Quality attributes of chocolate: a review

Zeenatu Suglo Adams
Vincent Abe–Inge
Jacob K. Agbenorhevi

MedCrave

Quality attributes of chocolate: a review

Author Details

Zeenatu Suglo Adams,[1,2] Vincent Abe–Inge,[2] Jacob K. Agbenorhevi[2*]

[1]Department of Food Science and Technology, Ho Technical University, Ghana

[2]Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, Ghana

*Corresponding Author:

Jacob K. Agbenorhevi, Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana,

Email: jkagbenorhevi@yahoo.com

Published By:

MedCrave Group LLC

February 02, 2023

Contents

Abstract

Cocoa and chocolate products are widely recognized around the world as things that are linked to emotional eating and offer instant gratification. Consumers' choice of chocolate is impacted by the presenting health attributes of the chocolates. In the market, certain chocolate products are increasingly labeled with the percent cocoa content. Depending on the labeling on the cocoa or chocolate product, the percent cocoa may refer to either the total cocoa solids or the nonfat cocoa solids. It has been shown that taste has been a major factor consumer depends on in choosing their chocolate products. The quality of chocolates is influenced by the ingredient composition, processing and storage conditions. Composition variations, chocolate surface roughness, and processing parameters all affect color parameters during chocolate production. The industry is concerned with fat bloom which degrades both visual and textural quality. Sugar bloom may also occour on top of the chocolate as a rough and uneven layer. Increase or decrease values of free fatty acid (FFA) are crucial in influencing chocolate quality. Furthermore, the quality attributes give information to the food product development team while making product formulation decisions. Associations/Organisations such as International Office of Cocoa and Chocolate/International Sugar Confectionery Manufacturers Association, Codex CAOBISCO/ECA/FCC and FDA also have standards for proximate values, additive composition, chocolate composition, chemical properties and microbial levels of chocolates products. In the studies reviewed, it has been shown that quality attributes influence consumers purchasing behaviour and aesthetic features of the chocolate.

Keywords: cocoa, ingredients, processing stages, fat bloom, sugar bloom, free fatty acid, chocloate, sensory attributes

Introduction

Consumers' demand and preference for distinctive or "specialty" cocoa and chocolate products with distinct features such as flavor, sugar content, and purported health advantages has increased over time. A consumer's purchasing decision is influenced by the color of chocolate. The presented health characteristics of chocolate influence consumers' choice of chocolate.[1] Cocoa is the primary component of chocolate. Forastero, Criollo, Trinitario, and Nacional cocoa beans are the four principal varieties used in chocolate manufacture. Each kind grows in a different tropical location and yields cocoa beans with distinct flavor profiles.[2,3] Fine cocoas are distinguished by their desired flavor and color and are commonly utilized in the production of specialty dark chocolates.[3] There are several product standards for cocoa powder and chocolate products, with the percentage cocoa solids concentration in commercially available cocoa powder and chocolate products varied significantly.

Chocolates are associated with emotional eating and provide instant pleasure and fulfillmen.[4] Lecithin is an important component of chocolate's overall quality, although codex specifies limit levels for the addition of emulsifiers, flavorings, pollutants, chocolate flavors, and other components. Futher more high or low values of free fatty Acid (FFA) are important in determining the quality of chocolate. Certain chocolate products are increasingly branded with the percentage cocoa content on the market. Flavor is considered the most important aspect people consider when selecting chocolate goods.[5] For example, U.S. Food and Drug Administration (FDA)[6] standards of identity specify that cocoa contain between 10%-22% cacao fat content, sweet chocolate contain not less than 15% by weight of chocolate liquor, and milk chocolate contain not less than 10% by weight of chocolate liquor.

The International Office of Cocoa and Chocolate/International Sugar Confectionery Manufacturers Association's (IOCC/ISCMA)[7] standards for sugar, fat, ash, and moisture must be followed by the manufacturer while producing chocolate products. The appeal of cocoa goods is mostly due to its sensory features, such as taste and flavor, and, like the wine and coffee sectors, chocolate demand has gotten increasingly sophisticated over the past decade. Premium chocolates with unusual ingredients, chocolates manufactured from single-origin cocoa beans, such as those produced in Ghana, Ecuador, or Venezuela, and organic and fair-trade chocolates have all gained popularity.[8,9] Several authors have investigated modifications in physical and chemical properties during chocolate production Afoakwa[10] and a large number of research have focused on the influence of process conditions and cocoa origin on volatile chemicals and chocolate flavor.[11,12] The majority of the alterations are caused by variations in roasting time, temperature, and bean makeup.[13,14] Conching temperature and size of the final particles has a significant impact on the rheological and sensory qualities. Conching is frequently performed by mixing chocolate at elevated heat (>40°C) and is considered a required step for obtaining an appropriate consistency of chocolate mass. Chocolate's viscosity, final texture, and flavor can be influenced by variations in conching temperature and time.[15,16] Changes in free fatty acid (FFA) levels, sugar bloom and fat bloom are significant in assessing chocolate quality.[17,18] Finally, tempering is necessary to get the proper amount and type of cocoa butter crystals, which impact final quality characteristics including such color, firmness, handling, finish, and shelf life.[19] The microbial levels of chocolates are also important in determining the overall wholesomeness of chocolates (Table 1). Cardiovascular health is one of the health advantages of chocolate eating. Dark chocolate has acquired considerable importance among various forms of chocolate due to its health advantages. This article aims to highlight some key aspects of how cocoa bean handling and chocolate processing effects of the quality of chocolate as well as some of the attributes that make chocolate high-quality.

Table 1 Microbiological quality of cocoa and chocolate products

Products name	Microbial test	n	c	m	M
Chocolates products	Molds (CFU/g)	5	2	10^2	10^4
	Coliforms (MPN/g)	5	2	1.8	10^2
	Salmonella/25g	5	0	0	-
	SPC/APC (CFU/g)	5	2	10^4	10^6
Chocolate confectionaries (chocolate bars, blocks, bonbons)	Molds (CFU/g)	5	2	10^2	10^3
	Coliforms (MPN/g)	5	2	1.8	10^2
	Salmonella/25g	5	0	0	-
	SPC/APC (CFU/g)	5	2	10^3	10^6
Cocoa Powder	Molds (CFU/g)	5	2	10^2	10^4
	Coliforms (MPN/g)	5	2	1.8	10
	Salmonella/25g	5	0	0	-
	SPC/APC (CFU/g)	5	2	10^4	10^6

n, number of sample units selected from a lot of food to be examined; c, Maximum allowable number of defective or marginally acceptable sample; m, Specified procedure for determining the acceptable level of microorganisms; values are often based on levels that are achievable under GMP; M, a threshold that, if exceeded in one or more tests, would lead a lot to be rejected because it would signal impending health risks or spoiled food

Quality attributes of chocolate

Chocolate consumption and purchasing behavior

Chocolate is one commodity that is enjoyed all around the globe.[20–26] It has evolved significantly since its inception, from a simple drink enjoyed by traditional inhabitants to a specialized commodity Cocoa is the primary component of chocolate. Cocoa production has increased in a sporadic but consistent manner during the previous 40 years. Cote d'Ivoire together with the production of Ghana fulfills about sixty percent (60 %) of the global cocoa production needed in the global chocolate industry.[27] Several factors influence consumption and shopping patterns for chocolate. According to a related study, some of these include taste, health reasons, brands, packaging.[28] One major factor which influences chocolate consumption and purchasing behaviour of consumers is taste. In as much taste is relative, it has a significant effect on the purchasing behaviour and consumption of consumers.[29,30] It is asserted in previous studies that, the taste of handmade chocolate is preferred to commercially produced chocolate by consumers.[31] Cadbury Dairy Milk, one of the popular brands revealed that taste has been the major factor consumers depend on in choosing their chocolate products.[5]

