

COMPARISON OF EMULSIONS STABILISED BY ANIONIC AND CATIONIC BIOPOLYMERS

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Abstract

Emulsions are used in the formulation of processed foods making it necessary to be stable over an extended period under varying stress conditions. In this study, oil-in-water emulsions were prepared by dispersing the oil into a water phase by using energy from ultrasonication. All the emulsions were prepared by sonicating for 5 minutes with a duty cycle of 0.5 at 20 kHz at using a sonotrode probe of 12 mm tip diameter. Two types of emulsions, a cationic and an anionic emulsion were formed by using two different food-grade emulsifiers and oil at 1% (w/v). The emulsifiers used for the study are sodium caseinate and gum Arabic that forms cationic and anionic oil droplets respectively, at pH 3. The emulsion quality was assessed by measuring the surface charge, particle size distribution and creaming stability. Gum Arabic stabilised emulsions had negative zeta-potential of -5.39 ± 0.779 mV while, sodium caseinate stabilised emulsions had a positive zeta-potential of $+16.13 \pm 0.929$ mV at an emulsifier concentration of 12 mg/ml. The particle size of cationic emulsions varied from 641.7 ± 39.47 to 402.93 ± 18.31 nm for sodium caseinate concentration ranging from 2 to 12 mg/ml. The stability of emulsions to various environmental stresses like the changes in pH (3 to 9), temperature (30 to 90 °C) and salt concentration (50, 100, 500 mM NaCl) was determined. Gum Arabic stabilised emulsions were free from flocculation on the addition of sodium chloride up to 500 mM while cationic sodium caseinate emulsions destabilised

Keywords: ζ -potential, creaming stability, freeze-thaw cycling, ultra-sonication

1. INTRODUCTION

Manufactured foods exist in structures such as emulsions and foams. The control of stability of such structures is an essential skill for food technologist. A wide range of materials for food use with emulsifying and stabilising ability are available. This includes surfactants (Tweens, lecithins, sorbitan esters, monoglycerides), proteins (whey protein isolate, β -lactoglobulin, gelatin, sodium caseinate) and polysaccharides (gum arabic, pectin, chitosan). Most of these species behave as surface-active agents that act by lowering the surface tension at air-water (foam) or oil-water (emulsion) interfaces. The ability of biopolymers to prevent re-coalescence of the separated phases of the dispersion is attributed to the viscoelastic membrane that forms structural barriers (Dickinson, 2015). Many processed food systems are structured in the form of an emulsion, for example, milk, beverages and sauces. A thorough understanding of the interactions between the components of the emulsion system is necessary to ensure long term stability. Conventional oil-in-water emulsion is the most basic and widely found emulsion. (McClements, 2015).

Emulsions are stabilised by a combination of thermodynamic and kinetics factors. Oil-in-water emulsions have an innate nature to separate into cream and serum phases due to thermodynamic factors. Though thermodynamically unstable, food emulsions could be kinetically stable for years (McClements, 2015). Several approaches are employed to bring stability in an emulsion system such as increasing the

concentration of droplets, reducing the size of droplets, shrinking the density difference between the oil and aqueous phases and rheological modification of interface, continuous phase or the dispersed phase (Perrechil and Cunha, 2010).

Several food biopolymers such as gums, proteins, starches and phospholipids are known to have emulsifying capacity. Emulsifiers are substances that align themselves on the oil/water interface to reduce the surface tension, thus ensuring stability of emulsion. The potency of a hydrocolloid is dictated by several factors including: (1) molecular properties like concentration, branching, molar mass, charge, conformation, hydrophobicity and interactions (2) bulk physicochemical characteristics like gelling, thickening and light scattering (Chung et al., 2013).

Cationic emulsion droplets can be formed by sodium caseinate (NaCas) at pH below its isoelectric point. Sodium caseinate is a dairy ingredient prepared from skim milk using numerous unit operations including acid precipitation and resuspension of caseins, neutralization using sodium hydroxide and drying. The commercial product has 86% protein and 5% ash (Zhang and Zhong, 2013). NaCas is a soluble mixture (α_{s1} , α_{s2} , β and κ) of disordered lipophilic protein with a high tendency to align as casein submicelles that co-exist with free casein under equilibrium (Dickinson et al., 1997; Dickinson et al., 2003). On the other hand, gum Arabic forms anionic droplets throughout the pH employed for food system. Gum Arabic is obtained by natural exudation from *Acacia senegal* trees. It is a potent emulsifier due to its

amphiphilic nature, water solubility and ability to create solutions of low viscosity at high concentration in relation to similar hydrocolloid gum. Gum Arabic comprises of highly branched organization of simple sugars that are structurally bound to a small amount of protein (~ 2% w/w). Though small, the protein fraction confers the hydrocolloid its emulsion stabilising activity (McNamee et al., 1998).

