Mayonnaise

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Introduction and Origins

Mayonnaise is an emulsion of oil droplets in water, a so-called oil-in-water (O/W) emulsion. Such emulsions are characterized by the presence of a dispersed phase of oil and oil-based ingredients, an emulsifier or combination of emulsifiers, and a continuous phase of water and water-based ingredients. The oil-based ingredients may be soluble or suspended in oil; likewise, the water-based ingredients may be soluble or dispersed in water. In mayonnaise, the emulsifier is typically egg-based, and the water phase typically contains vinegar.

O/W emulsions are prepared by simply blending an oil phase into a water phase in the presence of an emulsifier. Mayonnaise typically has a thick and spoonable texture that is derived from the viscosity of the water phase and/or the high dispersed oil content. The oil droplets in mayonnaise are typically of the order of 5 μm in diameter, resulting from a combination of the egg-based emulsifier and the manufacturing equipment. A light micrograph of a mayonnaise product is given in Figure 1, clearly showing a multiplicity of dispersed oil droplets (image courtesy K. Groves, Leatherhead Food Research).

Mayonnaise is believed to have originated in the mid-eighteenth century when the original concept was brought back to France in 1756 from Mahón, a city on Minorca. It was created for a victory banquet to celebrate the capture of Mahón by forces under Louis François Armand de Vignerot du Plessis, duc de Richelieu (1696–1788), a marshal of France and a grandnephew of Cardinal Richelieu. The new sauce, made with olive oil instead of cream, was named Mahónnaise in honor of the victory. The word evolved to mayonnaise, probably deriving from the old French words for egg yolk and to stir or blend, *moyen* and *manier*. Later on, the French chef Marie Antoine Carême (1784–1833) lightened the original recipe by blending the vegetable oil and egg yolk into an emulsion. This product, presumably containing water as part of the emulsion, became the basis for the mayonnaise product that we know today.

Perhaps, the first and most well-known commercial product was introduced by Richard Hellmann in the early twentieth century. Hellmann emigrated to New York City from Germany in 1903, and in 1905, he opened a delicatessen, selling salads that contained his wife's recipe for mayonnaise. Customer demand was such that Hellmann began selling the mayonnaise itself, in the 'wooden boats' that were used for weighing butter. The mayonnaise ultimately made it into jars, and in 1912, the label incorporated a 'blue ribbon' design to identify the preferred recipe. The blue ribbon survives to this day. Hellmann's mayonnaise is now owned by Unilever and is produced and consumed worldwide.

Types

Compositional Standards

Products sold as 'mayonnaise' are manufactured, distributed, and sold worldwide. The compositional standards vary widely, but there appears to be common agreement regarding the key components, namely, vegetable oil, acidifying agent, and egg components. These ingredient types will be described in section 'Key Ingredients.' The compositional standards tend to refer to a minimum content of fat or vegetable oil, with occasional references to the levels of the other key components.

In Europe, the Codex standard 168 for mayonnaise from 1989 quotes a minimum total fat content of 78.5% and a minimum 'technically pure' egg yolk content of 6%. However, this does not appear in the 2014 list of Codex standards but may still be considered to be a reference point for what tends to be known as 'real' mayonnaise; see succeeding text.

In the United States, the FDA 'Requirements for Specific Standardized Food Dressings and Flavorings,' Sec. 169.140 from 2013, quotes a minimum vegetable oil content of 65%, one or both of acetic acid (minimum 2.5%, from vinegar) and citric acid (minimum 2.5%, from lemon and/or lime juice), and egg yolk-containing ingredients.

In South Africa, Government Notice No. R. 92 of 1986 quotes a minimum vegetable oil content of 52%, together with an acidifying agent and 'egg or modified milk protein.'

In addition to the vegetable oil, acidifying agent, and egg components, there are a number of optional ingredients in all of the compositional standards, some of which are described in section 'Key Ingredients.'

Real Mayonnaise

Real mayonnaise tends to comply with the Codex compositional standard for mayonnaise, specifically the minimum fat and egg contents of 78.5% and 6%, respectively. For example, in the United Kingdom, Hellmann's Real Mayonnaise contains 79.1% fat (77% vegetable oil) and 8% egg and egg yolk.

Full-Fat Mayonnaise

Full-fat mayonnaise typically contains in the region 65–75% fat, although fat contents outside of this range are known. For example, Sainsbury's Mayonnaise in the United Kingdom contains 78% rapeseed oil, and Calvé Mayonaise in the Netherlands contains 70 g fat per 100 ml (approximately 66% w/w). The products with the lower fat contents in this category tend to include one or more thickening agents in the formulation in order to provide the desired thick and spoonable texture. The Calvé product, for example, contains xanthan gum.

