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Natural Rubber Powder Production from Latex

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Abstract. Natural rubber-based products are widely used in everyday life. There are three types of upstream processed natural rubber, that are crumb rubber, conventional rubber, and concentrated latex. Latex is easily damaged by clotting and contains 35-40% w/w of water so that the packaging volume is relatively large and inefficient in transportation. Latex also contains ammonia as an anti-clotting agent so the packaging must be special to prevent unpleasant odour. This study aims to create a pilot plant of the spray drying latex from simulation results then test the performance, evaluate the performance test results, as well as making improvements to the production of rubber powder. The steps of this research are data collection for spray dryer design, design verification, construction of spray dryer, spray dryer appliance testing, and characterization of rubber powder produced. The heating system used in the spray dryer is LPG gas-fired furnace. Testing is done by varying the spray dryer drying air temperature of 120°C, 150°C, and 180°C, the water content of the feed latex 70% and 80% w/w, as well as non-stick material such as talc powder and MgO. Rubber powder characterized by water content with digital tools moisture meter and analysed spectra with Fourier Transform Infrared Spectroscopy (FTIR). The results showed the optimum operating conditions for the production of natural rubber powder is drying air temperature of 150°C and the water content of the feed latex 80% w/w. Natural rubber powder produced contains 10 to 13% w/w water but still sticky so that the powder grains stick to each other. The FTIR spectrum analysis of natural rubber powder products show similarity with bonding group of polyisoprene natural rubber compound. Natural rubber powder product can also be used as a substitute for crumb rubber.

1. Introduction

Natural rubber derived from the rubber tree sap is currently widely used in everyday life. Latex is concentrated liquid and contains about 35-40% water. This will affect transportation costs that become less efficient because it is used to transport water as well. In addition, the required volume of packaging is also greater and need special handling because of latex late contain ammonia as an anticoagulant material so that latex does not clot and become damaged. Reduction of water content and activity has a positive effect on product quality [1]. In dry conditions, the packaging and transportation process becomes easier and can be stored longer. Latex in the form of liquid contains proteins that are vulnerable to overgrown by microbes. However, it can be minimized if the rubber does not contain water or solids as powder using technology to make the latex into powder by spray drying. Laboratory of Polymer and Membrane Technology - Institut Teknologi Bandung has simulated spray drying technology for the production of natural rubber latex powder with the help of ANSYS FLUENT software. The simulation results obtained in the form of equipment design, operating conditions, and prediction of dry rubber powder products.

To complete the previous research, the present study will generate what has been simulated and perfecting it. Fresh or concentrated latex still has high water contain that make the transportation process

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becomes inefficient. In addition, the use of ammonia as an anticoagulant material are volatile and has a characteristic odour that makes latex should be packed in particular way. Thus, the rubber in the form of powder becomes a solution to improve the transportation efficiency and handling of latex from plantation to finished goods processing plant. The purpose of this research is to build pilot plant based on simulation results, to test the performance of the pilot plant, to evaluate the performance test results, and making improvements to the production of rubber powder so it can be managed well. The benefit of this research is to obtain the optimum condition and efficient operation of the spray drying process to produce powder in the form of durable rubber and easily dissolved again with water so that the storage, transport, and use in downstream rubber industry becomes more convenient and flexible.

In several studies, there are some works that focused on the possibility to obtain ultrafine rubber powder, particles from micrometer to nanometer dimensions, based on rubber lattices, like styrene-butadiene, acrylonitrile-butadiene and natural rubber. According to Paiva et al, SBR rubber powder prepared by the chemical modification of latex with methyl methacrylate and colloidal silica followed by spray drying had dispersions without any additional treatment [2]. Preparing rubber nanoparticles using conventional methods is difficult, but rubber powder can be prepared from irradiation and spray-drying of rubber lattices [3].

Spray drying is the process of contacting the atomized liquid feed with a gas temperature higher than the liquid [4]. The spray drying process fluid feed change into a dry product from the solvent. Fluid feed nozzle produces atomized using granules are contacted with a medium hot dryer. The commonly used drying medium is air. The heat of the drying medium is used to evaporate the fluid solvent so as to produce the product of dry powder with a temperature that is not too high. The drying time of the granules is relatively short compared to other drying processes. According to Mujumdar (2006) spray drying process consists of three stages, atomization, evaporation, and separation.