Formation of emulsion with desired property depends upon a variety of interrelated factors including viscosity and composition of continuous and dispersed phases, the choice of surface-active material and emulsifying technique. Emulsification is achieved mostly by using energy intensive mechanical shearing operations such as colloid milling, high-speed mixing, microfluidization, high pressure homogenization and ultrasonication. The choice of emulsifying technique dictates the droplet size and its distribution (Purwanti et al., 2016). Ultrasonication is a convenient method to produce emulsions with small droplet size and lower polydispersity in view of the fact that it consumes less energy and surfactant (Hashtjin and Abbasi, 2015). On the contrary, the technique suffers certain disadvantages such as probable titanium contamination, complication in scaling up and acceleration of chemical degradative reactions (Quintanar-Guerrero et al., 1998).

In this study, two biopolymers of which one is a protein and the other is a polysaccharide were studied for their physical stability. The protein used here was sodium caseinate that formed positively charged droplets and the polysaccharide was gum Arabic that formed negatively charged droplets at pH 3. The response of the two emulsions to stress factors affecting the emulsions system such as variation in pH, temperature, salt concentration and freeze-thaw cycle are discussed.

2. Materials and methods

2.1. Materials

Gum Arabic (GA) powder, analytical grade sodium acetate anhydrous (99%), sodium chloride (99.9%), sodium hydroxide (NaOH) and acetic acid glacial (99.6%) were procured from HiMedia Laboratories Pvt. Ltd, Mumbai, India. Sodium caseinate (NaCas) was purchased from Sigma-Aldrich. Oil was obtained from Kamani Oil Industries Pvt. Ltd., Khopoli, India and used as such without further purification. All the solutions were prepared using Milli-Q water acquired from Millipore water purification system.

2.2. Solution preparation

Buffer solution was obtained by first preparing a 50 mM sodium acetate solution in Milli-Q water and consequently adjusting pH using acetic acid or 1 M NaOH. NaCas stock solution was prepared by dissolving 1.2% (w/v) sodium caseinate in acetate buffer (50mM, pH 3) for not less than 3 hours at room temperature using magnetic stirrer (Perrechil and Cunha, 2010). Gum Arabic stock solution was prepared by mixing 1.2% GA powder in buffer for not less than 3 hours to ensure complete hydration. Lower concentrations of emulsifier solutions were prepared by diluting with required quantity of buffer at the same pH and ionic strength.

2.3. Emulsion preparation

Primary emulsions of NaCas and GA were formed by homogenizing 1% (w/v) vegetable oil in buffer containing emulsifier of concentrations 0.2%, 0.4%, 0.6%, 0.8%, 1.0% and 1.2 %. Homogenization was achieved by first blending the oil and aqueous phases and subsequently subjecting to

ultrasonication (QSonica 700) at an amplitude of 50% for a duration of 5 minutes with a duty cycle of 0.5 (Noshad et al., 2016). The tip diameter of the probe was 12 mm. The pH of the emulsion formed was not adjusted after sonication.

2.4. Particle size measurement

The particle size of the emulsion samples is given by Z-Average size. It is the intensity weighted mean hydrodynamic size of a conglomeration of oil particles dispersed in aqueous phase. The emulsions were analyzed for size by Dynamic Light Scattering (DLS) using Zetasizer Nano, Malvern Instruments. The device uses the Stokes–Einstein Equation to correlate the size to Brownian movement of particles. Brownian movement of particles are measured and size is determined under the assumption that the larger particles have slower movement (Leong et al., 2009). The emulsions were diluted 100 times prior to particle size measurement.

2.5. ζ -potential

The velocity and direction of movement of droplets in a well-defined electric field determines the basis of its charge indicated by ζ -potential (Aoki et al., 2005). Particle electrophoresis instrument, Zetasizer Nano ZS, Malvern Instrument, UK was used to measure ζ -potential of diluted emulsion samples. The prepared emulsions were diluted 100 fold with buffer of the same pH and ionic strength in order to prevent multiple scattering effect (Noshad et al., 2016).

