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Potential of Bagasse as Raw Material for Lignosulfonate Surfactant

Rini Setiati, Aqlyna Fatahanissa, Shabrina Sri Riswati, Septoratto Siregar and Deana Wahyuningrum

Abstract

Anionic surfactants are generally used in surfactant injections because they are good, resistant in storage and stable. Furthermore, Commercially, anions are produced in the form of carboxylates, sulfates, sulfonates, phosphates, or phosphonates. The surfactants used in the process of implementing Enhanced Oil Recovery (EOR) are generally petroleum-based, such as Petroleum Sulfonate. Therefore, an increase in oil price, leads to an increase in the price of surfactant and the operational costs becomes relatively expensive. Lignosulfonate is a type of anionic surfactant which is made with lignin as raw material. This lignin is found in many plants, including wood stalks, plant leaves, peanut shells, corn cobs, bagasse, empty bunches of oil palm and wheat straw. Based on the results of previous studies, 25% of lignin component was discovered in bagasse. This may be a consideration that there is enough lignin in bagasse to be used as raw material in the production of lignosulfonate vegetable surfactants. Furthermore, lignin from bagasse is used because bagasse is easy to obtain, cheap and an environmental friendly vegetable waste. Currently, bagasse is only used as fuel in steam boilers and papermaking, cement and brick reinforcement, a source of animal feed, bioethanol, activated charcoal as adsorbent and compost fertilizer. This is a consideration to optimize the use of bagasse to become lignosulfonate as an alternative for surfactants in the petroleum sector. The purpose of this study is to show that lignin from bagasse has the potential of becoming a lignosulfonate surfactant. There are several studies that have processed bagasse into sodium lignosulfonate. The component test on the results showed that the surfactant component of sodium lignosulfonate from bagasse was almost the same as the commercial standard lignosulfonate component. Furthermore, the results of the HLB (Hydrophilic-Lipophilic Balance) value test show that the sodium lignosulfonate surfactant from bagasse can function as an emulsion form which is a required parameter for the surfactant injection mechanism. Based on the discussion of the study results, bagasse has the potential as a raw material to be processed into lignosulfonates.

Keywords: bagasse, lignin, lignosulfonate, surfactant

1. Introduction

Indonesia is an agricultural country centered on the equatorial landscape where the longest, longest and most photosynthetic process occurs throughout the year. The

initial product of photosynthesis is glucose which is synthesized from carbon dioxide (CO₂) and water with the help of sunlight in chlorophyll. High rainfall guarantees water availability and the progress of the oxidation process. The process of decomposition in tropical climates occurs at a fast rate so that there is enough CO₂ in the air. With radiation for about 10 hours a day, Indonesia is one of the most productive regions in the world. As a large archipelago, Indonesia also has vast fertile land for the cultivation of sugar-producing crops. Sugar-producing plants that grow and develop well in the tropics include sugar cane, palms (palm, coconut), and beet plants [1].

Sugarcane is a plant used as a raw material in the production of sugar. It has high sweet content on the stem and holds many benefits behind its distinctive sweet taste which are not only in terms of health but from various terms, such as industry, household consumption, agriculture and livestock. This plant consists of a grass that has many types and varieties, ranging from yellow, red, e.t.c. [2]. Sugarcane harvest is not influenced by the season where the harvest is still satisfactory, which is during the transition season [3]. The stalks of sugarcane harvested from plantations are trucked to the factory to be processed into sugar [4].

Sugarcane is a type of plant grown only in areas with tropical climates. In Indonesia, sugarcane plantations have an area around 400 to 500 hectares thousand hectares spread across Medan, Lampung, Solo, Tegal and Mojokerto [5]. Sugarcane as a raw material for the sugar industry is one of the plantation commodities that has a strategic role in the economy in Indonesia. With an area of approximately 415.66 thousand hectares in 2018, the sugar cane industry is a source of income for thousands of sugarcane farmers and workers in the sugar industry [6]. **Figure 1** below shows the conditions of the sugarcane plantation until the sugarcane is ready for harvest. Sugarcane harvesting is carried out by cutting the sugarcane stalks by workers and then preparing the clean sugarcane stalks to be processed into sugar or sugarcane juice with a sweet taste [7].

