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Sensory Considerations Generated by Biochemical Changes during the Fermentation of the Cocoa Almond

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Abstract

Cocoa is a crop of great economic importance all over the world, it is from this that the main raw material for the production of chocolate and other confectionery products is obtained, as well as other by-products such as pasta, butter, cocoa powder and liquor. Fermentation is carried out during the post-harvest of cocoa, it is the most important operation in the cocoa benefit, there the sensory attributes and physicochemical and biochemical quality characteristics of the cocoa almond are defined. This work presents an analysis of the changes in the physicochemical and biochemical characteristics of the cocoa almond generated by the effect of the fermentation process that determine the components of the sui generis flavor and aroma of chocolate. For the above, a bibliographic review of publications made between 2000 and 2021 was carried out. Present in the Scopus, ScienceDirect, Springer, ResearchGate, SciELO, Dialnet and Redalyc databases. The keywords used as search criteria in English and Spanish were: cocoa, cocoa beans, cocoa bean fermentation, chemical quality of cocoa. 200 documents were collected including review articles, research articles, mainly master's and doctoral theses and technical manuals. The reviewed publications report significant information about the microorganisms involved in cocoa fermentation, effects of fermentation on the pH of the cocoa bean, the physicochemical characteristics, the content of organic acids, the content of fat, sugars and proteins of the cocoa bean; the content of polyphenols and methylxanthines and the volatile compounds of the cocoa bean. Among the main conclusions are that the pH of the grain affects the biochemical reactions that form the flavor components such as free amino acids and peptides, among others. The total fat remains stable during fermentation, the sugar content of cocoa beans is affected by the fermentation process. The amount of proteins decreases during the fermentation time for all evaluated hybrids. During fermentation, the concentration of polyphenols is reduced because they are oxidized and polymerized to insoluble tannins of high molecular weight, this is why the bitter and astringent taste is reduced. The fermentation process and the varieties influence the volatile compounds and also determine the aromatic quality of the cocoa.

Keywords: *cocoa, cocoa fermentation, cocoa bean, physicochemical characteristics, biochemical characteristics.*

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1. INTRODUCTION

Cocoa (Theobroma cacao L.) is one of the crops of high economic importance worldwide and nationally (Suárez & Aranzazu, 2010). Because it is the main raw material for the manufacture of chocolate and other confectionery products (Koné et al., 2016), as well as cocoa-derived foods, including cocoa paste, powder and liquor (Vásquez et al., 2019). The fundamental stage during the post-harvest of cocoa is fermentation, in which the precursors of chocolate are produced. During fermentation, various microbial activities take place, mainly carried out by yeasts, as well as acetobacters and lactic bacteria. Which metabolize sugars present in the pulp, generating ethanol and other metabolites such as acetic acid. Acidification together with the increase in temperature generates physicochemical and biochemical changes in cocoa almonds, which determine the final characteristics of the bean and its quality. It should be noted that the cocoa fermentation process is affected by multiple factors, namely: cocoa variety, time and method applied, region or country, among others, together with other post-harvest operations such as drying and roasting. Of these stages, fermentation is considered by some authors to be the most important and significant operation in the flavor potential of chocolate (Crafack et al., 2014; Schwan & Wheals, 2004).

The fermentation process involves complex microbial activities and biochemical changes that lead to the formation of flavor precursors, the development of color, and the reduction of bitterness and astringency of the grains (Lima et al., 2011; Ozturk & Young, 2017), which are quality parameters in chocolate making. In some countries, shortcomings in cocoa fermentation have been reported; in Brazil, beans of different hybrids are usually fermented spontaneously in the same box, which affects the quality of the chocolate (Menezes et al., 2016; Visintin et al., 2017).

Similarly, the quality of the final product in Colombia is affected by the use of almonds from different clones in fermentation. Since each clone requires specific fermentation conditions (Horta-Téllez et al., 2019). In addition to this, the low technification and the little development of the profit standards affect the quality of the cocoa bean (Contreras Pedraza, 2017).

