Novel utilization of coffee processing by-products: 
kombucha cascara originated from ‘Gayo-Arabica’

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Abstract. One of the current significant environmental challenges that have to be dealt with by the majority of farmer in Indonesia, especially those on Gayo highlands - is the absence of an optimal utilization of coffee by-products or waste, which is deliberately produced in a great amount during the coffee processing. The Gayo highlands are located in the middle regions of Aceh province and widely known as the most extensive arabica coffee plantation all over Indonesia, with a total area 101,473 hectares. The aim of this research was to optimally utilize the by-products or the exfoliated cherry-pulp into the so called kombucha cascara bearing great economical potential. However, further information in terms of its optimum processing condition (the length of fermentation duration, concentration of kombucha starter) from the cherry pulp into kombucha cascara has been much unexplored. In order to reveal that, we were trying to apply the effects of wo determinants, namely: i) fermentation duration (8,12 days); ii) starter concentration applied (3%, 5%, and 7%) on kombucha cascara’s chemical parameters [pH, total phenolic amount, antioxidant activity] and sensory in the form of hedonic test. Such test enabled us in describing consumers’ preference based on its ‘pronounced’ the taste. Results showed that pH was ranged from 2.63 until 3.10, meanwhile, a relatively high antioxidant activity ranging from 25.78 and 51.69% noted with a total phenolic compound between 64.00 - 105.20 mg GAE (Galic Acid Equivalent) /ml were measured. This can be inferred that quality was shown to be deliberately affected both by the length of fermentation and starter’s concentration, albeit the first one was to be more affecting. The longer the fermentation period, the lower the acidity value, and interestingly, significant decreases by total phenolic compound and antioxidant activity were also measured. It is also concluded that 12-days fermentation process added with 5% started received the highest score for sensory test.

1. Introduction

Coffee (Coffea sp.) is one of the most important beverages in the world. Although there are over 120 species included, only two are attributed with significant economic importance they are: C. arabica or commonly known as ‘arabica’ and C. canephora or ‘robusta’ [1]. The plants are mostly planted in tropical countries; likewise in Indonesia that is listed as the fourth biggest world coffee producer after Brazil, Vietnam and Colombia. The total area of plantation is estimated about 1.25 millions of hectare,
in which 80% of the total area is majorly dominated by *robusta* and thus, it is referred as the major coffee commodity at the global level [2].

*Arabica,* contrarily, is more preferred due to its sweeter, milder taste due to less caffeine content, and more well-adapted to higher altitude (> 750 m a.s.l.). Its plantations are mostly located on the highlands at the tropical belts, such as the Gayo highlands located in the middle regions of Aceh. With a total area of plantation up to 101,473 hectares extended evenly in the three districts (Bener Meriah, Middle Aceh, and Gayo Luks) with 78,624 households being involved, thus, they are remarked as the most extensive arabica coffee plantation all over Indonesia. The average productivity is 773 tons per hectare, and a total production almost 62 tons per annum. Furthermore, the ‘Gayo-arabica’ coffee strongly attributed with special taste and an excellent flavor, is known as one of the best specialty coffee in the world [3]-[4].

One of the current significant environmental challenges being faced by most of farmer in Indonesia, especially those on Gayo highlands is the absence of an optimal utilization of coffee by-products or waste, which is deliberately produced in a great amount during the coffee processing. The coffee (cherry) fruit consists of several components. However, they can be generally divided into two: the bean as the main component and the cherry-pulp with high nutrients such as: carbohydrates (35%), protein (8.9%), fibre (30.8%), minerals (10.7%), sugar (4.1%), and some amount of polyphenolic compounds e.g. chlorogenic acid, flavonol, anthocyanidin, catechin, rutin, tannin, and ferulic acid [5]. These ‘by-products’ originated from the exfoliated cherry pulp, can be further dried and processed into *cascara*. It is served and drunk in a similar way like ‘tea’ although its flavor is specific natural taste and a kind of combination between sour taste and slightly sweet [6]-[7].

Despite of high nutrients containing in *cascara*, its typical taste still can’t fulfilled consumers’ preferences. Many consumer expected that *cascara* should be resembling to tea, nevertheless, this was not performed during a recent sensory taste as a result of an imbalanced combination between sweet and sour taste, which finally produces a slightly bitter or ‘odd’ taste, at the end [8]. He also proposed that some chemical components containing in the cherry pulp might contribute to that kind of ‘odd’ taste. Concerning the existing high nutrients in *cascara* and to increase the level of consumer’s acceptance, therefore, we would like to further improve the ‘taste’ via biochemical process or fermentation known as *kombucha* [9]. The fermentation process itself, in general, is defined as the process of decomposition of substrates generally in the form of macro-molecules into simpler ones; as the final products; with the involvement of various microorganism strains and enzymes, so that the final taste would have an additional- or special taste.

