Biogasoline production via catalytic cracking process using zeolite and zeolite catalyst modified with metals: a review

Nina Haryani\textsuperscript{1,2}, H. Harahap\textsuperscript{3}, Taslim\textsuperscript{3} and Irvan\textsuperscript{3,*}

\textsuperscript{1}Doctoral Program, Universitas Sumatera Utara, dr. Mansur street USU Campus Medan 20155
\textsuperscript{2}Chemical Engineering Department, Faculty of Engineering, University of Sriwijaya Raya Palembang Prabumulih street, Indralaya (OI) 30662, Sumatera Selatan
\textsuperscript{3}Chemical Engineering Department, Faculty of Engineering, Universitas Sumatera Utara, dr. Mansur street USU Campus Medan 20155

\*Email: irvan@usu.ac.id

Abstract. Biogasoline as an alternative fuel from vegetable oil is increasingly being studied by universities, research institutions, governments and others. The fact that the low yield of biogasoline is produced, the length of reaction time, how much energy is needed during the reaction, the high reaction temperature and expensive operating costs is a challenge in the scientific world to improve and develop further research. An appropriate process technology is needed in order to produce biogasoline fuel which is equivalent to the results of petroleum fractionation. Catalytic cracking process is one of the processes that are widely studied to produce biogasoline. Along with the development of biogasoline production, the use of catalysts in the cracking process has become increasingly diverse. It is in this paper that various biogasoline production with cracking processes using catalysts focused on zeolite and zeolite catalysts modified with metals will be reviewed, including an overview of cracking raw materials, types and characteristics of zeolite catalysts, operating conditions, and how the performance of each catalyst. Zeolite catalyst which is a heterogeneous catalyst is considered to have a good ability in selectivity, activity, and ease of modification so it is very influential on cracking results. Some zeolite catalysts modified with metals such as Zn/Zeolite, Au/HZSM-5, Ni-Mo/zeolite, Pd/HZSM-5, Pt/HZSM-5 are reported to be able to provide good performance to increase biogasoline yield and certainly become a useful new catalyst in the scientific world.

1. Introduction
Alternative fuels from vegetable oil or known as biofuels have long been used, and even various studies to create these fuels have been carried out in various countries in the world and continue to develop until now. Alternative fuels created are of course environmentally friendly, derived from renewable energy sources, efficiently used and affordable prices \cite{1}.

There are many alternative renewable energy sources especially from vegetable oil such as palm oil, soybean oil, castor oil, sunflower oil and others \cite{2}. By considering enough availability, it is easy to obtain, efficiently used and has a good chemical composition and characteristics, it can be selected vegetable oil suitable for biofuels. The types of vegetable oils with their fatty acid composition are shown in table 1.
Table 1. Various vegetable oils with fatty acid composition.