Currently, there is an increasing demand for high-quality cocoa beans (Perez et al., 2022), in order to meet consumer demands in terms of taste and quality (Costa et al., 2015), especially for the production of chocolate with a high cocoa content and gourmet products. From the above, an analysis of the changes in the physicochemical and biochemical characteristics of the cocoa bean is presented below, effects of the fermentation process determining the sensory quality of fermented cocoa.

2. MATERIALS AND METHODS

The present review work used information published between 2000 and 2021. The search was carried out in the databases Scopus, ScienceDirect, Springer, ResearchGate, SciELO, Dialnet and Redalyc. The keywords used as search criteria in English were: cocoa, cocoa beans, cocoa bean fermentation, chemical quality of cocoa. While the Spanish words that were used as search criteria were: cocoa, cocoa beans, cocoa bean fermentation, chemical quality of the cocoa bean. As a result, 200 documents were collected; which included review articles, research papers, theses (mainly master's and doctoral) and technical manuals. Subsequently, the collected documentation was analyzed, selecting those that investigated the effect of fermentation on physicochemical and biochemical characteristics of the cocoa bean such as: pH, organic acids, fat content, sugars and proteins, volatile compounds, polyphenols and methylxanthines content..

3. RESULTS AND DISCUSSION

3.1 Economic, environmental, and social aspects of importance in cocoa fermentation

Cocoa (Theobroma cacao L.) is one of the most demanded agricultural products in the world for its economic and nutritional value (Cruz-Tirado et al., 2020). In addition, it is the basic raw material for the manufacture of chocolate, pharmaceuticals, and cosmetics (Attipoe et al., 2021). The economic and social importance of cocoa is evidenced by the existence of between 5 to 6 million cocoa farmers worldwide and about 40 to 50 million people depend on cocoa for their livelihood (WCF, 2012). In the environmental context, cocoa is part of agroforestry systems, which account for 50 to 60% of the world's cocoa crop (Jagoret et al., 2017). The agroforestry systems of cocoa have advantages compared to monocultures, because it helps the conservation of biodiversity (Armengot et al., 2016), improves soil fertility, increases carbon sequestration (Niether et al., 2020) and promotes sustainability (Djuideu et al., 2021).

In Colombia, there are about 25 thousand peasant families that are dedicated to the cultivation of cocoa, which is represented in a greater proportion (90%) by small farmers (García-Cáceres et al., 2014; Naranjo-Merino et al., 2017). In addition to this, cocoa has been used as a substitute for illicit crops, which has been promoted after the signing of the peace agreement with the FARC (Revolutionary Armed Forces of Colombia) and by the support of international entities (Hernández-Núñez et al., 2022).

3.2 Overview of cocoa and its production in the world

Between 2018 and 2019, cocoa production in the world reached approximately 4,834 million tons. Which meant an increase of 3.9% compared to the 2017/2018 season (Guirlanda et al., 2021). Of which, 85% of global production is concentrated in seven countries: Ivory Coast, Ghana, Ecuador, Cameroon, Nigeria, Indonesia and Brazil (ICCO, 2019).

In Colombia, in 2018 the production of cocoa reached 56,867 tons, the departments of Santander, Antioquia and Arauca were the ones with the largest contribution. In the case of the department of Cesar; cocoa production was 1,902 tons for 2018, which represented 3.3% of the total national production (FEDECACAO, 2021). Amount higher than the 1,734 tons reported in 2017.

Characteristics of the cultivation and varieties of cocoa

The cocoa tree (Theobroma cacao L.) belongs to the Malvaceae family, which is native to Central and South America (Vasquez et al., 2019), this being the most cultivated species of all the species of the genus Theobroma (Abu et al., 2021). Cocoa trees grow well in very humid tropical areas (Copetti et al., 2014), under temperature conditions between 20 and 30°C, with rainfall of 1500-2000 mm and 2000 hours of sunshine per year (Afoakwa, 2010).

The main genetic varieties of cocoa are: Forastero, Criollo and Trinitario; a fourth variety that grows in Ecuador is called Nacional (Castro-Alayo et al., 2019). Each cocoa variety determines the crop yield, disease resistance, composition, taste and quality of the fermented dried cocoa beans (Afoakwa et al., 2008).

