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Research of rheological characteristics of mayonnaise with different varieties of honey added

Sergey Alekseevich BREDIKHIN[1], Vladimir Nikolaevich ANDREEV[1], Alexander Nikolaevich MARTEKHA[1*], Vasily Vladimirovich TOROPTSEV[1]

Abstract

Determination of food products rheological properties is becoming more and more important for assessing raw materials and finished products quality, as well as for predicting a semi-finished product behavior during processing. The influence of honey variety, rotor speed and homogenization time on mayonnaise rheological properties were studied in this work. The following honey varieties were used: acacia, linden, forest, spring. Refined sunflower oil was used to make mayonnaise. The mechanical process of mayonnaise homogenization was carried out at a rotor speed of 10,000 rpm and 12,000 rpm, for 2 and 4 minutes at room temperature. Mayonnaise with 75% oil phase was prepared according to a traditional recipe without preservatives added. Rheological properties measurements were carried out on a rotary viscometer with concentric cylinders at a temperature of 25 °C. The following parameters were calculated according to the experimental data: apparent viscosity, consistency index and flow index. The research results showed that the type of honey influenced the rheological properties of mayonnaise. They changed as the homogenization process duration and the rotor speed increased. The tested samples of mayonnaise with honey added belong to non-Newtonian systems, a pseudoplastic type of liquid.

Keywords: mayonnaise; rheological properties; water-in-oil emulsion; homogenization.

Practical Application: This present work has three main practical applications: enable the different varieties of honey as a functional ingredient into a mayonnaise system; provide knowledge and understanding of the rheological and textural properties of mayonnaise with different varieties of honey added; give insight into the influence of process parameters and composition of the oil phase on rheological properties of mayonnaise.

1 Introduction

Food raw materials of vegetable origin are exposed to various mechanical impacts during food processing. At the same time, production processes are organized in such a way as to ensure the highest possible level of the finished product quality. The study of the rheological properties and texture of food products contributes to the solution of this problem. Rheological analysis of food products allows determining the finished product structure with the specified characteristics in accordance with the technical regulations for this product. Determination of food products rheological properties is becoming more and more important for assessing raw materials and finished products quality, as well as for predicting the semi-finished product behavior during processing (Yildirim et al., 2016; Muadiad & Sirivongpaisal, 2022). Mayonnaise is a multicomponent, finely dispersed, water-in-oil emulsion of the direct water-in-oil type, which is stable over a wide temperature range (Gorji et al., 2016). Vegetable oil is an internal phase in it. Oil is present in the dispersion medium in the form of tiny droplets (Katsaros et. al., 2020).

Along with refined deodorized vegetable oil, the main components of mayonnaise are milk proteins, egg powder, stabilizers and water. Fat-soluble vitamins, sugar, salt, mustard and a variety of flavors are found in small amounts as well (Laca et al., 2010).

According to European technical regulations, mayonnaise must contain over 75% of edible vegetable oil, which is the product fatty phase. Its composition peculiarities and high organoleptic properties make it possible to classify it as a promising food product, and also determine mayonnaise as a sauce for various dishes. Mayonnaise stimulates appetite and improves digestion by increasing the nutritional value and enriching the taste of food. Mayonnaise is considered to be a product of high biological and physiological value (Taslikh et al., 2022).

The vegetable oil contained in mayonnaise provides the human body with physiologically active (essential) fatty acids, which lower blood cholesterol and help in preventing atherosclerosis; milk components and egg powder are sources of proteins and essential amino acids; sugar is a source of carbohydrates, it improves organoleptic characteristics; organic acids (acetic and citric) promote digestion, provide the required acidity and bactericidal purity, as well as ensure taste and aroma (Patil & Benjakul, 2019).

The nutritional value of mayonnaise is determined by the content of vegetable oil and the fact that it is a direct type of emulsion, easily absorbed by the body (Primacella et al., 2019).

