Chapter

Chocolate: Health, Processing, and Food Safety

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Abstract

Chocolate is a popular food product internationally, and it is consumed daily. Consuming chocolate has been linked to many human health benefits such as lower cholesterol levels, but there are some negative impacts such as weight gain because of its sugar content. Moreover, food safety issues related to chocolate have existed, and it can be contaminated by any biological, chemical, or physical hazards, which lead to many health issues. Regarding that, this chapter will discuss the benefits and negative impacts of consuming chocolate and provide the process of manufacturing the product.

Keywords: chocolate, health benefits, health risks, processing, food safety

1. Introduction

The cocoa bean is the seed of the cacao tree, it is a tropical plant indigenous to the equatorial regions of the Americas, but currently, it is cultivated in many countries with a warm, tropical climate. Cocoa is the main raw material to produce chocolate, which can value more than $100 billion [1]. Chocolate history started with the Maya, who were the first people who cultivated the cocoa plant in South America. During that period, chocolate was a cocoa drink prepared with hot water, and it can be flavored usually with cinnamon and pepper [2].

The Republic of Côte d'Ivoire, a country on the southern coast of West Africa, is the biggest producer of cocoa beans with more than 2 million tons annually. The national economy of Ivoirians depends on their export revenue from cocoa. Its population is more than 26 million, almost 6 million work in cocoa beans production, and almost 2,034,000 tons were produced in 2021 [1]. Many countries such as Ghana (883,652 tons), Indonesia (659,776 tons), Nigeria (328,263 tons), Cameron (295,028 tons), Brazil (235,809 tons), Ecuador (205,955 tons), Peru (121,825 tons), Dominican Republic (86,599 tons), and Colombia (56,808 tons) [3] that are considered top producers of cocoa come after Cote d'Ivoire.

This chapter is focused on the health benefits of chocolate, processing, type of chocolate, and finally, the safety aspect of chocolate production. Furthermore, the negative impact of chocolate on human health has been discussed.

2. Health benefits

There are numerous health benefits associated with the consumption of chocolate, which are due to its nutritional contents [4, 5]. A bar of chocolate with

a higher number of nutrients has high health benefits, for example, dark chocolate [5], which contains soluble fiber and is rich in minerals. In more detail, a 100-gram bar of dark chocolate with 70–85% cocoa consists of 11 grams of fiber, 67% of the daily value (DV) for iron, 58% of the DV for magnesium, 89% of the DV for copper, 98% of the DV for manganese. So, dark chocolate is the best type with regard to the number of nutrients [6].

Chocolate possesses antioxidant activity, which is very beneficial for human health [5] and can be attributed to the presence of polyphenols, flavanols, and catechins, among others [6]. According to Nora et al. [7], antioxidants play an important role in the enhancement of immunity and for preventing cardiovascular diseases and metabolic diseases including obesity, diabetes mellitus, and some types of cancer. According to Harvard T.H. Chan School of Public Health [8], numerous studies showed a link between consuming chocolate and health benefits. Studies showed that consumption of 6 grams of chocolate daily leads to reducing the risk of heart disease and mortality, which could be due to reduced blood pressure and inflammation.

It is considered that chocolate is one of the 30 best anti-inflammatory foods. It has been observed that inflammation could lead to many health problems, and chocolate works as an anti-inflammatory effect in the human system, subsequently protecting humans against diseases. A study carried out by Creveling [9] found that cocoa polyphenols help to regulate the bacterial composition of the intestine. The author observed that cocoa polyphenols increase the number of good gut bacteria and that trigger this anti-inflammatory response [9].

Consuming chocolate could help in maintaining cardiovascular health. According to a study, carried out on 49 adults (32 women, 17 men) to assess the effectiveness of consuming dark chocolate on cholesterol levels, the results indicated that consuming chocolate that contains plant sterols and cocoa flavanols as a low-fat diet could contribute to cardiovascular health by reducing cholesterol and improving blood pressure [10].

Another study proved that the flavanols in dark chocolate can boost the endothelium, the lining of arteries, which lead to producing nitric oxide that works to send signals to the arteries to relax, which lowers the resistance to blood flow, and as a result of this, it reduces blood pressure [6]. Moreover, a study from Walden University's School of Nursing has been done on participants who eat dark chocolate, and it has been found that consumption of dark chocolate reduces blood pressure [11].

Consumption of dark chocolate improves the function of the brain. A study that was carried out on healthy volunteers confirmed that consuming high flavanol cocoa for 5 days contributes to improved blood flow to the brain. Furthermore, it also helps in improving cognitive function in older adults with mild cognitive impairment [6]. Nordqvist [5] referred that researchers from Harvard Medical School indicated that drinking two cups of hot chocolate a day for older people could help in keeping the brain healthy and reduce memory decline. They have found that hot chocolate helped in improving blood flow to parts of the brain where it was needed. A similar study was published in 2014 showed that a cocoa extract that is called lavado could help in reducing or preventing nerve pathways found in patients with Alzheimer's disease and could contribute to slow symptoms such as cognitive decline [5].

