The effect of duck egg yolk and milk protein on rheological properties of mayonnaise

Moslavac[1] T., A. Pozderović, A. Pichler, K. Popović, M. Šilipetar

scientific paper

Summary

This study examined the influence of oil type (oil phase composition), whey powder content and duck egg yolk pasteurisation time on the rheological properties of salad mayonnaise. The mechanical process of homogenisation of mayonnaise was carried out at 10 000 o/ min. during the period of 3 min. at room temperature. The mayonnaise samples contained 70% oil with different proportions of sunflower oil and Olivita oil. Rheological tests were carried out in a controlled rotational viscometer (DV- III + Digital Rheometer - Brookfield Engineering Laboratories, USA) with concentric spindles, at the temperatures of 10 °C and 25 °C. From the obtained data, the rheological parameters consistency coefficient, flow behaviour index and apparent viscosity were calculated. The results of the research show that the addition of Olivita oil and whey powder and duck egg yolk pasteurisation time affect the rheological properties of mayonnaise. The addition of Olivita oil into the oil phase of mayonnaise reduces shear stress, apparent viscosity and consistency coefficient at 25 °C and 10 °C. Greater whey powder content and longer duck egg yolk pasteurisation time lead to an increase in apparent viscosity and consistency coefficient values of mayonnaise.

Key words: *sunflower oil, Olivita oil, duck egg yolk, rheological properties, mayonnaise*

Introduction

Mayonnaise is a semi-solid oil-in-water emulsion of edible vegetable oil, egg yolk, acetic and/or other edible organic acid, mustard, salt, sugar, allowed additives, with or without spices or spice extracts (Anon., 1999). According to the Regulation on the basic requirements for edible oils and fats, margarines and similar products, mayonnaise, sauces, dressings, salads and other products made of edible oils and fats, salad mayonnaise must contain at least 50% vegetable oil, which makes up its oil phase (Anon., 1999). Vegetable oils, the main ingredient in mayonnaise, have an important function in an emulsion, they contribute to the taste, the appearance, the texture and the oxidative stability of the emulsion in a very specific way (McClements and Demetriades, 1998). Rheological properties represent important quality parameters of oil-in-water emulsion products (sauces, dressings, mayonnaise). Knowledge of the rheological properties of such products is important in creating a certain consistency of mayonnaise (Štern et al., 2001) and in controlling product quality during production, storage and transportation (Juszczak et al., 2003). The rheological properties of mayonnaise, as well as of salad dressings and sauces, are mainly determined by the ratio and the composition of the oil phase and the presence of emulsifiers, stabilisers and thickeners (Wendin and Hall, 2001). The quality of oil-in-water emulsions, and their stability and viscosity depend on the homogenisation process (Wendin et al., 1999), the dispersion of vegetable oil droplets in the continuous water phase, the egg yolk (Guilmineau and Kulozik, 2007; Xiong et al., 2000; Laca et al., 2010), the type of carbohydrates (Ruiling et al., 2011) and the ratio and type of the milk component, whereby attention is paid to milk proteins. In this type of emulsion, oil droplets are mechanically dispersed in the continuous water phase of vinegar and the natural emulsifier in the egg yolk is used to increase the stability of the entire system (Kiosseoglou, 2003; Castellani et al., 2006). The use of different edible vegetable oils or combinations of vegetable oils for the purpose of obtaining the desired composition of fatty acids, may also

[1] **Tihomir Moslavac, PhD**, associate professor; **Andrija Pozderović, PhD**, associate professor; **Anita Pichler, PhD**, assistant professor; **Kristina Popović, B. S. Eng.**, **Marijana Šilipetar**, student; Josip Juraj Strossmayer University, Faculty of Food Technology, Osijek, Institute of Food Technology, Department of Oil and Fat Technology, Franje Kuhača 20, 31000 Osijek, e-mail: Tihomir.Moslavac@ptfos.hr, 031/224-356, 091/793-6960

enhance the nutritional and sensory traits of mayonnaise (Kostyra and Barylko-Pikielna, 2007). The addition of different ratios of Olivita oil (a mixture of three types of oil) into the oil phase with sunflower oil increases the ratio of monounsaturated oleic fatty acid and natural antioxidants, thus resulting in greater stability of mayonnaise in the face of oxidative spoilage. Rheological behaviour of mayonnaise is a reoccurring subject of research, since it influences consumer attitudes not only by its composition, consistency and taste but also by its use in salads, with French fries and in other dishes (Franco et al., 1995; Akhtar et al., 2005; Abu-Jdayil, 2003).

