Theobroma cacao L.: A FRUIT WITH COUNTLESS HEALTH BENEFITS

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ABSTRACT: *Theobroma cacao* L. is a widely appreciated ancient fruit, whose seeds represent a valuable economic resource for producing chocolate and cocoa butter. Although chocolate is known for its flavor and functional properties, the fruit pulp, transformed into cocoa honey after pressing, is still underutilized. The cocoa bean and the cocoa pulp have high nutritional value, rich in bioactive compounds, especially polyphenols, such as flavan-3-ols. Studies show that these compounds have several health benefits, including antioxidant and anti-inflammatory effects. Thus, in addition to its economic potential, the full use of cocoa contributes to the valorization of functional raw materials. This review explores the chemical composition of cocoa and cocoa honey, highlighting the factors that influence their composition and the benefits associated with their consumption.

Keywords: antioxidant activity; cocoa honey; phenolic compounds; health benefits;

Theobroma cacao L.: UMA FRUTA COM INÚMEROS BENEFÍCIOS PARA A SAÚDE

RESUMO: Theobroma cacao L. é uma fruta antiga amplamente apreciada, cujas sementes representam um valioso recurso econômico para a produção de chocolate e manteiga de cacau. Embora o chocolate seja conhecido por seu sabor e propriedades funcionais, a polpa da fruta, transformada em mel de cacau após a prensagem, ainda é subutilizada. O grão de cacau e a polpa de cacau possuem alto valor nutricional, ricos em compostos bioativos, especialmente polifenóis, como os flavan-3-óis. Estudos mostram que esses compostos apresentam diversos benefícios à saúde, incluindo efeitos antioxidantes e anti-inflamatórios. Assim, além de seu potencial econômico, o aproveitamento integral do cacau contribui para a valorização de matérias-primas funcionais. Esta revisão explora a composição química do cacau e do mel de cacau, destacando os fatores que influenciam sua composição e os benefícios associados ao seu consumo.

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1. INTRODUCTION

The genus *Theobroma sp.* is considered a Neotropical species native to the Amazon and has twenty-two described species, thirteen of which are present in Brazilian soil. Cocoa (*Theobroma cacao* L.) is one of the fruits that has commercial value (Campos-Vega, Nieto-Figueroa e Oomah, 2018; Mar *et al.*, 2024).

Originating from tropical regions such as South and Central America and parts of Africa, cocoa plays a fundamental role in the food industry. It is widely recognized as a raw material for producing products such as cocoa powder, cocoa liquor, cocoa butter, and chocolate (Alotaibi et al., 2024; Golodnizky et al., 2024).

The world's largest producer is Ivory Coast, with 2.18 million tonnes, followed by Ghana, Ecuador, and Cameroon (Walzburiech, 2024)According to information from the Brazilian Institute of Geography and Statistics (IBGE), Brazil ranked sixth, producing 273 thousand tons in 2022.

Chocolate is widely recognized as one of the most appreciated and consumed foods and beverages globally, standing out for its unique flavor and its variations in uses in different cultures (Alotaibi et al. 2024). The fruit is divided into peel, pulp, placenta, and seeds (Figure 1). The seeds consist of a germ and two cotyledons, surrounded by a layer of sweet mucilage (Campos-Vega, Nieto-Figueroa e Oomah, 2018).

