Determination of viscosity in O/W emulsions and correlation with prime oil phase

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Abstract

Oil-in-water (O/W) emulsions with 10%, 20%, 30% and 40% oil were prepared using soybean protein isolate (SI) 1, 2 and 3% as stabilizer. Viscosity of emulsions was determined. Microscope observation of all emulsions immediately after preparation was performed. Correlation among viscosity, emulsion droplet size and percents of oil phase were found. Emulsions prepared with high percent oil exhibit smaller average droplet size and greater stability.

1. Introduction

The emulsion system are known as thermodynamically unstable and the main purpose is to found some methods to stabilized them [1, 2]. The formation of emulsions is due to the surfactant like action of the polar components of the oil. The viscosity of an emulsion is correlated with the starting oil, but sometimes is observed and high variation in this factor [3]. The emulsion systems may exhibit some instability. Therefore, when developing emulsions for topical application it is interesting to verify whether they have suitable physical and mechanical characteristics [4]. The stability of emulsion systems, which varied in the proportion of the different emulsifying agents were investigated. Rheology studies, texture analysis and microscopic observation of formulations with and without emulsifiers were performed [5]. The influence of sodium chloride salt (NaCl) on the physical stability of sunflower oil-in-water emulsions (40 w/w%) stabilized by 7 w/w% bambara groundnut flour was investigated. Oil droplet sizes and emulsion microstructure were measured microscopically [6]. The different soy proteins studied, soy protein isolate (SPI), 7S globulin and 11S globulin were differently investigated by high-pressure (HP). HP unfolds the proteins, exposing hydrophobic sites, leading to improve functional properties of the proteins [7]. The interfacial properties of proteins and emulsifiers were studied extensively in the field of food colloid research. Emulsions form the basis of a huge range of food products were generally stabilized by either protein or emulsifiers. Proteins were shown to stabilize emulsions by forming a viscoelastic, adsorbed layer on the oil droplets, which form a physical barrier to coalescence [8]. Protein fractions were isolated from coconut: coconut skim milk
protein isolate (CSPI) and coconut skim milk protein concentrate (CSPC). The ability of these proteins to form and stabilize oil-in-water emulsions was compared with of whey protein isolate (WPI) [9]. Soy soluble polysaccharides (SSPS) were shown to prevent destabilization of soy protein isolate (SPI) dispersions and based oil-in-water emulsions under acidic conditions. Addition of SSPS above a critical concentration (0.25 wt%) increased the stability of 0.50 wt% SPI dispersions against aggregation and phase separation under conditions where SPI would normally precipitate (near its isoelectric point) [10]. Separation of water from oil emulsions was a significant subject in the petroleum industry and chemical processing. Experimental studies on separation of water from water-in-sunflower oil emulsions under a combined treatment of a radial electric field and elevated temperature were provided. The effects of voltage and temperature on separation time were investigated experimentally and theoretically [11]. The viscosity on liquids and liquid mixtures can be used at extraction of oils and fats [12].

The aim of this study is to investigate the influence of the oil phase on the stability of O/W emulsions using rheological characteristic as viscosity and microscopic observations.

2. Materials and methods
The sunflower oil was used for preparation of all emulsions. As stabilizer was used soybean protein isolates (SI with purity 95 %). The emulsions were prepared with different concentrations of protein solubilised in water. After that sunflower oil was added. The preparation was performed with homogenizer for 90 s mixing at temperature 25°C.

For all emulsions microscopic observation were provided by digital microscope Brasser with USB port on PC.

Dynamic and kinematic viscosity is important for the physical characteristic of liquids. Dynamic viscosity can be determined on three ways: method of falling ball, yield stress through the capillary and determination of resistance using a rotary viscometer.

Rheological analysis was performed with vertical falling ball viscometer. Spindle number 5 was used to obtain speeds of ball. For each speed, the dynamic viscosity (Pa.s) were calculated used experimental density and Stokes law equation 1 [13].

$$\eta = \frac{2}{9} \left( \rho_{em} - \rho_b \right) g r^2 \frac{1}{w_0} \quad \text{(vertically downwards if} \ \rho_p > \rho_g)$$

(1)

where: \(g\) is the acceleration of gravity (m.s\(^{-2}\)), \(r\) is the radius of the spherical ball (m), \(\rho_{em}\) is the density of emulsions (kg.m\(^{-3}\)), \(\rho_b\) is the density of the spherical ball (kg.m\(^{-3}\)), \(\eta\) is the dynamic viscosity (Pa.s), \(w_0\) - speed in steady moving, determined by the path per unit time.

