

Nano-emulsion system consisting of non-ionic surfactant, silicone, and polyol



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ABSTRACT

This study aimed to evaluate the optimum formulation of a niosomal nano-emulsion system consisting of silicone oil, non-ionic surfactant, and polyol. The nano-emulsions were prepared through a two-step homogenization procedure by a homogenizer and microfluidizer. The experiments were carried out by changing the composition ratio of dimethicone (DC200/100cs), polyglyceryl-2 dioleate, and glycerin, respectively. The variation of dimethicone resulted in showing a tendency for the content and particle size to be proportional. The variation of polyglyceryl-2 dioleate and the glycerin variation resulted in showing a similar tendency of the content and particle size to be inversely proportional. In zeta potential measurement, all nano-emulsions marked absolute value over around 30 mV, which is considered to be stable, while no significant correlation was observed with the variation. Based on these verifications, the author proposes the optimal conditions for preparing niosomal nano-emulsions.

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1. Introduction

Nano-emulsions, also referred to as mini-emulsions, are fine oil-in-water dispersions, having droplets covering the size range of 50–500nm (Mahdi Jafari et al., 2006; Halnor et al., 2018). Unlike microemulsions, which are also transparent or translucent and thermodynamically stable, nano-emulsions are only kinetically stable (Fernandez et al., 2004; Kumar et al., 2018). However, the long-term physical stability of nano-emulsions with no apparent flocculation or coalescence makes them unique, and they are sometimes referred to as “approaching thermodynamic stability”. Nano-emulsions exhibit better penetration efficacy of the ingredients due to the large surface area and low surface tension of the whole emulsion system, thus requiring only 3–10% of surfactants during preparation (Patel and Joshi, 2012). Moreover, a microfluidizer, a machine that makes nano-emulsions, is efficient in producing higher quality nano-emulsion formulations to optimize the stable

formulation with significant oil content by creating a Niosomes are one of the drug delivery carriers and were first published in the 70s. The structure of niosomes is a bilayer, and it consists of non-ionic surfactants such as polyglyceryl fatty acid and polyethylene glycol (PEG)-ylated surfactants, unlike liposomes (Kazi et al., 2010). The bilayer of liposomes is composed of phospholipids, which have safety and biocompatibility. However, phospholipid liposomes are expensive from a commercialization point of view and are easily broken down, whereas non-ionic surfactant niosomes have higher microbiological and chemical stabilities and are cheap (Gupta et al., 1996; Imran et al., 2016; Bartelds et al., 2018).

PEGs and PEG derivatives may include residual 1,4-dioxane produced during the ethoxylation process, so it may play a role in causing cancer (Alsohaimi et al., 2020). Furthermore, although PEGylated surfactants are nonionic surfactants, safety concerns have been reported when used for an extended period (Rang, 2019). Thus, there is a tendency to use surfactants that do not contain PEG.

In this study, in order to establish the optimal formulation of a niosomal nano-emulsion system that maintains stability even with high oil content, three variations of the content of silicone oil, non-ionic surfactant, and polyol were investigated and evaluated by particle size and zeta potential.

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2. Materials and methods

2.1. Materials

Dimethicone (DC200/100cs) was purchased from KCC silicone Co. (Korea). Glycerin was purchased from Ecogreen Oleochemicals (Indonesia). Polyglycerine-2 dioleate was obtained from Biobeautech (Korea). 1,2-hexanediol was purchased from Twin Chemicals, Inc. (Korea).

2.2. Preparation of nano-emulsions

Nano-emulsions were prepared using aqueous solutions composed of glycerin, polyglyceryl-2 dioleate, deionized water, and 1,2-hexanediol as the continuous phase and dimethicone as the dispersed

phase. In order to obtain fine droplets of nano-emulsions, a two-step homogenization procedure was conducted. The pre-emulsions were made with a homogenizer (CORETECH, Korea) at 3,000rpm for 30 min after heating each phase to 80°C. Thereafter, the pre-emulsions were further emulsified at 1200 bar three times using a microfluidizer (Micronox, Korea). In order to investigate the effects of dimethicone, polyglyceryl-2 dioleate, and glycerin on the physical properties of droplets, nano-emulsions were prepared by varying concentrations of these factors as summarized in Table 1: (i) the content of dimethicone was set from 15 to 33% (w/w). (ii) the content of polyglyceryl-2 dioleate was set from 1 to 7% (w/w). (iii) the content of glycerine was set from 10 to 68% (w/w). The prepared nano-emulsions were sampled, and their particle size and zeta-potential were determined.