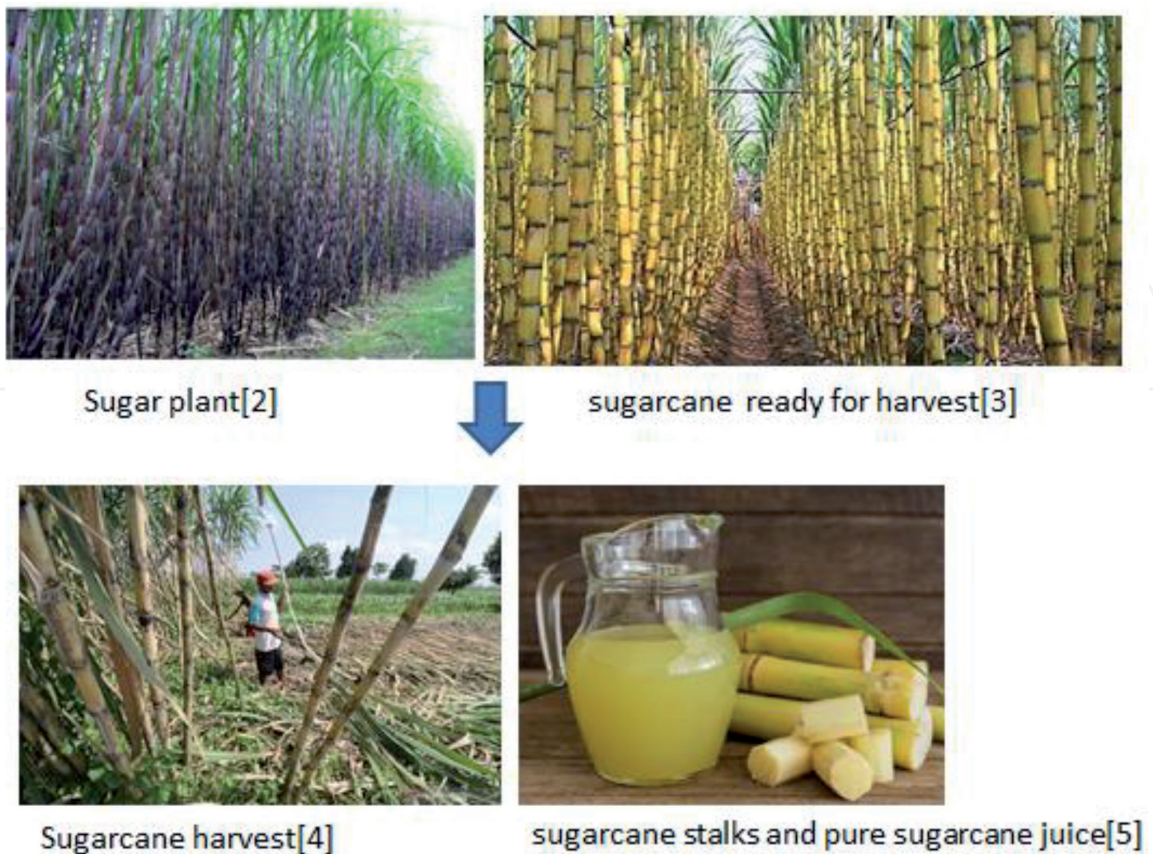


Figure 1.
Sugarcane from plants to consumers.

The main product of sugarcane is its extract which is used as the main ingredient in producing sugar. On a large scale, majority of sugar cane is used in the production of white and brown sugar. Sugarcane that enters the factory must be sugarcane that is ripe or has high brix and pol and is clean from all types of impurities (roots, shoots, dry leaves) [8–10]. Manual fellers, the results are better than sugarcane harvesting machines. Logging covers all parts of the sugarcane. The shoots and leaves are discarded and only the sugarcane stalks are used because what contains sucrose is sugarcane stalks. The cleanliness of sugarcane from manure depends on the skills of felling personnel and the application of felling SOPs in the field. In addition, milled sugarcane must be fresh, fresh sugarcane is sugarcane that is milled for no more than 48 hours [11, 12]. The distribution starts from sugarcane harvested from plantations [13, 14]. Sugarcane loaded onto trucks by humans and machines [15, 16]. And then transported to the sugar factory as shown in the following **Figures 2** and **3** below.

In **Figure 2**, you can see the process of transporting sugarcane, starting from cutting down sugarcane stalks by workers, collecting sugarcane stalks by workers or using grab folders, to transporting them to trucks either by workers or using grab folders. After the sugarcane is loaded into the truck, it is taken to the sugar factory to be processed. The sugarcane that has arrived at the sugar factory will be poured into the mill as shown in **Figure 3** below. The loading of sugarcane into the mill has used a system in such a way that the truck has been facilitated so that it can directly load the sugarcane mill [17, 18].

In **Figure 3**, there are no human workers who move sugarcane stalks to the sugar mill. Inside the factory, the sugarcane stalks harvested from plantations are processed into sugar by undergoing a five-time grinding process, after which it is



Figure 2.
Sugarcane transport to trucks.



Sugarcane arrives at the sugar factory[18]



Sugarcane enters the mill[19]

Figure 3.
Trucks deliver sugarcane to factories.

expelled as bagasse waste [19]. Sugarcane harvesting age from planting to ready harvest is 12 months. Sugarcane is harvested by cutting sugarcane stalks at the bottom and top. Sugarcane of good quality for making sugar must be maintained during harvesting. The following figure shows the process that occurs in a sugar factory to produce sugar and remove the rest of the sugarcane process as bagasse [20–22].

After arriving at the factory, sugar cane is processed into white sugar or brown sugar with factory equipment as shown in **Figure 4** below. The end result of this sugarcane process is the result of sugarcane waste/bagasse [23, 24].

In its production process, sugarcane produces 90% bagasse, 5% molasses and 5% water [25]. The waste obtained from sugarcane during the process of producing sugar is known as bagasse which is used as fuel, material for paper pulp, organic fertilizer and animal feed. Not many industries have developed products made from bagasse. The panel board manufacturing industry and the bagasse fiber-reinforced asbestos-producing industry are the small industries that have started developing bagasse. Sugarcane is a plant used as a raw material in the production of sugar and Monosodium glutamate (MSG) [26–28].

A total of 32% bagasse is produced from the weight of milled sugarcane. It contains cellulose, lignin and hemicellulose compounds which are by-products of the sugarcane extraction process [29, 30]. As seen in the following **Figure 5**, from the observation of plant cell wall macrofibrils, there are three main components, namely lignin, cellulose and hemicellulose. In hemicellulose itself there are pentose and hexose [31–33].

Lignin, which mainly accumulates in plant stems, fills the space in the cell wall between cellulose, hemicellulose and pectin [34, 35]. This substance is present in all vascular plants but not in Bryophytes, which supports the idea that lignin's original function is limited to water transport. Furthermore, as one of the main components in bagasse, lignin is a complex polymer with high molecular weight composed of phenylpropane units which are the main component of wood building blocks. Lignin content is more in softwood compared to hardwood [36–38].