2.6. Emulsion stability measurement

Creaming index was used to study emulsion stability over time. 8 mL of the emulsion samples were stored in uniformly sized centrifuge tubes for a period of one week and the height of the separated serum layer from the bottom and the total emulsion height were recorded regularly. Creaming index was defined as the ratio of serum height to the emulsion height, expressed in percentage. Creaming index could be evaluated from the following formula, where HE represents total height of emulsions, HC represents the thickness of cream separated on top (Nikbakht Nasrabadi et al., 2016).

$$CI\% = \frac{(HE - HC)}{HE} \times 100$$

2.7. Emulsion environmental stresses

The effect of environmental stresses (pH, temperature, NaCl concentration and freeze thaw) on Z-Average size and ζ -potential of 1% vegetable oil-in-water primary emulsions of sodium caseinate and gum Arabic were compared.

2.7.1. pH:

Emulsions using NaCas and gum Arabic emulsifiers of varying pH (3, 5, 7 and 9) were prepared and their Z-Average size and ζ -potential were recorded and compared. The pH variations were brought about by preparing sodium acetate buffer of required pH and emulsifier and oil were added and homogenized subsequently.

2.7.2. Heat treatment:

5mL of prepared emulsion sample was drawn in a glass test tube of dimensions-outer diameter 15 mm and height 150 mm. These were heated in a water bath for temperatures 30, 50, 70 and 90 °C, over a time of 30 minutes. The emulsions, after heating, were brought to 30 °C (Ogawa et al., 2003) and sampled for analysis.

2.7.3. Freeze-thaw cycling:

To assess the freeze thaw stability of NaCas and GA emulsions, 10 g of the sample was taken in capped plastic tubes of internal diameter 10 mm and frozen at -20 ± 2 °C for 22 hours. The frozen sample was thawed for not less than 2 hours at 25 ± 2 °C (room temperature), thus completing a freeze-thaw cycle. The cycle was run twice and its effect on emulsion properties were analysed before and after each cycle (Ariyaprakai and Tananuwong, 2015).

2.7.4. Sodium chloride (NaCl) addition:

Food processing operations demand situations when ionic strength of medium elevates. Therefore, it is beneficial to form emulsion system that does not change the droplet size on adding salt (Li et al., 2016). Sodium caseinate and gum Arabic primary emulsions with varying salt concentration (0 to 500mM) were prepared by adding and dissolving powdered sodium chloride into prepared emulsions (Ogawa et al., 2003). The emulsions with added salt were sampled for ζ -potential and Z-Average size analysis.

3. Results and Discussion

3.1. Effect of emulsifier concentration on sodium caseinate and gum Arabic emulsion properties

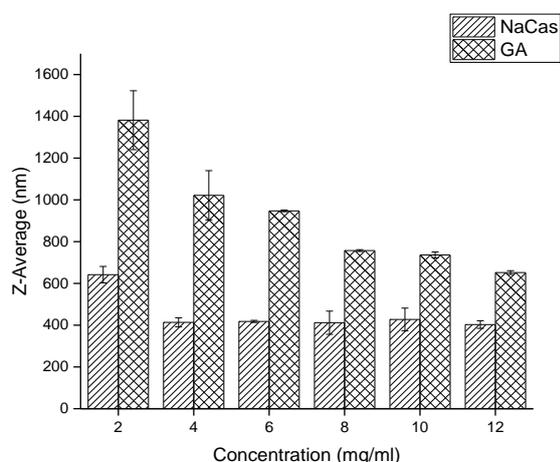


Figure 1: Z-Average size (nm) of sodium caseinate and gum Arabic stabilised oil-in-water emulsions, with the emulsifier concentration varied.

The quantity of emulsifier that is required to form a reasonably stable emulsion with desired properties is to be known from a practical viewpoint (van Aken, 2006). Sodium caseinate stabilised 10 mg/ml oil-in-water emulsions had a consistent Z-Average size around 400 nm for emulsifier concentrations 4, 6, 8, 10 and 12 mg/ml as observed from Figure 1. This observation is consistent with the results of experiments conducted by Sánchez and Patino (2005) at pH 7 and Srinivasan et al. (1999). However, at 2 mg/ml NaCas concentration, the emulsion size hiked up to 641.7 nm (polydispersity index, PDI<0.4) may be due to insufficient emulsifier to fully coat the oil surface that led the droplets to increase the size in order to reduce the surface area that requires protein coverage. Therefore, it can be inferred that a critical concentration of emulsifier is required to coat the oil droplets that gives minimum Z-average size. Further increase in concentration of NaCas emulsifier does not yield smaller droplets under the prevailing pH, ionic strength and emulsion forming condition but may form multilayers on the surface or remain in solution (Sánchez and Patino, 2005).