Other studies showed two concepts in which one school of thought argued that the perception of the taste of chocolate is influenced by Fair trade labelling.[32,33] The authors further asserts that if the taste is good, the perception of Fair-trade labelling sees a surge and agreed that the willingness for purchasing of organic or Fair-trade products is positively affected predominantly by taste. Contemporary researches have investigated the relationship between health and taste. Mostly, it has been argued that healthy products are not very much tasty. A related study agreed to this perception of consumers.[34] However, in another related study, it has been shown that despite consumers being knowledgeable about health consequences still choose chocolate based on good taste and not mainly the health benefits.[35] Hence, most consumers prefer chocolate sweetened with sugar to chocolate sweetened with only sweeteners and less sweet chocolates as confirmed in the studies where consumers preferred milk chocolate the most. Furthermore, in order to verify the benefit of any brand of chocolate to human health and the environment at large, consumers tend to fetch that information from organic labeling.[36] One literature revealed that consumers' choice of chocolate is impacted by the presenting health attributes of the same.[1] The authors of the same study revealed that advertisement only plays a role if it is focused on the protection of the health of consumers. Another set of researchers suggested in 2017 that the health benefits of chocolate were overemphasized in comparison to the perceived high value and low cost of green benefits.[37] Interestingly, Didier and Lucie revealed that organic labelling is beneficial in affecting the decision of consumers for better quality chocolate. This suggests that qualitative evaluation of consumers is highly impacted by their knowledge on the importance of approved sustainable merchandises.

As has been revealed, consumers usually have challenges in appreciating labels on products. The terms "organic" and "fair trade" are frequently used interchangeably by consumers.[1] That is, a number of these customers mistakenly assume that organic chocolate contains cocoa from Fair Trade, which is false. In addition, a bigger percentage of customers have misunderstandings regarding the information on labels.[22] Moreover, it has been indicated that the purchasing approach of consumers for organic goods or sustainable goods is related in satisfying a sense of responsibility. Organic consumers are likewise concerned that the product is not genetically engineered.

Benefits of chocolate consumption

Despite the harmful effects high consumption of chocolate causes, moderate consumption of the same has proven to provide health benefits.[38] Debatably, countries with high consumption of chocolate over the years have Nobel prize winners emerging from same countries as stated by an ecological article.[39] Many researches ranging from studies of humans and laboratory experiments on health benefits of consumption of chocolate are on the rise. One of the health benefits of consumption of chocolate focused on is cardiovascular health.[40] Chocolate products have several components. However, flavonoid is given much importance.[41] Through several pathways, consumers of chocolate may be protected from cardiovascular diseases because of the flavonoids component. Flavonoids may also have other influences by acting as as antioxidant, antiplatelet, and anti-inflammatory agent.[41] Other latent risk factors of cardiovascular diseases such as hypercholesterolemia, hypertension may be improved by flavonoids as wells as improvement on endothelial functions.[42] Apart from the cardiovascular health benefits consumption of chocolate may have, it also may have neurological health benefits and benefits on other ailments.[41] Owing to this, it has shown to have benefits by acting as anti-depressant. This health property may also be due to the fact that it encourages the formation of neurotransmitters, such as serotonin.[43,44] In the etiology of atherosclerosis, oxidative stress and decreased antioxidant defenses play a key role. For Americans, chocolate is the third most important source of antioxidants on a daily basis.[45] Chocolate's antioxidants have been shown to prevent plasma lipid oxidation.[46] Nevertheless, a counter research refutes chocolate's direct antioxidant potential, claiming that the significant increase in plasma total antioxidative capacity observed after eating flavonol-rich foods would be most likely due to increased uric acid levels arising from fructose metabolism, rather than flavonols.[38]

Raw materials of chocolate

Sales of chocolate over the years have shown that it is one of the commercial food products gaining prominence. There are a lot of components or raw materials used in the production of chocolate. One of the main raw materials as widely known is the cocoa bean. Other ingredients in the chocolate include sugar, cocoa butter, emulsifiers, fragrance, and milk components if needed. The International Office of Cocoa and Chocolate/ International Sugar Confectionery Manufacturers Association's (IOCC/ISCMA) standards for sugar, fat, ash, and moisture must be followed by the manufacturer while creating chocolate products (Table 2).

Table 2 IOCC/ISCMA proximate for chocolate

IOCC/ISCMA standards	
Ash	2.0- 3.0
Moisture	2.5 max
Sugar(briks)	55.0 max
Fat	30.0 -35.0

Source: IOCC/ISCMA = International Office of Cocoa and Chocolate/ International Sugar Confectionery Manufacturers Association

During processing, other components such as methylxanthines, aldehydes, esters, ketones, pyrazines, acids and alcohols may be added indirectly and inadvertently[47] with the rise in trepidations of health, consumption of too much fat has been of a major concern to many. Hence, in the production of chocolate, many chocolate producing companies have put measures in place to reduce the content of fat during chocolate production. One of these measures is the introduction of emulsifiers.[48] An example of emulsifier commonly used is the polyglycerol polyricinoleate (PGPR). The most popular emulsifier used in the manufacturing of chocolate is the soy lecithin. Currently, okra pectin has been shown as potential emulsifier or lecithin substitute in milk chocolate production.[24,25]

Chocolate processing

Due to the numerous trade of the colonies of America in Spanish countries, chocolate was introduced and popularize in the old continent as a beverage. Initially, the recipe of the Aztecs was followed until further improvement of taste and texture were considered which brought in the addition of sweeteners such as vanilla, cinnamon, sugar making the chocolate tastier and softer.[49] Major manufacturing companies of chocolate share common stages in chocolate processing. These processes include; (i) mixing, (ii) refining (iii) conching of chocolate paste, (iv) tempering and depositing and (v) moulding and demoulding. All of these in the various stages of chocolate processing have some massive effects on the changes of quality of the end product.[50]

It must be noted that mixing forms the basic stage of chocolate processing which involves mixing of vital ingredients. The operation of mixing usually utilizes time-temperature combination in two different aspects including mixing in continuity or in batches.[51] These are done in order to have fixed formulation consistency in the end product. Unlike batch mixing, continuous mixing is common practice used by big chocolate manufacturing companies like Cadbury and Nestle who make use of automatic kneaders resulting in chocolate with tough texture and plastic consistency.[52] Batch mixing involves mixing of ingredients of cocoa at 40°C and 50°C and thoroughly mixed for 12-15 minutes depending on the categorization of the product. Other authors reveal that the process of conching involves mixing, shearing and aeration at a temperature greater than 40°C. It is known that conching is very important to determine the quality of the chocolate including mainly its texture, color and flavor. The variation in conching time, temperature, type of equipment inarguably affects the aroma, viscosity and texture of end product.[53] Systems of conche have two main classifications which include universal and compact systems as refiner-conche or premix-refiner-conche systems and conventional systems with various designs. Universal systems are preferred to conventional systems in inexpensive production of compound chocolate. Unlike the former, the conventional system is preferred for high cost mass production of chocolate. Conventional system is more advantageous than universal system in flavour development.[54–56] Furthermore, conching is seen by some researchers as two phase process. There is a reduction of moisture content at the first stage and because of the fermentation of the cocoa, certain volatile acids such as acetic acid are removed.[57–59] Additionally, the solid surface is coated with fats. Butter and emulsifiers are added in the second stage to obtain homogenous and paste-like fluid mass. Hence, these stages are referred to as dry and wet phase respectively.

