Effect of different brewing techniques and addition of lemon peel (*Citrus limon*) on physico-chemical characteristics and organoleptic of cascara tea

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Abstract. Current application of coffee pulp into tea, called as cascara tea, has improved its usage but it might have an unpleasant aroma and taste. Thus, the addition of other resources such as lemon peel is suggested. This study aims to know the effect of brewing techniques and the ratio of cascara (dried coffee pulp) and lemon peel to physicochemical and organoleptic characteristics of cascara tea, along with the best treatment. This study was conducted by Nested design with two factors, i.e. brewing techniques and the ratio of cascara and lemon peel. The data were analyzed using Minitab 17 and Zeleny method. The results showed that brewing techniques had a significant effect on total phenolic content, caffeine content, color (except in yellowness) and pH. Meanwhile for both factors had a significant effect on all parameters. The best treatment was the ratio of cascara and lemon peel at 80:20% brewed using the decoction method.

1. Introduction
Indonesia is the largest coffee producing country after Brazil, Vietnam and Colombia with 9.6 million 60-kg bags of coffee production in 2018 [1]. During the processing of coffee beans, more than 90% of coffee pulp discharged as a waste which still contains nutrients that can improve human health. Some nutrients derived from coffee pulp are 1.48% of total phenolic content [2] and 1.3% of caffeine [3].

Current utilization of coffee pulp is being consumed as herbal tea, known as cascara tea. Previously, an online survey as the preliminary research of this study was conducted and it showed that 81.6% of 359 respondents were interested in cascara tea. However, consumer acceptance of the taste and aroma of cascara tea must be evaluated [4]. The survey also revealed that 41.7% of the 24 respondents rated the coffee pulp obtained from KUD Karangploso, Malang, East Java have an unpleasant aroma and taste compared to commercial cascara tea which has a sweet aroma and slight sour taste. Furthermore, several recommendations of fruit peel that can be used to improve its sensory properties were also obtained, including lemon peel which has the highest value (290 from 359...
respondents). Lemon peel has complex essential oils such as limonene that gives a distinctive aroma [5].

Tea quality can be determined from several factors such as the ratio of water and tea, leaf size, water temperature, and brewing techniques [6]. Brewing techniques and ratio of ingredients between lemon peel and coffee peel need to be considered. Tea brewing techniques are divided into two, namely infusion and decoction. Infusion is a technique for soaking tea with a certain water temperature in a teapot and is usually used to brew Camellia sinensis tea, while decoction is the process of brewing tea by boiling tea and water at the same time and it usually used to brew herbal tea that still has large particle sizes. Both of these techniques aim to extract bioactive compounds from materials [7]. This study aims to determine the effect of brewing techniques and the ratio of cascarilla (dried coffee pulp or peel) and lemon peel to physicochemical and organoleptic characteristics of cascara tea.

2. Materials and Methods
2.1 Materials
Materials used in this study were Cobra (Colombia Brazil) Arabica coffee peel obtained from KUD Karangploso, Malang, East Java and Lemon peel obtained from the local market in Malang. Chemicals used were Folin Ciocalteu, Na₂CO₃ (Merck), gallic acid powder, caffeine powder (Sigma Aldrich), CaCO₃ (Merck), chloroform, and aquades.

2.2 Methods
The research was conducted in Nested Design with two factors i.e. brewing techniques (infusion and decoction) and the ratio of cascarilla and lemon peel ((90:10)% (80:20)%, and (70:30)%), in four replicates. Brewing techniques used were a modification from Koczka [8]. Cascara obtained from KUD Karangploso, Malang, East Java was dried under the sun for 8-9 days, sorted and minimized the size. Lemon peel obtained from the local market was sorted, cleaned using warm water and dried using a cabinet dryer for 4 hours at 60°C.

Preliminary research was also conducted by online survey in two rounds. The first survey was given to 359 respondents by giving them the option of fruit peel that can be added into the tea and finding out their interest towards cascara tea. Meanwhile, the second survey was given to 24 respondents to compare the raw ingredient and brewed cascara tea between formulation from this research and commercial cascara tea.

Cascara and lemon peel as the raw materials were observed for water content based on AOAC standard [9], color by Color Grab Application, total phenolic content [10], caffeine content [11] and pH. Meanwhile, the observation for the brewed tea includes color by the color reader [12], pH [13], total phenolic content [10], caffeine content [11] and hedonic test [14].

Data was performed using Minitab 17 Statistical Software (Minitab Inc., State College, Pennsylvania, USA) followed by a Fisher LSD post-hoc and Tukey HSD post-hoc with confidence interval of 95% for any significant difference. The best treatment was chosen by using Zeleny method [15].