With a ligno-cellulose content, a fiber length of 1.7 to 2 mm and a diameter of about 20 micros, bagasse may actually be used as a raw material in chemical, petroleum, paper, brake canvas and mushroom industries. Therefore, it is economically utilized not only as a source of fuel energy in steam boilers, but also as a raw material for papermaking or a source of animal feed. In general, in Indonesia, sugar factories use bagasse as fuel after it undergoes a drying process. Another consideration used in selecting bagasse is because the sugarcane land is quite large, which is spread from Western to Eastern Indonesia, from North Sumatra, Palembang, Lampung, Java and Sulawesi, hence natural resources are readily available. This is

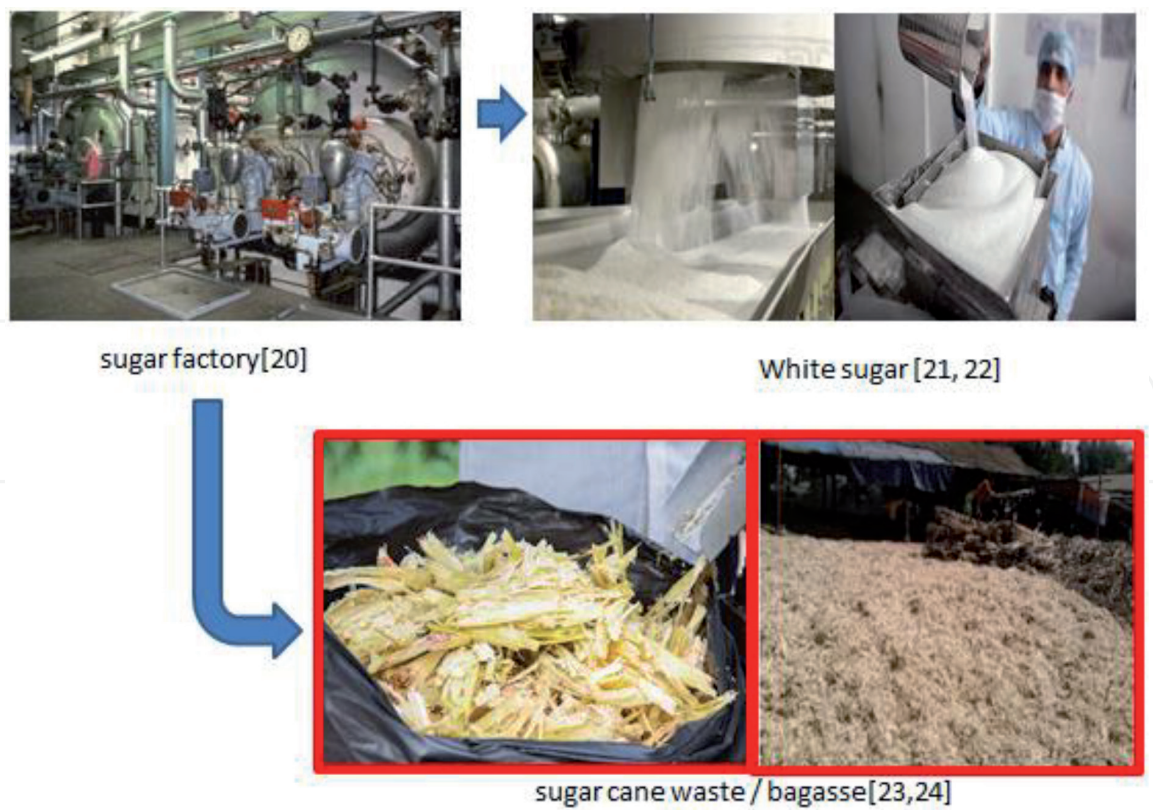


Figure 4.
The production process in a sugar factory.

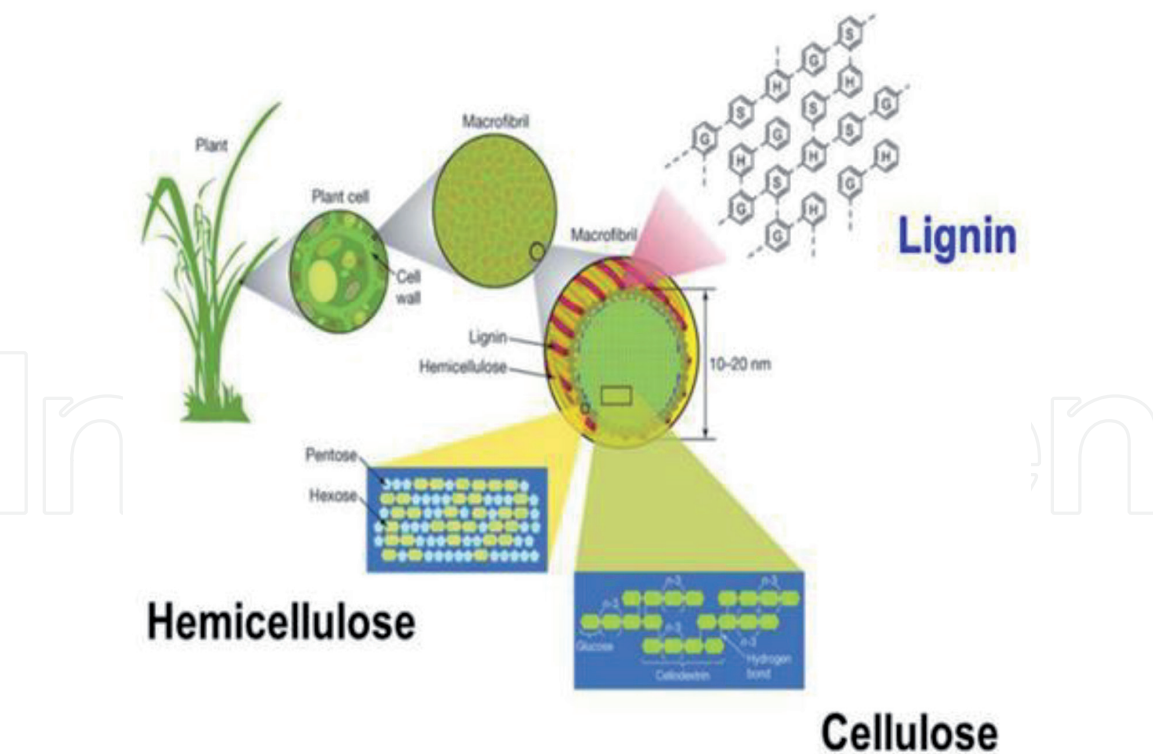


Figure 5.
Structure component of plant biomass [31].