Table 1: The general formula of nano-emulsions

Phase	Component	Content (%)
Dispersed	Glycerin	10-68
	Polyglyceryl-2 dioleate	1-7
	Deionized water	q.s. to 100
	1,2-hexanediol	2
Continuous	Dimethicone	15-33

2.3. Analysis of particle size and zeta-potential

The particle size and zeta-potential potential of nano-emulsions were measured by dynamic light scattering using Nanotracs Flex particle size analyzer (Microtrac, USA) and Stabino® particle charge mapping system (Particle Metrix, USA). All samples were diluted approximately 100-fold with distilled water prior to each measurement to avoid multiple light scattering effects. All measurements were taken in triplicate and described by the mean.

3. Results and discussion

3.1. The droplet properties of nano-emulsions depending on dimethicone content variation

In this study, the optimal formulation of nano-emulsion was investigated by particle size and zeta potential, which are important factors for evaluating the stability of nanoparticles. Zeta potential is the electrokinetic potential of particles, and the absolute values greater than 30mV are deemed to be strongly charged and stable (Honary and Zahir, 2013).

In this experiment, the droplet properties of the nano-emulsions according to the concentration of dimethicone were investigated. The change in particle size of nano-emulsions with increasing dimethicone content is shown in Fig. 1A. The particle size was observed to increase dependently as the dimethicone content increased and rapidly increased to more than 100nm at the dimethicone content of 30% or more. The reason is that the concentration of the dispersed phase increases while the concentration of the emulsifier is constant so that particles are formed in a direction in which the total interfacial area decreases (Knapik et al., 2010; Jo and

Kwon, 2014). The change in zeta potential is shown in Fig. 1B. The zeta-potential was measured to be around 60mV, but it tended to decrease at the dimethicone content of 30% or more gradually. Based on these results, the content of dimethicone was set to 25%.

3.2. The droplet properties of nano-emulsions depending on polyglyceryl-2 dioleate content variation

We focused on stabilizing the emulsion by setting a dimethicone content of 25%. To confirm the effects of polyglyceryl-2 dioleate on the droplet properties of nano-emulsions, they were investigated by varying the concentration of polyglyceryl-2 dioleate. Referring to Fig. 2A, as the content of polyglyceryl-2 dioleate increased, the particle size of the nano-emulsions showed a tendency to decrease. In all cases where the content of polyglyceryl-2 dioleate was 5% or more, particles of less than 100nm were formed, and no further decrease in particle size was observed. It is known that more emulsifiers can cover a larger interface area and thus make the particle size smaller. The phenomenon that the particle size does not decrease anymore is because the concentration of the emulsifier required to achieve the minimum particle size has already been reached (Knapik et al., 2010; Jo and Kwon, 2014). Referring to Fig. 2B, within a polyglyceryl-2 dioleate content range of 1-4%, the zeta-potential was relatively consistent, around 50mV, and at a content of 5%, the value increased to 61 mV, whereas at content above 5%, the value again gradually decreased. In summary, an optimal polyglyceryl-2 dioleate content to emulsify 25% of dimethicone is thought to be 5%.

3.3. The droplet properties of nano-emulsions depending on glycerin content variation

This study then investigated the droplet properties of nano-emulsions by varying the concentration of glycerin by setting a dimethicone content of 25% and polyglyceryl-2 dioleate content of 5%. Fig. 3A shows the effects of glycerin on the particle size of nano-emulsions. As the content of glycerin increased, the particle size of the nano-emulsions tended to decrease, but at the content of 68%, the particle size rather increased. This is because glycerin has the same structure as the hydrophilic group of polyglyceryl-2 dioleate so it is dissolved in the hydrophilic chain of the particle, and

the affinity of the emulsifier and water is decreased by glycerin, resulting in increased hydrophobicity of the interface area. However, when the concentration of glycerin is supersaturated, the emulsifier is easily dispersed in the aqueous phase, and the proportion of the emulsifier forming particles decreases (Sagitani et al., 1984). Fig. 3B shows the effects of glycerin on the zeta-potential. Within a glycerin content range of 10–50%, the zeta-potential was relatively consistent, around 30mV, and at a content of 60%, the value peaked at 61mV, whereas at a content of 68%, the value again decreased. Taken together, it was determined that the optimal glycerin content was 60% under the conditions of combining 25% dimethicone and 5% polyglyceryl-2 dioleate.