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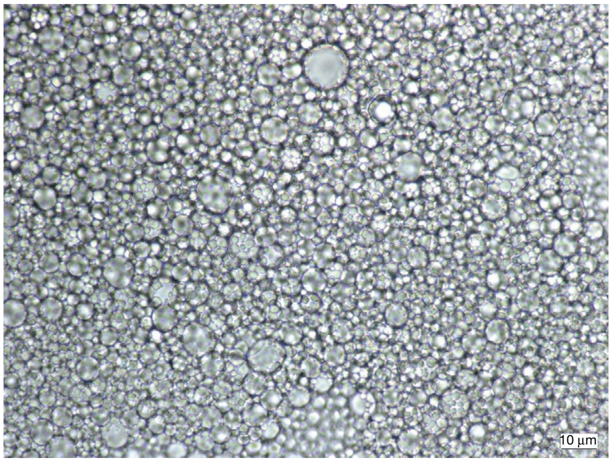

Figure 1 Light micrograph of full-fat mayonnaise.

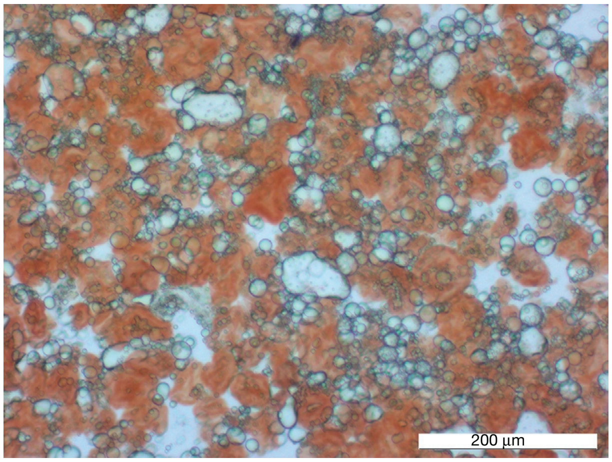

Figure 2 Light micrograph of light mayonnaise.

Confusingly, the 'Basics' mayonnaise from Sainsbury's in the United Kingdom contains only 25% rapeseed oil, presumably in an attempt to provide a low-cost option by replacing much of the oil with water. In this case, the texture has been maintained by the addition of modified maize starch, xanthan gum, and guar gum.

Light Mayonnaise

There are a multiplicity of 'reduced-fat' and 'light' mayonnaise products on the market, and they typically contain in the region 20–30% fat, although fat contents outside of this range are known. For example, in the United Kingdom, Hellmann's Light Mayonnaise contains 28% vegetable oil, and Sainsbury's Reduced Fat Mayonnaise contains 26% rapeseed oil. Both products contain modified maize starch and xanthan gum (also guar gum in Hellmann's) in order to provide the desired thick and spoonable texture. This combination of thickening agents is very common in dressing products generally.

Because of the reduced levels of fat, light mayonnaise requires lower levels of egg-based ingredients for emulsification. The Hellmann's and Sainsbury's products contain 4.2% egg and egg yolk and 3% egg yolk, respectively.

The microstructure of such products comprises a combination of an O/W emulsion as for full-fat and 'real' mayonnaise and a modified starch gel. It is likely that the starch gel dominates the texture with the emulsified oil droplets merely filling the structure. A light micrograph of a light mayonnaise is given in Figure 2, showing swollen starch granules (stained brown in iodine solution) and dispersed oil droplets (image courtesy K. Groves, Leatherhead Food Research).

Extra Light Mayonnaise

Extra light mayonnaise typically contains less than 10% fat. In the United Kingdom, Hellmann's Extra Light Mayonnaise contains 3% fat, with citrus fibers in addition to modified maize starch and xanthan gum being used to provide the desired thick and spoonable texture. Although hardly required for emulsification, the product contains 4% egg and egg yolk. The microstructure of extra light mayonnaise comprises a thickened starch-based water phase with a small amount of emulsified oil droplets.

Other Mayonnaise Types

Apart from the main types of mayonnaise products described earlier, there are a number of flavor variants, including garlic, lemon, and chili, as well more specialized types such as organic and egg-free. Egg-free mayonnaise contains alternative emulsification agents such as soya or pea protein.

Key Ingredients

Oils

The main types of vegetable oils that are used in mayonnaise products are rapeseed, sunflower, and soybean. These oils are all liquid at room temperature and can easily be emulsified at ambient temperature or above, depending on the required processing methodology. They tend to support omega-3 claims for the mayonnaise, depending on the levels applied. Sunflower oil can form waxes at chill temperatures, leading to cloudiness and possibly emulsion instability. It is therefore often 'winterized' to remove the waxes for use in mayonnaise.

