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The potency of robusta coffee pulp as a vinegar product

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Coffee processing produces 40-50 % of by-products that can damage coffee plants and cause environmental pollution. The coffee pulp as waste can be used for producing acetic acid solution as a preservative and hand-washing agent to prevent infection. The fermentation process can affect the quality of the acetic acid solution. This study aims to analyse the effect of yeast types and time fermentation as well as to determine the characteristics of acetic acid solution from Robusta coffee pulp. The experiment consists of two types of yeast: bread-fermented yeast, cassava-fermented yeast, and a combination of both yeasts. The second factor is time fermentation which consists of 13 and 16 days of fermentation. The study found that interaction between both yeasts significantly affected the acetic acid solution's moisture content and total soluble solids. Meanwhile, the factor of bread-fermented yeast and cassava-fermented yeast had a significant effect on the pH, acetic acid content, and reduced sugar. The study showed that the treatment of cassava-fermented yeast fermented for 13 days at room temperature can be used as an alternative to produce an acetic acid solution. The physicochemical quality of the acetic acid solution is acetic acid content is 1.983 ± 0.04 %, pH of 4.104 ± 0.04, reducing sugar of 1.505 ± 0.03 %, moisture content of 90.61 ± 0.294 %, and total soluble solid is 15.57 ± 0.153 %. However, the quality of the acetic acid solution from coffee pulp needs to increase, especially the lower acetic acid content and the light brown colour.

1. Introduction

Coffee is one of the most popular beverages and the largest trade commodities worldwide (Lachenmeier et al., 2020; Klingel et al., 2020). Orrego et al. (2018) reported that coffee is one of the most traded commodities, along with crude oils, consumed by millions daily. Indonesia is the fourth largest coffee producer in the world after Brazil, Colombia, and Vietnam which also play major roles in the global coffee trade, developments, and the country's economy (Orrego et al., 2018).

According to Berecha, (2011); Ameca et al., (2018); Klingel et al., (2020), there are two methods of coffee processing which are dry and wet methods that are most useful for coffee processing by farmers and producers. Both processes will produce green beans and by-products. Meanwhile, Mangku et al. (2022) found that there are three methods of coffee processing namely natural, honey, and full wash (wet processing). In the wet process, the coffee pulp is the main by-product and represents 55 % of the whole berry

(Murthy & Naidu, 2012; Ameca et al., 2018). Most of the coffee pulp generated during wet processing is deposited directly into huge waste disposal sites or river streams without undergoing any treatment (Geremu et al., 2016). Navia et al. (2011) stated that coffee processing creates problems (1) organic waste products, such as mucilage and pulp, (2) residue of coffee processing, which represents a major source of environmental pollution, and their disposal is usually done in the water resources closest to the processing sites, such as rivers and lakes. Pulp and mucilage consume the oxygen in water, resulting in the death of plants and animals due to the lack of oxygen or the increased acidity, (3) This fact can later result in a proliferation of undesirable microorganisms, bringing foul odours, attracting flies and other insects and rendering the water undrinkable as well as many other things which make the water useless.

As the production of coffee has increased, the resulting by-products of coffee generated during wet or dry processing also increased (Orrego et al., 2018). Orrego et al. (2018) also reported that wet coffee processing will produce coffee residuals such as 43.2 % (w/w) of skin and pulp, 11.8 % (w/w) mucilage and soluble sugars, and 6.1 % (w/w) silver skin or parchment. Meanwhile, Saisa & Maliya Syabriana. (2018) reported that fresh coffee cherries content of coffee pulp is 45 %, mucilage 10 %, parchment, and silver skin 5 %, and coffee beans 40 %. This means that 60 % of waste is produced when coffee is processed. According to Arpi et al. (2018), coffee processing produces coffee pulp around 43-50 % of coffee cherries. Coffee mucilage, rich in carbohydrates and nitrogen, is considered to be a potential substrate in the bio-based industry to produce value-added molecules and commodities, such as ethanol and lactic acids.

