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BIOACTIVE COMPOUNDS OF COCOA SEEDS (*THEOBROMA CACAO* L.): LITERATURE REVIEW

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ABSTRACT

Cocoa (*Theobroma cacao* L.) is a leading plantation commodity in Indonesia and is the main ingredient in chocolate production. The types of cocoa that are popularly used are criollo, forastero, and trinitario. The purpose of this review is to provide information about the bioactive compounds contained in cocoa and their health benefits. This review discusses the bioactive compounds contained in the seeds, seed coat, and skin of the cocoa pod. The bioactive compounds contained in cocoa are polyphenols and alkaloids. Polyphenols that are abundant in cocoa are a class of flavonoids, such as catechins, epicatechins, epigallocatechins, gallocatechins, proanthocyanidins, and anthocyanins. While the alkaloids commonly found in cocoa are theobromine and caffeine. Bioactive compounds derived from cocoa can be used as antioxidants, anti-inflammatory, antihypertensive and antidiabetic.

KEYWORDS: Cacao, Alkaloids, Polyphenols.

INTRODUCTION

Cocoa (Theobroma cacao L.) is the main ingredient in chocolate production. Among the world's largest cocoa-producing countries is Ivory Coast, followed by Ghana and Brazil in fifth place (Abballe et al., 2021). Indonesia is one of the third countries as cocoa producers, reaching 13% of world cocoa production (Towaha, 2014). There are about 20 known types of cocoa, but there are three that are popular, namely the Criollo, Forastero, and Trinitario types which account for 95% of the total world cocoa production (Panak Balentić et al., 2018). The Criollo type is referred to as the early movement of cocoa. This type of cocoa is now rare and is only found in old plantations in Venezuela, Central America, Madagascar, Sri Lanka, and Samoa. The main type of cocoa is Forastero which is a variety of cocoa called Amelonado, named after the shape of the melon fruit. This variety is especially suitable for cultivation in West Africa. The third type of kaka is called Trinitario, which is the result of hybridization between Forastero and Criollo trees (Fowler, 2009).

Cocoa is Indonesia's leading plantation commodity and is the third largest plantation commodity. Cocoa productivity plays a role in increasing state income, but it is still not supported by good technology. The low competence of farmers in managing farming shows that economic growth only increases the competence of farmers. (Managanta et al., 2019). However, the productivity of Indonesian cocoa is decreasing; this is because the Indonesian cocoa beans traded by farmers are generally not fermented first, so they are of low value even though the quality of the beans and prices on the international market are based on fermented cocoa beans (Manalu, 2018).

This cocoa product is consumed quite highly because it is an important source of elements such as calcium, iron, magnesium, potassium, and zinc. In addition, cocoa contains compounds that are healthy for the body so that they can act as anti-inflammatory, anticancer, antioxidant, and antimicrobial (Abballe et al., 2021). These properties are associated with the bioactive compounds contained in cocoa. In cocoa beans, about 10% is represented by phenolic compounds from the total constituents and consists of proanthocyanidins, flavonols or flavan-3-ols, and anthocyanins. This compound has quite high antioxidant activity in the food industry (De La Luz Cádiz-Gurrea et al., 2020). The content of polyphenolic compounds in cocoa beans varies due to differences in fruit ripeness, varieties or cultivars, growing places, and cocoa processing.

Bioactive Compounds In Cacao

Bioactive compounds are compounds found in plants and animals and are considered to have many benefits for humans. Cocoa contains various bioactive compounds, including phenolic compounds and alkaloids. Phenolic compounds are compounds that have one or more phenol rings, namely hydroxyl groups attached to aromatic rings. Phenolic compounds are divided into simple phenols and polyphenols (Belščak-Cvitanović et al., 2017). The many polyphenols found in cocoa are the flavonoid group, such as flavanols, flavonols, and anthocyanins (Żyżelewicz et al., 2018). Other bioactive compounds found in cocoa are alkaloids which play a role together with phenolic compounds in creating the characteristic bitter taste in cocoa. The alkaloids that are commonly found in cocoa are theobromine and caffeine (Júnior et al., 2020).

1. The flava-3ol Monomer (Catechin)

is a flavanol derivative belonging to the flavonoid group. The compounds included in the flava-3ol monomer are catechins, epicatechins, gallocatechins, and epigallocatechins. The catechins that are mostly found in cocoa are catechins and epicatechins, whereas gallocatechins and epigallocatechins are only found in small amounts. Catechins can be found in cocoa beans, cocoa bean skin, and cocoa pod skin. In cocoa beans, the main catechins are catechins and epicatechins which have an amount of ±35% of the total polyphenol content, while gallocatechins and epigallocatechins are compounds in small amounts, namely ±2-3% (Hii et al., 2009). Research shows that the fruit skin and skin of fresh cocoa beans contain catechins and epicatechins. Catechins in fruit peels and cocoa bean shells are very low compared to the higher epicatechin content (Quiroz-Reyes et al., 2013; Valadez-Carmona et al., 2018).