Olive oil is applied at relatively low levels in olive oil mayonnaise. At higher levels, it can tend to impart a bitter taste, is relatively expensive, and can form waxes at lower temperatures, especially in the case of the extra-virgin grades. For example, in the United Kingdom, extra-virgin olive oil mayonnaise from Waitrose contains 5% extra-virgin olive oil.

Egg Ingredients

Egg-based ingredients are used in all mayonnaise products primarily for the emulsification of the vegetable oils. The phospholipids and to some degree the proteins impart the emulsification ability of yolk. Egg yolk can also contribute color and flavor at the appropriate levels. The egg-based ingredients are generally egg yolk or a blend of whole egg and egg yolk. They are pasteurized and supplied in either liquid or frozen form.

The ingredients contain salt as part of the preservation system, for example, egg yolk '92-8' comprises 92% egg yolk and 8% salt. An alternative system is '92-7-1,' which comprises 92% egg yolk, 7% salt, and 1% potassium sorbate. Egg yolk powder is also used in some products.

Whole egg tends to be applied in products for which the egg white component contributes to the structuring of the water phase, resulting in a more spoonable-type texture. For the viscous products, egg yolk alone is used.

Modified egg yolk is applied in many products. In this case, the egg yolk has been treated with the phospholipase A2 enzyme to improve the emulsification capability and generally result in a firmer mayonnaise. Crucially, the enzyme-treated egg yolk has improved temperature stability and so can be applied in 'hot' manufacturing processes without 'scrambling.'

In mayonnaise manufacture, it is generally considered preferable to keep the egg and acids apart for as long as possible. This is due to acid damage, which can reduce the emulsification capability of the egg yolk and result in a thinner product. For this reason, the vinegar tends to be added as late as possible during the manufacturing process.

The application level for egg ingredients is determined by compositional standards legislation in some markets as described in section 'Types.' In practical terms, the appropriate ratio of egg to oil for acceptable emulsification is generally 1:10 for liquid egg ingredients or 1:20 for egg yolk powder.

Vinegars and Acetic Acid

Acetic acid, in the form of vinegar, is the main acidulant applied in mayonnaise products. Acetic acid is a weak acid and the undissociated form is especially suitable as it contributes significantly to the preservation and is a key factor in stability models such as CIMSCEE (Comité des Industries des Mayonnaises et Sauces Condimentaires de la Communauté Économique Européenne). Acetic acid is mostly undissociated at the pH values normally associated with mayonnaise products, typically in the range 3.5–4.5 and ideally less than pH 4.

The dissociated acid contributes to the reduction in pH, another key factor in stability models such as CIMSCEE.

Spirit vinegar is used widely in mayonnaise products because it is colorless and contributes little to the flavor (apart from the acid taste). It is typically supplied at a strength of 12% acetic acid in water but both 10% and 14% are common. The higher levels are preferable for transportation cost reasons.

Wine vinegars, both red and white, are also extensively used, as is balsamic vinegar in specialized products. In the latter case, the strength is usually 5% acetic acid in water, but this is generally not an issue as lower levels are used.

Occasionally, chemically synthesized, food-grade acetic acid is used in addition to the vinegar. This is likely to be for cost and manufacturing efficiency reasons.

Thickeners

A wide range of water-based gelling and thickening agents are used in mayonnaise products with the most common being modified starch, xanthan gum, and combinations of these. Guar gum, locust bean gum, carrageenan, and gelatin are also applied. The modified starch may be a preswelled cold-soluble version for products that are manufactured and filled under ambient conditions or a standard cook-up version for pasteurized products. Of the range of modified starches, the most useful tend to be those that are the most resistant to shear damage through the colloid mill emulsification devices. Accordingly, they require significant heat and shear energy in order to fully swell the granules and achieve full functionality.

The new generation of 'clean-label' starches and flours does not yet appear to be widely used in mayonnaise products, presumably because they are not sufficiently robust for the typical equipment and manufacturing processes.

Gelling and thickening agents are primarily applied in order to compensate for the loss of texture due to fat reduction at total fat levels of around 70% and below. Accordingly, there has been significant research to develop specific blends in order to match the product quality of the full-fat versions. The emergence of citrus fiber as a 'clean-label' thickening agent is an example of innovation in ingredients in this area.

Other Ingredients

Apart from the obvious flavoring ingredients such as garlic and chili, there are a huge number of other ingredients that are widely used in mayonnaise products. This section is not exhaustive in describing these.

Apart from vinegar and acetic acid, citric acid in the form of lemon or lime juice is used both for the flavor contribution and for pH reduction. Citric acid does not have the preservation capability of acetic acid. Then, there are around 23 or so acids that are approved according to EU legislation as given in Table 1. These acids are added in order to achieve a reduction in pH, and accordingly, strong acids that readily dissociate are used. Phosphoric acid is an example of such an acid. Such acids however are relatively rare in comparison with citric acid and especially acetic acid.

