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Influence of adsorbent-arak ratio and distillation period in bioethanol purification process using Balinese liquor as a raw material

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DOI: https://doi.org/10.37855/jah.2021.v23i01.08
Key words: Arak, adsorbent ratio, distillation period, bioethanol
Show Abstract

Metabolite profile of ethanol extract of Curcuma domestica Val. variety Turina-1

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DOI: https://doi.org/10.37855/jah.2021.v23i01.02
Key words: LC-MS, profile metabolite, ethanolic extracts, Curcuma domestica Val, Turina-1
Show Abstract

Determination of key parameters for grading dehusked coconut using principal component analysis

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Key words: Coconut, principal component analysis, score plot, grading
Show Abstract
Influence of adsorbent-arak ratio and distillation period in bioethanol purification process using Balinese liquor as a raw material

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Abstract

Arak is one of traditional Balinese drink that has potential alcohol content used as a raw materials in making bioethanol. The aim of this research was to identify the influence of adsorbent-arak ratio and distillation period on the characteristics of bioethanol and to identify the right method to produce bioethanol with the best characteristics using distillation-adsorptive purification method. This research used a randomized block design with factorial experiment. The first factor is an adsorbent-arak ratio, i.e. 1:2, 1:3 and 1:4. The second factor is the distillation period, i.e., 1, 2, 3 hr. Each factor is grouped into two groups based on the two times of arak production so that there are 18 experimental units. The data were processed using Analysis of Variance (ANOVA) and followed by Duncan test. The result shows that the ratio of adsorbent-arak and distillation period had a significant effect on ethanol content, density, specific gravity, API gravity, and heating value. The combination of 1:3 adsorbent-arak ratio and one-hour distillation period produced the best characteristic with the following criteria: ethanol content 91.86 %, density 0.8280 kg/L, specific gravity 0.8141, API Gravity 42.315, and heating value 11081.9 kcal/kg.

Key words: Arak, adsorbent ratio, distillation period, bioethanol

Introduction

In line with the recent development era, there is an increase in energy needs; fossil fuels that exist today cannot be expected for a long period of time. New alternative energy sources are needed which are sufficient and can save energy from fossil fuels (Jhonprimen et al., 2012). Bioethanol is a biochemical liquid from the fermentation process of sugar from carbohydrate sources using the aid of microorganisms. Bioethanol has been recognized as an important renewable and sustainable fuel source for the modern industry (Yang et al., 2012; Gunam et al., 2019).

Arak is one of the traditional Balinese liquor from traditional distillation of palm juice and coconut. Arak has the potential for high alcohol content (± 30 %) which is suitable to be used as a raw material for the production of bioethanol production (Sukadana and Tenaya, 2014). To improve the quality of bioethanol from Arak, further purification is necessary to increase the concentration of alcohol content. One of the purification methods which is commonly done is by distillation (Goering and Schrader, 1988).

Distillation is a method for separating two types of solutions based on the boiling point differences. However, according to Onuki et al. (2008), this method has several deficiencies. First, it is estimated that there are impurities with similar boiling point to ethanol mixed with ethanol after the distillation process so that the purity is low. Second, distillation which is a process of repetition of evaporation and condensation, requires high costs. Efforts that can be done to overcome this; a purification process is needed by means of adsorption as a continuation of the distillation process, to achieve a purity of around (90–95 % v/v). This process is known as the distillation-adsorption process (Mujiburohman et al., 2006; Patil and Patil, 2017).

Distillation-adsorption is a combination of two separation processes, namely distillation and adsorption. In this method, the distillation and adsorption processes are carried out simultaneously, that is, by means of the adsorbent column arranged together with a distillation tool. Furthermore, the distillate vapor will pass through the adsorbent column. The adsorbent will absorb water vapor so that the purity of ethanol rises. The difference between distillation-adsorption and other distillation methods is the addition of the additives substance which does not mix together with the solution but in a separate column. Thus, the separation between the additives and the solutions is not required (Silviana and Purbasari, 2008; Tang et al., 2013; Chopade et al., 2015). The adsorbent chosen in the bioethanol distillation-adsorption process is a hydrophilic adsorbent because it has the ability to absorb water. Silica gel is used because it has several advantages including being very inert, hydrophilic and the costs of synthesis are quite low. In addition, this material has a relatively stable thermal and high enough mechanic which relatively does not expand in organic solvents when compared to organic polymer solids (Purwaningsih, 2009).