Vinegar is an aqueous solution of acetic acid and other constituents and is known and consumed worldwide as a food condiment and preservative. Furthermore, in folk medicine, it is used in wound treatment, as well as a hand-washing agent to prevent infection (Gomes et al., 2018). Ouattara et al. (2019) reported that vinegar is defined as a 4 % acetic acid solution that is obtained from double-stage fermentation, alcoholic and acetic, performed, respectively, by yeasts and acetic acid bacteria. Vinegar is widely acknowledged for its functional features possessing antimicrobial properties, antioxidant activity, dietary, antidiabetic, and antitumor effects, as well as preventing cardiovascular diseases (Budak et al., 2014; Coelho et al., 2017). The quality of vinegar depends on fermentation, production methods, raw materials, and additives used. In addition, the acetic acid content, odour component, and organic acid and free amino acid composition affect the quality of vinegar (Kang et al., 2020).

Based on data in 2018, it is stated that 527.80 thousand tons of Robusta coffee were processed to produce coffee beans. From the total, 50 % of the processing results are coffee beans and the remaining 50 % (263.9 tons) are by-products (waste). The projection of Indonesian coffee production until 2023 is estimated to reach 777.12 thousand tons of ground coffee. Coffee production growth from 2019 - 2023 is expected to continue to rise, with an average increase of 1.43 % per year (Anonymous, 2019). This means that the more coffee production, the more coffee waste will be generated. The simple impact is a foul smell that quickly appears. This is due to coffee husks still have a high water content, which is 75 - 80 % therefore are very easily overgrown by spoilage microbes, this will disturb the surrounding environment if in large quantities it can pollute the air (Juwita et al., 2017).

Several researchers found that coffee pulp can be used for many products such as silage, molasses, alcohol, soft drinks, jam, pectin, and other products. However, there are only a few who produce vinegar. In light of these environmental concerns need to mitigate the negative environmental impacts of coffee waste from the coffee processing. The study aims to evaluate and analyse the type of yeast and fermentation time effects on quality and to determine the best processing method to produce vinegar. However, this study will increase the utilization of coffee waste to be an innovative product that has economic value and provide benefit for the farmers or producers.

2. Materials and Methods

The material used in this study was the Robusta coffee cherry pulp that grows 1200 m above sea level. The coffee cherries were harvested from a farmer managed by Bumdes Eka Giri Karya Utama located in Wanagiri Village, Sukasada District, Buleleng Regency. Robusta coffee is better grown in elevation ranges 200-700 m above sea level, meanwhile, in this location around 1200 m above sea level, the coffee plants slightly grow

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well. These conditions will affect the chemical composition, taste, and flavour of the coffee beans as well as the waste characteristics. The maturity of coffee cherries is optimally ripe and has a red skin colour of 95 %. The type of yeast used is bread-fermented yeast with the brand "Fermipan" with the composition of Saccharomyces cerevisiae (produced by S.I.L. France, imported by PT. Sangra Ratu Boga, Indonesia) and cassava fermented yeast with the brand "NKL" (Na Kok Liong produced by Ragi Tape NKL, Surakarta, Indonesia). Both yeasts were bought in a Cake Shop in Denpasar, Bali Indonesia. The equipment used in coffee processing includes pulper machine Type Horja (PD. Karya Mitra Usaha, Indonesia), huller MPK 2500 (PT. Bahagia Jayaindo, Indonesia), refrigerator model G236AH-BK (Merk Sanken), rotavapor R-300 BUCHI (Flawil, Switzerland), etc. The pulper machine is used to remove the pulp of coffee cherries from the beans and the huller machine is used to separate the outer skin and green beans. Instruments for chemical and physical analysis consist of Colorimeter CS-280 (Dongguan, Cina), oven, Soxhlet HM250C (Stuart, UK), desiccator, analytical scale, steak thermometer, Hygrometer, condenser, Memmert incubator N-15 (Germany), Centrifuge HC1120T, Autoclave Model HVE-50 (HIRAYAMA, JAPAN), UV-Vis Double beam spectrophotometer Libra S 60 (Biochrom Ltd, UK) and hand refractometer ATAGO (Master-53M JAPAN).

This research used a complete randomized design that consists of two factors, namely: the first factor is the type of yeast including bread-fermented yeast, cassava-fermented yeast, and mixed bread-fermented yeast and cassava-fermented yeast. The second factor is the time of fermentation, which consists of 13 days and 16 days. This research was replicated three times, therefore there are eighteen sample units.

