Rheological properties of different types of mayonnaise

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ABSTRACT

A MCR301 rheometer from Anton Paar, fitted with a PP50 plate/plate system was used to investigate the rheological properties of some full- and low-fat mayonnaises. The test conditions were relevant for the use of mayonnaise in the preparation of typical food dishes. A hysteresis test was run to investigate the thixotropic nature of the mayonnaise at +4°C. A strain controlled amplitude sweep was run at 4, 14 and 24°C. The samples were then cooled to -15°C at a rate of 0.5°C/min in rotation at 50 1/s to detect the freezing temperature of the different products.

A Malvern Mastersizer 3000 was used to measure particle sizes in a selection of the mayonnaises investigated. pH in the mayonnaise was measured directly at 20°C.

Commercially produced low fat mayonnaise did not behave very different from commercially full fat mayonnaise. The results did not show significant differences between the investigated mayonnaises on all the measured parameters, except for the particle size of the emulsion.

INTRODUCTION

Mayonnaise, which is one of the oldest sauces in the world, is still widely used. It belongs to the most important traditional food emulsions. Contrary to butter and margarine, which are water-in-oil emulsions, mayonnaise is an oil-in-water emulsion, similar as salad dressings or cream. The rheology of mayonnaise has been intensively studied as it influences the consumers' attitude, not only regarding texture and flavor. It also affects functional properties, such as an application on salads, decoration on sandwiches, French fries and as a flavor enhancer in various dishes[1,2].

The mayonnaise emulsion is conventionally prepared by carefully mixing of egg yolk, vinegar, oil, spices and some optional ingredients such as sugar, salt or sweeteners. Carefully mixing of mayonnaise retain closely packed foam of oil droplets, which contribute to its viscoelastic properties. Mayonnaise has time dependent characteristic, pseudo plastic-, and thixotropic behavior[3].

According to Codex Alimentarius Commission specifications[4], traditional mayonnaise must contain at least 78.5% total fat and 6% pure egg yolk. This is usually called full fat mayonnaise. Egg yolk is often used in mayonnaise as an emulsifier because it imparts desirable flavor, mouthfeel, and color. The emulsifying capacity of egg yolk is mainly due to presence of phospholipids, high density- and low density- lipoproteins (HDL and LDL). Non-associated proteins (livetin and phosvitin) along with LDL being the most important contributor to these emulsifying properties.

The good emulsifying properties of egg yolk lipoproteins are attributed to their highly flexible structures, allowing great affinity and adsorption at oil–water interfaces. Vinegar, salt, sugar and mustard are mostly added to mayonnaise as flavoring ingredients. But these ingredients also seem to play an important role for the physical stability of emulsions[5].

Usually a vinegar with a strength of 5-10% is used. This helps to give a vinegar content close to 0.5% and thus a pH of about 3.8-4.0 in the mayonnaise. At such a low pH in addition to low water activity, little or no bacterial problems are expected in full fat mayonnaise. This aspect together with the storage temperature, is of course, very important for mayonnaise used in seafood salads[6].

Over the past decade, the consumption of low fat food products, have become more than just a trend. Most consumers stick to nutritional guidelines regarding fat consumption due to importance of type- and amount of fat. There is also pressure on the food industry to moderate the consumption of fat in the diet or to use unsaturated fat. It is recognized that the amount and type of fat consumed may cause several diseases such as obesity, some type of cancer, hypertension, gallbladder and cardiovascular diseases. In addition, it is well known that intake of saturated fat is accompanying with increased risk of coronary heart disease and high blood cholesterol. These disadvantages have prompted the consumers to demand reduced fat products, or to use fats and oils with high nutrition of value[3].

As a result, food producers and scientists attempt to find novel ways to produce low-fat content and low-calorie mayonnaise without quality losses. Some examples of fat replacers used; Poly-saccharides, gums, carboxy-methyl-cellulose, pectins, fiber, and maltodextrose. These ingredients are also used as thickeners and stabilizers in low-fat food systems. Normally cold-swelling corn starch, guar kernel flour (E412), Xanthan gum (E415) etc. are used as stabilizers. However, the inclusion of fat analogs may result in loss of texture and sensory properties[7].

Large-scale production of mayonnaise is normally carried out using equipment specifically designed for such manufacturing. This process is often semi-automated. For Research & Development (R&D), pilot scale equipment is used. This is also the case for small scale production typical of the "ready to use" market – sandwich producers, caterers and other low-volume applications. These mayonnaise productions have to be produced in a manner which allows much flexibility, especially when changing formulas. Industrially production of mayonnaise normally takes place by using equipment such as either a;

- Beater or mixing machines
- Colloid Mills
- High pressure homogenizers (vacuum)
- Votators or Scrape Surface Heat Exchangers

The objective of the studies reported in this paper was to: investigate and compare rheological properties, particle size, pH and stability of some commercially produced full- and low-fat mayonnaises produced for the Norwegian food market.