The polyphenol content in cocoa is strongly influenced by environmental conditions and geographical location, such as weather, climate, soil type, and cocoa production planting area (Samaniego et al., 2020). In addition, the polyphenol content can be influenced by the types of cocoa varieties observed, where polyphenols are Forastero > Trinitario > Criollo. (Di Mattia et al., 2017). Cocoa polyphenols can also be affected by processing. Research shows that fermentation can reduce the polyphenol content of cocoa beans, and the resulting polyphenol content of cocoa beans without fermentation is higher. In addition, temperature can affect the polyphenol content of cocoa beans. Processing of cocoa beans using temperatures above 130^0C can significantly reduce the levels of polyphenols in cocoa beans. Other research shows that increasing the temperature and drying time causes the degradation of polyphenols and Maillard reactions in cocoa beans (Santhanam Menon et al., 2017).

The content of flavan-3 ol monomer compounds was obtained by the presence of extraction treatment on cocoa samples. Extraction is a way of separating a substance from a mixture. There are two methods that can be used to determine phenolic compounds, namely conventional and unconventional methods. Conventional extraction utilizes more extraction solvents and uses manual procedures. Extractions using conventional methods include maceration, soxhlet, and reflux extraction. The conventional method commonly used to test flavanol compounds in cocoa is maceration extraction because it can avoid damage due to heating. This extraction uses a simple process by soaking the refined sample in solvent and using a closed system with constant stirring at room temperature (Olejar et al., 2015). Flavanol extraction can also be carried out by unconventional methods. This method uses less solvent and has better reproducibility than conventional extraction. Unconventional methods include extraction with the help of ultrasound, microwaves, and enzymes (Alara et al., 2021).

The study conducted a comparison of the use of maceration extraction (Conventional) and ultrasound-assisted extraction (Non-conventional). The results show that ultrasound-assisted extraction produces more catechin and epicatechin compounds in cocoa compared to using maceration extraction (Quiroz-Reyes et al., 2013). The use of ultrasound-assisted extraction can increase the rate of solubility of compounds into the extraction solvent, so that the volume of the solvent can be reduced to produce better phytochemicals. This extraction also uses lower time and temperature so as to increase the extraction of polyphenols (Alara et al., 2021; Annegowda et al., 2010).

2. Proanthocyanidins

Proanthocyanidins are flavanol derivatives belonging to the flavonoid group. Compounds belonging to the proanthocyanidins are procyanidins and condensed tannins. There are seven types of proanthocyanidins in cocoa beans with different structures, namely procyanidins B1, B2, B3, B4, B5, C1, and D. The amount of procyanidin in cocoa beans is ± 58% of the total polyphenols in cocoa beans (Hii et al., 2009). In cocoa bean husks, the proanthocyanidins found are tannins with sizes varying from monomers to long-chain polymers (Okiyama et al., 2017).

The content of proanthocyanidin compounds was obtained by the presence of extraction treatment on cocoa samples. Proanthocyanidin extraction is almost similar to catechin extraction. Extraction of proanthocyanidin compounds can be carried out using conventional and non-conventional methods. The conventional extraction that is commonly used for this compound is maceration extraction to avoid damage due to heating, and is a relatively simple method (Olejar et al., 2015).

Extraction can be affected by several factors, such as the method used, time, temperature, the ratio of material to solvent, the nature and structure of the compound, and the polarity of the solvent used. Mixtures of solvents that can be used in cocoa extraction are methanol, methanol: water, ethanol: water, isopropanol: water, and acetone:water: acetic acid. Polyphenolic compounds in cocoa are difficult to dissolve when using pure solvents (methanol) because they have a high polarity. Meanwhile, extraction of cocoa bean husks with the help of ultrasound using a mixture of acetone:water: acetic acid solvents produces higher polyphenolic compounds (Fajardo Daza et al., 2020). The ratio of solvent to the material in extraction can affect the extraction results because the compounds extracted will be more and more along with the higher ratio of solvent use compared to the material used. Extraction time and temperature also affect the extraction results, where using the appropriate extraction time can cause the contact between the solvent and the material to become more intensive until it meets the saturation point of the solution. Using too long a time and high extraction temperature can cause a decrease in flavonol levels, where the active compounds that cannot stand the heat will be degraded due to the evaporation process taking too long and high temperatures (Widhiana Putra et al., 2020).