Industrial processing of cocoa beans yields a liquid called cocoa, which is then further processed to get solid cocoa and butter.[60] The manufacturing of cocoa powder and chocolate products uses these fresh ingredients.[61] Industry practices include mixing different sources and amounts of cocoa liquor, cocoa solids, and cocoa butter, depending on the kind of completed cocoa powder or chocolate products and their ultimate use.[61] Arguably, other researchers reveal three stages of conching which includes dry, paste and fluid phases.[52] In the first stage of drying, after the mass is transferred from the refiner, it is taken through the process of mixing, heating and aerating. The purpose of this stage is to cause a reduction of some volatile acids and further reduction in water content.[52] Volatile acid such as acetic acid becomes constant as a result of lack of water acting as vapour carrier. In the last stages, other additions of cocoa butter, polyglycerol polyricinoleate and lecithin are made. These additions increase the flowability.[62] Proper care and timings of lecithin addition must be taken into much consideration because addition of lecithin in the first stage of conching may lead to absorption by cocoa particles. Depending on time and the level of temperature, the performance of lecithin can be reduced.[63] Unlike the stage lecithin is added, the dry phase is important in removing moisture content and improving flow behaviours and flavour.[64] Under ideal conditions of temperature, the moisture content required to be depleted from milk chocolate is 0.1-0.5 g/100 g.[19] Conching temperature and speed of mixing affects conching time which affects efficiency of production.[65] Heat and aeration consequence on the mass of chocolate in the processing affects the desired flow behaviour and sensory features.

High temperature has demonstrated to be useful in mixing/conching stage making coating particles more fitting and cocoa butter more fluid.[66] Due to an increase in brown pigment synthesis via Maillard processes, heat oxidation and polymerization of polyphenols to create tannins[67] and Strecker degradation reactions[68] the browning index of cocoa beans rises with roasting duration. These modifications result in the creation of enticing chocolate flavors and colors. These criteria, however, should change depending on the product type and composition. Conching temperatures below 50°C, for example, may be recommended in milk chocolates to avoid Maillard reactions.[69] Optimized conching conditions are also essential when using sugar replacements such as sugar alcohols to avoid melting and particle aggregation. Sorbitol and maltitol, for example, are relatively hygroscopic sugar substitutes. Isomalt also produces agglomerates with a lot of moisture in them.[70] The mechanical effect that occurs during conching causes a decrease in particle radius, resulting in a rise in particle number. In this case, the number of particle contact sites as well as the kinds and magnitudes of chemical and mechanical interactions among them rise.[71] Aggregates undergo rheological changes as a result of conching, including a drop in plastic viscosity and an increase in pseudoplastic behavior.[65] In the molecular structure produced by conching, a lipid layer of approximately 34 nm can be applied to the surface of sucrose crystals.[72]

At the end of the conching process, triglycerides, glycolipids, and other small components are added to the chocolate mass.[72] The sugar crystals are covered with lecithin as it travels to the sugar-fat interface. As a result of deagglomeration, temperature values drop, indicating melting action.[73] Furthermore, the

structure's gaps widen, and these gaps are filled with cocoa butter. The variance in lubrication caused by flow characteristics is also attributable to structural differentiation. Using atomic force microscopy, some researchers investigated the mechanism of polyglycerol polyricinoleate emulsifier function as well as the impacts of various vegetable lecithin on cocoa butter-based suspensions.[74–76] They found that although cocoa butter had been immobilized on the sugar granules' surface, the coating was not homogeneous. On the other hand, when used to make chocolate, natural lecithin may have varied molecular structures, which can have a variety of consequences.[72] Furthermore, adding lecithin as early as possible in the wet-phase of the conching process can help achieve low viscosity values. Lecithin is an important component of chocolate's overall quality, although codex specifies limit levels for the addition of emulsifiers, flavorings, pollutants, chocolate flavors, and other components (Table 3)

Table 3 Codex standards for chocolates

Emulsifiers	
Component	**Maximum level**
Mono- and di-glycerides	15 g/kg
Lecithin	5-10 g/kg of the insoluble component of acetone
Ammonium salts of phosphatidic acids	7 g/kg
Polyglycerol polyricinoleate	5 g/kg
Sorbitan monostearate	10 g/kg
Sorbitan tristearate	10 g/kg
Polyoxyethylene (20) sorbitan monostearate	10 g/kg
Total emulsifiers	15 g/kg singly or in combination
Flavouring agents	
Natural flavours	in little doses to balance the flavor
Vanillin	in little doses to balance the flavor
Ethyl Vanillin	in little doses to balance the flavor
Contaminants	
Arsenic (As)	0.5-1 mg/kg
Copper (Cu)	15-30 mg/kg
Lead (Pb)	1-2 mg/kg
Chocolate flavour	
Coffee-chocolate	1.5% m/m or more of soluble coffee or the equivalent quantity ground coffee that has been roasted
Other flavoured chocolate types	A sufficient number of flavoring agents to convey the organoleptic features described in the food's label to the finished product.
Other ingredients	
Spices	very little quantities in order to balance the flavor
Salt (sodium chloride)	very little quantities in order to balance the flavor
Milk solids	5% m/m or less based on the dry matter

Source: Codex Alimentarious Commission, Codex standard for chocolate. Codex stan 87–1981.

Standards for chocolate and chocolate products

In the market, certain chocolate products are increasingly labeled with the percent cocoa content. The percent cocoa may refer to either nonfat cocoa solids or total cocoa solids, depending on the cocoa or chocolate product labeling. Various product standards apply to cocoa powder and chocolate products, with the percent of cocoa solids concentration in commercially available cocoa powder and chocolate products varied significantly. For example, the United States Food and Drug Administration (FDA) defines cocoa as having between 10% and 22% fat content, sweet chocolate as having not less than 15% by weight of chocolate liquor, and milk chocolate as having not less than 10% by weight of chocolate liquor. Cocoa powder and chocolate products have composition criteria set by the Codex Alimentarius (Table 4). Chocolate powder, for example, has at least 32 percent mass per mass (m/m) cocoa powder (29 percent m/m on a dry matter basis) and is made up of cocoa powder, sugars, and/or sweeteners.[77] According to the Codex (Table 4), chocolate should have at least 35 % total cocoa solids, while milk chocolate should contain at least 25 % total cocoa solids (CAD, 2003).

Table 4 Codex standard requirement for chocolate in percentage

	Standard requirement for chocolate in percentage (%)							
Chocolate products	**Total cocoa solid**	**Cocoa butter**	**Fat-free cocoa solid**	**Flour or starch (wheat, maize, rice**	**Milk solids**	**Milk fat**	**Total fat**	**Hazelnuts**
Standard chocolate	≥35	≥ 18	≥14					
Chocolate a la taza	≥35	≥18	≥14	<8 m/m				
Sweet chocolate	≥30	≥18	≥12					
Chocolate familiar a la taza	≥30	≥18	≥12	<18m/m				
Couverture chocolate	≥35	≥31	≥2.5					
Milk chocolate	≥25		≥2.5		≥12-14	≥2.5-3.5		
Family milk chocolate	≥20		≥2.5		≥20	≥5		
Milk chocolate couverture	≥25		≥2.5		≥14	≥3.5	≥31	
White cholate		≥20			≥14	≥2.5-3.5		
Gianduja chocolate	≥32		≥8		≤5			≥20 and ≤40
Gianduja milk chocolate					≥10			≥15 and ≤40
Chocolate para mesa	≥20	≥11	≥9					
Semi bitter Chocolate para mesa	≥30	≥15	≥14					
Bitter Chocolate para mesa	≥40	≥22	18					
Chocolate Vermicelli / Chocolate Flakes	≥32	≥12	≥14					
Milk Chocolate Vermicelli / Milk Chocolate Flakes	≥20		≥2.5		≥12	≥3		

Source: Codex Alimentarius (2016)

Types of chocolate

Right from the harvesting of cocoa beans to the processing into chocolate and other products, chocolate producing industries tend to produce different kinds and flavours of chocolate. These varieties of chocolate depend on the type of ingredient used and its features.[78,79] There are several types of chocolate with types including dark chocolate, white chocolate and milk chocolate. Among these types of chocolate, dark chocolate has gained some form of prominence because of its health benefits. Dark chocolate became part of the delicacies of the South Americans about 3000 years ago as history will have it and it was later shipped to Europe by Christopher Columbus.[80] In the sixteenth and seventeenth centuries, the medicinal properties of cocoa were announced leading to the preparation of a more bitter taste of the cocoa beverage.[81,82] These preparations were mostly carried out in pharmacies. Apparently, this led to the introduction of dark chocolate.[83] Irrespective of the several researches conducted in the past about the health benefits of dark chocolate, they seem not to meet modern scientific researches and therefore prove to be inconclusive. Despite this assertion, modern research which follows stricter standards have given basis to the medicinal health benefit of dark chocolate. Although many authors have asserted that consumption of dark chocolate is beneficial to those living with cardiovascular diseases, many others have questioned it excessive consumption by those living with same condition.[84]