The Criollo variety is cultivated in the countries of northern South America, Central America and some regions of Asia (Beg et al., 2017). The grains are white to light violet in color, due to the low anthocyanin concentration (Badrie et al., 2015). This variety is considered of high quality for its high content of cocoa butter, little astringency (Arana-Sánchez et al., 2015) and aromatic flavor (with floral, fruity, nutty, caramel and molasses notes) (Santander Muñoz et al., 2020). However, it is poorly cultivated because it is highly susceptible to diseases. Therefore, it represents between 5 and 10% of the world's cocoa production, being used for the manufacture of fine-flavored chocolate (Santander Muñoz et al., 2020; Wickramasuriya & Dunwell, 2017).

The Forastero variety accounts for about 90% of the world's cocoa production (Wahyuni et al., 2021), is cultivated in West Africa, mainly in Ivory Coast, Ghana, Nigeria and Cameroon. The grains are astringent and violet in color due to the presence of anthocyanins (Kongor et al., 2016). Unlike the Criollo variety, Forastero cocoa trees are productive and resistant to pests and diseases (Lima et al., 2011). However it has a basic and ordinary taste (Wahyuni et al., 2021). The beans are used for the production of cocoa mass, cocoa powder, cocoa butter and dark and white chocolate (Aprotosoaie et al., 2016).

The Trinitario cacao comprises the products of natural hybridization and recombination between the Criollo and Forastero varieties (Kongor et al., 2016; Lima et al., 2011). It is cultivated especially in the West Indies, South America and Central America (Aprotosoaie et al., 2016). This variety is known for its productivity, resistance to diseases and for having a basic taste of chocolate and wine notes (Saltini et al., 2013; Santander Muñoz et al., 2020).

The National cultivar grows only in Ecuador, it is considered a fine variety that produces the well-known grains Above; with distinctive notes of floral and spicy flavor (Afoakwa et al., 2008). The grains are used for the manufacture of high-quality dark chocolate (A.C. Aprotosoaie et al., 2016; Kongor et al., 2016).

3.3 Fermentation

Cocoa fermentation is a spontaneous and uncontrolled process (Magalhães da Veiga Moreira et al., 2017), where a great diversity of natural microorganisms are involved. Several authors have studied the microbial ecology of cocoa fermentation, which has allowed to establish that yeasts, lactic acid bacteria (LAC) and acetic acid bacteria (AAC) are the main groups of microorganisms that dominate fermentation (Moreira et al., 2013; Mota-Gutierrez et al., 2018; Nielsen et al., 2007; Visintin et al., 2016). Also, Bacillus species and filamentous fungi have been found at the end of the fermentation process (Ardhana and Fleet, 2003). However, the function of these microorganisms is not completely defined, it is only known that they can produce acids or bad odors, which have a negative impact on the quality of cocoa beans (Copetti et al., 2014).

Also, among the main objectives of fermentation are to facilitate the elimination and degradation of the pulp that covers the almonds; transform sugars present in the pulp to ethanol, produce acetic acid that penetrates the almond bark and generate lactic acid. These compounds together with the generated heat cause the death of the germ and therefore of the seed in order to produce the precursors of the chocolate flavor. In addition, fermentation contributes to the development of color and flavor, as well as to the reduction of bitterness and astringency of the grains. It should be noted that there are many factors that affect fermentation; therefore, in the physicochemical characteristics of cocoa beans. Some studies indicate that fermentation is influenced by the genotype (Moreira et al., 2013, 2016), preconditioning of cocoa pulp (Afoakwa et al., 2011, 2013; Nazaruddin et al., 2006), the tumbling and fermentation time (Hamdouche et al., 2019), country (Gu et al., 2013; Papalexandratou, Camu, et al., 2011), fermentation method (Guehi et al., 2010) and use of starter cultures (Lefeber et al., 2012; Sandhya et al., 2016).