This study examined the effect of oil type (oil phase composition), whey powder content and duck egg yolk pasteurisation time on the rheological properties of salad mayonnaise at the temperatures of 25°C and 10°C. The salad mayonnaise samples contained a 70% oil phase with sunflower oil and with mixtures of sunflower and Olivita oil in different ratios.

Materials and Methods

Materials

The following materials were used to make salad mayonnaise:

- Refined edible sunflower oil
- Olivita oil (edible salad oil, composition: rapeseed oil, sunflower oil, grapeseed oil)
- Alcohol vinegar
- Duck egg yolk
- Distilled water
- Table salt
- Mustard
- Tartaric acid
- Lactose
- Whey powder

Refined edible sunflower oil and Olivita oil were obtained from the IPK Oil Factory Čepin. Alcohol vinegar (9% acetic acid), table salt and mustard were purchased in a local shop. Duck egg yolk was bought from a private supplier and used in liquid form fresh and pasteurised at 68 °C. Lactose was obtained from Claro-prom Ltd. in Zagreb and tartaric acid (acidity regulator) from Alkaloid Skopje. Whey powder was obtained from the company Zdenka, composition: milk fat in dry matter up to 1%, proteins 12-14%, lactose 73-75%, ash 7-10%, water up to 6%.

Table 1 **Recipes for the preparation of mayonnaise samples**

Ingredients	Sample 1 100% SUN* (g)	Sample 2 80% SUN + 20% Olivita** (g)	Sample 3 70% SUN + 30% Olivita (g)	Sample 4 50% SUN + 50% Olivita (g)
Sunflower oil	140	112	98	70
Olivita oil	-	28	42	70
Duck egg yolk	16	16	16	16
Alcohol vinegar	8	8	8	8
Table salt	2	2	2	2
Mustard	2	2	2	2
Lactose	5	5	5	5
Tartaric acid	0.2	0.2	0.2	0.2
Distilled water	16.8	16.8	16.8	16.8
Whey powder	10	10	10	10

* SUN – sunflower oil

** Olivita oil

Preparation of the emulsion

The samples of salad mayonnaise used in this research were prepared in the traditional way, without the use of conservatives, in laboratory conditions, each sample weighing 200 g. The samples contained a 70% oil phase of sunflower oil (100%) or of a mixture of sunflower oil and Olivita oil in the ratios 80:20, 70:30 and 50:50.

The first four samples were made to examine the effect of oil type (oil phase composition) on the rheological properties of mayonnaise containing fresh duck egg yolk (8%) and other ingredients in the following ratios: distilled water (8,4%), alcohol vinegar (4%), table salt (1%), mustard (1%), lactose (2,5%), tartaric acid (0,1%) and whey powder (5%).

The mayonnaise samples were produced in the laboratory homogeniser D-500 (Wiggenhauser, Germany-Malaysia) with the rotor rotation speed of 10 000 - 30 000 °/min. The 15 mm diameter rotor and the 20 mm diameter stator were used. The first step in the preparation of the samples was the weighing of the necessary ingredients. ½ of sunflower oil was poured into the glass, and egg yolk, vinegar, distilled water and the other ingredients were added. The homogeniser was turned on, the rest of the sunflower oil (or Olivita oil) added slowly, and then homogenised for 3 minutes at 10 000 °/min. All the ingredients were at room temperature when used. The prepared samples were used to measure rheological properties.

Pasteurised egg yolk was obtained by heating at the temperature of 68°C during the period of 1 minute and 2 minutes. All the mayonnaise samples were prepared in the same manner, only some ingredients were changed, depending on the recipes of the samples.

