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Environmentally Friendly Natural Coagulants in the Coagulation Process in the Rubber Industry

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ABSTRACT

This research evaluates the use of natural coagulants, such as soursop and Aegle marmelos (Maja), in the latex coagulation process of the GT 1 clone type, compared with chemical coagulants such as formic acid and acetic acid, to gain an understanding of the characteristics of the rubber produced. Three types of crumb rubber (SIR 3 CV, SIR 3L, and SIR 3 WF) are produced from latex, while SIR 5, SIR 10, and SIR 20 are produced from treated latex coagulum. Rubber quality criteria are explained in the Indonesian Rubber Standard (SIR 3L/3WF) SNI 06-1903-2011. The use of natural coagulants, especially soursop, and Maja, in the coagulation of GT 1 clone latex shows an influence on coagulation time, Dry Rubber Content (DRC), initial plasticity (Po), Plasticity Retention Index (PRI), ash content, dirt content, and substance content evaporate. The results showed that natural coagulants had slower coagulation times, higher DRC values (especially in maja), and better PRI values compared to chemical coagulants. Despite having higher ash content, dirt content, and volatile matter content, all types of coagulants meet rubber quality standards. This research provides in-depth insight into the potential and advantages of natural coagulants, especially soursop, and maja, in the environmentally friendly rubber industry. In addition, analysis of rubber characteristics, such as plasticity, resistance to heating, and content of certain components, provides a comprehensive understanding of the impact of the use of natural coagulants on rubber quality.

1. INTRODUCTION

Crumb Rubber, which is the result of processing natural rubber, has an important role as a raw material in the industry, especially for making various tools and driving machines. This crumb rubber is made entirely from natural vegetable sources, with the main raw materials coming from garden latex and lumps (lumps of low-quality latex) (Mislimah & Ramadana, 2018). Types of crumb rubber, such as SIR 3 CV, SIR 3L, and SIR 3 WF, are produced from latex, while SIR 5, SIR 10, and SIR 20 are produced from treated latex coagulum. In this context, selecting the right rubber plant, such as clone GT 1 (Godang Tapeng), is crucial because this plant has superior properties, high latex productivity characteristics, and disease resistance. (Manurung et al., 2019). The standards are shown in **Table 1.** Below:

Table 1. SNI 06-1903-2011 *Standard Indonesian Rubber* (SIR 3L/3WF)

No	Characteristics	Satuan	Specification		Test method
			SIR 3L	SIR 3WF	
1	Po	%, min	0,02	0,02	ISO 1795
2	PRI	%, min	0,5	0,5	ISO 2930
3	Ash Content	%, max	0,8	0,8	ISO 247
4	Dirth Content	%, max	75	75	ISO 248
5	Volatille Content	%, max	30	30	ISO 249

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Latex, which is fresh sap from rubber trees, is usually produced by tapping rubber trees aged 4, 5, and 6 years. The latex coagulation process is a critical step in the rubber industry, and traditionally, chemical coagulants such as formic acid and acetic acid are used for this purpose. However, for the sake of environmental sustainability, this research focuses on the use of natural coagulants, namely soursop (SI) and maja or *Aegle marmelos* (MA), in the coagulation of latex-type clone GT 1.

Soursop, also known as Dutch jackfruit, is a flowering plant native to the Caribbean, Central America, and South America. In Indonesia, the largest production of soursop fruit is in the provinces of Central Java, West Java, and East Java. Soursop fruit has a unique composition, with 67.5% edible pulp, 20% skin, 8.5% seeds, and 4% pith (Lienggonegoro, 2020). The Annonaceous Acetogenins content in soursop stems and leaves show cytotoxic activity against cancer cells, while the water extract of the leaves contains flavonoids, tannins, and saponins which play a role in inhibiting tumor growth. Apart from being rich in vitamins A, B, and C, soursop fruit also contains sucrose, dextrose, levulose, and other compounds such as caffeine hydrocyanic acid, myric alcohol, and sterols. The high ascorbic acid content, around 62.64 mg per 100 grams of fruit, makes it potential as a potential natural coagulant in the latex coagulation process (Wiradharma, 2021).