also complemented by a plan of the local government to develop a sugar factory and sugarcane plantation. The development of sugarcane plantations supports the needs of the sugar industry, which in the making process will consequently produce a lot of waste. Each year, the amount of bagasse produced is quite abundant, easy

to obtain, and cheap. Based on data from the Indonesian Sugar Plantation Research Center (P3GI), bagasse is obtained by 32% of milled sugarcane weight or around 10.2 million tons/year or per milled season throughout Indonesia [39, 40]. About 50% of the bagasse produced in each sugar factory is used as boiler fuel and the rest is dumped as waste which has low economic value [41, 42].

2. Methodology

The study method starts from a review of the potentials contained in various sources in general. The lignin content was used to determine the use of bagasse as a surfactant raw material. Several other wastes that also contain lignin, cellulose and hemicellulose are seen in **Table 1** below.

Sources of lignin in **Table 1** are broad petioles, needle stalks, leaves, corn cobs, peanut shells, wheat straw, bagasse, oil palm empty bunches. From the source of lignin, the focus of research is bagasse, because bagasse is sugarcane waste. The focus of this research is only on the bagasse. In **Table 1**, it can be seen that bagasse is a type of waste containing 25% lignin, 25% hemicellulose and 50% cellulose. By processing the bagasse, it can be used as a solution for sugarcane solid waste. Another consideration for the decision to use bagasse is the chemical composition of bagasse. The chemical composition of bagasse consists of ash, lignin, cellulose, extract, pentose and SiO₂. Its chemical composition is shown in **Table 2** below.

Bagasse is a vegetable source that contains large amounts of lignin which is a byproduct of the sugarcane liquid extraction process. This extraction produces bagasse about 32% of milled sugarcane weight Based on chemical analysis, the

No.	Waste	Cellulose (%)	Hemicellulose (%)	Lignin (%)
1.	Broad leaf trunk ⁴¹	40–55	24–40	18–25
2.	Needle leaf trunk ⁴¹	45–50	25–35	25–35
3.	Leaf ⁴²	15–20	80–85	0
4.	Corn cobs ⁴²	45	35	15
5.	Peanut shell ⁴²	23–30	25–30	30–40
6.	Wheat straw ⁴³	30	50	15
7.	Bagasse ⁴³	50	25	25
8.	Palm empty bunches ⁴³	41,30 – 46,50	25,30 – 33,80	27,50–32

Table 1.
Components of lignin in various vegetable wastes.

Content	Level (%)
Ash	3.82
Lignin	22.09
Cellulose	37.65
Extract	1.81
Pentosan	27.97
SiO ₂	3.01

Table 2.
Chemical composition of bagasse [43].

average bagasse has a chemical composition of 3.28% ash, 22.09% lignin, 37.65% cellulose, 1.81% extract, 27.97% pentosan and 3.01% SiO₂. The lignin content of 22.09% is a good potential for bagasse to be processed into lignosulfonates. Most of the content in bagasse is ligno-cellulose which is a natural polymer with high molecular weight that is rich in energy. Therefore, a large amount has the potential of been used as an energy source [43, 44].

One of the determining factors for the success of a livestock business is feed, where more than half of the production costs are used to fulfill feed needs. Therefore, efforts need to be made to ensure that provision of feed is cheap, easy to obtain and not competitive with human needs. Forage is one of the main foods for livestock, but its continuous supply has encountered several obstacles due to the narrow land available for forage cultivation which reduces the availability of feed. One alternative to overcome the problem of feed availability is to utilize agricultural byproducts [45]. According to Sajjad Karimi [46], the by-product of sugarcane milling may be used as animal feed because it is tolerant of summer, resistant to pests and diseases and easily available in the dry season when forage is less available [47]. The utilization of sugarcane as a feed ingredient requires technology because it has high crude fiber and low crude protein content. As a feed, several ingredients need to be added to bagasse in order to complement the mineral requirements needed in the feed material [48–51].

Bagasse waste has the opportunity to be optimally utilized as alternative energy which is beneficial to community needs and is friendly to the environment [52]. Biomass is a material obtained from plants directly or indirectly and is used as energy or materials in large quantities. Furthermore, it is known as “Fitomass” and is often translated as bioresource or resources obtained from living organisms. Biomass may actually be used directly without going through charcoal production first [53]. Sugarcane bagasse is generally used as boiler fuel to produce the energy needed in the sugar-making process which simultaneously produces a large amount of waste. Bagasse fiber is made up of cellulose which contains active carboxyl groups and lignin which contains phenolic groups. Several studies have utilized bagasse as an adsorbent for the removal of Congo Red dye [54] and reduction of iron content in well water [55]. Carbonized bagasse charcoal at 250°C for 2.5 hours [56] is used in the removal of heavy metals such as Pb, Cu, Cr and Cd. Furthermore, the effectiveness of this charcoal absorption has been tested [57] for the remediation of magnesium, manganese, zinc and nitrates in leachate. Based on the analysis result, the effectiveness of this charcoal is higher compared to the use of bagasse fiber. The use of this charcoal to change the characteristics of peat water and improve its quality into clean water has not been reported [58–60]. The adsorption process is one of the efforts made to improve the quality of pray water using bagasse charcoal as an adsorbent. The ability of bagasse biomass is increased by means of carbonization activation [61]. Furthermore, as an energy substitute, bagasse has been studied as bioethanol. From lignocellulosic biomass, ethanol can be produced [62–65]. For example, from bagasse hemicellulocidrolisis, from the study of Canilha et al. reported the following results of 7.5 g / L, 0.30 g /g and 0.16 g/L [66]. The subject of discussion focuses on the characteristics and potential of lignocellulosic biomass, biomass conversion technology to ethanol and its potential development.