Rheological properties

Rheological tests of the mayonnaise samples were carried out in a controlled rotational viscometer,

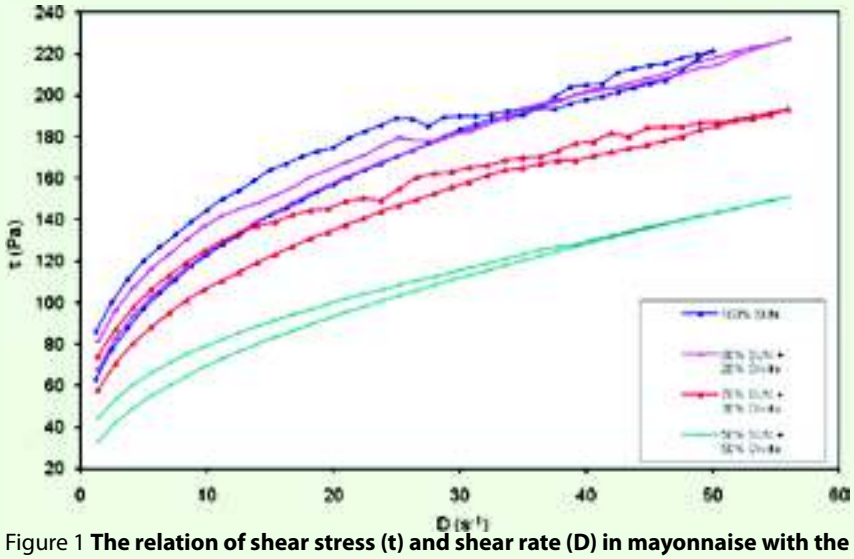

Figure 1 **The relation of shear stress (t) and shear rate (D) in mayonnaise with the addition of Olivita oil, at 25 °C.**

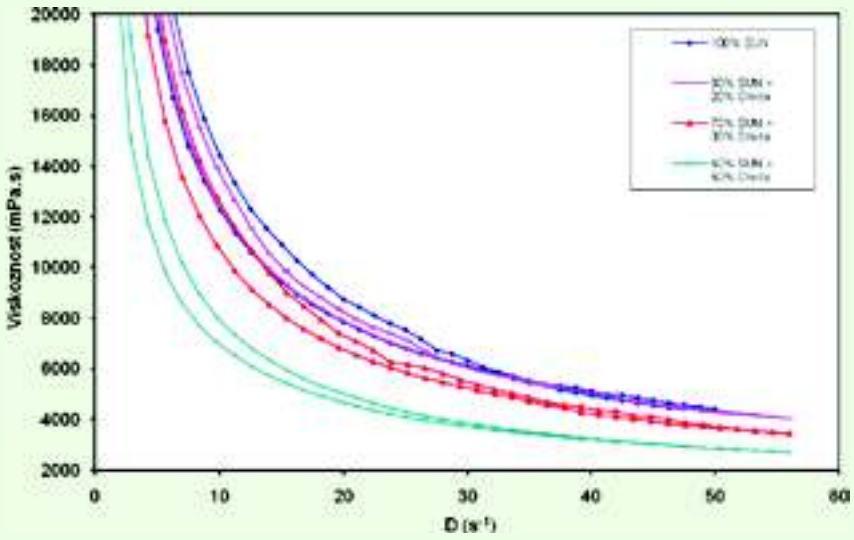

Figure 2 **The relation of apparent viscosity (m) and shear rate (D) in mayonnaise with the addition of Olivita oil, at 25°C.**

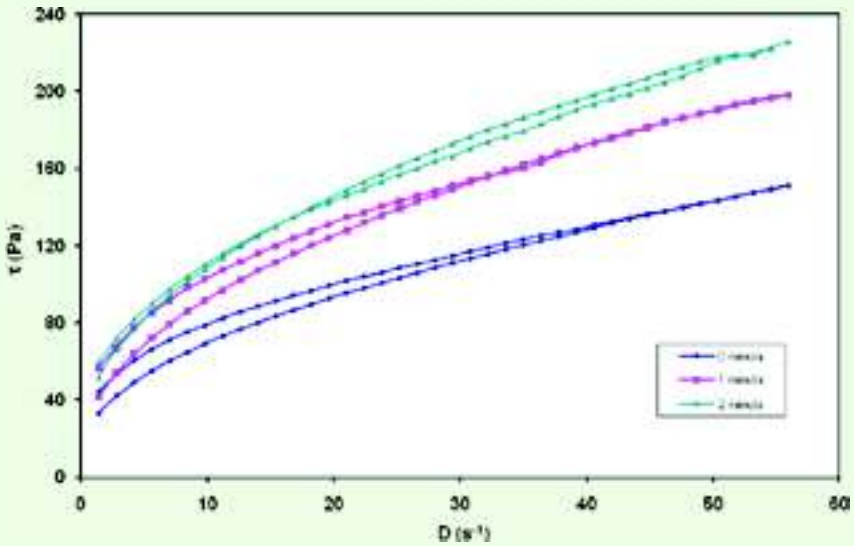

Figure 3 **The effect of duck egg yolk pasteurisation at 68°C on the rheological properties of mayonnaise, at 25°C.**