Mustard is applied in some products mainly for flavoring reasons. The proteins and phospholipids in mustard contribute to emulsification but are much less effective in this regard than egg yolk. The mustard may be added as the liquid product itself or as mustard flour. Some mayonnaise products do not contain mustard but instead contain a mustard flavoring in the form of AITC (allyl isothiocyanate), the pungent component of mustard, dissolved in oil.

Table 1 Acids permitted for use in foods in Europe

Sorbic acid	E200	Phosphoric acid	E338
Benzoic acid	E210	Metatartaric acid	E353
Acetic acid	E260	Adipic acid	E355
Lactic acid	E270	Succinic acid	E363
Propionic acid	E280	Alginic acid	E400
Boric acid	E284	Hydrochloric acid	E507
Malic acid	E296	Sulfuric acid	E513
Fumaric acid	E297	Gluconic acid	E574
Ascorbic acid	E300	Glutamic acid	E620
Erythorbic acid	E315	Guanylic acid	E626
Citric acid	E330	Inosinic acid	E630
Tartaric acid	E334		

Salt is another component of mayonnaise that plays a role in stability models due to its functionality as a preservative. It is added as a component of the egg ingredient and may also be added directly as a separate ingredient. Salt also makes an important contribution to the taste of many mayonnaise products. A key challenge in the current environment of salt reduction is achieving the necessary preservation at the lower fat levels. As the water content is increased, so the ingredients in the water phase contributing to the microbiological safety and stability have to increase too. This includes both vinegar and salt. Developing lower fat mayonnaise products that do not taste too sour or contain too much salt in comparison with the full-fat equivalents can be very difficult. This topic will be discussed further in section 'Health Effects of Mayonnaise.'

Sugar (sucrose) is applied in some mayonnaise products albeit at relatively low levels. It plays a role in preservation and contributes to the texture as well as the sweetness. Other sugars such as glucose and fructose, especially glucose/fructose syrup, are also used. Often, this is in combination with sugar for cost and manufacturing efficiency reasons. The current trend for sugar reduction may not be as significant for mayonnaise as for other food and beverage products because the starting levels are generally much lower and the major calorific contribution is from the fat.

Milk powder is sometimes added at low levels to impart some dairy-type flavoring notes. The small amount of protein added may make a small contribution to the emulsification of the oil phase.

The main types of coloring agents used in mayonnaise products are paprika extract, beta-carotene, and titanium dioxide. Most products are pale yellow or off-white in color and contain one of these coloring agents in order to compensate for differences in oil droplet size and color intensity of the main ingredients such as egg yolk. Titanium dioxide tends to be used for products with a relatively inefficient emulsification process, lower fat content, or larger oil droplet size, and that would otherwise result in a dull white appearance.

In addition to the key elements for preservation, namely, acetic acid, pH, salt, and pasteurization, chemical preservatives are occasionally used. The main preservative applied in mayonnaise products tends to be potassium sorbate, specifically to control the growth of spoilage organisms. These are often considered to be introduced during packaging; therefore, hot filling is another effective decontamination mechanism. Accordingly, potassium sorbate is mostly applied in products that are filled under ambient conditions.

The usage of unsaturated oils means that mayonnaise is prone to the development of rancidity through oxidation. Indeed, this is the critical quality deterioration mechanism and the main determinant of shelf life. Steps are usually taken during manufacture and filling to reduce the inclusion of oxygen, with vacuum emulsification and steam capping, for example, and the consumer advice to store the product in the fridge after opening also prolongs the life from a quality as well as a spoilage perspective. Even with these actions, rancidity can develop relatively quickly and the use of antioxidants is recommended. The antioxidant that tends to be applied in mayonnaise products is calcium disodium ethylenediaminetetraacetic acid.

Sources and Production of Mayonnaise

Introduction

Mayonnaise is manufactured worldwide in factories ranging from a few kilograms per day to several tonnes per hour. In its simplest form, the equipment is fairly straightforward, comprising blending, emulsification, and filling. The higher-fat products do not always require pasteurization as the vinegar and salt levels can control the microbiological status of the water phase, thus simplifying the manufacturing further. Accordingly, there are many artisanal producers of specialty mayonnaise products, selling their products through local outlets.

Emulsification

The colloid mill is the method of choice for the manufacture of mayonnaise, and many types are available, including both batch and continuous systems. They work on the rotor and stator principle with high shear forces generated that can effectively reduce the oil droplet size of even the most viscous products. The pumping action ensures that the shear forces are distributed evenly throughout the sample, but care has to be taken that particulates and other sensitive ingredients are not damaged too much. Pilot-scale colloid mills are available and have the advantage over many other unit operations in that they tend to be reasonably predictable in scale-up from pilot to factory production.

