Effects of Changes in Production on Stability
of Mayonnaise

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The main aim in this study is to investigate the stability and quality of mayonnaise products with special emphasis on how the changes in production affect the stability and quality of mayonnaise products. The main focus is to analyze the mayonnaise samples with selected analysis to understand effects on the changes in production. Mayonnaises are produced by Saarioinen Oy in Huittinen. Mayonnaises are analyzed fresh and after 2-week incubation in 37 °C.

The analysis used in this work study the oxidation products: peroxide value, anisidine value and the acid value, chemical structure of fatty acids: gas chromatography, physical structure of the samples: rheology measurements: viscosity, thixotropic and oscillatory measurements. To support the analysis and measurements sensory evaluations are carried out to link the instrumental analyses to sensory changes.

The main results in this study is that the changes in production did not affect the mayonnaises much. The biggest difference between the samples were the oxidation level of the incubated samples compared to fresh samples. The oxidation level in incubated samples after the changes in production were lower than in the mayonnaises made before the production changes. In conclusion the mayonnaises can be produced with different techniques to achieve the nearly same quality mayonnaise.

Keywords: mayonnaise, stability, fatty acids, oxidation, rheology, sensory quality

Contents

Abbreviations

BHA: butylated hydroxy anisole

BHT: butylated hydroxy toluene

BTEM: boron trifluoride-catalyzed esterification method

C: chitosan

C:D: number of carbon atoms and double bonds in fatty acid

E1: emulsion sample 1

E2: emulsion sample 2

E3: emulsion sample 3

E4: emulsion sample 4

E160a: beta carotene

E202: potassium sorbate

E412: guar gum

E415: xanthan gum

EDTA: ethylene diaminotetraacetic acid

EOs: essential oils

F: freshly analyzed mayonnaise

FE: fenugreek extract

GC: gas chromatography

GOX: glucose oxidase

GP: ginger powder

GSE: grape seed extract

L: lactoferrin

LC: lycopene crystals

LM: light mayonnaise

M: mustard

MD: mayonnaise dressing

N: novel technique production line

P: functional production line

PCHE: purple corn husk extract

R: mayonnaise analyzed after incubation

RE: rosemary extracts

SS: sesame sprouts

TBHQ: tertbutylhydroquinon

TE: tansy extracts

TM: traditional mayonnaise

TP: tocopherol

YPM: yellow powder mustard

1   Introduction

In this Master thesis, the stability and quality of mayonnaise will be studied through chemical and physical properties of mayonnaise. The chemical properties study the lipid structure and the oxidational changes in mayonnaise. Physical properties study the viscosity and other rheological features of the mayonnaise. This study is interested in the differences between different types of mayonnaises and how different ingredients affect the emulsion in mayonnaise and furthermore how the stability and quality will change during the shelf life. This study consists of three different types of mayonnaises: traditional and low-fat mayonnaise and mayonnaise dressing made with novel technique by Saarioinen Oy, Huittinen. Comparison samples are the same mayonnaises made with functional production line in Saarioinen Oy, Huittinen. Mayonnaises from both processes are analyzed fresh and after 2 weeks of incubation in 37 °C. This study does not observe or take a position on the nutritional values of mayonnaise.

1.1   What is mayonnaise?

Mayonnaise is a thick creamy sauce that contains vegetable oil, acidic component (e.g. acetic acid), egg yolk (contains a natural emulsifier — egg lecithin), sugar, salt and spices and other emulsifying and thickening agents (modified starch, guar gum and xanthan gum used most commonly). Mayonnaise contains traditionally 70-80 % fat. Due to the consumers' preferences, majority of the mayonnaise products on the market are low-fat mayonnaises. Low-fat mayonnaises have fat content around 20-40 %. Having substantially lower fat content fat-replacers also known as emulsifying and thickening agents are widely used to create the characteristic thick and creamy consistency of mayonnaise with lower fat. But how the characteristic consistency of the mayonnaise is possible to achieve? (Depree and Savage 2001; Yildirim, Sumnu, and Sahin 2016; Saarela et al. 2010)

Mayonnaise is an emulsion, this gives mayonnaise its characteristic consistency, without emulsion formation the consistency of mayonnaise is impossible to achieve. Mayonnaise, despite the fact it can have very high oil content, is an oil-in-water emulsion. An oil-in-water emulsion has two phases: water as continuous phase and oil as dispersed phase. An oil-in-water emulsion is formed by mixing the emulsifying and thickening agents, acidic component and flavoring agents together and then slowly blending in the oil. The

emulsion formed consists of a closely packed foam of oil droplets. Ideally the emulsion consists of spherical droplets of dispersed phase packed together in continuous phase. The dispersed phase can account for a maximum of 74 % of the total volume of the mayonnaise to keep the shape of the droplets spherical. But in mayonnaise the dispersed phase may account for 75 % or more of the total volume. This will cause formation of the honeycomb structure of closely packed and often distortion of the droplets from their normal spherical shape (Figure.1).

This close packing of the droplets allows them to interact very strongly with one another. The combination of these interactions gives mayonnaise its high viscosity. In fact, the viscoelasticity of mayonnaise reaches a maximum very quickly after preparation. This rapid viscoelasticity is mainly due to the flocculation of adjacent oil droplets. Flocculation of oil droplets forms a network, basically a weak gel. The strength of these interactions between the oil droplets depends on the Van der Waals attractions which are balanced to some extent by electrostatic and steric repulsion. The quality of the emulsion will depend on the right balance between these forces. If the attraction is too strong it will pull the droplets together causing the aqueous phase to be squeezed out and promoting coalescence of the droplets. And if the repulsion is too strong it will allow the droplets to slip easily past one another. This will produce an emulsion with low viscosity and prone to "creaming" as the oil droplets settle into their minimum volume allowing the water to drain out. This basic structure of mayonnaise can be achieved using egg yolk as an ingredient as egg yolk contains lecithin. Other emulsifiers and thickening agents will help with the formation of the structure and strengthen it. These are discussed further later. But eventually mayonnaise will break as oil droplets coalesce and the distribution of oil droplets changes. There are fewer, larger oil droplets which leads to the separation of the phases of the mayonnaise. (Depree and Savage 2001; Heertje 2014; Dickinson 2013)
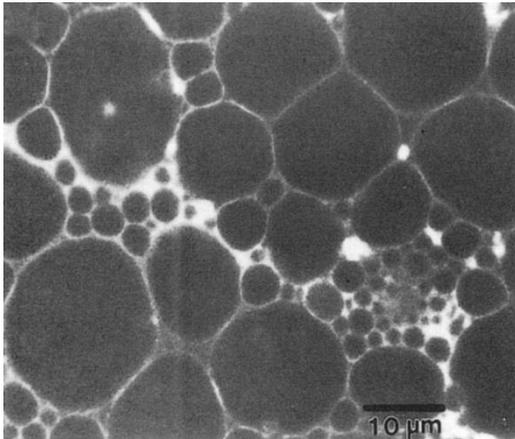
Figure 1.   Distorted oil droplets in honeycomb structure in mayonnaise by confocal scanning laser microscopy. (Heertje 2014)

1.2   Production of mayonnaise

Production of mayonnaise consists of two types of processes: batch and continuous process (Figure 2). These processes can be divided into cold and semi-hot processes. In cold process the entire process (mixing of ingredients, emulsion formation during homogenization) and the packing of the product are carried out in cold conditions, at the most in room temperature. In the semi-hot process, the microbiologically sensitive ingredients (water, spices) are pasteurized in approximately 80 °C for couple of minutes and cooled down. The rest of the semi-hot process is like cold process because the homogenization requires low temperature in order to form stable emulsion. (Saarela et al. 2010)
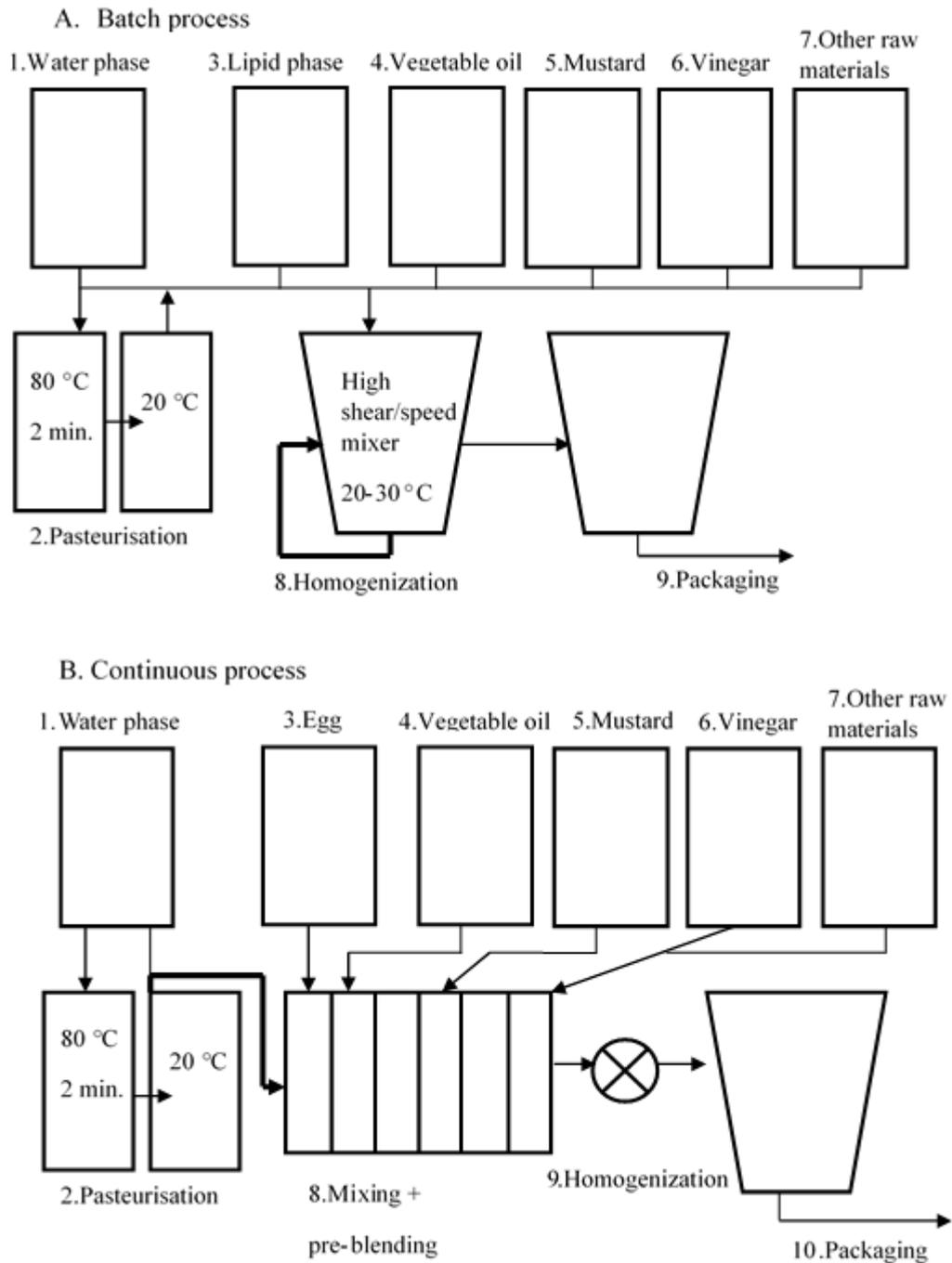
Figure 2. Process charts of mayonnaise production with the semi-hot process. A. Example of batch process. B. Example of continuous process. A and B similar with cold process but without the pasteurization. (Saarela et al. 2010)

Production of mayonnaise is mostly done by high shear or high-speed mixers. The first step in mayonnaise production whether it is batch or continuous process is the dissolving water soluble raw materials (e.g. sugar, salt and food preservatives) to water. In semi-hot process this mixture is pasteurized before, cold process does not include any heating. After the possible pasteurization, the lipid phase or egg and other emulsifying and thickening agents mixed with small amount of oil and are added separately. Next the rest of the oil is slowly added under vigorous stirring. In this stage the oil-in-water emulsion is created. Last of the raw materials (e.g. vinegar, mustard and spices) are mixed in the emulsion. In mayonnaise production, the order of addition of raw materials is reasonably the same in batch and continuous process. Some differences can be in the order of addition of raw materials. But significant difference in continuous process compared to batch process is that it is usually fully automated system. This gives the design stage of the equipment key role because from start to finish the production is automated to follow the program set. And therefore, variations cannot be made during the production. The raw materials are added through feeding pumps automatically. In batch process, some parts of the process can be automated. Still batch process is normally more flexible since the raw material can be either pumped automatically or added to the mixing tank before or after the homogenization. (Kerkhofs et al. 2011; Saarela et al. 2010)

1.3 Oxidation

Lipid oxidation is main cause for food spoilage for all the fat containing foods. It also causes the generation of off-flavors and off-odors, these are described as rancid. This causes the quality and stability of mayonnaise to weaken due to spoilage through auto-oxidation of the unsaturated and polyunsaturated fats in the oil in mayonnaise. There are three phases to auto-oxidation: initiation, propagation and termination. In the initiation phase, external energy, e.g. light, acts on the unsaturated fat in presence of catalyst, e.g. heavy metal ions, to produce free radicals. In the propagation phase the free radicals react with molecular oxygen to form peroxide radicals, the primary oxidation products. This leads to formation of more free radicals or decomposition into aldehydes, ketones, alcohols, hydrocarbons, volatile organic acids and epoxy compounds, the secondary oxidation products. In the termination phase when the concentration of reactive compounds reaches a sufficient level they react together to form stable compounds which give the product its characteristic rancid flavor. Auto-oxidation can be speeded up at high

temperature and is more rapid in mayonnaise because the oil in mayonnaise contains polyunsaturated fatty acids. (Depree and Savage 2001; Ghorbani Gorji et al. 2016; Campbell-Platt and International Union of Food Science and Technology 2009)