model DV-III+ Digital Rheometer - Brookfield Engineering Laboratories (USA), with concentric spindles SC4-28 and SC4-29. The viscometer was connected to a computer with the Rheocalc 3.2 software, which controlled the tests of the rheological properties of mayonnaise and processed the obtained data. The tests of the rheological properties of freshly made salad mayonnaise samples were carried out at the temperatures of 25° C and 10° C (consumption temperature and temperature after removal from the refrigerator). The thermostat TC-501P (Brookfield Engineering Laboratories) was used to keep the temperature of the mayonnaise samples constant during testing in the viscometer. The tests measured the dependence of shear stress (t) and apparent viscosity (μ) on shear rate (D), at shear rates ranging from 1,4 s^{-1} to 56 s^{-1} at upward measurement and from 56 s^{-1} to 1,4 s^{-1} at downward measurement. On the basis of this dependence, fluid type was determined. All the tested mayonnaise samples displayed *non-Newtonian* characteristics and were therefore pseudoplastic fluids with smaller or larger thixotropic loops. The values of the rheological parameters consistency coefficient (k) and flow behaviour index (n) were calculated in the Microsoft Excel programme, by application of linear regression analysis.

The rheological parameters consistency coefficient (k) and flow behaviour index (n) were calculated according to the Ostwald-Reiner power law:

$\tau = k \cdot D^n$

τ – shear stress (Pa)

D – shear rate (s^{-1})

k – consistency coefficient ($Pa \cdot s^n$)

n – flow behaviour index

Apparent viscosity (μ) was calculated by the formula:

$\mu = k \cdot D^{n-1}$

Results and Discussion

The results of the research on the effect of oil type, duck egg yolk and milk protein (whey powder) on the rheological behaviour of mayonnaise with a 70% oil phase at the temperatures of 25°C and 10°C, are shown in Figures 1 - 3 and in Tables 2 - 4.

The effect of oil type (oil phase composition) on the rheological properties and parameters of mayonnaise containing fresh duck egg yolk, at the temperatures of 25°C and 10°C, is shown in Figures 1 and 2 and in Tables 2. The Figures illustrate that the mayonnaise samples with the oil phase of sunflower oil (100%) have higher shear stress (t) and apparent viscosity (μ) values than the samples with different ratios of Olivita oil added into the sunflower oil. Increased Olivita oil content in the oil phase of mayonnaise reduces shear stress and apparent viscosity values.

The results of the rheological tests of the mayonnaise samples, expressed in rheological parameters in Table 2, show that the sample containing the oil phase of 100% sunflower oil has higher apparent viscosity (4430 mPa.s) than those with the oil phase containing a mixture of sunflower and Olivita oil, measured at the temperature of 25°C and the shear rate of 50 s^{-1}. Increased Olivita oil content added into the sunflower oil reduces apparent viscosity. It also reduces the consistency of mayonnaise, whereby consistency coefficient (k) is reduced from 80,433 $Pa.s^n$ in mayonnaise with 100% sunflower oil to 36,839 $Pa.s^n$ in mayonnaise with both sunflower oil (50%) and Olivita oil (50%) in the oil phase. The reason for this is the change of the oil phase composition effected by the addition of Olivita oil, which decreases the viscosity of the oil phase with sunflower oil, used to make mayonnaise. The addition of more Olivita oil into the oil phase increases the flow behaviour index (n). The same changes of rheological parameters were recorded during testing of the samples at the temperature of 10°C.

Table 2 **The effect of oil type on the rheological parameters of mayonnaise with fresh duck egg yolk, at 25°C and 10°C.**

Sample	μ at 50 s^{-1} (mPa.s)	k ($Pa.s^n$)	n	R^2
25 °C				
100% SUN*	4430	80.433	0.2558	0.99444
80% SUN + 20% Olivita	4333	71.816	0.2797	0.99701
70% SUN + 30% Olivita	3711	68.343	0.2578	0.99762
50% SUN + 50% Olivita	2844	36.839	0.3408	0.99440
10 °C				
100% SUN	5690	107.074	0.2485	0.99611
80% SUN + 20% Olivita	5130	105.941	0.2298	0.97917
70% SUN + 30% Olivita	5028	74.793	0.3236	0.99739
50% SUN + 50% Olivita	3939	43.325	0.3792	0.99111