| Vegetable Oil        | Fatty acid composition, % weight |
|----------------------|----------------------------------|
|                      | 16 : 0 | 16 : 1 | 18 : 0 | 18 : 1 | 18 : 2 | 18 : 3 |
| Cotton seed oil      | 28.7   | 0      | 0.9    | 13.0   | 57.4   | 0      |
| Rapeseed oil         | 3.5    | 0      | 0.9    | 64.1   | 22.3   | 8.2    |
| Safflower oil        | 7.3    | 0      | 1.9    | 13.6   | 77.2   | 0      |
| Sunflower seed oil   | 6.4    | 0.1    | 2.9    | 17.7   | 72.9   | 0      |
| Sesame seed oil      | 13.1   | 0      | 3.9    | 52.8   | 30.2   | 0      |
| Wheat germ oil       | 20.6   | 1.0    | 1.1    | 16.6   | 56.0   | 2.9    |
| Palm oil             | 42.6   | 0.3    | 4.4    | 40.5   | 10.1   | 0.2    |
| Corn oil             | 11.8   | 0      | 2.0    | 24.8   | 61.3   | 0      |
| Castor oil           | 1.1    | 0      | 3.1    | 4.9    | 1.3    | 0      |
| Soybean oil          | 13.9   | 0.3    | 2.1    | 23.2   | 56.2   | 4.3    |
| Peanut oil           | 11.4   | 0      | 2.4    | 48.3   | 32.0   | 0.9    |
| Hazelnut seed oil    | 4.9    | 0.2    | 2.6    | 83.6   | 8.5    | 0.2    |
| Walnut seed oil      | 7.2    | 0.2    | 1.9    | 18.5   | 56.0   | 16.2   |
| Almond seed oil      | 6.5    | 0.5    | 1.4    | 70.7   | 20.0   | 0      |
| Olive oil            | 5.0    | 0.3    | 1.6    | 74.7   | 17.6   | 0      |
| Coconut oil          | 9.7    | 0.1    | 3.0    | 6.9    | 2.2    | 0      |
| Canola oil           | 4      | -      | 2      | 60     | 20     | 10     |
| Camelina oil         | 5.6    | 0.1    | 2.8    | 15.0   | 19.5   | 37.0   |
| Macauba oil          | 18.78  | 3.2    | 2.62   | 53.46  | 15.98  | -      |
| Calliphylloxylon     | 22.9   | 0      | 10.74  | 3.14   | 37.40  | 0      |

Reference: [2], [3], [4], [5]

Based on a review of several existing biofuel studies, most are focused on making biodiesel, while making biogasoline or biokerosene is not as much as making biodiesel. However, it was from this biodiesel research that started the formation of a small amount of biogasoline and biokerosene so that research to produce biogasoline as developed by Chang and Wan [6], Alene et al [7], Schwab et al [8], Florentino and Sadain [9], Billaud et al [10], Fortes and Baugh [11], Bhatia et al [12] and others [6-12].

There are several processes to make biofuel from vegetable oil that have been carried out by researchers and can be a reference for further research with a more innovative process both technically and economically especially considering that there are still weaknesses in previous research. The process used is dilution, microemulsion, thermal decomposition, cracking, and transesterification [2].

The cracking process is very appropriate to produce biofuels, especially biogasoline without catalysts or catalysts [1, 3]. The catalytic cracking process has been carried out by several researchers as reported in a review written by Zandonai [3] and Xu [4]. Generally, the catalyst used is heterogeneous catalyst [13].

One heterogeneous catalyst is zeolite. Zeolites have a regular crystal shape with cavities connected in all directions causing the surface area of zeolites to be very large so that they are best used as adsorbents and catalysts [14]. Several studies that produce biogasoline has been carried out by cracking using zeolite catalysts [12-34].

Furthermore, research with zeolite catalysts has progressed where zeolites modified with metals such as Ni, Cu, Zn, Pd, Au and Pt have shown good results for catalytic cracking processes [1, 4, 5, 24, 30, 34-41]. Most catalyst preparations are carried out using methods such as the impregnation method and the Planck method [5, 38]. While for catalyst characteristics which include specific surface area, catalyst pore size distribution, cumulative pore volume, catalyst texture properties are
performed using a number of analyzes such as XRD (x-ray diffraction), N2 adsorption by BET (Brunauer-Emmet-Teller) method, TEM (transmission electron microscopy), SEM (scanning electron microscopy), BJH (Barret-Joyner-Halenda) and others [34-36].

In this paper, the catalytic cracking process with various zeolite and zeolite catalysts modified with metals will be reviewed. The effect and performance of the catalyst on biogasoline yield is an important review in this paper.

2. Cracking process

The definition of cracking process is a process of breaking large hydrocarbon molecules into small molecules with the help of thermal and or without the use of catalyst. This process is often called pyrolysis which is basically a thermal [3]. Pyrolysis itself is a process at high temperatures which causes the molecule to break and can be cracked. For vegetable oils this process starts at a temperature of 593 K [42]. Furthermore, cracking produces molecules and deoxygenation occurs simultaneously with the influence of heat. This process has been extensively studied and has been reported in several reviews [3, 43, 44, 45].