2.1 Sample preparation

The pulp of Robusta coffee was used as a sample to process before being analysed. The coffee pulp was cleaned and sorted to obtain good quality materials as used for a sample. 1500 mL of water was added to 1500 g of cleaned pulp and then blanched before it was extracted for 30 minutes. The filtrate continued to strain to get clear of filtrate then it was pasteurized at 80oC for 10 minutes. After pasteurization, the filtrate was cooled until the temperature was 27oC (room temperature). The 1500 mL of the filtrate was divided into six parts with a volume consisting of 250 mL for each treatment. Two samples were added with 5 g of bread-fermented yeast, two samples were added with 5 g of cassava-fermented yeast, and the last two samples were added by mixing 2.5 g of bread yeast and 2.5 g of cassava-fermented yeast (mixing yeast). All the samples were added with sugar (sucrose) of 50 g. The samples then were centrifuged at 100 rpm for 5 minutes to make a homogenous sample. All the samples were fermented for 2 days with the anaerobic condition and then continued to ferment for 13 days and 16 days at room temperature (30oC) with the aerobic condition. After fermentation was finished, the sample continued to distillate using rotavapor R-300 BUCHI for 1 hour for each treatment, then the filtrate was collected to analyse the chemical characteristics.
2.2 Chemical analysis procedure of acetic acid solution.

The chemical characteristics of the acetic acid solution were evaluated through moisture content, total soluble solids (TSS), pH, acetic acid content, and reducing sugar.

Moisture content

The moisture content of the sample (acetic acid solution) was analysed using the Gravimetric method (Kyaw et al., 2020). Firstly, the dish and its lid were dried in the oven at 105 °C for 3 h and then transferred to the desiccator to be cold. The dish and lid were weighed after cooling. Secondly, 3 g of the coffee sample was weighed and placed in the dish. The dishes with the samples were placed in the oven and dried at 105 ˚C for 3 h. After drying, the dish partially covered with a lid was transferred to the desiccator to be cold. The dish and sample were re-weighted after cooling, and the moisture content of the samples was calculated by Equation 1.

$$\% \text{ Moisture} = \frac{W1-W2}{W1} \times 100\% \quad (1)$$

Where, W1 = weight of the sample before drying (g)
W2 = weight of the sample after drying (g)

Total Soluble Solid (TSS)

Total dissolved solids were measured using a hand

refractometer. A sample of the acetic acid solution was placed on a refractometer prism, then readings were taken. Before and after readings, the refractometer prism was cleaned with alcohol. The refractometer number showed the total dissolved solids content (oBrix). A precipitate is formed or not in a reaction depending on the solubility of the solute. Precipitation can occur when the concentration of a compound exceeds its solubility. Testing of Total Soluble Solids of acetic acid solution was carried out using a Hand-Refractometer. First Refractometer was rinsed with distilled water and wiped with a soft cloth. The sample was dropped into the refractometer prism and measured with its o Brix (Wahyudi & Dewi, 2017). Testing the total soluble solids content began with a hand-refractometer calibration using distilled water, then 1-2 drops of the sample were dripped on the refractometer prism at 25 °C, then the Brix degree was measured. The degree of o Brix measured indicated the content of soluble solids in the solution (Ismawati, 2016).

pH

pH measurements were conducted using a digital pH meter (HI 8424 HANNA); a 10 mL homogenized sample (acetic acid solution) and 90 mL of distilled water were added, and the pH was read directly from the pH meter. The instrument was calibrated with standard buffer solutions of pH 7 and 4 before measuring the pH of the samples (Ezemba et al., 2021).