In general, the design of the chamber depends on the type of atomizer and liquid-air contact system selected [5]. Selection of an atomizer and liquid-air contact system is determined by the desired characteristics of the dry product and speed of production. Product specifications were obtained from small-scale testing results in the laboratory. However, product specifications are sometimes in the literature. Altitude chamber defined droplet diameter and the temperature difference between the air dryer and the particles product. The air dryer used is high temperature air. Air heating system (water heater) is an important support tools in the spray drying process. Use blower air flows toward the air heating system before entering the chamber. Air heating can be done directly or indirectly using steam, fuel oil, gas, electricity, and heating fluids.

2. Methods

The research was conducted in five major stages, namely the collection of data related to the design of the spray dryer simulation results, design verification simulation results, the construction process of a spray dryer, testing tools spray dryer that was created using baits fresh latex and perform characterization of the powder rubber produced. Flow diagram of the major stages of the experiment can be seen in Figure 1.

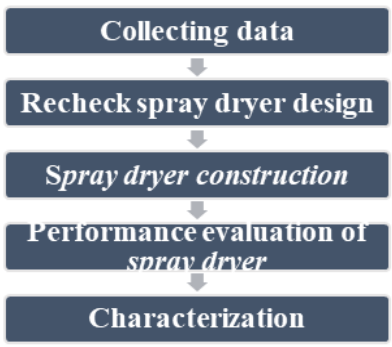

Figure 1. Implementation phase of research

The first stage in this study is data collection. The data collected from the results of previous research that has been conducted at the Laboratory of Polymer Technology and Membrane which was the simulation of spray drying of natural rubber latex. The second stage after the data collected is data verification. Data verified by conducting a literature review of the scientific journals and textbooks related to natural rubber and spray drying technology as well as perform repeated calculations. The third phase is the construction of a spray drying equipment. The fourth stage is a performance test of constructed spray drying. The test is carried out by varying the temperature of the drying air and the natural rubber latex feed water content as well as the non-sticking material. Natural rubber powder is stored in a cup every 10 minutes for 3 times or until 30 minutes. The rubber powder produced will be analysis for the water content using moisture meter. qualitatively observed stickiness and coagulated, also spectrum analysed with Fourier Transform Infrared Spectroscopy (FTIR).

2.1. Main Equipment

Detail specifications of main equipment are presented in Table 1.

Table 1. Specification of the main experimental equipment

Equipment	Specification
Feed tank	60 liter
Pump	Gear pump Oriental Koshin GL-25-5, outlet diameter 1”, power 1,5 kW, pressure 5 bar, capacity 58 L/min
Pressure nozzle	Pressure nozzle 0,3 mm with capacity 0,86 mL/s at 4 bar
Drying Chamber	Upper diameter 33 cm, height 64 cm cylinder section, cone height 74 cm, and bottom diameter 7 cm
Heater	LPG gas-fired furnace that can heat the air up to 200°C
Blower	Chuanfan Cx-75A. Outlet 4", capacity 1,22 Nm^3/min

The main equipment scheme is presented in Figure 2.