3.4 The microbiology of cocoa fermentation

Cocoa fermentation consists of two phases (Figure 1), the first phase is dominated by yeasts during the first 24-48 h of the process (De Vuyst & Weckx, 2016), these microorganisms perform several functions among the most important; converting the sugars of the pulp (glucose, sucrose and fructose) into ethanol and carbon dioxide, and a large amount of secondary metabolites such as higher alcohols, organic acids, esters, aldehydes and ketones (Pereira et al., 2017). Likewise, degrading the pulp through the activity of pectinases (Díaz-Muñoz & de Vuyst, 2021), decomposing the citric acid of the pulp (Koné et al., 2016), causing an increase in pH that facilitates the growth of bacteria.

In addition, they are recognized for influencing the generation of sensory characteristics of chocolate flavor and aroma (N. N. Batista, Ramos, et al., 2016).

In the first phase there is a decrease in the yeast population and an increase in the count of lactic acid bacteria, due to environmental conditions (lower glucose concentration, lower oxygen availability, an increase in temperature and pH) that occur after 24 to 72 h of fermentation (Schwan & Wheals, 2004). The BALS perform three functions during fermentation: in the first, the sugars present in the pulp, glucose and fructose mainly, are fermented to obtain smaller amounts of ethanol, acetic acid and lactic acid mainly. The second function is the use of citric acid present in the pulp, this is used by lactic acid bacteria during the production of acetic acid, acetaldehyde, diacetyl, lactic acid, acetoin and 2,3-butanediol and the third function refers to the conversion to mannitol of the fructose present in the pulp by some species (Ho et al., 2015).

In that order, in the second phase, there is greater aeration of the mass due to the degradation of the cocoa pulp, this favors the growth of acetic acid bacteria, to then intervene in the conversion of ethanol to acetic acid through oxidation (Lagunes Gálvez et al., 2007). Ethanol and diffused acetic acid cause the death of the embryo, disintegrate cell membranes, and release endogenous enzymes to develop taste precursors such as free amino acids, peptides and reducing sugars (Crafack et al., 2013).

3.5 Effect of fermentation on the physicochemical characteristics of the cocoa bean

Several studies have described that during the fermentation process glucose, fructose, sucrose and citric acid are metabolized from the pulp of cocoa beans by yeasts and bacteria, bringing with it the formation of heat, ethanol and organic acids (mainly acetic acid and lactic acid) that diffuse into the cotyledons (Ardhana and Fleet, 2003; Camu et al., 2007; de Melo Pereira et al., 2013; Lagunes Gálvez et al., 2007; Lefeber et al., 2011; Nielsen et al., 2007; Ouattara et al., 2017; Pereira et al., 2012; Visintin et al., 2016). The effect of heat and acidification stop germination, produce changes in cell membranes and affect the pH, organic acid content, fat content, sugars, proteins, polyphenols, methylxanthines and volatile compounds of cocoa beans (Afoakwa, 2014; Afoakwa et al., 2013, 2014; Afoakwa, Quao, Budu, et al., 2011; Afoakwa, Quao, Takrama, et al., 2011; De Brito et al., 2001; Febrianto and Zhu, 2020).

Effect of fermentation on the pH of the cocoa bean

The pH of cocoa beans is a physicochemical parameter that determines the fermentative quality of the beans (Afoakwa, Quao, Budu, et al., 2011). During fermentation, the pH of the cocoa pulp increases due to the consumption of citric acid (Kouamé et al., 2015). Ardhana and Fleet (2003) reported a variation of the pulp pH from 3.7 to 3.9 and from 4.8 to 4.9 during the fermentation of Trinitarian and Forastero grains, respectively. Meanwhile, Ramos et al. (2014) found pH values between 3.27 and 3.50 at the beginning of fermentation, reaching values between 4.45 and 4.84 after 156 h of fermentation using four different cocoa hybrids (PH16, PS1030, FA13 and PS1319) in Brazil. The increase in the pH of the cocoa pulp is accompanied by a decrease in the pH of the cocoa bean, due to the diffusion of ethanol and organic acids through the cotyledon (Hernández-Hernández et al., 2016).