Maja, otherwise known as bitter maja fruit, comes from Tropical and Subtropical Asia. Maja trees are resistant to harsh environments but are susceptible to losing their leaves. Even though maja fruit productivity levels tend to be low, this plant has traditional value as an antibiotic medicine for various diseases(Fatmawati, 2015). In traditional use, maja fruit is used to treat jaundice, constipation, chronic diarrhea, dysentery, stomachache, fever, asthma, and inflammation. The flesh of maja fruit is white and has a sour taste, but if left too long, it can produce an unpleasant odor and change color to black. Even though it has a low ascorbic acid content, around 8 mg per 100 grams of fruit, maja has potential value as a natural coagulant. The chemical content includes water, protein, fat, carbohydrates, ash, carotene, and several B vitamins, as well as acids (Sari, Putri, Siregar, Apriani, & Harahap, 2022)

Therefore, the main objective of this research is to understand the characteristics of rubber produced using natural coagulants, especially soursop, and maja, by analyzing Dry Rubber Content (DRC), Total Solid Content (TSC), Initial Plasticity (Po), Plasticity Retention Index (PRI), ash content, dirt content, and volatile matter content. The results of this characterization will be compared with the use of chemical coagulants, namely formic acid and acetic acid, to gain an in-depth understanding of the potential and advantages of natural coagulants in the environmentally friendly rubber industry.

2. METHODS

This research was conducted to determine environmentally friendly natural coagulants in the coagulation process in the rubber industry using soursop; Maja; then compared with chemical coagulants, namely acetic acid and formic acid so that we can know and determine the characteristics of the curry, clone GT 1 rubber is used. The volume of latex used was 100 ml and the volume of latex coagulant was 50 mL. This research was carried out with 3 samples per test. This research was carried out in the laboratory of PT Perkebunan Nusantara VII Unit Way Berulu and for latex collection in Sub-Division 3 Unit Way Berulu which has a plantation area of 38 Ha and tree age of 14 years with a rubber tapping system of ¼ S HO-1.1/D3. 1/4 S shows the width of the tapping on the rubber rod which is 1/4 of the diameter of the rubber rod (stem circumference). HO-1.1 shows the tapping period, namely the first year of the first period, while D3 means tapping is carried out every 3 days. The testing of rubber characteristics itself is adjusted to the testing standards that have been determined in the Indonesian Rubber Standard (SIR 3L/3WF) SNI 06-1903-2011, which apart from explaining the standard rubber quality values, also explains the standard testing methods. The following is a standard quality testing method shown in **Figure 1.**

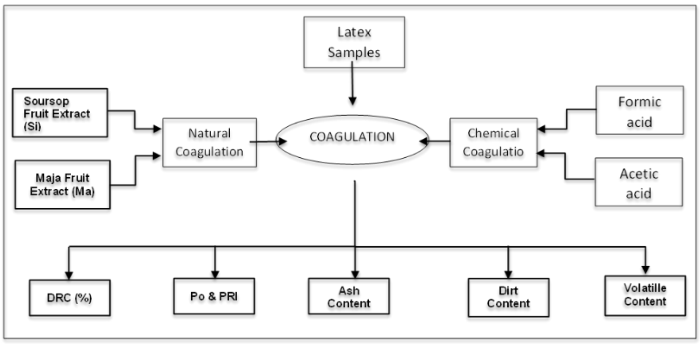

Figure 1. Experimental Method Flow Diagram

2.1 Natural Coagulant Preparation and Chemical Coagulant Preparation

In this research, two types of coagulants, namely natural coagulants and chemical coagulants, were prepared using different methods. First, for the preparation of natural coagulants, soursop fruit (SI) and maja (MA) were chosen as coagulant ingredients. The process begins by washing the fruit using running water until clean, then grinding it into an extract using a blender. The dregs resulting from the grinding are then filtered, and the pH of the fruit extract obtained is measured using a pH meter. The final step is to record the pH measurement results. Meanwhile, for the preparation of chemical coagulants, acetic acid and formic acid are prepared as coagulant ingredients. These two types of coagulants are an integral part of this research process, which will later be used in subsequent analyses and experiments.

The next process in this research involves latex sample preparation and Total Solid Content (TSC) testing. Latex samples were taken from the GT 1 clone rubber tree using the tapping method, and the latex that was collected was then filtered to separate it from dirt. At the TSC test stage, the processed latex is put into a petri dish, and an amount of 30 grams is measured and then deposited to form a lump. The latex lumps are then ground, and the weight of the dry latex is measured. Next, Total Solid Content (TSC) is calculated using a certain formula. The results of these two stages will be the basis for further analysis to understand the characteristics and quality of the latex used in this research.