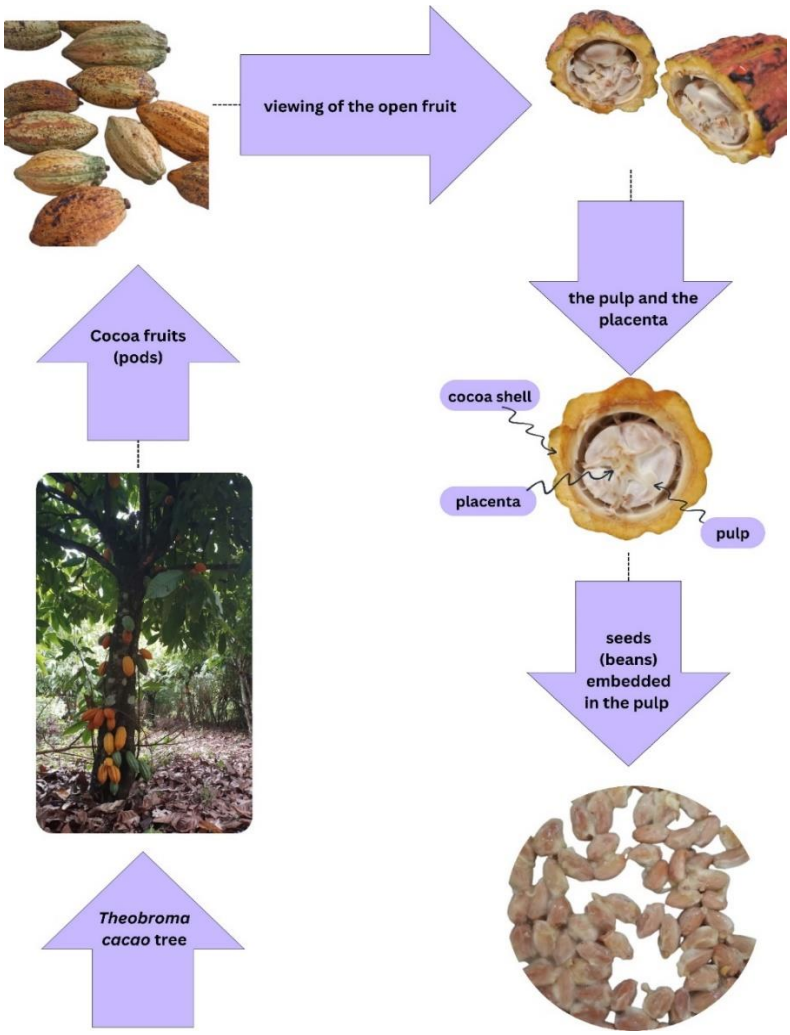

FIGURE 1 - Cocoa tree, whole and open fruit, highlighting the shell, pulp, placenta, and seeds.

The seeds, called cocoa beans, are obtained from the pods. The pods are oval, measuring between 12 and 30 cm in length, and containing 30 to 40 beans embedded in a mucilaginous pulp, which comprises approximately 40% of the fresh weight of the bean (Kongor *et al.*, 2016).

Cocoa and its derivatives are currently present in the world's diet. The economic exploitation of cocoa primarily relies on its seeds, also known as beans. Industries process these until chocolate is obtained. Brazil has a well-established production chain, as it cultivates the fruit and processes the beans (Guirlanda, Silva e Takahashi, 2021).

However, the cocoa industry's production chain is mainly focused on the exploitation of the bean. However, 80% of the cocoa in this scenario corresponds to waste, which in most cases is not economically used (Guirlanda, Silva e Takahashi, 2021).

Among these residues, cocoa juice, also known as cocoa honey, deserves special mention due to its characteristic sweet flavor. This byproduct is obtained from cocoa pulp by natural decantation, and natural or mechanical pressing (Guirlanda, Silva e Takahashi, 2021).

"Cocoa Honey" is obtained during the processing of cocoa, more specifically during the pulping stage of the seeds. This substance, sometimes considered a by-product, has distinct chemical characteristics that go beyond its simple sweet taste. Its composition includes a variety of compounds, such as polyphenols and other antioxidant compounds, giving it not only a unique sensory profile but also functional properties that have aroused interest in the food industry (Guirlanda, Silva e Takahashi, 2021).

The term ‘cocoa honey’ is used regionally in the producing regions to describe a pale-yellow liquid, resulting from the pressing of the mucilage around the seed, having in its composition mainly water, sugar, and non-volatile acids (Guirlanda, Silva e Takahashi, 2021).

Considering its composition combined with the fact that it is little explored commercially, it is possible to think of alternatives for its use, such as its use for the production of beverages (Barišić *et al.*, 2023; Guirlanda, Silva e Takahashi, 2021).

2. Chemical composition of cocoa and cocoa honey

Cocoa is known to be a rich source of polyphenols, bioactive compounds that have antioxidant and anti-inflammatory properties. The main polyphenols found in cocoa include flavan-3-ols (epicatechin, and monomeric catechin, as well as their oligomers of dimers to decamers, the procyanidins), with smaller amounts of anthocyanins (mainly cyanidin glycosides) and flavonols (quercetin glycosides) (Lecumberri et al. 2007; de Oliveira and Genovese 2013). The health benefits associated with consuming these polyphenols include improved cardiovascular function, reduced oxidative stress, and support for brain health (Lecumberri *et al.*, 2007; Oliveira, de e Genovese, 2013).

The polyphenols present in cocoa, such as procyanidin, epicatechin, and catechin, have antioxidant action, preventing the oxidation of free radicals. The polyphenol content in cocoa can vary according to the geographical origin, the variety of the plant, the climate, the type of soil, and the region of cultivation. According to the literature, the polyphenol content in cocoa powder can vary from 3.3 to 65 mg/g (Lecumberri *et al.*, 2007).