Figure 1. The eight different mayonnaises investigated in this study.

MATERIALS AND METHODS

<u>Mayonnaise</u>

The eight different variants of mayonnaise tested, are listed in Table 1, see also Fig. 1. The mayonnaises were purchased from local Norwegian food shops.

pH in the mayonnaise was measured directly[7,8] at 20°C. Each sample rested for 30 minutes before pH measurement (LAB PH meter, PHM 92 133R027N060, Radiometer, Copenhagen, Denmark).

The Malvern Mastersizer 3000 (S.nr. MAL1083189, Malvern, UK, 2013) fitted with a Hydro LV dispersion unit, was used to measure particle sizes in a selection of the mayonnaises investigated. Settings: Particle refractive index 1.51 and Particle absorption index 0.01.

Instrumental analysis and experimental set-up

The Physica MCR301 rheometer (Paar Physica, Anton Paar, Stuttgart, Germany, 2010) was used in both rotation and oscillation to characterize the mayonnaises[9].

A PP50 plate/plate system was used with a Peltier for temperature control.

The mayonnaise was placed on the Peltier plate. The plate was then lowered until the gap was 1 mm.

Initially a hysteresis test was run to investigate the thixotropic nature of the mayonnaises. The shear rate was increased linearly from 2 to 50 1/s in 125 s, was then kept at 50 1/s for 50 s and then reduced linearly to 2 1/s over a time period of 125 s. The enclosed area in the shear stress versus shear rate diagram was then calculated by a macro available in the RheoPlus software.

A strain-controlled amplitude sweep was then run at 10 rad/s from 0.01 up to 100% strain at 4°C. Then the system was heated to 14°C and the amplitude sweep was repeated. Finally, the temperature was increased to 24°C and the final amplitude sweep was repeated. The sample was then cooled to -15°C at a rate of 0.5°C/min in rotation at 50 1/s to detect the freezing temperature.

Data analysis

The data were analysed in RheoPlus and exported to Excel and the plotting program DPlot.

RESULTS

Fig. 2, 3, and 4 show results from the amplitude sweep performed at 4 °C. Fig. 5 shows the viscosity variation at 4 °C. The freezing temperatures are shown in Fig. 6.

The thixotropic behavior is shown in Fig. 7. The particle size distribution in one full fat- and one low fat mayonnaise is illustrated in Fig. 8.

Table 1. Approximate composition (% w/w) of the different low fat (LF) and full fat (FF) mayonnaise investigated (SFA-Saturated Fatty Acids). Values declared by the manufacturers except for the pH.

Mayonnaise	Appr. dry matter	Protein	Carbo-hydrate	Fat Content	SFA	Salt	pH
Prima FF	73.5	0.4	2.8	69.5	5.0	0.8	4.37
Prima LF	52.7	0.4	4.0	46.9	3 .4	1.4	4.08
First Price FF	76.2	1.1	2.6	72.0	5.0	0.5	4.13
First Price LF	55.5	1.0	4.6	49.0	4.0	0.9	4.20
Mills FF	82.6	1.0	2.0	79.0	5.0	0.6	4.03
Mills LF	48.9	1.0	6.0	41.0	3.0	0.9	3.95
Xtra FF	74.4	0.4	1.3	72.0	5.6	0.7	4.24
Xtra LF	46.2	0.7	4.9	40.0	3.3	0.6	4.20

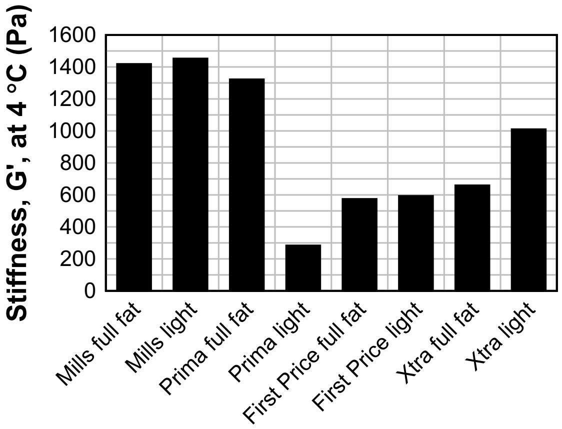

Figure 2. Elastic modulus in mayonnaise at 4 °C.