3. Anthocyanin

Anthocyanins are blue, red or purple pigments found in plants. Under acidic conditions it gives rise to red pigments, while under alkaline conditions it gives rise to blue pigments. Anthocyanins have antidiabetic, anticancer, anti-inflammatory, antimicrobial and anti-obesity properties, as well as prevention of cardiovascular disease. This anthocyanin is a bioactive component used in nutraceuticals and traditional medicine by reducing the risk of several diseases (Khoo et al., 2017). Anthocyanins in natural sources can be extracted using solvents and acids. The solvent was carried out to extract the anthocyanins and add acid to optimize the extraction of anthocyanins. Anthocyanins act as free radical scavengers by releasing hydrogen atoms to neutralize unpaired electrons in free radical compounds (Sampebarra, 2018).

Two anthocyanins are found in cocoa beans, namely cyanidin-3-galactoside and cyanidin-3-arabinoside. The anthocyanins represent 0.02-0.4% DM of defatted cocoa bean powder. The cyanidin-3-arabinoside compound in dry and non-fat cocoa is present in the range of 466-4552 mg kg-1 (Niemenak et al., 2006). The anthocyanin content of non-fermented cocoa bean extract will decrease due to an increase in the pH value. This is because anthocyanin is a red pigment and its stability will decrease when the pH is increased. The change in color from red is due to the influence of pH as the flavillum cations change from hydrates to a colorless carbinol base. Anthocyanin extract from non-fermented cocoa beans has the ability as an antioxidant or free radical scavenger. This is evidenced by the change in color from purple to yellow when the extract is added to the DPPH solution (Sampebarra, 2018).

Anthocyanins are compounds that are abundant in cocoa pod shells that function to modulate the immune system, have a compreventive effect for the prevention of coronary heart disease and cancer. However, anthocyanin levels can be degraded during processing, storage and extraction processes. Anthocyanin testing in cocoa pod shells can be carried out by cutting the cocoa pod skin into small pieces and drying it with wind at room temperature. The pieces were crushed and blended to get simplisa powder. The test was carried out with the addition of HCl, if the sample remains red then the sample contains anthocyanins. The antioxidant activity of cocoa pod extract obtained an IC50 value of 20.52 μg/mL so that it can be said to be very strong, because an antioxidant is said to be very strong if the IC50 value is less than 50 μg/mL (Lubis et al., 2018). Cocoa bean shell has active compounds that are no different from cocoa bean or cocoa pod shell. Cocoa beans contain polyphenols, catechins, leukocyanidins and anthocyanins (Yumas, 2017).

4. Caffeine

Caffeine (1,3,7-trimethyl xanthine) is often used for body resistance. Caffeine comes from plants and animals. Even more than 20% of angiosperm species contain alkaloids. Alkaloids are the most common secondary metabolites that have nitrogen atoms (Wink, 2008). This caffeine is one of the alkaloids contained in cocoa and contributes to the bitter taste (Júnior et al., 2020). Methylxanthines have different pharmacological properties between theobromine and caffeine. Caffeine is responsible for stimulating the central nervous system and heart and increasing the metabolic rate (Bartella et al., 2019).

5. Theobromine

Theobromine is one of the most abundant methylxanthines present in cocoa. These bioactive compounds have beneficial effects, namely as anti-diabetic, anti-cancer, neuroprotective, and anti-obesity (Jang et al., 2018). Theobromine in cocoa can be determined by analysis of chromatographic techniques using different detectors and is usually widely used for samples of fresh cocoa beans (Júnior et al., 2020). The theobromine in cocoa causes a strong physiological diuresis effect and stimulates the heart, and widens the arteries.

Cocoa beans contain 1.95% theobromine. The theobromine compound contributes to the characteristic bitter taste of cocoa beans. Fermentation time affects theobromine concentration. Theobromine, through the methylase process, can be converted into caffeine. Cocoa shell waste is lignocellulosic waste consisting of lignin, cellulose, hemicellulose, and extractive substances.

The cocoa bean husk contains theobromine compound with a percentage of 0.55. Theobromine belongs to the group of methylated xanthines, which are useful as stimulants. In addition, theobromine has several pharmacological activities such as anticancer, diuretic, cardiac stimulant, hypocholesterolemic, smooth-muscle relaxant, asthma, and coronary vasodilator. Theobromine has a role in the cocoa plant's self-defense mechanism and is often considered a toxic substance (Hartati, 2012). The comparison of the theobromine content in cocoa waste is that fruit skin has a concentration of 0.17 - 0.20%, cocoa bean skin has a concentration of 1.80 - 2.10%, and cocoa beans are 1.90 - 2.00.