3. Results and Discussion
3.1 Raw Materials Characterization
Moisture content, color, total phenolic content, and pH of coffee pulp and lemon peel are shown in Table 1.
Table 1. Chemical composition of coffee pulp and lemon peel.

| Parameter                        | Coffee pulp/Cascara | Lemon Peel          |
|----------------------------------|---------------------|---------------------|
|                                  | Fresh   | Dried  | Fresh   | Dried  |
| Moisture content (%)             | 84.17 ± 0.22 | 11.94 ± 0.04 | 80.63 ± 0.30 | 6.61 ± 0.05 |
| Lightness (L*)                   | 31.41 ± 1.11 | 23.63 ± 3.35*  | 56.5 ± 0.60 | 52.8 ± 0.42 |
| Redness (a*)                     | 11.05 ± 2.02 | 1.80 ± 4.8*   | 1.26 ± 0.35 | 10.26 ± 0.42 |
| Yellowness (b*)                  | 9.38 ± 3.86 | 1.85 ± 3.16*  | 42.23 ± 1.89 | 42.53 ± 0.14 |
| Total phenolic content (mg GAE/g)| 8 ± 1.01  | 4.36 ± 0.05  | -       | 5.16 ± 0.10  |
| pH                               | 4.2 ± 0.11 | 4.36 ± 0.05  | -       | 4.93 ± 0.07  |

Notes: Data mean ± standard deviation (n=3). (*) color by Color Grab Application

Based on Table 1, the dried form of cascara and lemon peel has a lower lightness (L*) and moisture content but higher pH compared to the fresh form. The drying process using temperature around 40°C can evaporate the acid in the material maximally so that the pH of the material will increase [16]. The redness (a*) and yellowness (b*) in dried cascara decrease because the drying process is capable of oxidizing compounds called polyphenols that can cause Millard reaction and produce a dark color, meanwhile there was an increase of redness (a*) and yellowness (b*) in lemon peel and cause the color changed into bright yellow and red [17].

3.2 The effect of brewing technique on physico-chemical characteristics of cascara tea

Table 2 shows the effect of the brewing technique on physico-chemical characteristics of cascara tea. Based on Table 2, brewing techniques have a significant effect on total phenolic content, caffeine content, lightness (L*), redness (a*) and pH but there was no significant effect (α=0.05) on yellowness (b*). According to Saklar [18], the content of chemical compounds in tea depends on how to brew it. The characteristics of the brewing process can be influenced by tea particle size, dry weight used and temperature. The higher the temperature used, the greater the ability of water to extract the chemical content of tea.

Table 2. Physico-chemical characteristics of cascara tea.

| Brewing Technique | Total phenolic content (mg GAE/g) | Caffeine content (mg/g) | Lightness (L*) | Redness (a*) | Yellowness (b*) | pH |
|-------------------|----------------------------------|------------------------|----------------|--------------|----------------|----|
| Infusion          | 17.51 ± 2.13 b                   | 1.16 ± 0.48 b          | 52.18 ± 12.79 a | 4.96 ± 1.50 b | 32.83 ± 7.74 a | 6.41 ± 0.12 a |
| Decoction         | 28.74 ± 3.69 a                   | 1.43 ± 0.62 a          | 45.72 ± 8.10 b | 12.69 ± 2.58 a | 32.50 ± 8.51 b | 5.97 ± 0.26 b |

Notes: Data mean ± standard deviation (n=4). Different notation showed significant difference (Fisher LSD, α=0.05)

3.3 The effect of brewing technique and ratio of cascara and lemon peel on physico-chemical of cascara tea

3.3.1 Total phenolic content and caffeine content

Table 3 shows the ratio of cascara and lemon peel in each brewing technique had a significant effect on total phenolic content and caffeine content (α = 0.05). The highest value of total phenolic and caffeine content in cascara tea was found from decoction and infusion technique with 10% lemon peel. Therefore the amount of lemon added can reduce the levels of total phenolic and caffeine content in cascara tea. According to Shofiat et al. [19] chemical content in tea depends on the ingredients and ratio of the tea. Cascara has 37.9 mgGAE/g of phenolic [20], meanwhile lemon peel has 5.07 – 25.24 mgGAE/g [21] so the higher the amount of lemon peel added, it cannot increase the phenolic content in tea. On the other hand, the decrease in caffeine content in cascara tea due to the addition of lemon peel because it does not contain caffeine [22].
Table 3. Total phenolic content and caffeine content of cascara tea.