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[1] *Moscow Timiryazev Agricultural Academy, Russian State Agrarian University, Moscow, Russian Federation*
*Corresponding author: man6630@rgau-msha.ru

The emulsifying ability of egg yolks is mainly due to the presence of phospholipids, high and low density lipoproteins. Vinegar, salt, sugar and mustard are added to mayonnaise as flavoring agents. These ingredients appear to play an important role in ensuring the emulsion physical stability (Santos Ferreira et al., 2022). Lutein, phycocyanin and other compounds (Alvarez-Sabatel et al., 2018), processed beet (Raikos et al., 2016) and fruit components (pulp) provide oxidation stability, as well as the specific taste and color of mayonnaise. This increases consumer interest in new food products. Determination of rheological properties is an important criterion for food products quality (Singla et al., 2013; Nogueira et al., 2022), including products that are water-in-oil emulsion (mayonnaise, sauces, margarine). Knowing these products rheological properties is important for developing a certain consistency of mayonnaise (Thaiudom & Khantarat, 2011), for quality control during production, for storage and transportation (Heydari et al., 2021). The rheological properties of mayonnaise are mainly determined by the proportion and composition of the oil phase, the presence of emulsifiers, stabilizers and thickeners (Kantekin-Erdogan et al., 2019). The quality of these products, their stability and viscosity depend on the homogenization process (Aganovic et al., 2018), the dispersion of fat droplets in the aqueous continuous phase of mayonnaise, egg yolk (Yang et al., 2020), the type of carbohydrates (Shen et al., 2011), as well as the milk component proportion and type (Saygili et al., 2022; Bredikhin et al., 2022a). Fat droplets are mechanically dispersed in the continuous aqueous phase of vinegar, and the action of a natural emulsifier from egg yolks (phospholipids, proteins) provides greater stabilization of the entire system in products of this emulsion type (Bredikhin et al., 2022b).

The homogenization process parameters (rotor speed, duration) and the choice of the rotor-stator system, which forms the oil phase droplets of a larger or smaller diameter, provide different medium stability and play an important role in the formation of a water-in-oil emulsion (Kumar et al., 2021). The influence of four types of honey added, as well as the homogenization process parameters (rotor speed, preparation duration) on mayonnaise rheological properties at a measurement temperature of 25 °C were investigated in this work.

2 Materials and methods

2.1 Materials

The following ingredients were used to make the mayonnaise with honey added: oil phase 75% (refined sunflower oil), egg yolk, honey, acetic acid, sea salt, tartaric acid, distilled water (Table 1). Refined sunflower oil constituted the oil phase of mayonnaise (Sloboda, Russia). Vinegar and sea salt were purchased from a local store. The egg yolk was bought from a private supplier and prepared fresh. Four types of honey (acacia, spring, linden, forest) were purchased from a private supplier as well. Tartaric acid was bought from the Novaprodukt company and added as a mayonnaise acidity regulator.

2.2 Mayonnaise preparation

Mayonnaise samples were prepared in the traditional way in the laboratory at room temperature in the amount of 300 g for each sample. The preparation of mayonnaise was carried out on a laboratory homogenizer of the Ultra Turrax T25 IKA model with the rotor speed range of 3,500 – 24,000 rpm. A rotor-stator system (type S25 D-14 G-KS) was used to make mayonnaise. A control mayonnaise sample was prepared with a 75% oil phase consisting of refined sunflower oil and other ingredients listed (Table 1).

Samples were prepared by the required ingredients pre-weighing and adding of ½ part sunflower oil, fresh egg yolk, vinegar, water, honey and other ingredients. Then the homogenizer was turned on, the rest of the sunflower oil was slowly added, and homogenized for 2 min at the rotor speed of 10,000 rpm. Mayonnaise samples were prepared at room temperature. Rheological properties measurement was carried out thereafter. Other samples of mayonnaise were prepared in the same way. The exception was that the individual ingredients varied depending on each sample recipe and the homogenization process parameters.