From Figure 1, it could be observed that as the concentration of gum Arabic is increased from 2 to 12 mg/mL, the droplet size gradually falls, indicating that the higher the concentration of gum Arabic that is available, the smaller the size of droplets. However, this observation does not hold true for indefinite increase in emulsifier concentration. Nakauma et al. (2008) noted that after a certain level, increase in gum Arabic concentration does not reduce the droplet size and present study has obtained similar results. When the comparison between NaCas (protein) and GA (polysaccharide) emulsions are made, we observe that more quantity of carbohydrate is required to cover the oil surface in order to impart stability against creaming and coagulation. Higher amount of gum Arabic is required as less hydrophobic residues are available in the polysaccharide than in protein (NaCas) molecules.

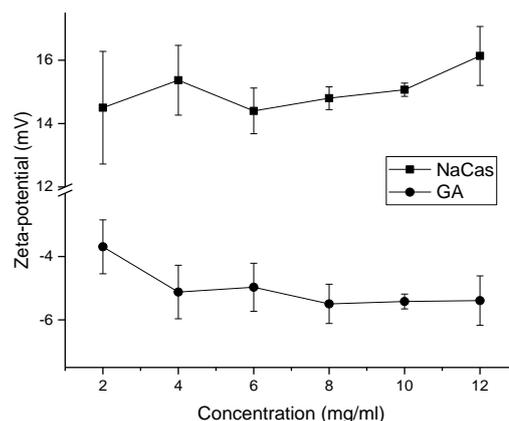
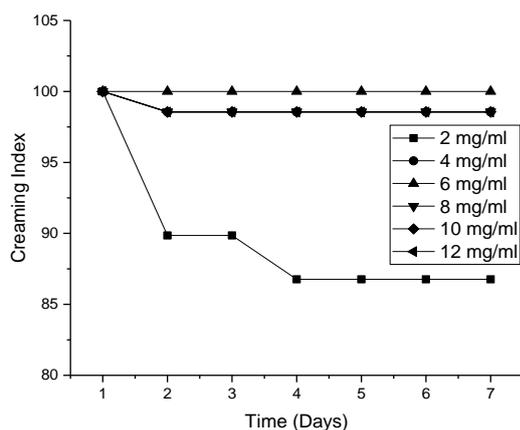


Figure 2: Zeta-potential of sodium caseinate and gum Arabic stabilised oil-in-water emulsions, with the emulsifier concentration varied at pH 3.

The stability of emulsion structure depends on the charge possessed by the oil droplets in the aqueous phase. When the electrostatic repulsion between the droplets are high, the emulsified oil tends to be dispersed in the aqueous phase more effectively over longer period of time. From Figure 2, it can be observed that NaCas at pH 3 forms cationic emulsion droplets while gum Arabic at the same pH produces anionic droplet. Irrespective of the nature of charge, the magnitude of charge plays a significant role in providing stability to emulsions. The greater the magnitude of positive or negative charge on the droplets, the better repulsion between them and subsequently have fair amount of stability. Sodium caseinate emulsions have ζ -potential +14.4 to +16.13 mV for emulsifier concentration of 6 mg/mL and 12 mg/mL respectively. This positive charge could give stability to emulsions by electrostatic stabilisation (Dickinson et al., 2003). In gum Arabic emulsion, charge varies in the order of -5 mV. In spite of having a low negative charge, the stability of gum Arabic emulsions are comparable to sodium caseinate emulsions due to steric stabilisation offered by the polysaccharide on the interface (Nakauma et al., 2008). In both the types of emulsions, no considerable variation in ζ -potential is observed in response to variation in concentration of emulsifier within the evaluated range (2-12 mg/mL).