Studies have shown that the polyphenols present in cocoa can positively influence cardiovascular health by inhibiting lipid peroxidation, platelet activation, and/or cyclooxygenase and lipoxygenase activities enzymes whose action produces prostaglandins, thromboxanes, and leukotrienes, also called eicosanoids. These substances are homeostatic agents, involved in maintaining the integrity of the inflammatory, cardiovascular, and renal systems, in addition to increasing the levels of endothelium-derived relaxing factor, nitric oxide, a free radical that acts in the signaling of different biological processes (Agrawal e Nirmal, 2025; Alum, 2025; Dias, Negrão e Krieger, 2011; Igbayilola, Grema e Jibrin, 2024; Lecumberri *et al.*, 2007).

Cocoa polyphenols have also been associated with antimutagenic activity, and by decreasing oxidative damage to DNA, through the reduction of 8-hydroxy-2`-deoxyguanosine levels, the biomarker related to this damage (Lecumberri *et al.*, 2007).

Cocoa is a fruit rich in dietary fiber (DF), which is present mainly in the pulp of the fruit. DFs are classified as isolated or synthetic non-digestible carbohydrates, with three or more monomeric units, determined by the Food and Drug Administration (FDA) as having beneficial physiological (Alst, 2024; Lecumberri *et al.*, 2007). The beneficial effects on human health include reducing the incidence of chronic intestinal disorders and diseases such as obesity, diabetes, and cardiovascular disease (Lecumberri *et al.*, 2007).

Cocoa seeds, also called beans, are surrounded by a sweet, white, mucilaginous pulp, slightly attached to the placenta, with about 80% moisture and 15% monosaccharides. It represents approximately 40% of the raw grain in wet weight, in addition to being a rich medium for microbial growth (Freitas *et al.*, 2022; Moretti *et al.*, 2023).

According to Normative Instruction N°. 1 of January 7, 2000, from the Ministry of Agriculture, Livestock and Supply (MAPA), the Brazilian agency responsible for managing public policies to stimulate agriculture, foster agribusiness, and regulate and standardize services linked to the sector, cocoa fruit pulp is defined as a non-fermented and undiluted product obtained from the edible part, except seeds (beans), through an appropriate technological process, with a minimum content of total solids (Brasil, 2000). The pulp or puree should be ivory white in color, slightly acidic in flavor, and have its aroma (Ribeiro *et al.*, 2021).

In this regulation, the cocoa pulp must present, according to the General Standards of Identity and Quality established, content of soluble solids in °Brix, at 20 °C of 14 °Bx, pH of 3.4, total acidity expressed in citric acid (g/100g) of 0.75, total natural cocoa sugars (g/100g) ranging from 10 to 19, and 10 (g/100g) of total solids (Brasil, 2000). The pulp is mainly composed of moisture (80%) and monosaccharides (15%), and the acidic pH is due to the concentration of compounds such as citric acid (Paz, 2010).

In the physicochemical evaluation of mixed fruit pulps with different concentrations of cocoa and açaí, (Ribeiro et al. 2021) reported that açaí has a higher concentration of phenolic compounds (sample with 50% açaí and 50% cocoa) than cocoa pulp. However, cocoa pulp has a higher number of antioxidants when its content is increased in the blend evaluated (30% açaí and 70% cocoa), (Ribeiro *et al.*, 2021).

Some authors consider that cocoa honey is the liquid obtained that runs off during the fermentation process and is called cocoa sweat (Balladares *et al.*, 2016). However, for other authors, cocoa honey is obtained before the fermentation stage (Ferreira, Trevizan e Dias, 1982). Currently, many producers extract honey via centrifugation but do not remove the mucilage completely, as small residues of pulp will be essential for the fermentation stage. Due to this, in the literature, we find different terminologies and results about cocoa pulp and honey.

Because it has a high sugar content, the pulp plays an important role in the fermentation of the bean. Microorganisms such as yeast, lactic and acetic bacteria participate in the fermentation process, which is responsible for the essential precursors of the characteristic flavor and final sensory information of chocolate. For the manufacture of chocolate, one of the essential steps is the fermentation of the bean and subsequent drying. It is worth noting that the composition of the pulp is influenced by the genotype of the cocoa, the origin of the pod, and the degree of ripeness (Moretti *et al.*, 2023).

Cocoa cultivation is economically important for Brazil. However, the incidence of a fungal disease (witches' broom) in 1989 led to the development of cocoa hybrids, to overcome losses in cocoa crops (Moretti *et al.*, 2023).

