The Effect of Cabbage Waste Concentration and Fermentation Time on The Decaffeination of Arabica Coffee

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ABSTRACT

The purpose of this study was to determine the effect of the concentration of cabbage waste and fermentation time on the caffeine content reduction of Arabica coffee from Pangalengan. Decaffeination is carried out using a wet fermentation method using protease enzyme activity produced by lactic acid bacteria from cabbage waste. Protease enzymes can break down the slime layer on coffee beans so that caffeine is decomposed through the esterification process to become chlorogenic acid. Fermentation was carried out anaerobically in a fermenter with a capacity of ± 2L with a fermentation time of 72 hours and sampling every 6 hours. The concentration of cabbage waste ranged from 10-80% (w/w). Arabica coffee beans were tested for caffeine content (%) using a UV-Vis spectrophotometer. According to the study’s findings, the caffeine level decreases as the concentration of cabbage waste increases. Meanwhile, the caffeine level decreases as fermentation time increases. The addition of 80% concentration of cabbage waste with 48 hours of fermentation time produced the optimum results for the Arabica coffee decaffeination process. This method achieved a decaffeination efficiency of more of 96% and met the quality standards outlined in SNI 01-3542-2004

KEYWORDS

Arabica coffee
Cabbage waste
Caffeine
Decaffeination
Lactic acid bacteria

INTRODUCTION

In 2022, Indonesia’s coffee production will reach 794.8 thousand tons [1]. After Brazil, Vietnam, and Columbia, Indonesia is now the fourth largest coffee exporting country [2]. One of the procedures that must be done carefully and appropriately to produce high-quality coffee is the post-harvest process. According to Ahmed et al. [3] and Colombo et al. [4], cultivars, environmental circumstances, and agricultural management determine the physical quality, flavour of coffee, and chemical content of coffee beans. Azuan et al. [4] then included processing, fermentation, and roasting.

One of the stages of post-harvest primary processing to improve coffee quality is fermentation [5]. Fermentation is one of the coffee processing processes that can reduce levels of caffeine or decaffeinate. Through the fermentation process of phenolic compounds and the antioxidant activity of mung beans can be increased [6]. Coffee with high levels of caffeine will cause insomnia, challenge, increase, and increase fast heart rate in some persons who have low
caffeine resistance. As a result, decaffeination is required for persons with low caffeine tolerance. [7].

Microorganisms, such as lactic acid bacteria, are commonly used in the fermentation process [8]. Cabbage waste is one source of lactic acid bacteria. According to a 2022 report from the Indonesian Central Statistics Agency, Indonesia produces 1.40 million tons of cabbage [9]. It is claimed that 60% of cabbage is wasted, while only 40% is used. Cabbage waste comes in the form of decaying cabbage leaves. If this waste is not recycled, it will harm the ecosystem and cause many diseases. Physically, vegetable waste is quickly damaged due to its high-water content, but chemically, it contains relatively high levels of vitamins, minerals, and protein [10]. There has been no research on the influence of lactic acid bacteria from cabbage waste on Arabica coffee fermentation, so research on the effect of fermentation time and cabbage waste concentration on arabica coffee decaffeination is required.

LITERATURE REVIEW

Arabica Coffee

Arabica coffee is the most common variety of coffee, accounting for roughly 60% of global coffee production. Arabica coffee is known to provide health benefits, one of which is owing to its antioxidant characteristics [11]. It has a higher value as an export commodity than Robusta coffee, although the process is more complex. Coffee washing is one of the post-harvest handling processes [12], which begins with sorting coffee berries, fermenting, washing, and drying [13]. The pulp and skin of cherries are mechanically removed in this procedure, and the beans are placed in water tanks and soaked in water for 6-72 hours to remove the mucilage [14].

Caffein and Decaffeination

Caffeine (1,3,7-trimethylxanthine) is a purine alkaloid present in over sixty plant species, with substantial quantities in coffee beans, tea, and cocoa [15]. Caffeine is a competitive antagonist of adenosine receptors, which accounts for most of its physiological effects on animal nervous systems [16]. Caffeine can also cause gastrointestinal problems, palpitations, and an increase in blood pressure [17]. Decaffeination is used to reduce caffeine levels and the detrimental effects they carry [18]. Decaffeination can be accomplished through a variety of processes, one of which being fermentation with lactic acid bacteria derived from cabbage waste.