Antioxidants are substances that can retard this oxidation process of lipids. The antioxidants can be synthetic or natural antioxidants. The synthetic antioxidants such as butylated hydroxy toluene (BHT), butylated hydroxy anisole (BHA), tert-butylhydroquinon (TBHQ) and ethylene diaminotetraacetic acid (EDTA) can prevent rancidity. BHT and BHA are widely used antioxidants. But lately the growing trend is to utilize antioxidants from natural sources. Some of these natural antioxidants are discussed and studied in Table 1 by Ghorbani Gorgi et al.: gallic acid, ascorbic acid, tocopherol (TP), lactoferrin (L), rosemary extracts (RE), phytic acid, mustard (M), lycopene crystals (LC), ginger powder (GP), fenugreek extract (FE), black glutinous rice, grape seed extract (GSE), essential oils (EOs) extracted from *Carum copticum*, chitosan (C), tansy extracts (TE), clove, anthocyanin extracted from purple corn husk (PCHE), seaweed and glucose oxidase (GOX). (Campbell-Platt and International Union of Food Science and Technology 2009; Ghorbani Gorji et al. 2016)

Table 1. Antioxidants in different mayonnaises and the effects to the stability and quality of the mayonnaise. (Ghorbani Gorji et al. 2016)

Product	Antioxidant/pro-oxidant (concentration)	Results
Mayonnaise (soy oil)	GOX	450 U/kg: slowed down oxidation reactions
Dijon mustard mayonnaise	EDTA, RE, M	Decreased photooxidative volatile levels.
Mayonnaise (sunflower oil)	L, propyl gallate, EDTA	Only EDTA had strong antioxidant effect.
Mayonnaise	TBHQ, BHT, FE	FE and TBHQ decreased lipid oxidation. Are more effective than BHT.
Mayonnaise (rapeseed oil)	LC	Slowed down the development of off-flavor, off-odor, and color changes.
Mayonnaise and salad dressing (olive oil)	Natural spices and herbs such as (parsley, ground black pepper, basil and hot paprika) and their extracts	With extracts better microbiological and antioxidative quality.
Mayonnaise (rice bran oil)	Oryzanol, Squalene, TP, Tocotrienols	Enhanced the stability and balanced fatty acid composition.
Mayonnaise (corn oil)	GP	Improved the oxidative stability.
Mayonnaise (rapeseed oil)	GSE	Improved the oxidative stability.
Mayonnaise (corn oil)	Juice of basil leaves (JBL), BHT	JBL reduced the oxidation process of during 12 weeks of storage.
Mayonnaise (sunflower oil)	EOs, BHA, BHT	High concentration of EOs can replace BHA and BHT.
Mayonnaise (soy oil)	Yellow powder mustard (YPM), paste mustard	YPM increased oxidative stability.
Mayonnaise	C, EDTA	Decreased the lipid oxidation process of mayonnaises. C slowed down the lipid oxidation process during storage.
Mayonnaise (soy oil)	TP, TBHQ	TP decreased hydroperoxide formation.
Mayonnaise	TE	TE increased oxidative stability.
Mayonnaise (soybean oil)	PCHE, BHT, EDTA	The antioxidative effect of PCHE was higher than BHT and EDTA.
Mayonnaise	Sesame sprouts (SS), EDTA, BHT	SS powder decreased oxidation during storage. Not good sensory perception.
Mayonnaise (soybean oil)	Eugenol-lean fraction isolated from clove buds	Significantly higher antioxidant activity than mustard mayonnaise. Stable beyond 6 months.

One of the factors affecting lipid oxidation in mayonnaise is the chemical structure of lipids. The susceptibility of lipid molecule to oxidation depends on the number and location of the double bonds. Saturated lipids (containing no double bonds) are more stable to lipid oxidation than unsaturated fats (containing 1 or more double bonds). But the physical and sensory characteristics of the mayonnaise cannot be achieved by using only saturated lipids instead of unsaturated lipids. (Ghorbani Gorji et al. 2016)

Lipid oxidation can be detected by sensory analysis as rancid smell and taste. Ghosh et al. studied the rancid-acid removal by irradiation of virgin coconut oil. Semi-trained panelists were selected to evaluate the oil samples and reference samples (copra flavor, octanoic acid). Attributes such as appearance, color, odor, turbidity and homogeneity were evaluated by using 9-point hedonic scale. This study found that irradiated oil samples and non-irradiated samples remained both unchanged up to 28 days and had no difference. Irradiating samples after 28 days it increased the acceptability of the oils. This study gives some guide lines of oil rancidity. (Ghosh et al. 2016)

1.4 Raw materials effecting the stability and quality of mayonnaise

Raw materials in mayonnaise can have effect on the stability and quality of mayonnaise. These raw materials can help to form the right balance between the interactions in mayonnaise. But can also weaken the balance.

1.4.1 Emulsifying and thickening agents

Emulsifiers are small molecules with interfacial and surface physical chemistry properties. This means that they also possess amphiphilic properties. These amphiphilic properties are due to coexistence of lipophilic and hydrophilic properties in the same molecule. Emulsifiers show the affinity to both polar and non-polar substances (Figure 3). Hydrophilic part will form a hydrogen bond with polar solvents such as water. Simultaneously lipophilic part of emulsifying structure will be attracted to non-polar surroundings such as hydrocarbon chains of glycerides or non-polar solvents.
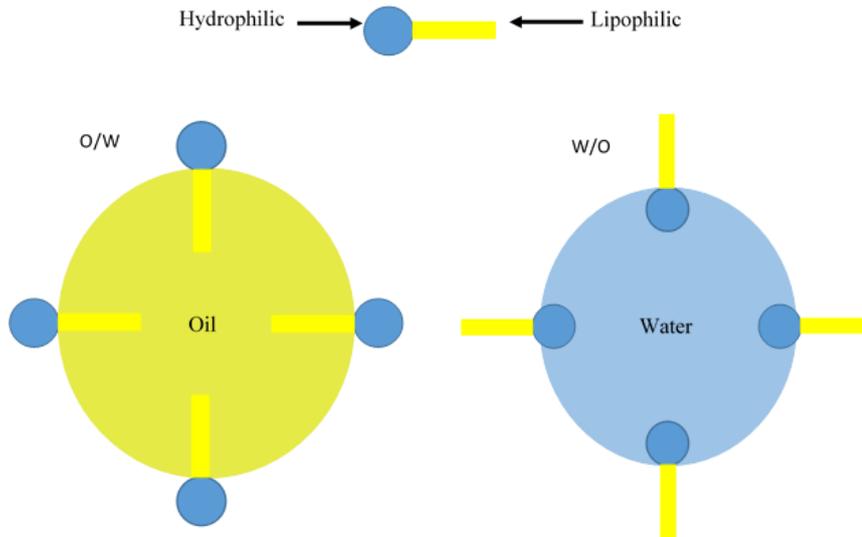
Figure 3. The working mechanism of emulsifiers in oil-in-water (O/W) and water-in-oil (W/O) emulsions.

Thickening agents are the most common food additives used to thicken the texture and increase the viscosity of the food and drink products. Most common thickening agents are starch and gum-based. (Norn 2014; Emerton and Choi 2008)

1.4.1.1 Egg yolk

Egg yolk has a complex structure. This structure can be divided into two main fractions: non-soluble protein aggregates (also known as granules) and plasma that contains low-density lipoproteins including lipovitellin, lipovitellinin and livetin and soluble proteins (Figure 4). Egg yolk is emulsion itself when in liquid form.

The outstanding properties for forming the emulsion is mainly due to this complex structure. Egg yolk also gives mayonnaise flocculation properties that improve the texture of the emulsion. Phospholipid lecithin, proteins and lipoproteins: lipovitellin,

lipovitellinin and livetin are thought to be the most essential to the emulsion forming properties of egg yolk. (Depree and Savage 2001; Anton 2013)
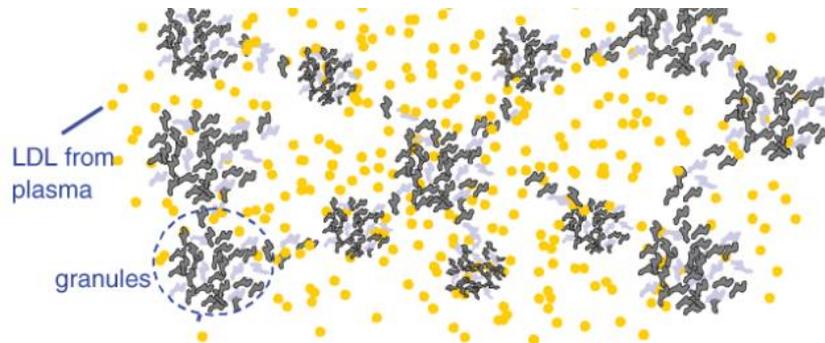

Figure 4. Nano and micro structure of egg yolk. (Anton 2013)

Egg yolk forms mainly used in food industry are pasteurized salted or sugared frozen egg yolk and dried yolk. Because the superior emulsifying properties of egg yolk are due to the structure, highly processed egg yolk has inferior properties compared to fresh egg yolk. The pasteurization of egg yolk does not affect the emulsifying properties to excess, unlike freezing or freeze-drying egg yolk. Mayonnaise made with egg yolk processed this way contains larger oil droplets which means that the phases of mayonnaise separate more easily. The reason for this is that when egg yolk is frozen below −6 °C an irreversible gelation occurs. The gelation makes the egg yolk difficult to combine with other raw materials and due to that it limits usefulness of the egg yolk. The most general accepted method to limit the gelation of egg yolk is addition of 10 % salt or sugar. Frozen sugared or salted egg yolk is relatively stable. Although freezing extended periods causes changes in quality and functionality of egg yolk. (Depree and Savage 2001)

Besides the lecithin, the pH of the emulsion has an essential effect on the stability of the emulsion. The viscoelasticity and stability of the mayonnaise should be highest when the pH is close to the average isoelectric point of the egg yolk proteins. The viscoelasticity was found to be highest at the pH of 3.9. (Depree and Savage 2001; Kiosseoglou and Sherman 1983)

1.4.1.2 Other emulsifying and thickening agents

Xanthan gum, modified celluloses and galactomannans (guar and locust bean gum) are the most commonly used thickeners in food industry. These polysaccharides are firm polydisperse macromolecules with mainly hydrophilic character. The polysaccharides are used for thickening and gelling of water phase in emulsion which in mayonnaise is the continuous phase. The polysaccharides are under the technical label of hydrocolloids. The physicochemical mechanism of each hydrocolloid is determined by the molecular structure of the component carbohydrate polymer. (Dickinson 2013)

Xanthan gum is widely used for stabilizing particle suspensions and emulsions due to its extremely high low-shear viscosity of water phase of low polymer content, approximately 1 g/kg. Xanthan traps and immobilizes oil droplets in the xanthan polymer network, which forms an effective yield stress that is more than enough to overcome the buoyancy forces acting on the individual droplets. Besides xanthan also starches are commonly used as thickeners. Starch can be heat-induced gelatinization where starch granules produce opaque thermoreversible gel on cooling. In addition, modified starch/cellulose has capacity to function as emulsifiers due to the ability to absorb in oil-water interface. Also, guar gum and some types of pectin has these properties. This surface activity has two possible ways. In the first the nonpolar character of chemical groups attached to the hydrophilic polysaccharide backbone, typical to hydrophobically modified starch/cellulose. In the second the presence of a protein moiety the emulsifier is linked covalently to the carbohydrate polymer, typical to guar gum and sugar beet pectin. (Dickinson 2013)

1.4.2 Raw materials effecting the stability

Salt improves the quality and stability of the mayonnaise in three diverse ways. Firstly, salt helps to disperse the egg yolk granules and make more surface-active material available. Secondly, salt neutralizes any charges on proteins. This allows the lipovitellin to absorb water and that strengthens the layer on the surface of the oil droplets. So, the granules swell. Thirdly the neutralization of any charge allows adjacent oil droplets to interact more strongly (Figure 5.) Earlier it was mentioned that pH 3.9 is the isoelectric point of the egg yolk proteins. Yet adding salt can compensate the isoelectric point for

the pH values different to isoelectric point, but only to some extent. Salt can have undesirable effects when used in excess. This will cause the egg yolk proteins to aggregate in continuous phase rather than forming the coating on the oil droplet. (Depree and Savage 2001; Kiosseoglou and Sherman 1983)
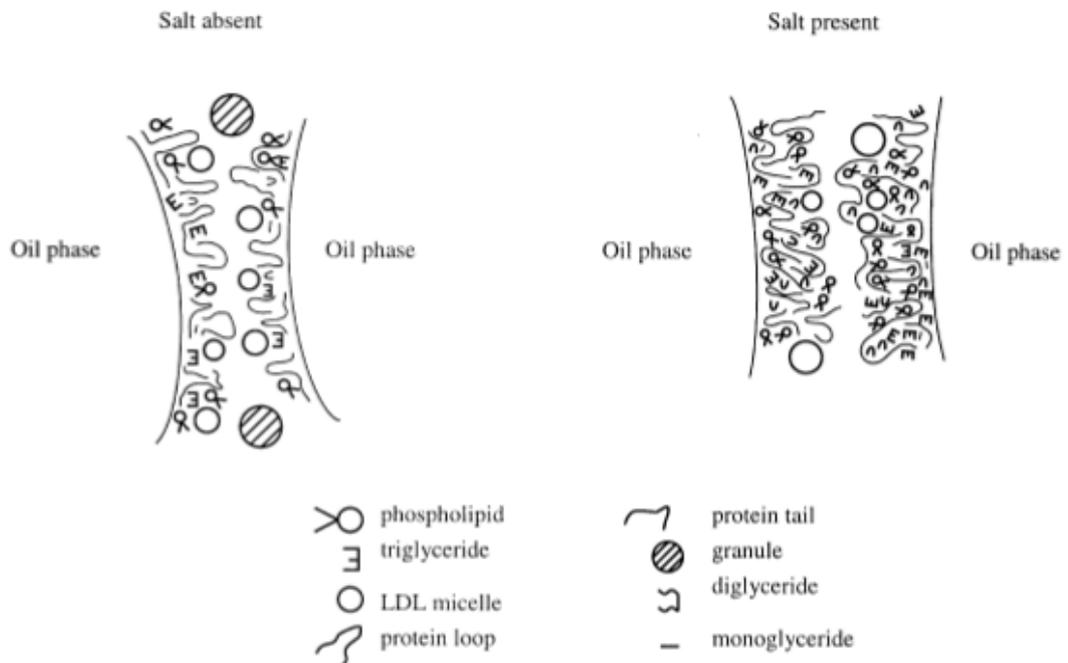

