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# The Effect of Absorbent Type on Scrubber to Reduce Tar in Syngas

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**ABSTRACT**

Biomass Gasification is an attractive renewable energy technology. Biomass waste, as well as a renewable energy source and also, could be used as raw material to produce syngas. Nevertheless, the biomass is containing tar. The downdraft gasifier is considered to produce less tar, however, the syngas still containing tar which makes blocking and fouling of engines. Therefore, reducing tar is needed, one of them using a wet scrubber that is technically and economically viable to obtain clean syngas. Wet scrubber using absorbent to make absorption. This paper investigated the effect of variations on the type of absorbent in the scrubber to reduce tar in syngas. The absorbent used is vegetable glycerine food grade as a solvent and coconut shell charcoal with a mesh of 10-20 as a packing material. There are two variations of absorbent. Firstly, using only vegetable glycerine food grade and the second using vegetable glycerine food grade and coconut shell charcoal. Each variation was given a vegetable glycerine food-grade discharge of 31.5 ml/s. The results showed that variations in the absorbent of vegetable glycerine food grade and coconut shell charcoal resulted in higher tar removal rates is 100% in Acids, 51.88% in Furans, 65.04% in Alcohols, 35.12% in Ketones.

## 1. Introduction

Biomass has attractive renewable resources to be an alternative energy source for replacing or substituting fossil fuel which has depleted fast year to year. However, biomass is a low-level energy fuel to increase the energy using innovative thermochemical processes such as gasification and pyrolysis [1]. Gasification is an attractive renewable energy technology because it is relatively simple and economical [2]. The gas produced from gasification is called syngas or synthetic gas, which is a mixture of carbon monoxide, hydrogen, and methane, along with carbon dioxide and nitrogen [2]. The gasification process has trough four stages, that is drying, pyrolysis, oxidation, and reduction. Volatile release and tar formation occur in the pyrolysis step [3].

Tar formed from the high molecular weight hydrocarbons in impurities of the organic type present in the syngas that refractory and their removal by the various processes like catalytic, thermal, or physical, is challenging [4]. Tar can condense or polymerize into more complex structures

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in exit pipes, heat exchangers or on particulate filters [5]. Therefore, could cause erosion of metallic components, alkali metals cause metal corrosion at high temperatures, nitrogen bound to fuel forms NOx during combustion which all will makes blocking and fouling of engines. While sulphur and chlorine producing harmful pollutants for humans and acid corrosion of metals [6]. Reduce tar is needed to affect the success of the syngas application [7]. There are many mechanism methods such as scrubber, filter, cyclone and electrostatic precipitator to reduce tar. And the wet scrubber is widely regarded as an effective method for reducing tar and other contaminants [8].

Wet scrubbers reduce pollutants from syngas streams by bringing the syngas stream into contact with the scrubbing liquid. The gas stream is sprayed with the liquid, by forcing it through a pool of liquid, or by some other contact method such as packing material. Wet scrubbers that reduce syngas pollutants namely absorbent [9]. In general, water is used as a solvent absorbent but the hydrophobic characteristic of water shown low solubility of tar compounds [7]. Oil absorbents has high performance to tar absorption mediums at higher than 60% tar reduce compared to water, which can only remove hydrophilic tar compounds and only 38.9% hydrophobic tar compounds [10]. Gas and liquid velocity, and specific surface area to reduce tar could be affect the tar reduce efficiency [11].

In this work, the gasification process in the downdraft gasifier will investigate the effect of variations on the type of absorbent in the scrubber to reduce tar in syngas. The absorbent used is vegetable glycerine food grade as a solvent and coconut shell charcoal as a packing material. There are two variations of absorbent. Firstly, using only vegetable glycerine food grade and the second using vegetable glycerine food grade and coconut shell charcoal. The effect of variations on the type of absorbent in the scrubber was analysed by GC-MS (Gas Chromatography-Mass Spectrometry).