Cocoa powder which is mostly referred to as cocoa solid is dark in nature. The dark colour of cocoa solid is what confers the colour to dark chocolate. As mentioned earlier, in contemporary times, there has been the production of three types of chocolate which includes dark chocolate, white chocolate and milk chocolate. The composition of white and milk chocolate includes cocoa butter, milk, and sugar with no cocoa solids and high-fat milk with additions of sugar and low amounts of cocoa bean solids (<10% of total weight) respectively (Corti et al., 2010). Notably, the Westerner views dark chocolate as one with a higher content of cocoa and vice versa for milk chocolate also referred to as sweet chocolate.[85] Although all these types of chocolate are consumed, it has been reported that white and milk chocolate do not have any considerable medicinal benefit unlike dark chocolate which has been reported to have substantial medicinal benefits.[63] There are mostly 300 detectable chemical compounds in cocoa beans.[86] In the processing of cocoa beans for the making of dark chocolate, many other substances also appear in it during fermentation and roasting.[87,88] Apart from these identifiable compounds, authors argue that there may be other unidentifiable compounds attributing to the medicinal benefit consumption of dark chocolate affords the consumer.[89] Dark chocolate unlike the other types of chocolate; white chocolate and milk chocolate, has proven to be healthy. Despite these claims, it is imperative to know that most of the chocolate types on the market are full of high fat, simple sugars and calories.[40] These types of chocolate include white and milk chocolate. High consumption of these kinds of chocolate may lead to type 2 diabetes, weight gain and even cardiovascular diseases.[90]

Sensory quality attributes

In recent decades, food sensory research has embraced the assessment of emotions connected with eating.[4] Emotions have a strong influence on decision-making, and real sensations of happiness, sadness and rage shape our food choices. Data on product acceptability, according to some experts, does not provide a complete picture of actual product acceptance.[91] A product's emotional quality is frequently a hidden feature that can be exploited as additional information on approval or as a commercial benefit to impact consumer choices. Emotional measurements, according to research, provide extra information to explain overall approval.[91] Furthermore, rather than utilizing solely liking scores, multiple research have shown that emotional profiles may be utilized to distinguish between different products.[92] According to King and Meiselman[4] an emotion is "a quick, powerful feeling that is often centered on a referent." Along with functional and abstract notions, emotion is one of the conceptual categories connected with eating.[93] Furthermore, good and negative emotions have an impact on food consumption.[94] For example, one study discovered that good emotions were reported to cause food intake more regularly than negative feelings in everyday life.[94] Furthermore, according to recent studies, customers' predicted emotions will influence their behavior when consuming filled chocolates.

A practical strategy for innovation in consumer research and sensory science was created in awareness of the importance of understanding consumer emotions related to food goods. The EsSense Profile® is one of the most modern techniques.[4] This method was created to measure emotions related with foods and, more broadly, in the context of product creation. Cocoa and chocolate products are widely recognized around the world as products that provide immediate pleasure and satisfaction and are affiliated with emotional eating.[95] Furthermore, chocolate can provide you more energy, less fatigue, an enhanced mood, and the joy that comes with sensory pleasure. Chocolate's hedonic appeal is based on sight, color, texture, and taste, as well as memories of past chocolate experiences, according to research. Chocolate, on the other hand, attracts people for a variety of reasons.[96] It is widely claimed, for example, that it relieves stress, anxiety, and depression. Overall, it can be claimed that it has a positive effect on mood.[95] Chocolate quality is influenced by structure, processing conditions, and raw material quality as these factors influence not only the physical qualities but also the sensory quality of chocolate.[97] Most essential amongst these sensory quality attributes are flavour, texture and appearance.

Flavour

Flavour which is the most essential factor in determining chocolate acceptability and preference. Furthermore, flavour is one of the quality attributes which increases chocolate consumption rates all over the globe. Chocolate flavour is the result of several processing operations, most importantly fermentation, drying, roasting of the cocoa bean processing stage and conching of the chocolate making process.[98] The most important and critical among these processes in the inception of chocolate flavour is the fermentation stage.[99] As explained by Ziegleder[98] more than six hundred chemical compounds have been showed to play a major role in the development of cocoa flavour and subsequently in chocolate. These compounds significantly increase during fermentation stage and stabilized during the roasting stage of the beans.[100] Raw material quality such ripening quality and variety of cocoa contribute to flavour of cocoa and chocolate. Amongst the several types of cocoa, fine-flavour cocoa according to chocolatiers is highly appreciated for its special quality attributes especially flavour. It has prominent flavour attributes hence is the best choice for chocolate production and consumer choice. About 95% of this kind of cocoa is produced in Columbia as reported by the International Cocoa Organization (ICO).[100]

Texture

Generally, the texture of a food product constitutes sub-parameters such as hardness, spreadability, gumminess, springiness, elasticity, crunchiness, crispiness, chewiness, cohesiveness and adhesion. Although all these attributes are interrelated the sub-textural attributes of essence in quality characteristics is hardness for chocolate bars and spreadability and adhesion for chocolate spread. Surface smoothness is yet another textural attribute essential in evaluating the textural quality of chocolate. As stated by Barisic et al.[101] good quality chocolate is smooth and soft. Chocolate texture, specifically hardness, is a measure of the melting rate of chocolate in the mouth during consumption.[102] The texture of chocolate depends on its composition and types as well as nature of component ingredients. Specifically, the particle size distribution, mean particle size and specific surface area of cocoa and other ingredients influence both spreadability and hardness of chocolate. The suitable particle size for chocolate ranges from 17μm - 30 μm according to Afoakwa et al.[15] Hence desirable textural properties of chocolate is achievable by satisfying this particle size range during the refining stage of the chocolate making process.

Appearance

Appearance includes all visual phenomena namely color, glossiness, shape, surface roughness, haze and shinniness. The appearance of chocolate includes mainly glossiness and is directly related to surface smoothness, composition, morphology and finishing as revealed by Briones et al.[103] Glossiness is an optical phenomenon based on a combination of both optical and physical characteristics. Spectacular reflection is mainly responsible for glossiness Schomaker et al.[104] in products including chocolate bars. Surface roughness of chocolate molds, temperature of chocolate molds, quality of mold core and demolding are factors that influence chocolate. In addition to these factors is the tempering process of chocolate manufacture. Tempering in chocolate making is required for the formation of stable fat crystals (form V fat crystals or β2 fat polymorphs). Stable fat crystals or polymorphs are required for chocolate to possess desired quality attributes such as a glossy appearance, good snap, melting rate and stability against fat bloom. Poorly tempered chocolate is susceptible to fat bloom[105] which causes chocolate to lose its glossiness, texture and snap. In measuring the appearance (glossiness) of chocolate, the glossmeter is used for instrumental analysis.[103,104] Whereas human panelists are used for sensory-based analysis.[106]

Physicochemical attributes of chocolate

The technique employed in chocolate processing, distributed particle size and composition of the ingredients or the recipe can have a tremendous effect on characteristics such as the sensory perception, physical properties and the rheological behavior of

the chocolate. Bloom refers to the gray cast, streaks, or spots that appear on chocolates. There are two types of bloom: sugar and fat bloom.

