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Review Article
Cocoa (*Theobroma cacao* L.) Beans Processing Technology: A Review of Flavonoid Changes

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Abstract
Cocoa (*Theobroma cacao* L.) beans are the primary ingredient used in the production of chocolate. It contains bioactive compounds, specifically flavonoids, which are beneficial to one's health. The essential flavonoid is an epicatechin, catechin and procyanidin monomer. Cocoa plant varieties are classified into three types: Criollo, Forastero and Trinitario. Flavonoids levels differ between varieties due to genetic factors, variety, degree of fermentation, processing parameters and plantation environmental conditions. Flavonoids can help to maintain immune homeostasis by increasing nutrient absorption and metabolism, lowering the risk of coronary heart disease and acting as an anti-hypertensive agent in the form of cocoa powder. Fermentation, drying, roasting and alkalization are the most common processing steps used by the cocoa bean industry. Flavonoids in cocoa can change during processing and the levels of flavonoids in each processed product vary. The fermentation stage reduces the flavonoid content of cocoa beans by up to 80%. When drying cocoa beans at low temperatures or for a short period, the flavonoid content does not decrease significantly. The high-temperature roasting step in a short time outperforms the long-time low-temperature roasting step. The alkalization process can reduce flavonoids in cocoa beans by up to 78.5%. Dark chocolate has a higher flavonoid content than other processed cocoa products such as cocoa powder, milk chocolate and white chocolate. The review will discuss flavonoid benefits from a health perspective, the processing effect on flavonoid content and the processed cocoa products with the highest flavonoid content.

Key words: Antioxidant, cocoa, fermentation, alkalization, metabolism, homeostasis

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INTRODUCTION

Cocoa (*Theobroma cacao* L.) is a natural biological resource that is widely used in World and Indonesia is one of them. Cocoa is one of the essential plantation commodities for the national economy and is classified as a non-climacteric fruit[1]. The beans are a necessary part of the cocoa fruit. Cocoa beans are the primary ingredient in processed chocolate products that are widely available to people. It has a distinct taste and flavour that is well-liked[2]. It also contains bioactive compounds that benefit health. However, the bioactive cocoa beans can change during processing due to heating, adding milk and sugar additives.

Flavonoids are a type of polyphenolic compound that is bioactive. They contain 6-8% of their dry weight in flavonoid compounds. Most flavonoids are flavan-3-ol (also known as flavanols), catechins, epicatechins and proanthocyanidins. Because polyphenols are hydrophilic, flavonoids can be found in the non-lipid fraction. Flavonoids content in each cocoa bean will vary. It is due to several factors, including the fermentation process, drying cocoa beans, roasting process and extraction, which can remove up to 85% of the flavanol content[3]. Flavanols improve cardiovascular health by lowering the risk of cardiovascular morbidity and mortality from other chronic diseases. In addition, flavanols are beneficial to hypertensive individuals because they can lower blood pressure[4].

The flavonoids content of each chocolate product varies. Dark chocolate contains the most flavonoids of any cocoa bean product and white chocolate has the most minor[5]. Cocoa butter, powdered milk, skim milk, soy lecithin emulsifier and vanillin are the ingredients used to make white chocolate. The number of flavonoids in the processed product is determined by the amount of cocoa mixed in. The higher the concentration or amount of cocoa mixed, the higher the flavonoid content. Because of the presence of tannins, the higher the flavonoid content, the bitterer the chocolate taste. The review discusses the beneficial effects of flavonoids, the impact of processing on flavonoid content and the processed cocoa products containing much more flavonoid content.

Bioactive components of cocoa beans and their health benefits: Cocoa bean flavonoids: The polyphenol in cocoa beans has antioxidant properties. It is a chemical substance that is made up of more than one phenolic group. The polyphenols in cocoa are mostly flavonoids. Flavonoids in food are classified into six classes: flavonols, flavones, flavan-3-ols, flavanones, anthocyanins and isoflavones. Flavan-3-ol is the most abundant flavonoid in cocoa. It consists of epicatechin, catechin and procyanidin monomer[6,7]. Flavanols can be made up of 1-3% weight of cocoa beans and their oligomeric fraction (procyanidin) 6-8% by weight of cocoa beans[8]. According to Muscatello *et al.*[9], the most abundant flavonoid group consists of two aromatic carbon rings, benzopyran (A- and C-rings) and benzene (B-ring). Flavanols are water-soluble and can be oxidized both enzymatically and non-enzymatically. Procyanidins are flavonoids that account for 58% of total polyphenols in raw cocoa beans[10].

Flavanol monomer consists of catechins and epicatechins. Catechins are the pigments that give cocoa beans their purple and brown hues. With a 1:0.1 ratio, epicatechin is more dominant than catechin. Raw cocoa beans contain approximately 60% flavonols by weight of total phenolic with procyanidin monomers and oligomers. The bioavailability of catechins in their (-) and (+) forms differs in absorption power. In chocolate, the concentration of (-)-catechins is higher than (+)-catechins. However, (-)-catechins have a lower bioavailability than (+)-catechins[11]. Flavonoids can be found in the cocoa fraction that does not contain solid fat. The flavonoid of cocoa beans is greatly affected by processing. It compounds capable of scavenging free radicals. Flavonoids are temperature-sensitive[12]. Fermentation, drying, roasting, alkalization, storage conditions and industrial processing protocols all have an impact on flavonoid content[13].