Figure 5. Egg yolk components absorbed on adjacent oil droplets when salt is absent and present. (Depree and Savage 2001)

The type of salt that best suits for these purposes has been studied. The highest effect on the emulsifying properties is when egg yolk is salted with unionized NaCl. Mayonnaise made with unionized NaCl salted egg yolk showed higher stability, viscosity and firmer emulsion when assessed by measuring the tendency to spread under its own weight compared to ionized NaCl or KCl salted egg yolk. This is due to effect of ions in water interactions. Small Na^+-ions have high electric field that tends to promote interactions between water molecules to form structures. Also, polyvalent ions affect similarly. This increases viscosity of emulsions. Unlike large monovalent ions (K^+, I^-, Cl^-) that tend to disrupt these water interactions. (Harrison and Cunningham 1986; Depree and Savage 2001)

Sucrose can weaken the interactions in emulsion. This is probably due to the shielding of reactive groups. This prevents egg white proteins and charged carbohydrates such as carboxylmethyl cellulose from interacting with egg white proteins and effectively forming cross-links between oil droplets. Although Huck-Iriart, Candal and Herrera also find that sucrose in a presence with sodium caseinate increases the emulsion stability. Strong protein-sugar of interactions modify the structure of the emulsion by decreasing the droplet size which then increases the stability of the emulsion. (Depree and Savage 2001; Huck-Iriart, Candal, and Herrera 2011)

Mustard increases the stability of emulsion. The flavor is formed by volatile sulphur compounds, these compounds are soluble in oil and slightly soluble in water. Therefore, mustard can act as emulsifying agent. Mustard has also antioxidant effect of mayonnaise. Studies show that mayonnaise containing mustard has longer shelf-life than mayonnaise without mustard. This is due to the conjugated dienes. In mayonnaise containing mustard the number of conjugated dienes was increasing slower and the mayonnaise contains less conjugated dienes than mayonnaise without mustard. (Depree and Savage 2001; Lagunes-Galvez et al. 2002; Ghorbani Gorji et al. 2016)

1.5   Rheology

Rheological measurements are useful tools for physical characterization of foods such as gels and emulsions. Rheological measurements of emulsions provide information about the physical properties and their behavior under different conditions. Furthermore, differences in physical properties and behavior of similar products can be analyzed and compared e.g. traditional mayonnaise and light mayonnaise. According to Tabilo-Munizaga and Barbosa-Cánovas light mayonnaise has slightly longer viscoelastic regions under strain in stress sweep analysis. Also, the results of this analysis indicate that traditional mayonnaise has more stable structure than light mayonnaise even though traditional mayonnaise can show phase separation during storage. When the mayonnaises where compared in yield stress analysis, the results suggest that the traditional mayonnaise can be pumped easier than light mayonnaise. However, the flow behavior in both mayonnaises indicates a uniformity of the microstructure. The study by Wendin and Hall indicates that fat content affects the properties of salad dressings the most. Also, the viscosity of the salad dressings increased when the fat and thickener contents increase.

Also, Peressini, Sensidoni and de Cindio studied the rheological differences between four different emulsions in Table 2 with determined nutritional values.

Table 2. Characteristics of emulsion samples (E1, E2, E3, E4) in previous study by Peressini, Sensidoni and de Cindio (Peressini, Sensidoni, and de Cindio 1998).

Nutritional values	E1	E2	E3	E4
Fat (g per 100 ml)	76.2	68.6	63.4	48.0
Carbohydrate (g per 100 ml)	0.5	1.0	3.3	8.7
Protein (g per 100 ml)	1.3	1.3	1.4	1.0
Ash (g per 100 g)	1.5	1.1	1.1	3.4
Moisture (g per 100 g)	16.6	24.9	27.9	42.3
Water activity	0.97	0.97	0.97	0.96
pH	3.9	4.0	4.0	3.7

To distinguish differences between the four emulsion samples oscillatory test was conducted. The results show that emulsion samples with higher fat content (E1, E2) are more elastic than the samples with lower fat content (E4). Emulsion sample 3 showed higher elasticity than E2 although it had lower fat content than E2. This was due to higher carbohydrate content. The reduction of fat was balanced with increasing carbohydrates, this gives E3 its high elastic behavior. Even though E3 is highly elastic it has also the highest viscous behavior after mechanical stirring so it is the most sensible to deformation. The most stable of the samples was sample E1. Emulsifying and thickening agents also affect the stability of the emulsion. Yildirim, Sumnu and Sahin studied how the change in emulsifying and thickening agents (sodium caseinate, xanthan gum and lecithin-whey protein concentrate) affect the stability. They found sodium caseinate to be the most effective emulsifying and thickening agent. In the presence of sodium caseinate the stability and viscosity of the double-emulsified mayonnaise increased while its particle size decreased. This reduction in particle size in known to improve the rheological properties of double mayonnaise. Rheological measurements can analyze e.g. viscoelastic

properties, structural differences and stability of the emulsions by measuring shear behavior. (Peressini, Sensidoni, and de Cindio 1998; Wendin and Hall 2001; Tabilo-Munizaga and Barbosa-Cánovas 2005; Yildirim, Sumnu, and Sahin 2016; Mezger 2011)

1.6 Aim of the practical work

The main aim of the work is to investigate the stability and quality of mayonnaise products with special emphasis on how the changes in production affect the stability and quality of mayonnaise products. The goal is to produce nearly identical mayonnaises regardless of the process. The main focus is to analyze the mayonnaise samples with selected analysis (fatty acid composition, acid value, peroxide value, anisidine value and rheological measurements) to understand effects on the changes in production. Mayonnaises are produced by Saarioinen Oy in Huittinen.

2   Materials and methods

Three mayonnaise samples are produced with the novel technique production line (N) and compared to the same mayonnaises produced with functional production line (P) which uses different production method in Saarioinen Oy, Huittinen. Mayonnaise samples are traditional mayonnaise (TM), light mayonnaise (LM) and mayonnaise dressing (MD). TM contains oil (75 %), water, egg yolk, vinegar, sugar, salt, mustard powder, thickening agent (E415), preservative (E202) and coloring agent (E160a). LM contains water, oil (30 %), vinegar, egg yolk, sugar, modified cornstarch, salt, mustard powder, thickening agents (E415, E412), preservative (E202), citrus aroma and coloring agent (E160a). MD contains water, oil (27 %), sugar, vinegar, mustard seeds, modified cornstarch, salt, thickening agents (E415, E412) and preservative (E202). The major differences between these samples are the amount of oil used and the emulsifying and thickening agents used (egg yolk versus other emulsifying and thickening agents modified cornstarch, E415 and E412). After the production of all the mayonnaises, from both production lines N and P, were analyzed fresh (F) and after 2 weeks of incubation in 37 °C (R). Together 12 different samples 6 from each process.

For sensory evaluation and rheological measurements mayonnaise samples did not require any pretreatments and the samples were stored in refrigerator. For the mayonnaise samples used in chemical analysis, acid, peroxide and anisidine values and fatty acid composition, the oil was required to be separated from the mayonnaises. The samples were centrifugated to separate the oil from the mayonnaise. First the mayonnaise samples were stored in freezer in falcon tubes. The samples were thawed in cold water bath. After thawing the samples, the mass of the falcon tubes was balanced with the precision of 0.1 g. The samples were centrifuged with Sorvall TC centrifuge for 15 minutes with G-value of 4 500. The separated oil phase was pipetted into empty falcon tube.

2.1   Acid, anisidine and peroxide value

The acid value was determined according to Nordic Committee on Food Analysis Method No. 38, 4th Edition 2001 to analyze the free fatty acids in the separated oils. The acid value is defined as the number of mg of NaOH needed to neutralize 1 g of sample. The reagent solutions of ethanol (EtaxB) -diethyl ether (Sigma-Aldrich, Diethyl ether, puriss

p.a) (1:1, v/v) and 0,1 M NaOH (Sigma-Aldrich, Sodium hydroxide, puriss p.a, opened: 9.12.2013) was made. For the determination of the concentration of NaOH, oxalic acid was titrated with the NaOH solution. The concentration was calculated. Two parallel samples from each oil sample were weighed. The weighed amount of oil should require at least 0.2 ml of NaOH solution to be neutralized, according to this 3 g of F samples was weighed in Erlenmeyer flasks and 2 g of R samples. Then phenolphthalein (1 % phenolphthalein in ethanol solution) was added to the ethanol-diethyl ether solution before neutralizing with NaOH to faint pink color. 50 ml of the freshly neutralized ethanol-diethyl ether solution was added to the oil samples and then titrated with NaOH until neutralized (faint pink color is visible for 10 seconds). The acid values of all the oil samples were calculated. (Nordic Committee on Food Analysis 2001)

The anisidine value was determinated according to IUPAC Method 2.504, 7th Edition 1987 to analyze the number of aldehydes in the oil samples. The *p*-anisidine value is defined by convention as 100 times the optical density measured in a 1 cm cell of a solution containing 1.00 g of the oil in 100 ml of reagents. The reagent solution of 2.5 g/l *p*-anisidine (Aldrich, *p*-anisidine, 99%) in acetic acid (J.T. Baker, Acetic acid, 99-100 % glacial) was made. Two parallel samples from each oil sample were weighed according to standard for F samples 4 g and for R samples 2 g in 25 ml volumetric flasks. The volumetric flasks were diluted to volume with isooctane. 2 ml of each sample solutions was pipetted into cuvettes (VIS 340-800 nm). The absorbance of all the samples were measured with spectrophotometer at 350 nm wavelength. The reference cell of the spectrophotometer was filled with solvent. The 5 ml of each solution was pipetted into each test tubes and 1 ml *p*-anisidine solution was added and shaken with test tube agitator and let to rest for 10 min. Acetic acid- *p*-anisidine solution reacts with aldehydic compounds in the oil sample and forms a yellowish color, the intensity of the color depends on amount of aldehydic compounds and their structure. After 10 min 2 ml of each sample solution was pipetted into cuvette and the absorbance was measured again at 350 nm using blank in a reference cell. Blank was prepared in the same way as the sample but without the oil. One blank was used as reference for 8 samples. (IUPAC 1987)

The peroxide value was determined according to AOCS Official Method Cd 8b-90, Revised 2003 and Nordic Committee on Food Analysis Method No. 158, 1997 to analyze the peroxides and other same type of products of oxidation. The peroxide value is a

quantity of all substances in the sample expressed in terms of milliequivalents of peroxide per 1 kg of sample which oxidize potassium iodide. The reagent solutions acetic acid (J.T. Baker, Acetic acid, 99-100 % glacial)-isooctane (Rathburm, Iso-octane) (3:2, v/v), saturated potassium iodide, 0.01 M sodium thiosulfate and starch indicator was made. The determination of sodium thiosulfate with 3 parallel samples was conducted by mixing 25 ml distilled water, 2 ml 4 M H_2SO_4, 1 ml 0.002 M potassium iodate together then adding 5 ml saturated potassium iodide and titrating immediately with 0.01 M sodium thiosulfate solution until faint yellowish-brown color. Then starch indicator was added and titrating continued until blue color disappears. The concentration of sodium thiosulfate was calculated. Then the actual peroxide value was analyzed. Two parallel samples from each oil sample were weighed. The samples were weighed according the expected peroxide value, according to this 4 g of F samples was weighed in Erlenmeyer flasks and 2 g of R samples. To the Erlenmeyer flasks 50 ml acetic acid-isooctane solution and 0.5 ml saturated potassium iodide solution was added and let stand and shaking 3 times during 1 min so that iodine is liberated. After 1 min 30 ml water was added. Titration was started with 0.01 M sodium thiosulfate and continued until the yellow color from iodine was faint. Then starch indicator was added and titration continued until blue color disappears in this point all the iodine has been liberated from the reagent layer. Also, blank samples were determined. The peroxide values of all the samples were calculated. (AOCS 2003; Nordic Committee on Food Analysis 1997)

2.2 Fatty acid composition

Fatty acid composition of the oil of the mayonnaises was determined according to standard procedure to analyze the fatty acid composition of the F samples qualitatively and quantitatively. In the gas chromatography (GC) analysis, the boron trifluoride-catalyzed esterification method (BTEM) produces volatile fatty acid methyl esters from the oil samples. The BTEM esterified fatty acids and free fatty acids. In the analysis 0.5 mg of oil is required, there for each oil sample is weighed with larger amount and the diluted into known concentration with hexane. Then the amount of solution containing 0.5 mg of oil was pipetted into glass tubes with screw joint caps. Internal standard (triheptadecanoin, TAG 17:0) was added in all the samples so that the amount is 5 % of all lipids Then the hexane was evaporated and 100 µl toluene and 500 µl boron trifluoride-methanol was added. Samples were incubated in 90 °C for 60 min. The chemical reaction

of this analysis is shown in Figure 6. When cooled down 800 µl distilled water and 1 ml hexane was added and the vigorously shaken with test tube agitator for 10 sec. Two phases appeared, the upper hexane phase contains the fatty acid methyl esters and is carefully pipetted into auto sampler bottle.

$$R\text{-}COOH + CH_3OH \xrightarrow{\quad BF_3 \quad} R\text{-}COOCH_3 + H_2O$$
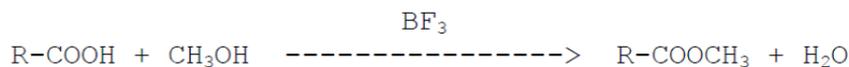
Figure 6. The chemical reaction of the esterification with BTEM.