(3a)



(3b)

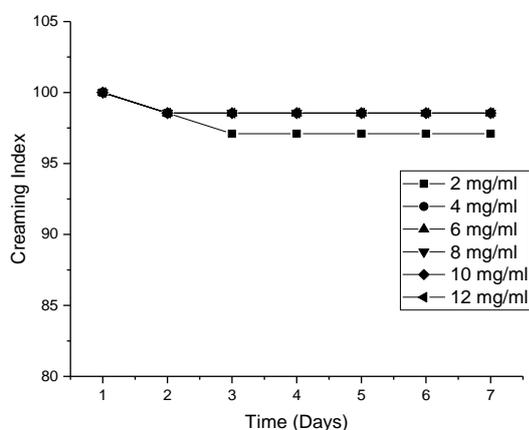


Figure 3: (a): Creaming index of oil-in-water emulsions stabilised by sodium caseinate. (b): Creaming index of oil-in-water emulsions stabilised by gum Arabic as emulsifier.

Sodium caseinate and gum arabic stabilised emulsions exhibited good stability to creaming over the period studied. Only the sodium caseinate emulsions with least concentration of emulsifier (2 mg/mL) destabilised by creaming as observed in Figure 3(a). This may be due to insufficient protein concentration. Meanwhile, we can observe that gum arabic coated emulsions at the same concentration are more stable than sodium caseinate emulsions. This observation contradicts the theory that more amount of carbohydrate is required to stabilise oil droplets than protein. Nevertheless, no other concentration variation of emulsifier studied had creaming index variation of significance.

Sodium caseinate and gum Arabic stabilised oil-in-water emulsions at an oil concentration of 10 mg/ml and emulsifier concentration of 10 mg/ml were used for studying environmental stress factors like change in pH, NaCl concentration, freeze-thaw cycling and temperature. Therefore, all further references to sodium caseinate stabilised emulsions and gum Arabic emulsions in this article refer to an emulsion prepared with 10 mg/ml oil and 10 mg/ml emulsifier.

3.2. Effect of pH on sodium caseinate and gum Arabic emulsion properties

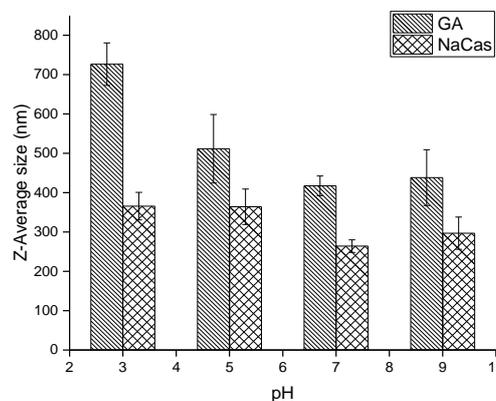


Figure 4: Effect of variation of pH on gum Arabic and sodium caseinate stabilised oil-in-water emulsions on Z-Average size of droplets.

Emulsions prepared using protein and then subjected to pH variations coagulated as the pH values had to go through the isoelectric point (pI) of sodium caseinate (Surh et al., 2006) which is around 4.6 (Belyakova et al., 2003). Therefore, buffers of various pH (3, 5, 7 and 9) were prepared and emulsions were formed separately using sodium caseinate emulsifier and oil. The same protocol was followed to evaluate the effect of variation of pH of gum Arabic stabilised emulsions in an attempt to maintain uniform conditions between the emulsions compared.

The protein and polysaccharide emulsions with 10 mg/ml oil concentration and 10 mg/ml emulsifier show a varied droplet size due to pH change. From Figure 4, it is seen that the protein stabilised oil droplets could form smaller size than the carbohydrate stabilised droplets. Proteins in general are more effective at coating the lipid droplet surface due to their amphiphilic nature. Gum Arabic emulsions exhibit sizes of 0.4 - 0.5 μm at all studied pH except 3. This may be due to insufficient charge to repel the surrounding oil droplets, leading to large sized oil droplets. Sodium caseinate stabilised emulsions exhibited slightly higher droplet size (Z-Average size) at pH 3 and 5 than the sizes recorded at pH 7 and 9. The close proximity of pH 5 and 3 to isoelectric point of the emulsifier is held responsible for probable coalescence and slightly higher particle size (Surh et al., 2006).