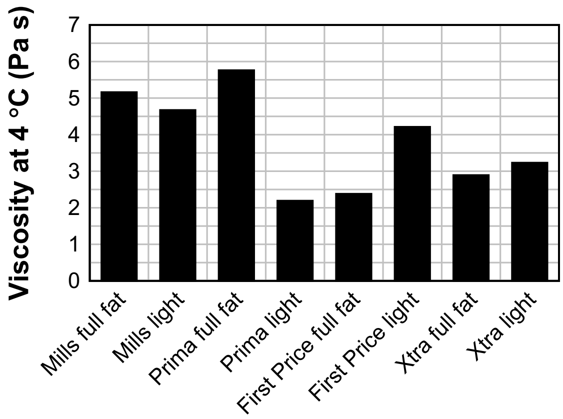

Figure 5. Viscosity of the different mayonnaises at 4 °C at a shear rate of 50 1/s.

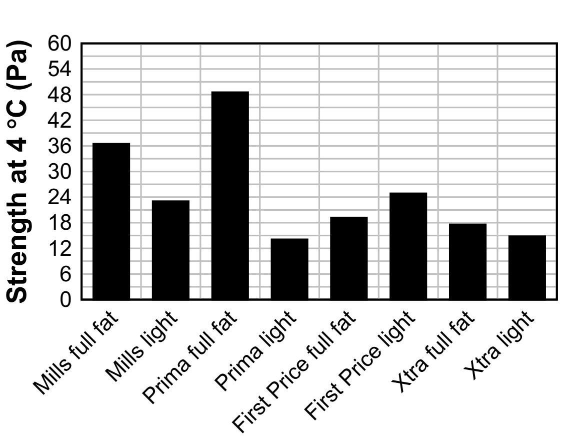

Figure 3. Stress at the limit of the linear viscoelastic region (LVR) at 4 °C.

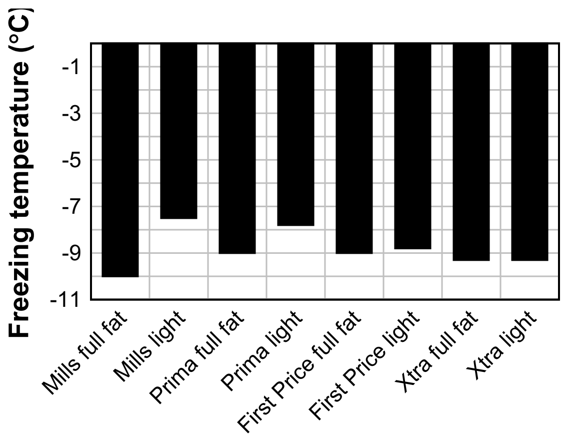

Figure 6. Freezing temperature variation.

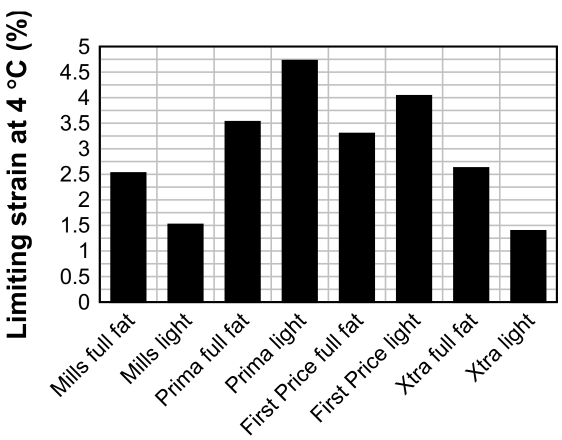

Figure 4. Strain at the limit of the linear viscoelastic region (LVR) at 4 °C.

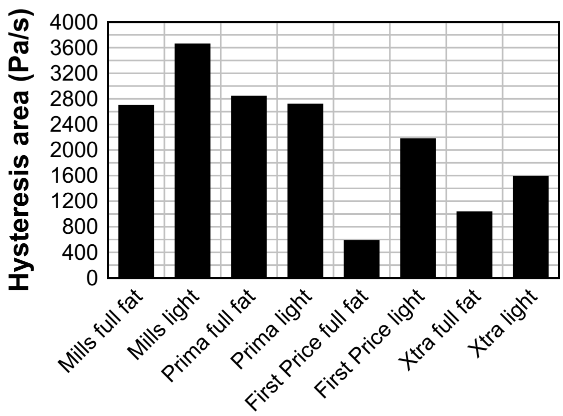

Figure 7. The hysteresis area showing the thixotropic variation.

