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A New Emulsifying Agent: *Cucumis sativus* Linnaeus Mucilage

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Authors' contributions

This work was carried out in collaboration between all authors. Authors OAB and TOA designed the study and wrote the protocol. Authors OAB, TOA and EGA managed the literature search, analysis of the study and statistical analysis of the study, while author OAB wrote the first draft of the manuscript. All authors read and approved the final draft.

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ABSTRACT

Aim: This study aims at investigating the emulsifying properties of *Cucumis sativus* mucilage, compare with gelatin and tragacanth with further assessment of their combined effects on the emulsion properties.
Place and Duration of Study: Department of Pharmaceutics and Pharmaceutical Technology, Olabisi Onabanjo University, Nigeria and Department of Pharmaceutics and Industrial Pharmacy, University of Ibadan, Nigeria between September 2014 and July 2015.
Methodology: Cod liver oil and liquid paraffin emulsions were prepared by the wet gum method with the different emulsifying agents. Primary emulsions of cod liver oil were prepared using a ratio of 4:2:1 for oil, water and gum while 3:2:1 was used for liquid paraffin. *Cucumis* was also combined with gelatin and tragacanth respectively at different ratios (1:1, 1:2 and 1:3). The emulsions were assessed for emulsion type, creaming, viscosity, globule sizes and size distribution.

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Results: The emulsions formulated were creamy and dilution tests showed that they were oil-in-water in nature. The ranking of the creaming for cod liver oil and liquid paraffin emulsions was tragacanth>*Cucumis*>gelatin and gelatin>*Cucumis*>tragacanth respectively. There were significant differences (p<0.001) in the viscosities of the emulsions with tragacanth having the highest values. The average globule sizes ranged between 2.5-97.5 µm. The effect of storage on the viscosity showed that viscosity of emulsions decreased with time.
Conclusion: The results of this study indicates *Cucumis sativus* mucilage could be useful as a primary emulsifying agent in oil-in-water emulsions.

Keywords: Emulsion; emulsifying agents; Cucumis sativus; gelatin; tragacanth.

1. INTRODUCTION

Emulsion is a thermodynamically unstable, biphasic system, consisting of two immiscible liquids, in which one is finely dispersed as droplets in the second phase [1]. There are different classes of pharmaceutical emulsions: oil-in water (o/w), water-in-oil (w/o) and multiple emulsions (oil-in-water-in-oil o/w/o, water-in-oil-water w/o/w) [1]. Emulsions can also be classified according to droplet size: macroemulsions (1-100 µm), microemulsions (100Å-100 nm) and nanoemulsions (20-200 nm) [2]. Emulsions are useful in masking taste of drugs [3], reduce drug toxicity [4] and the micro and nano emulsions are useful for drug targeting [5]. The instabilities occurring in emulsions are creaming, cracking and phase inversion. Due to the instability of emulsions, an emulsifying agent is needed to stabilize the emulsion [6]. Emulsifying agents are classified into 4 groups: Synthetic, natural, finely divided solids and auxiliary materials [7].

Natural emulsifying agents are derived from plants or animals and they effect their emulsifying properties by forming multimolecular sheaths around emulsion droplets, imparting a charge to dispersed droplets and by increasing the viscosity of the system [8]. Mixture of emulsifiers have been used to produce stable emulsions in the past, this is because some agents are more useful as primary emulsifiers while others are secondary.

Cucumis sativus Linnaeus (Family Cucurbitaceae) commonly known as cucumber is an herbaceous plant with pubescent stems and unbranched tendrils up to 30 cm long. Leaves are alternate and simple, with 3-7 palmate lobes and serrated margins. The flowers are yellow, warty cylindrical fruits, yellow to green in colour and about 50 cm long. The plant grows to about 2-5 m long. It grows well in moist, well drained, sandy soil rich in organic matter and slightly alkaline. It is native to India and now found in most part of the world [9]. It is consumed mostly as salad and it has been found to have medicinal uses. It is used as a soothing agent and emollient for treating irritated skin [10]. The leaves, stems and roots are generally used for anti-diarrhoeal, detoxicant and anti-gonorrhoeal agents by the Chinese [11].