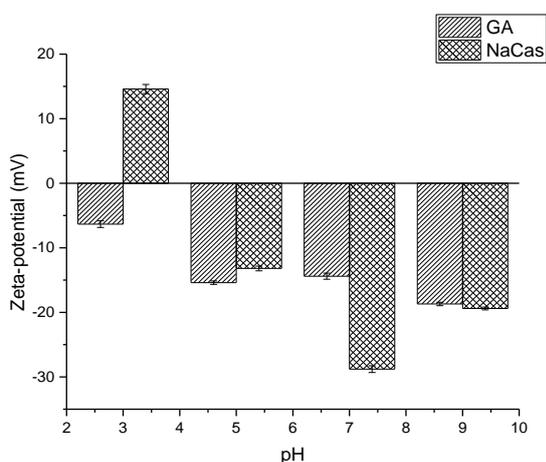


Figure 5: Effect of variation of pH on gum arabic and sodium caseinate stabilised oil-in-water emulsions on zeta-potential of droplets.

The effect of pH on the ζ -potential of NaCas and GA stabilised emulsions vary significantly as one could view NaCas and GA as two different types of biopolymers- one is a protein and the other is a polysaccharide. Polysaccharides exhibit the same sign charge throughout the pH range, though the magnitude of the charge of the emulsions they stabilise varies. From Figure 5, it is evident that gum Arabic stabilised primary emulsions exhibited negative charge throughout the tested pH range (3-9). The overall negative charge of GA emulsions may be attributed to the presence of $-\text{COO}^-$ group on the acidic polysaccharide. Also the magnitude of the charge on gum Arabic stabilised emulsion remains fairly constant at pH 5, 7 and 9. Only at a low pH of 3, the ζ -potential takes considerably reduced value of -6.33 mV. The minor fraction of proteins present in gum Arabic, at significantly low pH could exhibit cationic behavior and may have contributed to reduced ζ -potential at pH 3 (Chanamai and McClements, 2002). As widely accepted, gum Arabic is a natural conjugate between protein and polysaccharide, with polysaccharide portion making up the major fraction and protein fraction a meager 1.7% (Matsumura et al., 2003). However, this study has been conducted well above the isoelectric point of gum Arabic which is predicted as 1.8 (Jayme et al., 1999).

Stable emulsions of sodium caseinate were formed at all evaluated pH- 3, 5, 7 and 9. From Figure 5, it could be seen that at pH 3, sodium caseinate emulsions have a positive ζ -potential of +14.6 mV. NaCas emulsions at other pH values of 5, 7 and 9 show negative ζ -potential values. Proteins are zwitterionic biomolecules and their overall charge can be decided by the ions present in the surrounding solution. Therefore, at pH 3 positive charge exists on protein coated emulsions. This charge is neutralized at isoelectric pH ($pI \approx 4.6$) and protein in solution precipitate. When emulsion pH is increased from pH 3 to pH 5, precipitation occurs as pH of aqueous phase nears pI . At pH fairly above pI , proteins solubilize again with a reversed charge. Therefore, we observe negative ζ -potential for emulsions at pH 5 and above. Except around pI of protein, the emulsified droplets have sufficient repulsive interaction among them to keep them in dispersed state. This repulsive interaction collapse only around isoelectric point, resulting in droplet aggregation (Perrechil and Cunha, 2010).

3.3. Effect of salt addition on sodium caseinate and gum Arabic emulsion properties

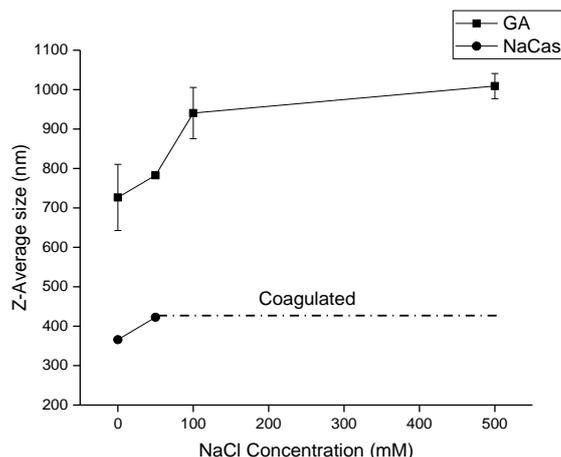


Figure 6: Effect of added sodium chloride on gum Arabic and sodium caseinate stabilised oil-in-water emulsions on Z-Average size of droplets.