2.3 Rheological properties

The rheological properties of freshly prepared mayonnaise samples with pumpkin and rice oils added were measured on a Brookfield rotary viscometer with concentric cylinders. The viscometer was connected to a computer equipped with Rheocalc 3.2 software, which controlled rheological properties measurement and processed the data obtained. The study of mayonnaise samples rheological properties was carried out at temperatures of 25 °C and 10 °C. Maintaining of the samples constant temperature during the viscometer measurement was carried out with a thermostat model TC-501P from Brookfield. The dependence of shear stress (τ) and apparent viscosity (μ) on shear rate (D) in the range of rates 2.15–136.6 1/s (increasing measurement) and 136.6–2.15 1/s (reverse measurement), as well as the thixotropy phenomenon i.e. the ability to restore viscous and plastic properties after the load removal and deformation cessation were investigated in the work.

The type of mayonnaise rheological model was defined according to the experimental data obtained. The studied samples were determined to have non-Newtonian properties and belong to a pseudoplastic liquid type. The calculated values of rheological parameters - consistency index (k) and flow index (n) were obtained with Microsoft Excel with the application of the linear regression method.

Table 1. Recipe for making mayonnaise with honey added.

Composition	Sample	
	Share (%)	Weight (g)
Refined sunflower oil	75	225
Fresh egg yolk	7.7	23.1
Honey	3.8	11.4
Acetic acid	4	12
Sea salt	0.9	2.7
Tartaric acid	0.1	0.3
Distilled water	8.5	25.5
TOTAL	100	300

Equation 1 describes the stepwise Ostwald-Rainer law used to calculate rheological parameters.

$$\tau = k \cdot D^{n} \tag{1}$$

τ is the shear stress in Pa; D is the shear rate in 1/s; k is the consistency index in $Pa \cdot s^n$; n is the flow index.

Equation 2 was used to calculate the apparent viscosity of mayonnaise samples

$$\mu = k \cdot D^{n-1} \tag{2}$$

μ is the apparent viscosity in Pa·s.

3 Results and discussion

The research results of the influence of the honey variety and the homogenization process parameters during mayonnaise preparation on the change in rheological properties, measured at the temperature of 25 °C, are shown in Figures 1-3 and 4 and in Tables 2 and 3. The relationship between the shear stress and the shear rate for spring honey measured at 25 °C is shown in Figure 1.

The results show that honey belongs to a Newtonian fluid because the direction goes through the coordinate system origin. The rheological properties of the honey varieties studied, expressed in terms of rheological parameters, are presented in Table 2.

The results show that forest honey has the highest viscosity and consistency index, while linden honey has the lowest viscosity.

The studied samples of mayonnaise with honey exhibit non-Newtonian, pseudoplastic properties. The ratio of the shear stress and the shear rate of mayonnaise prepared with acacia honey confirms its belonging to non-Newtonian liquids (Figure 2).

The authors of Bredikhin et al. (2022b) confirm that mayonnaise is a non-Newtonian liquid and exhibits the yield stress, pseudoplasticity, and thixotropy. The authors of Bredikhin et al. (2022a) indicate the pseudoplastic behavior of mayonnaise with characteristics depending on the raw material composition.

Empirical flow curves with a high degree of adequacy are described by the Herschel - Bulkley model.

The effect of honey varieties on the rheological parameters of mayonnaise prepared at the homogenizer rotor speed of 10,000 rpm and the homogenization time of 2 minutes measured at 25 °C is shown in Table 3.