## 2. Materials and Methods

This experiment used a downdraft gasifier and the feedstock used is wood pellets. Each variation in this research uses 25 kg of wood pellets. The characterizations of wood pellets are shown in Table 1. The proximate test was performed using the ASTM D7582-12 standard and for the ultimate test at BPPT, PTSEIK.

**Table 1**
The proximate and ultimate analysis of wood pellet

| | % |
|---|---|
| Proximate analysis | |
| Moisture Content | 8,9 |
| Volatile Matter | 77,63 |
| Ash | 5,24 |
| Fixed Carbon | 8,24 |
| Ultimate analysis | |
| C | 48,10 |
| H | 6,11 |
| N | 0,20 |

The downdraft gasifier was made from stainless steel with a capacity of 10 $m^3/h$. The gasifier temperature was set at 400 °C and kept for 30 min before the gasifier fills with wood pellets. When the feedstock finish is supplied into the gasifier, the gasification process was producing syngas. The syngas flows to the gas cleaning unit, namely the cyclone heat exchanger, and will continue into the scrubber. The schematic of each type of gas cleaning unit used in this paper is shown in Figure 1.

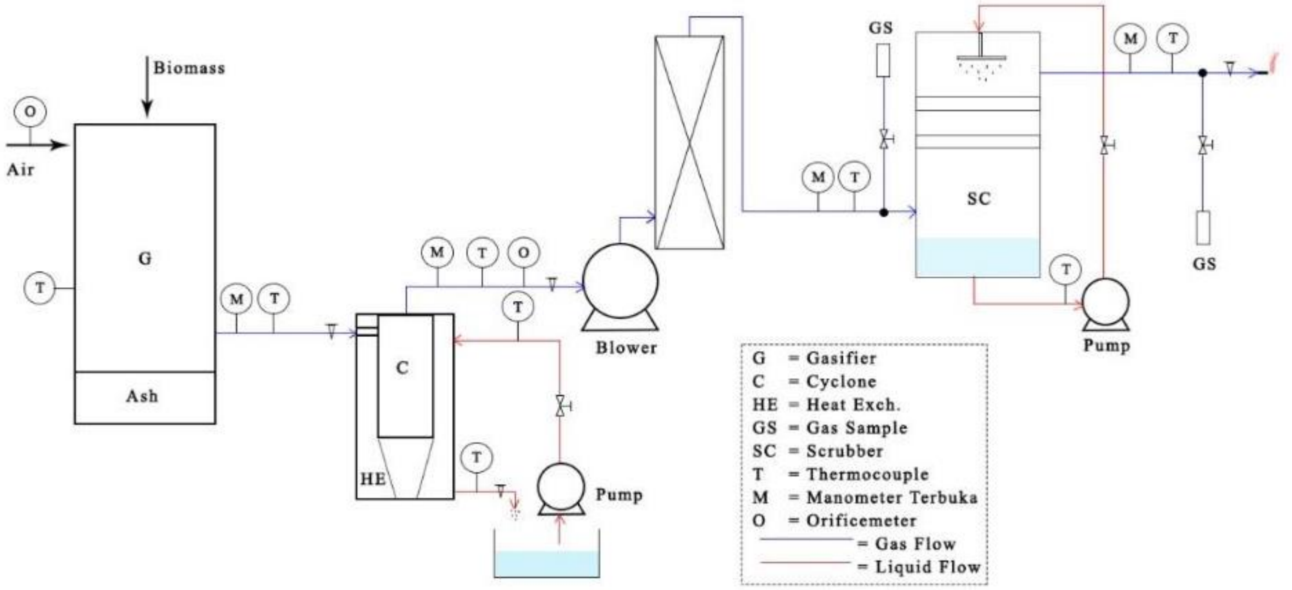


**Fig. 1.** The process scheme of the experimental setup

The scale of the wet scrubber used is 20 cm x 30 cm and 80 cm in height. The wet scrubber consists of a tray column and a packed column. The experimental study was carried out at two variations of the absorbent type. The absorbent used is vegetable glycerine food grade as a solvent and coconut shell charcoal with a mesh of 10-20 as a packing material. The first variation using only glycerol and the secondary uses glycerol and coconut shell charcoal. Glycerol was sprayed from the top of the packed bed. In each variation, a glycerol discharge of 31.5 x 10-6 $m^3$/s will be given. While the height of the packed bed for the second variation is 1.5 cm.