| Brewing Technique | Ratio of cascara and lemon peel | Total phenolic content (mg GAE/g) | Caffeine content (mg/g) |
|-------------------|--------------------------------|----------------------------------|------------------------|
| Infusion          | (90:10)%                        | 19.64 ± 1.05 a                   | 1.74 ± 0.140 a         |
|                   | (80:20)%                        | 17.93 ± 0.50 b                   | 1.09 ± 0.09 b          |
|                   | (70:30)%                        | 14.96 ± 0.60 c                   | 0.64 ± 0.09 c          |
| Decoction         | (90:10)%                        | 32.22 ± 3.44 a                   | 2.12 ± 0.15 a          |
|                   | (80:20)%                        | 28.96 ± 0.58 a                   | 1.47 ± 0.09 b          |
|                   | (70:30)%                        | 25.05 ± 1.83 b                   | 0.69 ± 0.16 c          |

Notes: Data mean ± standard deviation (n=4). Different notation showed significant difference (Fisher LSD, α=0.05)

3.3.2 Color measurement

Table 4 shows the ratio of cascara and lemon peel in each brewing technique had a significant effect on the lightness (L*), redness (a*) and yellowness (b*) of cascara tea (α = 0.05).

Table 4. Color measurement of cascara tea.

| Brewing Technique | Ratio cascara and lemon peel | Lightness (L*) | Redness (a*) | Yellowness (b*) |
|-------------------|------------------------------|----------------|--------------|-----------------|
| Infusion          | (90:10)%                     | 38.67 ± 1.28 c | 6.06 ± 1.22 a| 23.3 ± 3.75 b   |
|                   | (80:20)%                     | 53.75 ± 3.58 b | 5.57 ± 1.15 a| 33.95 ± 2.25 a  |
|                   | (70:30)%                     | 64.12 ± 3.72 a | 3.25 ± 0.93 a| 34.25 ± 2.75 a  |
| Decoction         | (90:10)%                     | 37.97 ± 2.45 c | 11.54 ± 1.01 b| 23.84 ± 3.68 c  |
|                   | (80:20)%                     | 45.04 ± 1.51 b | 15.65 ± 0.59 a| 33.91 ± 1.85 b  |
|                   | (70:30)%                     | 54.14 ± 1.56 a | 10.89 ± 0.82 b| 40.76 ± 1.50 c  |

Notes: Data mean ± standard deviation (n=4). Different notation showed significant difference (Fisher LSD, α=0.05)

Based on Table 4, the higher the ratio of lemon peel, the higher the value of lightness (L*) and yellowness (b*) but decreasing the value of redness (a*). Lightness (L*) and yellowness (b*) value increased with the addition of the lemon peel and cause the loss of dark color in tea. Lemon peel had carotenoid pigments that contribute to lightness and yellowness in tea [19]. According to Nafisah and Widyaningrisih [21] dried cascara has tannin content which can affect tea brightness. The higher the amount of cascara, the darker the color of the tea. It is shown that tea with ratio of 90:10 % had the highest redness (a*) values. Cascara contains theaflavin which responsible for yellowness and thearubigin for redness [17].

3.3.3 pH

Table 5 showed the ratio of cascara and lemon peel in each brewing technique had a significant effect on the pH of cascara tea (α=0.05).

Table 5. pH measurement of cascara tea.

| Brewing Technique | Ratio of cascara and lemon peel | pH     |
|-------------------|--------------------------------|--------|
| Infusion          | (90:10)%                        | 6.27 ± 0.05 b |
|                   | (80:20)%                        | 6.45 ± 0.12 ab |
|                   | (70:30)%                        | 6.52 ± 0.22 a |
| Decoction         | (90:10)%                        | 5.8 ± 0.11 b |
|                   | (80:20)%                        | 5.85 ± 0.31 b |
|                   | (70:30)%                        | 6.27 ± 0.22 a |

Notes: Data mean ± standard deviation (n=4). Different notation showed significant difference (Fisher LSD, α=0.05)
From Table 5, the higher the ratio of lemon peel, the higher the pH of the tea. According to Muzaki and Wahyuni [24] the more ginger that is mixed into the tea leaves from South Africa, the pH value of steeped tea decreases. This is because ginger contains total phenolic contents which are able to release protons (H+) in solution. These total phenolic content compounds include acidic compounds. When compared with the results of the study, there were significant differences. The differences in raw materials used, the pH value of the lemon peel used is greater than that of the coffee pulp so that the amount of lemon peel added cannot reduce the pH value.

3.4 Sensory evaluation
Sensory evaluation involved 104 untrained panelists. Table 6 showed the organoleptic characteristics of cascara tea. It can be seen that brewing technique and the ratio of cascara and lemon peel had a significant effect on color, flavor, taste, aftertaste, appearance and overall (α = 0.05).