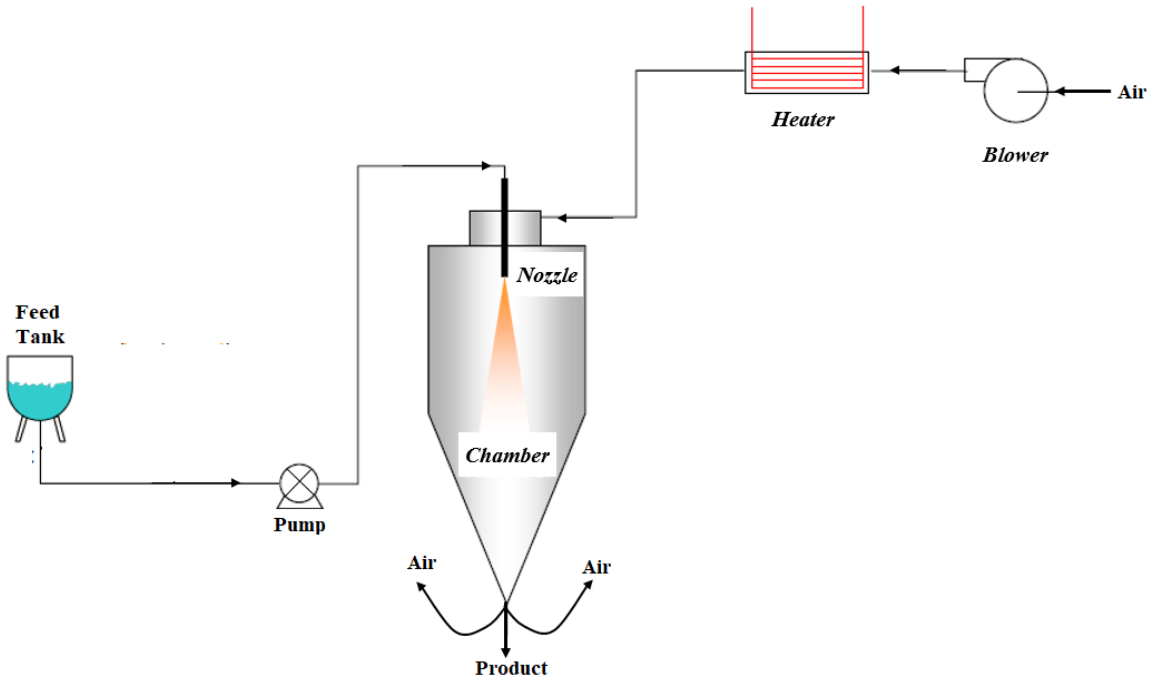

Figure 2. Scheme of the main equipment

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2.2. Equipment and Material

Equipment and materials in this experiment are presented in Table 2.

Table 2. Equipment and material experimental

Equipment	Material
Bucket bait tank	Latex
Pump	Water
Pressure nozzle	Air
drying Chamber	LPG gas
Furnace	Formic acid
High pressure regulator	Talak
High pressure cooker	MgO Powder
Blower	
pressure gauge	
Thermocouple	
Shell	
Stainless steel pipe	
Pipe insulator	
Oven	
Evaporation plate	
Spatula	
Analytical balance	
Digital moisture meter	
Digital Anemometer	

The experiment was conducted by varying drying air temperature and latex feed water content. The selected air dryer temperature variations were 120, 150, and 180oC. The three variations are selected because of the five temperatures the water is estimated to have been well vaporized. Variations of selected feed water content are 70%, and 80%. Both variations are selected because with the water content is not too thick latex, viscosity is not too high. This experiment using a pressure nozzle that cannot be operated for a fluid with high viscosity. In addition, variations are made by adding non-stick ingredients such as talc powder, and MgO. The variables are kept constant throughout the experiment is the feed flow rate of natural rubber latex exit nozzle of 0.86 mL/s and drying air flow rate of 1.22 Nm3/min.

3. Results and Discussion

3.1. Furnace Performance

The furnace fuel is LPG gas. Test performance of the furnace is done by heating the air conditioning as much as 1.22 Nm3/min by varying the drying air temperature of 120, 150, and 180˚C. The air conditioning temperature furnace entrance 27˚C. LPG as a fuel has a lower heating value (LHV) 46.04 MJ / kg. LPG gas needs and the efficiency of the furnace for each variation of the drying air temperature is presented in Figure 3.

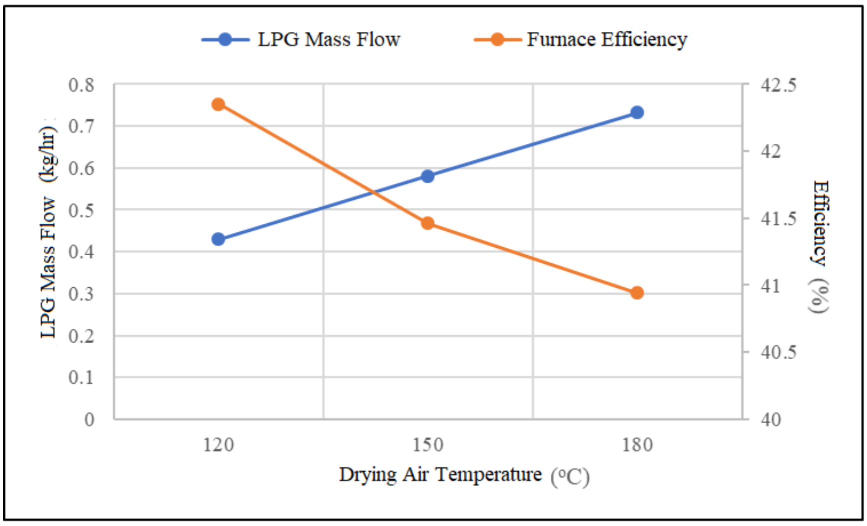


Figure 3. LPG gas requirements and furnace efficiency for each variation of dryer air temperature

