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INFLUENCE OF INGRETIENS ON RHEOLOGICAL BEHAVIOR OF HOMEMADE MAYONNAISE

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ABSTRACT. The present article presents the influence of some ingredients used for the preparation of homemade mayonnaise like thickening agents (potato versus cornstarch) and two types of oil (olive versus sunflower) on the viscosity and rheological behavior. The results show the increase of the viscosity when cornstarch or potato, and olive oil instead of sunflower oil are used for the preparation of the homemade mayonnaise. The rheological parameters, material constancy, K, and flow index, n, were determined by Power law model. They show the positive influence of thickening agents on stability of homemade mayonnaise, increasing the viscosities comparative to the sample without agents. The values of index flow, n between 0.3249 and 0.6482, lower than 1, confirms for all analyzed samples the shear-thinning (pseudoplastic) behavior ($R^2 > 0.99$).

Keywords: *cornstarch, potato, olive oil, sunflower oil, viscosity, shear-thinning*

INTRODUCTION

Mayonnaise is a stable emulsion prepared by egg yolk, spices, mustard, vinegar or lemon juice, water, and oil (not less than 65% for fat mayonnaise), with or without thickening agents [1].

Each component has a significant role. Egg yolk, which contains a natural emulsifier – egg lecithin, and mustard, the most commonly used, offers a desirable flavour, mouth feel, colour and the physical stability of emulsions [2]. Vinegar/lemon juice, salt, pepper are added to mayonnaise as antimicrobial

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preservation, aroma, pH controller and flavouring ingredients [3]. Emulsifiers offer commotion at the outer boundary of oil-water in order to promote functionality and steadiness of fine droplets during or after emulsification [4].

The thickening agents are necessary to increase the viscosity and the structure stability of emulsion, and so to avoid the phase's separation [5]. Stabilizers offer great rheological influence by adsorption mechanism and are essential for long-term emulsion stability [6].

The mayonnaise was prepared dispersing the oil droplets in the continuous phase, water phase, containing all other components. In this way, the semi-solid oil in water (O/W) emulsion is prepared.

Power Law (Equation 1) and Herschel-Buckley models (Equations 2) are the most used in order to describe the rheological behavior of mayonnaise [7].

$$\tau = K\dot{\gamma}^{n} \tag{1}$$

$$\tau = \tau_0 + K\dot{\gamma}^{n} \tag{2}$$

where: τ is the shear rate (Pa), τ_0- the yield stress (Pa), $\dot{\gamma}$- shear rate (1/s), K – material constancy (Pas.^{n}) and n – flow index (-).

The rheological parameters, material constancy, K, and the dimensionless flow index, n, characterize the rheological behavior of dispersion systems, fluids, solutions. K shows the average viscosity of the fluid in the domain of tested shear rate, and n determines if the fluid is Newtonian (n=1), or Non-Newtonian, pseudoplastic/shear-thinning (n<1) or dilatant/shear-thickening (n>1).

Equation 3, in accordance with the Newton's law, gives the apparent viscosity, η_a, as a function of shear rate, offering the possibility to determine the rheological parameters by linearization:

$$\eta_a = \frac{\tau}{\dot{\gamma}} = K\dot{\gamma}^{n-1} \tag{3}$$

The objectives of the present work are to compare the influence of different sorts of oil and thickening agents on the viscosity, and to establish the rheological behavior of homemade mayonnaise.

RESULTS AND DISCUSSION

The viscosity curves obtained by plotting measured apparent viscosity as a function of rotation speed (RPM) for different samples of mayonnaise using sunflower (SF) oil are presented in Figure 1.

The apparent viscosities increase in the presence of the thickening agents, potato and cornstarch, comparative to the samples without agents. The apparent viscosities of mayonnaise containing cornstarch are higher than those containing potato, when the mayonnaise is prepared with sunflower oil. The differences of the apparent viscosities are higher at low rotation speed and lower at high rotation speed.