*SUN – sunflower oil

μ - apparent viscosity at the shear rate of 50 s^{-1} (mPa.s)

k – consistency coefficient ($Pa.s^n$)

n – flow behaviour index

R^2 – coefficient of determination

Table 3 **The effect of whey powder content on the rheological parameters of mayonnaise with fresh duck egg yolk, at 25°C and 10°C.**

Whey powder content	μ at 56 s^{-1} (mPa.s)	k ($Pa.s^n$)	n	R^2
25 °C				
1 %	1155	18.087	0.3124	0.99496
3 %	1445	21.811	0.3196	0.99398
5 %	2110	30.678	0.3304	0.99558
10 °C				
1 %	1450	20.908	0.3311	0.99495
3 %	1785	22.083	0.3685	0.99521
5 %	2730	36.735	0.3464	0.99681

Table 4 **The effect of duck egg yolk pasteurisation time at 68°C on the rheological parameters of mayonnaise, measured at 25°C and 10°C.**

Duck egg yolk pasteurisation time (min)	μ at 50 s^{-1} (mPa.s)	k ($Pa.s^n$)	n	R^2
25 °C				
0 min	2844	36.839	0.3408	0.99440
1 min	3778	46.478	0.3535	0.99547
2 min	4289	47.595	0.3766	0.99343
10 °C				
0 min	3939	43.325	0.3792	0.99111
1 min	5060	72.636	0.3213	0.99495
2 min	5210	74.096	0.3002	0.99134

Table 3 illustrates the results of the research on the effects of milk protein in whey powder on the rheological properties of mayonnaise containing fresh duck egg

yolk, measured at the temperatures of 25°C and 10°C. The table shows that the addition of whey powder at preparation of mayonnaise affects its rheological properties, whereby the increase in the ratio of whey powder from 1% to 3% and 5% increases the viscosity of mayonnaise. Increased whey powder content influences the rheological properties of mayonnaise. The 5% ratio of whey powder increased apparent viscosity to 2110 mPa.s at the shear rate of 56 s^{-1}, measured at the temperature of 25°C. Increased whey powder content also increased the consistency of the samples: the mayonnaise with greater whey powder content (5%) had a higher consistency coefficient (k), of 30,678 Pa.s^n, whereas the mayonnaise with less whey powder (1%) had a lower one, 18,087 Pa.s^n, measured at 25°C. Flow behaviour index (n) also increased with the increase of whey powder ratio. The same changes were recorded at measurement of rheological properties at the temperature of 10°C.

The effect of egg yolk pasteurisation time (1 min, 2 min) at 68°C on the rheological properties of mayonnaise, measured at 25°C and 10°C, is expressed in rheological parameters in Figure 3 and in Table 4. Figure 3 shows how duck egg yolk pasteurisation at the temperature of 68°C for 1 minute and 2 minutes affects the rheological properties of mayonnaise. Egg yolk pasteurisation causes thermal degradation of proteins, lipoproteins and phospholipids (lecithin – emulsifier traits), which results in higher shear stress values in these mayonnaise samples in comparison with those made with fresh egg yolk. Shear stress value is higher in mayonnaise with the duck egg yolk pasteurised for 2 minutes.

Table 4 shows apparent viscosity values at the shear rate of of 50 s^{-1}, illustrating that pasteurisation time effects an increase in the viscosity of mayonnaise. Apparent viscosity of mayonnaise with fresh duck egg yolk was thus 2844 mPa.s, of mayonnaise with the egg yolk pasteurised for 1 minute 3778 mPa.s, and of mayonnaise with the egg yolk pasteurised for 2 minutes 4289 mPa.s, measured at the temperature of 25°C. Longer egg yolk pasteurisation (2 minutes) also increased consistency coefficient (k) and flow behaviour index (n) values. Measurement of the rheological properties of the samples at 10°C revealed higher apparent viscosity and consistency but lower flow behaviour index values.

Conclusion

All the mayonnaise samples displayed *non-Newtonian,* pseudoplastic flow with a certain thixotropic loop area.

The examined samples displayed different rheological properties, depending on the oil type (oil phase composition), whey powder content and duck egg yolk pasteurisation time.

Increased ratio of Olivita oil added into the oil phase of mayonnaise reduced shear stress, apparent viscosity and consistency coefficient values, at the temperatures of 25°C and 10°C.