Cucumis sativus derived ingredients are being used in cosmetics as skin conditioners. These ingredients have been assessed for safety in cosmetics by CIR Expert Panel [12].

In the present study, the mucilage of *Cucumis sativus* was used as an emulsifier in codliver oil and liquid paraffin emulsions and compared with standard emulsifiers (gelatin and tragacanth). The combined effect of this mucilage with gelatin or tragacanth on the emulsion properties were also determined.

2. MATERIALS AND METHODS

2.1 Material

Tragacanth gum and gelatin gum were obtained from BDH Chemicals, England, Cod liver oil and Liquid Paraffin were procured from Tunnex Laboratory Engineering, Nig, Ltd. *Cucumis sativus* gum was prepared in the laboratory of the Department of Pharmaceutics and Industrial Pharmacy, University of Ibadan. All other reagents were of analytical grade.

2.2 Methodology

2.2.1 Extraction of *Cucumis sativus* mucilage

Cucumber was procured from a local market in Ibadan, South west Nigeria washed and peeled. The inner mucilaginous part was cut and hydrated in chloroform water double strength for 3 days with intermittent stirring. It was strained through a muslin cloth and the filtrate precipitated

with ethanol (96%$^{v}/_{v}$). The precipitate was washed with diethyl ether and dried in hot air oven (Laboratory oven TT-9083; Techmel and Techmel, TX, USA) at 40°C [13].

2.2.2 Preparation of emulsions

Codliver oil emulsions were prepared by wet gum method, using different types of polysaccharide emulsifiers (*Cucumis sativus* mucilage, gelatin and tragacanth gum). These emulsifying agents were also used in combination at different ratios (Table 1). The primary emulsions were prepared using a proportion of 4:2:1 for cod liver oil while 3:2:1 was used for liquid paraffin. The required amount of gum was triturated with water to form a mucilage, the oil was added gradually with constant trituration until the primary emulsion was formed and then made up to volume with water [14]. The same procedure was repeated with liquid paraffin (Table 2).

2.2.3 Determination of emulsion type

Emulsion drops (3) were added to 10 mL of water and the miscibility of the emulsions with water was observed. Dye staining method was also used to confirm emulsion type by putting 3 drops on a slide and a drop of methylene blue was added and viewed under a light microscope. This was done for all the emulsions.

2.2.4 Creaming, coalescence and flocculation studies

Emulsion (10 mL) was poured into a measuring cylinder, covered and allowed to stand undisturbed for 2 weeks. Measurements of cream height were taken at different time intervals and appropriate plots prepared from the data. The emulsions were carefully observed daily for signs of coalescence and flocculation throughout the period of the experiment.

2.2.5 Determination of emulsion droplet size

A drop of emulsion was placed on a slide and mixed with a drop of methylene blue. This was viewed under a digital microscope using a calibrated eye piece. The colourless oil droplets were measured. A TS View CX Image® Software, File version 6.2.4.3 was used to analyse the data and the globule size distribution was plotted.

2.2.6 Determination of emulsion viscosity

The viscosity of the emulsions was determined at different time intervals with a Brookfield viscometer (model RVVDV-II+ P, Brookfield Eng Labs Inc., Middle Boro, MA, USA) using spindle size 07 at a shear rate of 50 rpm at 27 ± 2°C.

3. RESULTS AND DISCUSSION

Emulsions consist of two or more completely or partially immiscible liquids, such as oil and water, where one liquid is being dispersed in the other in the form of droplets [15]. At the interface of each droplet, the molecules of the two liquids are in direct contact with each other, which is thermodynamically highly unfavourable. Sensory evaluations such as emulsion colour, texture, and appearance are an important part of emulsion designs and serve as guidelines to

Table 1. Composition of cod liver oil emulsion

Ingredients (%)	F1	F2	F3	F4	F5	F6	F7	F8	F9
Cod liver oil	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Cucumis			12.50	6.25	4.17	3.13	6.25	4.17	3.13
Tragacanth	12.50			6.25	8.33	9.37			
Gelatin		12.50					6.25	8.33	9.37
Water	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Water q.s	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 2. Composition of liquid paraffin emulsion

