

Comparison of Different Types of Dispersing Agent on Zeta Potential and Particle Size Analysis of Sago Starch Dispersion as Bio-filler for Natural Rubber Latex Films

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ABSTRACT. The incorporation of sago starch into the latex compound will act as bio-filler to accelerate the degradation process of natural rubber (NR) latex based product including latex gloves. However, well-dispersed of sago starch in NR latex compound is necessary in order to have a better biodegradation of the latex products. In this study, sago starch dispersion was prepared with different types (anchoid and nonyl phenol) and loading percentages (4, 5 and 6 wt.%) of dispersing agent. Results of sago starch dispersion with 5 wt.% loading of anchoid as dispersing agent shown highest zeta potential value (-34.8 mV) and the smallest particle size (531.2 nm). The addition of the anchoid sago starch dispersion into NR latex compound also produces better NR latex films mechanical properties (tensile strength: 21.72 MPa; elongation at break: 1269.5%; tear strength: 63.76 MPa) compared to NR latex films with nonyl-phenol sago starch dispersion. These results support the potential of anchoid as dispersing agent for NR latex bio-filler.

Keywords: *Dispersing agent, Zeta potential, Particle size, Sago starch, Natural rubber latex;*

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1. INTRODUCTION

Disposable products such as natural rubber (NR) latex gloves is one of the world highest consumable products as it is designed for disposal after single use [1]. This scenario caused the volume of rubber solid waste disposal increase each year. Furthermore, the disposed gloves normally take few years to degrade in the natural environment due to the presence of inorganic materials such as antioxidants and sulphur crosslinks that make NR latex films resistant to microbial infections [2]. Thus, the combination of rubber system with bio-materials is a feasible option. Misman and Azura [3] had proven that the incorporation of sago starch as biodegradable natural filler in NR latex films was able to accelerate the degradation process of NR latex films. The degradation of NR latex films occurred due to the breakdown of glucosidic linkages of amylose and amylopectin by means of enzymatic hydrolysis by microorganism which consumed the sago starch as source of nutrients [2].

In order to have a better and accelerated biodegradation, well-dispersed of sago starch in NR latex is a necessity. This is achieved by preparing the sago starch bio-filler in aqueous form which mixed with dispersing agent, stabiliser, and water. However, there are different types of dispersing agent (or surfactant) with a different stabilisation mechanism can be used to prepare the dispersion. According to Moore and Spencer [4], the most common physical property used in classifying the surfactants is ionic: anionic, cationic, non-ionic and amphoteric/zwitterionic. Usually, in the NR processing, surfactants that are either anionic or non-ionic in nature are added to improve the stability [5]. Due to their amphiphilic nature [6], the hydrophilic part of the surfactant molecule will tend to interact with the aqueous media, whereas the hydrophobic part will adsorb itself onto the rubber particle, therefore enhancing the stability of the particles against

flocculation and coagulation. The general mechanism of interaction of anionic and non-ionic surfactant with the aqueous phase as shown in Fig. 1.

Considering the above factor, this study will be focusing on the effect of using anionic (anchoid) and non-ionic (nonyl phenol) surfactants as well as their loading percentages on the sago starch dispersion; prepared by using ball milling. Ball milling is selected due to the capability of this technique to reduce crystalline region and modify the particle size of filler [7]. The stability of the dispersion will be characterised by zeta potential and particle size analysis. Besides, the mechanical properties of both anchoid and nonyl phenol-loaded NR latex films will also be determined and compared.

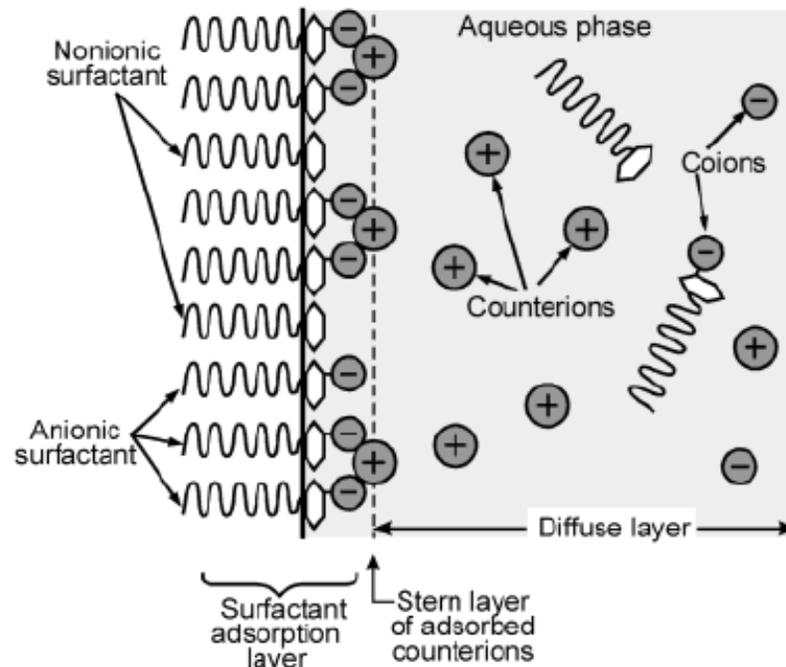


Fig.1 Interaction of anionic and non-ionic surfactant with the aqueous phase. The Stern layer consists of adsorbed (bound) counterions, while the diffuse layer contains free ions involved in Brownian motion [8]