In the study carried out by Moretti et al. (2023), 16 cocoa hybrids from different regions of Brazil, specifically from the states of Espírito Santo and Bahia, were analyzed. The objective was to investigate the sugar content, cello-oligosaccharides with prebiotic potential, and

enzymatic activity. Considering that cocoa pulp is predominantly made up of sugars, it became essential to evaluate possible variations in this major component among the samples analyzed.

The results indicated that the cocoa pulp contains, on average, 76% sugars, with a variation of approximately 20% in sugar levels among the hybrids analyzed. Regarding the sugar profile, the reducing sugars were the most prevalent, presenting average concentrations of 38.7 g/kg for glucose, 50.8 g/kg for fructose, and 19.9 g/kg for sucrose. The total sugar content, based on dry matter, ranged from 695.94 to 857.03 g/kg. Whereas, cocoa beans (beans) have higher concentrations of sucrose and a minimal amount of maltose has been identified. (Moretti *et al.*, 2023).

The higher reducing sugar content in the pulp directly impacts the availability of metabolites for consumption by microorganisms. Almost all samples demonstrated higher concentrations of fructose, except for sample PS1319, from Espírito Santo, which presented a higher sucrose content. This exception can be explained by the lack of standardization in the cocoa harvesting process, which is carried out manually and depends on the subjective assessment of the degree of ripeness of the fruits (Moretti *et al.*, 2023).

TABLE 1 - Chemical composition of pulp and cocoa beans fermented.

Compounds	Cocoa Pulp	Fermented Cacao Beans
Carbohydrates	High concentration, mainly in the form of sugars	Present, but in lower proportion than in pulp
Proteins	Low	High content, an important source of amino acids
Fibers	Moderate	High content, especially in the shells
Minerals	Low	High content, including magnesium, iron, and zinc.
Lipids	Very low	Moderate, primarily in the form of cocoa butter
Phenolic Compounds	Present, but in lower amounts than in beans	High concentration, contributing to antioxidant properties

Another interesting fact is that the pulp of ripe pods contains mainly reducing sugars, that is, glucose and fructose. However, the pulp of green pods is mainly made up of sucrose. Therefore, during the ripening process, sucrose is the main sugar (along with other polysaccharides). As the fruit ripens, the glucose and fructose content increase due to the activity of invertase, an enzyme responsible for catalyzing the hydrolysis of sucrose into fructose and glucose (Moretti *et al.*, 2023).

Cello-oligosaccharides (COS) are soluble oligomers derived from cellulose, characterized by beta-1,4 linkages between glucose molecules and a degree of polymerization (DP) of less than 6. Humans cannot digest these oligomers, allowing them to serve as prebiotics for the colon microbiota. In studies of Moretti et al. (2023) most of the evaluated samples presented cellobiose (C2) and cellotriose (C3) as the main COS.

Cocoa pulp represents an excellent matrix for fermentation due to the combination of sugar and COS content, since microorganisms have distinct substrate preferences, allowing variability in microbial growth and favoring an efficient fermentation process (Moretti et al., 2023).

Cocoa honey is obtained by pressing the pulp. This product is therefore easily fermented if not stored correctly. Cocoa honey has also been shown to have significant antioxidant capacity due to the presence of polyphenols present in the fruit. The antioxidant capacity of

cocoa honey can vary depending on the quality of the harvest and the place of cultivation (Guirlanda et al., 2021).

3. Factors that interfere with the chemical composition of cocoa

The polyphenol content in cocoa can vary due to several factors, such as geographic origin (planting region – agronomic and environmental factors), plant variety, climate, and soil type. The processing of the bean to obtain chocolate also influences the number of polyphenols, that is, the chemical composition of chocolate differs from that of the fruit (EFRAIM, Barreto ALVES e Calil Pereira JARDIM, 2011).

For the formation of aromatic compounds, which contribute significantly to the formation of the desirable flavor, reduction of bitterness, and astringency of chocolate, it is necessary that during the processing of cocoa, a series of chemical reactions occur with the flavonols present in the bean, such as oxidation, complexation, leaching, and hydrolysis of proteins and carbohydrates (EFRAIM, Barreto ALVES e Calil Pereira JARDIM, 2011).

Chocolate production involves the processing of cocoa beans, divided into pre-processing stages (harvesting, fermentation, and drying) and other processes, such as roasting, refining, conching, tempering, and crystallization. Fermentation and drying play crucial roles in defining cocoa quality, in addition to favoring the formation of precursors responsible for the characteristic aroma and flavors of chocolate (Britto de Andrade *et al.*, 2021).

During these stages, the reduction in the total phenol content (from 395.15 to 154.96 mg ECE g^{-1}) is directly linked to the development of the desired aroma and flavors. In the interference, there is a significant decrease in polyphenols, with approximately 30% being reduced in the first 48 hours and up to 90% at the end of the process (Britto de Andrade *et al.*, 2021).