Samples are the analyzed together with external standards (FAME37 and GLC68D) in Shimadzu GC-2010 with AOC-20i auto injector and flame ionixation detector (Shimadzu Corporation, Kyoto, Japan) with wall coated open tubular column DB-23 (60 m x 0.25 mm, liquid film 0.25 µm, Agilent Technologies) with helium as a carrier gas with injection temperature 270 °C, column temperature 130 °C and detector temperature 280 °C. The injection volume was 0.5 µL. Total amount of fatty acids and their mass percentages are calculated.

2.3   Rheology measurements

The rheological measurements (flow curve, thixotropy and oscillatory measurements: amplitude and frequency sweep) were conducted with Anton Paar Modular Compact Rheometer (MCR 102, Anton Paar, Austria) and analyzed with standard methods by RheoPlus Software, Anton Paar.   For the oscillatory measurements parallel-plate measuring (Figure 7) system with measuring plate (Anton Paar, PP15, diameter: 14.973 mm) was used and for the flow curve and thixotropy measurements cone-and-plate measuring system (Figure 7) with measuring cone (Anton Paar, CP50-1, diameter: 49,98 mm, cone angle: 0,997°, truncation: 101 µm) was used.
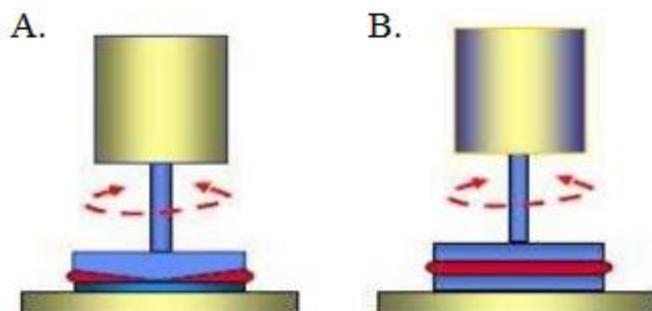
Figure 7. Rheology measurement systems. A. Cone-and-plate system. B. Parallel-plate system.(Ngwa 2015).

For the measurements mouth-like condition was set. The temperature of the bottom plate was set to 36 °C, the average temperature of human mouth and the measuring system was covered with metal cover and little water was added in the bottom of the metal cover to prevent water evaporation. (Microlife n.d.; Mezger 2011)

2.4   Sensory analysis

The sensory evaluations were conducted to support the results from analysis and measurements. The sensory evaluations were held in Saarioinen Oy, Huittinen. The panel consisted of 3 expert panelists. The panelists were employees in Saarioinen Oy, Huittinen with extensive experience in sensory evaluations and mayonnaise products. The sensory analysis samples were F and R versions of the TM, LM, MD made with N and P lines. The samples were randomly numbered, and the order of the samples was randomized (AB, CD, EF variations, F and R mayonnaises evaluated separately). For the rancidity of the odor diacetyl (Fluka, Diacetyl (2,3-Butadion), puriss > 99.5 %, opened: 1.9.1980) and butyric acid (Fluka, Butyric acid, puriss p.a ≥ 99.5 %, opened: 29.6.1998) were used as comparison samples. The comparison samples for the basic tastes were 2 % sucrose solution (Alfa Aesar, Sucrose, 99 %), 0.2 % sodium chloride solution (Alfa Aesar, Sodium Chloride, crystalline powder, 99+ %), 0.07 % caffeine solution (Alfa Aesar, Caffeine, 99 %), 0.07 % citric acid solution (Alfa Aesar, Citric Acid, 99+ %) and 0.018 % L-glutamic acid solution (Alfa Aesar, L-glutamic acid monosodium salt monohydrate, 98+ %). The sensory evaluation forms consisted of question about appearance (color, smoothness, air bubbles, solid particles and fat separation), odor (vinegar and rancid

odor), taste (sweetness, sourness, saltiness, bitterness, umami, rancid and vinegar taste), mouthfeel/texture (smoothness, gel-like, foam-like, slimy, oily). Question types were mainly 5-point hedonic scale (smoothness, air bubbles, solid particles, fat separation, vinegar odor and taste, rancid odor and taste, foam-like, gel-like, slimy and oily) and 9-point hedonic scale (sweetness, sourness, saltiness, bitterness and umami). Select one questions were used to describe whether the sample was comparable to fresh and merchantable mayonnaise or not and to describe whether rancidity of the odor was closer to diacetyl or butyric acid. Open questions were used to describe the color, appearance, odor, taste and mouthfeel/texture of the samples. Also paired comparison test was to determine whether the N or P sample of the TM, LM and MD had thicker consistency. The results are statistically analyzed with t-test.

3   Results and Discussion

3.1   Fatty Acid Composition

The rapeseed oil contains approximately saturated fatty acids: 16:0 palmitate and 18:0 stearate and unsaturated fatty acids: 16:1 palmitoleate acid, 18:1 oleate acid, vaccinate acid, 18:2 linoleate acid, 18:3 linolenate acid, 20:0 arachidate acid, 20:1 eicosanoate acid and 22:1 erucic acid. The GC analysis shows that all the samples contained high amount of 18:1(n-9) methyl oleate acid, 18:2(n-6) methyl linoleate acid, 18:3(n-3) methyl linolenate acid, 16:0 methyl palmitate acid, 18:1(n-7) methyl vaccenate acid, 18:0 methyl stearate acid, 20:1(n-9) methyl 11-eicosanoate acid and 20:0 methyl arachidate acid. Furthermore, samples also contain small amount of 1.3 µg/mL methyl palmitoleate acid (TM), 3.0 µg/mL erucic acid methyl ester (MD) and 0.4 µg/mL (LMN) and 9.6 µg/mL (LMP) pentadecanoic acid methyl ester. These not common fatty acids for rapeseed oil most likely in the samples due to the other ingredients in the samples. Pentadecanoic acid methyl ester is most likely contamination during the analysis because it is most common to find in bovine milk products. The quantitative results of the TM, LM and MD samples are shown in Table 3 (TM), Table 4 (LM) and Table 5 (MD). The change of the production line did not have any effect on the amount of compound found. Figure 8 displays the comparison of compounds found in different samples. (Bocianowski, Mikołajczyk, and Bartkowiak-Broda 2012; "Crambe, Industrial Rapeseed, and Tung Provide Valuable Oils" 2006; Archer Daniels Midland Company 2015).

Table 3. The results of the GC analysis for the TMNF and TMPF samples (compounds (C:D: number of carbon atoms and double bonds in fatty acid), concentrations, correction factors and amount of the compounds).

TMN & TMP		TMN			TMP		
C:D	Compound	Concentration (mg/mL)	Correction factor	Amount of Compound (µg/mL)	Concentration (mg/mL)	Correction factor	Amount of Compound (µg/mL)
16:00	Methyl Palmitate	0.0194	0.1470	18.9	0.0197	0.1657	19.1
16:1(n-7)	Methyl Palmitoleate	0.0012	0.1551	1.3	0.0013	0.1748	1.3
18:00	Methyl Stearate	0.0115	0.2036	11.3	0.0087	0.1672	8.5
18:1(n-9)	Methyl Oleate	0.2522	0.1505	250.9	0.2564	0.1697	255.1
18:1(n-7)	Methyl Vaccenate	0.0146	0.1421	13.7	0.0151	0.1602	14.1
18:2(n-6)	Methyl Linoleate	0.0876	0.1451	84.0	0.0885	0.1635	84.8
18:3(n-3)	Methyl Linolenate	0.0415	0.1445	39.6	0.0786	0.3025	75.0
20:00	Methyl Arachidate	0.0027	0.1488	2.6	0.0026	0.1678	2.6
20:1(n-9)	Methyl 11-eicosenoate	0.0052	0.1465	5.0	0.0055	0.1652	5.3

Table 4. The results of the GC analysis for the LMNF and LMPF samples (compounds, concentrations, correction factors and amount of the compounds).

LMN & LMP		LMN			LMP		
C:D	Compound	Concentration (mg/mL)	Correction factor	Amount of Compound (µg/mL)	Concentration (mg/mL)	Correction factor	Amount of Compound (µg/mL)
15:00	Pentadecanoic Acid Methyl Ester	0.0005	0.1451	0.4	0.0099	0.1630	9.6
16:00	Methyl Palmitate	0.0194	0.1464	18.9	0.0212	0.1645	20.6
18:00	Methyl Stearate	0.01	0.1477	8.2	0.0097	0.1660	9.5
18:1(n-9)	Methyl Oleate	0.25	0.1499	249.4	0.2262	0.1631	225.1
18:1(n-7)	Methyl Vaccenate	0.01	0.1415	13.8	0.0108	0.1590	10.1
18:2(n-6)	Methyl Linoleate	0.09	0.1445	83.5	0.0747	0.1600	71.6
18:3(n-3)	Methyl Linolenate	0.04	0.1440	39.1	0.0327	0.1618	31.3
20:00	Methyl Arachidate	0.00	0.1482	2.5	0.0027	0.1666	2.6
20:1(n-9)	Methyl 11-eicosenoate	0.01	0.1459	4.9	0.0049	0.1640	4.7

Table 5.The results of the GC analysis for the MDNF and MDPF samples (compounds, concentrations, correction factors and amount of the compounds).

MDN & MDP		MDN			MDP		
C:D	Compound	Concentration (mg/mL)	Correction factor	Amount of Compound (μg/mL)	Concentration (mg/mL)	Correction factor	Amount of Compound (μg/mL)
16:00	Methyl Palmitate	0.0186	0.1467	18.1	0.0185	0.1420	18.0
18:00	Methyl Stearate	0.0082	0.1481	8.0	0.0080	0.1433	7.8
18:1(n-9)	Methyl Oleate	0.2488	0.1503	247.5	0.2479	0.1455	246.6
18:1(n-7)	Methyl Vaccenate	0.0144	0.1418	13.5	0.0143	0.1373	13.4
18:2(n-6)	Methyl Linoleate	0.0863	0.1448	82.8	0.0855	0.1402	82.0
18:3(n-3)	Methyl Linolenate	0.0411	0.1443	39.3	0.0405	0.1397	38.7
20:00	Methyl Arachidate	0.0026	0.1486	2.6	0.0026	0.1438	2.5
20:1(n-9)	Methyl 11-eicosenoate	0.0056	0.1463	5.4	0.0060	0.1416	5.8
22:1(n-9)	Erucic Acid Methyl Ester	0.0031	0.1375	2.8	0.0035	0.1331	3.2
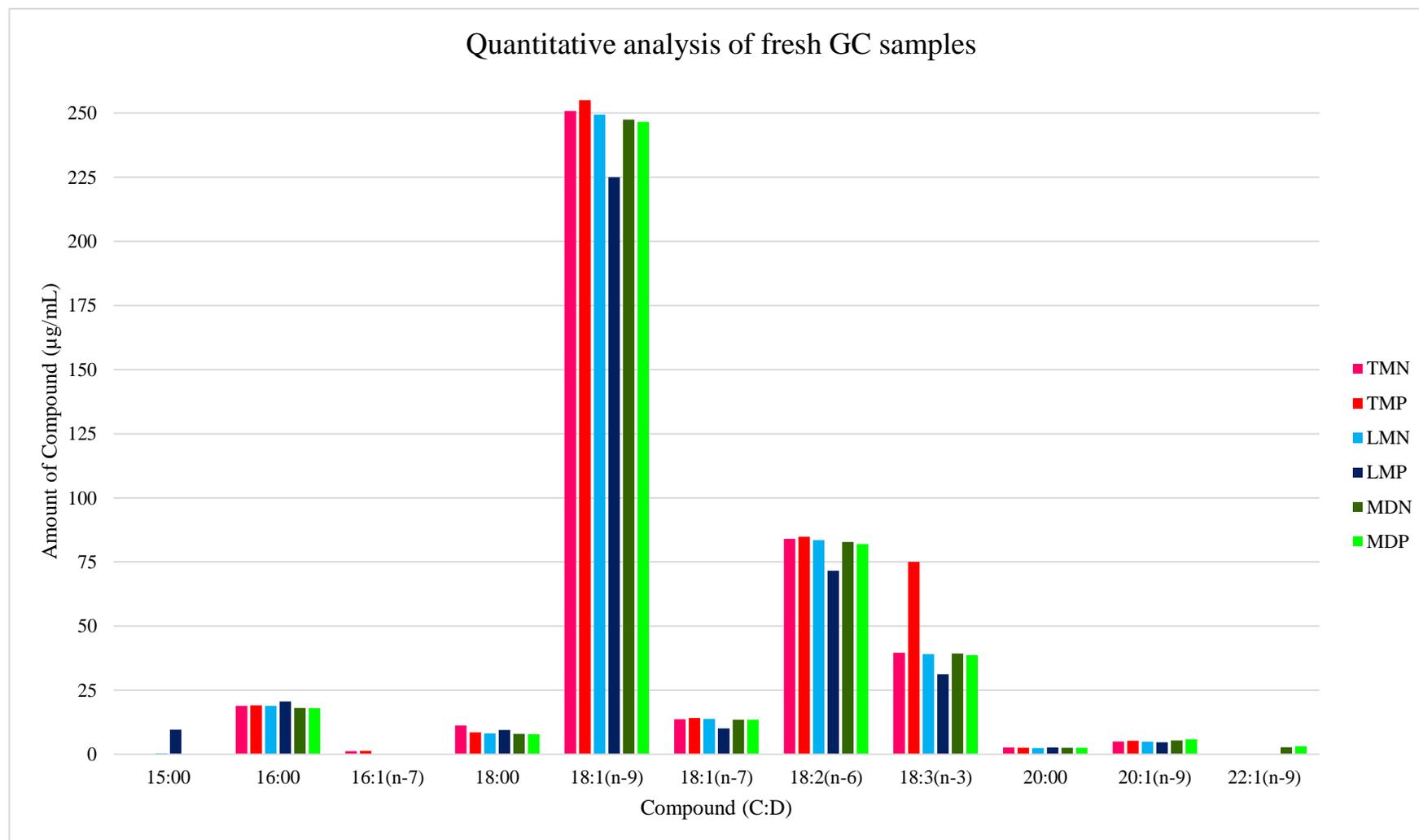
Figure 8. The results of the quantitative analysis. The comparison of the compounds found and the amount of the compounds in chromatograms.