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Liquid paraffin	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Cucumis			16.66	8.33	5.55	4.17	8.33	5.55	4.17
Tragacanth	16.66			8.33	11.11	12.49			
Gelatin		16.66					8.33	11.11	12.49
Water	16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67	16.67
Water q.s	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

design the emulsification process and verify the quality of the produced emulsion. If emulsion properties comply with the set standards (i.e., their values are within an acceptable range), manufacturers can be confident that their customer base will be satisfied with the product. The emulsions prepared in this study were creamy, smooth-textured and with a pleasant appearance. With regards to this aspect, the emulsion formulations were considered acceptable.

3.1 Emulsion Type

Determination of emulsion type is a crucial aspect of the formulation. This is because emulsion type generally determines the overall usefulness of the preparation. In this study, all formulations were miscible with water indicating oil in water emulsion (o/w). The dye-staining test also confirmed that. Oil in water emulsions are acceptable for internal preparations. The formulations in this study can serve as delivery systems for oral preparations or carriers for parenterals.

3.2 Creaming, Coalescence and Flocculation Studies

Creaming is the migration of droplets to the top or bottom of emulsion systems depending on the densities of the two liquid phases [2]. Creaming is a form of instability in emulsion, though it is reversible if the oil droplets do not coalesce. Coalescence occurs if two droplets come into close contact for an extended period of time (e.g., due to flocculation or accumulation in a creamed layer), the small liquid film that separates the two droplet membranes will gradually start to thin [15]. The speed with which this film thinning occurs is a function of the hydrodynamic properties of the film, the colloidal interactions between the two membranes, and the membrane composition itself. The thickness of the film can vary with time. The close contact of the two membranes will eventually cause them to become distorted. Flocculation is the process whereby two or more droplets come together and form an aggregate without losing their individual integrity [16]. Flocculation depends on the frequency with which droplets collide and the efficiency of the collisions. Whether the droplets will aggregate after a collision is a function of the colloidal interactions between the droplets [17]. The plots of creaming height against time for cod liver oil and liquid paraffin emulsions are presented in Figs. 1 and 2 respectively. The ranking of creaming rate was tragacanth>*Cucumis*>gelatin for cod liver oil emulsion, while liquid paraffin emulsion was gelatin>*Cucumis*>tragacanth (Table 2). When the gums were combined, cod liver oil emulsions containing *Cucumis*/tragacanth (F4) and *Cucumis*/gelatin (F8) did not cream until after 72 and 96 hours respectively (Fig. 1). Liquid paraffin emulsion containing *Cucumis*/tragacanth (C4 & C5) did not show any creaming until after 240 and 190 hours respectively (Fig. 2). *Cucumis* was able to stabilize the emulsions for about 24 hours before the onset of creaming. This could imply that *Cucumis* may be applicable as a primary emulsifier which would then require