Fat bloom

The chocolate industry is concerned with fat bloom since this degrades both visual and textural quality.[107] Fat bloom appears as a white film on the surface and an overall dampening of the distinctive gloss. Fat bloom can occur as a result of a variety of factors including tempering, cooling rate after tempering and exposure of well-tempered chocolate to elevated temperatures. Because stable V crystals are absent, poorly tempered chocolate is susceptible to fat bloom. After the tempering process, rapid reduction of temperature leads to fat blooming which results from the formation of unstable polymorphs. Fat bloom occurs when storage temperatures are excessively high or oscillate between hot and cold, causing the cocoa butter to melt and recrystallize. [108] High or fluctuating temperatures cause the conversion of cocoa butter from stable βV forms to unstable βVI[109] which easily migrate to the surface and recrystallize leading to bloom formation. Because exotic fats typically contain less solid fat than cocoa butter, they may interfere with the development of a constant V shape after heating and may speed up the blooming phase during storage.

One research claims that the liquid triacylglycerol (TAG) phase is essential for bloom formation because of its relative importance and quantitative temperature change.[110] A fat bloom can occur when fat migrates to the TAG phase's liquid surface and recrystallizes there. The two fundamental ideas of bloom growth during storage are phase separation and polymorphic modification.[111] The segregation of high- and low-melting TAG groups in cocoa butter, with the high-melting TAG group producing bloom, is referred to as phase separation. It was discovered that under metastable conditions, high-melting fractions of cocoa butter can detach from the matrix.[112] This concept was used to describe why the composition and melting characteristics of chocolate and fat bloom are dissimilar. Further, it was argued that pseudometastable regions only appear when chocolate is cold too quickly. The phase separation theory was reintroduced by Schlichter-Aronhime and Garti, who claimed that the βVI form of cocoa butter is not a true polymorphic form, but rather a separation of the solid crystal into two different phases. As the density of the crystal lattice rises, the restricted assimilation of liquid TAG groups causes separation. As a result, phase separation occurs when a lower melting point form is converted to a higher melting point form.[113] According to the polymorphic transition theory, fat bloom develops as cocoa butter crystals change from an unsteady to a more stable polymorphic form. The six polymorphic forms were described using X-ray diffraction spectroscopy by Wille and Lutton. Every time they noticed bloom, they consistently discovered the VI form, which led them to believe that the conversion of cocoa butter from the V to the VI form caused fat bloom.[114] Well-tempered chocolate changes from V to VI while being stored. Temperature changes and elevations during storage speed up transformation. It was shown that keeping well-tempered chocolate at 5°C effectively stopped the transition from V to VI and the production of blooms discovered that bloom wasn't always present when well-tempered chocolate went from state βV to βVI. As a result, the fundamental idea guiding bloom growth in chocolate is still a mystery. It is legal to add milk fat and milk fat components to pure chocolate products (dark and milk), since they successfully prevent bloom and are less expensive than cocoa butter.[115] Another study discovered that milk fat addition causes the detrimental softening of chocolate, and therefore that high-melting milk fat components prevent this Waldron et al.[116] However, it is unclear how milk fat and its constituent parts stop bloom.

Sugar bloom

On top of the chocolate, there is a rough and uneven layer which is sugar bloom. Condensation causes sugar bloom when the chocolate is taken out of the refrigerator. The sugar in the chocolate will dissolve as a result of the moisture. When the water is removed, the sugar cools and solidifies on the exterior into rough, uneven crystals. This offers the chocolate a sour appearance. Many foods also include significant levels of free fatty acids (FFA), which are often considered to exist as triacylglycerols in which fatty acids are esterified to a glycerol backbone. Such FFAs have often been identified as vital flavor contributors in foods, such as dairy and animal products.[117,118] FFAs were previously believed to have contributed to flavor solely through fragrance, possibly directly or indirectly via oxidative rancidity products.

In a separate study, researchers looked at how intestinal circumstances affected lipolysis, polyphenol release, and bioaccessibility in dark, milk, and white chocolates. Biochemical analysis in one study revealed that FFA values in cocoa nad subsequently in chocolate is affected by storage of pods and further drying. Fermentation stage in the production of chocolate also was reported to have some form of effect on the FFA values. Increase or decrease values of free fatty Acid (FFA) are important in determining the quality of chocolate (Table 5). In a related study, the authors showed that for low calorie dark chocolate, there was seen to be an increase in the FFA values during the ninety days of storage. A consumer's purchasing decision is influenced by the color of chocolate. The color of the product is influenced by raw material quality, storage, and processing conditions. A study reported that milk chocolate samples showed luminance ranging, chroma, and hue angle values of 28.69–31.45, 9.55–11.70, and 0.75–0.81, respectively, which were all within acceptable range.[119–122] Variations in composition, roughness of the chocolate surface, and processing factors all affect color parameters during chocolate production.[118,123–126]

Table 5 The impact of cocoa beans on the chemical properties of chocolates and EU heavy metal restrictions in chocolate products

Attribute	Quality characteristics	Food safety concern	Causes
Flavour (strength of cocoa or chocolate flavour, residual acidity, bitterness & astringency)	i. Free fatty acid levels (Mouldy off flavour)	Presence of mycotoxins; ochratoxin A formation	i. Extended fermentation.
			ii. Slow or insufficient drying.
			iii. Storage in humid circumstances.
			iv. Extended fermentation
			v. Germinated and bruised beans are susceptible to mould growth.
	ii. Phenols; guaiacol (Smoky/Hammy off-flavours)	Presence of mineral oil hydrocarbons (MOH) and polycyclic aromatic hydrocarbons (PAH)	i. Smoke contamination during drying as a result of improper fuel, poor construction, problematic operation, or inadequate dryer maintenance.
			ii. By contaminating the dry beans in the store with smoke.
	iii. Acetic acid and lactic acid (Acid taste)		i. Deep box fermentation
			ii. improper turning are two examples.
			iii. Too quick drying
	iv. Polyphenols (Bitterness & Astringency)		i. Some planting materials
			ii. Absence of fermentation
Dioxins limits for heavy metals in cocoa butter			
Total dioxins (WHO-PCDD/ F-TEQ)			1 0.75 pg/g fat
Total dioxins and dioxin-like PCBs (WHO PCDD/F-PCB- TEQ):			1.25 pg/g fat
Total PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180 (ICES - 6):			40 ng/g fat
Cadmium limits in cocoa Products (from 1 Jan 2019)			
≥ 30% total dry cocoa solids milk chocolate			0.10 mg/kg
Chocolate with less than 50% total dry cocoa solids; milk chocolate with at least 30% total dry cocoa solids			0.30 mg/kg
Chocolate with at least 50% total dry cocoa solid			0.80 mg/kg
Cocoa powder supplied to end users or as a component in sweetened cocoa powder sold to end users (drinking chocolate)			0.60 mg/kg

Source: CAOBISCO/ECA/FCC Cocoa Beans.[7]

Conclusion

Chocolate processing has a significant impact on the quality of the final product. Cardiovascular health is one of the well-being advantages of chocolate eating. The percentage of cocoa may refer to total cocoa solids or nonfat cocoa solids, depending on how the cocoa or chocolate product is labeled. The most important consideration for consumers when buying chocolate is flavor. Changes in free fatty acid FFA[127,128] levels are important in determining the quality of chocolate. The color of chocolate impacts customer purchasing decisions.[129] Sugar bloom is a rough and uneven coating that is placed on top of the chocolate mixture. Fat bloom can be caused by a number of conditions, including tempering, cooling process after tempering, and exposing well-tempered chocolate to high temperatures.[130–132] Color characteristics in chocolate manufacture are affected by composition variations, chocolate surface roughness, and processing variables.

Acknowledgments

None.

Conflicts of Interest

The authors declare there are no conflicts of interest.