3.2   Acid, anisidine and peroxide value

The oxidation for the TM (Figure 9.), LM (Figure 10.) and MD (Figure 11.) samples are highly due to the formation of peroxide radicals (peroxide value) and aldehydes (anisidine value). The values increase considerably during the 2-week incubation. The acid value increases only slightly so the free fatty acids have less influence on the oxidation process during the incubation. The oxidation level of the novel technique production line is somewhat lower compared to the oxidation level of the functional production line.
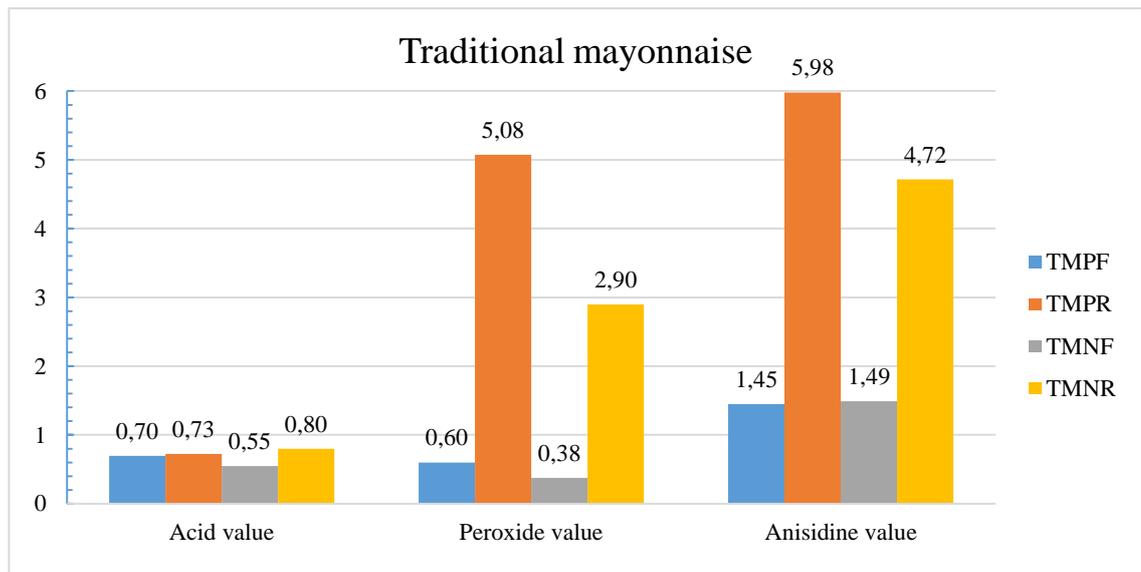
Figure 9. The oxidation products of the TM. Comparison of fresh and after 2-week incubation. Also between the different production lines.
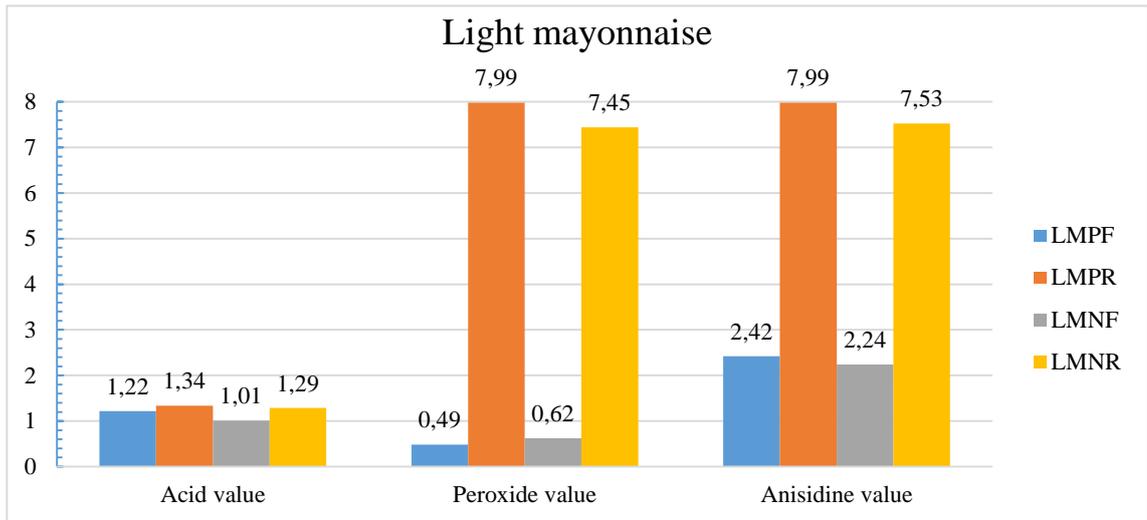
Figure 10. The oxidation products of the LM. Comparison of fresh and after 2-week incubation. Also between the different production lines.
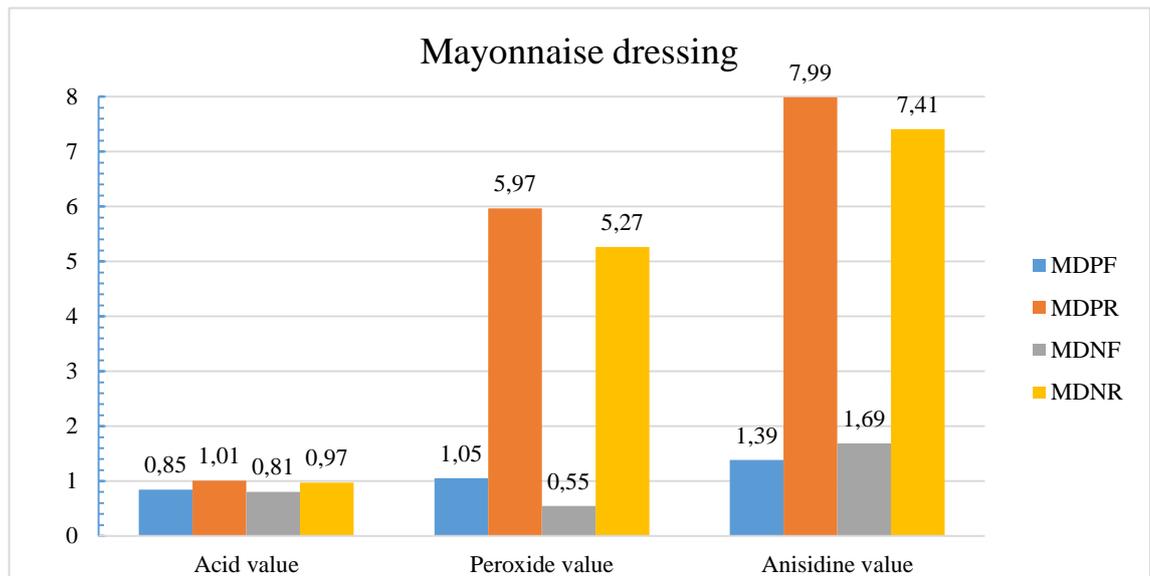
Figure 11. The oxidation products of the MD. Comparison of fresh and after 2-week incubation. Also between the different production lines.

3.3   Rheology analysis

The amplitude sweep shows for all the samples that the consistency of the samples is gel-like because in all the curves the storage modulus greater than the loss modulus. The curves for the TM are the highest which indicates that the TM has the most gel-like consistency and respectively MD has the least gel-like consistency when though it has gel-like consistency (Figure 12). When comparing the F and R samples there are nearly no difference of the consistency in TM, LM and MD samples. Also, when comparing the N and P samples only in LM sample they have slight difference between the LMFP, LMRP and LMFN, LMRN. The gel-like consistency of the LMFP and LMRP samples is thicker than for LMFN and LMRN but the viscosity difference is slight. All the curves for all the samples also show the gel point, which is the point where the loss modulus becomes greater than the storage modulus, so the gel-like consistency becomes liquid-like. For the TM and LM samples it comes at the end of the curve, showing that the structure of the samples is stable. For MD samples the gel point comes little bit earlier which indicates that the structure is slightly less stable. Amplitude sweep determines the strain amplitude for the frequency sweep.

Frequency sweep curves show that in all the samples the elastic behavior dominates the viscous behavior because also in the frequency sweep the storage modulus curves are greater than the loss modulus curves (Figure 13). This means that the samples are stable at rest. TM and LM samples are equally stable but the MD curves show that it is slightly less stable at rest than the TM and LM samples. MD also have some irregularities in the curves (peaks) indicate that the MD sample was not smooth but contained e.g. solid particles.
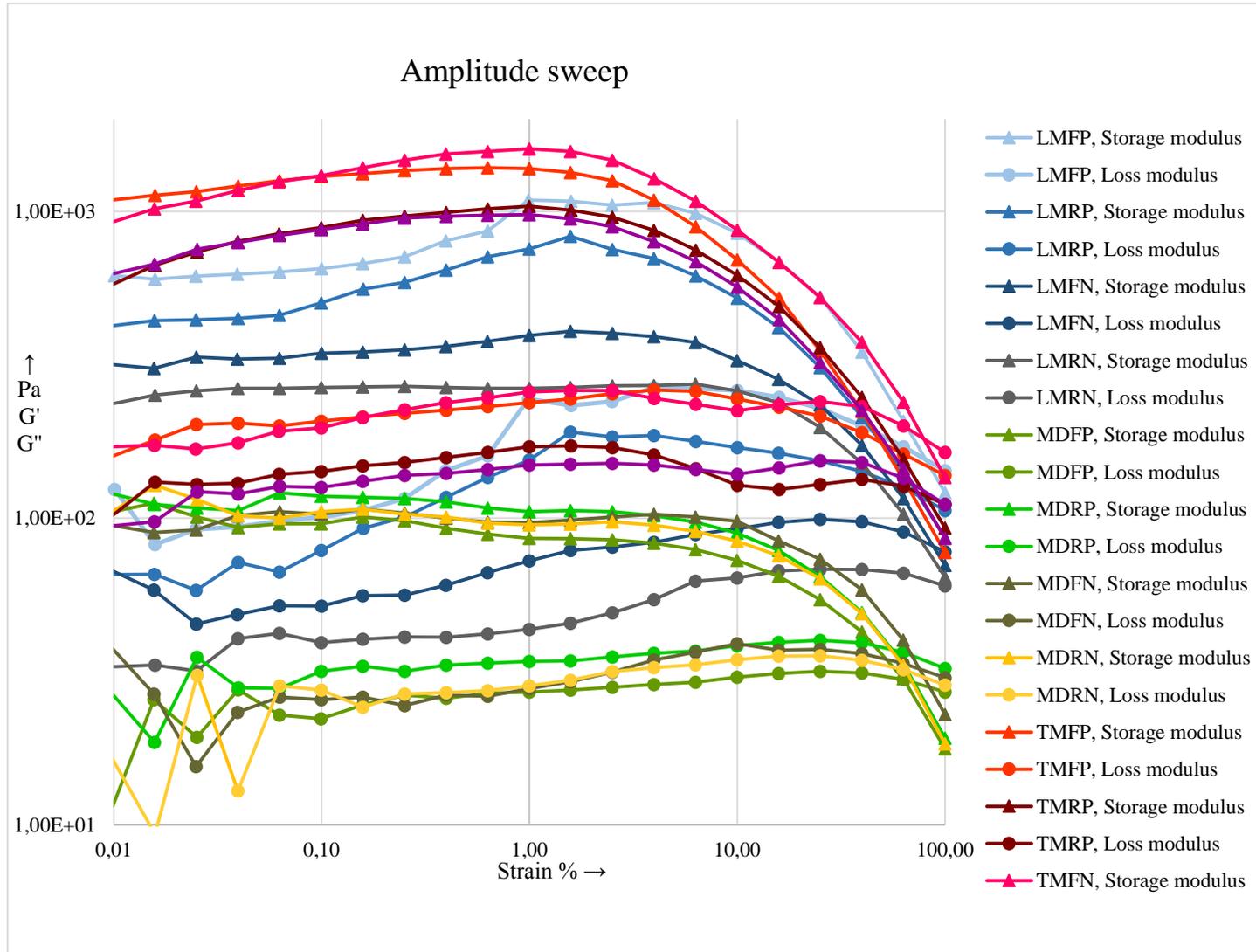
Figure 12. Amplitude sweep with storage and loss modulus curves for all the samples showing the gel-like consistency and the gel point of the samples.
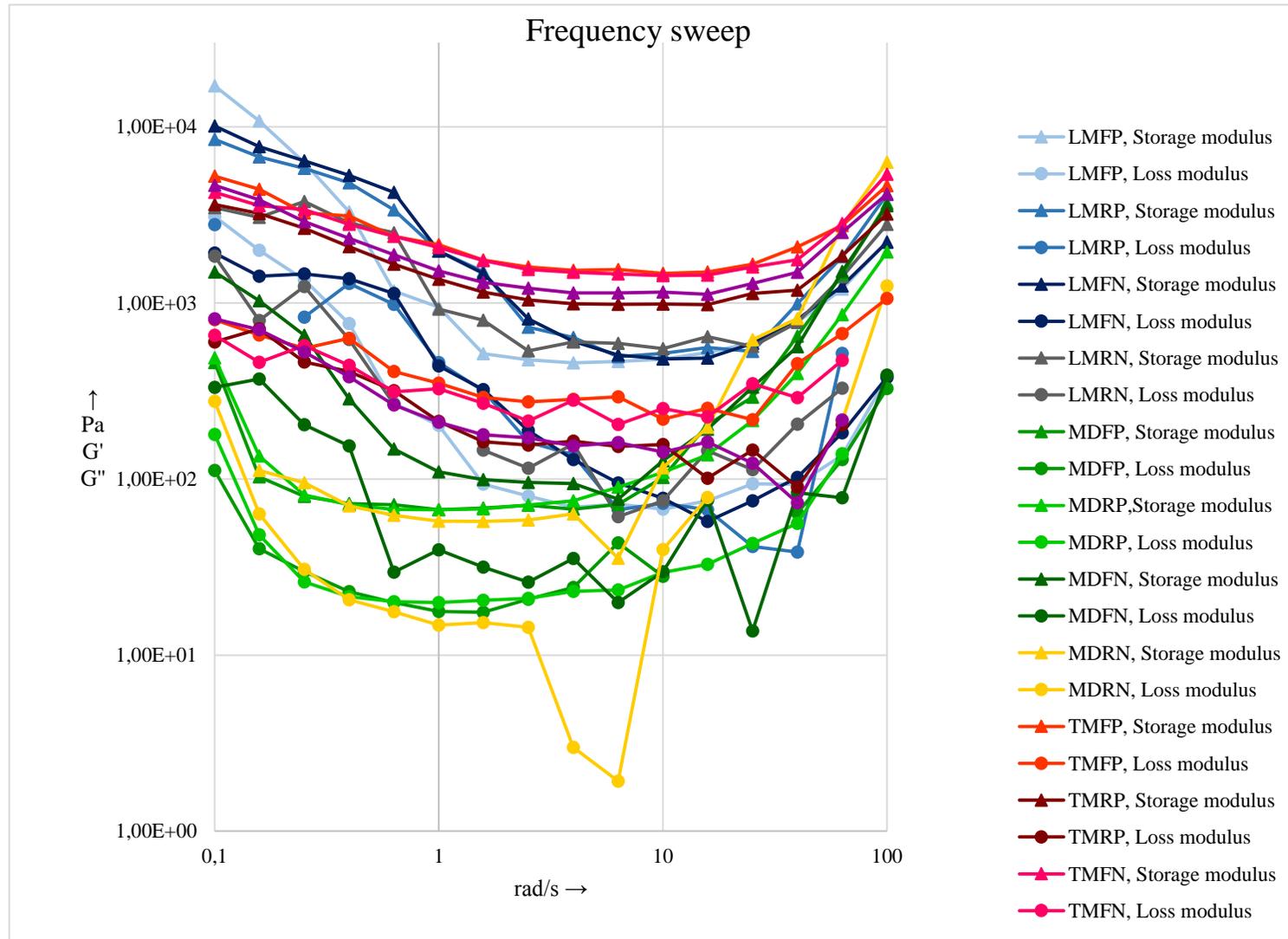
Figure 13. Frequency sweep indicates that the samples have greater elastic properties than liquid properties and have physical stability at rest.