Flavonoid's health benefits: Cocoa flavonoids, specifically catechins, epicatechins and procyanidins, have been the focus of many studies. Flavonoids found in cocoa are metabolized by enzymes in both the small intestine and colon. Flavonoids interact with colon microbes, which aid in the growth of probiotic microbes. Similarly, epicatechin will be converted to have a low molecular weight, which will then be absorbed by the colon and aid digestion by probiotic microbes[14]. The effects of microbes metabolizing flavonoids are positive, as they help promote homeostasis of the immune system and boost nutrient absorption and metabolism. In addition, flavonoids have an antimicrobial activity that can inhibit commensal or pathogenic microorganisms[15]. Finally, flavonoids can make biotransformation by intestinal epithelial cells so that they can be circulated in the bloodstream and secreted back into the intestine for additional metabolic or biological activities[15].

Cocoa derivative products containing high levels of flavanols will have different effects. Consumption of cocoa-derived products high in flavonoids has a physiological impact. It is affected by factors such as experience, mood and satiety. Sensory dissatisfaction causes a bad mood. Several studies have shown that eating chocolate can improve mood and happiness[16,17]. Flavonoids have been shown in epidemiological studies to reduce coronary heart disease. It is related to the fact that consuming flavonoids can lower blood pressure and improve endothelial function. When it consumed dark chocolate regularly, Flow-Mediated Dilation (FMD) increased by 4%[18]. In cocoa powder, cocoa bean flavonoids have an anti-hypertensive effect[4]. The increased bioavailability of nitric oxide produced by flavanols reduces blood pressure and insulin resistance[19]. The Angiotensin-Converting Enzyme (ACE) changes play an essential role in blood pressure regulation, where angiotensin one is converted to angiotensin two by flavanols and procyanidins. These modifications are desirable for hypertensive patients because they can prevent ACE from activating the NADPH-oxidase enzyme. The enzyme will cause nitric oxide to be oxidized to peroxy nitrate[4].

Flavonoids can degrade Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP). The decrease in blood pressure is caused by angiotensin one conversion and increased nitric oxide synthase activity. Increased blood flow in the arteries did not affect flavonol consumption. The addition of sugar to chocolate product samples, on the other hand, can reduce flavonoid activity in degrading SBP and DBP[20]. According to Ioannone *et al.*[21], dark chocolate consumption decreasing triglycerides, total cholesterol and Low-Density Lipoprotein (LDL) cholesterol for six months.

Furthermore, the polyphenol fraction can prevent resistance to elevated LDL by suppressing the formation of atherosclerosis[3]. In addition, epicatechin and procyanidin-rich cocoa products help your body's antioxidant capacity and blood plasma triglyceride oxidation[22]. The following Table 1. summarizes the health benefits of flavonoids extracted from processed cocoa beans.

Cocoa's Influence on Flavonoid Content

Cocoa varieties: The cacao plant is classified botanically into three varieties: Criollo, Forastero and Trinitario, each of which has fine grade, bulk grade and fine grade. According to legend, Criollo is a type of cocoa plant that the Mayans highly valued and whose existence is extremely rare. Criollo has a slightly bitter taste and is more aromatic than other bean plants. The Criollo cocoa is indigenous to Mexico, Central America and northern South America. Criollo is currently grown in the Dominican Republic, Peru, Colombia, Papua New Guinea, Indonesia and Madagascar[23]. This variety is used in chocolate production to the tune of 5-10%[24].

Up to 80% of chocolate production is made from Forastero cocoa, followed by Criollo and Trinitario. Forastero is a more complex bean than Criollo and produces lower-priced cocoa beans[24]. Forastero cocoa originates in the Amazon region of Guyana and is now available in Ghana, Ivory Coast, Sao Tome and Principe, Togo, Nigeria, Brazil, Indonesia and Malaysia[23]. Overall, the highest quality cacao was the original Forastero from Ecuador (better known as Arriba), followed by the Criollo[25].

Trinitario is a hybrid between the Forastero and Criollo cocoa varieties. The chocolate produced by Trinitario is used less extensively (about 10-15%)[24]. However, it has a well-known strong aroma. Although it originated in Trinidad, the Trinitario plant has been cultivated in Venezuela, Ecuador, Cameroon, Samoa, Sri Lanka, Java and Papua New Guinea[23].

Flavonoid content of different cocoa varieties: Each bean variety has differences. Criollo cocoa beans, for example, contain approximately two-thirds of the polyphenolic compounds found in Forastero cocoa beans. Polyphenols are typically around 6-8% in cocoa beans[23]. Variables like genetics, bean variety and fermentation stage can affect the phenolic concentration in cocoa beans[26]. It further explains the various types of cocoa beans grown in each region.

Caligiani *et al.*[25] discovered that Forastero from Ecuador had higher (-)-epicatechin and caffeic acid derivatives than Criollo from Grenada, Trinitario from Trinidad and Forastero Ghana. Variations in genotype, growing conditions and postharvest handling of cocoa plants can all contribute to this. According to Othman *et al.*[26], the difference in concentration of (-)-epicatechin can be influenced by the region of origin of cocoa. According to the findings, the concentration of (-)-epicatechin in the sample ranged from 270-1235 mg/100 g of cocoa beans. In addition, it found Sulawesi cocoa bean samples with low pH cotyledons to have higher antioxidant potential than Ghana and Cote d'Ivoire cocoa beans. Finally, it indicates that Sulawesi cocoa has higher polyphenol content than Ghanaian and Cote d'Ivoire cocoa.