Recently, López Hernández et al. (2019) reported pH values between 6.22 and 6.35 in CCN51 cocoa beans in three stages of maturity at the beginning of fermentation, reaching pH values between 5.54 and 5.75 at the end of the process. It has been reported that the state of maturity of cocoa influences the pH of the bean and other physicochemical characteristics (Cubillos Bojacá et al., 2019). The pH of the grain affects the biochemical reactions that form the flavor components such as free amino acids and peptides, among others. A strong acidification of the cotyledon (pH 4.0 – 4.5) generates a non-specific proteolysis of the proteins present in the cotyledon, which causes a low flavor potential of the cocoa. In contrast, a moderate acidification of the cotyledon (pH 5.0 – 5.5) causes a specific proteolysis, which results in cocoa with a high flavor potential (Crafack et al., 2014).

3.6 Effect of fermentation on the organic acid content of the cocoa bean

During the fermentation of cocoa beans, microorganisms break down the sugars in the pulp, which results in the production of alcohols and organic acids (Kadow et al., 2015; Schwan & Wheals, 2004).Several studies have reported that the predominant organic acids in cocoa fermentation are: acetic acid, lactic acid (Camu et al., 2008; Lefeber et al., 2010; Papalexandratou, Falony, et al., 2011; Pereira et al., 2012). Also, other organic acids have been detected such as: isobutyric, isovaleric, gluconic, malic, succinic and oxalic among others (Camu et al., 2007; Hamdouche et al., 2019; Mota-Gutierrez et al., 2018). These acids diffuse into the grains, whereby a series of biochemical reactions takes place that lead to well-fermented grains (Afoakwa et al., 2013). However, highly acidic grains have fewer flavor precursors and give acidified products (Moreira et al., 2013).

Lagunes Gálvez et al. (2007) evaluated the cocoa fermentation process in the Dominican Republic where they obtained the maximum concentration of acetic acid (22.5 ± 2.1 mg/g dry matter) and lactic acid (0.70 ± 0.86 mg/g wet matter) in the pulp after 72 h and 120 h, respectively. Meanwhile, Papalexandratou, Vrancken, et al. (2011) found in the pulp acetic acid values of 12.0 ± 0.4 mg/g – 18.7 ± 0.1 mg/g between 96 h and 120 h of fermentations carried out in boxes carried out in Brazil. Anjou, A., et al. (2011) analyzed the production of metabolites during cocoa bean fermentations performed in Brazil and Ivory Coast, the results of this study showed the highest level of acetic acid (15.1 mg/g ± 0.14 mg/g) in the pulp after 126 h of fermentation in Ivory Coast; while in Brazil, the highest concentration of acetic acid (28.4 ± 0.71 mg/g) was obtained at 72 h of fermentation. From the above, the way fermentation is carried out, the site and its characteristics influence the dynamics of metabolite production that is linked to the native microbiota of each country.

3.7 Effects of fermentation on the fat, sugar and protein content of the cocoa bean

Fang et al. (2020) evaluated the chemical and flavor changes of cocoa almond during fermentation carried out in China. They found that the fat content varied between 42.90% and 54.45%. Similarly, Servent et al. (2018) evaluated the effect of natural fermentation on free and total fat content, in samples from Madagascar, Dominican Republic and Ecuador. These results showed that the total fat remains stable during fermentation, where the average fat content was 53.02 ± 0.74% and 54.43 ± 0.70% for samples from Dominican Republic, 52.26 ± 1.06% and 55.19 ± 1.86% for samples from Madagascar and 50.45 ± 0.08% and 55.16 ± 0.98% for samples from Ecuador were found for unfermented cocoa and fermented cocoa (114 h). Cocoa butter is considered the most important component from the commercial point of view, the content of which in cocoa beans depends on the growing conditions, cocoa variety and the production area (Samaniego et al., 2021; Torres-Moreno et al., 2021).