The methods for the sampling and analysis of tars is trapping the tar by condensation on cold surfaces or filters, by absorption in a cold organic solvent with impinger bottles [5]. The sampling of tars analysed using GC-MS. The sampling was located at the entrance and exit of the scrubber as shown in Figure 1.

## 3. Results and Discussions

### *3.1 Gasification Process Without Scrubber*

Figure 2 presents the results of the GC from syngas without a scrubber. The syngas dominant containing CO with the value of 18.939%. CO occurs due to incomplete combustion. One of the causes of the high CO value is tar in the syngas. Tar formed due to the high moisture content in the biomass. Values of 5-10% moisture content are generally acceptable for the pyrolysis process in gasification [9]. Even though the moisture content of the pellets is 8.9%, the Moisture content will be evaporating during the gasification process then condenses into a bio-oil product or commonly called tar.

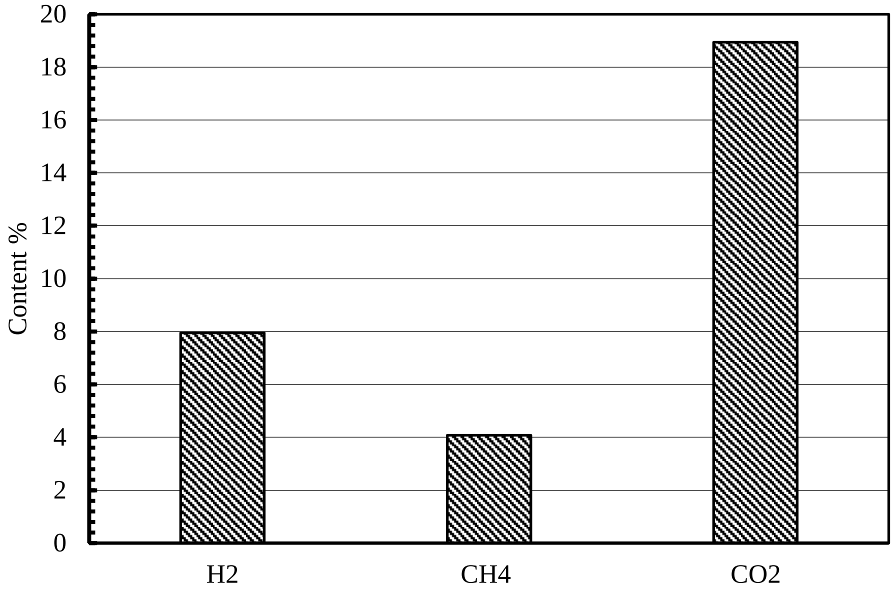


**Fig. 2.** Gasification gas content

### *3.2 The Effect of Glycerol as Absorbent on Scrubber to Reduce Tar in Syngas*

In this study, the result from GC-MS has several impurity compounds that couldn't be correctly identified. The % area value for each compound indicates the content value in the tar sample. The known compounds are grouped according to the type of tar. The reduction of tar in the syngas is shown through a removal rate table. To determine the removal rate, we used following equations:

$$Removal\ Rate\ (\%) = \frac{(Area\ (\%)\ without\ Scrubber - Area\ (\%)\ with\ Scrubber)}{(Area\ (\%)\ without\ Scrubber} \times 100 \quad (1)$$

Table 2 shows the removal rate of the chemical composition of tar compounds on the variation of only glycerol. In the type of acid compounds, scrubbers could reduce all up to 100%. The removal rate for furans compounds was only able to reach 3.47% while in alcohols up to 9.97%. Ketones compounds could be reduced up to 24.47% and phenols up to 11.71%.