Other factors like climate, sunlight intensity, fruit maturity, harvest time and pest attack can impact the flavonoid content in cocoa. According to Oracz and Nebesny[27], Forastero from Brazil contains the most phenolic compounds in mg GAE/g dry weight, 173.58. On the other hand, the phenolic compound content of Trinitario from Papua New Guinea was the lowest, 76.14. Also, the level of fruit maturity impacts the polyphenolic content in cocoa beans. Polyphenols in the cocoa act as a plant defence system. It is against pathogens and adverse environmental conditions during the ripening process[28]. Therefore, the polyphenolic concentration decreases as cocoa pods mature. Reported flavonoid compounds in various cocoa varieties are presented in Table 2.

Table 1: Summarizes the health benefits of flavonoids derived from processed cocoa beans

Product	Bioactive compounds	Health effect	References
Cocoa capsules	Flavanols	Consumption of flavanol-rich cocoa at a dose of 220 mg for four weeks can decrease LDL and triglyceride levels while increasing HDL levels and decreasing the arachidonic acid/eicosapentaenoic acid ratio	Davinelli *et al.*[47]
Natural forastero cocoa powder	Epicatechin	10 µM epicatechin and 1 µM mL^{-1} cocoa polyphenol extract increased insulin sensitivity in HepG2 cells, which averted liver dysfunction. Insulin sensitivity is restored when glucose uptake increases, glycogen synthesis is maintained and glucose production decreases	Cordero-Herrera *et al.*[48]
Cocoa beverage	Flavanols	For one week, consuming 0.96 g of total polyphenols and 0.48 g of flavanols for breakfast can increase HDL cholesterol and serum insulin levels	Basu *et al.*[49]
Dark chocolate	Flavanols	Due to its use in combination with other ingredients such as sugar, chocolate and so on, low polyphenol dark chocolate (<60 mg flavonols) affects increasing body mass index	Grace *et al.*[50]
Cocoa powder and dark chocolate bars	Flavanols	Acts as a preconditioning agent by activating antioxidant induction pathways in endogenous systems to protect the heart and brain from acute oxidative stress	Barrios *et al.*[51]
Cocoa powder (non-alkalized and alkalized)	Flavan-3-ols	In blood plasma,(-)-epicatechin has a higher bioavailability than (+)-catechin and (-)-catechin	Ellinger *et al.*[52]
Dark- dan white chocolate	Flavan-3-ols	A total of 1.23% flavan-3-ols can lower urinary creatinine levels and increase pyruvate and 4-hydroxyphenylacetate levels, which are bacterial phenolic compounds with a slight effect on human metabolism	Ostertag *et al.*[53]
Processed cocoa-based products (chocolate bars and chocolate drinks)	Epicatechin	Amount of epicatechin contained in a product determines the amount of blood pressure reduction. The higher the amount of epicatechin included, the greater the blood pressure dropping effect	Ellinger *et al.*[54]
Dark chocolate	Epicatechin	Consuming at least 58 mg epicatechin daily for four weeks has increased DNA resistance to oxidative stress	Spadafranca *et al.*[55]

Table 2: Flavonoid compound findings in various cocoa bean varieties

Cocoa varieties	Flavonoid compounds	Findings	References
Criollo cocoa beans	Flavanols: catechins, epicatechins; flavonols: quercetin-3-o-galactosidase, quercetin-3-o glucosidase	In comparison to other varieties, Criollo's polyphenol content is easier to reduce during processing	Elwers and Gotti *et al.*[56,57]
Forastero cocoa beans	Flavanols: catechins, epicatechins; flavonols: quercetin-3-o-galactosidase, quercetin 3-o-glucosidase; anthocyanidins: cyanidin 3-o-β-D-galactosidase; cyanidin 3-o-α-L-arabinose	Oxidation of anthocyanins and the formation of amino acid complexes with phenolic compounds decrease the total polyphenol content. Organic fermented cocoa beans contain more flavonoids than non-organic fermented cocoa beans	Da Silva Oliveira *et al.*[58]
Trinitario cocoa beans	Flavanols: catechins, epicatechins; flavonols: quercetin-3-o-galactosidase, quercetin 3-o-glucosidase; anthocyanidins: cyanidin 3-o-β-D-galactosidase, cyanidin 3-o-α-L- arabinose	Between Criollo and Trinitatio, there was no significant difference in total polyphenol and (-)-epicatechin content	Elwers *et al.*[56]

Flavonoid content changes during cocoa bean processing: It can turn cocoa beans into a variety of products. The physical and chemical properties of cocoa beans will undoubtedly be affected by the processing process. Fermentation, drying and roasting are the most common stages of cocoa bean processing. In addition, proper processing is required to maintain essential compounds such as flavonoids in a processed cocoa product. Table 3. shows the changes in flavonoid compounds at each stage of the cocoa bean processing process.