Sucrose is the predominant sugar (about 90% of the total sugars) in cocoa beans, followed by fructose and glucose which represent about 6% of the total sugars (Afoakwa, 2010). According to Febrianto et al. (2021), the sugar content of cocoa beans is affected by the fermentation process. Tupac et al. (2013) reported an increase in the content of reducing sugars during fermentation, with a change from 3.57 mg/g to 10.69 mg/g at the end of fermentation. In contrast, the amount of non-reducing sugars decreased from 30.56 mg/g to 6.11 mg/g (80% decrease) at the end of fermentation (6 days). These same authors also reported a decrease in the total sugar content, obtaining 34.13 mg/g at the beginning of the fermentation and 16.81 mg/g at the end of the fermentation. The decrease in the content of non-reducing sugars is caused by the cotyledon invertase enzyme that hydrolyses sucrose into glucose and fructose, which in turn causes the content of reducing sugars to increase (Afoakwa, Quao, Budu, et al., 2011).

Moreira et al. (2018) studied the protein content at the beginning and end of fermentation of different cocoa hybrids grown in Brazil. They found that the amount of proteins decreases during the fermentation time for all the hybrids evaluated. The protein concentration ranged from 0.58 ± 0.07 mg/mL – 0.80 ± 0.02 mg/mL at the beginning of fermentation, then decreased to reach values between 0.12 ± 0.01 mg/mL and 0.41 ± 0.08 mg/mL at the end of fermentation. The decrease in protein content is due to proteolysis, catalyzed by the enzymes aspartic endoprotease and carboxypeptidase (Gu et al., 2013); this is why oligopeptides and amino acids are obtained, which are important for the development of cocoa flavor (Romero-Cortes et al., 2013).

3.8 Effect of fermentation on the content of polyphenols and methylxanthines of the cocoa bean

Cocoa and cocoa-based products (cocoa powder, cocoa liquor and chocolate) are a rich source of polyphenols and methylxanthines, these being responsible for the bitter and astringent taste (Batista, de Andrade, et al., 2016). Previous studies have reported that these compounds exert beneficial effects on human health, due to their antioxidant, anti-inflammatory, anti-cancer, cardioprotective, neuroprotective and chemopreventive properties (Andújar et al., 2012; Aprotosoaie et al., 2016; Jean-Marie et al., 2021; Martin and Ramos, 2021). The polyphenols in cocoa beans represent about 12% to 18% of the dry weight, where proanthocyanidins constitute about 58% of the total polyphenols, followed by catechins (37%) and anthocyanins (4%) (Khan et al., 2014).

During the fermentation of cocoa beans, the concentration of polyphenols is reduced because they are oxidized and polymerized to insoluble tannins of high molecular weight, thereby the bitter and astringent taste of the beans is reduced (Kongor et al., 2016). At the same time, a brown color is produced that is characteristic of well-fermented grains. It should be noted that polyphenols are a quality parameter used to predict the flavor potential of cocoa beans and their suitability for chocolate manufacturing (Camu et al., 2008).

Carrillo et al. (2013) studied the influence of different geographical areas (Andean Region, Orinoco and Pacific) of Colombia on the total polyphenol content of cocoa beans. This study showed significant results in the content of polyphenols among the sampled producing farms, with values between 44,940 ± 1,174 and 70,090 ± 1,988 mg GAE/g. The authors found incidence of the region where cocoa is produced on this variable. Similarly, Grassia et al. (2019) found variations in the content of total phenols according to the cocoa producing country. In this study, the highest content of total phenols (19.7 mg/g) was obtained in the hybrid grains of Ghana, compared to the creole grains of Peru (11.2 mg/g) and Ecuador (15.4 mg/g). The amount of bioactive compounds in cocoa is influenced by the cocoa variety, the degree of maturity (harvest season), the geographical origin, soil conditions, climatic conditions, agronomic management and the post-harvest process (mainly fermentation and drying) (Kongor et al., 2016; Wollgast & Anklam, 2000).

Caffeine and theobromine are the main methylxanthines in cocoa, the content of which depends on the cocoa genotype. Unfermented almonds of the forastero variety from West Africa contain about 4% theobromine and 0.2% caffeine (in dry matter without fat). On the other hand, American fine grains are characterized by their high caffeine content (0.30 – 0.60%) and a theobromine content ranging from 2.8% to 3.5% (in fat-free cocoa solids) (Urbańska et al., 2019).