Cabbage Waste

Cabbage has a nutritional composition due to its high antioxidant and phytochemical content, which includes carotenoids, glucosinolates, isothiocyanates, phenolic compounds, and vitamins E and C [19]. Cabbage crop yield totaled 1,437,463 tons, with 63,849 ha harvested [9]. Most of the time, the supply of perishable vegetables such as cabbage exceeds the demand, resulting in a lot of rotting and wasted cabbage due to inefficient storage systems [20]. Cabbage waste includes lactic acid bacteria, which create protease enzymes capable of breaking down the slime layer on coffee beans, allowing caffeine to be degraded via the esterification process and converted to chlorogenic acid [21].
Fermentation

One of the post-harvest steps that influences coffee quality is fermentation [22]. The fermentation process's major goal is to remove the mucilage layer, which is high in polysaccharides (pectin), and to reduce the water content of the coffee beans [23]. Lactic acid bacteria can be used in the fermentation process to break down the mucus layer into protopectin, sugar, alcohol, and acids, which will then be discharged from the horn's skin [24].

Coffee mucilage consists of polysaccharides (pectin), cellulose, and starch [25]. Mucilage can cause mold to form on the coffee beans, lowering the quality of the product. Enzymes found naturally in coffee fruit and microorganisms obtained from the environment aid in the fermentation process [23]. The chemical reactions that occur in the fermentation process are as follows:

\[
\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 + 2\text{ATP}
\]

PROCEDURES

Pretreatment of Cabbage Waste

The cabbage waste used is the wilting and browning leaves bought from the Cibogo Sarijadi market. The cabbage trash was first sorted, then washed and dried in the sun for two hours. Following that, 120 g of NaCl was added to 2 kg of cabbage waste, which was then placed in a plastic container and knotted (anaerobic). NaCl is used to eliminate glucose from cabbage and prevent bacterial growth. Cabbage waste is fermented for three days. The fermentation of cabbage waste results in the generation of lactic acid bacteria from lactose [10].

Decaffeination Process of Arabica Coffee

The caffeine content of Arabica coffee beans was tested using a UV-Vis spectrophotometer [26]. A calibration curve was first created by diluting a standard solution of 0-20 ppm to a maximum wavelength of 272.9 nm. The coffee beans were crushed in a mill and sorted through a sieve shaker with a mesh of 35. The coffee powder is then dissolved in 150 mL of hot water. A hot coffee solution is filtered through the mouthpiece using filter paper to prevent coffee grounds from passing through. The coffee solution was mixed with 1.5 g of calcium carbonate before being placed in the separating funnel and extracted with 25 ml of chloroform [27]. The extract was dissolved in 1 L of distilled water and tested for caffeine content.

DISCUSSION

Effect of Cabbage Waste Concentration on Decaffeination of Arabica Coffee

A graph showing the effect of variations in the concentration of cabbage waste on caffeine content is presented in Figure 1.
According to Figure 1, the caffeine content is the same at 0% concentration, namely 0.8667%, because no additional cabbage waste is introduced. There is a significant drop with a cabbage waste concentration of 10% - 30%. This occurs because of a change in the composition of the pulp and mucilage caused by endogenous peanut metabolic activity and bacterial metabolic activity during the fermentation process. Lactic acid bacteria are found in cabbage waste. Lactic acid bacteria create protease enzyme activity, which causes caffeine levels in Arabica coffee beans to drop [28]. Caffeine, like protein, has an amide group. Protease enzymes hydrolyze proteins during fermentation to convert them to amino acids. The protease enzyme will break down the mucus layer on the coffee bean down to the caffeine-containing cytoplasm [23]. Caffeine will be broken down into chlorogenic acid so that the molecular weight and size of the caffeine compound is reduced, and it is easier to diffuse through the cell walls and dissolve in water.

However, at cabbage waste concentration of 40% - 80%, the curve gradually lowers because the addition of a larger concentration causes the reaction speed to approach the maximum line, such that the enzyme cannot work faster at the maximum reaction rate limit or $V_{\text{max}}$ [29]. The more cabbage waste added, the lower the caffeine level of Arabica coffee beans. The higher the concentration, the higher the microbial content, and thus the lower the caffeine content [30].