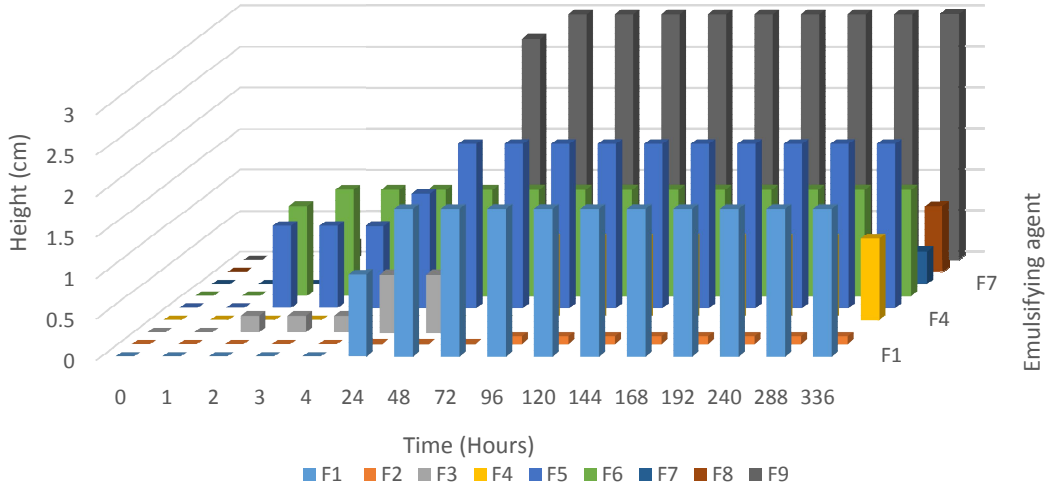

Fig. 1. Plot of cream height against time for cod liver oil emulsions

an additional agent to further strengthen the system. The droplets of the emulsions seem not to coalesce nor flocculate from the physical observations made and creaming could be said to be prevalent among instabilities observed in the systems.

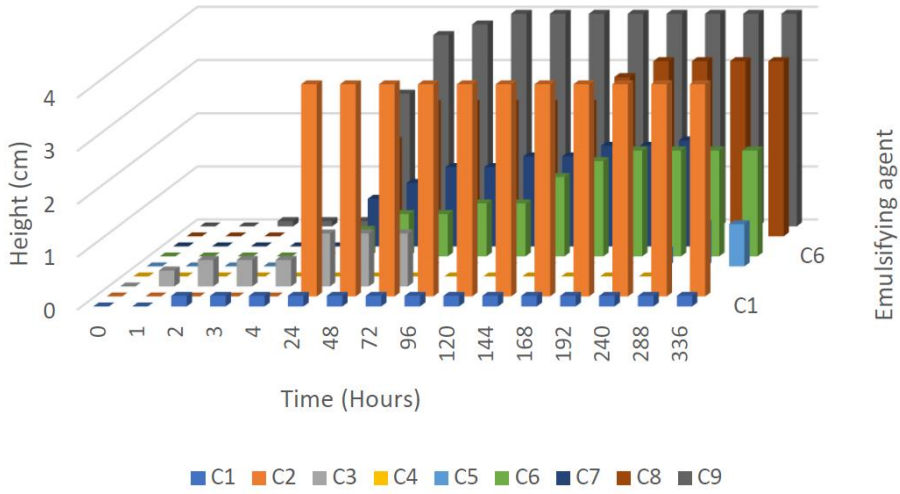

Fig. 2. Plot of cream height against time for liquid paraffin emulsion

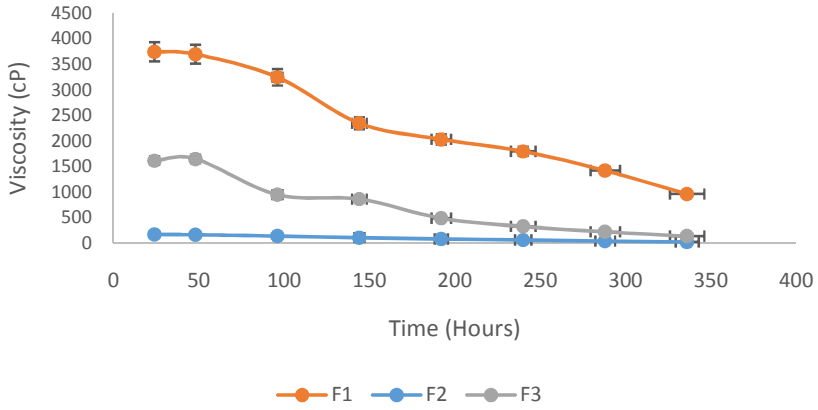

Fig. 3. Effect of storage time on viscosity of cod liver oil emulsions prepared with single emulsifier