Furnace efficiency is 41 to 42.3%. The efficiency value represents the absorbed energy to increase the drying air temperature of the overall heat supply. The value is not up to 50% meaning half of the energy supplied to the furnace is wasted or unused. This can be evidenced by the high temperature of the furnace exhaust gas. Furnace exhaust gas has a high temperature in the range of 230 up to 380˚C. The high temperature exhaust gas can be utilized by installing an economizer so as to improve the efficiency of the furnace and is no longer much energy is wasted.

3.2. Spray Drying Performance with Natural Rubber Latex Feed

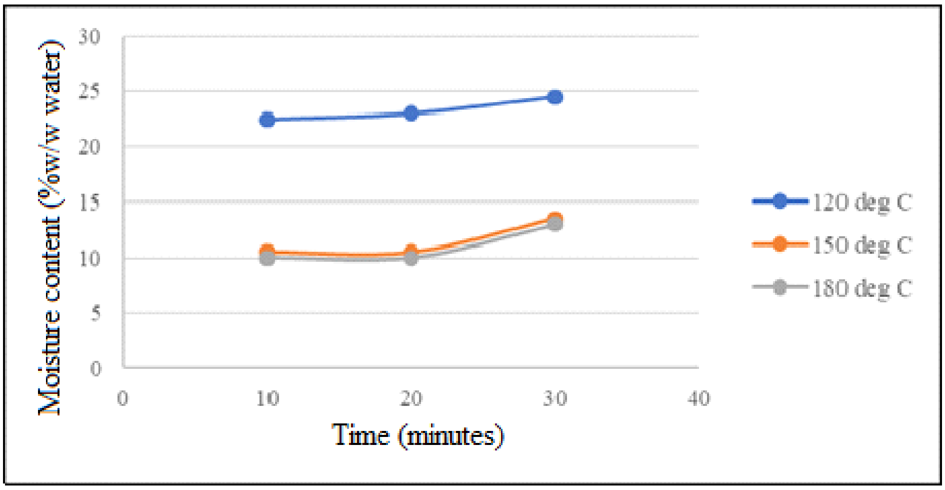
Natural rubber latex is supplied from PTPN VIII Jalupang farm, Subang in concentrated latex form with dry rubber content (KKK) about 60% -w/w or moisture content about 40% -w/w. The test results of concentrated latex water content showed a water content of 39.38% -w/w. The concentrated latex was diluted to 70 and 80% w/w of water to be fed the spray drying process. The test results density of PTPN VIII concentrated latex or latex diluted presented in Table 3.

Table 3. Natural rubber latex density test results

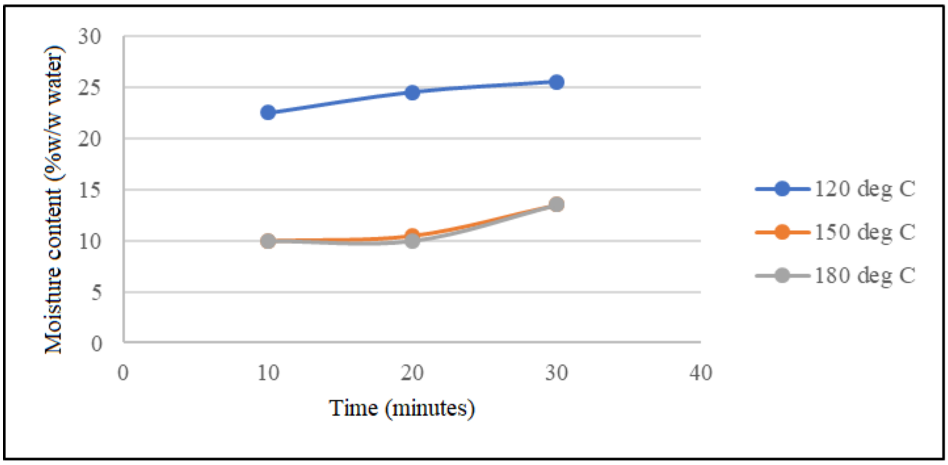
Type of Latex	Concentred Latex	Latex 70%-w/w Water	Latex 80%-w/w Water
Density (kg/m^3)	943.70	974.08	981.02

Operating temperature for drying air entered the chamber optimum based on Figure 5 is 150˚C. At temperatures of drying air entered the chamber at 120˚C, water content of rubber powder products is still high at above 20% w/w water. Operating temperature 150˚C can be achieved with fuel consumption of LPG is lower than the operating temperature of 180˚C. At temperatures of drying air entered the chamber of 150 and 180˚C, levels water product powder rubber that generated could it says same, that is amount 10 - 13.5% w/w, so that the selected optimum operating temperature is 150˚C.