The sensory quality of chocolate depends on the formation of volatile substances generated by fermentation and Maillard reactions that occur during drying, roasting and conching (Brito de Andrade et al., 2021).

Among all the stages, fermentation is considered the most complex and decisive for the success of production. However, the fermentation of cocoa beans occurs spontaneously (not standardized), depending mainly on the activity of microorganisms with residues of the pulp present in the bean, as they are rich in reducing sugars, and consequently promote the fermentation process (Herrera-Rocha *et al.*, 2023).

Biochemical reactions occur during fermentation, which is aided by enzymes present in the fruit pulp, in addition to endogenous metabolites from the bean, which result in the production of compounds characteristic of chocolate, which are related to its aroma and flavor (Herrera-Rocha *et al.*, 2024)

Drying cocoa beans at low temperatures and for short periods does not significantly reduce the flavonoid content. However, most of the flavonoids can be reduced during the next processing step, which is roasting (Taş e Gökmen, 2016).

However, studies show that a total of five metabolites (ethyl-methyl pyrazine, sorbitol, maltol, vanillin, and coumaric acid) that are associated with different premium fine chocolate flavor notes showed significant increases, except coumaric acid, when cocoa beans are roasted and dried (Taş e Gökmen, 2016).

One of the reactions that occur during the roasting of beans is the Maillard reaction, which was first described in 1912 by the French biochemist Louis Camille Maillard. This chemical reaction is considered one of the most important, as it is related to the conversion of several flavor precursors, such as amino acids and reducing sugars, into volatile organic compounds responsible for the flavor of cocoa (Yang *et al.*, 2024; Zheng, Ou e Ou, 2019).

Although the Maillard reaction provides desirable characteristics to the final product (chocolate), it reduces the nutritional value by modifying essential amino acids such as lysine, consequently affecting the protein content. In addition, it produces compounds considered mutagenic and carcinogenic, such as α-dicarbonyl compounds (α-DCs). Therefore, optimizing the ideal conditions for roasting the bean is very important (Taş and Gökmen, 2016).

In the studies of Taş and Gökmen (2016) who evaluated cocoa samples immersed in water, alkaline treatment (sodium carbonate), and untreated observed that the predominant α-dicarbonyl compound was 3-deoxyglucosone (3-DG). Regarding the influence of treatments on the degradation of this compound, alkalinization caused a decrease of almost 50% in the initial concentration of 3-DG, since degradation is favored in an alkaline medium while increasing the roasting temperature to 150°C in samples that were alkalinized caused an 88% reduction in 3-DG.

α-Dicarbonyl compounds (α-DCs) are toxic end products formed during the Maillard reaction and caramelization during thermal processing of foods. These compounds act as final precursors of advanced glycation in foods (Zheng et al. 2019; Yang et al. 2024).

α-Dicarbonyl compounds are organic compounds with low molecular weight and yellow coloration. They are formed from the fragmentation of sugar during non-enzymatic browning and are intermediates formed in caramelization, Maillard reaction, and oxidative degradation. In the literature, 18 types of α-DCs have been identified in various foods, such as glyoxal (GO), methylglyoxal (MGO), 3-deoxyglucosone (3-DG), and diacetyl (DA), which are considered the most representative (Cha, Debnath e Lee, 2019; Yang *et al.*, 2024).

Dicarbonyl compounds are highly reactive and are therefore the main intermediates in the formation of advanced glycation end products (AGEs). AGEs are a class of molecules with a heterogeneous structure and are irreversible products resulting from the spontaneous process of reactions that occur between the reactive carbonyl group and reducing sugars, nucleic acids, lipids, and proteins (Coccini *et al.*, 2024).

The abnormal accumulation of (AGEs) can lead to a dysfunctional state, called dicarbonyl stress, and cause increased modification of proteins and DNA, in addition to triggering several diseases, contributing to the alteration and aging of cells and tissues (Coccini *et al.*, 2024).

Alkalization is another type of processing that affects the chemical composition of cocoa and has been used for almost two centuries. This process aims to reduce the acidity, astringency, and bitterness of cocoa, as well as produce darker colors and more intense flavors. In this process, cocoa is treated with a food-grade alkaline solution to increase its pH (Sioriki *et al.*, 2021).