References

1. Bullock G, Johnson C, Southwell B. Activating values to stimulate organic food purchases: can advertisements increase pro-environmental intentions? *Journal of Consumer Marketing*. 2017.
2. Ziegleder G. *Flavour development in cocoa and chocolate*, Industrial Chocolate Manufacture and Use, 4th edition. Wiley-Blackwell. 2017.
3. Kongor JE, Hinneh M, Van Walle D, et al. Factors influencing quality variation in cocoa (Theobroma cacao) bean flavour profile - A review. *Food Res Int*. 2016;82:44–52.
4. King SC, Meiselman H L, Carr BT. Measuring emotions associated with foods: Important elements of questionnaire and test design. *Food Quality and Preference*. 2013;28(1):8–16.
5. Fernandes S, Chaudhuri S, Vidyasagar A. Success crowns Cadbury dairy milk: Brand and culture analysis. *International Journal of Applied Business and Economic Research*. 2017;15(2):177–189.
6. Update guideline for assessment of Microbiological quality of processed food product repealing FDA circular No. 2013-010 "revised guidelines for the assessment of Microbiological quality of processed foods. 2021.
7. Ramakrishna Chethana, Sunki Reddy, Pradeep Singh. Preparation and Properties of Probiotic Chocolates Using Yoghurt Powder. Microbial Examination of Chocolate and Other Cocoa Products. International Office of Cocoa and Chocolate/International Sugar Confectionery Manufacturers Association (IOCC/ISCMA), Brussels, Belgium, 1973. *Food Nutr Sci*. 2013;4(3):5.
8. Torres Moreno M, Tarreg A, Costell E, et al. Dark chocolate acceptability: influence of cocoa origin and processing conditions. *Journal of the Science of Food and Agriculture*. 2012;92(2):404–411.
9. Ali AME, Shekib LA, Elshimy NM, et al. Producing and Quality Attributes of Low Calories Dark Chocolate Using Different Intense sweeteners and Wheat Fiber Isolate. *American Journal of Food Science and Technology*. 2021;9(1):1–7.
10. Afoakwa EO. Chocolate Science and Technology, 2st Edition. *Wiley-Blackwell Publishers*. 2010;54–101.
11. El Deep S, Yousif E, El Azab M, et al. Effect of roasting, conching and tempering processes on the quality characteristics of cocoa beans and chocolate. *Food Sci Technol*. 2000;45(4):585–602.
12. Cambrai A, Marcic C, Morville S, et al. Differentiation of chocolates according to the cocoas geographical origin using chemometrics. *J Agric Food Chem*. 2010;58(3):1478–1483.
13. Frauendorfer F, Schieberle P. Changes in key aroma compounds of criollo cocoa beans during roasting. *J Agric Food Chem*. 2008;56(21):10244–10251.
14. Ducki S, Miralles-Garcia J, Zumbe A, et al. Evaluation of solid-phase micro-extraction coupled to gas chromatography–mass spectrometry for the headspace analysis of volatile compounds in cocoa products. *Talanta*. 2008;74(5):1166–1174 .
15. Afoakwa EO, Paterson A, Fowler M, et al. Particle size distribution and compositional effects on textural properties and appearance of dark chocolates. *J Food Eng*. 2008;87(2):181–190.
16. Afoakwa EO, Paterson A, Fowler M, et al. Flavour Formation and Character in Cocoa and Chocolate: A Critical Review. *Crit Rev Food Sci Nutr*. 2008;48(9):840–857.
17. Mayank S, Kumar JD. Chocolate formulation as drug delivery system for pediatrics. *Indonesian Journal of Pharmacy*. 2012;23(4):216–224.
18. Rosales CK, Suwonsichon S, Klinkesorn U. Ability of crystal promoters to delay fat bloom development in heat□resistant compound chocolate with or without the presence of crystal inhibitor. *International Journal of Food Science & Technology*. 2017;52(11):2343–2351.
19. Bolenz S, Thiessenhusen T, Schäpe R. Fast conching for milk chocolate. *European Food Research and Technology*. 2005;218(1):47–54.
20. Mundel J, Huddleston P, Vodermeier M. An exploratory study of consumers perceptions: what are affordable luxuries?. *Journal of Retailing and Consumer Services*. 2017;35(1):68–75.
21. Van Kleef E, Kavvouris C, Van HCM. The unit size effect of indulgent food: How eating smaller sized items signals impulsivity and makes consumers eat less. *Psychology & health*. 2014;29(9):1081–1103.
22. Rousseau S. The role of organic and fair trade labels when choosing chocolate. *Food Quality and Preference*. 2015;44:92–100.
23. Li N. Diffusion through fat crystal networks. *Rutgers*. 2017.
24. Datsomor DN, Agbenorhevi JK, Kpodo FM, et al. Okra Pectin as Lecithin Substitute in Chocolate. *Scientific African*. 2019;3:00070.
25. Kissiedu KO, Agbenorhevi JK, Datsomor DN. Optimization of sensory acceptability of milk chocolate containing okra pectin as emulsifier. *International Journal of Food Properties*. 2020;23(1):1310–1323.
26. Benjamin TA, Francis Mensah, Anthony Asamoah. Farmers Assessment of the Government Spraying Program in Ghana. *Journal of Economics and Sustainable Development*. 2013;4(7):92–99.
27. Voora V, Bermúdez S, Larrea C. Global market report: cocoa. *JSTOR*. 2019.
28. Del Prete M, Samoggia A. Chocolate consumption and purchasing behaviour review: Research issues and insights for future research. *Sustainability*. 2020;12(14):5586.

29. Weiss BH, Omahony M, Wichchukit S. Various paired preference tests: Experimenter effect on "take home" choice. *Journal of sensory studies*. 2010;25(5):778–790.

30. Thaichon P, Jebarajakirthy C, Tatuu P. Are you a chocolate lover? An investigation of the repurchase behavior of chocolate consumers. *Journal of Food Products Marketing*. 2018;24(2):163–176.

31. Cime CT, Tunick MH, Trout RE. The chemical and attitudinal differences between commercial and artisanal products. *NPJ Science of Food*. 2019;3(1):1–4.

32. Enax L, Krapp V, Piehl A, et al. Effects of social sustainability signaling on neural valuation signals and taste-experience of food products. *Front Behav Neurosci*. 2015;9:247.

33. Didier T, Lucie S. Measuring consumers willingness to pay for organic and Fair Trade products. *International Journal of Consumer Studies*. 2008;32(5):479–490.

34. De Pelsmaeker S, Schouteten JJ, Gellynck X. Do anticipated emotions influence behavioural intention and behaviour to consume filled chocolates?. *British Food Journal*. 2017;119(9):1983–1998.

35. Steinhauser J, Janssen M, Hamm U. Consumers purchase decisions for products with nutrition and health claims: What role do product category and gaze duration on claims play?. *Appetite*. 2019;141:104337.

36. Mai LW. Consumers willingness to pay for ethical attributes. *Marketing Intelligence & Planning*. 2014;32(6):706–721.

37. Banjarnahor W, Napitupulu L, Situmeang F. The Effect of Green Advertisements: Broadening the Differences Between Self-Benefit Appeal versus Environmental Benefit Appeal. *Advanced Science Letters*. 2017;23(1):121–125.

38. Latif R. Chocolate/cocoa and human health: a review. *Neth J Med*. 2013;71(2):63–68.

39. Messerli FH. Chocolate consumption, cognitive function, and Nobel laureates. *N Engl J Med*. 2012;367(16):1562–1564.

40. Larsson SC. Coffee, tea, and cocoa and risk of stroke. *Stroke*. 2014;45(1):309–314.

41. Corti R, Flammer AJ, Hollenberg NK. Cocoa and cardiovascular health. *Circulation*. 2009;119(10):1433–1441.

42. Latham LS, Hensen ZK, Minor DS. Chocolate-guilty pleasure or healthy supplement?. *J Clin Hypertens)*. 2014;16(2):101–106.

43. Silva NR. Chocolate consumption and effects on serotonin synthesis. *Arch Intern Med*. 2010;170(17):1608–1609.

44. Rose N, Koperski S, Golomb BA. Mood food: chocolate and depressive symptoms in a cross-sectional analysis. *Arch Intern Med*. 2010;170(8):699–703.

45. Stacul F, Vander Molen AJ, Reimer P, et al. Contrast induced nephropathy: updated ESUR contrast media safety committee guidelines. *European radiology*. 2010;21(12):2527–2541.