The acacia honey mayonnaise control sample has the apparent viscosity of 3.118 Pa·s at the shear rate of 77.82 s^{-1}, the consistency factor of 77.42 $Pa \cdot s^n$, and the flow index of 0.2624 measured at 25 °C. When using linden honey in mayonnaise preparation, a slight increase in the apparent viscosity of 3.294 Pa·s and the consistency index of 78.46 $Pa \cdot s^n$ was observed, in comparison with the application of acacia honey. Forest honey showed a higher viscosity and consistency (Table 2) compared to other honey varieties studied. The use of forest honey in mayonnaise preparation showed higher values of the apparent viscosity of 3.427 Pa·s and the consistency index of 101.26 $Pa \cdot s^n$, as well as a decrease in the flow rate of 0.2224 (Table 3).

The research results of the influence of the homogenization process parameters (rotor speed, homogenization duration) on the received honey mayonnaise rheological properties are shown in Figures 3 and 4.

The calculated values of the flow index rheological parameter (n = 0-1) show that mayonnaise under study belongs to the pseudoplastic type. Figure 3 shows the effect of the homogenization time (2 min, 4 min) at the rotor speed of 10,000 rpm on the rheological properties of acacia honey mayonnaise, expressed by rheological parameters measured at 25 °C.

The results obtained show that preparation of mayonnaise with 2-minutes' homogenization gives the apparent viscosity of 6.253 Pa·s at the shear rate of 30.36 1/s (Figure 3A),

Table 2. Rheological properties of different honey varieties measured at 25 °C.

Sample	μ* (Pa·s)	k ($Pa \cdot s^n$)	n
Spring honey	4.0977	6.4787	0.8948
Forest honey	16.2311	17.304	0.9853
Linden honey	3.5486	7.3142	0.8339
Acacia honey	5.6809	6.0935	0.9839

*Apparent viscosity at shear stress of 77.82 1/s.

Table 3. The effect of honey variety on the rheological parameters of mayonnaise.

Honey variety	μ* (Pa·s)	k ($Pa \cdot s^n$)	n
Spring	3.083	63.11	0.3067
Forest	3.427	101.26	0.2224
Lime	3.294	78.46	0.2719
Acacia	3.118	77.42	0.2624

*Apparent viscosity at shear stress of 77.82 s^{-1}.

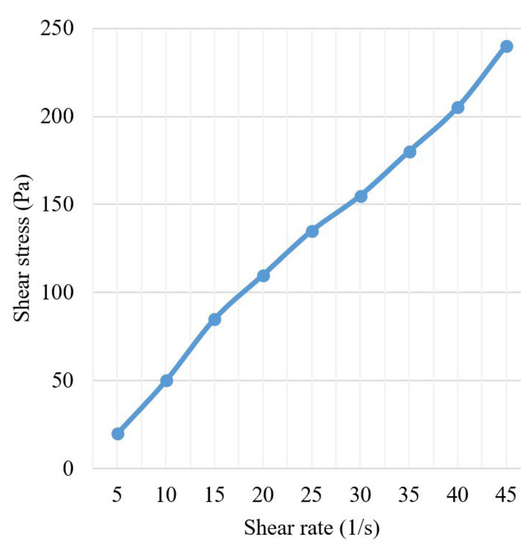


Figure 1. The relationship between the shear stress and the shear rate of spring honey at 25 °C.