Colloid mills are especially suitable for mayonnaise due to the high viscosities that are required, but a number of other emulsification devices may be applicable in specific cases. The key task is to reduce the mean oil droplet diameter to ideally around 3–5 μm, and this can also be achieved using high-pressure homogenizers, high-shear mixers, membrane devices such as those supplied by Micropore Technologies, and the recently reported magnetohydrodynamic dispersion device. As in all manufacturing operations, the key task is to select the most appropriate equipment for the desired product quality and production efficiency reasons. This may require a combination of unit operations, including storage tanks for intermediate and finished products.

Emulsification processes tend to be more predicable when a preemulsification step is included. Working on the 'rubbish in, rubbish out' principle, an initial high-shear mixing step to produce a crude emulsion with a consistent mean oil droplet diameter means that a single pass through the colloid mill may be sufficient to achieve the required consistency. As part of a rigorous quality assurance scheme, monitoring the properties of the preemulsion, with appropriate control measures, is essential.

In section 'Key Ingredients,' the challenges in selecting the most appropriate starch ingredient for the application were described. The colloid mill step can be especially damaging to the integrity of swollen starch granules; therefore, highly robust modified starches are mostly applied. These not only will be more stable to the high-shear emulsification step but also are more difficult to cook up in the first place, requiring more heat and shear energy than other grades. It is therefore essential to monitor the status of the starch granules in the finished product and to ensure compatibility between the starch and the process, especially if a change is made. Pregelled starches are also available but tend to have more limited use in mayonnaise products due to the generally reduced robustness when compared to the cook-up versions.

Batch and Continuous Processing

Mayonnaise products are manufacturing using three basic types of process, namely, batch, continuous, and batch–continuous.

Batch processing is probably the simplest and involves the manufacture of individual batches of product in a suitable vessel and subsequent direct filling. The batch vessel ranges in size from 50 to 500 kg or more, incorporates ingredient addition and product evacuation, and operates under a vacuum to reduce the incorporation of air. A high-shear impeller generates a suitable preemulsion and the product circulates through a colloid mill device at the bottom of the vessel via a return loop back into the vessel. The mayonnaise is circulated and emulsified until the appropriate product quality has been achieved. The vessel is temperature-controlled via a jacket for either high- or low-temperature processing steps. Batch processing requires careful control and consistency of the ingredient addition and key timings in order to achieve acceptable product quality for each of the batches.

Continuous processing takes the liquid ingredient streams and combines them in a continuous manner immediately before emulsification. There may be four or six different streams and the challenge is to ensure a constant flow rate of each such that the final mayonnaise has the correct composition. In practice, this can often be difficult as the quantities of the ingredient streams may differ widely, and they may have differing viscosities. For example, in the case of full-fat mayonnaise, the quantity of oil will be much greater than any of the other ingredient streams, and for light mayonnaise, the starch/water stream will have the highest viscosity. Particular difficulties are likely to be encountered with extra light mayonnaise with a very low oil content and a very viscous starch/water stream.

Batch–continuous processing combines the two approaches in order to achieve a consistent quality product at a high throughput. In this case, relatively small batches, say, 250 kg, of preemulsion are produced and then pumped into intermediate storage tanks. This achieves a consistent feed for the subsequent colloid mill final emulsification step. The combined preemulsion batches are then processed on a continuous basis through the colloid mill and then to the filler. This combination of consistent preemulsion and long run time for the colloid mill means that the final mayonnaise product is optimized for quality and manufacturing efficiency. This methodology can be applied to all kind of products with varying levels and viscosities of the ingredient streams.

Ingredient Streams

As with all products, mayonnaise manufacture requires the addition of the ingredients in a consistent and predictable manner. In the batch process, this will involve the simple and direct addition of the ingredients in their standard liquid or powder form. However, even in this case, and certainly in the continuous and batch–continuous processes, the preparation of liquid ingredients streams may be appropriate. These are based on solutions or dispersions in oil or water and will include one or more of the following.

The starch may be added either as a cold water slurry or as a gelatinized dispersion. In the latter case, the starch/water mixture will have been heated to swell the starch granules and then maintained at a high temperature or cooled prior to adding as an ingredient stream. Other minor components such as salt, sugar, and preservative may also be added at this stage.

The remaining aqueous ingredients may be added as a separate stream. This includes any other thickening agents such as xanthan gum, salt, and sugar if not added with the starch, preservative, and antioxidant. Again, this could be a slurry, dispersion, or solution of the ingredients in water. The lemon juice, mustard, and any acids, apart from the vinegar, may be added at this stage.