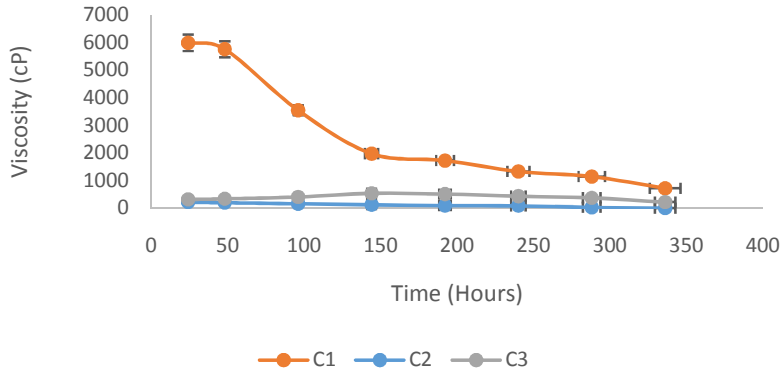

Fig. 4. Effect of storage time on viscosity liquid paraffin emulsions prepared with single emulsifier

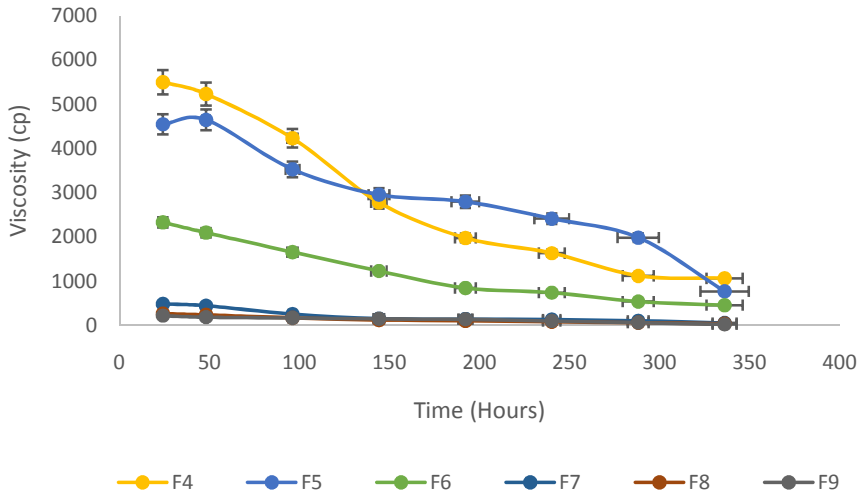

Fig. 5. Effect of storage time on viscosity of cod liver oil emulsions prepared with combined emulsifier

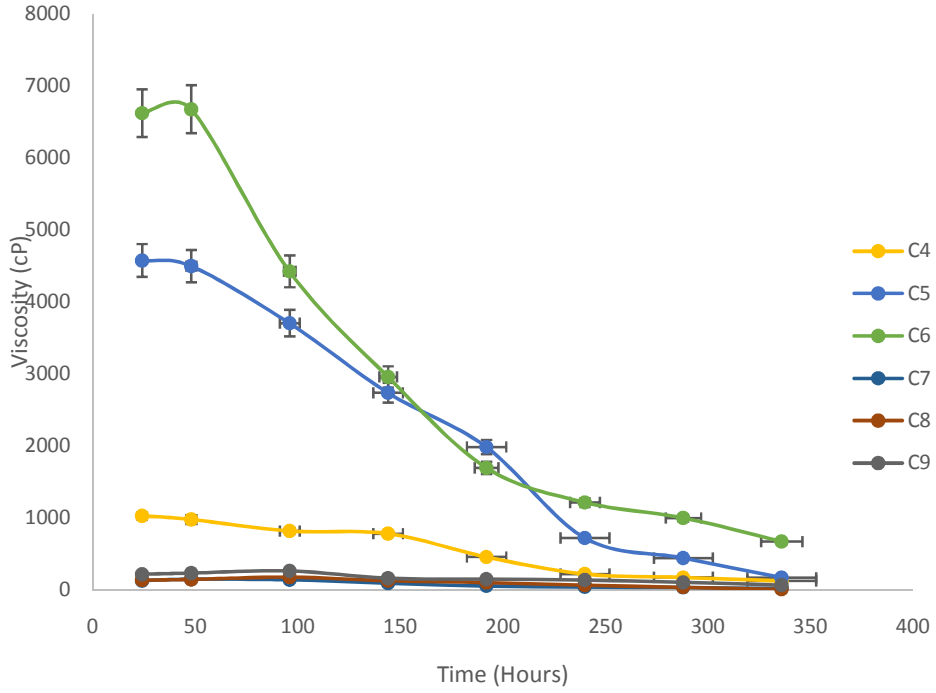

Fig. 6. Effect of storage time on viscosity of liquid paraffin emulsions prepared with combined emulsifier

