizes in the pack, i.e., after production, this results in a much harder product because the margarine can no longer be overworked mechanically. The lower the oil content, the harder the product. Primary bonds between the crystals stay intact even during the mechanical overworking; secondary bonds are broken up. Strong primary bonds therefore contribute greatly to hardness. The higher the shear stress during overworking, the more the continuous structure turns into a grainy structure. Air or gas, whipped in intentionally or unintentionally, also influences hardness. Proportional to the amount of gas, the number of crystals per volume decreases; margarine becomes softer. By comparison, for butter, churning leads to an *air* content of 5%, soft margarines contain 10-20% air or nitrogen.

6. MARGARINE PRODUCTION:

Production of margarine consists of some principal steps starting from refined oils and fats. These principal steps are shown in the figure. Apart from the fat blend, the properties of the finished product are really influenced only by steps C and D. The composition of the ingredients has only a minor influence. Posthardening after packaging cannot be influenced and is based on the properties that are inherent from steps C and D.

A — **Premix, proportioning pumps or systems in between**

B — **Stirrer, static mixers**

C — **Crystallizers (multiple)**

D — **Scraped surface heat exchangers destroying natural hardness**

E — **Post crystallization and hardening**

Steps of margarine production

6.1 Ingredient Preparation:

There are two extreme variations in the way that ingredients are prepared and added. On the one hand, it is possible to prepare single aqueous or oily solutions of single ingredients and then blend them with the fat blend, the water, and the milk by means of a multihead proportioning pump (proportioning process); static mixers built into the tubes then emulsify the mixture. On the other hand, the complete margarine composition including fat and water phase and all ingredients can be mixed in one batch from which the emulsion is then directly processed through a scraped surface heat exchanger (premix process). In between those two extremes, all intermediates of ingredient and emulsion preparation are possible, and there are examples in the industry for all of these intermediate steps. Using the premix process, the water content of the emulsion is checked only once per batch (continuously good agitation assumed). If proportioning pumps are used, the water content has to be checked at intervals on a statistical basis over the period of production. The aqueous phase should be pasteurized. This can be done with the whole emulsion as well as with single solutions. Soured milk as such cannot be pasteurized because the protein would coagulate and become sandy. This would be possible only after the addition of protection colloid. However, pasteurization is not necessary if the milk has been soured under hygienic conditions and the source sweet milk has been pasteurized. This means that the soured milk has the same bacteriological status as a post-pasteurized soured milk except for the souring cultures. These stay alive, but they are no longer active in margarine because the temperature is too low and the size of the water droplets does not allow for it.

6.1 Milk souring:

As a source for the production of soured milk, pasteurized fresh milk or milk that is reconstituted from milk powder and water is used. The milk is pasteurized and soured with cultures such as *Streptococcus lactis* or *S. cremoris.* Souring can be carried out with parts of a mother culture that is inoculated or by using deep-frozen or freeze-dried cultures purchased from a third party. Souring itself also follows this pattern. Ripening of the milk takes about 12 h. The soured milk is stored in hygienic, cooled batches and transported via a piping system. Cleaning of this system requires special care. When proportioning pumps are used, milk is dosed *via* a dosing cylinder. In addition to bacteriological souring, there is also the possibility of chemical souring. For that purpose, citric acid or lactic acid is added to the sweet milk. The influence on the milk protein is similar to bacteriological souring; however, none of the flavors that develop in bacteriologically soured milk will be present. If milk, buttermilk or whey powder is used, it is dissolved in water and stored in a batch. For cleaning, there are the same requirements as for milk.

6.2 Water-soluble ingredients:

The water-soluble ingredients such as salt, preservatives and water soluble flavors are prepared singly or as a mixture. Usually, they are rinsed into the storage batch by circulation over a Venturi-tube or collected from mother solutions. Such solutions can also be purchased as such (e.g., brine).

6.3 Oil-soluble ingredients:

These include lecithin, mono and diglycerides, vitamins and, to some extent, oil soluble flavors. Oil-soluble ingredients are dissolved either in a single oil or in the relevant margarine fat blend. In both cases, the amount of fat from the prepared ingredients has to be taken into account when calculating the total composition. If one-oil margarines (e.g., sunflower margarine) are produced, the oil for dissolving the ingredients must be the same oil as for the margarine, unless legislation allows for a certain amount of foreign triglycerides. To avoid crystallization of the emulsifier (monoglycerides and monodiglycerides), the ready-prepared ingredients mixture has to be stored warm ($T > 55°C$). Depending on the ingredients, it may also be necessary to agitate to avoid sedimentation.

6.4 Oil/fat blend:

There are two principal possibilities for preparation of the fat blend. One is to blend fully refined oils and fats the other is to compose the blend from crude oils and to refine the complete blend. Of course, it is also possible to combine both alternatives, which means blending fully refined oils and fats with fully refined fat partial blends. The assembly of the oil in a batch is done gravimetrically over a composition weigh scale or volumetrically over a rotary piston meter or a mass flow meter. With today's methods of electronic process control, it is possible to compensate for the volume differences of oils and fats of different temperature so that flow meters can provide the same accuracy as weigh scales if the amounts are not too small. Bacteria cannot grow in the oil-fat composition. It is therefore not necessary to pasteurize the oil blend. Pipes should be flushed regularly with hot oil to remove the fat sediments on their walls. In fact, it is important to exclude water from these vessels and pipes to maintain quality.