46. Balemans CEA, Ten Dam MA, Reichert LJM, et al. Do not downplay the impact of kidney damage. 2010.

47. Barišić V, Kopjar M, Antun J, et al. The chemistry behind chocolate production. *Molecules*. 2019;24(17):3163.

48. Ashkezary M.R, Yeganehzad S, Vatankhah H, et al. Effects of different emulsifiers and refining time on rheological and textural characteristics of compound chocolate. *Ital J Food Sci*. 2018;30(1):26–36.

49. Verna R. The history and science of chocolate. *Malays J Pathol*. 2013;35(2):111–121.

50. Glicerina V, Balestra F, Dalla Rosa M, et al. Effect of manufacturing process on the microstructural and rheological properties of milk chocolate. *Journal of Food Engineering*. 2015;145(6):45–50.

51. Deou J. Control of the rheological properties of chocolate suspensions by optimizing the morphological properties of the particles. *HAL Open Science.* 2021.

52. Afoakwa EO. Cocoa processing and chocolate technology, in Cocoa and coffee fermentations. *CRC Press Boca Raton*. 2014.

53. Bolenz S, Amtsberg K, Lipp E. New concept for fast continuous conching of milk chocolate. *Eur Food Res Technol*. 2005;220(1):47–54.

54. Aidoo RP, De Clercq N, Afoakwa EO, et al. Optimisation of processing conditions and rheological properties using stephan mixer as conche in small-scale chocolate processing. *Int J Food Sci Technol*. 2014;49(3):740–746.

55. Fowler MS, Coutel F. Cocoa beans: from tree to factory. *Becketts Industry*. 2017;4:9–49.

56. Saputro AD, Van De Walle, Caiquo BA, et al. Rheological behaviour and microstructural properties of dark chocolate produced by combination of a ball mill and a liquefier device as small scale chocolate production system. *LWT*. 2019;100(1):10–19.

57. Di Mattia C. et al. Effect of different conching processes on procyanidin content and antioxidant properties of chocolate. *Food Research International*. 2014;63:367–372.

58. Owusu M, Petersen MA, Heimdal H. Effect of fermentation method, roasting and conching conditions on the aroma volatiles of dark chocolate. *Journal of Food Processing and Preservation*. 2012;36(5):446–456.

59. Owusu M, Petersen MA, Heimdal H. Relationship of sensory and instrumental aroma measurements of dark chocolate as influenced by fermentation method, roasting and conching conditions. *J Food Sci Technol*. 2013;50(5):909–917.

60. Beckett ST. The science of chocolate. *Royal Society of Chemistry*. 2019.

61. Yanus RL, Hagit Sela, Eitan JC, et al. Trace elements in cocoa solids and chocolate: an ICPMS study. *Talanta*. 2014;119:1–4.

62. Glicerina V, Romani S. Advances in yield stress measurements for chocolate. *Advances in Food Rheology and its Applications*. 2017; 459–481.

63. Wolf B. Chocolate flow properties, In Becketts industrial chocolate manufacture and use, Fifth edition. *John Wiley & Sons Ltd*. 2017;274–297.

64. Fischer A, Abubaker T, Hasselbarth A, et al. Understanding the impact of conching on chocolate flavour using a combination of instrumental flavour analysis and tasting techniques. *Expr Multidiscip Flavour Sci*. 2008;12:309–312.

65. Vera GV, Sánchez BT, Rivera JM, et al. Influence of temperature and mixing speed on dynamic rheological properties of dark chocolate mass during conching. *Food Science and Food Biotechnology Essentials*. 2014;2:247–252.

66. Jolly MS, Blackburn S, Beckett ST. Energy reduction during chocolate conching using a reciprocating multihole extruder. *Journal of Food Engineering*. 2003;59(2):137–142.

67. Patras A, Brunton NP, ODonnell C, et al. Effect of thermal processing on anthocyanin stability in foods; mechanisms and kinetics of degradation. *Trend Food Sci Technol*. 2010;21(1):3–11.

68. Krysiaka W. Influence of roasting conditions on coloration of roasted cocoa beans. *Journal of Food Engineering*. 2006;77(3):449–453.

69. Engeseth NJ, Pangan MFA. Current context on chocolate flavor development-a review. *Curr Opin Food Sci*. 2018;21:84–91.

70. Afoakwa EO, Quao J, Budu AS, et al. Effect of pulp preconditioning on acidification, proteolysis, sugars and free fatty acids concentration during fermentation of cocoa (*Theobroma cacao*) beans. *Int J Food Sci Nutr*. 2011;62(7):755–764.

71. Glicerina V, Balestra F, Dalla RM, et al. Effect of manufacturing process on the microstructural and rheological properties of milk chocolate. *Journal of Food Engineering*. 2015;145:45–50.

72. Kindlein M, Elts E, Briesen H. Phospholipids in chocolate: Structural insights and mechanistic explanations of rheological behavior by coarse-grained molecular dynamics simulations. *Journal of Food Engineering.* 2018;228:118–127.

73. Glicerina V, Balestra F, Dalla Rosa M, et al. Rheological, textural and calorimetric modifications of dark chocolate during process. *Journal of Food Engineering*. 2013;119(1):173–179.

74. Middendorf D, Juadjur A, Bindrich U, et al. AFM approach to study the function of PGPRs emulsifying properties in cocoa butter based suspensions. *Food Structure*. 2015;4:16–26.

75. Middendorf D, Bindrich U, Mischnick P, et al. Atomic force microscopy study on the effect of different lecithins in cocoa-butter based suspensions. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*. 2016;499:60–68.

76. Alimentarius C. Standard for chocolate and chocolate products. *Codex Stan.* 2016;87–1981.

77. Abt E, Fong SJ, Gray P, et al. Cadmium and lead in cocoa powder and chocolate products in the US Market. *Food Addit Contam Part B Survveill*. 2018;11(2):92–102.

78. Corti R, Perdrix J, Flammer AJ, et al. Dark or white chocolate? Cocoa and cardiovascular health. *Rev Med Suisse*. 2010;6(239):499–500.

79. Petyaev IM, Bashmakov YK. Dark chocolate: opportunity for an alliance between medical science and the food industry?. *Front Nutr*. 2017;4:43.

80. Dillinger TL, Barriga P, Escárcega S, et al. Food of the gods: cure for humanity? A cultural history of the medicinal and ritual use of chocolate. *J Nutr*. 200;130(8):2057–2072.

81. Pucciarelli DL, Grivetti LE. The medicinal use of chocolate in early North America. *Mol Nutr Food Res*. 2008;52(10):1215–1227.

82. Paternotte S, Labrude P. Chocolate in some French pharmaceutical or medicinal books from XVIIth, XVIIIth and XIXth centuries. Its beneficent and inconvenient, proved or imaginary, effects. *Rev Hist Pharm*. 2003;51(338):197–210.

83. Lippi D. Chocolate in history: food, medicine, medi-food. *Nutrients*. 2013;5(5):1573–1584.

84. Bernaert H, Blondeel I, Allegaert L, et al. Industrial treatment of cocoa in chocolate production: health implications. *Chocolate and Health*. 2012;4:17–31.

85. Ngo MK, Misra R, Spence C. Assessing the shapes and speech sounds that people associate with chocolate samples varying in cocoa content. *Food Quality and Preference*. 2011;22(6):567–572.

86. De Araujo QR, Gattward JN, Almoosawi S, et al. Cocoa and human health: From head to foot–a review. *Crit Rev Food Sci Nutr*. 2016;56(1):1–12.

87. Petyaev IM, Bashmakov YK. Cocobiota: implications for human health. *J Nutr Metab*. 2016;2016:7906927.

88. Kothe L, Zimmermann BF, Galensa R. Temperature influences epimerization and composition of flavanol monomers, dimers and trimers during cocoa bean roasting. *Food Chem*. 2013;141(4):3656–3663.