3.3 Emulsion Viscosity

Viscosity is a measure of resistance to flow when shear stress is applied. The plot of viscosity of emulsions containing individual polymers are presented in Figs. 3 and 4. The viscosity of the emulsions was observed to be decreasing with time except for liquid paraffin emulsion emulsified with *Cucumis* that increased initially for some hours before decreasing. This initial increase could have been due to flocculation which leads to increase in viscosity [18]. Flocculation arises because of attractive forces between the droplets and leads to the formation of flocs of dispersed

phase [2]. Flocculation and coalescence has been said to be one of the major mechanism of instability in emulsions [19]. There were significant (p<0.001) differences in the viscosities of the emulsions with a ranking of tragacanth>*Cucumis*>gelatin for both cod liver oil and liquid paraffin emulsions. The viscosity as shown in Table 3 revealed that the viscosity of cod liver oil emulsions reduced as the concentration of the standard emulsifiers increased in the emulsifier combination, whereas, it increased in liquid paraffin emulsions. The type of oil used seem to modify the viscosity of the formulations when the emulsifiers were combined.

The viscosity of cod liver oil and liquid paraffin emulsions containing combined emulsifiers are presented in Figs. 5 and 6 respectively. The viscosities were observed to gradually decrease with time. The viscosity of formulations F5, C6-C9 increased initially before decreasing, while formulations F5, C7 and C8 eventually cracked.

The high viscosities observed in emulsions containing *Cucumis* and combination of *Cucumis*/tragacanth could be due to their polysaccharide nature, that enables them to form extended network in the continuous phase which thus becomes highly viscous [20] and can even

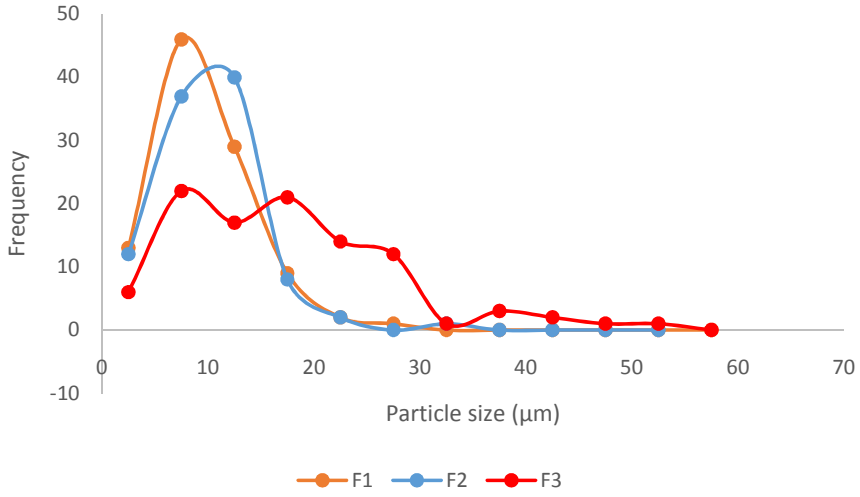

Fig. 7. Globule size distribution of cod liver oil emulsion containing single emulsifier