**Table 2**
List of tar compounds in syngas from variation glycerol on scrubber

| Tar Compounds | Area (%) | | Removal Rate (%) |
|---|---|---|---|
| | Without Scrubber | With Scrubber | |
| Acids | 16,19 | 0 | 100 |
| Furans | 10,67 | 10,3 | 3,47 |
| Alcohols | 15,24 | 16,76 | -9,97 |
| Ketones | 19,98 | 15,09 | 24,47 |
| Phenols | 20,06 | 17,71 | 11,71 |

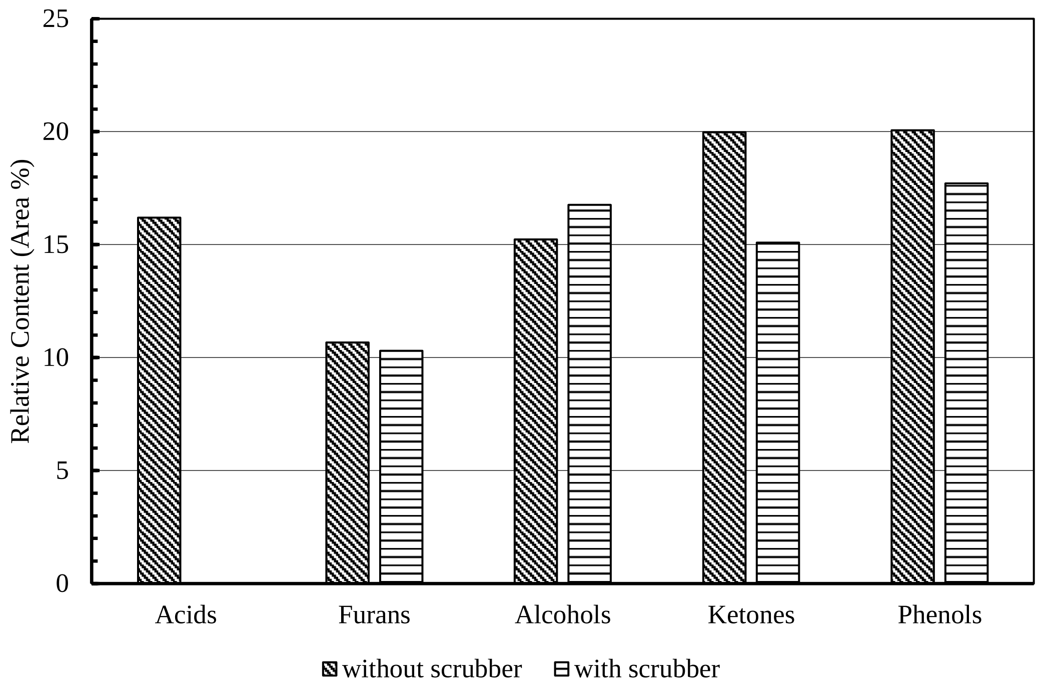


**Fig. 3.** Graph of Comparison of chemical composition groups from variation glycerol on scrubber

The difference in the atomic number of carbon (C) is shown in Table 3. C2 almost completely reduction up to 92.89%. in C3, C7, and C8, the variation of used only glycerol couldn't reduce it even increasing by 33.09%, 9.24%, and 16.81%. C4 completely reduced to 100%. Whereas, in C5 and C6, reduced up to 19.76% and 74.65%.