2.2 Coagulation Process

The latex coagulation process is explained as follows: An empty beaker is weighed to obtain the initial weight, then 100 grams of latex is put into it to obtain the wet latex weight. Mixing the natural coagulant with latex was carried out in a ratio of 1:2, stirring using a stirrer until homogeneous. The latex coagulation time was recorded using a stopwatch until the latex was coagulated. After the coagulation process, the rubber is separated from the water in a measuring cup. pH measurements and color analysis of the coagulated water were carried out. Coagulation time data were translated into graphs to evaluate the relationship between coagulant type and latex coagulation time. This process provides a detailed view of the latex coagulation method in this study and is the basis for further analysis regarding the influence of coagulant type on latex coagulation time.

2.3 Rubber Characteristics Test

The process of testing the physical and chemical characteristics of latex consists of several careful steps. First, in the Dry Rubber Content (DRC) test, wet rubber is processed by grinding it using a rolling mill 6 times. Then, the weight of the dry rubber is weighed to calculate the DRC. The DRC data results were analyzed and represented in graphs to evaluate the relationship between coagulant type and DRC. Next, the Plasticity Retention Index (PRI) test involves a series of steps, starting from testing dry rubber on a plastimeter to get the Po value, to testing dry rubber that has been dried at a temperature of 130^{o}C to get the Pa value. PRI test result data is also represented in a graph of the relationship between the type of natural coagulant and PRI.

The next test involves a dirt level test and a volatile matter level test. In the dirt content test, the sample is ground into sheets, then cut into pieces and heated with a solvent and mineral turpentine. After the filtration process, the sample is heated in an oven, and the final result is weighed to determine the level of impurities. The dirt content data is then linked to the type of coagulant in the graph. Meanwhile, in the volatile matter content test, the sample is prepared by grinding it once to a maximum thickness of 1.5 mm. The next process involves heating in an oven, drying in a desiccator, and measuring the level of evaporated substances. The test results for volatile matter levels are linked to the type of coagulant in a graph for further analysis regarding the characteristics of the latex produced.

3. RESULT AND DISCUSSION

This research aims to evaluate the use of environmentally friendly natural coagulants in the rubber industry coagulation process, using soursop and maja, and compare them with chemical coagulants such as acetic acid and formic acid. Testing of rubber characteristics is adjusted to the Indonesian Rubber Standard (SIR 3L/3WF) SNI 06-1903-2011, including the standard test methods listed in **Table 2.**

Table 2. Experimental Results Data

Type Coagulant	Coagulant	pH	Vol. Coagulant (mL)	Vol. Latex (mL)	Coagulation Time (mnt)	TSC (%)	DRC (%)	Po (%)	PRI (%)	AC (%)	DC (%)	VC (%)
Standard	-	6,5	-	-	240	33,5	-	-	-	-	-	-
Natural Coagulant	SI	6	50	100	69		25,88	37,88	85,92	0,41	0,09	0,34
	MA	5,5	50	100	29		31,02	40,38	92,98	0,44	0,05	0,55
Chemical Coagulant	AF	3,5	50	100	9		29,97	42,16	80,76	0,23	0,01	0,35
	AA	4,5	50	100	20		24,50	45,05	79,77	0,27	0,02	0,43
SNI SIR 3L/3WF	-	-	-	-	-	-	-	Min 30	Min 75	Maks 0,50	Maks 0,02	Maks 0,80

While:
SI = soursop
MA = maja
AF = formic acid
AA = acetic acid
AC = *ash content*
DC = D*irt content*
VC = *volatile content*

3.1 Effect of Coagulant Type on Latex Coagulation Process and Latex Coagulation Time

Coagulation time is measured from the time the coagulant is mixed with the latex sample until the latex forms a perfect lump that does not release liquid when pressed and does not return to its original shape. All types of natural coagulants, containing organic acids such as ascorbic acid and citric acid in varying amounts, are capable of coagulating latex. On the other hand, chemical coagulants produce clots more quickly than natural coagulants. The influence of the type of coagulant on the latex coagulation process can be seen in **Figure 2.**