Historically, thermal cracking of vegetable oils began in the twentieth century, where "Universal Oil Product Company, Chicago US" carried out the process of pyrolysis made from cotton seed [46] and also Seal Oil [47]. The company is trying to find an alternative fuel from vegetable oil through a process similar to cracking petroleum with temperatures ranging from 718 - 758 K and a pressure of 931.36 kPa. The product is distilled to produce 57.8% organic components for cotton seeds at the gasoline boiling point and 59.9% for oil seals. The gaseous products are light hydrocarbons, carbon oxides, water and nitrogen [3].

In 1947, Chang and Wan investigated the pyrolysis process of tung oil with a reaction temperature of 400-500°C in a thermal cracking reactor. From the process produced biodiesel fuel and a small amount of biogasoline and biokerosene [6]. The formation of biogasoline became the beginning of the interest of researchers to focus on biogasoline production.

2.1. Catalytic cracking using zeolite catalyst

In its development, the process of cracking vegetable oils is carried out using a catalyst (catalytic cracking) which takes place at high temperatures and pressures, where the breakdown of fatty acids can be directed and change them with different reaction paths. The purpose of using a catalyst is to reduce the temperature and speed up the reaction time, in addition to the presence of the catalyst can make a selective process for the desired reaction [3].

Vegetable oil used in making biogasoline with catalytic cracking process are palm oil [1, 12, 20, 22, 31, 35, 36, 41, 15-18], coconut oil [21, 39], soybean oil [26, 34], rapeseed oil [21, 24, 30], cotton seed oil [29], carinata oil [37], camelina oil [37], sunflower oil [21, 32], carbera manghas oil [40], callophylluminophyllum L. oil [5, 39], and jatropha oil [23]. In addition, raw materials from bio-oil have also been studied [19, 28].

In general, triglycerides are raw materials used for thermal and or catalytic cracking process. The use of triglycerides for the thermal cracking process turns out to be less useful because it produces acrolein and triolein, which are very toxic in the product. Beside of that, it produces coke which results in high viscosity in oil. Pre-treatment of raw materials by convert them into methyl esters through the transesterification process will prevent the formation of toxic material in the reaction product [32, 48].

For the selection of catalysts, zeolite catalyst performance is effective and promising in the process of converting triglycerides into biogasoline. This makes it a favorite and widely used in various cracking processes [48]. The use of this catalyst is considered more useful because it does not require additional materials such as ethanol and methanol [1]. Table 2 shows several studies on biogasoline production using zeolite catalysts.
## Table 2. Biogasoline production from vegetable oil by catalytic cracking process using zeolite catalyst.