**Table 3**
List of atom number in syngas from variation glycerol on scrubber

| Carbon Atomic Number | Area (%) | | Removal Rate (%) |
|---|---|---|---|
| | Without Scrubber | With Scrubber | |
| C2 | 14,2 | 1,01 | 92,89 |
| C3 | 6,92 | 9,21 | -33,09 |
| C4 | 1,09 | 0 | 100 |
| C5 | 34,86 | 27,97 | 19,76 |
| C6 | 15,62 | 3,96 | 74,65 |
| C7 | 6,06 | 6,62 | -9,24 |
| C8 | 3,39 | 3,96 | -16,81 |

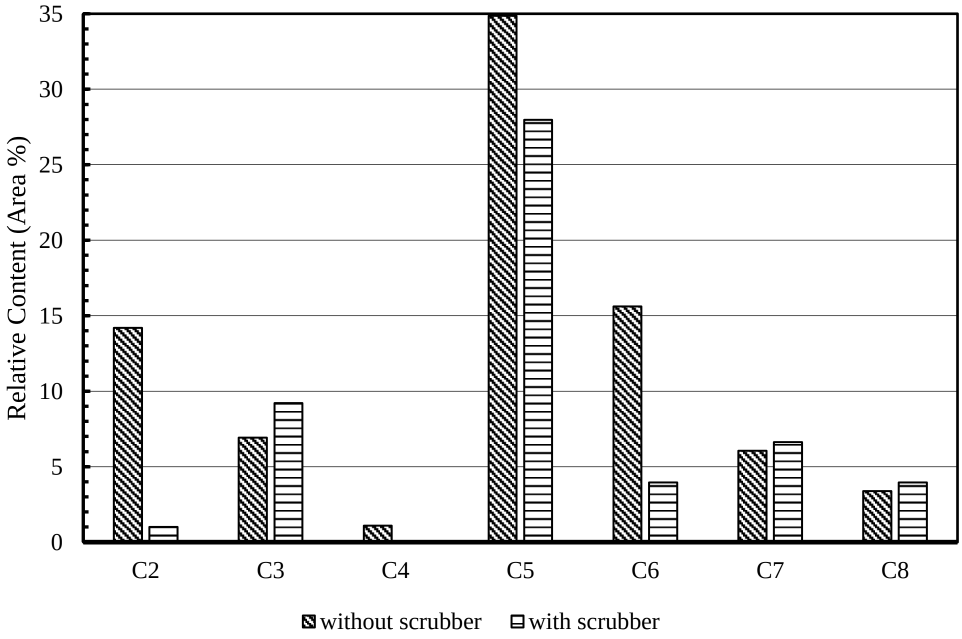


**Fig. 4.** Comparison graph of carbon atomic number (C) from variation glycerol on scrubber

### *3.3 The Effect of Glycerol and Coconut Shell Charcoal as Absorbent on Scrubber to Reduce Tar in Syngas*

Table 4 shows the removal rate of tar on variations of glycerol and coconut shell charcoal. In the acid compounds, these absorbent variations are also able to reduce up to 100%. The removal rate for furans, alcohols, ketone compounds was higher than variation glycerol on scrubber, these are reaching 51.88%,65.04%, and 35.11%. Meanwhile, phenols increased by 4.40%.

**Table 4**
List of tar compounds in syngas from variation glycerol and coconut shell charcoal on scrubber

| Tar Compounds | Area (%) | | Removal Rate (%) |
|---|---|---|---|
| | Without Scrubber | With Scrubber | |
| Acids | 13,72 | 0 | 100 |
| Furans | 14,59 | 7,02 | 51,88 |
| Alcohols | 19,51 | 6,82 | 65,04 |
| Ketones | 18,14 | 11,77 | 35,12 |
| Phenols | 21,58 | 22,53 | -4,40 |