The optimum latex feed water content based on Figure 5 is 80% w/w. Rubber with 80% w / b latex feed water content is easier to pump. Rubber latex feed moisture content of 70% w/w has a rubber content of more than bait latex with water content of 80% w/w. It causes more quickly formed a layer of rubber on the gear pump to the motor no longer strong enough to turn the gear pump and gear pump must be in maintenance. Maintenance gear pump is done by soaking it with turpentine oil so that a layer of rubber on the gear pump oil dissolved in turpentine. The experimental results show that 70% b / b water latex bait can run up to 4 flights before motor of gear pump no could rotate gear pump again, while attack bait Latex 80% w/w water can run up to 5 attacks before the motor gear pump gear pump cannot play anymore.



(a)



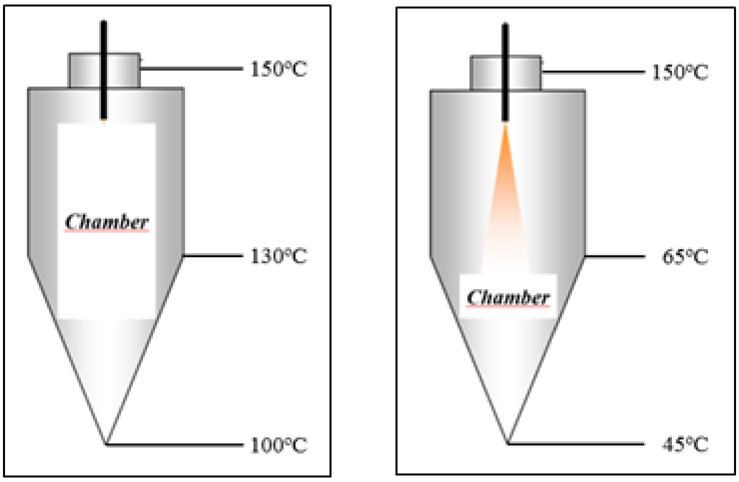
(b)

Figure 4. The water content of the rubber powder product at a temperature of 120, 150, and 180°C to the moisture content of feed (a) 70% and (b) 80% w / w water

Operating temperature for drying air entered the chamber optimum based on Figure 5 is 150˚C.At the entrance chamber drying air temperature of 120oC, moisture content of rubber powder products is still high at above 20% w/w water. Operating temperature 150˚C can be achieved with fuel consumption of LPG is lower than the operating temperature of 180˚C. At temperatures of drying air entered the chamber at 150 and 180˚C, the water content of powder rubber products produced can be said to be equal, at 10 - 13.5% w / w, so that the selected optimum operating temperature is 150˚C. The water content of latex optimum feed based on Figure 5 is 80% w/w.

Rubber with 80% -w/w latex feed water content is easier to pump. Rubber with 70% -w / w latex feed water content has more rubber content than latex feed with 80% -w / w water content. It causes more quickly formed a layer of rubber on the gear pump until the motor no longer strong enough to turn the gear pump and gear pump must be in maintenance. Maintenance gear pump is done by soaking it with turpentine oil so that a layer of rubber on the gear pump dissolved in turpentine oil. The results showed 70% attack latex feed w / w water can run up to 4 attacks before the motor gear pump cannot turn the gear pump again, while the decoy attack latex 80% w/w water can run up to 5 attacks before the motor gear pump cannot turn the gear pump again.

When the spray drying process takes place, the heat energy carried by the drying air is used to evaporate the solvent from the feed. This is indicated by the change in the temperature profile throughout the chamber. Temperatures along the chamber during the spray drying process lasts less than the temperature throughout the chamber when only flowed air dryer only. The temperature profile chamber to a temperature of 150˚C while before the feed is sprayed latex and latex sprayed when the bait is presented in Figure 5.