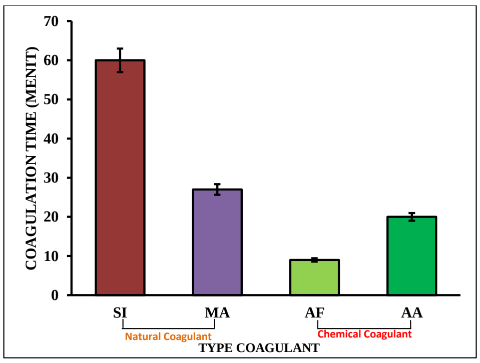

Figure 2. Effect of coagulant type on latex coagulation time

This research revealed that Maja extract had the fastest coagulation time (27 min) among natural coagulants, while 1% formic acid was the chemical coagulant with the fastest time (9 min). Soursop extract, on the other hand, produced the longest coagulation time (69 min). In general, chemical coagulants tend to have faster coagulation times than natural coagulants. Significant differences in coagulation times are caused by variations in pH values, where low pH values favor fast coagulation times. The purpose of adding coagulants is to lower the pH of the latex to reach the isoelectric point, causing the positive and negative charges to balance (Achmad et al., 2022b). Coagulants also act as a source of H^+ ions which disrupt the latex protein structure, resulting in the formation of rubber lumps. The coagulation time for samples without coagulant reached 240 min, indicating natural degradation of the protein membrane and evaporation of water into the air (Puspitasari et al., 2018).

3.2 Effect of Coagulant Type on Dry Rubber Content (DRC)

Dry Rubber Content (DRC) is the percentage of the number of rubber particles in a rubber sample. The heating process lasts for 30 minutes before the DRC calculation is carried out to ensure perfect dryness of the crepe being measured, with the aim that the DRC value can be obtained with high accuracy and a low margin of error. The results of the DRC analysis of various types of coagulants can be seen in **Figure 3.**

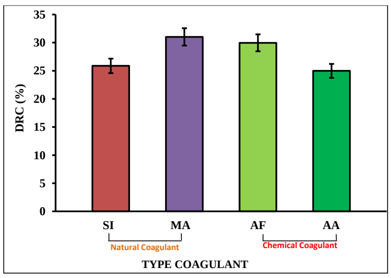

Figure 3. Effect of coagulant type on Dry Rubber Content (DRC)

The highest DRC value for natural coagulants was obtained by Maja with a DRC value of 31.02% and the highest DRC value for chemical coagulants was obtained by formic acid of 24.50%. A high DRC value indicates that the water content in latex is lower, while a low DRC value indicates that the water content is high. The chemical coagulant, namely acetic acid, produces 40 mL of serum with a pH of 4.5, while the natural coagulant, namely soursop, produces 30 mL of serum with a pH of 6 and the grapefruit coagulant produces 15 mL of serum with a pH of 5. The white color indicates that the rubber content is not completely coagulated, which results in the DRC value being smaller. The greater the DRC value, the better the quality of the rubber produced (Achmad et al, 2022c).

This research also measures the percentage of TSC (Total Solid Content) of rubber. TSC is the number of solid substances contained in latex. TSC is measured without using coagulants, which is a natural coagulation process. The TSC values obtained in this study ranged from 32.47% to 34.66%. The average TSC value is greater than the average DRC value, namely 31.37%. The TSC value is 2% greater than the DRC value, namely 31.37% for natural lemon coagulant with a concentration of 100%. This is because TSC still contains compounds other than rubber such as protein, water, and carbohydrates (Puspitasari et al., 2018).

3.3 Effect of Coagulant Type on Initial Plasticity (Po)

Rubber plasticity is measured to obtain initial plasticity (Po) and final plasticity (Pa) values, from which the Plasticity Retention Index (PRI) is calculated. The plasticity value of rubber is divided into two aspects, namely the Po value which reflects the strength of the rubber. **Figure 4** shows the results of the analysis of the influence of the type of natural coagulant on the initial plasticity value.