Acetic acid content

Samples of each treatment as much as 10 mL were homogenized with distilled water up to 100 mL in a volumetric flask. Ten millilitres of the solution was added with phenolphthalein indicator (± 2-3 drops) and then titrated with 0.01 N NaOH solution until the pink colour was stable and then the amount of NaOH solution needed was calculated (Nurhasanah & Zona, 2021). (BM of Acetic Acid = 60.05 g/mol).

$$\%\ \text{Acetic acid} = \frac{\text{Volume NaOH (ml)} \times \text{N NaOH} \times \text{MW Acetic acid} \times \text{df}}{\text{Volume of Sample (ml)} \times 1000} \times 100\% \quad (2)$$

Where, N = normality of NaOH
MW = molecular weight of acetic acid
df = dilution factor

Reducing sugar

Analysis of reducing sugars using the Nelson-Somogyi method (Romadhoni et al., 2017). 1 mL sample was added with distilled water until the final volume was 10 mL. The mixture was taken at 1 mL and added 9 mL of distilled water. Samples were taken at 1 mL and mixed with 1 mL of Nelson's solution (a mixture of Nelson A & B; 25:1 v/v), then heated at 100°C for 20 minutes. The sample was cooled to room temperature. The sample was added with 1 mL of arsenomolybdate solution and 7 mL of distilled water and then shaken. The mixture was put into a cuvette and the absorption of visible light was measured at a wavelength of 510 nm. The absorbance value obtained was reduced by the absorbance value of the blank so that the absorbance value of the sample was obtained. The absorbance value of the sample was converted to reducing sugar content (mg/mL) based on the standard solution regression equation. The reducing sugar content of the sample was calculated by the following formula.

$$X = \frac{y - a}{b} \quad (3)$$

Where, x = reducing sugar concentration
y = absorbance of a sample
a and b = constants of a standard curve

$$\%\ \text{Reducing sugar} = \frac{(x \frac{\text{mg}}{\text{mL}} \times df \times 100\%)}{\frac{\text{mg}}{\text{mL}}\ sample} \quad (4)$$

Where, x = reducing sugar (mg/mL)
df = dilution factor

2.3 Statistical analysis

The experiments were replicated three times and the data obtained in the physical-chemicals analysis will be submitted to the Analysis of Variance (ANOVA) with a confidence level of 95 %. The analysis will be continued to Duncan's multiple range test (DMRT) while the effects of the processing methods were significantly different, using Minitab Version 16 (Nakpatchimsakun et al., 2023).

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3. Results

The acetic acid solution produced from coffee by-products was affected by the kind of yeast types used and the fermentation process. The interaction of yeast types and fermentation times had a significant effect ($P < 0.05$) on the moisture content and the total soluble solids (TSS) of the acetic acid solution. The characteristics of the acetic acid solution that was produced are shown in Table 1.

Total Soluble solids (TSS) consist of many compounds such as sugar, pigment, vitamins, and minerals. Sugar is the most abundant content of TSS in vinegar (Zubaidah, 2010). This research found that the yeast types and fermentation times had a significant effect ($P < 0.05$) on the total soluble solid of the acetic acid solution. The TSS content of the acetic acid solution ranged from 13.37 ± 0.153 % to 15.57 ± 0.153 % and the higher TSS of 15.57 ± 0.153 % result was given by cassava fermented yeast with fermentation for 13 days. Meanwhile, the lower TSS is 13.37 ± 0.153 % was produced by mixing yeast, and 13 days of Fermentation (Table 1).

Based on this study the treatments of bread-fermented yeast and cassava-fermented yeast had a significant effect ($P > 0.05$) on pH, acetic acid content, and reducing sugar as well. The average value of pH, acetic acid, and reducing sugar of the acetic acid solution was presented in Table 2.

The interaction of both treatments of fermentation time and yeast types, in which the fermentation time gave no significant effect ($P > 0.05$) on the pH of the acetic acid solution, meanwhile, the yeast types gave a significant effect ($P < 0.05$) on the pH. The pH of the acetic acid solution ranges from 4.104 ± 0.04 to 4.889 ± 0.12. This pH is higher than the pH of grave vinegar ranging from 2.59-2.98 found by Kang et al. (2020). In this study, the highest pH 4.889 ± 0.12 was produced by bread-fermented yeast and showed significantly different with both treatments namely cassava fermented yeast and mixing of both yeasts. Otherwise, the lowest pH 4.104 ± 0.04 was produced by cassava fermented yeast.