(a) (b)

Figure 5. The temperature profile of chamber (a) before the feed latex sprayed, it contains only air dryers and (b) after the feed latex 80% w / w water sprayed

The optimum operating conditions of spray dryer from the experimental are the input drying air temperature enter chamber at 150˚C and the feed latex water content of 80% w/w was used for non-stick material rubber powder. The 2% -w/w mixed-in rubber sticky material into the latex feed is varied, namely talc powder and MgO powder. Powder products of rubber latex from spray drying results that have been mixed with non-stick agent talc and MgO powder is still sticky. However, the addition of non-stick material does not degrade the performance of the spray drying. Performance of spray dryer with a non-stick material variation talc powder and MgO powder is presented in Figure 6.

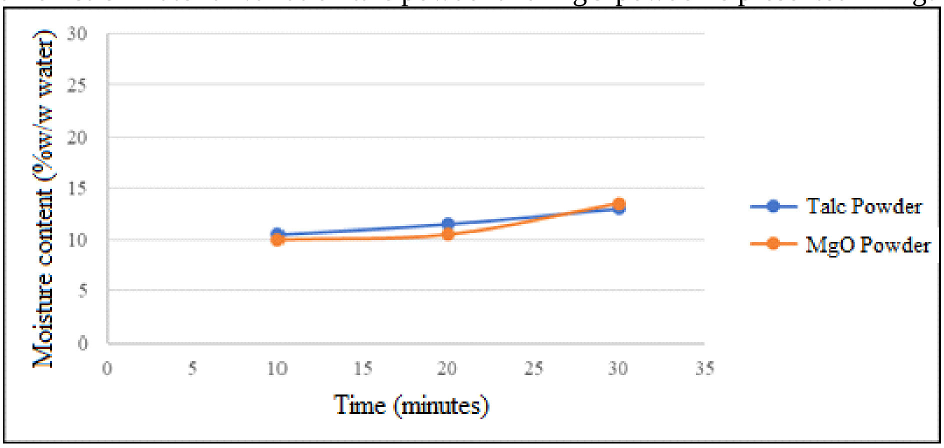


Figure 6. Performance spray drying a mixture of natural rubber latex with non-stick material

3.3. Analysis of Natural Rubber Powder Spectrum

The result of the FTIR spectrum analysis yield curves percent transmittance against wave numbers. Each bonding group has a unique wave number that distinguishes it from other clusters of bonds. The result of the FTIR spectrum analysis for natural rubber powder samples are presented in Figure 7.