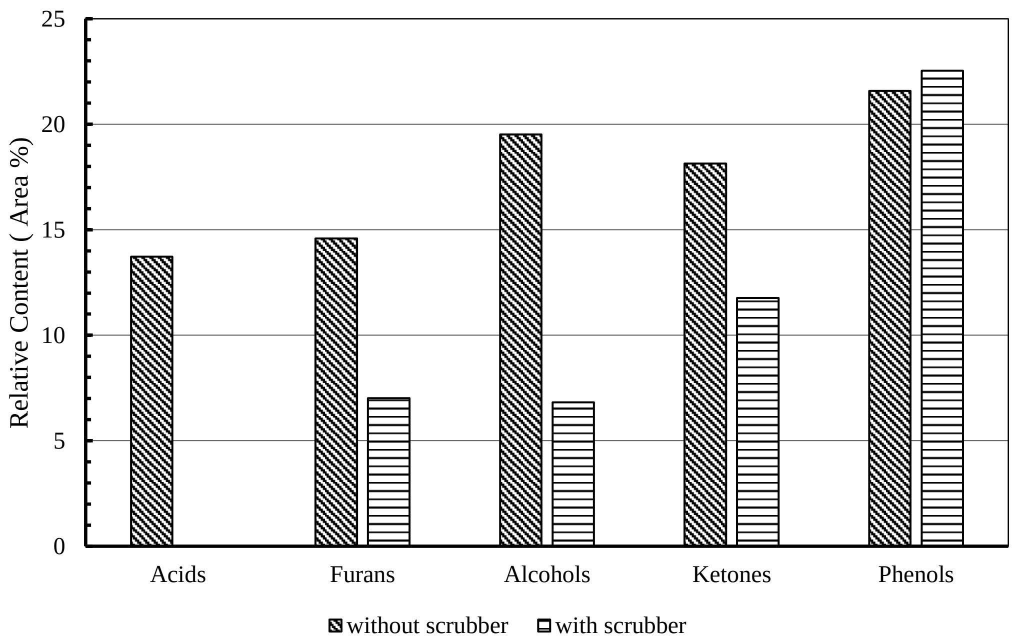


**Fig. 5.** Graph of Comparison of chemical composition groups from variation glycerol and coconut shell charcoal on scrubber

The difference in the carbon atomic number (C) in the absorbent variation of glycerol and coconut shell charcoal is shown in Table 5. At C2 the scrubber was able to completely reduce up to 100%. At C3-C7 the scrubber could reduce to 69.72% at C3, 67.56% at C4, 35.12% at C5, 70.05% at C6, and 25.40% at C7. Nevertheless, the C8 variation of glycerol did not reduce it, it increased by three times, namely 351.78%.

**Table 5**
Differences in the carbon atomic number (C) in the variation of glycerol absorbent and coconut shell charcoal

| Carbon Atomic Number | Area (%) Without Scrubber | With Scrubber | Removal Rate (%) |
|---|---|---|---|
| C2 | 11,03 | 0 | 100 |
| C3 | 5,02 | 1,52 | 69,72 |
| C4 | 6,32 | 2,05 | 67,56 |
| C5 | 33,97 | 22,04 | 35,12 |
| C6 | 23,04 | 6,9 | 70,05 |
| C7 | 5,63 | 4,2 | 25,40 |
| C8 | 2,53 | 11,43 | -351,78 |