Consumption of chocolate also helps to protect human skin against skin disease because of cocoa flavanols [6, 11, 12]. Also, chocolate contains theobromine, which helps pregnant women against complications of pregnancy, which is known as preeclampsia. According to a study that was done on pregnant women, as they were given a higher amount of chocolate, they had a 40% less chance of getting

preeclampsia [13]. Studies also showed that consuming chocolate can help in protection against cancer as Brook [14] indicated in a study, which was published in the Journal of the American Society of Hypertension, that people who consume many flavonoids or antioxidant-rich chocolate have lower chances of developing cancer, compared with those who do not.

3. Side effects associated with chocolate consumption

As discussed in the last section, there are numerous health benefits associated with the consumption of chocolate; however, there are also some negative effects on human health such as childhood hyperactivity, migraine, and headaches. According to a study conducted in the Bogalusa Heart, to identify the presence of caffeine in children's snacks, the results indicated the presence of a large amount of caffeine in children, which could be due to eating foods such as chocolate [15]. Bruso [16] referred to that according to the University of Maryland Medical Center, approximately 8% of children in the US younger than 18 have hyperactivity at some point. These cases are often treated by behavioral therapy and medication, but some parents resort to changing children's diets by avoiding chocolate in their children's meals. The Medical Center reported that this change is an effective method but only in a small percentage of children [16].

According to Nowaczewska et al. [17], there are 25 studies have indicated the prevalence of chocolate as a migraine trigger. Two studies of them indicated that chocolate is not a migraine trigger because no participant has reported that chocolate is a trigger factor. Also, other studies considered chocolate a migraine trigger in a small percentage of participants (ranging from 1.3 to 33) Nowaczewska et al. [17]. According to Kelishadi [15], there are some authors who say migraine and tension-type headache occur due to the consumption of some type of foods: one of them is chocolate. Also, another study indicated that chocolate could provoke a migraine attack in some patients who think themselves sensitive to it. [15]. An increase in migraines in some people upon eating chocolate could be due to cocoa's tyramine, histamine, and phenylalanine content [5]. It has been also reported that consuming more chocolate could lead to bone health issues. Nordqvist [5] mentioned in a study, which was published in The American Journal of Clinical Nutrition, low bone density in older women who consume chocolate every day. Also, it has been reported that some chocolate includes a high amount of heavy metals such as cadmium and lead, which can affect the kidneys and bones [5]. A study found that almost all samples (43 chocolate products) contain more than 0.3 mcg of cadmium per serving, which means more than the recommended level identified by the World Health Organization [5].

4. Production of chocolate

The cacao tree is considered a sensitive plant, and it requires protection from wind and needs shade in its early years [18]. The cocoa tree needs a semi-shaded environment (50% light and 50% shade). In the cocoa plantations, there are many tall trees beside cocoa trees to provide the required shade and shall not prevent the light [19]. The cocoa plant also needs high rainfall and temperatures to grow. Therefore, it can only grow in a narrow band of countries between 20 degrees north and south of the equator [20]. The suitable temperature for growing is between 25 and 27°C (between 77 and 81°F). The tree cannot resist the high dry or wet. The perfect rainfall should be between 1250 and 2500 mm per year. The cocoa tree requires fertile, slightly acidic, and well-drained soil [21].

The wild cocoa tree can grow up to 12–15 m but to make harvesting easier, most farmers grow it to less than 5 m. Regarding blooms, it blooms and bears fruit all year round, which means that the cocoa tree has both flowers and fruits at the same time [21]. Moreover, the most producing period is from October to February and from May to August [22].

The products could be different in many properties such as shape, texture, and size. The length can be started from 15 cm to over 35 cm. One ripe fruit contains 20–75 cocoa beans, the length of each one can be from 1 cm to 3 cm, embedded in a white pulp. The nutritious cocoa bean is considered very high beneficial as it contains fat (50%) and carbohydrates (25%), as well as proteins, theobromine, niacin, vitamins (including A, B1, B2, and B6), and minerals (calcium, iron, potassium, magnesium, sodium, and phosphorus) [21].

4.1 Varieties of cocoa

There are three types of chocolate, which are Criollo, Forastero, and Trinitario. These types are dominant varieties [23]. It was named officially in 1753 by the Swedish scientist Carl von Linné [24]. According to the chocolate society [25], the most productive and common type is Forastero beans, which are because of their high yielding in Brazil and W Africa. On the other hand, Criollo and Trinitario beans are better in quality, but they are lower yielding, which made them very expensive.