*Kombucha* has been favored as healthy drink in several countries e.g. China, Germany, and Russia [10] (Dipti et al., 2003), nowadays, it has been preferred in the U.S [11] due to its positive health effect in preventing non-communicable-diseases (cancer and CVD), reducing inflammation, and enhancing the digestive- immune system in general. Moreover, the symbiosis between bacteria and yeast would bring growth-hemmed effects against pathogenic bacteria [12]. Initial inputs as substrates are usually made from coconut water, hot tea, lemon balm, mint leaves, jasmine flower, wine etc. [13]-[14]-[15].

Specifically, *kombucha* is a kind of fermented tea that is added with sugar and natural bio-compounds resulted from the Symbiosis Between Bacteria and Yeast or abbreviated as SCOBY, which is literally defined as natural agents that are able to produce bio-compounds as the microorganisms action; including the fungi spreading-out evenly on the surface of *kombucha*, have the ability to decompose the sugar block molecules, into various acids e.g. acetic-, carbonate-, condroitine sulfate-, folate-, gluconate-, glucorolate-, lactic-, usnate-acid, simple sugar compounds, vitamins (mostly representing from B1, B2, B3, B6, B12, B15 and C), alcohols, and diverse polyphenols and hyaluronic acid with strong antioxidant effects. Some microorganisms mainly representing the lactic-acid bacteria group e.g.: *Acetobacter xylinum, A. xylinoides, Bacterium gluconicum, A. acetii, A. pasteurianus.* Meanwhile, *Schizosaccharomyces pombe, Saccharomyces ludwigii, Kloekcera apiculata, Saccharomyces cerevisiae, Zygosaccharomyces bailii, Brettanomyces bruxellensis, B. lambicus, B.custers ii, Candida dan Picha* are classified as several strains of yeast [12]-[16]. Figure 1 presents the
appearance of fermented *kombucha*-tea, which was originally originated from fermented tea, while the floating thin white layer can be found at the surface.

Figure 1. *Kombucha* tea.

Fermentation process is usually affected by various factors, *e.g.* types of (plant) serving as input or substrates, the duration of fermentation, temperature, added sugar- or starter concentration. All of these would determine the characteristics performed by *kombucha* [17]-[18]. Common duration of fermentation requires 8-12 days. Jamilah [19] had conducted a 12 day-fermentation with a step-wise concentration of starter: 2%, 4%, 6% and 8%. Contrasting, an 8 day-fermentation duration with a varied concentration of starter: 0%, 5%, 10%, 15%, 20% and 25% [% w/w] were conducted by Syahbandini [20]. His result showed that concentration of 5% resulted the best sensory and chemical characteristics.

So far, there has been no publication about the characteristics of *cascara* resulted from the *Gayo-arabica*. Moreover, it also remained unknown whether fermentation duration and the concentration of starter had an effect to the chemical characteristics and sensory test of *kombucha cascara* in terms of its quality. Hence, we would like to investigate the effects of two factors against the chemical characteristics and the sensory.

2. Materials and methods

Research was conducted at the Laboratory of Food Processing, Modification and Industry; one of the laboratoria belongs to the Department of Agricultural Product Technology, Faculty of Agriculture, Syiah Kuala University in Banda Aceh. Analytical scale, plastic pail, glass container, cup test for sensory, food filter, spoons, organoleptic test form, paper labels, pulper, glass-cuvette, plastic mate, chemical glasses, measurement glasses with marker, gas stove, erlenmeyer glasses, titration burette, ball-pipette, beaker glasses and UV-VIS spectrofotometer.

Aquadest, chloroform, Diphenylpicrylhydrazyl (DPPH) solution, ethanol (70% v/v), FeCl₃, K₃Fe(CN)₆, *kombucha* starter, natrium hydroxide (NaOH) 0.1 N, phenophtalein as indicator, water (H₂O).

Meanwhile, the applied raw material was the *exfoliated* coffee cherry pulp belongs to Gayo-arabica type that was obtained from coffee farmer in Middle Aceh. *Kombucha* starter (SCOBY) was purchased from the producer in South Tangerang, Banten, west Java, Indonesia.