Fermentation: Cocoa processing starts with fermentation. The formation of a brown liquid from complex flavonoid compounds was measured as the fermentation index parameter. It is responsible for the distinct flavour of cocoa beans. As a result, fermentation significantly affects flavonoid content[29]. Epicatechin and catechin levels in plant material can be reduced by up to 80% during fermentation, according to Payne *et al.*[30]. The polyphenol content, including flavonoids, was significantly reduced from 115-43 mg g^{-1} dry weight in fermented cocoa beans. Non-fermented cocoa beans have a much higher flavonoid content. However, these cocoa beans will lack the distinct flavour associated with cocoa beans.

Drying: Drying is done to reduce the moisture content of cocoa beans to around 6-7%. In this condition, mould does not contaminate the beans. However, according to Indiarto *et al.*[29], the amount of heat used to dry cocoa beans significantly affects their flavonoid content. Freeze-dried cocoa beans had the highest flavonoid content, followed by sun-dried and oven-dried, respectively. These findings are consistent with the heat-sensitive nature of flavonoids found in cocoa beans[31].

Nieto-Figueroa *et al.*[32] also investigated various cocoa bean drying techniques. Their dryers are microwave, forced-air drying and forced-air drying-extrusion. Microwaves are thought to be the most effective for retaining flavonoids and other polyphenolic compounds. It is due to the drying rate is quick with microwave[32]. Therefore, the microwave-dried cocoa had the highest flavonoid content, followed by forced-air drying and forced-air drying-extrusion.

Roasting: Following the drying stage, cocoa beans will enter the roasting stage before being processed into finished food. Roasting can shape the colour, texture and aroma characteristics of cocoa beans, which result from oxidation and protein degradation, polymerization of polyphenols including flavonoids and Maillard reactions[33]. Flavanol is one of the flavonoids found in cocoa beans. According to Ioannone *et al.*[34], the flavanol content of short-term high-temperature roasting was higher than that of long-term low-temperature roasting. As a result, the flavonoid content decreases with increasing roasting levels. According to Indiarto and Rezaharsamto[35], high temperatures in food processing can degrade nutrients and bioactive compounds. It was roasting cocoa beans at temperatures higher than 70°C causes epicatechin to degrade[36]. It is due to the increased epimerization of epicatechin into catechins. Payne *et al.*[30] found that roasting reduced the epicatechin content of cocoa beans by up to 82% at a temperature of up to 120°C. The catechin content increased when the roasting temperature reached 120°C. Although the value of catechins is low during the processing stage, levels can rise when the cocoa beans are roasted. According to Gültekin-Özgüven *et al.*[37], Roasting cocoa beans can remove up to 65% of polyphenols, including flavonoids.

Alkalization: Alkalization, known as the Dutch process, is a typical process used to produce processed products, such as cocoa powder. This procedure is carried out to improve the product's colour, aroma and taste to satisfy customers[38]. As a result, the flavanol content of cocoa is significantly reduced during this process. The flavanol content of alkalized cocoa is approximately 78.5% lower than natural cocoa[5]. Generally, this is used to make high-quality cocoa powder[30]. The Maillard reaction product interacts with polyphenols to change the flavonoid content. Following immersion in concentrated alkali (sodium hydroxide), followed by exposure to oxygen, can decrease polyphenol compound content[39].

Miller *et al.*[38] investigated the effects of alkalization treatment on flavonoid compounds under three conditions. At pH 6.77-7.13; 7.22-7.52; and 7.69-8.6, respectively, light, medium and strong alkalization occurs. However, under light alkalization conditions, it kept 40% of natural flavonol levels. At medium alkalization, it maintained 22% of flavonol compounds. There was a significant decrease in the content of flavonoid compounds. Payne *et al.*[30] discovered that the alkalization process reduced flavonoid monomers, specifically epicatechin and catechins. Thus, proper pH conditioning can result in a pleasant taste and a high flavanol compound.

Cocoa bean-processed products: Cocoa powder is one of the processed intermediate products of cocoa beans. Cocoa powder is produced by pressing roasted beans, then ground

Table 3: Changes in flavonoid compounds at each stage of the cocoa bean processing

Processing stages	Findings	References
Fermentation	Flavonoids in cocoa beans were reduced by up to 80% during fermentation	Payne *et al.*[30]
Fermentation	Flavonoid content of fermented cocoa beans decreased significantly from 115-43 mg g^{-1} dry weight	Suazo *et al.*[33]
Fermentation	During fermentation, epicatechins and catechins are reduced by 10-70%	Caligiani *et al.*[25]
Fermentation	Epicatechins are reduced by approximately 120-140 mg g^{-1} cocoa beans during fermentation	Di Mattia *et al.*[59]
Fermentation	After fermentation at room temperature, the catechins and epicatechins in cacao can be reduced to 90-120 mg g^{-1}	Niemenak *et al.*[60]
Drying	Freeze drying preserves the flavonoids in cocoa beans	Majid and Di Mattia *et al.*[31,59]
Drying	Epicatechin and catechin concentrations in natural cocoa beans were 16.0 mg g^{-1} and when dried, they decreased by 26%, to 12.8 mg g^{-1}, using the freeze-drying method and by 29%, to 12.4 mg g^{-1}, using the sunlight drying method	Payne *et al.*[30]
Drying	While it is possible to dry at high temperatures, it must be done quickly, such as with a microwave	Nieto-Figueroa *et al.*[32]
Drying	The epicatechin and catechin content was reduced by approximately 50 and 60%, respectively, during the drying process	Coelho *et al.*[61]
Roasting	Roasting can cause specific colour, texture and aroma characteristics in cocoa beans, one of which is the polymerization of polyphenols, particularly the flavonoid group, resulting in a decrease in their content.	Suazo *et al.*[33]
Roasting	To maintain the cocoa beans' flavonoid, roasting at high temperatures for a brief period is preferable to roasting at low temperatures for an extended period	Ioannone *et al.*[34]
Roasting	At 70°C, roasting can reduce epicatechin levels by up to 82%; at 120°C, epicatechin epimerase converts epicatechin to catechins	Seem *et al.*[36]
Roasting	Traditional roasting at 200-220°C significantly reduced the flavonoid content compared to an oven set to 180°C	Djikeng *et al.*[62]
Roasting	After roasting, the flavonoid content of cocoa beans decreased by approximately 76.92%	Gültekin-Özgüven *et al.*[37]
Alkalization	Alkalization process can reduce flavonoids in cocoa beans by up to 78.5%	Katz *et al.*[5]
Alkalization	Alkalization, followed by heat treatment, leads to a decrease in polyphenol compounds	Caligiani *et al.*[63]
Alkalization	Alkalization can significantly decrease the flavanol content of cocoa powder by up to 60%	Langer *et al.*[13]
Alkalization	Light and medium alkalization can keep natural flavanol levels at approximately 40 and 22%, respectively	Miller *et al.*[38]
Alkalization	Content of epicatechin and catechin decreases as the degree of alkalization increases.	Payne *et al.*[30]