Acetic acid content became a parameter that determined the quality of the vinegar. The Increasing acetic acid content in vinegar will increase the quality level. Based on statistical analyses the type of yeast had a significant effect ($P < 0.05$) on the acetic acid con-

Table 1. Physicochemical characteristics of the acetic acid solution in various types of fermentation

Treatments	Moisture content (%)	Total Soluble Solid (%)
Bread Fermented Yeast; 13 days Fermentation	95.75 ± 0.116 a	14.17 ± 0.153 ^{b}
Bread Fermented Yeast; 16 days Fermentation	92.50 ± 0.116 b	13.57 ± 0.321 ^{c}
Cassava Fermented Yeast, 13 days Fermentation	90.61 ± 0.294 ^{c}	15.57 ± 0.153 ^{a}
Cassava Fermented Yeast, 16 days Fermentation	92.65 ± 0.222 ^{b}	15.37 ± 0.153 ^{a}
Mixing yeast, 13 days Fermentation	91.42 ± 0.281 ^{c}	13.37 ± 0.153 ^{c}
Mixing yeast, 16 days Fermentation	88.36 ± 0.126 d	14.07 ± 0.231 ^{b}

Means ± standard deviation with different superscript letters in the same column were significantly different ($P < 0.05$)

Table 2. The chemical characteristics of the acetic acid solution in various types of yeasts and fermentation times

Treatments	pH	Acetic acid (%)	Reducing Sugar (%)
Type of Yeast			
Bread Fermented Yeast	4.889 ± 0.12 a	0.738 ± 0.20 c	1.440 ± 0.24 [a]
Cassava Fermented Yeast	4.104 ± 0.04 [c]	1.983 ± 0.04 [a]	1.505 ± 0.03 [a]
Mixing Yeast	4.707 ± 0.02 [b]	1.625 ± 0.06 [b]	1.385 ± 0.18 [a]
Times of Fermentation			
13 days Fermentation	4.610 ± 0.43 [a]	1.397 ± 0.72 [a]	1.550 ± 0.05 [a]
16 days Fermentation	4.523 ± 0.39 [a]	1.500 ± 1.40 [a]	1.337 ± 0.13 [b]

Means ± standard deviation with different superscript letters in the same column were significantly different ($P < 0.05$)

centration of the acetic acid solution. Otherwise, the fermentation time and the interaction of both treatments did not significantly affect ($P > 0.05$) the acetic acid concentration. Table 2 shows that the acetic acid concentration ranges from 0.738 ± 0.20 % to 1.983 ± 0.04 %. The highest acetic acid content of 1.983 ± 0.04 % was found in fermented using cassava fermented yeast. Meanwhile, the lowest acetic acid concentration of 0.738 ± 0.20 % was given by fermentation with bread-fermented yeast, and between both yeasts indicated significant differences.

Reducing the sugar content of the coffee pulp can contribute to acetic acid formation during the fermentation process. The increase of reducing sugar in raw material will increase the acetic acid content of the acetic acid solution. The reduced sugar content of the acetic acid solution ranged from 1.337 to 1.550 % (Table 2). These values were lower than that of 25.13 to 39.09 % obtained by Ouattara et al. (2019). Table 2 showed that the types of yeast were not significantly affected ($P > 0.05$) by reducing the sugar content of the acetic acid solution. Meanwhile, the times' fermentation had a significant effect ($P < 0.05$) on reducing sugar content. The reduced sugar of fermentation for 13 days 1.550 ± 0.05 % is higher than the acetic acid solution that fermentation for 16 days is 1.337 ± 0.13 % and both fermentation times showed significantly different.

4. Discussion

Moisture content can affect the quality of the acetic acid solution. The moisture content of the acetic acid solution is influenced by the water content of raw material, the addition of water in the extraction step, and the evaporating time used during the processing of the acetic acid solution. Based on the statistical analysis, the interaction of both treatments from the types of yeast and fermentation times significantly affected the moisture content of the acetic acid solution. Table 1 shows that the moisture content of the acetic acid solution from all combination treatments ranges from 88.36 ± 0.126 % to 95.75 ± 0.116 % indicating that the acetic acid solution still has a higher moisture content that causes decreasing quality, especially acetic acid content. This moisture content is slightly higher than those obtained from the vinegar by Ouattara et al. (2019) of 80.03 % to 88,67 %. Increasing in time fermentation tends to decrease moisture content. Using cassava-fermented yeast gave a lower moisture content of 90.61 ± 0.294 % than bread-fermented yeast except with combination of both yeasts showed a significant difference ($P < 0.05$) due to slightly higher moisture content. Probably due to cassava fermented yeast (NKL) consisting of many microorganisms that used the substrate of coffee pulp for growth and therefore, it increased the moisture in the acetic acid solution. According to Triani et al. (2019) & Ester et al. (2021), acetic acid in vinegar is oxidized by acetic acid bac-