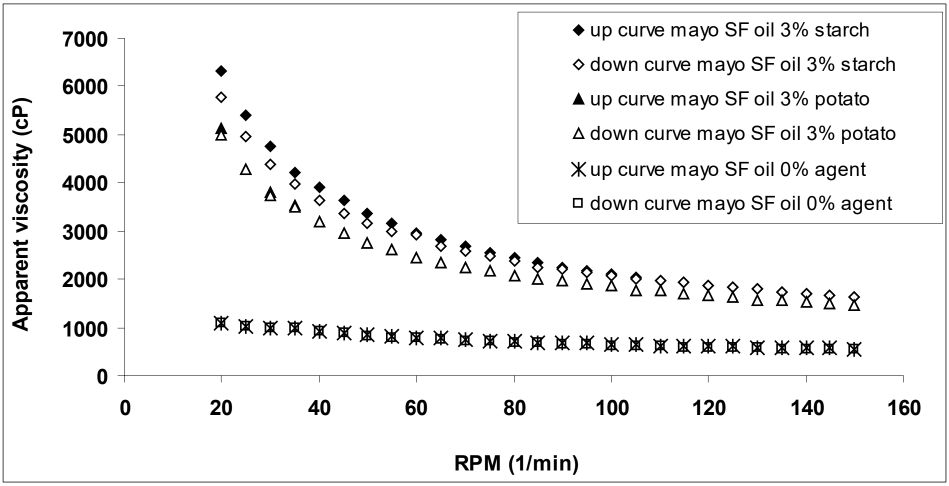

Figure 1. Influence of thickening agents on viscosity of sunflower (SF) mayonnaise.

For the same rotation speed, e.g. at RPM = 50, the viscosity of sunflower mayonnaise without thickening agent is 832 cP, 2768 cP for sample with 3% potato, and 3168 cP for the sample with 3% cornstarch. Comparative, at RPM = 150, the viscosity of the sunflower mayonnaise without thickening agent decreases at 541 cP, 1461 cP for the sample with 3% potato, and 1637 cP for sample with 3% cornstarch.

In the next step, olive oil replaces sunflower oil, as an important component of the diet, but not so often used for mayonnaise in our country.

Figure 2 shows the viscosity curves for mayonnaise samples prepared with olive oil. In this case, the apparent viscosities of mayonnaise containing potato are higher than those containing cornstarch.

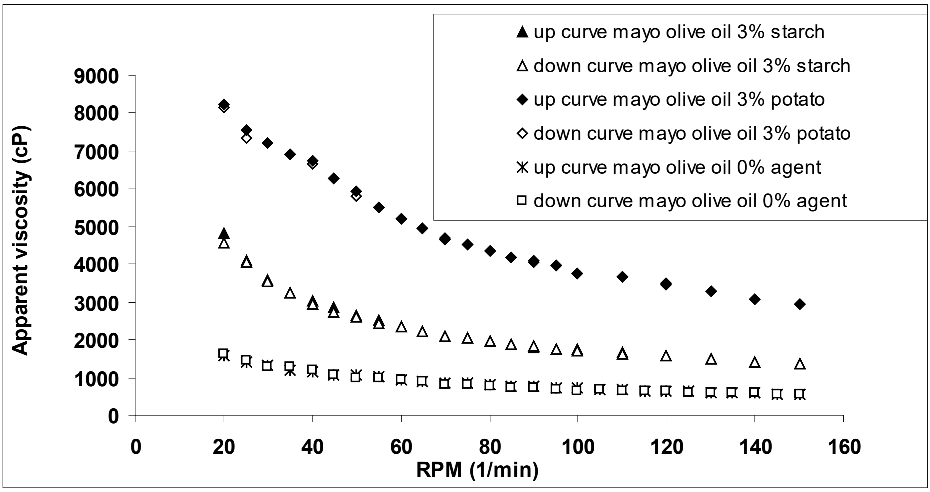

Figure 2. Influence of thickening agents on viscosity of olive oil mayonnaise.

The differences between viscosities are higher at low rotation speed and lower at high rotation speed, as in the sunflower oil mayonnaise.

In olive oil mayonnaise, at RPM = 50 the viscosity is 1000 cP for the sample without thickening agent, 5820 cP for the sample with 3% potato, and 2592 cP for sample with 3% cornstarch. At RPM = 150, the viscosity of the mayonnaise without thickening agent decreases at 554.7 cP, 2955 cP for sample with 3% potato, and 1365 cP for the sample with 3% cornstarch.