The research was an experimental type using two different factors that were investigated. The first one was the fermentation duration or abbreviated as ‘F’, consisting of two level: F₁= 8 days, F₂= 12 days. The second one is the step-wise concentration of *kombucha* starter referred as ‘K’ (K₁= 3%, K₂= 5%, K₃= 7%); in triplicates (N_total= 18 units). The quantitative-data was summarized and recorded in a table, then noticed as mean values (average). While, the qualitative-ones were using descriptive analysis.
2.1. The making process of ‘cascara’

The method defined by Nafisah dan Widyaningsih [21] was referred during the making process of cascara with little modification. Preparing raw materials: red coffee cherries were separated from the coffee beans using special machine called as ‘pulper’, then the exfoliated cherry pulp was collected, sun-dried for three days, and selected based on good quality, such as: intact pulp, uniform pulp thickness, red-brown color were intended to be applied as cascara. Cascara processing: approximately 100 grams of cascara added with 5 litres of hot water (T= 65-75 °C), were added with 10% (w/v) white-sugar and stirred until homogenous. The filtrate was then removed and the brownish liquid resembling to tea – referred further as cascara. This would served as the input or substrate and be added with starter. The end product would be known as kombucha cascara.

2.2. The making process of ‘kombucha cascara’

The method for making kombucha cascara reported in advance by Nurhayati et al. [22] (2018) with slight modification was referred as our basic procedure. The already prepared cascara was cooled down until room temperature (T= 25 °C). Previously, a glass jar was labelled from 1 to 18. Each glass was filled with approx. 250 ml cascara. Diverse concentrations of 3%, 5%, and 7% (v/v) were added, the opening part was closed and covered with sterile napkin. Fermentation duration of 8 and 12 days were applied in this experiment. After exceeding the duration, the liquid was filtrated. The remaining filtrate was used and further subjected in chemical analyses and sensory tests.

2.3. Chemical analyses and sensory test

Measurement of pH [23], total phenolic amount by using Folin-Ciocalteau (mg GAE/ml) [24], antioxidant activity by applying DPPH method (‰) [25] were prepared for chemical work. In order to enable us to describe consumer’s preference, hedonic test was served as sensory test and the results were presented qualitatively based on the Likert scale (1= not at all; 2= slightly fond, 3= neutral, 4= fond, 5= very fond) [26].

3. Results and discussion

Kombucha cascara was able to be made via the fermentation process of exfoliated cherry pulp or by-products obtained from the ‘Gayo-arabica’. Its physical property did not differ much with the conventional kombucha in general (Figure 2). Further chemical analysis and sensory test were also then performed. Table 1 presents the chemical and sensory value of kombucha cascara based on two factors: fermentation duration and starter concentration.
Table 1. pH value of kombucha cascara based on two factors.

| Treatment | Starter concentration | pH* Value | TPC* (mgGAE/ml) | AA* (%)* | Sensory Test$ | Remarks |
|-----------|-----------------------|-----------|-----------------|----------|---------------|---------|
| F1=8 days | K1=3%                 | 2.8       | 105.20          | 42.38    | 3.55          | fond    |
|           | K2=5%                 | 3.0       | 98.05           | 48.80    | 3.17          | neutral |
|           | K3=7%                 | 3.1       | 98.20           | 51.69    | 3.68          | fond    |
| F2=12 days| K1=3%                 | 2.6       | 66.12           | 25.78    | 3.60          | fond    |
|           | K2=5%                 | 2.6       | 64.00           | 35.72    | 3.76          | fond    |
|           | K3=7%                 | 2.8       | 64.91           | 37.48    | 3.63          | fond    |

*Value is the average of triplicates; * Total Phenolic Compounds; ¶ Antioxidant Activity; $ Likert scale: 1= not at all; 2= slightly fond, 3= neutral, 4= fond, 5= very fond

3.1. pH value

The range of pH was low, namely between 2.63 and 3.10, with an average of 2.87. The range of pH was low, namely between 2.63 and 3.10, with an average of 2.87. A lower pH value was performed by 12- rather than by 8-days of fermentation in three different concentration of starter (K1, K2, K3) that could be related with the formation of metabolites in the form of organic acids resulted from the nutrient’s decomposition in the media or substrates (Table 1). The amount of organic acids produced was relatively high, this has deliberately affected the decreasing value of pH. Such tendency was also observed by Jayabalan et al. [27] (2014), who reported a significantly negative correlation between pH value vs. organic acids’ amount. Longer fermentation duration was associated with the lower pH had been also reported [28]-[29]-[30]-[31].

Moreover, microbial activity; in this case the bacteria and yeast containing in the starter might also have an effect by the lowering of pH. Briefly summarized, the fermentation process is usually started with the decomposition of sugar with the involvement of yeast and finally produces alcohols as an end product. Meanwhile, the lactic acid bacteria usually utilize glucose, glucoronic acids, and alcohols for producing their end products, namely acetic acids [27]. By the fermentation process of kombucha, two main components of metabolites are produced: monosaccharide, organic acids, and vitamins as the major [32]; meanwhile, lactic acids, phenolic acids, vitamin B, and some enzymes as the minor ones [33].