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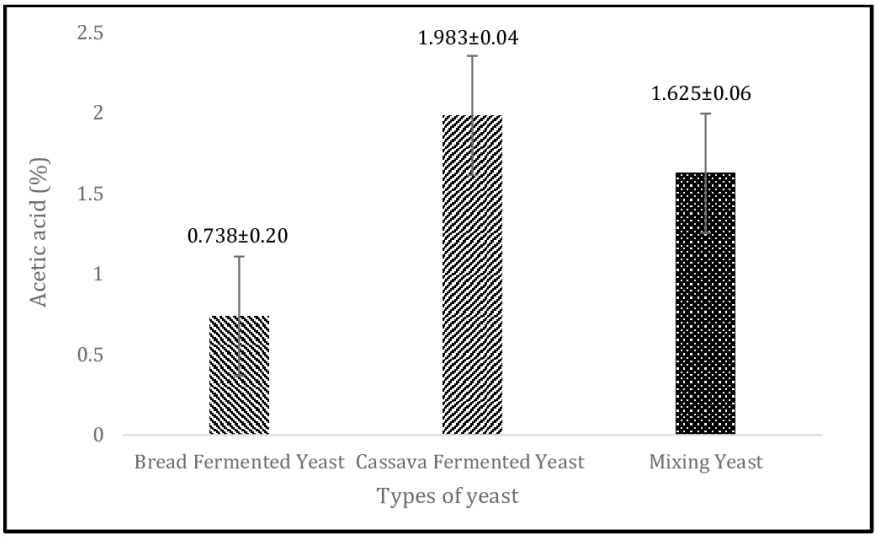

Figure 1. Acetic acid concentration (%) in the acetic acid solution in various types of fermentation

teria to produce H2O and CO2 therefore decreasing acetic acid concentration. Navia et al. (2011) reported that the decomposition is related to soluble solids, pH, and microorganisms present in the raw materials. However, while the moisture content is higher 92.50 ± 0.116 %, therefore, the acetic acid concentration in vinegar is lower.

The lower TSS content will make the acetic acid solution look clearer than the higher TSS content. However, this TSS content of 13.37-15.57 % is higher than was studied by Kang et al. (2020) who found the TSS content of grave vinegar ranges from 8.30-9.53 % o Brix. This is probably due to cassava fermented yeast containing many microorganisms that cause the breakdown of large compounds, thus increasing simple compounds. The cassava fermented yeast (NKL) consists of many types of microorganisms such as Amylomyces sp. Aspergillius sp, Mucor sp, Saccharomyces sp, Candida sp, and Acetobacter aceti (Ninsix, 2013). Wicklund et al. (2020) reported that yeast strains of Saccharomyces cerevisiae, S. bayanus or S. bayanus var. uvarum produce ciders of good quality. In addition, during fermentation, the total soluble solid (TSS) decreases due to the increase in fermentation time. Zubaidah, (2010) reported the decrease in total soluble solids during fermentation was due to the hydrolysed of sugar into alcohol and CO2 which is then used by acetic acid bacteria as a carbon resource. Increasing the TSS content in the coffee pulp will increase the formation of acetic acid concentration in the acetic acid solution.