From viscosity curves, it is obvious that in each case the apparent viscosity decrease with the increase of speed rotation (RPM). The rheological behavior, in both cases of sunflower and olive oil mayonnaise, is typically for shear-thinning fluids.

The Power law model (Equation 3), used in the present study, in form (4) offers the possibility to establish rheological behavior and the rheological parameters, K and n.

$$\log \eta_a = \log K + (n-1)\log \dot{\gamma} \tag{4}$$

Equation 5 calculates the shear rates (1/s), in accordance with the indication of Rheometer Brookfield DV-III ULTRA manual [8].

$$\dot{\gamma} = 0.08244 \cdot N \tag{5}$$

In Equation (5) SRC = 0.08244 is the shear rate constant and N is the rotational speed (RPM), selected on the display of Brookfield Rheometer. The shear rate constant (SRC) is calculated in accordance with the Brookfield Rheometer Manual indications, considering the dimensions of measuring container and the disc spindle.

The shear-thinning (pseudoplastic) behavior is confirmed by the values of flow index, n lower than 1 (Table 1).

The highest value of material constancy, K, as the average of the measured viscosities, is obtained for homemade mayonnaise prepared with olive oil and potato (first), than cornstarch (second), followed by samples prepared with sunflower (SF) oil containing cornstarch (first) and then potato (second).

Potato seems to be a better thickener, also stabilizer, than the cornstarch, when the mayonnaise is prepared with olive oil. Cornstarch is a better thickener, stabilizer, when the mayonnaise is prepared with sunflower oil.

At the same time, the viscosity curves obtained with the increase, named “up curve”, and decrease of shear rate “down curve”, show no significant difference, only maybe at low shear rates.

This means that there is no significant thixotropy in any of the prepared mayonnaises for the range of rotational speed used.

Table 1. Rheological constants for mayonnaise samples

Sample	Equations	Material constancy	Flow index n (-)	R^2
Up curve SF oil 0% agent	$\eta = 1.36\dot{\gamma}^{-0.3518}$	1.360	0.6482	0.9903
Down curve SF oil 0% agent	$\eta = 1.39\dot{\gamma}^{-0.3758}$	1.390	0.6242	0.9921
Up curve SF oil 3% starch	$\eta = 8.794\dot{\gamma}^{-0.6751}$	8.794	0.3249	0.9995
Down curve SF oil 3% starch	$\eta = 7.775\dot{\gamma}^{-0.6254}$	7.775	0.3746	0.9989
Up curve SF oil 3% potato	$\eta = 6.62\dot{\gamma}^{-0.6067}$	6.620	0.3933	0.9984
Down curve SF oil 3% potato	$\eta = 6.537\dot{\gamma}^{-0.6009}$	6.537	0.3991	0.9986
Up curve Olive oil 0% agent	$\eta = 2.42\dot{\gamma}^{-0.5837}$	2.420	0.4163	0.9992
Down curve Olive oil 0%	$\eta = 2.202\dot{\gamma}^{-0.5541}$	2.202	0.4459	0.9934
Up Olive oil 3% starch	$\eta = 8.798\dot{\gamma}^{-0.6171}$	8.798	0.3829	0.9984
Down curve Olive oil 3%	$\eta = 7.575\dot{\gamma}^{-0.5991}$	7.575	0.4009	0.9991
Up curve Olive oil 3% potato	$\eta = 12.491\dot{\gamma}^{-0.5590}$	12.491	0.4410	0.9915
Down curve Olive oil 3%	$\eta = 12.413\dot{\gamma}^{-0.5543}$	12.413	0.4457	0.9910

The obtained material constancy K is almost equal at the increase of shear rate, “up curve”, with the value obtained at the decrease of shear rate, “down curve”.

The differences which appear in results can be are attributed to the different combination of ingredients with oil and to the mixing speed, no mechanically controlled.

The index flow n, with values between 0.3249 and 0.6482, lower than 1, for all analyzed mayonnaise, confirms the shear-thinning systems.