Study and development of science and technology in the field of making various composite materials to fulfill various purposes/needs have been widely carried out by educational and industrial circles. This study is reasonable due to the abundant availability of reinforcing fiber raw materials from organic composite reinforcing fibers such as bamboo, pineapple, sugarcane, banana and palm fibers [67] or inorganic reinforcing fibers and the quite high need/demand for processed

composite materials on the market. Baggase fiber is one of the many natural fibers found in Indonesia. Post-harvest activities and processing of agricultural/plantation products, including the use of by-products and their processing residues, are still not optimal. In the sugarcane processing industry, the amount of bagasse produced may be up to 32% of each processed sugarcane. Till date, its use as raw material for the manufacture of particle boards, boiler fuel, organic fertilizers and animal feed is limited and has low economic value. Furthermore, the use of bagasse fiber as a reinforcing fiber for composite materials have very important meaning in terms of the utilization of industrial waste, especially the sugar-making industry in Indonesia which has not been optimized from an economic perspective and the utilization of its processed products. The results of this study are expected to bring new innovations in the development of non synthetic fiber-reinforced composite material technology. Therefore, bagasse fiber may be used as an alternative raw material, because it is easily obtained, almost available in all regions of Indonesia, a plantation crop widely cultivated by many farmers in Indonesia, more environmental friendly, a natural fiber and easier to process.

Bagasse is organic waste which is produced in many sugarcane processing factories in Indonesia. Bagasse is easy to obtain, does not endanger health and can be decomposed naturally (biodegradability). Therefore, the use of composite reinforcing fibers will be able to overcome environmental problems [68].

Several studies have also demonstrated the feasibility of using pre-treated bagasse at high consistency conditions to produce ethanol with a theoretical yield approaching 65% [69]. The production of bioethanol from bagasse can be obtained by engineering the evolution of the super active fermentation yeast *Saccharomyces cerevisiae* through the suppression gene deletion process. This may have detrimental effects on fermentation and the overexpression of all metabolic pathways for the fermentation of glucose, xylose, arabinose sugars and processes for higher tolerance to inhibitors [70]. There are many benefits that may be obtained from bagasse waste as shown in the following table (**Table 3**).

More study efforts are needed in relation to the use of bagasse as another product with more value, as shown in the following figure. In this **Figure 6**, it can be seen that the use of bagasse is applied to four major parts, namely for energy, biochemicals, food and materials. As an energy use, bagasse is used as charcoal, pellets, biogas, bioethanol, heat and electricity. As a biochemical, bagasse can be made for biopylomers, vanillin, enzymes, xylitol and furfural. Meanwhile, for food needs, bagasse can be made as protein, animal feed, fertilizer, soil conditioner. And finally, for material needs, bagasse can be used as an adsorbent, construction, textile fiber, boards and paper.

No.	Application	Reference
1.	Bagasse charcoal	[57, 61]
2.	Adsorbent	[55, 56]
3.	Organic composite reinforcement	[68, 71]
4.	Biomass	[53, 67]
5.	Animal feed	[46–52]
6.	Bioethanol	[69, 70]
7.	SLS surfactant	[72, 73]

Table 3.
Results of the study carried out on the benefits of this waste.