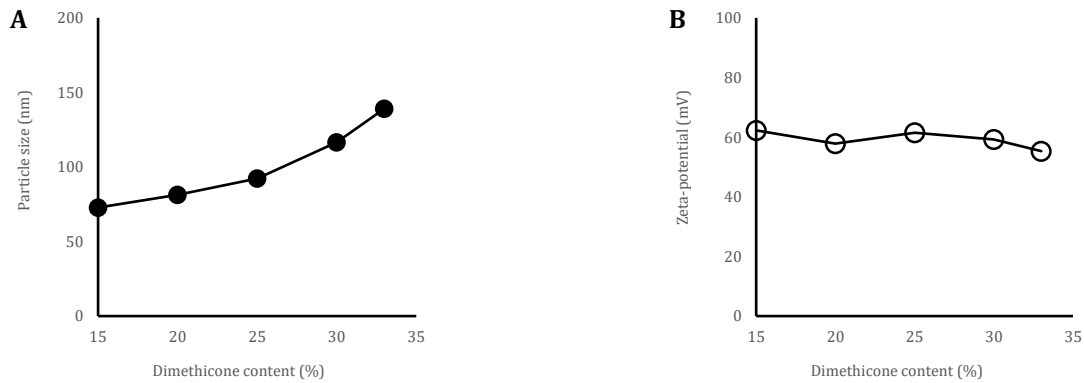


Fig. 1: (A) Particle size depending on dimethicone content variation. (B) Zeta-potential depending on dimethicone content variation

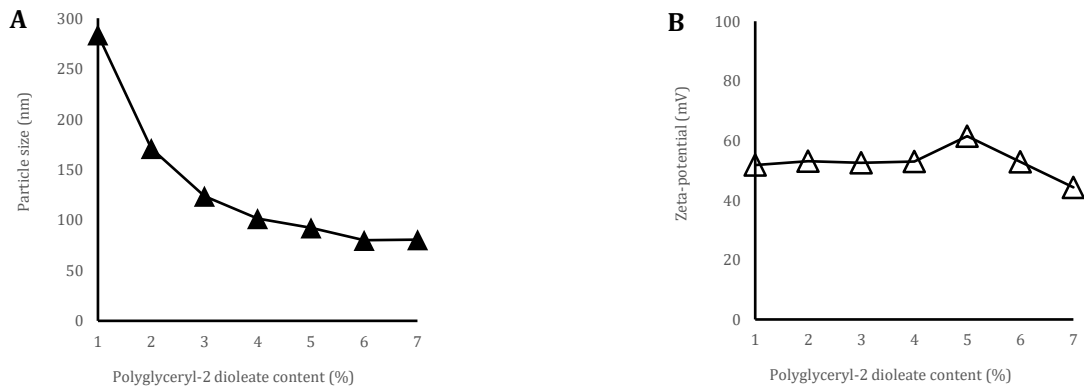


Fig. 2: (A) Particle size depending on polyglyceryl-2 dioleate content variation. (B) Zeta-potential depending on polyglyceryl-2 dioleate content variation

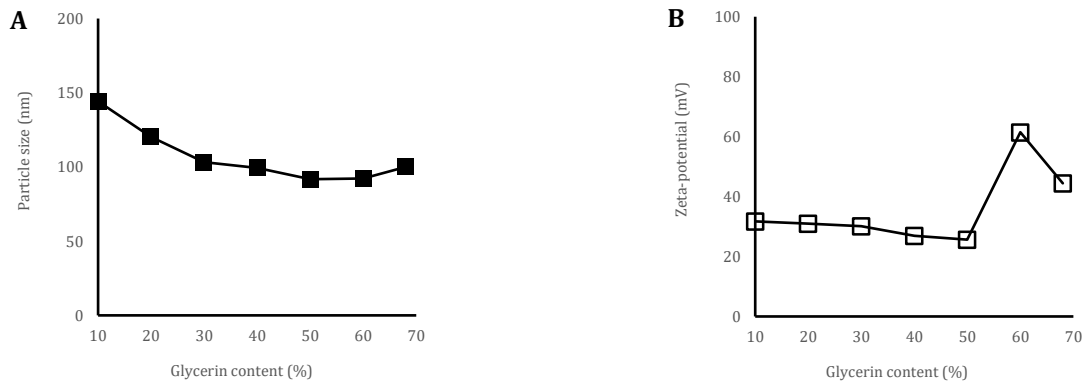


Fig. 3: (A) Particle size depending on glycerin content variation. (B) Zeta-potential depending on glycerin content variation

4. Conclusion

This study shows that it is possible to prepare stable nano-emulsions containing 25% of dimethicone via polyglyceryl-2 dioleate and glycerin. To this end, it is important to combine dimethicone, polyglyceryl-2 dioleate, and glycerin in an optimal concentration ratio. This is because the droplet properties of nano-emulsions were greatly affected by the concentration of these factors. Resultantly, the nano-emulsions were optimized with the composition of 25% of dimethicone, 5% of polyglyceryl-2 dioleate, and 60% of glycerin, remaining highly stable even with a large amount of 25% oil. The rationale for this study was to describe commercially available conditions and suggest background data for further research.

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Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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