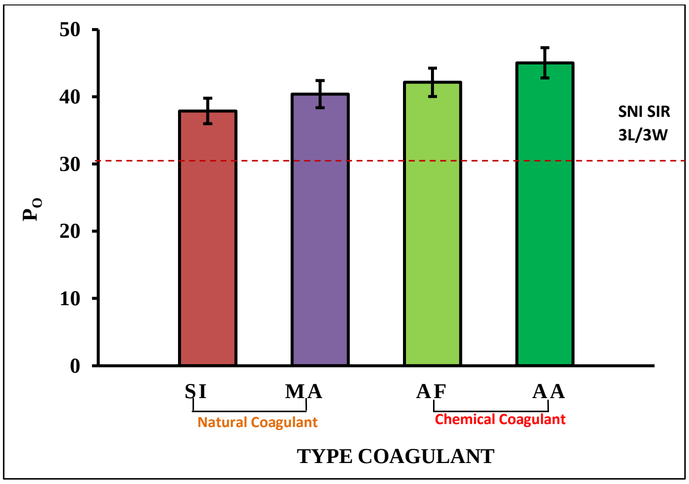

Figure 4. Effect of coagulant type on initial plasticity value

The analysis results showed the highest Po value from acetic acid (45.05) while soursop and maja had the lowest Po values (37.88 and 40.38). Although formic acid has a lower Po value than acetic acid, this is due to the increase in temperature in the oven during testing (Mayasari & Wirapraja, 2019). Both natural and chemical coagulants meet SNI 06-1903-2011 standards for SIR 3L and 3WF with a minimum Po value of more than 30%. The relationship between Po and Pa can be seen in **Figure 5** which depicts the Po and Pa values for each type of coagulant.

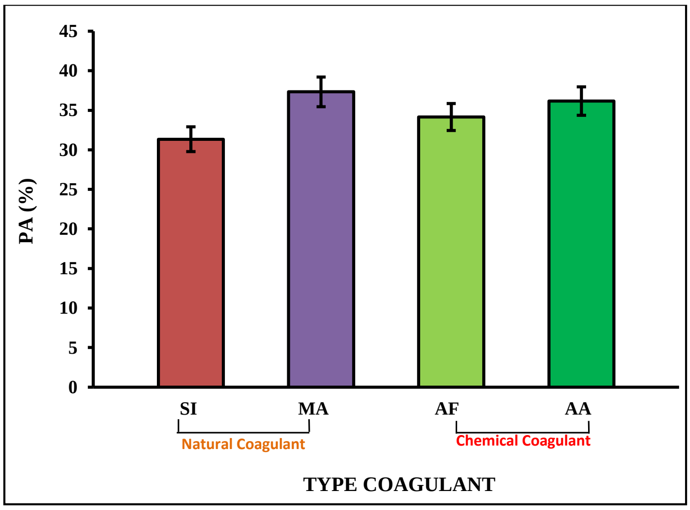

Figure 5. Effect of coagulant type on Pa value

Based on analysis standards in the PTPN VII Unit Way Berulu laboratory, the Po value for acetic acid and formic acid produces a high value due to the low concentration of acid used so that the rubber structure is not damaged due to the addition of acid. The Po value in grapefruit, soursop, and maja fruit produces a high pH value so it does not damage the rubber structure (Achmad, Amelia, et al., 2022).

3.4 Effect of Coagulant Type on Plasticity Retention Index (PRI)

PRI (Plasticity Retention Index) reflects the resistance of rubber to heating which causes a reaction between the long chains of isoprene in rubber and oxygen in the air, forming an oxide layer and resulting in damage to the rubber structure when heated. The Thermal Oxidation process can produce rubber that is black and less elastic. The PRI value is calculated as a comparison between the rubber plasticity value before heating (Po) and after heating (Pa) (Lorenza et al., 2021). The influence of the coagulant type on the PRI value can be seen in **Figure 6.**

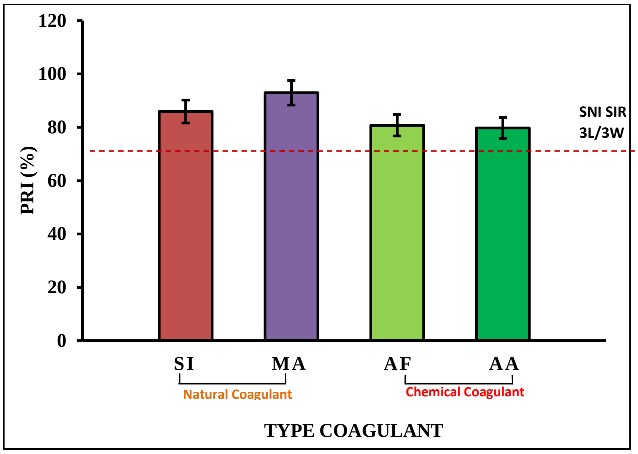

Figure 6. Effect of coagulant type on PRI value

From the analysis results, the highest PRI value was obtained from maja (92.98%), while the highest chemical coagulant was formic acid (80.76%). Natural coagulants, especially maja, show a higher PRI because they have a high pH value, support intact long-chain isoprene, and inhibit Thermal Oxidation (Achmad, Amelia, et al., 2022). Even though acetic acid and formic acid meet the requirements of SNI 06-1903-2011, their PRI values (80.98% and 81.34%) are lower than natural coagulants. The low PRI value of chemical coagulants is caused by damage to the long chain of isoprene during the coagulation process, which results in the durability of the long chain of isoprene decreasing and it being more susceptible to Thermal Oxidation. Natural coagulants with higher pH produce better PRI values than chemical coagulants (Maryanti, 2016).