Table 3. Properties of the emulsion formulations

Formulations	Creaming rate (cm/hour)	Viscosity (Cp)	Globule size (µm)
F1	0.0056	5983.33± 28.87	9.70 ±135.06
F2	0.0004	220.00 ± 20.00	10.25±154.64
F3	0.0015	320.00 ± 20.00	17.35±131.73
F4	0.0039	1023.33 ± 25.17	9.30±130.48
F5	0.0044	4570.00 ± 26.46	9.25±119.97
F6	0.0017	6616.67 ± 20.82	7.85±144.15
F7	0.0008	125.00 ± 5.00	16.30±144.03
F8	0.0030	131.67 ± 10.41	11.35±128.11
F9	0.0098	213.33 ± 11.55	13.55±112.80
C1	0.0001	3750.00 ± 86.60	13.00±100.85
C2	0.0107	173.33 ± 11.55	11.55±111.66
C3	0.0092	1616.67 ±28.87	11.15±108.76
C4	0.0000	5500.00 ± 100.00	9.50±102.03
C5	0.0022	4550.00 ± 132.29	70.95±350.83
C6	0.0070	2333.33 ± 115.47	7.15±92.83
C7	0.0090	486.67 ± 30.55	11.45±112.28
C8	0.0100	266.67 ± 15.28	66.00±337.72
C9	0.0115	221.67 ± 22.55	21.35±118.75

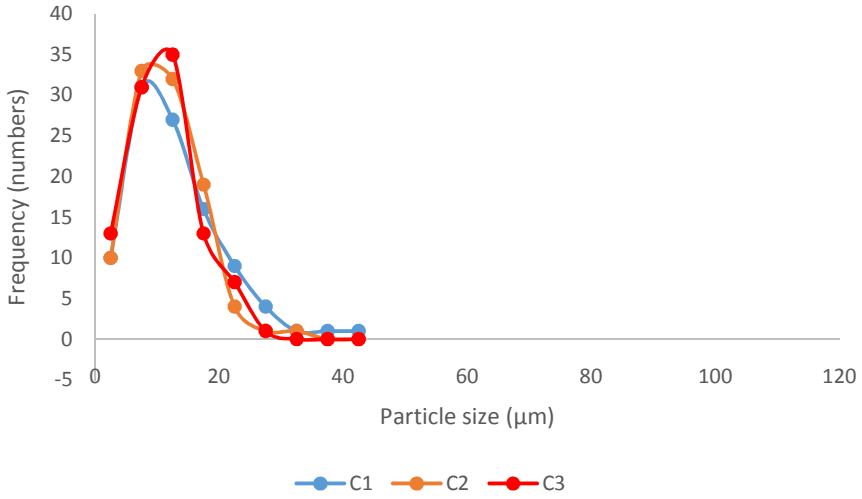

Fig. 8. Globule size of liquid paraffin emulsions containing single emulsifiers

form a gel [21,22]. Gelatin is a high molecular weight protein derived from animal protein [23]. Proteins adsorb at the oil-water interface, thereby, emulsifying and stabilizing the emulsion [24,25]. Combining the properties of protein and polysaccharide as in combination of *Cucumis* and gelatin, was valuable in maintaining a fairly stable viscosity when compared to those containing *Cucumis*/tragacanth combination.

3.4 Droplet Size and Size Distribution

The droplet size of emulsion is important for the stability of emulsions [26]. The droplet size range was 7.15-70.95 µm (Table 3), indicating the emulsions formed were macromolecular [2]. The size frequency distribution plot of cod liver oil emulsions containing single emulsifier is shown in Fig. 7. The size distribution of emulsions containing *Cucumis* was significantly (p<0.001) wider than those of gelatin and tragacanth. The bimodal size distribution of emulsions prepared with only *Cucumis* (Fig. 7), indicates that coalescence seem to be occurring within the system [27]. This fact was corroborated with the eventual cracking of the *Cucumis* stabilized cod liver oil emulsion. The size distribution of liquid paraffin emulsions was slightly similar as shown in Fig. 8.

4. CONCLUSION

Water-in-oil emulsions were formed with all the emulsifying agents used. *Cucumis* was able to form emulsions that were stable for 24 hours. All other emulsifiers generally formed stable emulsions, though with creaming which was easily reversible. *Cucumis*/tragacanth emulsifiers produced stable emulsions having small droplet sizes and high viscosities. *Cucumis* can be more acceptable as a primary emulsifying agent for o/w emulsions.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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