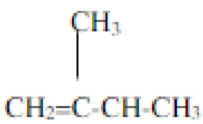


Figure 7. The chemical structure of natural rubber monomer

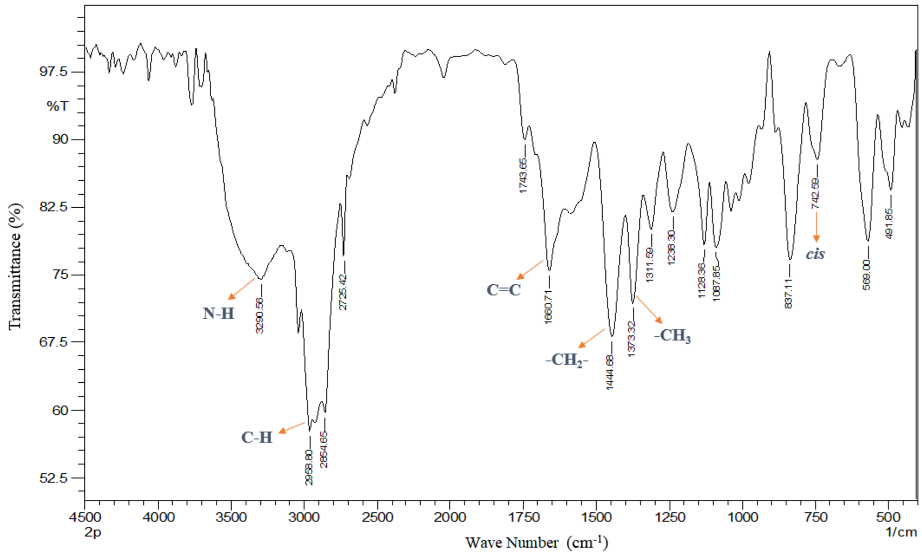


Figure 8. FTIR spectrum of natural rubber powder samples

Characteristic of natural rubber is having unsaturated C = C bond that forms the position of cis C = C bond that forms the cis position read on the FTIR spectrum. Other groups such as the CH bond, -CH2 -, and -CH3 existing in the structure of natural rubber are also accepted FTIR spectrum. The FTIR spectrum of natural rubber powder also indicates that there is a NH group. The NH group can be derived from a protein contained in natural rubber latex or may also be caused by spray drying feed used is concentrated latex containing ammonia. Thus, the true natural rubber powder is a natural rubber compounds and prove that the spray drying process does not damage the rubber compound.

3.4. Comparative Study between Natural Rubber Powder and Crumb Rubber

Crumb rubber is dry rubber processing process through various stages. The raw material comes from the crumb rubber latex is processed into a coagulum using formic acid. The processing of rubber crumb rubber itself is the processing of rubber raw materials (in solid form) by means crushing, blending, and drying which aims to get dry rubber. Crushing aims to obtain rubber crumbs that are ready to be dried, the drying is done by using heating for 3 hours with the temperature further 122˚C.Tahap is pressing to get the bale-bale of dried rubber crumb with a press machine.

The impurities contained in the crumb rubber is very damaging properties for the finished goods, especially rubber bending resistance and durability. These properties are important in determining the quality of motor vehicle tires, so the higher the level of crumb rubber impurities, the lower the quality. Production process of crumb rubber requires many stages of process, material like used of formic acid, tools for obtaining crumb rubbers, drying using heaters, pressing tools, and other supporting tools.

Latex preservation process used in dry form by using spray drying technology is more effective and efficient when compared with the manufacturing process of crumb rubber. The resulting product is non-stick so that the rubber powder fused together to form a thin sheet with low moisture content makes the product more durable and more flexible in its use. Bonding groups in the crumb rubber is the same with groups bonding natural rubber powder that is detectable group C = C who plays cis. The cluster is characteristic of the polyisoprene natural rubber compound. The FTIR spectrum of crumb rubber are presented in Figure 9.

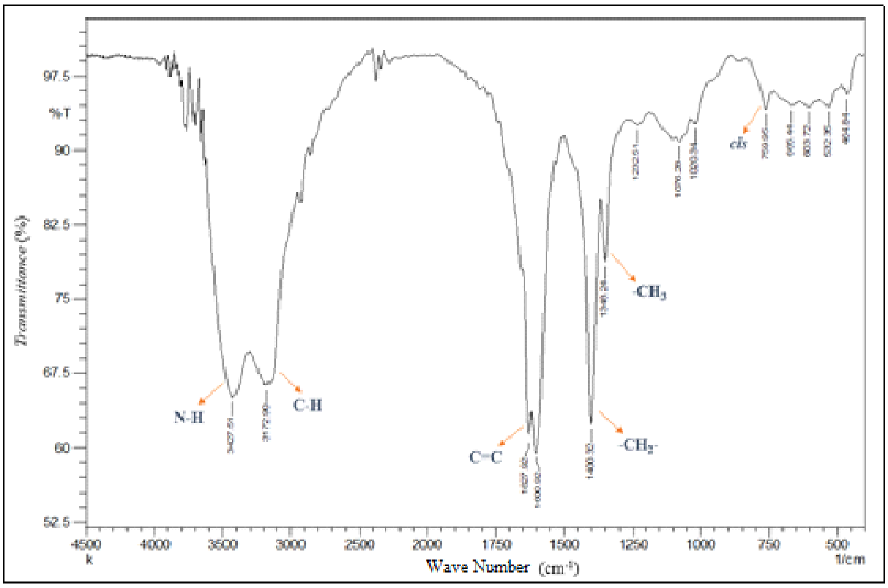


Figure 9. The FTIR crumb rubber spectrum

4. Conclusion

It can be concluded that the optimum operating conditions for natural rubber latex spray drying is the drying air temperature of 150°C entered the chamber and feed moisture content of 80% latex w/w. The resulting rubber powder product is actually a compound of natural rubber, natural rubber compound that does not react and form other compounds not damaged as a result of the spray drying process. The non-stick material of talc powder and MgO powder mixed into the natural rubber latex bait is incapable of making the natural rubber powder product non-stick. However, the mixture does not degrade the performance of spray drying.

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