The bulk oil or oils will be added as an ingredient stream. This may be simply the rapeseed oil or sunflower oil, or a blend if this is applied, or with a small amount of olive oil for this type of product. The bulk oils will generally be stored in bulk tanks and may be chilled or have nitrogen blankets in order to reduce the amount of oxidation.

The oil ingredient stream includes all of the minor oil-soluble ingredients such as the colors and flavors, together with an appropriate amount of the bulk oil in order to balance the quantities and ensure consistent addition rates of these components.

The vinegar or blend of vinegars is added as a separate ingredient stream. As stated previously, the vinegar is often added as the last ingredient stream in order to reduce the impact on the functionality of the egg ingredients for emulsification. In some manufacturing processes, the addition of the vinegar assists in the cooling of the water phase streams that have been heated for pasteurization or starch cooking.

The egg ingredients are added as a separate stream at an early part of the process in order to achieve efficient emulsification before many of the other ingredients, such as the vinegar, are added. The egg ingredients tend to be supplied in bulk containers under chilled conditions, can separate somewhat during storage, and have a limited shelf life. As stated previously, they are also always pasteurized and contain salt.

Hot and Ambient Processing and Filling

Depending on the microbiological status of the ingredients and of the finished product, the mayonnaise product may be processed under ambient conditions or with heat, and ambient- or hot-filled.

Ambient processing is reserved for those products in which the microbiology is controlled by the formulation itself. The high-fat products tend to have a small number of ingredients that are considered to be a relatively low microbiological risk, such as salt and sugar, meaning that heat treatment for decontamination is not necessary.

Hot processing is applied to those products in which the formulation cannot control the microbiology without further interventions. There are likely to be a larger number of ingredients that pose a higher level of microbiological risk, and pasteurization is required in order to achieve the appropriate microbiological status. Hot processing is also required in order to activate the cook-up starches that are used in most mayonnaise products containing 70% fat and below.

Ambient filling is reserved for those products in which the packaging does not pose an enhanced microbiological risk. Either the packaging has been decontaminated in a previous step or the microbiology is controlled by the product. The product itself may have been ambient- or hot-processed according to the criteria described earlier. In addition, the products are likely to contain potassium sorbate as a preservative.

Hot filling is primarily applied as a mechanism for decontaminating the packaging and ensuring acceptable microbiological status. It is most often conveniently combined with hot processing, thus avoiding the need to cool the product before filling.

Patterns of Consumption of Mayonnaise

Sauce Market

Mayonnaise may be considered to be part of the global sauce category although the various market reports tend to differ in the subdivision below this level, making comparisons difficult. For example, sauces may be divided into 'cold' and 'hot,' mainly according to the host food, so cold sauces include mayonnaise, ketchup, barbecue sauces, salad dressings, and mustard and are characterized by a long open shelf life of at least 4 weeks under chilled conditions. Hot sauces then include cooking sauces for casseroles and stir-fries, with a relatively short open shelf life of a few days under chilled conditions.

A global food markets report on sauces from Leatherhead Food Research in 2010 defined sauces as follows:

- Cooking sauces (wet and dried (including soy sauce in China))
- Accompaniment sauces (e.g., ketchup)
- Mayonnaise and salad dressings
- Other sauces (e.g., mustard, vinegar, soy (excluding China), and other sauces)

In this context, the global sauce market amounted to more than 30.2 million tonnes in volume terms in 2008, with value sales in excess of USD 67.4 billion. The mayonnaise and salad dressing sector was the second largest, comprising around 26% global market value.

Mayonnaise Consumption

The global leader in the consumption of mayonnaise is Russia at about 5.1 kg per capita in 2013, over three times the amount for the United Kingdom (1.6 kg) and five times the amount for Germany (1.0 kg). Overall, the top 10 is dominated by eastern European countries as shown in Table 2.

The United States and Canada do not make the top 10 but nevertheless consume 1.9 kg per capita. This amounts to around USD 2 billion worth of mayonnaise in the United States. Within this, low-fat mayonnaise has doubled in size in the United States since 2005 and is now worth over USD 500 million.

Table 2 Global league table of mayonnaise consumption

1	*Russia*
2	Lithuania
3	Ukraine
4	Belarus
5	Belgium
6	Estonia
7	Latvia
8	Chile
9	The Netherlands
10	Poland

Availability, Absorption, and Metabolism

The nutritional characteristics of mayonnaise are dominated by those of the component oils, which are present at relatively high levels, from 20% in light or reduced-fat mayonnaise to 80% in full-fat and 'real' mayonnaise. The component oil in a mayonnaise product is usually rapeseed oil, sunflower oil, or soybean oil, as discussed in section 'Key Ingredients,' with the occasional use of olive oil in appropriate products.