Flow curve of all the samples indicates that the samples are shear-thinning due to deformation of the sphere-shaped oil droplets to ellipses (Figure 14). The TMFN and TMFP samples have the lowest shear-thinning properties, the second lowest are LMFP and LMRP samples, the third lowest LMFN, LMRN, TMRP and TMRN. The MD samples have the highest shear-thinning properties. The less shear stress needed the easier the samples start the shear-thinning.

The starting point in the thixotropic analysis is low-shear condition it represents the viscosity at rest, then the increase in shear stress level causes structural decomposition and thirdly the decrease in shear stress causes structural regeneration (Figure 15.) The samples TMFN, TMFP, LMFN and LMFP have highest the viscosity the TMRN, TMRP, LMRN and LMRP have somewhat lower viscosity, the oxidation causes decrease in viscosity. The MD samples have the lowest viscosity. All the samples have good structural regeneration. This indicates that the samples endure well in conditions where shear stress is present e.g. pumping through piping.
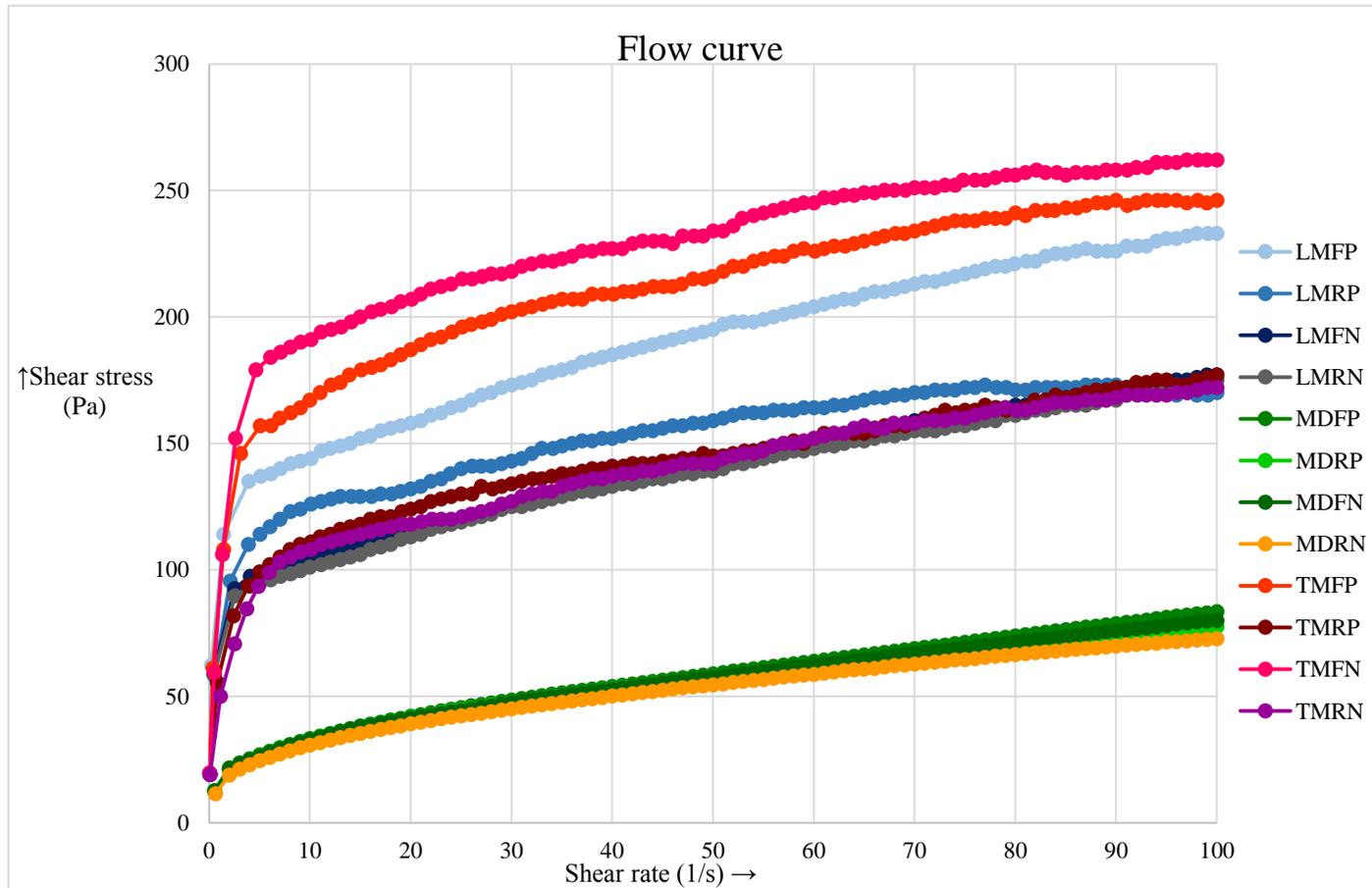
Figure 14. Flow curve indicates the shear-thinning properties of the samples. The less shear stress needed, the more shear-thinning the sample.
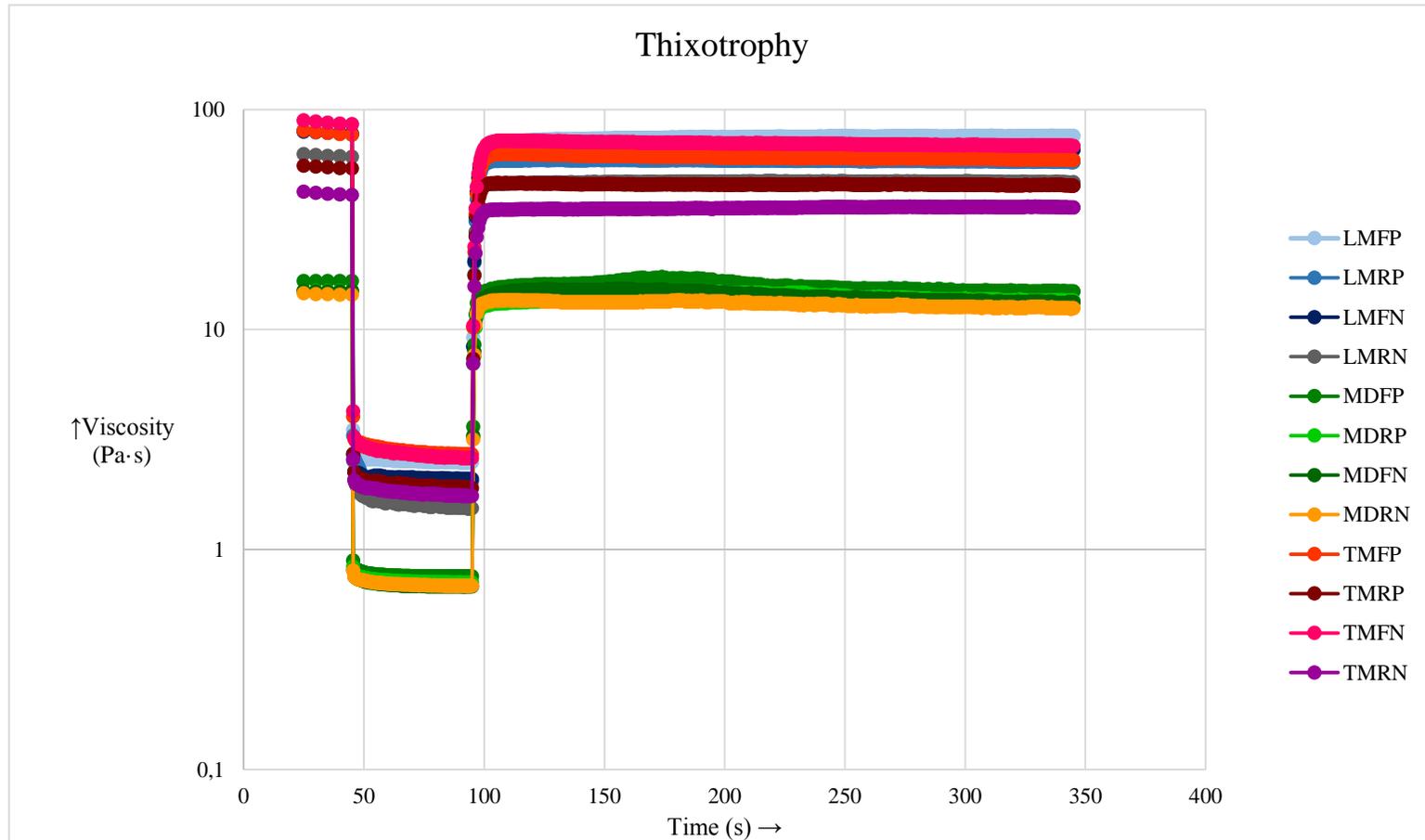
Figure 15. The thixotrophy analysis indicates the shear stress durability and the viscosity of the samples.