3.5 Effect of Coagulant Type on Ash Content

Ash Content in rubber shows the amount of inorganic material in the material. The ash content affects the density and adhesion between rubber particles, thereby affecting the Weight to Strength Ratio (Achmad & Deviany, 2022). Analysis of the influence of the type of natural coagulant on the PRI value can be found in **Figure 7.**

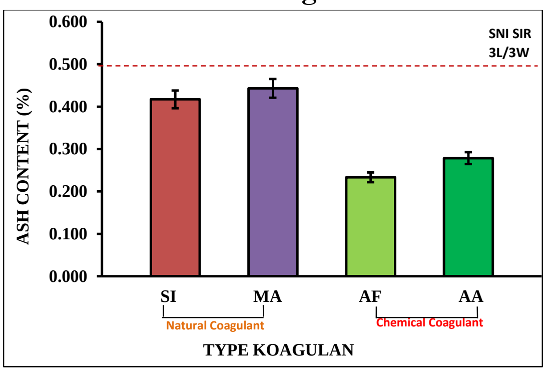

Figure 7. Effect of coagulant type on Ash Content

The analysis results showed that the highest ash content values were obtained from maja (0.4431%) and soursop (0.4173%), while formic acid (0.2333%) and acetic acid (0.2786%) had the lowest ash content. The low ash content in chemical coagulants is caused by the low levels of inorganic compounds in these two acids. On the other hand, natural coagulants have higher ash content because the fruit extract contains various compounds and minerals (Ca, Mg, P, and K) along with acids. (Achmad, Amelia, et al., 2022). However, all types of coagulants meet the requirements of SNI 06-1903-2011 for SIR 3L and 3WF with an ash content of less than 50%.

3.6 Effect of Coagulant Type on Dirth Content

The dirt content is the amount of solid impurities contained in the latex. The dirt level is very important because the dirt level directly affects the characteristics of the latex. High levels of dirt usually occur due to improper latex processing such as unclean storage and contamination in the form of fibers and sand contained in natural coagulants. (Achmad, Amelia, et al., 2022). Testing dirt levels uses a type of heating device, namely Infrared, which functions to heat the sample until it removes the dirt that sticks to the Erlenmeyer flask, then the dirt will be filtered to get the dirt analysis test results. Infrared is electromagnetic light that has a longer wavelength than visible light, namely between 700 nm and 1 mm. The results of the analysis of the influence of coagulant type on dirt content values can be seen in **Figure 8.**