Utilization of Bioactive Compounds

1. Antioxidant

Antioxidants are compounds that can delay, prevent and slow down oxidation reactions. The main function of antioxidants is to break chain reactions due to free radicals so that free radicals can be neutralized. In foodstuffs, oxidation can be caused by an imbalance between antioxidants and free radicals, causing oxidative damage to lipids, vitamins, and proteins (Nwachukwu & Aluko, 2019). Oxidation in these foods can cause damage to nutrients and cause unwanted aromas and can endanger health. This is the interest of researchers to examine the antioxidants contained in foodstuffs. Research shows that cocoa can inhibit cell damage due to free radicals (Oracz & Żyżelewicz, 2020).

Cocoa is a good source of antioxidants for the body because it contains high levels of polyphenols and alkaloids which can also act as antioxidants. Antioxidants can be used as preservatives because they prevent the formation of rancidity and unwanted flavors. Antioxidants can also minimize the occurrence of cancer, coronary heart disease, diabetes, and inflammatory disorders (Domínguez-Pérez et al., 2020).

2. Anti-inflammation

Inflammation is a protective response to foreign substances in the body. Foreign substances that enter the body cause reactions by releasing prostaglandin compounds, proinflammatory cytokines, interlueins, nitric oxide, and leukotrienes (Wang et al., 2018). This can lead to the formation of free radicals in the body, so the body needs ingredients that can prevent inflammation (Hasim et al., 2019). Anti-inflammatory is a drug that can reduce the symptoms of inflammation due to tissue damage. Currently there are many drugs that are commonly used to prevent inflammation, but these drugs are considered to reduce immunity and stomach disorders. Reducing the use of anti-inflammatory drugs can be done by consuming natural anti-inflammatories from plants. Research shows that the polyphenolic compounds contained in cocoa have anti-inflammatory properties. This can happen because the polyphenols in cocoa can form prostaglandins, inhibiting the metabolism of arachidonic acid and the release of histamine during inflammation (Latif, 2013).

3. Anti-Hypertension

Hypertension is an important factor in the development of cardiovascular disease. To reduce this, pharmacological therapy can be carried out. Angiotensin Converting Enzyme (ACE) has been commonly used as a drug in blood pressure regulation because it can convert angiotensin I to angiotensin II and deactivates bradykinin. Autolysis of cocoa beans can inhibit ACE 30-80%. Autosylate produced at a low pH of around 3.5 resulted in more ACE inhibition compared to pH 5.2. So the high inhibition of ACE from autolysis is based on its hydrophobic content and aromatic amino acid residues (Domínguez-Pérez et al., 2020).

Consumption of cocoa products can have a good effect on controlling blood pressure. This is because it contains high levels of flavonoids that can significantly reduce systolic and diastolic blood pressure. The average systolic blood pressure was 3.8 mmHg lower in the group who consumed more chocolate, thus proving that high chocolate consumption can reduce cardiovascular disease (Halim et al., 2016).

4. Anti-diabetic

Diabetes mellitus is a chronic degenerative disease characterized by prolonged hyperglycemia that occurs due to insufficient insulin production by the pancreas. Uncontrolled hyperglycemia can cause damage to the body's systems, especially the nervous and cardiovascular systems. However, bioactive compounds from animal and plant sources can help control glycemic functions, such as increasing insulin secretion and insulin action, or can inhibit glucose absorption (Domínguez-Pérez et al., 2020).

Cocoa powder contains antioxidants as compounds that can stop damage to pancreatic beta cells due to free radicals so that they can help insulin secretion. In addition, cocoa powder has a high enough fiber content and low glycemic index so that it can stabilize blood sugar levels because it slows the release of glucose into the bloodstream (Restuti et al., 2020).

CONCLUSION

Bioactive compounds are compounds found in plants and animals and are considered to have many benefits for humans, such as antioxidants, anti-inflammatory, antihypertensive, and antidiabetic. Cocoa contains bioactive compounds, including polyphenols and alkaloids. The polyphenols that are abundant in cocoa are the flavonoid group, such as catechins, epicatechins, epigallocatechins, gallocatechins, proanthocyanidins, and anthocyanins. At the same time, the alkaloids commonly found in cocoa are theobromine and caffeine. The content of bioactive compounds in cocoa is strongly influenced by the type of cocoa, processing (fermentation, time, and heating temperature), and extraction (method, temperature, time, and type of solvent).

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