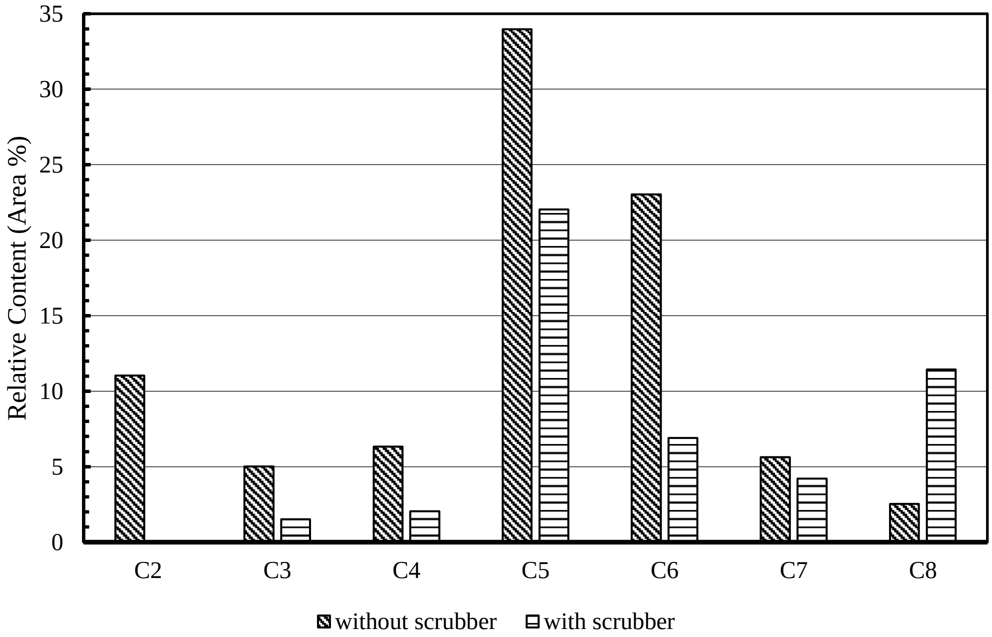


**Fig. 6.** Comparison graph of carbon atomic number (C) on variation of glycerol absorbent and coconut shell charcoal

### *3.4 Tar Analysed*

Glycerol is a non-polar (hydrophobic) compound, so it will affect the dissolved compounds. Alcohols and phenols are polar (hydrophilic compounds) which tend to release H+ ions from their hydroxyl groups. Therefore, the solubility of alcohol and phenol in glycerol is low and almost insoluble. In the variation of glycerol, the alcohol increased by 9.97% but the presence of coconut shell charcoal could reduce the alcohol content to 65.04%.

In addition to the polarity factor, tar compounds easily dissolve at low temperatures due to their high density, viscosity, and surface tension. The solvent temperature affects tar reducing efficiency significantly by influencing the viscosity of the solvent and consequently mass transfer coefficient [8]. The higher the temperature of the solvent, the lower the viscosity of the solvent, then the rate of glycerol in the scrubber being faster. This makes contact between the gas and glycerol is rapid. Similarly, contact with charcoal will expand the surface area. In the variation of glycerol, the temperature of glycerol increasing, this is what affects the increase in the alcohol value up to 9.97%. Charcoal could make the pressure drop value lower. The lower the pressure drop will be more efficient the scrubber to reduce tar. The results show the variation of glycerol and coconut shell charcoal has a higher tar removal.