| Feed                     | Catalyst          | Operating Conditions | Reactor | Result                        | Reference |
|--------------------------|-------------------|----------------------|---------|-------------------------------|-----------|
| Palm oil                 | HZSM-5            | 360-420 T°C          | FBR     | Biogasoline (40–70%)         | [12]      |
| Palm oil                 | HZSM5, β-zelite, USY | 350-450 T°C           | FBR     | Biogasoline (28%)            | [15]      |
| Palm oil                 | HZSM-5            | 400-450 T°C          | FBMR    | Biogasoline (44,4% wt)       | [16]      |
| Palm oil                 | REY Zeolite       | 400 – 500 T°C        | TRR     | Biogasoline (59,1% wt)       | [17]      |
| Palm oil                 | REY Zeolite       | 450 T°C              | TRR     | Biogasoline (30-40%)         | [18]      |
| Bio-oil                  | Zeolite, ZSM-5    | 450-500              | HPR     | Biogasoline (91,67%)         | [19]      |
| Palm oil                 | HZSM-5            | 350-500 T°C          | FBMR    | Bioasoline (28,87%)         | [20]      |
| Coconut, Rapeseed, Mustard, Sunflower | HZSM-5, HY  | 450 T°C              | FBR     | Biogasoline (26,9 – 40,1%)  | [21]      |
| Palm oil                 | HZSM-5            | 350-500 T°C          | FBMR    | Biogasoline (17,11%)         | [22]      |
| Jatropha oil             | HZSM-5            | 400 T°C              | FBR     | Biogasoline (11,6%)         | [23]      |
| Rapeseed oil             | HZSM-5            | 550 T°C              | FBDFR   | 32 – 41% (C5-C10)           | [24]      |
| Microalga, Chlorella, Soybean | ZSM-5 | 350 T°C              | FBR     | Biogasoline (19,4%)         | [25]      |
| Rapeseed oil             | NaY/USY           | 360 T°C              | FBR     | Biogasoline (70%)           | [26]      |
| Rubber                   | HZSM-5            | 400-440              | PR      | Biogasoline (50,9%)         | [27]      |
| Bio-oil                  | HZSM-5, Zeolite   | 340-430 T°C          | FBR     | Biogasoline (63,6-71,8%)    | [28]      |
| Bio-oil                  | Y-Zeolite, halloysite-Y-zeolite | 480-540 T°C    | FBR     | Biogasoline (29,9%)         | [29]      |
| Rapeseed oil             | ZSM-5, HZSM-5    | 550 T°C              | FBDFR   | Biogasoline > 32%           | [30]      |
| Palm oil                 | HZSM-5            | 420 T°C              | BR      | Biogasolin (14,8%)          | [31]      |
| Sunflower oil            | Na/HZSM-5         | 450-550 T°C          | TBR     | Liquid product (> 80 %wt)   | [32]      |
| Waste tire               | Natural zeolite   | 300-600 T°C          | BR      | Light hidrocarbon (biogasoline, biodiesel) 12% | [33]      |
HZSM-5 catalyst, which is a synthetic zeolite, is commonly used in the catalytic cracking process to produce biogasoline [1, 12, 16, 20-24, 27, 28, 30-32, 34]. The active catalyst of HZSM-5 and being able to produce more gasoline than β-zeolite has been reported by Tamunaidu [49, 50]. But unfortunately this catalyst supports the formation of a lot of gas thereby reducing the liquid fraction [15, 17, 48].

Other catalysts such as ZSM-5, REY zeolite, USY, β-zeolite, HY, Y-zeolite, halloysite-Y-zeolite, Na / HZSM-5 and natural zeolite became catalyst choices for future researchers [17-19, 24-26, 33]. For the ZSM-5 catalyst it was able to provide excellent results with biogasoline yield reaching 91, 67% by Hew [19] and 70% by Ishihara [26]. A study by Li [27] using a NaY/USY catalyst also produced a large enough biogasoline yield of 63.6 – 71.8%.

In 1999, Bhatia from Malaysia studied the process of converting palm oil into fuel and other chemical compounds with the HZSM-5 catalyst in a fixed-bed reactor (FBR) at operating temperatures ranging from 360°C to 420°C with results showing 40 - 70% palm oil can be converted into aromatic compounds and hydrocarbons such as biogasoline, biokerosene and biodiesel [12]. In the same year, Twaiq et al made liquid fuel which still based on palm oil using a catalyst HZSM-5, USY, and β-zeolite. The resulting product has a biogasoline yield of 28% through a cracking process using a fixed bed reactor at a temperature of 350 – 450°C [15].

Research with palm oil produced by the Malaysian State Industry was carried out by Ooi using a fixed bed micro reactor (FBMR) through a thermal catalytic cracking process at an operating temperature of 400 – 450°C. The catalyst of HZSM-5 and the ratio of oil to catalyst (gram/gram of catalyst) is 6-10. The highest percentage of biogasoline yield from the research results is 44.4% wt at 440°C [16].

Tamunaidu and Bhatia [17] researched in depth the REY zeolite catalyst which was relatively new at that time in producing biogasoline. The catalytic cracking process uses a transport riser reactor (TRR) with the result obtained 59.1% of biogasoline yield. In 2009, Bhatia re-examined the making of biogasoline using a transport riser reactor. The REY zeolite catalyst was investigated for its effect during the cracking process which took place at 450°C. This research produces 30-40% biogasoline [18].