2. MATERIALS AND METHODS

NR latex was purchased from Zarm Scientific and Supplies Sdn. Bhd. with the initial properties of dry rubber content (DRC) of 60.00%, total solid content (TSC) of 61.52%, mechanical stability time (MST) of 970 s, and volatile fatty acid number (VFA no.) not exceeding 0.2. Meanwhile, sago starch was obtained from Sago Link Sdn. Bhd. Other compounding ingredients such as diethyldithiocarbamate (ZDEC), zinc oxide (ZnO), potassium oleate, potassium hydroxide (KOH), antioxidant and sulphur were obtained from Bayer (Malaysia) Sdn. Bhd.

2.1 Preparation of sago starch dispersion and NR latex films. The dispersed sago starch was prepared by mixing sago starch with different types (anchoid and nonyl phenol) and loading percentages (4, 5 and 6 wt.%) of dispersing agent, stabiliser and distilled water. The mixture was then stirred using a mechanical stirrer (Wise Stir HS-120A, Korea) and transferred into the ball mill jar and left mixing at 35 rpm for 18 hours. The sago starch dispersion was then used as filler to NR latex compound as per listed in Table 1 in order to produce biodegradable NR latex films. Zeta potential and particle size analysis: The particle size distributions of NR latex and sago starch dispersions were measured using Malvern™ (Worcestershire, UK). The sample used was 1 g of NR latex or sago starch dispersion which was pre-dispersed in 10 ml of deionised water.

Table 1 Formulation for sago starch filled NR latex compound

Ingredients	Dry weight (pphr)
NR latex (60 wt.%)	100.00
Sago starch dispersion (25wt.%) ***	10.00
KOH (10 wt.%)	0.30
Potassium oleate (20 wt.%)	0.25
Antioxidant (50 wt.%)	0.50
ZnO (50 wt.%)	0.25
ZDEC (50 wt.%)	0.75
Sulphur (50 wt.%)	0.50

*** Sago starch dispersion prepared with anchoid and nonyl phenol

2.2 Films mechanical properties tests. Tensile and tear tests were carried out according to ASTM D412 and ASTM D624 respectively by using Instron Machine (Model 3366, USA) with the crosshead speed of 500 mm/min. The films were cut into dumbbell and crescent shapes (die type C). The results are based from the average of 5 samples.

3. RESULTS AND DISCUSSION

3.1 Zeta potential and particle size analysis. Zeta potential was the key indicator of stability of the dispersion. It was a measure of the magnitude of the electrostatic or charge repulsion/attraction between sago starch particles. For a stable dispersion, the value of zeta potential should be above +30 mV or below -30 mV. If the value is within -30 mV to +30 mV, the dispersion is considered as not stable [9]. Zeta potential and particle size analysis of sago starch dispersion for each type of dispersing agents are shown in Fig. 2.

For the sago starch dispersion containing anchoid dispersing agent, loading of 4 wt.% showed results of zeta potential -15.2 mV which indicating as not stable dispersion, while for 5 and 6 wt.% loading, the zeta potential value showed -34.8 and -31.5 mV respectively. Although both 5 and 6 wt.% loading dispersing agents showed a stable dispersion, 5 wt.% loading anchoid dispersion was more stable than 6 wt.% loading dispersion based on highest value obtained.

Besides, the particle size of each dispersion was 595.8, 531.2 and 714.9 nm for 4, 5 and 6 wt.% loading anchoid respectively. For 5 wt.% anchoid loading, the dispersion has the smallest particle size. This size of particle was the nearest to the size of NR latex, which was 482 nm, where more homogenous compound can be achieved. Thus, 5 wt.% anchoid loading can be concluded to be the optimum loading of dispersing agent in sago starch dispersion. While for 4 wt.% loading, the lack of amount of dispersing agent gave lesser stabilizing effect for the sago dispersion. Extra dispersing agent in 6 wt.% loading dispersion resulted in reversing effect due to the agglomeration of particles.

For nonyl phenol, the similar percentages of dispersing agent are used which were 4 to 6 wt.%. The zeta potential for all these three dispersion falls within the range of non-stable dispersion which were -11.00, -7.84 and -7.92 mV for 4, 5 and 6 wt.% loading respectively. Meanwhile, the particle size of dispersion obtained were 356.0, 795.7 and 3560.0 nm for 4, 5 and 6 wt.% loading, respectively. The particle size of dispersion with 6wt% surfactant loading was very big compared to 4 and 5 wt.% loading dispersion. This phenomenon can be said as flocculation. In the similar volume of dispersion, too much surfactant might cause the collision between particles and thus lead to particle flocculation. The particles flocculation acts as a stress concentration point reduced the tensile strength of the NR latex films [10].