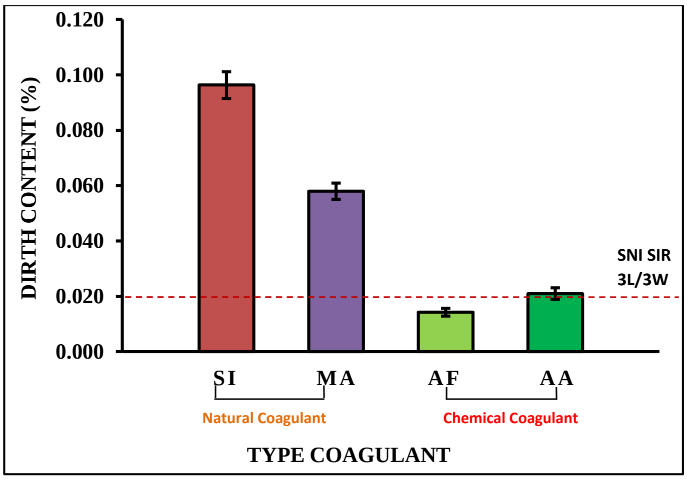

Figure 8. Effect of coagulant type on Dirth Content value

The analysis results show that chemical coagulants have lower impurity values than natural coagulants. The impurity levels of formic acid and acetic acid as chemical coagulants are 0.014% and 0.021% respectively, while the lowest natural coagulant is Maja (Ma) with a value of 0.058%. The low levels of impurities in natural coagulants are due to minimal contamination from other ingredients in the latex, and the lemon coagulant appears clear. Chemical coagulants are produced with homogeneous quality, while natural coagulants have higher levels of impurities (0.096%) due to the presence of solid particles that are difficult to separate by filtration (Puspitasari et al., 2018). Chemical coagulants meet the requirements of SNI 06-1903-2011 for SIR 3L and 3WF (impurity content less than 2%), while natural coagulants do not meet SNI standards because they are difficult to separate with conventional filtration. Further separation by centrifugation can improve the cleanliness of natural coagulant extracts, but this process has disadvantages in the form of longer preparation times and low productivity.

3.7 Effect of Coagulant Type on Volatile Content Levels

Volatile Content is the number of volatile substances in rubber. The level of evaporative substances directly indicates the level of dryness of the rubber. This is because rubber has high levels of volatile substances which are more susceptible to the growth of microorganisms and fungi (Valentina, Herawati, & Agus, 2020). Rubber that has a high level of volatile matter also has a lower Weight to weight-to-strength ratio. The vapor content is obtained by comparing the weight of the rubber before the heating process and after heating. The difference in weight before and after heating will be used to determine the value of the vapor content. The results of the influence of the type of natural coagulant on the value of volatile matter levels can be seen in **Figure 9.**

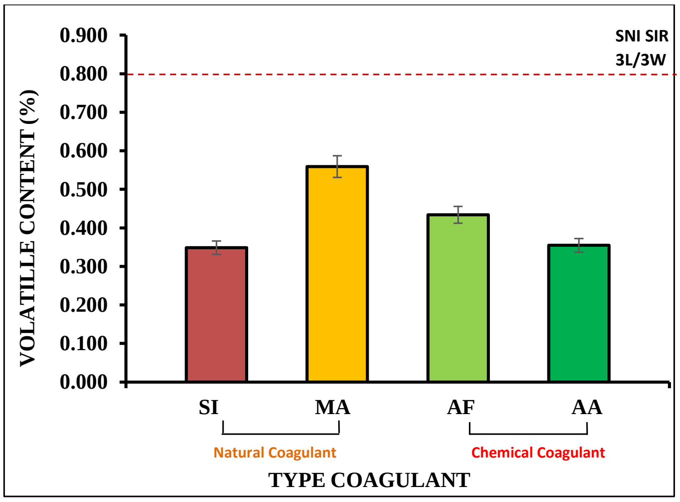

Figure 9. Effect of coagulant type on the value of volatile matter levels

The graph shows that the value of volatile matter produced by natural coagulants is not too different from chemical coagulants. The lowest volatile matter content was found in soursop (SI) at 0.348%, while Maja (MA) had the highest value among natural and chemical coagulants at 0.559%. Chemical coagulants, such as acetic acid, have a volatile matter content of 0.4339%. The high levels of volatile substances in Maja natural coagulant are caused by the "slimy" nature of Maja fruit extract, which contains a lot of volatile substances and the instability of the oven temperature when heating. The high value of volatile matter content in chemical coagulants is caused by the addition of water when diluting the acid concentration (Puspitasari et al., 2018). However, all types of coagulants meet the requirements of SNI 06-1903-2011 for SIR 3L and 3WF, namely with a volatile substance content of less than 80%

4. CONCLUSION

This research evaluates the use of natural coagulants, such as soursop and maja, as environmentally friendly alternatives in the latex coagulation process of the GT 1 clone type when compared with chemical coagulants such as formic acid and acetic acid. The research results show that soursop and maja can act as natural coagulants with characteristics that comply with rubber quality standards, as explained in the Indonesian Rubber Standard (SIR 3L/3WF) SNI 06-1903-2011. The influence of coagulant type on various parameters, such as coagulation time, Dry Rubber Content (DRC), initial plasticity (Po), and Plasticity Retention Index (PRI), illustrates that maja as a natural coagulant has many advantages. Although chemical coagulants tend to have faster coagulation times and higher Po values, better PRI values in maja indicate better rubber resistance to heating. Even though natural coagulants have higher ash content, dirt content and volatile matter content, they still meet the requirements of rubber quality standards. Thus, this research provides in-depth insight into the potential and advantages of using natural coagulants in the sustainable rubber industry.

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