Meanwhile, research by Nurjannah et al using HZSM-5 and Si/Al has produced 28.87% biogasoline, 16.70% biokerosene and 12.20% biodiesel with catalytic cracking process of palm oil oleic acid. The reaction takes place at 350-500°C in a fixed bed micro reactor [20].

The interesting catalytic cracking process was carried out by Hew et al using bio-oil raw materials. The Taguchi L9 method found optimum operating conditions for the catalytic cracking process of ZSM-5 catalysts and zeolites at 400°C, 15 minutes reaction time and 30 grams of catalyst. In these conditions the biogasoline yield was 91.67% [19].

Doronin with various raw materials (coconut, rapeseed, mustard, sunflower seeds) and also various catalysts namely HZSM-5, HY, SiO2, montmorillonite, Al2O3 and Al-Si have produced 26.9 - 40.1% biogasoline yield [21]. Other research have been carried out by Botas in 2012 with the HZSM-5 catalyst and ZSM-5 catalyst in 2014. The cracking of rapeseed oil in his research has resulted in biogasoline yield of 32 -37%. With this catalyst most of the total deoxygenation is carried out with marked CO formation and a small amount of CO2 and H2O addition [24].

Y-Zeolite and halloysite-Y-zeolite catalyst has been studied by Abbasov et al (2014). Their research is quite interesting because good performance was shown from this catalyst during the cracking process and obtained 46-55% biogasoline yield [20]. Furthermore, Wang et al (2014) from China did his research to produce of biogasoline from the bio-oil and ethanol distillate fraction by the co-cracking process using fixed bed reactors. They studied the effect of reaction temperature, pressure and DF / Ethanol ratio. The best results were obtained for 25.9% wt of biogasoline and hydrocarbon phase of 98.3% at 400°C and a pressure of 2 MPa with a DF / ethanol ratio of 2: 3 [28].
The production of biogasoline with waste tire raw material have been studied by Ayanog˘lu and Yumrutas (2014) using natural zeolites. They use a batch reactor to make biogasoline with a reaction temperature of 300 – 600°C. The results of this study were light hydrocarbons (biogasoline, biodiesel) of around 12% and heavy hydrocarbons 25% [33].

Different from other studies, Dong et al (2014) have conducted catalytic pyrolysis using raw materials of microalga chlorella pyrenoidosa. They examined the performance of catalytic pyrolysis in one stage and two stages of the process then compared the two. The results were found that the yield of light carbon olefin with two stages of the process three times more than the one stage of the process. Cracking yield was obtained for 19.4% of biogasoline yield [25].

Research using two stages of the process (transesterification and thermal cracking process) has also been carried out made from sunflower oil raw material [32]. Their research states that the transesterification process as a pretreatment stage before carrying out the cracking process, gives a better end result. The use of triglycerides for thermal cracking without pretreatment is less useful because it produces acrolein and triolein, which are very toxic in the product. It also produces coke which results in high viscosity in oil. With this pretreatment these unwanted things can be prevented.

The fuel properties after cracking of sunflower oil and its methyl esters have been compared to determine the superiority of the transesterification process as a triglyceride pretreatment stage. The transesterification process lasts for 3 hours with a reaction temperature of 60°C using methanol and KOH catalyst. The methyl ester product is further processed through a thermal catalytic cracking process using Na/HZSM-5, γ-Al₂O₃, and MnO₂ / γ-Al₂O₃ catalysts in tubular packing bed (TBR) reactors with temperatures varying from 150 – 550°C. Products in the form of light hydrocarbons are obtained > 80% at temperatures of 450°C and 500°C.

The two stages of the above process can be used as a solution to increase biogasoline yield which is still low so far. A good pretreatment will produce methyl esters optimally, of course it will be advantageous to be used as raw material for the next process [1, 25, 32].