CONCLUSIONS

The oil type (sunflower or olive) and thickening agents (potato or cornstarch) used for preparation of homemade mayonnaise influenced the viscosity.

The mayonnaise samples prepared with olive oil and potato had the highest viscosities, followed by the samples prepared with sunflower oil and cornstarch.

The rheological behavior of the homemade mayonnaise shows the shear-thinning (pseudoplastic) behavior, which means the decrease of viscosity with the increase of shear rate.

The rheological flow index, n lower than one, determined by the Power law model, confirms the shear-thinning behavior.

In all the analyzed samples, no significant thixotropy was observed.

EXPERIMENTAL SECTION

Each sample was prepared in the same way. First, the egg yolk, salt, pepper, mustard, lemon juice and water were added and mixed together, forming the water phase in around 5-10 minutes. After that, the smashed potatoes or cornstarch powder was added to water phase.

In order to avoid the phase inversion in our emulsion, the last component, oil phase, was added, slowly gradually, during 20-25 minutes forming the mayonnaise. The mayonnaise was made by manually mixing with a wooden spoon, which can be characterized as slow mixing procedure, RPM<150.

The samples were prepared in a 500 mL plastic bowl, and kept in refrigerator until the measurements take place.

In this way, the prepared mayonnaise, semi-solid oil in water (O/W) emulsion, obtained by dispersing the oil particles in the continuous water phase had a firm texture, stability and yellow color.

The pH values, measured with a Hanna Instruments pH meter, are around 4.5. In order to measure the viscosity, the samples of each mayonnaise were transferred in a 250 mL backer with the diameter of 80 mm.

The differences between samples observed in this work are given by the used thickening agents (smashed potatoes and cornstarch powder), and type of oil (sunflower and olive).

Table 2 presents our mayonnaise composition comparative to other standard recipes [7].

The viscosity was measured using the Rheometer Brookfield DV-III ULTRA, and the spindle disc 03, with the diameter of 3.5 mm. The measurements were made without guard leg. The valid measurements were collected considering the operating instructions of the Brookfield Rheometer manual. The recommended range of the torque is from 10% to 100%.

Table 2. Composition of mayonnaise

Components	**Our sample Formula %**	**High fat Formula %**	**Low Fat Formula %**
Vegetable oil (sunflower or olive)	70	80	50
Egg yolk	5.0	6.0	4.0
Sugar	-	1.0	1.5
Salt, piper	1.0	1.0	0.7
Mustard	4.0	0.5	1.5
Water and lemon juice	17.0	7.5	35.3
Vinegar	-	4.0	3.0
Thickeners	3.0	-	4.0

Viscosity, in cP equivalent to mPas, was recorded after around 15-30 seconds at each shear rate, when the numbers on the display were stabilized. Sometimes, longer time was necessary to wait, due to the jumping values.

The measuring temperature in each case was around 20.0 ± 1.0 ^{0}C, assured by a water thermostat.

REFERENCES

1. D. McClements; K. Demetriades; *Food Sci. Nutrition*, **1998**, *38(6),* 511-536
2. A. Morna; *Annals of the University of Oradea*, **2019**, *XVIII (A)*, 75-83
3. D. J. McClements; *Food Emulsions: Principles, Practice and Techniques*, 3nd ed., CRC Press, Publisher Boca Raton, FL, **2015**, chapter 4

4. P. Chivero; S. Gohtani; H. Yoshii; A. Nakamura; *Sci. Technol*., **2016**, *69*, 59-66
5. D. Saha; S. Bhattacharya; *J. Food Sci. Technol.*, **2010**, *47(6)*, 587–97
6. A. Paraskevopoulou; D. Boskou; V. Kiosseoglou; *Food Chemistry*, **2005**, 90, 627-634
7. T. Bergecliff; *Degree project work*, *Viscosity and Acid Stability in Low-fat Mayonnaise with Varying Proportions of Xanthan Gum and Guar Gum*, **2016**, Linnaeus University, Sweden
8. Brookfield DV-III ULTRA Rheometer Manual No. M98-211-D0911.