4.1.1 Trinitario

This type of cocoa exists on the Island of Trinidad after a hurricane nearly destroyed the local Criollo crops in 1727. As a result, farms are replanted with the Forastero type, which was brought from Venezuela, and cross-fertilized with the native Criollo type [25]. Therefore, a new type appears, which is known now as Trinitario. This type merged the best two types, which are Forastero (which is featured by the hardiness and is very high in yielding) and the Criollo type (which is featured by great taste) [21]. As a result, the Trinitario variety is classified as fine flavor cocoa, but it is less intense than the Criollo type [26]. The properties of this type are usually varied because of the parents as they have different characters, and it can be grown where Criollo cocoa was once grown including in Mexico, the Caribbean islands, Colombia, Venezuela, and parts of Southeast Asia [21]. The percentage of the world's production is uneven regarding the Walter Matter [26] approximately only 5% of the world's production, and according to Bar & Cocoa, proved that the production is less than 10% globally. However, according to the chocolate society [25], this type represents about 12% of the world's cocoa production, and in 2020, the Ministry of Foreign Affairs confirmed that the production represents approximately 10–15%.

4.1.2 Criollo

This type was cultivated by the Maya more than 2500 years ago. It is considered a high-quality variety compared with others. Also, it is very complex with regard to cultivation and handling; consequently, it represents less than 5% globally, and it is the rarest type [27]. It is cultivated in Central America, northern South America, the Caribbean, and Sri Lanka. It has a delicate and sweet flavor, so it is often mixed with different types because of its rarity and high cost [28]. According to its characteristics, the pods are red or green before ripeness with less than ½ in length, and it has a very accentuated tip at the lower end, marked with 10 deep furrows. Its surface is smooth and round-shaped. Moreover, it is plump with fresh white cotyledons, and it is very easy to ferment [27].

4.1.3 Forastero

This is the most common type of cocoa, its native most likely to the Amazon basin. These days, it is grown mostly in Africa, Ecuador, and Brazil. It is represented almost 80% of the world's cocoa production, because of its properties, which include hardness, and resistance to diseases. There are many subspecies of Forastero such as Cundeamor and Calabacillo [21]. This type was discovered by the Spanish in the heart of the Amazon [27]. It grows in West Africa and Brazil [26].

4.2 Diseases of cocoa fruit

4.2.1 Black pod

It is mostly cultivated cocoa in small labor-intensive farms for less than 2 hectares (5 acres) to protect the product against disease and pests. Even though, still, there are many losses of production globally, which approximately range from 30 to 100%. The most popular diseases of the cacao tree are pod rots. It is called a black pod as a result of fungus (Phytophthora), which spreads very quickly on the pods under rainy and humid climate conditions, with a lack of sunshine, and temperature under 21°C (70 °F). Therefore, control is required by using copper-containing fungicides, and the infected pods should be removed to reduce spread.

4.2.2 Witches' broom

Witches' broom, which is caused by *Moniliophthora perniciosa*, has a very dangerous effect on products [29]. It is one of the most risky diseases throughout South America. High temperature and high humidity are good environments for this disease. Therefore, it must be following good sanitation and remove any infected materials, which are difficult because it could not show any visible symptoms. Also, fungicides must be used to protect the cocoa [30].

4.2.3 Frosty pod

This disease is caused by *Moniliophthora roreri* fungus, and it is considered a highly infectious disease that impacts the production of cocoa. It is spread rapidly by water movement, wind, or the movement of pods [30].

4.2.4 Swollen shoot

This one is only found in West Africa, which is a huge problem in Togo, Ghana, Cote d'Ivoire, and Nigeria. It is transmitted by mealybugs. This natively results from trees that grew in the rain forests of West Africa, so it is not native to the cocoa plants [30].

Table 1 includes the main estimated losses of cocoa production annually because of diseases [31].

4.3 Pest

There are over 1500 different insects that feed on cocoa; however, there is only 2% of economic importance. Mirid bugs such as Helopeltis are the most common and important insects in attacking cocoa, and the main pest in Malaysia and Indonesia is the cocoa pod borer. The most popular insect pests are including broad mite, flower-eating caterpillars, Helopeltis, and yellow peach moth [31].

Disease	Region	Estimated world production loss (tonnes)
Black pod (phytophthora fungus)	Africa, Brazil, Asia	450,000
Witches broom (fungus)	Latin America	250,000
Frosty pod rot (fungus)	Latin America	30,000
Swollen shoot virus	Africa	50,000
Vascular streak dieback (virus)	Africa	30,000

Source: https://www.daf.qld.gov.au/business-priorities/agriculture/plants/fruit-vegetable/fruit-vegetable-crops/cocoa/pests-and-diseases-of-cocoa.

Table 1.
Estimated losses of cocoa production annually because of diseases.