The addition of whey powder at preparation of mayonnaise affected its rheological properties, whereby the increase in the ratio of whey powder from 1% to 3% and 5 % increased the apparent viscosity and the consistency coefficient of mayonnaise, at the temperatures of 25°C and 10°C.

Duck egg yolk pasteurisation at the temperature of 68°C (for 1 minute and 2 minutes) caused thermal degradation of proteins, lipoproteins and phospholipids (lecithin), resulting in higher shear stress, apparent viscosity and consistency coefficient values than those of the samples containing fresh egg yolk, measured at the temperatures of 25°C and 10°C.

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Einfluss des Eidotters der Ente und Milchproteine auf rheologische Eigenschaften der Majonäse

Zusammenfassung

In dieser Arbeit wurden der Einfluss der Ölart (Zusammensetzung der Ölphase), Anteil der Molke im Pulver und Zeit der Pasterisation des Enteeidotters auf rheologische Eigenschaften der Majonäse untersucht. Der mechanische Homogenisationsprozess der Majonäse wurde bei 10 000 °/Min in der Zeit von 3 Minuten bei Zimmertemperatur durchgeführt. Die Majonäse enthält 70 % Öl mit verschiedenen Anteilen von Sonnenblumenöl und Olivitaöl. Die Messungen der rheologischen Eigenschaften wurden auf Rotationsviskosimeter (DV- III + Digital Rheometer-Brookfield Engineering Laboratories, USA) mit konzentrischen Zylindern bei Temperatur 10° C und 25° C durchgeführt. Aus den bekommenen Resultaten wurden rheologische Parameter, Konsistenzkoeffizient, Geläufigkeitsindex und scheinbare Viskosität errechnet. Die Untersuchungsresultate haben gezeigt, dass die Zufügung von Olivitaöl, Molke im Pulver und Pasterisationszeit des Enteeidotters rheologische Eigenschaften der Majonäse beeinflussen. Mit der Zufügung des Olivitaöls in die Ölphase der Majonäse kommt es zur Verringerung der Gleitanstrengung (smično neprezanje), der scheinbaren Viskosität und des Konsistenzkoeffizients bei 25° C und 10° C. Die Zufügung von größerem Anteil der Molke im Pulver und Pasterisation des Enteeidotters führt zu Vegrößerung der scheinbaren Viskosität und des Konsistenzkoeffizients der Majonäse.

Schlüsselwörter: *Sonnenblumenöl, Olivitaöl, Enteeidotter, rheologische Eigenschaften, Majonäse*

Influenza del tuorlo d'uovo di anatra e delle proteine di latte sulle caratteristiche reologiche di maionese

Sommario

In quest'articolo è stata esaminata l'influenza del tipo d'olio (composizione di fase oleosa), percentuale di siero di latte in polvere e tempo di pasterizzazione del tuorlo d'uovo di anatra sulle caratteristiche reologiche di maionese per insalata. Il processo meccanico di omogenizzazione di maionese è stato fatto a 10 000 giri per minuto e nel tempo di 3 minuti alla temperatura ambientale. La maionese contiene il 70% d'olio con vari percentuali d' olio di girasole e d'olio Olivita. Le caratteristiche reologiche sono state misurate sul viscosimetro rotazionale (DV- III + Digital Rheometer-Brookfield Engineering Laboratories, USA) a cilindri concentrici alle temperature di 10 oC e 25 oC. Dai dati ottenuti sono stati contati i parametri reologici: coefficiente di consistenza, indice di scorevolezza e viscosità apparente. I risultati di ricerca hanno mostrato che l'aggiunta d'olio Olivita, siero in polvere e tempo di pasterizzazione del tuorlo d'uovo di anatra influiscono sulle caratteristiche reologiche di maionese. Con l'aggiunta d'olio Olivita nella fase oleosa si riducono lo sforzo di taglio, viscosità apparente e coefficiente di consistenza alle temperature di 25 oC e 10 oC. L'aggiunta di una percentuale maggiore di siero di latte in polvere e la pasterizazzione del tuorlo d'uovo di anatra fanno aumentare la viscosità apparente ed il coefficiente di consistenza di maionese.

Parole chiave: *olio di girasole, olio Olivita, tuorlo d'uovo di anatra, caratteristiche reologiche, maionese*

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Received: April 23, 2012
Accepted: May 30, 2012