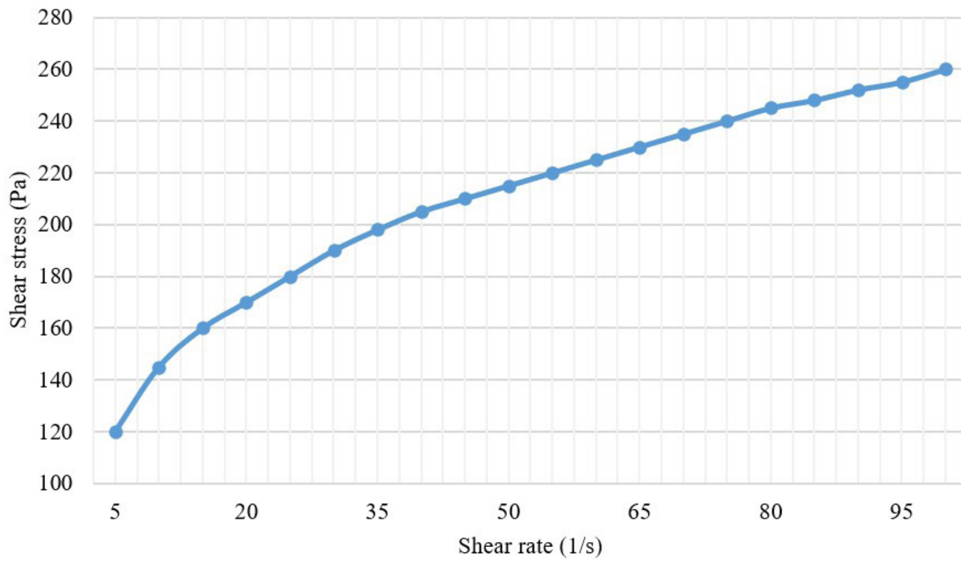


Figure 2. Dependence of the shear stress and the shear rate of mayonnaise with acacia honey (10,000 rpm, 2 min) at 25 °C.

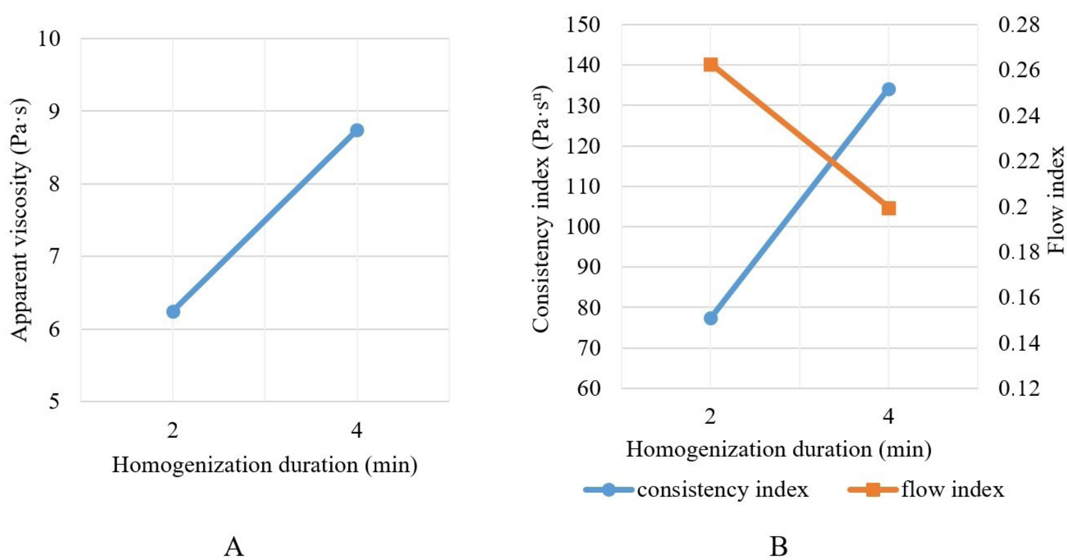
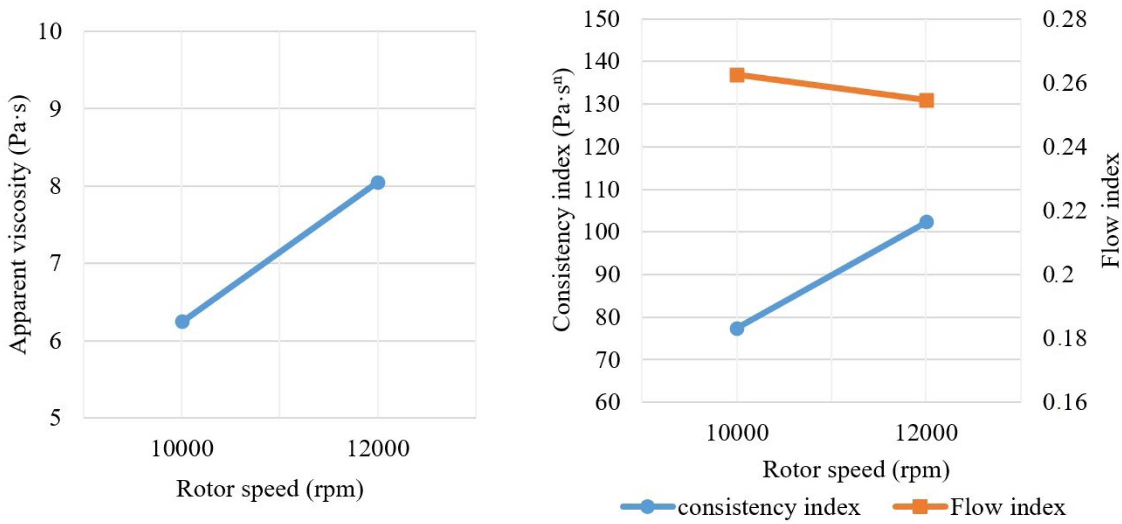