3.4 Sensory analysis

In the sensory analysis the questions for appearance were: smooth: Is it smooth? (scale 1-5: not at all-extremely), air bobbles: Are there visible air bobbles? (scale 1-5: not at all-extremely), solid particles: Are there visible solid particles? (scale 1-5: not at all-extremely), fat separation: Is there visible fat separation? (scale 1-5: not at all-extremely), likeness: Is the sample comparable to merchantable product? (yes=1, no=2), if not, quality: Evaluate the quality when compared to merchantable product? (scale 1-5: not eatable-extremely good) (Figures 16-18). The appearance of all the mayonnaise samples were smooth, without air bobbles or solid particles, almost all of the samples were considered to be comparable to merchantable product except TMNR and TMPR, but their quality was still pretty good. None of the differences between the answers were statistically significant.
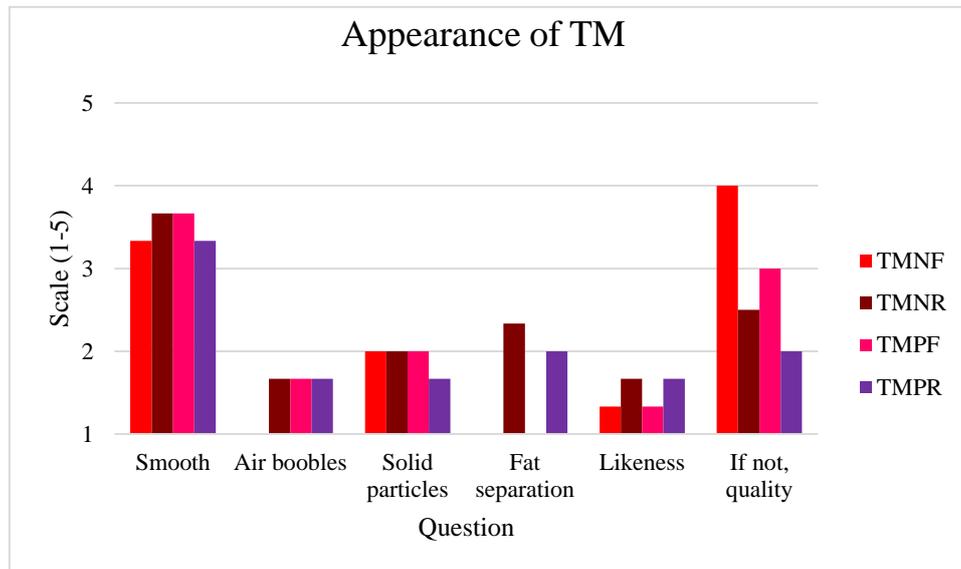
Figure 16. The results for the appearance of the traditional mayonnaise.
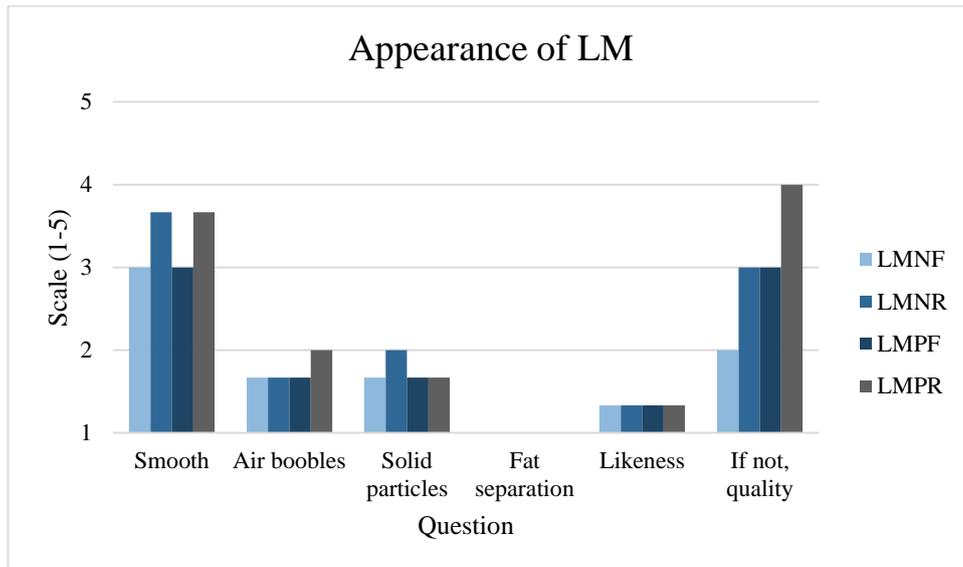
Figure 17. The results for the appearance of the light mayonnaise.
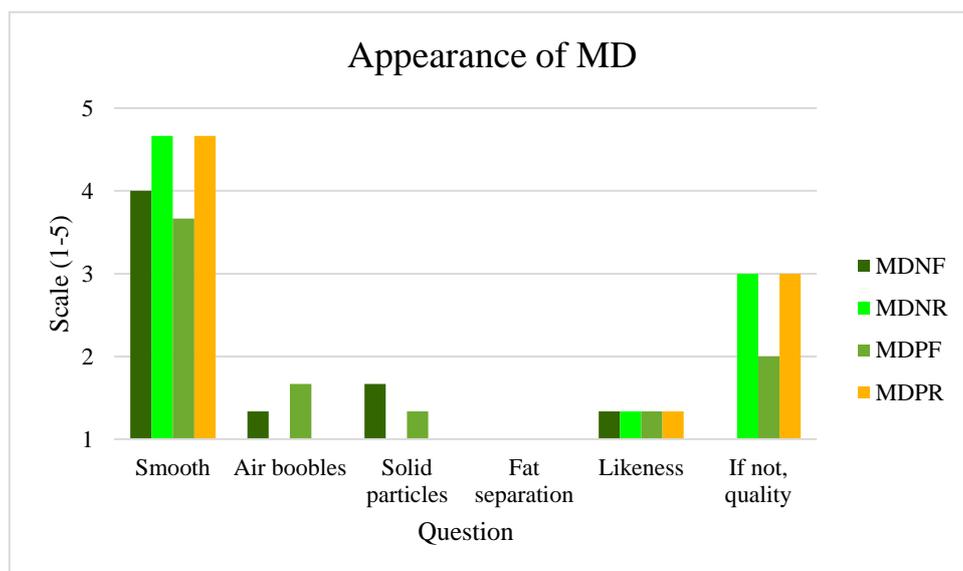
Figure 18. The results for the appearance of the mayonnaise dressing.

Questions for the smell of the samples were: vinegary: Does the sample smell like vinegar? (scale 1-5: not at all-extremely), rancidity: Does the sample smell rancid? (scale 1-5: not at all-extremely), closeness of the rancidity: Is the rancid smell closer to butyric acid or diacetyl? (1=butyric acid, 2=diacetyl), likeness: Is the sample comparable to merchantable product? (yes=1, no=2), if not, quality: Evaluate the quality when compared to merchantable product? (scale 1-5: not eatable-extremely good) (Figures 19-21). All the

mayonnaises were thought to be slightly vinegar smell, the incubated samples were thought to be pretty rancid, the rancidity for all the samples were thought to be closer to the smell of diacetyl than butyric acid. The incubated samples were not comparable to the merchantable product and the quality compared to merchantable product was satisfying or bad. The only statistically significant difference was the difference in rancidity between TMPF (not rancid at all) and TMPR (very rancid).
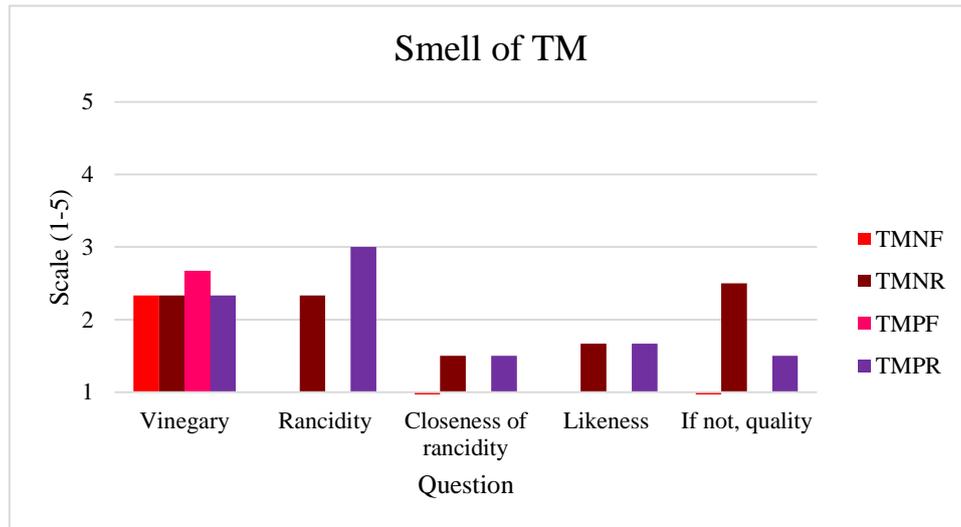

Figure 19. The results of the smell of the traditional mayonnaise.
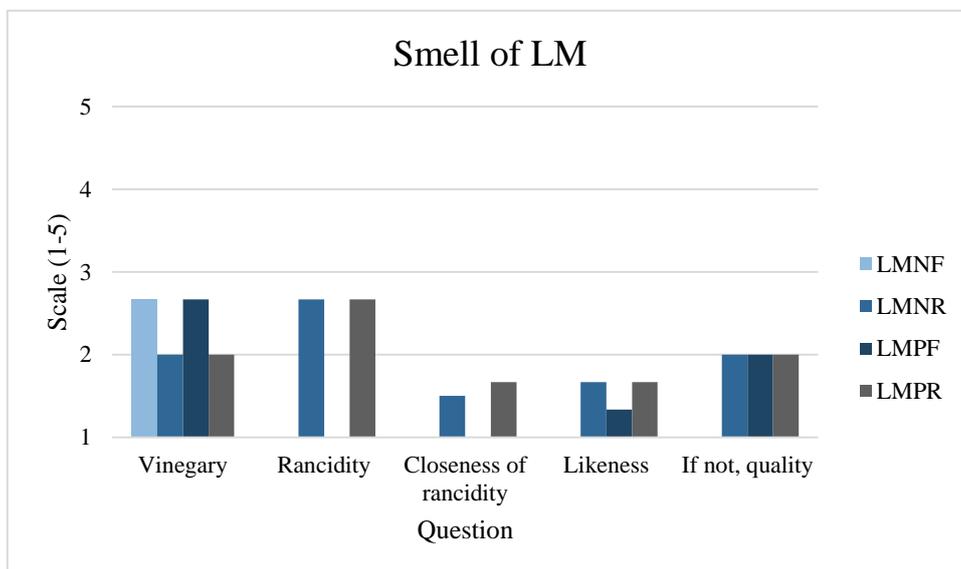
Figure 20. The results of the smell of the light mayonnaise.
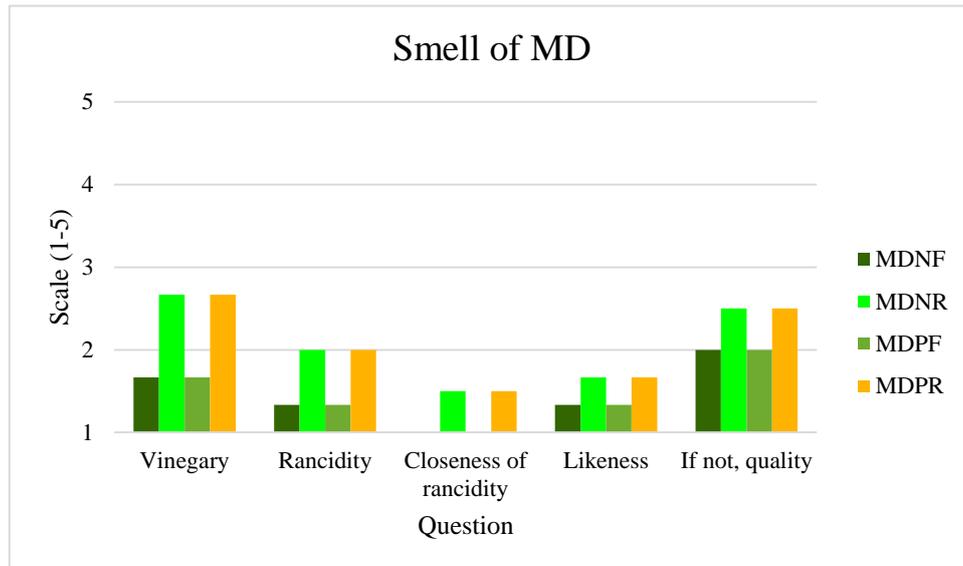
Figure 21. The results of the smell of the mayonnaise dressing.