The bioavailability, absorption, and metabolism of the common vegetable oils used in mayonnaise products are described in the relevant chapters of this encyclopedia. There are no known aspects that apply to mayonnaise over and above those of the component oils. It is possible however that future nutritional studies may take into account the water-continuous basis of this product type, and the presence of other components such as salt and acid, to determine whether the bioavailability, absorption, and metabolism of the oil may be enhanced.

Health Effects of Mayonnaise

Introduction

The impact of mayonnaise products on dietary health extends beyond the bioavailability, absorption, and metabolism of the component oils as described in section 'Availability, Absorption, and Metabolism.' Of particular concern is the fat content that can be as high as 80% and is generally around 30% even for the light and reduced-fat versions. Therefore, the potential solutions for reducing the fat level while maintaining product quality are of interest. In a similar vein, there are moves to reduce the salt and sugar levels, although in these cases, the challenge is around preservation as well as product quality. And finally, the presence of common allergens means that the 'free-from' agenda is relevant too.

Omega-3

Mayonnaise products contain omega-3 and omega-6 fatty acids from the component oils. As stated in section 'Key Ingredients,' the oil component is usually rapeseed oil, sunflower oil, or soybean oil, and the fatty acid compositions of these oils are described in the relevant chapter of this encyclopedia. In the United Kingdom, Hellmann's Real Mayonnaise and Hellmann's Light Mayonnaise both claim to be 'a good natural source of omega-3,' containing 8.4 g/100 g and 2.6 g/100 g, respectively, of omega-3 fatty acids 'from plant sources.' They also contain 16.8 g/100 g and 6.1 g/100 g, respectively, of omega-6 fatty acids.

Other mayonnaise products such as the one from Sainsbury's in the United Kingdom give a breakdown of the saturates, monounsaturates, and polyunsaturates, but do not quote the levels of omega-3 or omega-6 fatty acids.

Allergens

The nature and composition of mayonnaise products are such that they tend to contain some of the components that require labeling as allergens. Chief among these is egg, the emulsifying agent present in all except the egg-free versions.

Mustard is the next most popular allergen with many mayonnaise products containing this as an ingredient mainly for flavoring reasons. Some products such as Hellmann's mayonnaise in the United Kingdom contain mustard flavoring but not mustard itself. The mustard flavoring tends to be AITC in oil, as described in section 'Key Ingredients,' and as such is not protein-based as are all allergens apart from sulfite/sulfur dioxide. However, as a precaution and to guard against adverse reactions to AITC, mustard allergen labeling tends to be carried out.

Other allergens may be present depending on the mayonnaise formulation, for example, dairy when milk powders are used for flavoring reasons.

Fat Reduction

Full-fat and 'real' mayonnaise can contain 75–80% fat and may therefore be considered to be unhealthy as part of the obesity agenda. A single portion or tablespoon of mayonnaise (15 ml/14 g) can contain 11 g fat, and for this reason, the light and reduced-fat versions are important for some sectors of the population.

As described in sections 'Types' and 'Key Ingredients,' fat reduction in mayonnaise products has been successfully achieved using a range of gelling and thickening agents such as modified starch and the emerging ingredients such as citrus fiber. The extra light products containing as little as 3% fat have demonstrated that acceptable thick and spoonable textures can be achieved using these ingredients. However, such compositions, especially the highly viscous water phases, can present significant problems during manufacturing. An alternative approach that is especially suitable for liquid, water-based systems is that of water-in-oil-in-water (WOW) double emulsions.

WOW emulsions have been studied for many years for their ability to reduce the fat contents of water-continuous emulsions by 'hiding' some additional water inside the oil droplets as a second emulsion. Figure 3 is a light micrograph of a WOW emulsion, clearly showing the internal water droplets (image courtesy K. Groves, Leatherhead Food Research). WOW emulsions are prepared by firstly emulsifying the internal water phase into the oil using a highly lipophilic emulsifier. Polyglycerol polyricinoleate, PGPR (E476), is especially suitable for this purpose although lecithins have also been used. This water-in-oil emulsion is then emulsified into the external water phase using an egg ingredient such as egg yolk as the emulsifier. In this way, an emulsion has been created in which the internal water phase is considered to be part of the oil, increasing the effective oil content.

Various studies have been carried out to demonstrate the fat-reducing capability of WOW double emulsions. A project at Leatherhead Food Research involved the reduction of the fat content of a mayonnaise-type sauce by 20% using WOW double emulsion technology. The resulting emulsions were characterized using rheology and sensory analysis and found to be similar to the full-fat equivalent products prepared as standard O/W emulsions. Figures 4 and 5 clearly demonstrate these effects. WOW double emulsion technology therefore appears to be a potential alternative to the use of gelling and thickening agents for mayonnaise products containing around 70% fat or less. The potential challenges to this appear to be the requirement to use PGPR as an additional emulsifier and the requirement for two emulsification steps.