89. García Blanco T, Dávalos A, Visioli F. Tea, cocoa, coffee, and affective disorders: vicious or virtuous cycle?. *J Affect Disord*. 2017;224:61–68.

90. Salmeron J, Hu FB, Manson JE, et al. Dietary fat intake and risk of type 2 diabetes in women. *Am J Clin Nutr*. 2001;73(6):1019–1026.

91. Ng M, Chaya C, Hort J. Beyond liking: Comparing the measurement of emotional response using Essense Profile and consumer defined check-all-that-apply methodologies. *Food Quality and Preference*. 2013;28(1):193–205.

92. Spinelli S, Masi C, Dinnella C, et al. How does it make you feel? A new approach to measuring emotions in food product experience. *Food Quality and Preference*. 2014;37:109–122.

93. Thomson DMH, Crocker C, Marketo CG. Linking sensory characteristics to emotions: An example using dark chocolate. *Food Quality and Preference*. 2010;21(8):1117–1125.

94. Evers C, Adriaanse M, Ridder DT, et al. Good mood food. Positive emotion as a neglected trigger for food intake. *Appetite*. 2013;68:1–7.

95. Paoletti R. *Chocolate and health.* Milan: Springer, Italy. 2012.

96. Parker GB, Brotchie HL. Mood States effects of chocolate. *J Affect Disord*. 2006;92(3):147–153.

97. Jovanović OL, Pajin BS. Sensory and instrumental evaluation of physical characteristics of laboratory-made chocolate. *Acta Periodica Technologica*. 2002;33(33):19–25.

98. Ziegleder G. Flavour development in cocoa and chocolate. *Becketts Industry*. 2017;5:185–215.

99. Moreira I, Costa J, Vilela L, et al. Influence of S. cerevisiae and P. kluyveri as starters on chocolate flavor. *J Sci Food Agric*. 2021;101(10):4409–4419.

100. Fernández NM, Rodríguez CM, Herrera Rocha, et al. Dissecting industrial fermentations of fine flavour cocoa through metagenomic analysis. *Sci Rep*. 2021;11(1):1–14.

101. Barišic V, Petrovic J, Lonˇcarevic I, et al. Chocolate and Cocoa Industry Quality Requirements. *Cocoa Beans*. 2015;15–23.

102. Ziegler GR, Mongia G, Hollender R. Role of particle size distribution of suspended solids in defining the sensory properties of milk chocolate. *Int J Food Prop*. 2001;3(1):175–192.

103. BrionesV, Aguilera JM, Brown C. Effect of surface topography on color and gloss of chocolate samples. *Journal of Food Engineering*. 2006;77(4):776–783.

104. Schomaker M, Schraer MC, Lorcher M. Measurement and Control of the Gloss of Chocolate. *Chem Eng Technol*. 2020;43(11):2336–2343.

105. Lindecrantz A. Inestigation of seedpowder technology for pre-crystallization processing of dark chocolate-Effect on fat crystal structure and storage stability. *Division of Food Science*. 2014.

106. Saputro AD, Muhammad DRA, Sunarharum WB, et al. Physical characteristics of chocolate made from cocoa bean fermented at different duration:a preliminary study. *IOP Conf Ser: Earth Environ Sci*. 2021;653:12039.

107. Rosales CK, Suwonsichon S, Klinkesorn U. Ability of crystal promoters to delay fat bloom development in heat-resistant compound chocolate with or without the presence of crystal inhibitor. *Int J Food Sci Technol*. 2017;52(11):2343–2351.

108. Afoakwa EO, Kongor JE, Budu SA, et al Changes in biochemical and physico-chemical qualities during drying of pulp preconditioned and fermented cocoa *(Theobroma cacao*) beans. *J Nutrition Health Food Sci*. 2014;2(3):1–8.

109. Masuchi MH, Grimaldi R, Kieckbusch TG. Effects of sorbitan monostearate and monooleate on the crystallization and consistency behaviors of cocoa butter. *J Am Oil Chem Soc*. 2014;91(7):1111–1120.

110. Ghosh V, Ziegler GR, Anantheswaran RC. Fat, moisture, and ethanol migration through chocolates and confectionary coatings. *Crit Rev Food Scie Nutr*. 2002;42(6):583–626.

111. Zhao H, James BJ. Fat bloom formation on model chocolate stored under steady and cycling temperatures. *Journal of Food Engineering*. 2019;249(5):9–14.

112. Bricknell J, Hartel RW. Relation of fat bloom in chocolate to polymorphic transition of cocoa butter. *Journal of the American Oil Chemists Society*. 1998;75(11):1609–1615.

113. KintaY, Hatta T. Composition and structure of fat bloom in untempered chocolate. *Journal of Food Science*. 2005;70(7):450–452.

114. Ghazani SM, Marangoni AG. The triclinic polymorphism of cocoa butter is dictated by its major molecular species, 1-palmitoyl, 2-oleoyl, 3-stearoyl glycerol (POS). *Crys Growth Des*. 2018;19(1):90–97.

115. Ewens H, Metilli L, Simone E. Analysis of the effect of recent reformulation strategies on the crystallization behaviour of cocoa butter and the structural properties of chocolate. *Curr Res Food Scie*. 2021;4:105–114.

116. Waldron DS, Hoffman W, Buchhiem W, et al. Role of milk fat in dairy products. *Advanced Dairy Chemistry*. 2020;2:245–305.

117. Neethling J, Hoffman LC, Muller M. Factors influencing the flavour of game meat: a review. *Meat Scie*. 2016;113:139–153.

118. Aidoo RP, Afoakwa EO, Dewettinck K. Optimization of inulin and polydextrose mixtures as sucrose replacers during sugar-free chocolate manufacture–Rheological, microstructure and physical quality characteristics. *Journal of Food Engineering*. 2014;126:35–42.

119. Konar N. Enrichment of milk chocolate by using EPA and DHA originated from various origins. *Effects on Product Quality*. 2018;20(6):745–755.

120. Arunkumar KV. Evaluating the processed beans of different cocoa *(Theobroma cacao L.*) accessions for quality parameters. *J Phytol*. 2019;11:1–4.

121. Doko K, Blaži´C, ˇCkar D. Physical Properties of Chocolates Enriched with Untreated Cocoa Bean Shells and Cocoa Bean Shells Treated with High-Voltage Electrical Discharge. *Sustainability*. 2021;13(5):2620.

122. Büsser S, Jungbluth N. LCA of chocolate packed in aluminium foil based packaging. *ESU-services*. 2009.

123. Craig WJ. Codex standard for chocolate. *Codex Stan 87*.1976;2–9.

124. Food and Agriculture data. *FAOSTAT*. 2017.

125. Finkbeiner M. The international standards as the constitution of life cycle assessment: the ISO 14040 series and its offspring, in Background and future prospects in life cycle assessment. *Springer*. 2014;2(4):85–106.

126. Hainmueller J, Hiscox M, Tampe M. Sustainable development for cocoa farmers in Ghana. *International Growth Centre*. 2011.

127. Krysiak W. Influence of roasting conditions on coloration of roasted cocoa beans. *Journal of Food Engineering*. 2006;77(3):449–453.

128. Moss B. Water pollution by agriculture. *Philos Trans R Soc B Biol Scie*. 2008;363(1491):659–666.

129. Ntiamoah A, Afrane G. Environmental impacts of cocoa production and processing in Ghana: life cycle assessment approach. *Journal of Cleaner Production*. 2008;16(16):1735–1740.

130. Origins of Cocoa and its spread around the World. *ICCO International Cocoa Organization*. 1973.

131. Oyenuga AA, Bhamidimarri R, Researcher PD. Upcycling ideas for sustainable construction and demolition waste management: Challenges, opportunities and boundaries. *IJIRSET*. 2017;6(3):4066–4079.

132. Recanati F, Allievi F, Scaccabarozzi G, et al. Global meat consumption trends and local deforestation in Madre de Dios: assessing land use changes and other environmental impacts. *Procedia Engineering*. 2015;118:630–638.