into a powder form with a fat content of 10%[40]. Typically, this cocoa powder will be alkalized or Dutch-processed to improve its flavour, colour and texture. Studies found that cocoa powder polyphenol and flavonoid levels changed during the manufacturing process[41]. Light, medium and strong alkalization of cocoa powder reduced epicatechins and catechins in mg/100 g by 223 and 88; 69 and 70; 26 and 36; and 4 and 9, respectively[30]. The highest total flavonoids were found in natural cocoa liquor, followed by unroasted cocoa beans, roasted cocoa beans, alkalized cocoa liquor and cocoa powder[37].

Chocolate is another popular product made from cocoa. Chocolate is a uniformly processed product made by combining cocoa, milk, sugar and other ingredients. Before cocoa can be processed into chocolate, it must be ground and transformed into cocoa powder or cocoa butter. Chocolate is high in flavonoids and flavanols, specifically catechins, epicatechins, procyanidins and derivatives[5,36]. Gültekin-zgüven *et al.*[41] found that the presence of cocoa in chocolate affects the flavonoid content. Chocolate comes in three distinct varieties: dark, milk and white[42]. These three types of chocolate have different flavonoid and cocoa compositions[43].

The cocoa content of dark chocolate determines its quality. According to data, dark chocolate has the highest cocoa content. Dark chocolate can contain up to 80% cocoa bean solids, with additional cocoa butter[44]. Because it contains more cocoa, it has a higher flavonoid content, contributing to its bitter taste. There are approximately 951 mg g^{-1} flavonoids per 40 g serving of dark chocolate[45].

Milk chocolate is made by combining 20-25% cocoa beans, cocoa butter, sugar and milk powder[44]. Milk chocolate is lighter in colour than dark chocolate due to the lower cocoa bean content. Additionally, the flavour is sweeter, but the distinctive bitter taste of chocolate is retained. By dry weight, milk chocolate contains approximately 24% flavonoids[46]. According to Katz *et al.*[5], milk chocolate contains 70 mg of flavanols+procyanidins per 100 g of chocolate.

White chocolate comprises cocoa fat (20% by weight), sweeteners and milk components[36]. Cocoa butter is extracted from cocoa beans to make white chocolate. White chocolate is produced by avoiding roasting the cocoa beans, thereby preventing them from turning black. White chocolate contains few whole cocoa beans, so many people mistakenly think it is a sweetener. White chocolate contains only about 12% flavonoids per 100 g of chocolate[46]. The following table summarizes the flavonoid content of various processed cocoa bean products.

CONCLUSION

Flavonoids are the most abundant bioactive components in cocoa beans and they have been linked to improved health. The fermentation, drying, roasting and alkalization processes are used to convert cocoa beans into intermediate and downstream products. Physicochemical properties change throughout the process, resulting in compounds that contribute to chocolate's distinctive flavour and aroma, but flavonoid content has decreased significantly. In terms of nutrition and health benefits, cocoa-based products are considered "superfoods." Innovation is required to reduce flavonoid degradation during processing while maintaining physicochemical and organoleptic parameters.

SIGNIFICANCE STATEMENT

This study discovers the cocoa beans contain a high concentration of polyphenolic compounds, particularly the flavonoid group, that can be beneficial for enhancing the body's health and nutrition. This study will help the researcher to investigate alternative technological innovations that will help prevent the degradation of flavonoids in cocoa beans by minimizing the quality loss in their processed products that many researchers were not able to explore. Thus, a new theory on preservation techniques for flavonoid compounds in cocoa beans and their processed products may be arrived at.

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REFERENCES

1. Indiarto, R., A.N. Izzati and M. Djali, 2020. Post-harvest handling technologies of tropical fruits: A review. Int. J. Emerging Trends Eng. Res., 8: 3951-3957.
2. Indiarto, R., E. Subroto and N. Sukri, 2021. The chocolate conching technique and its impact on physicochemical properties: A mini-review. Int. J. Emerging Trends Eng. Res., 9: 785-790.
3. Grassi, D. and C. Ferri, 2013. Cocoa, Flavonoids and Cardiovascular Protection. In: Polyphenols in Human Health and Disease, Watson, R.R., V.R. Preedy and S. Zibadi (Eds.)., Elsevier, Amsterdam, Netherlands, ISBN-13: 978-0-12-815504-2, pp: 1009-1023.