Aladdin et al. (2006) and Brunetto et al. (2007) found that theobromine and caffeine concentrations decrease as fermentation time increases. These authors suggest that the reduction of these compounds is caused by diffusion from the cotyledons and not by chemical degradation. Recently, Melo et al. (2021) reported a decrease in theobromine and caffeine concentrations during cocoa fermentation, where theobromine was reduced from 17.29 mg/g (unfermented beans) to 9.79 mg/g (after 144 h of fermentation); while, caffeine decreased from 15.63 mg/g to 5.88 mg/g. However, Septianti et al. (2020) reported an increase in theobromine concentration during fermentation using local clones from Indonesia, resulting in the highest level (36.37 mg/g) of theobromine at the end of fermentation (6 days).

3.9 Effect of fermentation on the volatile compounds of the cocoa bean

The sensory quality of the cocoa bean depends on the volatile compounds that are generated during fermentation, drying, roasting and conching (Crafack et al., 2014). Previously, about 600 volatile compounds that determine the aroma and taste in chocolate and cocoa products have been reported (Aprotosoaie et al., 2016; Kongor et al., 2016). Some studies have indicated that fermentation produces significant effects on the volatile compound content of cocoa, even greater than drying (Pallares-Pallares et al., 2016; Rodriguez-Campos et al., 2012).

Rodriguez-Campos in 2011 determined volatile compounds such as alcohols, carboxylic acids, ketones, aldehydes, pyrazines, and esters during the fermentation and drying of Forastero variety cocoa beans. They identified thirty-nine volatile compounds during the cocoa fermentation and drying process. During the fermentation they identified six alcohols, eight acids, seven esters, four aldehydes and ketones. The most predominant volatile compounds in the fermentation by chemical group and their odor ratio were: 1,3-butanediol, acetic acid (astringent and vinegar), ethyl acetate (pineapple) and acetoin (butter). In the drying, six alcohols, six acids, six esters, five aldehydes, ketones and pyrazines were identified; where the main volatile compounds by chemical group correspond to those identified in the fermentation. However, on drying there was a decrease in acetoin, ethyl acetate; coupled with an increase of 1,3-Butanediol and acetic acid (Rodriguez-Campos et al., 2011).

Utrilla-Vázquez et al. (2020) studied the volatile compounds involved during the fermentation and drying of five varieties of cocoa beans Regalo de Dios, Carmelo, Lagarto, Rojo Samuel and Rainbows from the Mayan lands in Chiapas, Mexico. The results of the study indicated that aldehydes were the chemical group with the largest peak area (70-90%) at the end of fermentation (144 h) for all varieties. It has been reported that a high concentration of aldehydes is favorable for cocoa quality (Menezes et al., 2016). In fermented dried almonds, acids and alcohols presented the largest peak areas (50-85%) in the five varieties. The authors of this study highlighted that the fermentation process influences the volatile compounds, as well as the characteristics of the five varieties and also determine the aromatic quality of cocoa.

4. CONCLUSION

The Fermentation is a critical biochemical process for the transformation of cocoa almonds to chocolate, since at this stage physicochemical and biochemical changes occur; which lead to the formation of the brown color, development of flavor precursors (free amino acids, reducing sugars and peptides) and decrease of the astringency and bitter taste of the cocoa bean. During the cocoa fermentation process it is necessary to control variables such as: the variety, the time and method of fermentation; as well as the specific conditions of each country, regions and sub-regions related mainly to the climate or microclimates and the native microbiota of each locality. When comparing these factors on the physicochemical and biochemical characteristics of the cocoa almond, differences were found in the values before and after fermentation, even in the same country or locality. The above implies a high heterogeneity in the final quality and sensory attributes of fermented cocoa almonds, which is favored by microbial diversity and the low control of the microbiota responsible for developing the fermentation. Therefore, it is expected that in the coming years there will be more research aimed at determining the behavior of yeasts and bacteria that will allow obtaining better physical and sensory characteristics from fermentation as a biochemical process in favor of the quality of the cocoa almond; either through the use of starter cultures or other techniques, so that cocoa beans with homogeneous and reproducible characteristics can be obtained.

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