Salt and Sugar Reduction

Salt and sugar reduction activities in foods and beverages have mainly focused on gradual reductions and the use of alternative ingredients. In the case of salt, this has mostly been potassium chloride, and for sugar, a combination of ingredients for sweetness and texture. There are many options available

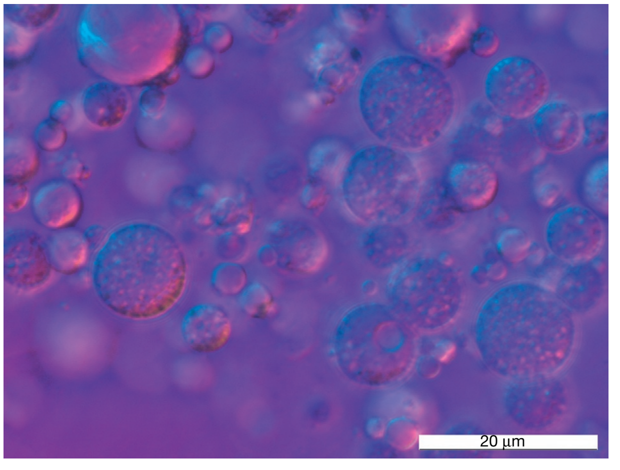

Figure 3 Light micrograph of WOW emulsion.

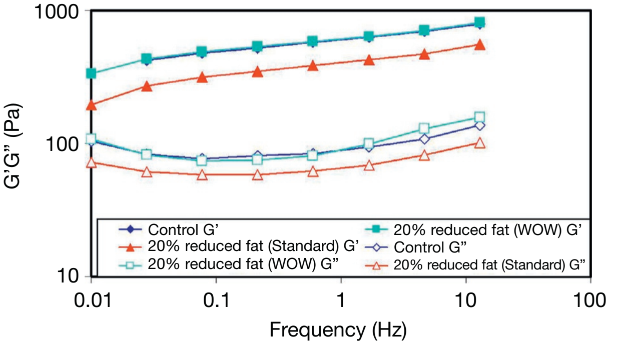

Figure 4 Rheology of emulsions.

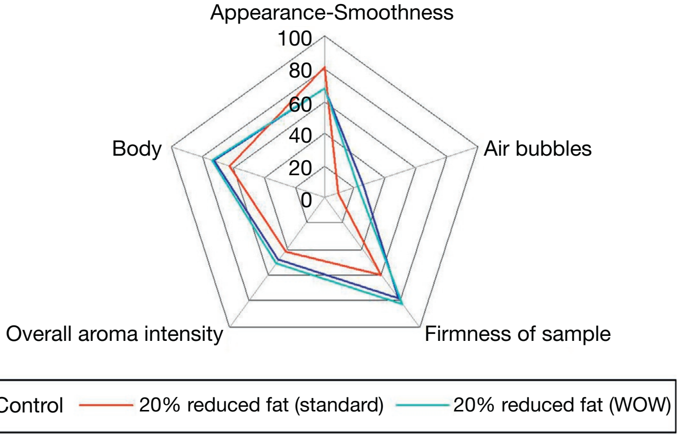

Figure 5 Sensory properties of emulsions.

although in general terms, these have not been applied significantly in mayonnaise products. As stated previously, salt is important for preservation, so care must be taken in reduction or replacement exercises. Sugar, when used, is generally at relatively low levels and contributes little to the calorific value in comparison with the fat.

WOW double emulsions have also been studied for the capability to reduce salt levels in thickened water-based foods. In this case, the technology relies on the internal and external water phases being of differing compositions, specifically the majority, if not all of the salt being present in the external water. The hypothesis is that the internal water is swallowed without being detected in the mouth; therefore, it does not need to contain any salt. A study reported in 2010 incorporated all of the salt in the external phase of a thickened soup-type WOW emulsion, with sensory assessments of the resulting saltiness. It was demonstrated that a salt reduction of 10% could be achieved with acceptable sensory performance. A potential challenge in the application of this technology in mayonnaise products appears to be the preservation of the internal water phase, although a balancing of the acetic acid and pH levels between the two water phases would assist in this.

As for salt reduction, it is possible that WOW emulsion technology could be used for sugar reduction, although there do not appear to be any reported studies. This is a potential area for future research.

See also: Emulsifiers: Types and Uses; Food Colloids and Emulsions; Stabilizers: Types and Function.

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