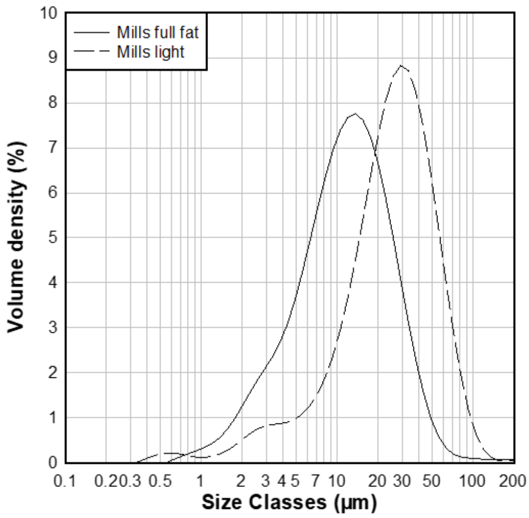

Figure 8. The particle size distribution in Mills Full Fat- and Mills Low Fat Mayonnaise.

DISCUSSION

The pH of the mayonnaises measured at room temperature (20–21°C) are shown in Table 1. As the table shows, pH is reasonably similar in all the mayonnaises; both in the full- and in the low-fat varieties. The pH varies for all samples within the range 3.95 – 4.37. This is of importance when comparing the different mayonnaises. The pH of mayonnaise can have a dramatic effect on the structure of the emulsion[10,11,12]. The viscoelasticity and stability of the mayonnaise should be at its highest when the pH is close to the average isoelectric point of the egg yolk proteins, and hence the charge on the proteins is minimized[13].

Emulsion stability usually involves preventing droplet coalescence, flocculation, and creaming. Creaming is not usually problem in mayonnaises that have high fat contents (~80%), because the droplets are so closely packed together so that they cannot move. However, in products with low fat content, creaming is usually prevented by adding a thickening agent such as a gum or a starch to the aqueous phase to slow down the droplet movement. Thus, LF mayonnaise samples normally show a higher stability than FF samples because of the increased viscosity of the aqueous phase from the addition of carbohydrates. Normally this phenomenon slow down oil droplet movement[14]. It has been shown that flocculation occur in low fat mayonnaise due to some added polymer concentrations[15].

In this screening test of commercial light- and full fat mayonnaise, there were little or no significant differences associated with pH and rheological properties tested (elastic modulus, strain, viscosity stress). However, when comparing mayonnaise from the four different manufactures, some minor differences were observed. This is due to hysteresis showing thixotropic variation between *First Price* full- and low fat mayonnaise, Fig. 7. Some differences also occur between the *Prima* full- and low-fat products regarding stress and viscosity at 4 °C; Fig. 3 and Fig. 5.

Particle size is a substantial parameter for emulsion systems as it affects rheology, stability, storage life, texture, and taste of the emulsion[6]. Regarding the particle size distribution in emulsions like mayonnaise, it is of great importance regarding the texture. Previously thickeners like propylene glycol (PGA) and guar gum were added to low fat products in order to maintain viscosity, texture characteristics and mouthfeel. When fat is replaced by a thickener, the water phase becomes thicker and a structure is built up, keeping the oil droplets in place[16].

Many starch based thickeners are industrially used today. As an example, xanthan gum (a polysaccharide produced from simple sugars using a fermentation process by the bacteria *Xanthomonas campestris*) and guar flour are used in low fat mayonnaise from Mills. By utilizing both of these thickeners, a synergy effect is usually obtained associated with increasing viscosity[17]. This phenomenon may explain the larger particles found in LF mayonnaise, which is shown in Fig 8.

Microscopic images have also confirmed formation of a stable cohesive layer of added thickeners surrounding oil droplet in low fat mayonnaise[18]. The reason, why in Fig. 8 we only show the particle size distribution in Mills LF- and FF mayonnaise, is that Mills is the only producer who declare which thickeners they use in their products.

Regarding the freezing temperature of the mayonnaises investigated, Fig. 6 shows that only two producers had products where the low fat variants freezed at a higher temperature than the corresponding full fat variant. In spite of about 20% increase in water content of the low fat variants, the freezing point was about the same for the other products (-9°C). The freezing point may give information about the stability of the emulsions. From both practical experiences as well as from the literature, large differences in freeze-thaw stability of emulsions prepared with different oils are observed[19]. Since oil-in-water emulsions are thermodynamically unstable systems, it was interesting to investigate them during environmental changes, like cooling and freezing as illustrated in Fig. 6.

CONCLUSIONS

The conclusions of this screening study can be summarized as follows:

- Commercially produced low fat mayonnaise did not behave very different from commercially full fat mayonnaise.
- The results did not show significant differences between the investigated mayonnaises on all the measured parameters, except for the particle sizes of the emulsions.

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