2.2. Catalytic cracking using zeolite catalysts that are modified with metals

In the use of zeolite catalysts, several factors must be considered, including activity, selectivity, use time and ease of regeneration. Zeolite catalyst in the cracking process can control the activity and selectivity, but unfortunately the amount of biogasoline yield produced is low. Its performance can be improved through modification with metals such as Cu, Ni, Zn [1, 22, 50].

The production of biogasoline using zeolite catalyst which is modified with metals has not been studied too much when compared to research using zeolites. Table 3 shows some of these studies. Roesyadi et al [22] compared the effect of HZSM-5 catalysts without and with the impregnation of Cu, Ni and Zn metals on biogasoline yields. The Zn/HZSM catalyst gives the highest yield compared to other catalysts, which is 29.38% at 450°C. However, they recommend the Ni/HZSM catalyst for biogasoline selectivity in palm oil cracking.

In line with the above recommendations [22], Ni/HZSM5 catalysts showed the best performance as catalysts in research by Botas with biogasoline yields of 32 - 41% [30]. Zeolite catalysts with Ni and Mo metals or NiMo/zeolites have been used in several studies even though the yield of biogasoline is still low [5, 24, 30, 35, 38, 39, 39].

A catalyst that is relatively new which has never been used at that time is Au/HZSM-5. Cracking process with this catalyst produces biogasoline yields of 4 to 15% [36]. Later, the renewal of other catalysts in biofuel production was also discovered by Budianto [1]. Budianto studied the influence of HZSM-5 catalysts with and without Pt and Pd impregnation in the production of biodiesel. His research turned out to produce biogasoline yield of 29.38%. The RBD (refinery, bleaching, deodorize) process is done first, then the cracking process is continued. After the RBD process, 55% oleic acid and 30% palmitic acid are obtained, which will then be cracked using HZSM-5, Pt/HZSM-5 and Pd/HZSM-5 catalysts. The results show that the amount of biogasoline yield increases with the reduced amount of biodiesel and biokerosene yields.
Table 3. Biogasoline production from vegetable oil by catalytic cracking process using zeolite which is modified with metals.

| Feed          | Catalyst          | Operating Conditions | Reactor | % Yield | Reference |
|---------------|-------------------|----------------------|---------|---------|-----------|
| Palm oil      | NiMo/Zeolite      | 300-320°C            | 1, 1.5, 2 | BR      | 11.93%    | [35]     |
| Palm oil      | Au/HZSM-5         | 330-550°C            | 1       | FBMR    | 4.15%     | [36]     |
| Palm oil      | Zn/HZSM-5         | 350-500°C            | 2       | FBMR    | 28.38%    | [22]     |
| Palm oil      | Ni/HZSM-5         | 350-500°C            | 2       | FBMR    | 17.55%    | [22]     |
| Palm oil      | Ni/HZSM-5         | 350-500°C            | 2       | FBMR    | 18.05%    | [22]     |
| Hypocynabalea  | Ni/HZSM-5         | 350-500°C            | 2       | FBMR    | 28.38%    | [22]     |
| Camelina oil  | Zn/ZSM-5          | 450, 500°C           | 0.2, 0.6 | FBR    | Hydrocarbon biofuel | [30]     |
| Carinata oil  | Zn/Na-ZSM-5       | 450, 500°C           | 0.2, 0.6 | FBR    | Hydrocarbon biofuel | [30]     |
| Rapeseed oil  | Ni/ZSM-5          | 550-550°C            | 2       | FBFR    | 32.37%    | [24]     |
| Rapeseed oil  | Ni/HZSM-5         | 550-550°C            | 2       | FBFR    | 32.37%    | [24]     |
| Coconut oil   | Ni/MNZ            | 360, 410, 450, 500°C | -       | FBR    | 11.73%    | [39]     |
| Cerbera manghas oil | Co-Ni/  | 300-375°C           | 2       | BR      | 1.97%     | [40]     |
| Palm oil      | Zn/HZSM-5         | 300, 400°C           | 1       | FBR     | 2.54%     | [41]     |