4. Grassi, D., G. Desideri and C. Ferri, 2010. Blood pressure and cardiovascular risk: What about cocoa and chocolate? Arch. Biochem. Biophys., 501: 112-115.
5. Katz, D.L., K. Doughty and A. Ali, 2011. Cocoa and chocolate in human health and disease. Antioxid. Redox Signal., 15: 2779-2811.
6. Chin, E., K.B. Miller, M.J. Payne, W.J. Hurst and D.A. Stuart, 2013. Comparison of antioxidant activity and flavanol content of cacao beans processed by modern and traditional Mesoamerican methods. Heritage Sci., Vol. 1. 10.1186/2050-7445-1-9.
7. Indiarto, R., Y. Pranoto, U. Santoso and Supriyanto, 2019. *In vitro* antioxidant activity and profile of polyphenol compounds extracts and their fractions on cacao beans. Pak. J. Biol. Sci., 22: 34-44.
8. Vega, C. and C. Kwik-Uribe, 2012. *Theobroma cacao*-An Introduction to the Plant, Its Composition, Uses and Health Benefits. In: Cocoa Butter and Related Compounds, Garti, N. and N.R. Widlak (Eds.)., AOCS Press, pp: 35-62.
9. Muscatello, M.R.A., R.A. Zoccali and A. Bruno, 2018. Citrus Fruit Polyphenols and Flavonoids: Applications to Psychiatric Disorders. In: Polyphenols: Mechanisms of Action in Human Health and Disease, Watson, R.R., V.R. Preedy and S. Zibadi (Eds.)., Elsevier Inc., pp: 119-131.
10. Oracz, J., D. Zyzelewicz and E. Nebesny, 2015. The content of polyphenolic compounds in cocoa beans (*Theobroma cacao* L.), depending on variety, growing region and processing operations: A review. Crit. Rev. Food Sci. Nutr., 55: 1176-1192.
11. Jalil, A. and A. Ismail, 2008. Polyphenols in cocoa and cocoa products: Is there a link between antioxidant properties and health? Molecules, 13: 2190-2219.
12. Hu, S.J., B.Y. Kim and M.Y. Baik, 2016. Physicochemical properties and antioxidant capacity of raw, roasted and puffed cacao beans. Food Chem., 194: 1089-1094.
13. Langer, S., L.J. Marshall, A.J. Day and M.R.A. Morgan, 2011. Flavanols and methylxanthines in commercially available dark chocolate: A study of the correlation with nonfat cocoa solids. J. Agric. Food Chem., 59: 8435-8441.
14. Williamson, G. and M.N. Clifford, 2017. Role of the small intestine, colon and microbiota in determining the metabolic fate of polyphenols. Biochem. Pharmacol., 139: 24-39.
15. Oteiza, P.I., C.G. Fraga, D.A. Mills and D.H. Taft, 2018. Flavonoids and the gastrointestinal tract: Local and systemic effects. Mol. Aspects Med., 61: 41-49.
16. Scholey, A. and L. Owen, 2013. Effects of chocolate on cognitive function and mood: A systematic review. Nutr. Rev., 71: 665-681.
17. Smith, D.F., 2013. Benefits of flavanol-rich cocoa-derived products for mental well-being: A review. J. Funct. Foods, 5: 10-15.
18. Bernaert, H., I. Blondeel, L. Allegaert and T. Lohmueller, 2012. Industrial Treatment of Cocoa in Chocolate Production: Health Implications. In: Chocolate and Health, Conti, A., R. Paoletti, A. Poli and F. Visioli (Eds.)., Springer, New York, USA, ISBN: 978-88-470-2037-5, pp: 17-31.
19. Grassi, D., C. Lippi, S. Necozione, G. Desideri and C. Ferri, 2005. Short-term administration of dark chocolate is followed by a significant increase in insulin sensitivity and a decrease in blood pressure in healthy persons. Am. J. Clin. Nutr., 81: 611-614.
20. Bauer, S.R., E.L. Ding and L.A. Smit, 2011. Cocoa consumption, cocoa flavonoids and effects on cardiovascular risk factors: An evidence-based review. Curr. Cardiovasc. Risk Rep., 5: 120-127.
21. Ioannone, F., G. Sacchetti and M. Serafini, 2017. Effect of dark chocolate extracts on phorbol 12-myristate 13-acetate-induced oxidative burst in leukocytes isolated by normo-weight and overweight/obese subjects. Front. Nutr., Vol. 4. 10.3389/fnut.2017.00023.
22. Wang, J.F., D.D. Schramm, R.R. Holt, J.L. Ensunsa, C.G. Fraga, H.H. Schmitz and C.L. Keen, 2000. A dose-response effect from chocolate consumption on plasma epicatechin and oxidative damage. J. Nutr., 130: 2115S-2119S.
23. Oracz, J., E. Nebesny and D. Zyzelewicz, 2015. Changes in the flavan-3-ols, anthocyanins and flavanols composition of cocoa beans of different *Theobroma cacao* L. groups affected by roasting conditions. Eur. Food Res. Technol., 241: 663-681.
24. Rusconi, M. and A. Conti, 2010. *Theobroma cacao* L., the food of the gods: a scientific approach beyond myths and claims. Pharmacol. Res., 61: 5-13.
25. Caligiani, A., D. Acquotti, M. Cirlini and G. Palla, 2010. 1H NMR study of fermented cocoa (*Theobroma cacao* L.) beans. J. Agric. Food Chem., 58: 12105-12111.
26. Othman, A., A.M.M. Jalil, K.K. Weng, A. Ismail, N.A. Ghani and I. Adenan, 2010. Epicatechin content and antioxidant capacity of cocoa beans from four different countries. Afr. J. Biotechnol., 9: 1052-1059.
27. Oracz, J. and E. Nebesny, 2016. Antioxidant properties of cocoa beans (*Theobroma cacao* L.): Influence of cultivar and roasting conditions. Int. J. Food Prop., 19: 1242-1258.
28. Fraga, C.G., M. Galleano, S.V. Verstraeten and P.I. Oteiza, 2010. Basic biochemical mechanisms behind the health benefits of polyphenols. Mol. Aspects Med., 31: 435-445.
29. Indiarto, R., Y. Ranoto, U. Santoso and Supriyanto, 2019. Evaluation of physicochemical properties and antioxidant activity of polyphenol-rich cacao bean extract through water blanching. Pak. J. Nut., 18: 278-287.
30. Payne, M.J., W.J. Hurst, K.B. Miller, C. Rank and D.A. Stuart, 2010. Impact of fermentation, drying, roasting and Dutch processing on epicatechin and catechin content of cacao beans and cocoa ingredients. J. Agric. Food Chem., 58: 10518-10527.