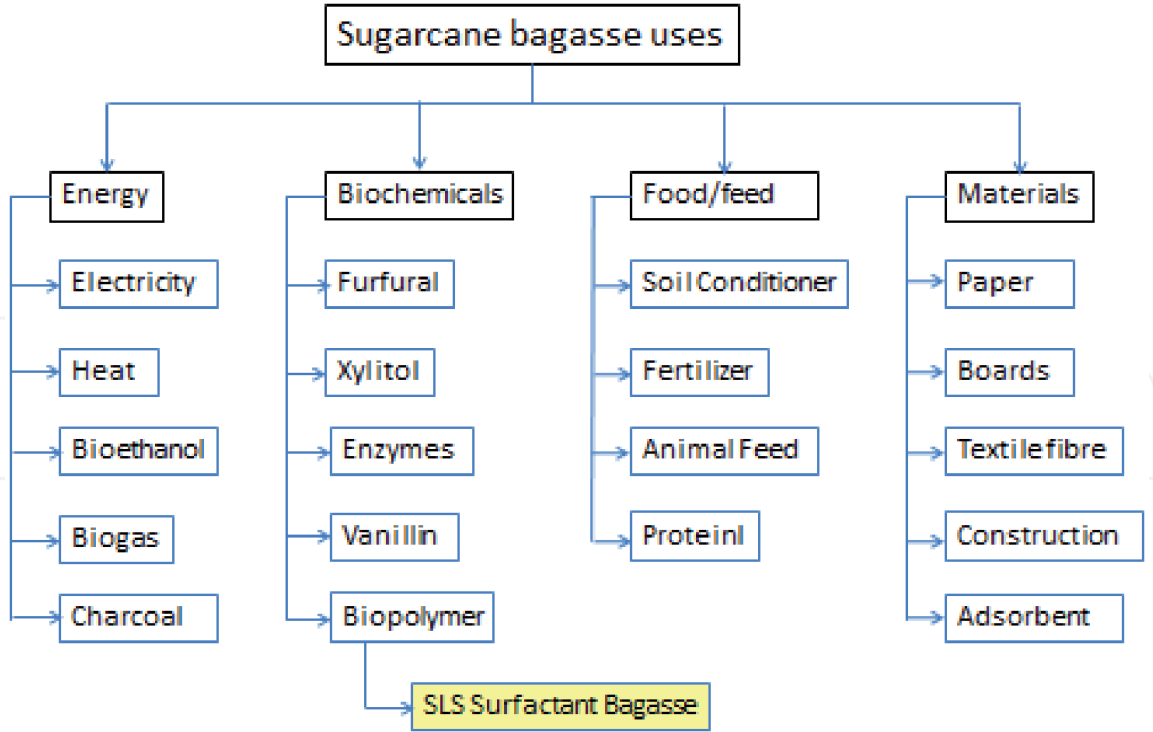


Figure 6.
Bagasse utilization diagram [74].

Several previous studies also stated that bagasse is a fiber containing cellulose with an active carboxyl group and lignin with a phenolic group. This research was conducted by Collepari [72] and Setiati [73], processing bagasse into surfactant sodium lignosulfonate. This research is the manufacture of biopolymers which is part of biochemistry due to the large amount of lignin contained in bagasse. According to previous studies, the lignin content in bagasse was 25% as shown in **Table 1** above [75]. This type of surfactant is used as a raw material for fluid injection in oil fields to increase petroleum production. **Figure 6** above shows the position of the SLS surfactant bagasse synthesis which is part of the biopolymer.

The hoarding of bagasse as waste for a certain time cause problems, because this material is flammable, pollutes the surrounding environment and takes up a large area for storage [76]. So that this waste must be handled properly, by using it into other products.

The four main categories of bagasse application are currently being studied and utilized by the community. Various exploitation efforts continue to be made to minimize bagasse because sugarcane plantations and sugar factories are still developing [77]. Therefore, technological developments are still needed in processing and utilizing bagasse.

3. Results and discussion

One of the uses of bagasse is as a biopolymer, which is processed into Sodium LignoSulfonate (SLS) surfactant. SLS surfactant is an anionic surfactant, a type of surfactant that is widely used in the surfactant injection process in oil reservoirs. The function of this surfactant is to form a middle phase emulsion so that there is a decrease in interfacial tension (IFT) between the oil in the reservoir and the oil that sticks to the rock because it is difficult to move [78, 79]. With the availability of surfactants, the interfacial tension is low so that oil can be easily produced. The remaining oil in the reservoir can be removed and produced to increase oil recovery.

Processing of bagasse into SLS surfactant is carried out through two processes, namely hydrolysis and sulfonation [80–82]. Hydrolysis is the separation of lignin from bagasse by using a sieve analysis to obtain a size of 80 mesh. The lignin obtained is reacted with a sulfonation process using sodium bisulfite reagent to obtain sodium lignosulfonate surfactant [83]. The following figure shows the complete process from bagasse synthesis to SLS surfactant.

The synthesis process shown in **Figure 7** begins with the process of isolating lignin from bagasse. This process uses NaOH as a reagent, by heating for 5 hours at a temperature of 100°C. Then titrated using H₂SO₄ until a precipitate appears then filtered and dried, to become lignin. The lignin formed is then processed into lignosulfonate surfactants by a sulfonation process using NaHSO₃ as a reagent, reflux for 5 hours at a temperature of 150°C. As a result, it is dried to become lignosulfonate powder.

Lignosulfonates are lignin derivatives containing sulfonates that have hydrophilic groups which include sulfonate groups, phenyl hydroxyl and hydroxyl alcohol and hydrophobic groups (carbon chains) [84]. Therefore they are included in the anionic surfactant group.

The SLS surfactant produced from the synthesis of bagasse was tested for the components which it contains, using the FTIR (Fourier Transform Infra-Red) test. Tabulation of FTIR test results is seen in the following **Table 4**. Graph of FTIR test results can be seen in **Figure 8**.

From the **Figure 8** below, it is observed that the four clearest peaks show the absorption peak at wave number 1635.34 cm⁻¹ as the stretching vibration region of alkene functional group –C=C– aromatic, wave number 1384.64 cm⁻¹ as the stretching vibration region of sulfonate functional group S=O, wave number 1114.65 cm⁻¹ as the bending vibration region of carboxylate functional group C=O and wave number 462,832 cm⁻¹ as the bending vibration region of ester functional group S-OR.

The results of FTIR test showed that the lignosulfonate formed has components of alkenes, sulfates, carboxylic acids and esters. The synthesized SLS surfactant