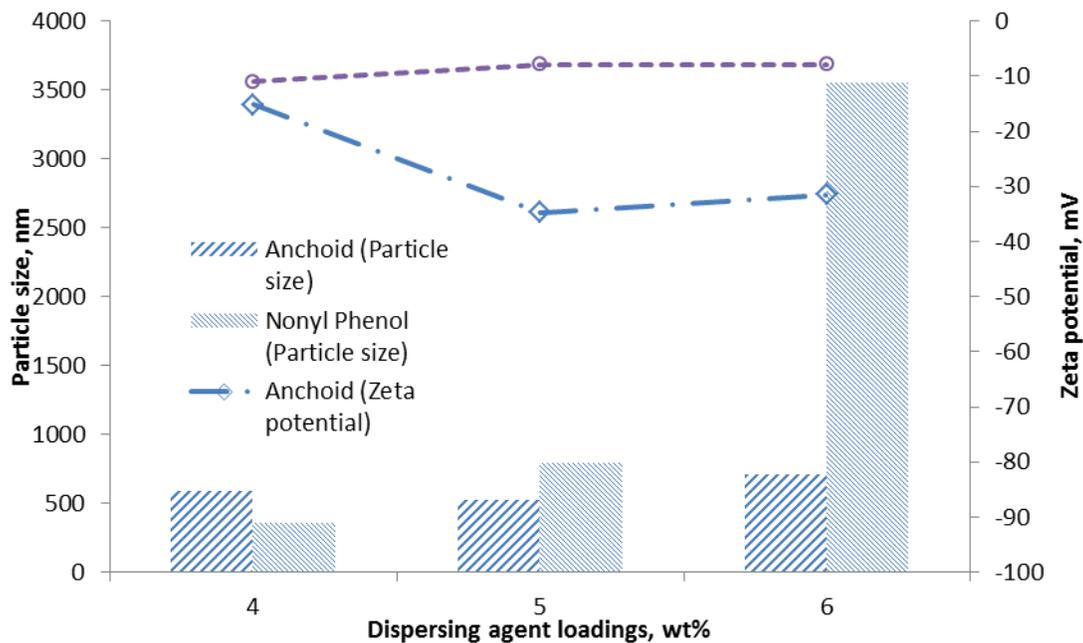


Fig. 2 Zeta potential and particle size analysis of sago starch dispersion with different loading percentages of dispersing agents

Nonyl phenol was non-ionic surfactant which, according to Shegokar and Müller [11], the hydrophobic parts of the dispersing agent adsorb on the particle surfaces as the “anchor chain”, while the hydrophilic parts pull out from the surface to aqueous medium, creating a stabilizing layer. Zirak and Pazeshki [12] also reported that the addition of non-ionic surfactant caused increasing of particle size indicating the coalescence of fillers. This is due to the weak steric repulsion forces exerted on each particle surface caused a low frequency of collisions between the particles. During collision, particles are moving actively and thus prevent the particles to coalesce and combine with each other.

3.2 Mechanical properties. Table 2 showed the comparison of mechanical properties between anchoid-loaded and nonyl phenol-loaded NR latex films 5 wt.% loading of dispersing agent. Based on Table 2, both types of NR latex films showed quite similar values of tensile modulus. However, for tensile strength, elongation at break (EB) and tear strength, the anchoid-loaded NR latex films always possessed greater value than nonyl phenol-loaded NR latex films. The tensile strength, EB and tear strength of NR latex films at 5 wt.% loading of anchoid were 21.72 MPa, 1269.5% and 63.76 MPa respectively. Meanwhile, with the same loading percentage, nonyl phenol-loaded NR latex films showed the tensile strength, EB and tear strength were respectively 19.85 MPa, 1248.0% and 51.87 MPa.

Table 2 Comparison of mechanical properties between NR latex films with different dispersing agents

Properties	Anchoid	Nonyl phenol
Tensile strength (MPa)	21.72	19.85
Elongation at break (%)	1269.5	1248.0
Modulus (MPa)	0.7611 (M100)	0.8340 (M100)
	1.3035 (M300)	1.3980 (M300)
	2.1230 (M500)	2.1230 (M500)
Tear strength (N/mm)	63.76	51.87

This phenomenon might due to the better and stronger dispersion of filler in the anchoid-loaded NR latex films. It is well known that the dispersion stability is related to high zeta potentials [9]. If the particles have a

large zeta potential, they will repel each other. Hence, the higher the zeta potential, the more stable the dispersion obtained. It is known that the NR latex always preserved in basic condition to prevent destabilisation. Therefore, NR latex particle surface is surrounded by negatively charged. It is considered that the negatively charged of anchoid adsorbed to the sago starch particle surface, enhances the negative potential between NR latex and sago starch filler particles.

4. SUMMARY

In summary, 5 wt.% anchoid loaded sago starch dispersion can be concluded as an optimum composition to be introduced in NR latex system. When the stability of the sago starch dispersion was high and good enough which can be indicated by zeta potential, it can help to improve the mechanical properties of the NR latex films as the filler was well-dispersed in the films.

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