**Effect of Cabbage Waste Concentration on Decaffeination Efficiency**

The graph of the effect of the concentration of cabbage waste on the efficiency of reducing the caffeine content of Arabica coffee is presented in Figure 2.
According to Figure 2, the higher the concentration of cabbage waste, the greater the efficiency of reducing the caffeine level of Arabica coffee beans. There is no efficient caffeine content at a concentration of 0% in every hour of fermentation time since there is no additional concentration of cabbage waste, so there is no drop in caffeine content. The optimal concentration for reducing caffeine content occurred at a concentration of 80% cabbage waste addition. At such proportion of cabbage waste, decaffeination efficiency was greater than 80% at all fermentation sample times. After more than 48 hours of fermentation, the peak efficiency of more than 90% was obtained. High concentration of cabbage waste concentration contain high level of protease enzymes produced by proteolytic bacteria. The Protein is broken down into amino acids due to the activity of the protease enzyme, which decreases the caffeine level of coffee. Caffeine molecules in coffee form the same bonds as proteins, therefore the protein breakdown process increases free amino acids. Lactic acid bacteria with protease enzymes operate as catalysts, accelerating processes in the decaffeination process [31].

Effect of Fermentation Time on Decaffeination of Arabica Coffee

The graph of the effect of time on Arabica coffee decaffeination is presented in Figure 3. According to Figure 3, the caffeine content of Arabica coffee beans decreases as fermentation time increases. Caffeine levels drop dramatically between 0 and 48 hours for all cabbage waste concentrations. At 80% cabbage waste concentration, caffeine content can reach 0.034% after 48 hours fermentation. This occurs because lactic acid bacteria degrade the protein in the coffee slime layer, allowing caffeine to dissolve and levels to fall. However, the fall becomes mild and tends to remain stationary from 48 hours to 72 hours because the longer the fermentation period, the faster the reaction approaches the maximum line, but at the maximum limit, the active side of the enzyme is full, and the enzyme becomes inactive.

The outside of the coffee bean contains a slime layer composed of 80% pectin and 20% sugar [34], which serves as a substrate for the inoculum. The inoculum will lower the substrate,
allowing water to easily enter the bean via the skin of the horn and permeate into the coffee bean, dissolving the caffeine [32]. Caffeine is easily dissolved in water [33], but caffeine is still attached to other compounds in coffee, thus the process of breaking down this protein will cause the substance to be liberated from other compounds and dissolve into the water [34]. Caffeine bonds to one water molecule, allowing it to dissolve.

Figure 3. Graph of Effect of Fermentation Time on Decaffeination

The drop in caffeine level during the decaffeination process is also caused by the esterification process, which breaks down complex caffeine molecules into chlorogenic acid [35]. Caffeine's reduced size and molecular weight make it easier for it to pass through cell membranes and dissolve in water. Chlorogenic acid will degrade into various organic molecules and dissolve in the fermentation medium after being isolated from caffeine [36]. The longer the fermentation process is carried out, the more chlorogenic acid dissolves in the fermentation media, resulting in a decreased caffeine level.

Effect of Fermentation Time on Coffee Decaffeination Efficiency

The graph of the effect of fermentation time on the efficiency of reducing the caffeine content of Arabica coffee is presented in Figure 4. According to Figure 4, increasing the fermentation duration increases the efficiency of lowering caffeine concentration because the longer the fermentation time, the more protein is degraded by lactic acid bacteria. The optimum efficiency gain occurred at 48 hours, when decaffeination efficiency for all variation of cabbage waste concentrations tended to increase significantly, reaching more than 80%. Increasing the fermentation duration to 54-72 hours does not result in a substantial gain in efficiency. Fermentation for a longer period may also be undesirable since the caffeine content is too low.
CONCLUSION

1. The concentration of cabbage waste affects the decaffeination process of Arabica coffee, the higher the concentration of cabbage waste added, the lower the caffeine content and the greater the efficiency of reducing the caffeine content of Arabica coffee beans.

2. Fermentation time affects the decaffeination process of Arabica coffee, the longer the fermentation time, the lower the caffeine content and the greater the efficiency of reducing the caffeine content of Arabica coffee beans.

3. The optimum conditions for the fermentation process occur when the concentration of cabbage waste is 80% added and the fermentation time is 48 hours because it can reduce the caffeine content from 0.5767% to 0.0340% with a reduction efficiency value of 96.083%.

LIMITATION AND FUTURE RESEARCH

This research is not completely perfect, therefore there are several recommendations for future research, including:

1. Continuity of research with concentration variations of more than 80% as comparative data.

2. Continuation of research to carry out organoleptic tests on the final sample of fermented coffee beans in order to obtain the quality of the aroma and taste of fermented Arabica coffee.

3. Microbiological analysis.

4. Enzyme activity test to determine protease enzyme activity in the fermentation process

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