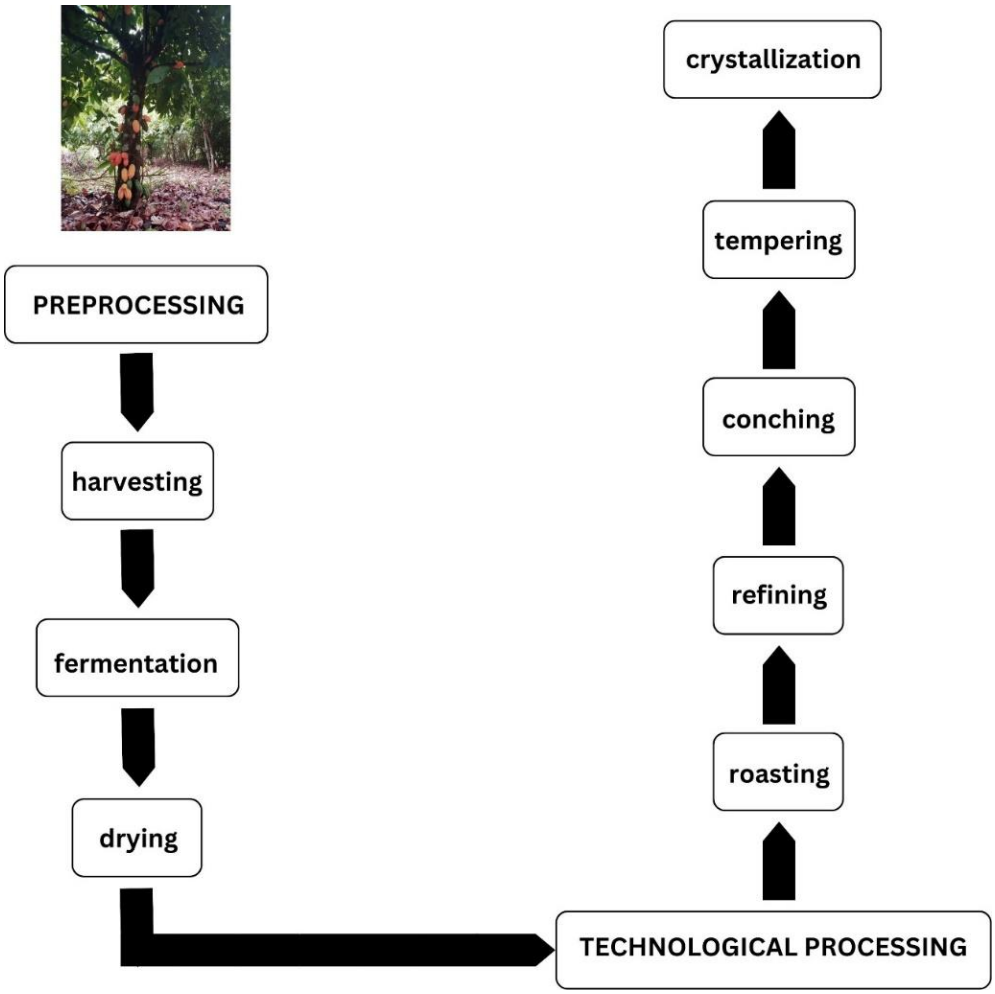

FIGURE 2 - Stages in chocolate production.

It is worth noting that chocolate sales are divided into two categories, according to sensory quality. The largest portion of cocoa production, around 95%, is made up of Forastero cultivars, which are commonly used in confectionery and are associated with more basic chocolate notes. Meanwhile, native cultivars, or hybrids of the Criollo or Trinitario type, which have a fine flavor, associated with floral and fruity notes, are intended for the production of premium and highly valued (healthier) chocolates, as they have less sugar, and are generally sold with 70% or more cocoa content (Herrera-Rocha *et al.*, 2024).

The nutritional benefits of chocolate, especially dark chocolate with a high cocoa content, have gained prominence due to the growing search for healthier and more functional foods (Taş e Gökmen, 2016).

In the food industry, chocolate is generally marketed in three main categories: white, milk and dark, which are differentiated by the proportion of milk, cocoa butter and cocoa mass used in their formulation (Table 2). The cocoa content present in chocolate influences the amount of nutrients; since the amount of cocoa solids and total fat are high, and the concentration of carbohydrates is low (Alotaibi *et al.*, 2024).

TABLE 2 - Main differences in the composition of dark, milk and white chocolate.

Composition	dark chocolate	milk chocolate	white chocolate
cocoa mass	high proportion	lower than dark chocolate, usually between 30% and 50%	none
cocoa butter	high proportion	moderate	high
milk	none or very little	high proportion	high
source of fats	cocoa butter fat	fat from cocoa butter and some fat from milk	cocoa butter fat

The fat content of chocolate varies according to the type, reflecting differences in its composition. Dark chocolate, for example, has a low-fat content and contains virtually no milk, in addition to having the highest cocoa mass content among all types of chocolate. On the other hand, white chocolate does not contain cocoa mass and is composed essentially of cocoa butter, sugar, and milk. Due to its high cocoa content and lower number of additives, dark chocolate is often considered a healthier option for consumption (Alotaibi *et al.*, 2024).