The effect of salt concentration on the stability of emulsions is a crucial factor in order to use the emulsions for practical purposes. It is evident from figure 6 that the gum Arabic emulsions could withstand variations in salt concentration and exist in emulsified state when salt up to a concentration of 500mM is added. Nakamura et al. (2004) indicated that gum Arabic emulsions are stabilised predominantly by steric stabilisation and electrical effects imparted by minerals present in the aqueous phase have little effect on overall emulsion structure. This is true due to the fact that emulsions are stable to flocculation. However, we can observe that gum Arabic the droplet size has significantly increased with rise in NaCl concentration through 50, 100 and 500 mM, indicating that electrostatic forces imparted by small protein fraction also play their roles.

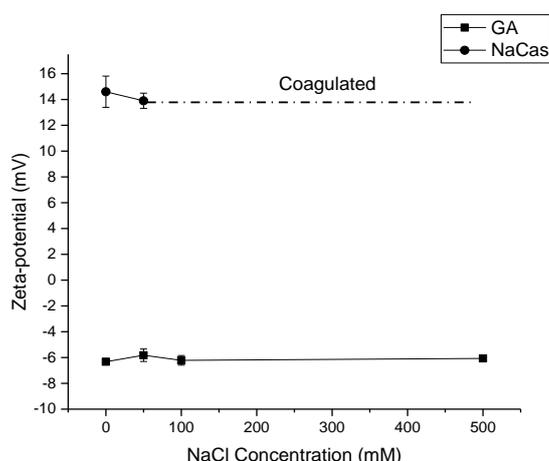


Figure 7: Effect of added sodium chloride on gum Arabic and sodium caseinate stabilised oil-in-water emulsions on zeta-potential of droplets.

The increase in salt concentration of 1 % gum Arabic stabilised oil-in-water emulsions show no considerable change in ζ -potential when the salt concentration is varied (Figure 7). The ζ -potential dropped only from -6.33 to -6.07 on varying the salt amount from 0 mM to 500 mM. Addition of salt would have reduced surface charge due to compression of the electrical double layer (Jayme et al., 1999). However, the reduction in ζ -potential is not prominent due to the highly acidic pH used in the study.

3.4. Effect of freeze-thaw cycling on sodium caseinate and gum Arabic emulsion properties

Table 1: Z-Average size and zeta-potential of emulsions stabilised by sodium caseinate and gum Arabic subjected to two freeze-thaw cycles.

Emulsion type	Sodium caseinate emulsions		Gum Arabic emulsions	
Measured property	Z-Average size	ζ-potential	Z-Average size	ζ-potential
Fresh emulsion	427.27 ± 54	15.07 ± 0.21	735.9 ± 14	-5.42 ± 0.23
Cycle 1	961.2 ± 89	13.4 ± 0.57	868.6 ± 59	-6.17 ± 0.26
Cycle 2	Coagulated	Coagulated	1119 ± 67	-6.09 ± 1.3

The emulsions prepared from protein and polysaccharide as emulsifiers in our study showed varied responses to freeze-thaw treatment. Gum Arabic stabilised emulsions showed significant increase in Z-Average size as the number of freeze-thaw cycle increased (Table 1). In addition, the polysaccharide emulsions maintained their physical integrity and did not coagulate on subjecting to two freeze-thaw cycles. On the other hand, sodium caseinate stabilised emulsions had a tremendous size increase in the first cycle and coagulated after the second freeze-thaw cycle. The emulsion destabilisation may have occurred because of the following physicochemical changes during freezing: (1) the formation of ice crystals in the aqueous phase, bringing the oil droplets close together, (2) the formation of ice crystals may have led to a situation where the emulsifier molecules are devoid of water and are not sufficiently hydrated, (3) the concentration of ions in the available aqueous phase after water crystallisation would have been considerably high, thus screening the electrostatic repulsive interactions between droplets, (4) the ice crystal could rupture the oil globule membrane, thus collapsing the structure of emulsion, (5) the fat crystals could also penetrate the oil globule membrane leading to partial coalescence on freezing and complete coalescence on thawing (McClements, 2004; O'Regan and Mulvihill, 2010)