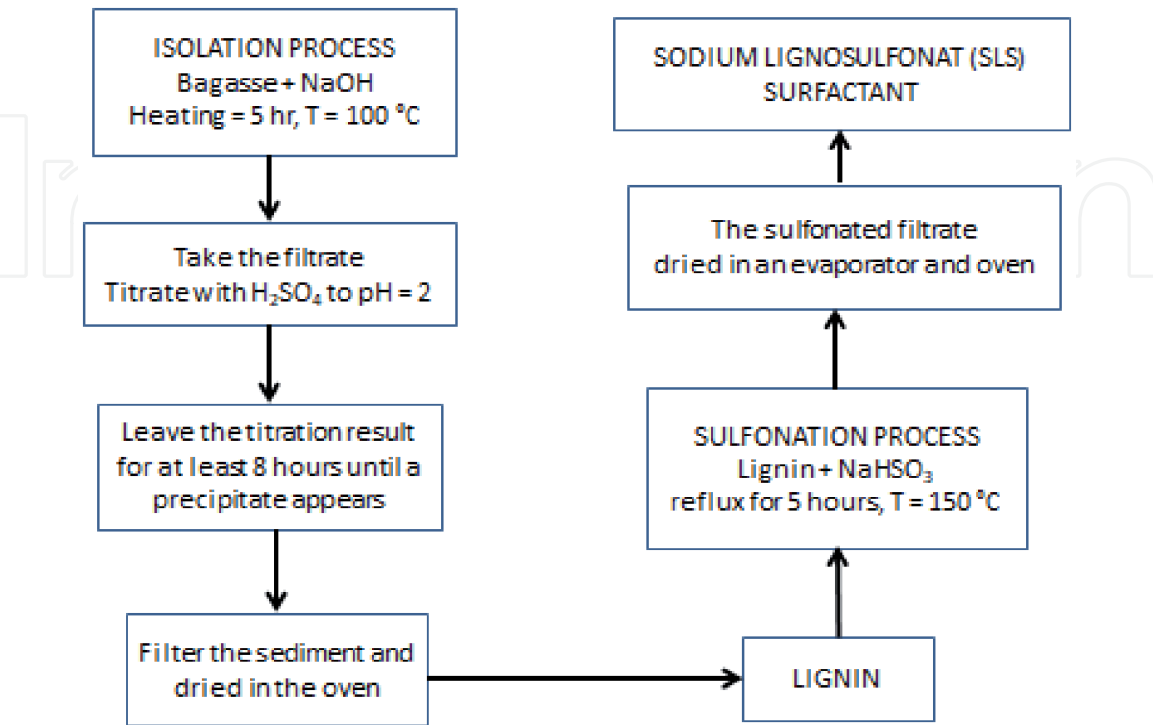


Figure 7.
Synthesis process of SLS surfactant from bagasse [73].

No.	Component	Wave number(cm^{-1})
1.	Alkene C=C	1635.34
2.	Sulfonate S=O	1384.64
3.	Carboxylic Acids C=O	1114.65
4.	Ester S-OR	462.832

Table 4.
Spectrum of FTIR results of lignosulfonate from bagasse.

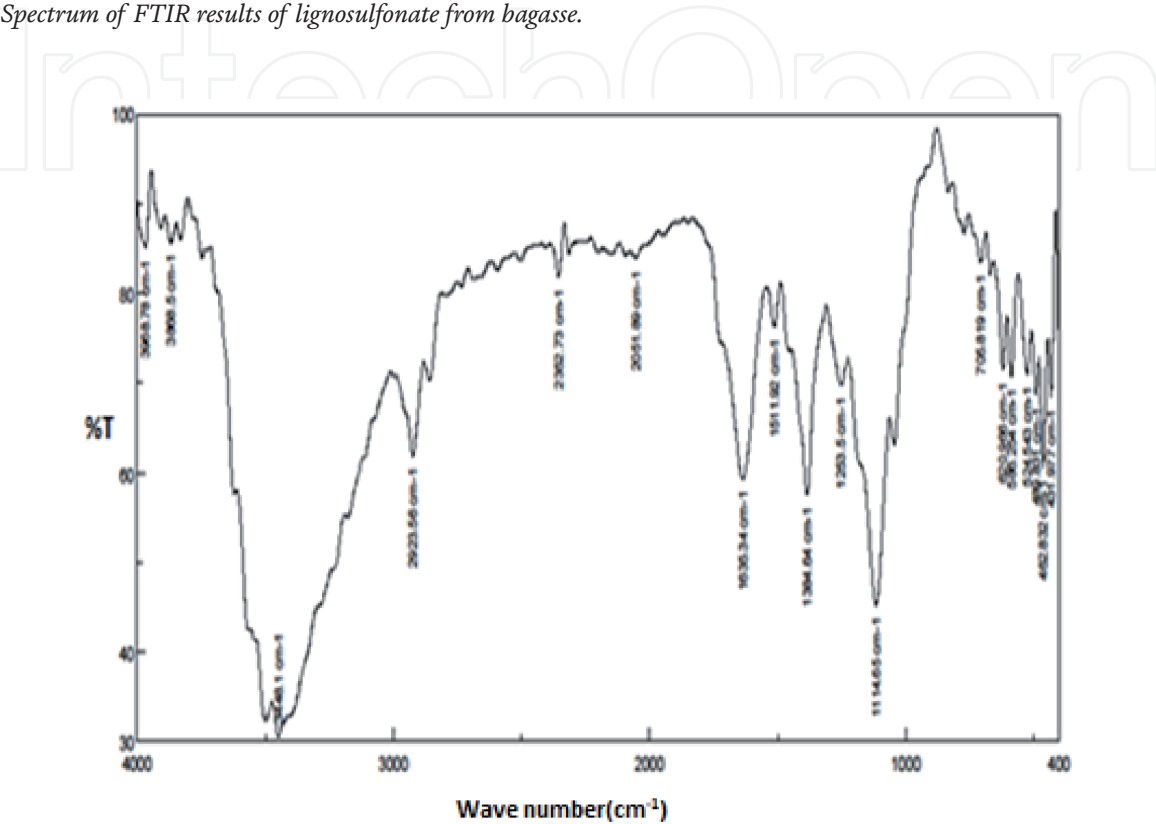


Figure 8.
FTIR test curve of SLS surfactant bagasse.