Studies on the use of adsorption distillation methods in the purification process have been carried out, one of which is in the process of separating isopropyl alcohol-water mixtures (Silviana and Purbasari, 2008; Mujiburohman et al., 2006; Banat et al.,...
2003). The adsorption distillation method was also investigated by Rizki et al. (2012), based on the results of the study it was found that the most effective process for ethanol purification is the adsorption distillation process with the ethanol content produced at 98 % (v/v). Furthermore, research conducted by Yuliana et al. (2015) reported purification process based on the adsorbent-ethanol ratio. It is known that with an adsorbent-ethanol ratio of 1:2, the purity of bioethanol obtained is 99.7 % (v/v). Based on this, a study was conducted to identify the effect of adsorbent-arak ratio and distillation period in order to obtain the best bioethanol characteristics in the bioethanol purification process using arak with the distillation-adsorption method.

Materials and methods

Material: The arak fermented coconut obtained from Duda Village in Karangasem and Dawan Village in Klungkung with ± 30 % alcohol content (v/v), and granular white silica gel adsorbent (non-food grade) obtained from Bratachem.

Research design: This research used a two factor randomized block design with factorial experiment. The first factor was the weight ratio between adsorbent and arak which consists of three levels, namely, 1:2, 1:3, and 1:4. The second factor was the distillation time consisting of three levels, namely, 1, 2, and 3 hr grouped into two groups based on times of arak production so that 18 experimental units are obtained. The experimental data were analyzed using the ANOVA and DMRT.

Research implementation: Initially, the silica gel adsorbent was physically activated; physical activation was carried out by heating the adsorbent on the furnace at a temperature of 200 ± 2 °C for 2 hours. Physical activation is carried out to increase the absorption ability of silica gel adsorbents. Then, the activated adsorbent was inserted into the adsorbent column contained in the distillation according to the adsorbent-arak ratio (1:2, 1:3, 1:4). The volume of arak used for each ratio was 1; 1.5; and 2 L, while an adsorbent was used as much as 0.5 kg for each ratio. The arak that was used was obtained from local arak maker from two regions, namely from Duda and Dawan villages. The alcohol content was measured first using an alcohol meter and entered into the feed column according to the adsorbent: arak ratio (1:2, 1:3, 1:4). Arak was heated until the temperature reaches 80°C and was kept constant. The distillation process was carried out at 80°C because ethanol boils at 78.4°C while water was 100°C. Furthermore, the steam produced by the arak will pass through the adsorbent column and the water vapor produced from the heating process will be adsorbed by the silica adsorbent gel. The ethanol vapor will pass through the cooling column and then accommodate in the distillate tank. The period of distillation-adsorption process was carried out according to the experimental variables (1, 2, 3 hr). The distillate obtained from the distillation process was then counted according to the observed parameters. Meanwhile, the used of silica gel adsorbent was removed from the distillation tool and then reactivated for further use.

The variables observed: Ethanol content (SNI: Indonesian National Standard, 3565:2009), density, Specific Gravity, API Gravity and heating value (Tjokrowisastro and Widodo, 1990).

Data analysis: The data were analyzed according to the variant (ANOVA) and continued with Duncan’s multiple comparison

Results

Bioethanol content: Based on the results of the ANOVA, it is known that the adsorbent-arak ratio, duration of distillation and interaction between treatments, has a very significant effect on the ethanol content obtained from the purification process by the adsorption distillation method. Based on Table 1, it is known that the highest level of bioethanol produced in the adsorption distillation process is the weight ratio of adsorbent-arak is 1:2 with distillation period for one hour which is equal to 92.65 % and the longer the distillation period, the bioethanol content will decrease, as shown in Table 1.

Table 1. Average value of bioethanol (v/v)

<table>
<thead>
<tr>
<th>Adsorbent-arak ratio</th>
<th>Distillation period (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1:2</td>
<td>92.65±0.54a</td>
</tr>
<tr>
<td>1:3</td>
<td>91.86±1.05a</td>
</tr>
<tr>
<td>1:4</td>
<td>90.79±0.90b</td>
</tr>
</tbody>
</table>

Same letter after the average value shows non significant difference at P=0.05.

Density: Based on Table 2, the highest bioethanol density obtained through purification by the distillation-adsorption method is a combination treatment ratio of 1:2 for three hours with a density of 0.8463 (g/ml). The lowest bioethanol density was produced by a combination of 1:2 ratio treatments for one hour with a density of 0.8258 (g/ml) and this treatment combination was not significantly different from the bioethanol density produced by the combination of 1:3 ratio treatments for one hour with a density of 0.8280 (g/ml). Based on the average value of bioethanol density, it is known that the longer the distillation process, thus the higher bioethanol density obtained.