3.2. Total phenolic compounds (TPC)

Total Phenolic Compounds or TPC at three different concentration at 8 and 12 days was ranged between 64.00 and 105.20 mgGAE/ml; with an average of 82.75 mgGAE/ml (Table 1). This value is much higher compared to cascara originated from non-arabica type with 39.73 mg GAE/ml being reported [8] was resulted from. A longer the duration did not affect significantly by the amount of TPC. The concentration differences (3, 5, and 7%) were not too much different, and this might also have an effect by the final TPC value. However, the fermentation duration of 12 days had a more deliberately effect on the TPC and this could be linked with the changes in the fermentation milieu as a result of significant increased of organic acids’ amount. A relatively quite low pH might be responsible by the deterioration of antioxidant or bio-compounds, including the phenolic ones. Heat, enzymes, and the changing of pH value might be deteriorated the phenolic compounds. Thus, we can say that further fermentation process would lead to lower TPC.

Compared with the results of the total phenol cascara analysis conducted previously by Limbong [27], which was 39.73 mg GAE / ml, this kombucha cascara has a higher average total phenol, namely 82.75 mgGAE / ml. This shows that cascara processing by fermentation into kombucha can increase total phenol which has positive implications for increasing its functional properties.
3.3. Antioxidant activity (AA)

A value range of 25.78-51.69% with an average of 40.31% were measured within the Antioxidant Activity or AA (Table 1). An 8-days of fermentation was associated with higher AA. The longer the fermentation, however, there was a tendential that AA-value was lowering. Fermentation duration has a significant impact on the AA as the process itself might be biochemically responsible by the diminishing of some bio-compounds or antioxidants, such as phenolic and polyphenolics. The produced organic acids might lead to antioxidant’s deterioration process performed by common kombucha tea and this finally resulted in the decreases of AA [33]. These results were consistent with the TPC results, higher AA was exhibited at shorter fermentation duration (8 days). In short, we can stated that the longer the duration was, the lower the AA. General pattern showed that the fermentation would increase the TPC via biotransformation involving various enzymes available within the microbial kombucha. Thus, the higher the concentration of starter, the higher the amount of produced microbes, enzymes and finally the TPC, as well [34]. However, the increasing tendency would be limited by an optimum point, and anyhow the curve would be slowly going down after reaching its peak. This is in accordance with the result involving the fermentation of kombucha tea delivered by Suprijono [35]. The optimum values was noticed at 7 or 8 days of fermentation, while, a decreasing tendency was observed at the 10th or 14th day [33]-[34]. In our result, we can conclude that higher AA was performed at 8 days of fermentation; depending on the starter concentration.

3.4. Sensory taste

Taste is one of the major and important components within sensory test and this is targetted to measure consumer’s acceptance, qualitatively. Taste involves perception of constituents after being dissolved in saliva, oil or water by taste receptors in the taste buds found superficially on the tongue and other parts of the mouth [35]. The whole sensory taste components that can be described e.g. fragrance, taste, texture would be captured, tasted by the tongue and they would be united in one ‘single’ taste of food or drinking products -. The sensory test didacted in a Likert scale parameter is presented on Table 1.

The value of Likert scale was in the range between 3.17 (neutral) up to 4.76 (fond), with an average of 4.56 (fond). A fermentation of 12 days with 5% starter concentration performed the highest score. Meanwhile, similar concentration rate but with 8 days of fermentation were noticed with the lowest Likert scale (Table 1). The longer the fermentation, the better the performance of decomposed substrates containing high amount of organic acids but tasty. Fermentation duration of 12-days resulted a very low pH value (2.6 – 2.8) and such ‘taste’ description was in accordance with the previous result describing the taste characteristics and components of kombucha, such as acetic acids, glucoronate acids, lactic acids, carbonate acids, folate acids, gluconate acids, condroitin sulfate, and hyalourenic acids [16].

4. Conclusions

This research clearly showed another potential or a novel utilization of coffee processing by-products from the cherry pulp belong to Gayo-arabica, that could be added value as cascara via the additional of starter; a kind of symbiosis between bacteria and yeast or ‘SCOBY’ which enabled the fermentation process. The application of SCOBY was able to decompose cascara containing high nutrients and turn it into functional-drink with health-benefit effect; called kombucha cascara. Its pH range was between 2.63-3.10; 64.00-105.20 mgGAE/ml of TPC compounds; and 25.78-51.69% of AA. Both factors: fermentation period and starter concentration were shown to have a significant effect to its quality. The longer the duration of fermentation was, however, the lower the pH value, TPC and AA. The best sensory test result was performed under 12 days-of fermentation with a 5% of starter addition. Further research attempt should be more concentrated on the analysis of bio-active- and volatile-compounds containing in the kombucha cascara. Moreover, its commercial potential should be confirmed and compared with other types of commercial kombucha.
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