Questions of the taste of the mayonnaises were: sweetness: How sweet is the sample compared to the standard liquid? (scale 1-9: extremely less- extremely more), saltiness: How salty is the sample compared to the standard liquid? (scale 1-9: extremely less- extremely more), bitterness: How bitter is the sample compared to the standard liquid? (scale 1-9: extremely less- extremely more), sourness: How sour is the sample compared to the standard liquid? (scale 1-9: extremely less- extremely more), umami: How umami is the sample compared to the standard liquid? (scale 1-9: extremely less- extremely more), rancidity: Does the sample taste rancid? (scale 1-5: not at all-extremely), vinegary: Does the sample smell like vinegar? (scale 1-5: not at all-extremely), likeness: Is the sample comparable to merchantable product? (yes=1, no=2), if not, quality: Evaluate the quality when compared to merchantable product? (scale 1-5: not eatable-extremely good) (Figures 22-24). The sweetness, saltiness, bitterness, sourness, umami flavors were not production line or incubation depended, more depended on the recipe. The incubated R samples taste rancid and the quality compared to merchantable products were bad to very bad. There were no statistical differences between the answers.
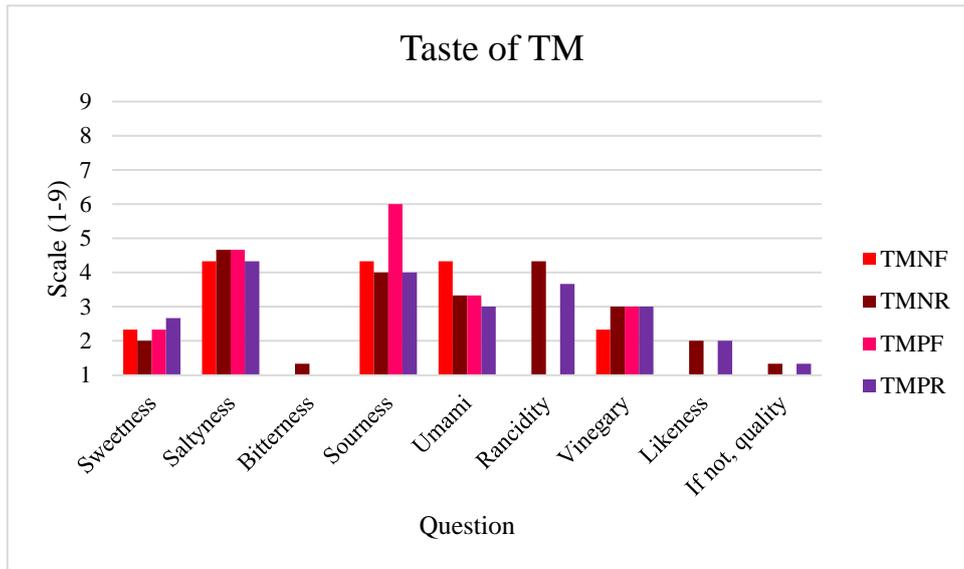
*Figure 22. The results of the taste of the traditional mayonnaise.*
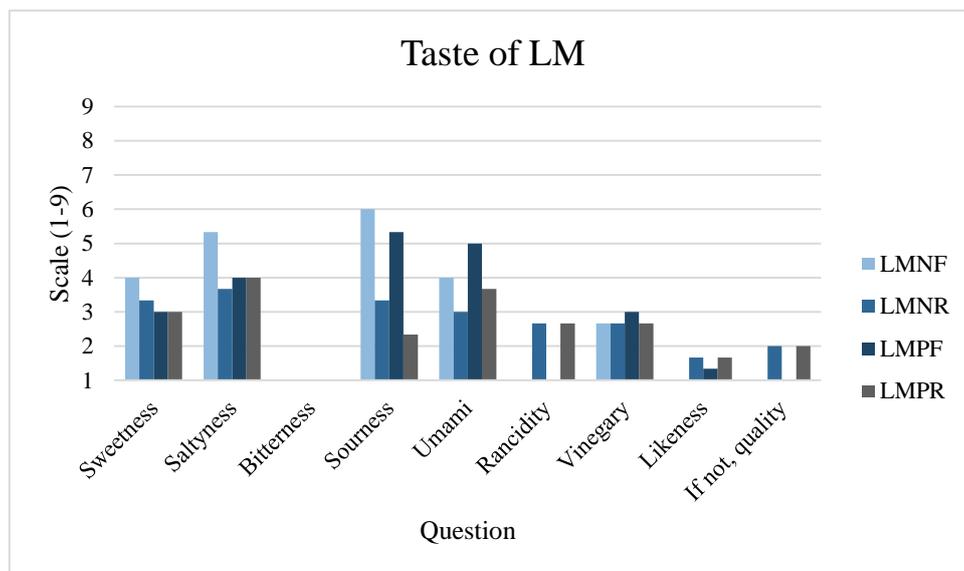
*Figure 23. The results of the taste of the light mayonnaise.*
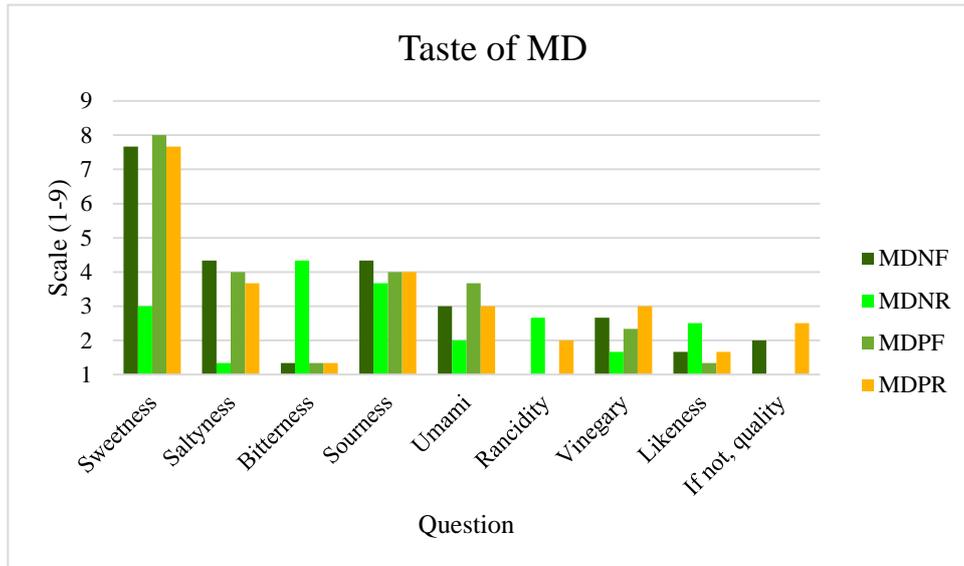
Figure 24. The results of the taste of the mayonnaise dressing.

Questions for the texture/mouthfeel of the mayonnaises were: smooth: Is the texture/mouthfeel smooth? (scale 1-5: not at all-extremely), foamy: Is the texture/mouthfeel foamy? (scale 1-5: not at all-extremely), gel: Is the texture/mouthfeel gel-like? (scale 1-5: not at all-extremely), slimy: Is the texture/mouthfeel slimy? (scale 1-5: not at all-extremely), oily: Is the texture/mouthfeel oily? (scale 1-5: not at all-extremely), likeness: Is the sample comparable to merchantable product? (yes=1, no=2), if not, quality: Evaluate the quality when compared to merchantable product? (scale 1-5: not eatable-extremely good) (Figures 25-27). The texture/mouthfeel of the mayonnaises are smooth, gel-like and oily, mostly comparable to merchantable product if not the quality is bad. No statistically significant differences.
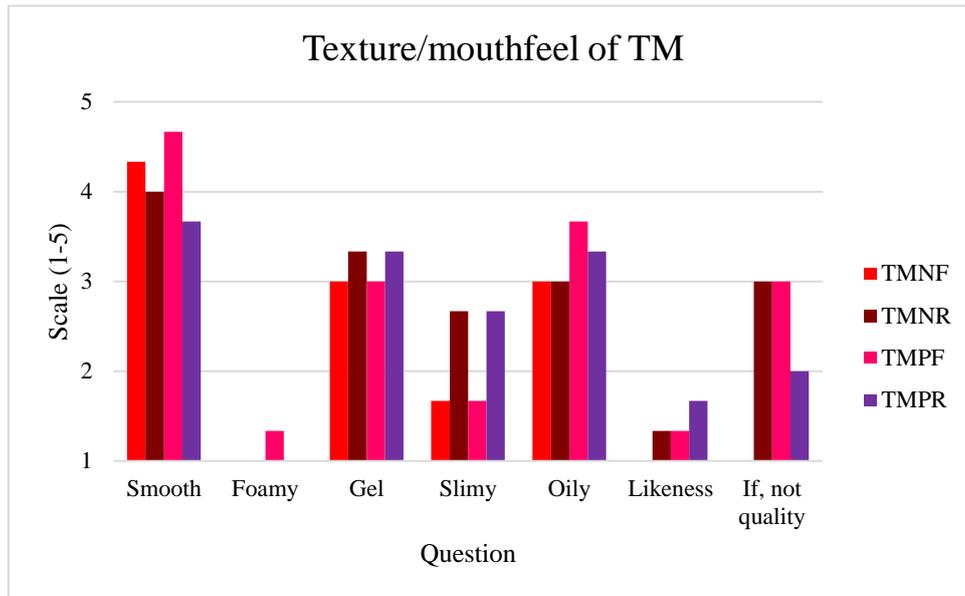
*Figure 25. The results of the texture/mouthfeel of the traditional mayonnaises.*
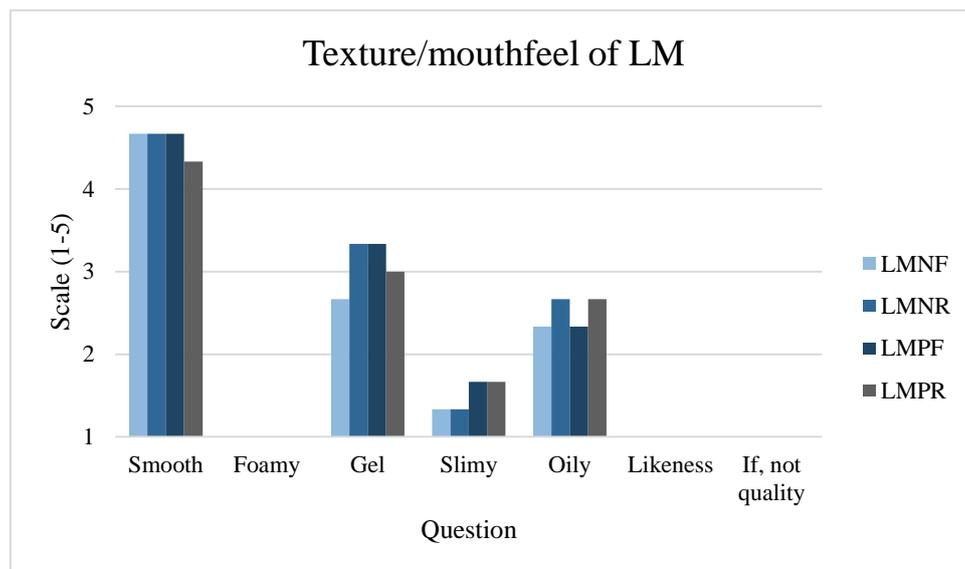
Figure 26. The results of the texture/mouthfeel of the light mayonnaises.
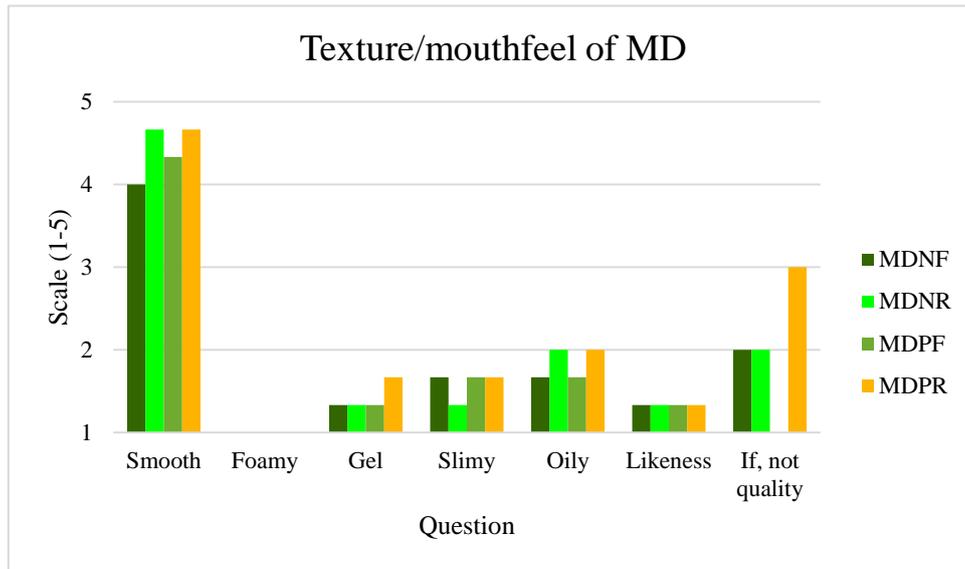
Figure 27. The results of the texture/mouthfeel of the mayonnaise dressings.

The overall quality of the samples was thought to be similar when comparing the production lines, but the R samples were thought to have lower quality than the N samples. When comparing the possible thickness changes between the products made in different production line the mayonnaise made with functional production line was thought to be thicker, but the comments were that there is barely any difference between them (Figure 28).
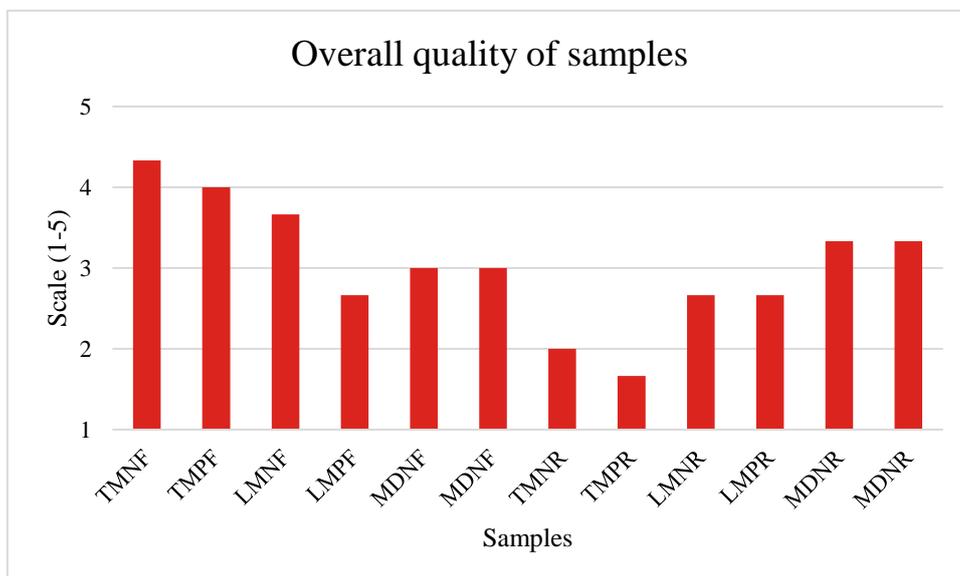

Figure 28. The overall quality of different mayonnaise samples.

4 Conclusions

The purpose of this study was to compare same products made with different production lines. The novel production line had different mechanism to produce mayonnaise than the functional production line. After all the chemical, physical and sensory analysis the mayonnaises made with different production lines are similar on with slight differences in how the oxidation affects the mayonnaise, the mayonnaise made with the novel technique seems to endure incubation better and the quality of the mayonnaise is better. The stability of the mayonnaise that can endure oxidation more is better. But all in all the differences are small and both of the techniques are suitable for making these mayonnaises.

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