Table 2. Average density value of bioethanol (g/mL)

<table>
<thead>
<tr>
<th>Adsorbent-arak ratio</th>
<th>Distillation period (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1:2</td>
<td>0.8258±0.001a</td>
</tr>
<tr>
<td>1:3</td>
<td>0.8280±0.003a</td>
</tr>
<tr>
<td>1:4</td>
<td>0.8311±0.003c</td>
</tr>
</tbody>
</table>

Same letter after the average value shows non significant difference at P=0.05.

Specific gravity: Based on Table 3, the highest specific bioethanol gravity obtained through purification by the distillation-adsorption method is the combination of 1:2 ratio treatments for three hours with a specific gravity of 0.8321. In line with the increasing distillation period an increase in the value of specific gravity bioethanol.

Table 3. Bioethanol specific gravity average value

<table>
<thead>
<tr>
<th>Adsorbent-arak ratio</th>
<th>Distillation period (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1:2</td>
<td>0.8120±0.001b</td>
</tr>
<tr>
<td>1:3</td>
<td>0.8141±0.003c</td>
</tr>
<tr>
<td>1:4</td>
<td>0.8172±0.003d</td>
</tr>
</tbody>
</table>

In the data analysis applied software program of SPSS 25. Same letter after the average value shows non significant difference at P=0.05.
API gravity: Based on Table 4, the highest bioethanol API gravity obtained by purification using the distillation-adsorption method is a combination of 1:2 ratio treatment, one hour distillation period with API Gravity of 42.761 and the combination of these treatments is not significantly different from the API Gravity bioethanol produced by a treatment combination of 1:3 ratio, distillation period for one hour, ratio 1:3, distillation period of two hours and ratio of 1:4, distillation period for one hour. The lowest API Gravity bio-ethanol produced by a combination treatment ratio of 1:2, for three hours are 38.557. The longer the distillation period, the API value will be reduced.

Table 4. Average value of API gravity

<table>
<thead>
<tr>
<th>Adsorbent-arak ratio</th>
<th>Distillation period (hour)</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:2</td>
<td>42.761±0.31</td>
<td>39.925±0.13</td>
<td>38.557±0.71</td>
<td></td>
</tr>
<tr>
<td>1:3</td>
<td>42.315±0.59</td>
<td>41.163±0.01</td>
<td>40.244±0.38</td>
<td></td>
</tr>
<tr>
<td>1:4</td>
<td>41.658±0.58</td>
<td>40.610±0.40</td>
<td>39.557±0.08</td>
<td></td>
</tr>
</tbody>
</table>

Same letter after the average value shows non significant difference at $P=0.05$.

Heating value: Based on Table 5; it is known that the heating value of the produced bioethanol shows a decrease with the longer time of distillation-adsorption and decreasing the adsorbent-arak ratio. The heating value produced by bioethanol is closely related to the bioethanol content; it is known that the longer the distillation-adsorption process, the bioethanol content will decrease, it is due to the increased of water content in the distillate.

Table 5. Average value of heating value (kcal/kg)

<table>
<thead>
<tr>
<th>Adsorbent-arak ratio</th>
<th>Distillation period (hour)</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:02</td>
<td>11091.8±6.90</td>
<td>11056.3±4.26</td>
<td>11035.9±8.38</td>
<td></td>
</tr>
<tr>
<td>1:03</td>
<td>11081.9±13.20</td>
<td>11044.0±8.80</td>
<td>11028.7±1.67</td>
<td></td>
</tr>
<tr>
<td>1:04</td>
<td>11067.3±12.97</td>
<td>11029.6±2.83</td>
<td>10998.3±15.79</td>
<td></td>
</tr>
</tbody>
</table>

Same letter after the average value shows non significant difference at $P=0.05$.

Discussion

Bioethanol content: That result is caused by the silica gel which adsorbs the distillate is starting to be saturated, so the water vapor formed during the distillation process is not adsorbed properly, which results in a decrease in the content of bioethanol obtained. According to the research conducted by Satria and Bernardi (2009), the longer the adsorption process is carried out, the higher the purity of ethanol obtained until at a certain point it reaches a saturated condition. In this situation, extending the adsorption time no longer increases the purity of ethanol. This is in accordance with the results of research Chopade et al. (2015), where the absorption of water by adsorbents takes place quickly in the first 60 minutes of the adsorption process and according to Wirawan et al. (2014), a decrease in the concentration of bioethanol during the distillation process showed that the adsorbent used had been saturated. The longer the distillation is done, the level of saturation of the adsorbent increases so that it affects the decrease of the concentration of bioethanol produced. Meanwhile, for the treatment of adsorbent-arak ratio, the greater the weight ratio of adsorbent-arak, therefore the content of bioethanol obtained will be increased because the increase in the adsorbent dose is used which provides a greater surface so that water absorption by silica gel is more effective (Qu et al., 2012).