White and milk chocolate have similar compositions and health benefits, such as reducing diabetes, cancer, cardiovascular disease, and hypertension. Both contain cocoa butter, a fat that is separated from cocoa beans (Alotaibi *et al.*, 2024).

4. Health benefits associated with cocoa consumption

Throughout history, cocoa has often been seen as a medicine rather than a food. In the 16th century, Europeans, for example, used cocoa and chocolate in liquid form as vehicles for medicines, in addition to its being considered a medicine in itself (Efraim et al., 2011).

Cocoa is a fruit rich in polyphenols, mainly flavonoids, which are bioactive compounds related to several health benefits, due to their antioxidant, anti-inflammatory, and immunomodulatory properties (Figure 3). Preclinical studies and human trials show that the consumption of cocoa and chocolate can impact the regulation of the immune system (Atanassova et al., 2023; Martín and Ramos, 2017).

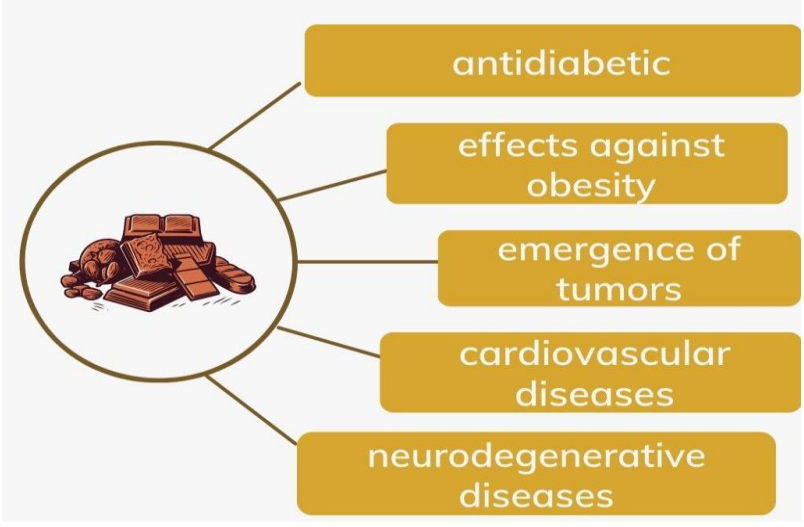

FIGURE 3 - Main health benefits from cocoa consumption.

The effects on immune modulation are associated with several effects of polyphenols on the immune system, including their anti-inflammatory, antioxidant and anti-allergic properties. These compounds influence both innate and acquired immunity, through the regulation of cytokine production and the activation of lymphocyte-dependent and -independent pathways. In addition, cocoa consumption has been related to changes in the

composition and dynamics of the intestinal microbiota, directly impacting the intestinal immune system, especially due to the high concentration of fiber (Atanassova *et al.*, 2023).

4.1 Beneficial effects against fatigue in patients with relapsing-remitting multiple sclerosis and cardiovascular diseases

Multiple Sclerosis (MS) is an autoimmune disease, in which the immune system attacks the body itself. In this disease, the central nervous system (CNS) is affected and is characterized by demyelination and neurodegeneration. This pathology can manifest itself in a relapsing-remitting or progressive form. Relapsing-remitting multiple sclerosis (RRMS) is caused by episodes of acute inflammation followed by periods of partial or total recovery. On the other hand, progressive multiple sclerosis (PMS) is characterized by more pronounced neurodegeneration and continuous axonal loss, resulting in a progressive worsening of symptoms (Adibi *et al.*, 2024).

Studies indicate that consuming cocoa for four weeks can alleviate fatigue in patients with chronic fatigue syndrome (CFS) by modulating neurotransmitters. The antioxidants in cocoa, such as flavonoids, play a key role as anti-fatigue compounds. In addition, cocoa contains methylxanthines, substances that are beneficial for the vascular system and the central nervous system (Adibi *et al.*, 2024).

In the literature, numerous studies have studied the potential of phenolic compounds, especially polyphenols. Cocoa is mainly composed of two classes of polyphenols, flavan-3-ols (catechins) and procyanidins (Chen *et al.*, 2024; Galatro *et al.*, 2024; Gotti *et al.*, 2006; Hollands *et al.*, 2018; Liu *et al.*, 2024; Mao *et al.*, 2024).