31. Majid, H. and H.A. Rining, 2018. The effect of drying techniques on the antioxidant capacity, flavonoids and phenolic content of fermented local cocoa bean. J. Adv. Res. Appl. Mech., 47: 11-15.
32. Nieto-Figueroa, K.H., N.V. Mendoza-García, M. Gaytán-Martínez, A. Wall-Medrano, M.G.F. Loarca-Piña and R. Campos-Vega, 2020. Effect of drying methods on the gastrointestinal fate and bioactivity of phytochemicals from cocoa pod husk: *In vitro* and *in silico* approaches. Food Res. Int., Vol. 137. 10.1016/j.foodres.2020.109725.
33. Suazo, Y., G. Davidov-Pardo and I. Arozarena, 2014. Effect of fermentation and roasting on the phenolic concentration and antioxidant activity of cocoa from Nicaragua. J. Food Qual., 37: 50-56.
34. Ioannone, F., C.D. di Mattia, M. de Gregorio, M. Sergi, M. Serafini and G. Sacchetti, 2015. Flavanols, proanthocyanidins and antioxidant activity changes during cocoa (*Theobroma cacao* L.) roasting as affected by temperature and time of processing. Food Chem., 174: 256-262.
35. Indiarto, R. and B. Rezaharsamto, 2020. A review on ohmic heating and its use in Food. Int. J. Sci. Technol. Res., 9: 485-490.
36. Seem, S.A., Y.V. Yuan and J.C. Tou, 2019. Chocolate and chocolate constituents influence bone health and osteoporosis risk. Nutrients, 65: 74-84.
37. Gültekin-Özgüven, M., I. Berktaş and B. Özçelik, 2016. Change in stability of procyanidins, antioxidant capacity and *in-vitro* bioaccessibility during processing of cocoa powder from cocoa beans. LWT Food Sci. Technol., 72: 559-565.
38. Miller, K.B., W.J. Hurst, M.J. Payne, D.A. Stuart, J. Apgar, D.S. Sweigart and B. Ou, 2008. Impact of Alkalization on the antioxidant and flavanol content of commercial cocoa powders. J. Agric. Food Chem., 56: 8527-8533.
39. Li, Y., Y. Feng, S. Zhu, C. Luo, J. Ma and F. Zhong, 2012. The effect of Alkalization on the bioactive and flavor related components in commercial cocoa powder. J. Food Composition Anal., 25: 17-23.
40. Beg, M.S., S. Ahmad, K. Jan and K. Bashir, 2017. Status, supply chain and processing of cocoa-A review. Trends Food Sci. Technol., 66: 108-116.
41. Gültekin-Özgüven, M., İ. Berktaş and B. Özçelik, 2016. Influence of processing conditions on procyanidin profiles and antioxidant capacity of chocolates: Optimization of dark chocolate manufacturing by response surface methodology. LWT Food Sci. Technol., 66: 252-259.
42. Glicerina, V., F. Balestra, M.D. Rosa and S. Romani, 2016. Microstructural and rheological characteristics of dark, milk and white chocolate: A comparative study. J. Food Eng., 169: 165-171.
43. Cheng, C.M., A.M.M. Jalil and A. Ismail, 2009. Phenolic and theobromine contents of commercial dark, milk and white chocolates on the Malaysian market. Molecules, 14: 200-209.
44. Montagna, M.T., G. Diella, F. Triggiano, G.R. Caponio and O.D. Giglio *et al*., 2019. Chocolate, "Food of the gods": History, science and human health. Int. J. Environ. Res. Public Health, Vol. 16. 10.3390/ijerph16244960.
45. Engler, M.B. and M.M. Engler, 2004. The vasculoprotective effects of flavonoid-rich cocoa and chocolate. Nutr. Res., 24: 695-706.
46. Pimentel, F.A., J.A. Nitzke, C.B. Klipel and E.V. de Jong, 2010. Chocolate and red wine-a comparison between flavonoids content. Food Chem., 120: 109-112.
47. Davinelli, S., G. Corbi, A. Zarrelli, M. Arisi and P. Calzavara-Pinton *et al*., 2018. Short-term supplementation with flavanol-rich cocoa improves lipid profile, antioxidant status and positively influences the AA/EPA ratio in healthy subjects. J. Nutr. Biochem., 61: 33-39.
48. Cordero-Herrera, I., M.Á. Martín, L. Goya and S. Ramos, 2014. Cocoa flavonoids attenuate high glucose-induced insulin signalling blockade and modulate glucose uptake and production in human HepG2 cells. Food Chem. Toxicol., 64: 10-19.
49. Basu, A., N.M. Betts, M.J. Leyva, D. Fu, C.E. Aston and T.J. Lyons, 2015. Acute cocoa supplementation increases postprandial HDL cholesterol and insulin in obese adults with type 2 diabetes after consumption of a high-fat breakfast. J. Nutr., 145: 2325-2332.
50. Farhat, G., S. Drummond, L. Fyfe, G. McDougall and E.A.S. Al-Dujaili, 2015. Comparison of the effects of high versus low-polyphenol dark chocolate on body weight and biochemical markers: A randomized trial. EC Nutr., 2: 354-364.
51. Barrios, M., L.C. Orozco and E.E. Stashenko, 2018. Cocoa ingestion protects plasma lipids in healthy males against *ex vivo* oxidative conditions: A randomized clinical trial. Clin. Nutr. ESPEN, 26: 1-7.
52. Ellinger, S., A. Reusch, L. Henckes, C. Ritter and B.F. Zimmermann *et al*., 2020. Low plasma appearance of (+)-catechin and (−)-catechin compared with epicatechin after consumption of beverages prepared from nonalkalized or alkalized cocoa—a randomized, double-blind trial. Nutrients, Vol. 12. 10.3390/nu12010231.
53. Ostertag, L.M., M. Philo, I.J. Colquhoun, H.S. Tapp and S. Saha *et al*., 2017. Acute consumption of flavan-3-ol-enriched dark chocolate affects human endogenous metabolism. J. Proteome Res., 16: 2516-2526.
54. Ellinger, S., A. Reusch, P. Stehle and H.P. Helfrich, 2012. Epicatechin ingested via cocoa products reduces blood pressure in humans: A nonlinear regression model with a bayesian approach. Am. J. Clin. Nutr., 95: 1365-1377.
55. Spadafranca, A., C.M. Conesa, S. Sirini and G. Testolin, 2010. Effect of dark chocolate on plasma epicatechin levels, DNA resistance to oxidative stress and total antioxidant activity in healthy subjects. Br. J. Nutr., 103: 1008-1014.