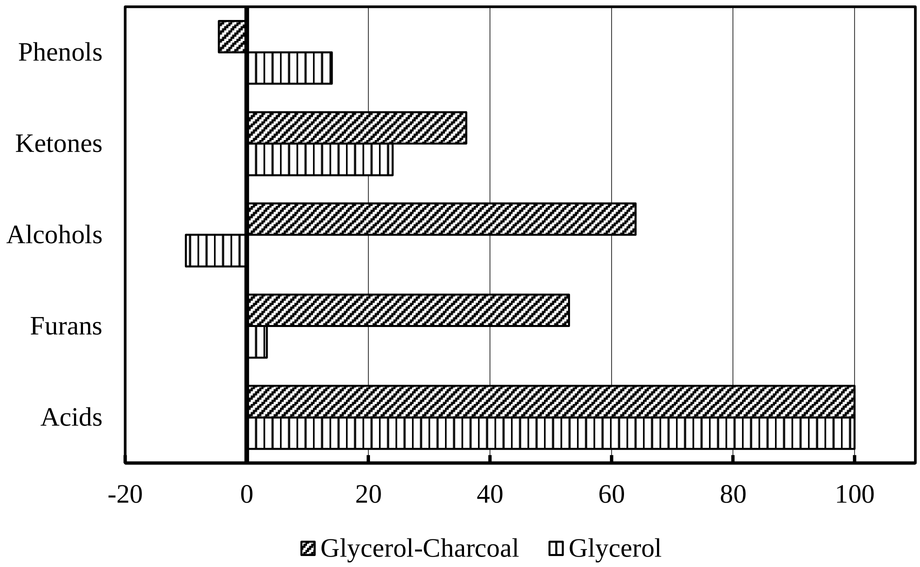


**Fig. 7.** Comparison of chemical composition groups

The shorter the value of carbon or simple chain hydrocarbon compounds, the easier and faster to burn. It is known that both variations of absorbent can reduce the carbon value. In Figure 8 variation of glycerol and coconut shell charcoal produce a high removal rate value compared to glycerol. Whereas in both variations, C8 is increasing. C7-10 itself is a derivative of lignin compounds. Where lignin compounds are insoluble in most organic solvents [12]. In the variation of glycerol and charcoal the C8 value is very high.

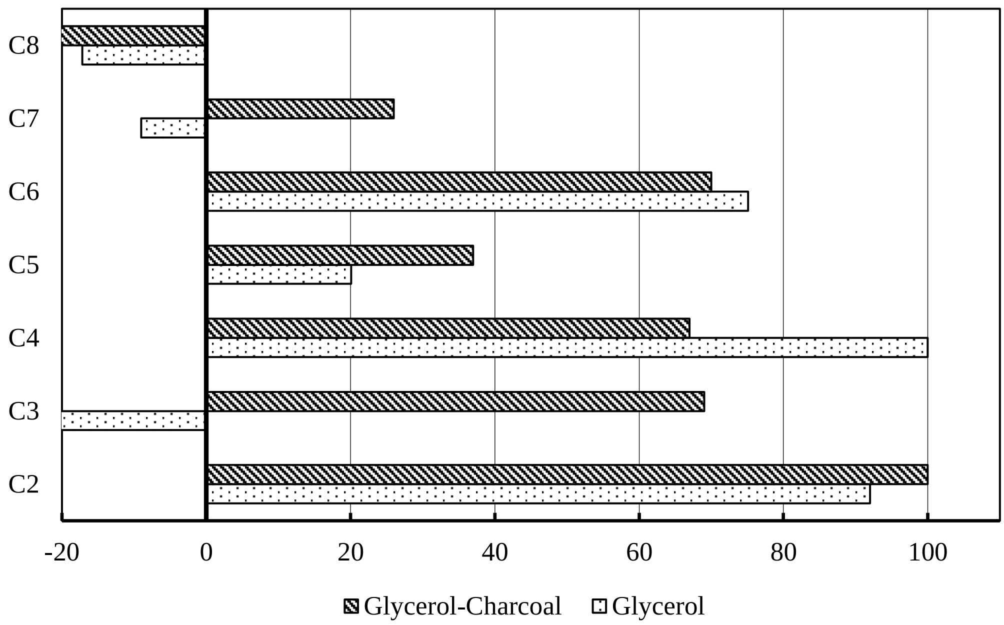


**Fig. 8.** Comparison of the difference in the atomic number of carbon (C)

## 4. Conclusions

Experiments were conducted on downdraft gasifiers that used wood pellets as biomass feeds. The syngas produces of gasification obtaining contains $H_2$ of 7.948%, $CH_4$ of 4.084 %, and $CO_2$ of 18.939%. CO is dangerous air pollution and can damage the engine. One of the causes of the high CO value is the tar in the syngas. Scrubber to reduce tar with absorbent variations glycerol and coconut shell charcoal resulted in a high removal rate in reducing tar. The viscosity, density, and polarity of the absorbent used in the scrubber affect its ability to reduce tar compounds. In addition, temperature and pressure drop are also important factors in reducing tar.

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