6.5 Emulsifying:

To emulsify the oil and water phases, they have to be mixed carefully. Depending on the process chosen, this is done at least partly in the premix batch or later in the proportioning pump. Usually additional static mixers built into the pipes complete the task. Emulslfying is easily accomplished because all margarine compositions contain sufficient emulsifiers that support it. At first, an emulsion of the type oil in water is built; this is converted by phase inversion into an emulsion water in oil.

6.6 Cooling (Crystallization) and Working of the Emulsion:

To achieve the desired consistency, the margarine fat-oil blend must be properly composed to achieve these properties. Within the given limitations of the specific fat blend, the consistency of the margarine can be heavily influenced by processing. In principle, processing is a sequence of cooling steps that start crystallization at different temperature levels, i.e., holding zones that allow for further crystallization without cooling and application of mechanical stress to break up secondary bonds to the degree desired. Heat has to be deducted as well to cool down the emulsion and to remove heat of crystallization. Fats and oils crystallize relatively slowly, some very slowly. If slowly crystallizing fats such as palm oil at 60°C are set in a bath of 0°C and are cooled down, it takes up to 2 h until they are fully crystallized.

6.8 Packing:

Today, margarine is immediately packed after it has left the processing unit. The packaging material's task is to give optimal protection to the product during transport, shelf life, and use. For household margarine, an appealing design would improve sales promotion. In addition to the mechanical protection that the product needs as it leaves the processing unit in a soft state, protection from light and oxygen is necessary. Beyond that, the packaging should be as water tight as possible to prevent margarine from drying out. Surface water evaporates from the product until the head space between product and packaging (lid) is saturated. If the pack is tight, drying out is low. If not, water vapor can escape the pack so that it evaporates more and more from the product surface. A dark yellow surface, the characteristic color of the dried out fat phase, remains.

7. SPECIAL MARGARINES:

Margarines for special purposes differ in their properties of use, characterized by their C-value and their solids content. C-value gives an idea of the hardness or softness of margarine. Usually, it ranges from 100-1500, but could be higher. Margarines with C-value less than 100 are not spreadable, as they are too soft and flow away. A C-value of >1500 designates margarine that is too hard and difficult to spread.

7.1 *Cream Margarine*: Usually, cream margarines have low melting points (30-34°C). They are used for cake fillings and decoration and must be whippable, i.e., hold the air whipped in, which is achieved mainly by the enormous number of fine crystals. In spite of their low melting point, they must have a high fat content. Despite that, a quick melting in the mouth (steep dilatation curve) is required, combined with a cooling effect. Coconut oil is ideal for such products. The good creaminess of such margarines is based on quick crystallization. Therefore, interesterified lard is also a good starting material. Coconut oil has a very fluctuating price and is usually very expensive. Therefore, it is used mainly for premium-brand cream margarines. In cases in which a firmer consistency is desired, the proportion of hardened oil has to be increased at the expense of oil or hardened oil.

7.2 *Bakery Margarine*: Bakery margarines have a higher melting point (35-38°C) than those products produced for direct consumption. They do not have to melt in the mouth, but are designed to separate the crumbs as long as possible by breaking the continuity of the protein starch structure. This characteristic and their function as nuclei for boiling (steam formation that puffs the baked goods) ensure tender cake. The composition of bakery margarines resembles that of firm cream margarines.

7.3 *Puff Pastry Margarine*: Puff pastry margarine has to meet high demands on its tenacity. In puff pastry, it has to ensure that the many layers of the laminate stay separated. In the lamination process (whether hand or machine made), the thin layer of margarine must not break, but has to adapt to the laminate in smooth, very thin layers, i.e., it has to have high plasticity. Its C-value is very high (up to 2600), and its melting point of 40-44°C is considerably higher than that of bakery margarine. Yet even today, puff pastry margarine is sometimes produced on cooling drums. The plasticity of margarines is inversely related to the amount of product that postcrystallizes after having left the processing unit and emulsifying unit.

7.4 Half-Fat Margarine: Most margarine laws allow for half-fat margarines with fat contents prescribed 40%. The demand for these products has increased considerably over the past 30 years, because they offer a real opportunity for reduced calorie intake while maintaining good taste. In such reduced-fat products, the water phase has to be stabilized with thickeners, because the emulsion and the crystal network alone are not able to guarantee temperature stability and good shelf life properties. In addition, dry matter is increased by the addition of milk proteins as milk powder. Half-fat margarines normally contain preservatives, because the water droplet distribution is much coarser than with normal margarine, and therefore they are much more sensitive toward microorganisms that find ideal conditions in which to grow. The production of sterile half-fat margarines is not a problem, however, because machinery for aseptic filling exists. The only drawback is some expenditure for the sterilization of the packaging material. The crucial point is the period of open shelf life, i.e., the period of use at home. Even if produced and delivered in a sterile condition, a non preserved low-fat margarine is exposed during use to ambient conditions that can cause quick spoilage.