Figure 3. The effect of the homogenization duration on the rheological properties of acacia honey mayonnaise.

the consistency index of 77.42 Pa·s^n and the flow index of 0.2628 (Figure 3B). If we increase the homogenization time when preparing mayonnaise from 2 min to 4 min, an emulsion with the higher viscosity of 8.736 Pa·s (Figure 3A), the consistency index of 134.24 Pa·s^n and the lower flow index of 0.1995 is obtained (Figure 3B).

Figure 4 shows the effect of the homogenizer rotor speed (10,000; 12,000 rpm) during 2 min of acacia honey mayonnaise preparation on the rheological parameters measured at 25 °C.

The results of the calculated values of these samples rheological parameters show that the rotor speed affects the change in rheological properties as well. When preparing mayonnaise at the rotor speed of 10,000 rpm, the apparent viscosity of mayonnaise is 6.253 Pa·s at the shear rate of 30.36 1/s (Figure 4A), the consistency index of 77.42 Pa·s^n, and the flow index of 0.2628 (Figure 4B). A further increase in the rotor speed up to 12,000 rpm when preparing mayonnaise causes the formation of an emulsion with the higher apparent viscosity of 8.039 Pa·s (Figure 4A) and the consistency index of 102.32 Pa·s^n (Figure 4B). The most optimal homogenizer rotor speed is considered to be 12,000 rpm. In this case the water-in-oil emulsion system becomes more stable, since smaller fat droplets are formed. They are finely dispersed in the aqueous phase of the emulsion.



A B

Figure 4. The effect of the rotor speed on the rheological properties of acacia honey mayonnaise.

4 Conclusions

The tested mayonnaise samples with the addition of honey belong to non-Newtonian systems, a pseudoplastic type of liquid. The type of honey influenced the rheological properties of mayonnaise with the oil content of 75%. Rheological properties with the higher apparent viscosity and consistency index, as well as the lower flow index compared to the use of spring, linden and acacia honey varieties were obtained when using forest honey variety in the preparation of mayonnaise. Spring honey mayonnaise had the lowest apparent viscosity and consistency, as well as the highest flow index. The homogenizer rotor speed, as well as the homogenization duration, influenced the change in the rheological properties of mayonnaise with honey. Mayonnaise with the higher viscosity and consistency, as well as the lower flow index, was obtained at the rotor speed of 12,000 rpm compared to 10,000 rpm. Higher viscosity and consistency, as well as the lower flow index were obtained with a 4 minutes' homogenization time compared to a 2 minutes' treatment. Empirical flow curves with a high degree of adequacy were described by the Herschel - Bulkley model.

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