The pH of the acetic acid solution shown is in line with that of vinegar from mango juice is 4.25 studied by Adebayo-Oyetoro et al. (2017). The highest pH of 4.889 ± 0.12 produced by bread-fermented yeast is probably due to yeast containing only Saccharomyces cerevisiae which can break down the carbohydrate to alcohol and therefore can increase the pH. The highest pH was also due to the lowest content of acetic acids is 0.738 ± 0.20 % (Table 2). This is in line with what was stated by Cempaka et al. (2023) under anaerobic conditions, yeast produce ethanol that can increase the pH. Meanwhile, cassava fermented yeast contains many microorganisms such as yeast, mould, and bacteria that can convert carbohydrates to alcohol and then oxidation alcohol to acid compound decreasing the pH. According to Fauziah et al. (2020), cassava fermented yeast contains many microorganisms such as mould, yeast, and bacteria. The longer fermentation for 16 days gave a lower pH of 4.523 ± 0.39 than the fermentation for 13 days of 4.610 ± 0.43. However, both fermentation time does not show a significant difference in the pH of the acetic acid solution (Table 2). Fauziah et al. (2020) reported that longer fermentation can increase the alcohol and acid content and then decrease of pH. Probably, this range of pH of

4.104 ± 0.04 to 4.889 ± 0.12 is favourable for growing Saccharomyces cerevisiae. Triani et al. (2019) & Ester et al. (2021) reported that the optimum pH for Saccharomyces cerevisiae is around 3.5-6.5.

This acetic acid content is lower than that of 1.08 to 4.26 % obtained by Ouattara et al. (2019) due to the vinegar from mango juice having higher reducing sugar and lower moisture content than Robusta coffee pulp. In this study, there is a tendency that the use of bread-fermented yeast will decrease acetic acid content (Figure 1). The highest content of acetic acid was given by cassava fermented yeast probably due to acetic acid bacteria contained in the yeast oxidation of the alcohol to acetic acid in aerobic conditions. This is related to the research found by Fauziah et al. (2020) that alcohol will oxidize to acetic acid by acetic acid bacteria in aerobic conditions. In line with what was studied by Nurhasanah & Octarya, (2018) it was found that cassava-fermented yeast is better used for vinegar production from banana peel. Luzón-Quintana et al. (2021) reported the different microorganisms responsible for each process along with the physicochemical properties of the final products. The raw material employed for vinegar production plays an important role in the final characteristics of the developed product. Based on this study, acetic acid concentration in acetic acid solution is still low due to higher water content. Reducing moisture content can be done by increasing the time of the evaporating process. According to Indonesia National Standard, (2020) (SNI 01-3711-1995) & FDA (Adebayo-Oyetoro et al., 2017), the vinegar product contains a minimum of 4 % of acetic acid. Meanwhile, vinegar in this study contains less than the standard namely ranging from 0.738 ± 0.20 % to 1.983 ± 0.04 % which means that it does not fulfil the standard yet. However, it needs to increase evaporating time and sugar concentration to increase the acetic acid concentration.

The increasing fermentation time can decrease the sugar content in acetic acid solution due to being hydrolysed into alcohol and CO2. Shamsudin et al. (2019) & Kong et al. (2018) stated that the increase in reducing sugar content is due to the hydrolysis of polysaccharides present in the vinegar, such as pectin, cellulose, and starch, into reducing sugars. In addition, the increase in reducing sugar is also caused by converting sucrose sugar into glucose and fructose (reducing sugar) by an invertase enzyme that is produced by Saccharomyces cerevisiae (Triani et al., 2019) & (Ester et al., 2021).

Conclusion

The characteristics of the acetic acid solution were affected by the types of yeast and fermentation time. The use of cassava fermented yeast (NKL) can produce better characteristics of the acetic acid solution than bread-fermented yeast and mixing both yeasts. Increasing fermentation time tends to increase acetic acid content but decreases pH and reduces sugar. Production of acetic acid solution from Robusta coffee pulp can use cassava fermented yeast with fermentation for 13 days at room temperature. The characteristic of the acetic acid solution that was produced has a moisture content of 90.61 ± 0.294 %, a total soluble solid is 15.57 ± 0.153 %, reducing sugar of 1.505 ± 0.03 %, the acetic acid content of 1.983 ± 0.04 %, and pH of 4.104 ± 0.04. However, the quality of the acetic acid solution is still low, therefore it needs to improve especially for the acetic acid content that doesn't fulfil the standard quality yet, and also the colour of the acetic acid solution still looks light brown.

Conflicts of interest

The authors declare no conflicts of interest.

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