Density: That result is caused by water vapor formed during the distillation process of bioethanol adsorption is not completely absorbed by the silica gel adsorbent because the adsorbent has begun to saturate, so that the formed water vapor joins the distillate which causes an increase in the value of the distillate density obtained. This is in accordance with Bahtiar's (2013) study, which states that the increase in the density value in bioethanol is due to the water content which is still present in distilled bioethanol. The smaller the density means the lighter the specific gravity and the quality is better. Based on the research carried out by Kholidah and Abtokhi (2015), the value of ethanol content gives a great effect on the value of density. The higher the value of the ethanol content, therefore the longer the carbon chain and causes the carbon chain to be broken easily with the increasing temperature, and the ethanol experiences evaporation resulting in reduction of the density value.

Specific gravity: That result is caused by the speed of mass transfer of water into the silica adsorbent will continue to decrease with the increase of the time of adsorption, so the concentration of water out of the old column, the longer the time it will increase so that the specific gravity value obtained through the distillation-adsorption method increases (Jannah, 2016). The lowest specific gravity of bioethanol is produced by a combination of 1:2 ratio treatments for one hour with a specific gravity of 0.8120 and this combination of treatments is not significantly different from the specific gravity bioethanol produced by a combination treatment ratio of 1:3 for one hour with a specific gravity of 0.8141. The greater the ratio of adsorbent-arak, the more silica gel composition is used, thus the more surface area of the adsorbent and increases the water molecules absorbed in the adsorbent (Dyartanti et al., 2012) this causes an increase in alcohol content in the distillate. The increase of alcohol, automatically the weight or density of the distillate will be lower in which it also causes the specific gravity of the mixture has a low value. This is caused by the specific gravity is the ratio between the density of the substance and the density of water, therefore the density of the substance is decreasing as a result the specific gravity will also be low (Sutanto et al., 2013).

API gravity: That result is related to the absorption of silica gel adsorbent towards water which decreases in accordance with the increase of time. Meanwhile, for the treatment of adsorbent-arak ratio the greater the weight ratio of adsorbent-arak, thus the API gravity obtained will be higher. Because, the quantity of adsorbent fed is more so that the contact between the adsorbent and the mixture is more evenly distributed which results in more impurities in the form of water so that the purity of bioethanol and API Gravity value will increase (Hidayat et al., 2015; Al-Saidy and Al-Dokheily, 2014). The value of API gravity is closely related to specific gravity, where API gravity is the inverse measure of liquid fuel to water (Bint-E-Naser and Hossain, 2017). Accordingly to Kholidah (2014), the purpose of examining API Gravity is to indicate fuel quality, if the specific gravity value is low so the API Gravity value is high; consequently, the quality of the fuel is getting better because it contains more fuel than impurities such as water and paraffin.

Heating value: That result is confirmed by the research carried
out by Sutanto et al. (2013), where bioethanol which has higher alcohol content tends to release greater heat when compared to bioethanol with lower content. The heating value of organic waste bioethanol ranges from 10,000–11,000 kcal/kg, while the heating value of liquid fuels generally ranges from 10,160–11,000 kcal/kg. A greater heating value will cause more flammability so that the quality is better (Wijaya et al., 2012).

Based on the results of the research that has been carried out, the following conclusions can be drawn: The treatment of adsorbent weight ratio, distillation period, and interaction between treatments affect the characteristics of bioethanol obtained from the distillation-adsorption purification process. The combination of the weight ratio of adsorbent treatment 1:3 and one hour distillation period gives the best bioethanol characteristics in the purification of bioethanol from arak by the distillation-adsorption method with the criteria of bioethanol content of 91.86%; density 0.8280 kg/l; specific gravity 0.8141; API Gravity 42.315; and a heating value of 11081.9 kcal/kg. Based on the above research, it is recommended that in the adsorption distillation process it is better to use a distillation tube made of heat-resistant material, using an electric heat source in which its temperature can be regulated and it remained unchanged which minimizes the leakage that occurs in the distillation apparatus.

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