Furthermore, cocoa is a fruit rich in procyanidins, theobromine, epicatechin, catechins, and caffeine (Gotti *et al.*, 2006; Hollands *et al.*, 2018; Pagliari *et al.*, 2022), compounds that are related to reducing the risk of cardiovascular diseases, hypertension, atherosclerosis, and cancer.

Studies have reported that phytochemicals present in the fruit are capable of interacting with specific molecular targets that are linked to the pathogenesis of chronic diseases in humans, such as cardiovascular diseases, cancer, obesity, diabetes, skin aging and neurodegenerative diseases (Adibi *et al.*, 2024; Hollands *et al.*, 2018).

4.2 Effects as an antidiabetic

Diabetes mellitus (DM) is a disease that presents with prolonged hyperglycemia because the hormone insulin is not synthesized in the necessary quantity by the pancreas or when the body does not use the insulin synthesized correctly. This condition, in the long term, can cause serious damage to other parts of the body, such as the nervous and cardiovascular systems. This disease is classified as chronic degenerative (Domínguez-Pérez *et al.*, 2020; Gu *et al.*, 2024; Kelly *et al.*, 2024; Tao *et al.*, 2024).

Studies suggest that bioactive compounds, such as those present in cocoa, may act to control glycemic functions. One example is the role of hydrolysate of unfermented cocoa beans obtained at pH 3.5 and 5.2, which showed greater insulin secretion. While trials with diabetic rats that received a single oral dose of hydrolysate of unfermented cocoa beans (600 mg/kg) showed a greater antihyperglycemic effect (Domínguez-Pérez *et al.*, 2020).

In the research by Smith (2013) flavanol, a bioactive component found in chocolate, was evaluated to determine its influence on patients who ingested two daily servings of 100g of flavanol-rich dark chocolate bars or 100g of flavanol-free white chocolate bars. The data indicated that the consumption of flavanol-rich dark chocolate bars for 15 days reduced systolic and diastolic blood pressure and improved insulin sensitivity.

4.3 Effects against obesity

Obesity is a disease that has grown significantly in recent decades, generally among children and adolescents, due to the high consumption of processed foods (Kim *et al.*, 2024; Stinson *et al.*, 2024). This disease is defined as the abnormal accumulation of fat in the human body (Domínguez-Pérez *et al.*, 2020).

Some drugs are available to alleviate obesity, such as Orlistat, phentermine/topiramate, lorcaserin, and bupropion/naltrexone. However, these drugs can have undesirable side effects. Because of this, there is a growing number of studies investigating the effectiveness of food-derived compounds in maintaining obesity (Domínguez-Pérez et al., 2020).

Cocoa proteins have antiobesogenic potential, as the consumption of these proteins can help reduce the onset of obesity-related inflammatory diseases (Domínguez-Pérez *et al.*, 2020). In addition to proteins, bioactive compounds such as theobromine, (+)-epicatechin, procyanidin B2, and quercetin have been reported to modulate adipogenesis by inhibiting the differentiation of white adipocytes, promoting brown adipogenesis, and enhancing lipolysis (Wang *et al.*, 2024; Zhang *et al.*, 2024).

4.4 Effects against the emergence of tumors

Cancer is defined as a set of diseases that involve the uncontrolled growth of defective cells, and can arise in any organ or tissue, in addition to having the ability to spread to other parts of the human body (Dareng *et al.*, 2024; Domínguez-Pérez *et al.*, 2020; Gehrels *et al.*, 2024; Schreurs *et al.*, 2024).

Studies suggest that the antioxidants, peptides, and proteins present in cocoa have antitumor capacity. These peptides are formed during the fermentation of cocoa beans from the albumin and vicilin present in the bean (Domínguez-Pérez *et al.*, 2020; Martín e Ramos, 2017; Martin e Ramos, 2021).

5. Future considerations and perspectives

Cocoa, like cocoa honey and chocolate, has a chemical composition rich in compounds that are beneficial to health, which is why its consumption is encouraged by doctors and nutritionists. However, most people believe that only chocolate is important to include in their diet and forget that the rest of the fruit is also rich in various antioxidants and fibers, which give this fruit numerous benefits to human health.

The exploration of the bean and the stages of chocolate production are increasingly being improved, to achieve new aromas and flavors for premium chocolates. The trend is that over the years, dark chocolate will be one of the most consumed because it has a greater amount of cocoa mass. However, this does not exclude the potential that white chocolate, milk chocolate, and cocoa honey can achieve from the market.

Disclosure statement

The authors reported no potential conflict of interest.

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