Table 6. Organoleptic characteristics of cascara tea.

| Brewing Technique | Ratio cascara and lemon peel | Color | Flavor | Taste | Aftertaste | Appearance | Overall |
|-------------------|-----------------------------|-------|--------|-------|------------|------------|---------|
| Infusion          | (90:10)%                    | 5.85 ± 0.06 | 5.73 ± 0.14 | 5.74 ± 0.14 | 5.59 ± 0.14 | 6.02 ± 1.33 | 5.90 ± 1.26 |
|                   | (80:20)%                    | 1.56 ± 0.14 | 1.41 ± 0.06 | 1.61 ± 0.06 | 1.53 ± 0.06 | 1.53 ± 0.06 | ±1.26 ± 0.06 |
|                   | (70:30)%                    | 5.71 ± 0.06 | 5.49 ± 0.14 | 5.52 ± 0.14 | 5.51 ± 0.14 | 6.01 ± 1.23 | 5.87 ± 1.26 |
|                   |                             | 1.55 ± 0.06 | 1.48 ± 0.06 | 1.56 ± 0.06 | 1.58 ± 0.06 | 1.58 ± 0.06 | ±1.36 ± 0.06 |
| Decoction         | (90:10)%                    | 5.29 ± 0.06 | 6.02 ± 0.14 | 5.55 ± 0.14 | 5.53 ± 0.14 | 5.78 ± 0.14 | 6.00 ± 1.26 |
|                   | (80:20)%                    | 1.73 ± 0.06 | 1.57 ± 0.06 | 1.84 ± 0.06 | 1.68 ± 0.06 | 1.68 ± 0.06 | ±1.52 ± 0.06 |
|                   | (70:30)%                    | 6.11 ± 0.06 | 5.96 ± 0.14 | 5.09 ± 0.14 | 5.30 ± 0.14 | 6.40 ± 0.14 | ±5.76 ± 0.14 |

Note: Score in hedonic scale 1: Dislike extremely, 2: Dislike very much, 3: Dislike moderately, 4: Dislike slightly, 5: Neutral, 6: Like slightly, 7: Like moderately, 8: Like very much, 9: Like extremely. Average score of sensory attributes cascara tea with lemon peel. Different notation showed significant difference (Tukey HSD, α=0.05).

Based on Table 6, the color of cascara tea showed the highest score in decoction technique with ratio of (90:10)% and the lowest in infusion technique with ratio of (70:30)%. From the panelist perspective, decoction technique is more preferable compared to infusion because the color produced is more attractive. Generally, tea with darker color has lower tannin content because when tannin is exposed to the light and air for a long time then the color will turn darker. Besides tannin, there are several other chemical components such as catechins [25].

The flavor of the cascara tea added with lemon peel had one of the scents which are linalool. Linalool is an essential oil and easily evaporates. From Table 6, panelists like tea with more lemon peel ratio in it, because the lemon peel contains essential oils and other components such as limonene and citral [26]. However, the heat process in the decoction technique causes the excessive extraction of aroma and not preferred by panelists.

For the taste of astringent, the average value ranging from 4.5 to 5.7 means that panelists’ preference is a slightly dislike to neutral. The bitter taste of the brewed cascara tea reduces the level of panelists preference. It is because the lemon peel contains essential oils which contain several compounds such as limonin [27]. Meanwhile, taste and aftertaste are sharing the same score because both of it related to the acceptance of the product.

For the appearance of cascara tea, panelists prefer that has a color that tends to be dark and with no sediment left in the brewed tea [28]. Overall, panelists prefer cascara tea added with lemon peel which
has a dark color, less strong lemon peel aroma, less bitter taste, slightly bitter aftertaste left on the tongue and clear appearance with no sediment left in the brewed tea.

3.5 Best treatment
The best treatment was selected using the Zeleny method [15]. The parameters calculated are total phenolic content, caffeine content, color, pH and organoleptic characteristics. Six parameters for organoleptic characteristics are color, flavor, taste, aftertaste, appearance and overall. The best treatment was the ratio of cascara and lemon peel at (80:20)% brewed using the decoction technique. The best treatment offers total phenolic contents of 28.96 mgGAE/g, the caffeine content of 1.47 mg/g, lightness (L*) of 45.04, redness (a*) of 15.65, yellowness (b*) of 33.91, pH value of 5.85, and organoleptic value of each parameter ranging from 5 to 6 which means neutral to slightly like.

4. Conclusions
The brewing technique had a significant effect on total phenolic content, caffeine content, lightness (L*), redness (a*) and pH. Meanwhile, the ratio of cascara and lemon peel in each brewing technique had a significant effect on total phenolic content, caffeine content, color, pH and organoleptic. The best treatment with the Zeleny method was cascara tea with the ratio of cascara and lemon peel of (80:20)% by decoction technique. It has total phenolic content of 28.96 mgGAE/g, caffeine content of 1.47 mg/g, lightness (L*) 45.04, redness (a*) 15.65, yellowness (b*) 33.91, and pH of 5.85.

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