was compared to a commercial lignosulfonate surfactant, namely Patricia lignosulfonate. This surfactant consists of an alkene component with a wave number of $1630\text{--}1680\text{ cm}^{-1}$, a sulfonate group with wave number of 1350 cm^{-1} , Carboxylic acids with wave number of $1000\text{--}1300\text{ cm}^{-1}$ and an ester with wave number of $500\text{--}540\text{ cm}^{-1}$ [85]. Compared to commercial lignosulfonate, SLS surfactant bagasse has a constituent component which is exactly the same as the comparator commercial lignosulfonate. There is only a slight difference in the absorption peak wave number detected, for example the alkene on SLS surfactant bagasse is 1635.34 cm^{-1} , which is still in the range of comparator lignosulfonate wave numbers of namely $1630\text{--}1680\text{ cm}^{-1}$. Meanwhile, the sulfonate element in SLS surfactant bagasse is at a wave number of 1384.64 cm^{-1} , shifted slightly to the left compared to commercial lignosulfonate which has a sulfonate wave number of 1350 cm^{-1} , which indicates that this deviation only occurs by 2.56%. Furthermore, the carboxylic acids component with a wave number of 1114.65 cm^{-1} is still in the comparator lignosulfonate range, namely $1000\text{--}1300\text{ cm}^{-1}$, while the last element (ester) provides a measurement result that deviates slightly to the right. Based on the results from the measurement of SLS surfactant bagasse, the ester is at a wave number of $462,832\text{ cm}^{-1}$, while the comparator lignosulfonate has a wave number between 500 and 540 cm^{-1} . The deviation that occurs in this element is 7.4%.

The other indicator for the success of SLS surfactant bagasse as a raw material for surfactant injection in the EOR process may be seen from the HLB (Hydrophilic–Lipophilic Balance) value. HLB determination was used to determine the classification of the surfactant. The Myers table was the standard HBL value used in which the emulsion-forming fluid has an HLB value of 8–11 [86]. The components that needed to be known were the lipophilic and hydrophilic groups. This component is known from the atomic element which is measured based on the NMR (Nuclear Magnetic Resonance) test.

Based on the NMR spectrum analysis of the SLS surfactant bagasse sample, it turns out that the atomic number of C = 11, O = 8, H = 16 and S = 1. The molecular mass of the lignosulfonate monomer may be determined by looking at the presence of C, O, H and S atoms in their structure. Therefore, the empirical formula of the lignosulfonate monomer is $(C_{11}H_{16}O_8S)_n$, with a relative molecular mass of 308.06.

Furthermore, based on the NMR analysis, it is easy to identify which groups are classified as hydrophilic or lipophilic. The Lipophilic group consists of the elements ($=CH-$, $-CH_2-$, $-CH_3$), while the hydrophilic group consists of the elements ($=SO_3Na$) and $(-OH)$ elements. The grouping is seen in the **Table 5** below.

Based on the number of lipophilic and hydrophilic element atoms, this HLB value may be calculated using the equation as follows:

$$HLB = 20 * (M_h) / (M_l + M_h) \tag{1}$$

Where: M_h = the molecular weight of hydrophilic group.
 M_l = the molecular weight of the lipophilic group

$$M_h = (SO_3Na) + (OH) \times 3 = (32 + 48 + 23) + 51 = 154 \tag{2}$$

$$M_l = (CH) \times 3 + (CH_2) \times 3 + (CH_3) \times 2 = 111 \tag{3}$$

$$HLB = 20 * (M_h) / (M_l + M_h) = 20 * 154 / (111 + 154) = 11.62 \tag{4}$$

The result calculation, SLS surfactant bagasse has an HLB value of 11.62. Therefore, based on **Table 6**, it is suitable for use in the O/W (oil in water) emulsion type system, which means that the surfactant is soluble in water [86].

Furthermore, the HLB value was determined empirically with a scale of 0–20, as shown in **Table 6** below. The higher the HLB value, the more hydrophilic the surfactant and the more soluble it is in water, or known as an O/W (Oil in Water) emulsion. Meanwhile, lower HLB value indicates that the surfactant is a W/O

Classification	Group	Number
Lipophilic Groups	=CH-	3
	-CH ₂ -	3
	-CH ₃	2
Hydrophilic Groups	-SO ₃ Na	1
	-OH	3

Table 5.
Grouping of bagasse NaLS surfactant functional groups.

HLB Value Range	Application
2–6	W/O emulsion
7–9	Wetting agent
8–18	O/W emulsion
3–15	Detergent
15–18	Solubilization

Table 6.
HLB value and its application [86].

(Water in Oil) emulsion, which will be more soluble in oil [86, 87]. Surfactants are usually amphiphilic organic compounds, which contain hydrophobic (tail) and hydrophilic (head). In addition, they spread in water and absorb at the interface between air and water or at the interface between oil and water.

Therefore, this SLS surfactant bagasse may be used as an injection fluid because it forms an O/W emulsion and is dissolved in water. In accordance with the injection mechanism, the surfactant is dissolved in the formation water and is injected into the reservoir to push the oil trapped in the rock pores. So, SLS surfactant bagasse has the potential of been used as a surfactant injection in the enhanced oil recovery process.

4. Conclusions

Based on studies conducted on bagasse and its application as a new, more useful product, it appears that the lignin content in bagasse has the potential to be processed into sodium lignosulfonate (SLS) surfactant. This SLS surfactant functions as an injection liquid to increase oil recovery. The laboratory test results corroborate these claims, which show that bagasse SLS surfactant as lignosulfonate has four main components, namely alkenes, sulfonic acids, carboxylic acids and esters. Furthermore, it has an HLB ((Hydrophilic–Lipophilic Balance) value of 11.62 which indicates that it functions as an emulsifier that dissolves in water and forms a surfactant solution. SLS surfactant bagasse forms an emulsion and reduces interfacial tension (IFT), so that oil granules are easier to produce. So it can be concluded that bagasse has good potential to be used as raw material for lignosulfonate surfactants.

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