56. Elwers, S., A. Zambrano, C. Rohsius and R. Lieberei, 2009. Differences between the content of phenolic compounds in Criollo, Forastero and Trinitario cocoa seed (*Theobroma cacao* L.). Eur. Food Res. Technol., 229: 937-948.
57. Gotti, R., S. Furlanetto, S. Pinzauti and V. Cavrini, 2006. Analysis of catechins in *Theobroma cacao* beans by cyclodextrin-modified micellar electrokinetic chromatography. J. Chromatogr. A, 1112: 345-352.
58. Da Silva Oliveira, C., L.F. Maciel, M.S. Miranda and E. da Silva Bispo, 2011. Phenolic compounds, flavonoids and antioxidant activity in different cocoa samples from organic and conventional cultivation. Br. Food J., 113: 1094-1102.
59. Di Mattia, C., M. Martuscelli, G. Sacchetti, I. Scheirlinck, B. Beheydt, D. Mastrocola and P. Pittia, 2013. Effect of fermentation and drying on procyanidins, antiradical activity and reducing properties of cocoa beans. Food Bioprocess Technol., 6: 3420-3432.
60. Niemenak, N., C. Rohsius, S. Elwers, D.O. Ndoumou and R. Lieberei, 2006. Comparative study of different cocoa (*Theobroma cacao* L.) clones in terms of their phenolics and anthocyanins contents. J. Food Compos. Anal., 19: 612-619.
61. Coelho, C.M.M., C. de Mattos Bellato, J.C.P. Santos, E.M.M. Ortega and S.M. Tsai, 2007. Effect of phytate and storage conditions on the development of the 'hard-to-cook' phenomenon in common beans. J. Sci. Food Agric., 87: 1237-1243.
62. Djikeng, F.T., W.T. Teyomnou, N. Tenyang, B. Tiencheu and A.T. Morfor *et al*., 2018. Effect of traditional and oven roasting on the physicochemical properties of fermented cocoa beans. Heliyon, Vol. 4. 10.1016/j.heliyon.2018.e00533.
63. Caligiani, A., A. Marseglia and G. Palla, 2016. Cocoa: Production, Chemistry and Use. In: Encyclopedia of Food and Health, Caballero, B., P.M. Finglas and F. Toldrá (Eds.)., Elsevier Ltd., pp: 185-190.