Pt and Pd are precious metals that are transition metals. They have many electrons which are easily delocalised. This can affect the reaction especially to break covalent bonds during cracking. Therefore, its use is considered to increase the amount of yield and have better selectivity [1]. Meanwhile, Zhao and Wei [37] cracked the Carinata oil using a Zn/Na-ZSM-5 catalyst at varying temperatures of 400, 450 and 500°C. Zhao [4] also investigated the catalytic cracking process of camelina oil with the Zn/ZSM-5 catalyst. Both of his studies produced hydrocarbon fuels. The frequency of oil extraction and hourly liquid space velocity are considered important factors for producing liquid hydrocarbons. The optimum conditions were reached at 550°C, space velocity at 1.0 h⁻¹ and the extraction compressive frequency was 15 Hz. The Zn/HZSM-5 catalyst is also used by Widayat in oil palm cracking which produces a biogasolin yield of 2.54% [41]. Furthermore, Savitri’s research uses...
Calophylluminnophyllum L. oil as raw material [5, 38] which contains not only palmitic, oleic and linoleic acids, but several long chain fatty acids C_{19}, C_{22}, C_{23} are also present in this oil. The cracking process takes place in an autocluster batch reactor (ABR) and uses a NiMo/zeolite catalyst. From this research, biogasoline yield < 15% was obtained.

3. Conclusions
Biogasoline production can be done by catalytic cracking using zeolite and zeolite catalyst modified with metals. Zeolite catalyst which is a heterogeneous catalyst, in its use must be considered several factors including activity, selectivity, time of use and ease of regeneration. In the cracking process, zeolite catalyst can control the activity and selectivity where the activity and selectivity is influenced by the characteristics of the catalyst. Therefore we need an appropriate catalyst preparation method and active metal content so that the catalyst characteristics are good and have a good effect on cracking results.

Biogasoline production through the process of catalytic cracking triglycerides directly turned out to be less precise because it forms acrolein and triolein compounds (toxic compounds) and the formation of coke. With two stages of the process where the first stage of the process as a pretreatment followed by the catalytic cracking process will give better results [32, 1, 25]. The use of ZSM-5 catalyst was able to provide excellent results in the cracking process with biogasoline yields reaching 91.67% [19] and 70% [26]. In addition, biogasoline yields were also produced quite large in research with NaY/USY catalysts, namely 63.6 - 71.8% [27].

Catalytic cracking process can produce biogasoline at temperatures ranging from 300-550°C. The catalytic cracking of bio-oil into biogasoline is recommended at a temperature of 400°C, a reaction time of 15 minutes and a catalyst of 30 grams. With this condition, biogasoline yield of 91.67% is produced [19]. Meanwhile, the reaction temperature at 450°C is likely to produce high octane gasoline, low heavy oil and gas. However, the problem is the formation of coke on the catalyst, resulting in deactivation of the catalyst by the buildup of coke on the catalyst surface. Therefore, residence time is needed as a solution to increase biogasoline yield and reduce coke formation [49].

In the use of zeolite catalysts modified with metals, Ni/HZSM-5 catalysts have the best performance. Cracking with this catalyst is capable of producing the highest biogasoline yield among other biogasoline studies with a metal modified zeolite catalyst that is equal to 32 - 41% [24, 30]. However, Au/HZSM-5, Pt/HZSM-5 and Pd/HZSM-5 catalysts appear as catalyst renewal with different types of modified metals from most of the metals studied although they are not economically efficient [36, 1].

The review of some biogasoline production studies in this paper is expected to provide an overview of the development of biogasoline production through the catalytic cracking process using zeolite and zeolite catalysts modified with metals. In addition, it can provide information about the types of zeolite catalysts that have good performance in the cracking process and also the right operating conditions for producing biogasoline so that optimal biogasoline yield is obtained.

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