3.5. Effect of heating on sodium caseinate and gum Arabic emulsion properties

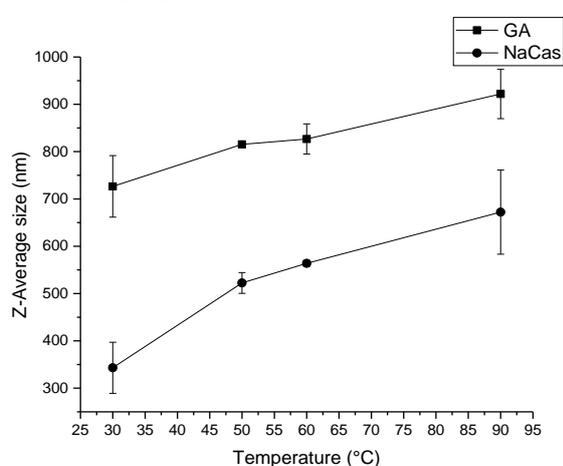


Figure 8: Effect of temperature on gum Arabic and sodium caseinate stabilised oil-in-water emulsions on Z-Average size of droplets.

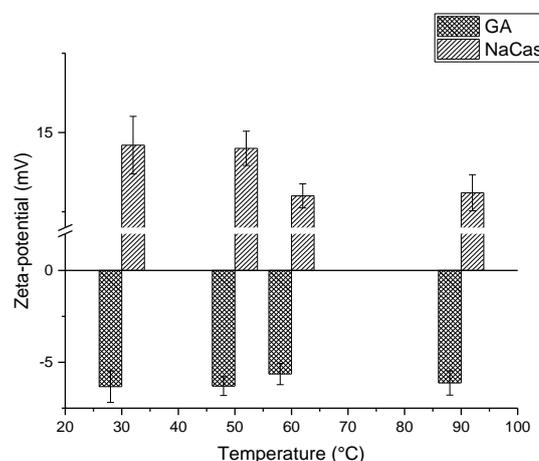


Figure 9: Effect of temperature on gum Arabic and sodium caseinate stabilised oil-in-water emulsions on zeta-potential of droplets.

On subjecting sodium caseinate and gum Arabic emulsions to varying temperatures of 30, 50, 60 and 90 °C, the Z-Average size of the droplets showed a slightly increasing trend (Figure 8). The droplets size of sodium caseinate emulsions at 30 °C was 343.1 ± 54 nm which increased to 672.1 ± 89 nm on heating to 90 °C. Our result shows that heating of sodium caseinate emulsions increases their droplet size. This result is consistent with the studies of Srinivasan et al. (2002) which indicated that larger diameters of NaCas stabilised oil droplets were obtained on heating than unheated control emulsions at a given protein concentration. A review on heat treatment of milk protein stabilised emulsions by Raikos (2010) suggested that non-adsorbed proteins present in the serum interacted with the adsorbed proteins of interface causing fat globule aggregation resulting in increased particle size.

The increase in Z-Average size of gum Arabic stabilised oil-in-water emulsions on heating is less prominent than sodium caseinate stabilised emulsions. On increasing the temperature of gum Arabic emulsions from 30 °C to 90 °C the droplet size varied from 726.5 ± 65 nm to 921.8 ± 52 nm respectively. On comparison with the protein sodium caseinate, the lesser extent of droplet size increase of the polysaccharide gum Arabic on raising temperature could be due to the fact that unlike protein, polysaccharides do not unfold to expose non-polar groups (Charoen et al., 2011). From figure 9, it can be inferred that there was no influence of heat on the ζ-potential of evaluated emulsions of gum Arabic. This was consistent with the results of Charoen et al. (2011). No significant change in ζ-potential was observed in emulsions stabilised with either polysaccharide or protein on heating to temperatures up to 90 °C.

4. CONCLUSION

In this study, the comparison of the properties of sodium caseinate stabilised emulsions and gum Arabic stabilised emulsions reveal in a concise way that protein stabilised emulsions are more vulnerable to environmental stresses than carbohydrate stabilised emulsions. Gum Arabic has proved to be effective in providing steric protection against the degradative factors of the aqueous phase. Though sodium caseinate formed smaller emulsion droplets with fairly large

charge, it was susceptible to coagulation on subjecting to freeze-thaw and addition of sodium chloride salt. Further, the polysaccharide had provided an improved stability to stress factors such as varying pH, salt concentration and freeze-thaw cycling. Though the proteins are labile to heat damage, the heat stability of both gum Arabic and sodium caseinate were comparable. Therefore, both proteins and polysaccharides can be used to prepare emulsions but the choice of emulsifier has to be made depending on the conditions they may be subjected during processing, transit and storage.

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