There is a relationship among dynamic and kinematic viscosity. It can be represented by the density of the liquid and the measured viscosity [13]. The kinematic viscosity is calculated using equation 2.

$$\nu = \frac{\eta}{\rho} \cdot m^2.s^{-1}$$

(2)

where: \(\eta\) – dynamic viscosity of emulsions, Pa.s;
\(\rho\) – density of emulsions, kg.m\(^{-3}\).

The density of ball was determined as described in [13] but the density of the emulsions as described in [14].

3. Results and discussion
The 12 emulsions were prepared with 10, 20, 30 and 40 % oil and 1, 2% and 3% SI. The compound of oil and water phases, density, dynamic and kinematic viscosity for the emulsions is presence in Table 1.

With decreasing of water and increasing of oil phases the density and viscosity increased. After calculations the kinematic viscosity exhibit appropriate values compared with dynamic viscosity. For pure sunflower oil the dynamic viscosity was finding from 334.28 10\(^3\)Pa.s to 359.12 10\(^3\)Pa.s according literature data [16].
Table 1. Compound, density and viscosity of investigated emulsions.

| em № | oil, % | water, % | ρ, kg.m⁻³ | η, 10³Pa.s | ν, 10⁶ m².s⁻¹ |
|------|--------|----------|------------|------------|---------------|
| 1    | 10     | 89       | 0.889      | 97.431     | 0.110         |
| 2    | 20     | 79       | 0.884      | 107.811    | 0.122         |
| 3    | 30     | 69       | 0.883      | 123.597    | 0.140         |
| 4    | 40     | 59       | 0.882      | 127.936    | 0.145         |
| 5    | 10     | 88       | 0.913      | 102.890    | 0.113         |
| 6    | 20     | 78       | 0.874      | 104.259    | 0.119         |
| 7    | 30     | 68       | 0.871      | 125.695    | 0.144         |
| 8    | 40     | 58       | 0.870      | 145.444    | 0.167         |
| 9    | 10     | 87       | 0.913      | 116.958    | 0.128         |
| 10   | 20     | 77       | 0.909      | 121.781    | 0.134         |
| 11   | 30     | 67       | 0.868      | 136.170    | 0.157         |
| 12   | 40     | 57       | 0.849      | 166.389    | 0.196         |

Immediately after preparation the microscopic observation of each emulsion was performed. Polydisperse emulsions with different particle sizes from small to large were observed. Emulsion 1 prepare with 10% oil exhibit large droplet size among 5 to 20 μm. The emulsions with large droplets size were unstable [15]. With the increasing of % of oil smaller droplets appear and seen in emulsion 4 prepared with 40% oil and size among 4 to 5 μm. These results are presence on Figure 1 a) and b).

*Figure 1. Microscopic observations for emulsions 1 and 4.*
Dynamic viscosity of emulsions was determined by Stokes law but first was determined the density [14]. After that the kinematic viscosity of all emulsions was calculated. All results are presence in Table 1. With the change of the composition of different emulsions the change of density and viscosity were observed. Emulsions prepared with 40% oil exhibit high density and viscosity. On the pictures seen the individuality droplets. The size of droplets connected with oil phase and show larger droplets, apparently presenting coalescence. The droplet size of emulsions is a main characteristic of the efficiency of them. To yield stable emulsions with a high oil phase should allow the formation of the smallest droplets and stable emulsions [5]. This stability in O/W emulsions is strongly influenced by the droplet size and concentration. In this case, emulsions containing smaller droplets and greater concentration of droplets Fig. 1b) exhibit greater viscosity than emulsions containing larger droplets Fig. 1a).

Graphical view among dynamic viscosity, density and oil percent is presence in Figure 2.
On the figure are presence three series of emulsions. In all series observed that the high viscosity and density connected with great oil phase. On the Fig. 2a) presence emulsions 1-4. Dynamic viscosity determined to $127.936 \times 10^3$ Pa.s in emulsion 4 prepared with 40 % oil phase. On the Fig. 2b) presence emulsions 5-8 and dynamic viscosity determined to $145.400 \times 10^3$ Pa.s in emulsion 8. On the Fig. 2c) presence emulsions 9-12 and dynamic viscosity determined to $166.389 \times 10^3$ Pa.s in emulsion 12. Increasing the viscosity in three series connected with increasing of protein. According the microscopic observation [15] stable emulsion appeared at low protein concentration. In this case, emulsions containing smaller droplets, greater concentration of oil an 1 % SI showed greater stability.

4. Conclusions
Different oil-in-water (O/W) emulsions were investigated. Polidesperse emulsions were obtained. The particle size of them varied among 4 to 20 μm depending from oil phase. Experimental density, dynamic and kinematic viscosities were determined. Good correlation among rheological parameters and droplet size were found. After all observations were conclude that emulsions prepared with high percent oil and small amount of protein exhibit smaller average droplet size and greater stability.

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