5. Processing of cocoa

5.1 Harvesting cocoa

The coco plant life on average is 25 years, and the product needs range from 150 and 165 days for complete maturation. There is no specific season for ripening as it can be harvested all year round [19]. Beans grow in pods that sprout out of the trunk and branches of cocoa trees. The size of the pods is almost the same as the football size. The pods start green and then convert to orange, which means they are ripe and ready for harvesting [32].

When the pods are ripe, harvesting should be done manually, as using machines will lead to damage to the tree, the clusters of flowers and pods that grow from the trunk [32], as the tree is weak, which makes the picking a hard job for workers [18]. For picking, workers use short, hooked blades mounted on long poles to reach the highest products [32]. After picking cocoa from trees, it is collected in baskets and transported to the braking operation [32]. In this step, it is split, and the cocoa beans are removed. Pods can contain upward of 50 cocoa beans each [18]. The pods are opened, and the beans are removed within a week to 10 days after harvesting to avoid germinating [33].

5.2 Fermentation of cocoa

Fermentation of cocoa after harvesting is a critical process [34]. This process leads to getting the aromas to the cocoa and knowing the difference between many types of cocoa. However, for some traditional dishes, unfermented beans are used in parts of Mexico and Central America. The fermentation method could take 2–8 days; it depends on the type of cocoa [18]. It is fermenting the pulp of Forastero type for 5–7 days, and the pulp of Criollo type for 1–3 days [29].

During fermentation, the cocoa beans are placed in large, shallow, heated trays or covered with large banana leaves. If the weather is good, it is heated by the sun with the importance of noticing that it is necessary to move them up frequently to allow the beans to come out for fermentation equally [32]. In this method, the juicy sweating of the pulp is drained and the germ in the seed is killed by the heat, and the flavor will be improved. As well as the color will be changed to brown. This step is implemented in sun-dried or kiln-dried to reduce the moisture content to 6–7 % [29]. Throughout the fermentation of cocoa beans, the top layer of the beans is covered with banana leaves, because the bottom part of the banana leaf consists of natural yeast and microorganisms, which help to strengthen the natural fermentation [18].

5.3 Drying

After fermentation, a drying process must be implemented, which is an important step to enhance the cacao flavor [35]. The drying is done by the sun, and it should turn the beans as well in this step to be equally dried. It can dry on wooden floors, which can be covered by a sliding roof during rainy weather. Electric dryers are used on large farms [18]. The drying stage period could take between 2 and 10 days in the nature processing [36]. During drying, the color of cocoa beans is changed from reddish-brown to dark brown [18]. As a result of this process, the humidity of the cocoa is reduced from 60% to 7% [35].

In this method, the polyphenol content of cocoa beans is reduced, many numbers have been reported in a review study, which was done by [37], and depending on many studies include a reduction from 77 to 44%, a 72% reduction, a 30% reduction, and a 26% reduction. In addition, sun drying reduces the phenolic content and antioxidant activity of cocoa beans.

However, according to a study that was done by [36] to compare the methods of drying cocoa beans to evaluate antioxidant activity, to determine phenolic compounds and methylxanthine content, and to determine the presence of ochratoxin A, four methods are used:

Dryer with stainless steel platform and plastic roof with UV protection (DP):

Artificial dryer, using the wooden platform with an artificial heat source, through forced and heated air circulation with electric resistance and temperature controlled by a thermostat at 60°C (AD);

Traditional dryer in the barge with wooden platform and drying by direct sunlight (TD);

Mixed dryer with stainless steel platform and mobile plastic roof with UV protection for drying coverage and exposure to sunlight (MD).

It has been found that the best method is the traditional drying method, in which drying is by the sun directly to maintain the phenolic compound content in the cocoa beans, as the phenolic compound content is reduced in different methods, particularly in the artificially oven-dried method. Also, the traditional method is the best in retention of cocoa antioxidant activity and the methylxanthine content in dry seeds, which confirm that these chemical compounds are impacted by changing temperature. The reason for the traditional method being the best could be because it uses less than milder temperatures.

5.4 Manufacturing process of chocolate

5.4.1 Cleaning

The first process that must be done in the industry is cleaning the cocoa beans probably by using sieves and brushes [19]. There are many cleaning steps to remove any contamination, for example, twigs, stones, and dust [29]. In general, the manufacturing operations are different slightly because of the various types of cocoa trees; however, most industries use similar machines to convert cocoa beans to cocoa butter and chocolate [32].

5.4.2 Roasting

The roaster step is very important in processing chocolate, and that is done by drying beans at a temperature of 100°C, then roasting beans at a temperature range between 100°C and 160°C. It could be different depending on the type. The balance in roasting is very necessary as increasing it will lead to the bitterness of the beans

and less than required will not improve the aromas [19]. A study [38] has proved that roasting at high temperature influences cocoa beans and has no influence on roasting time. Moreover, roasting at 160°C leads to undesirable burnt odor and flavor and a low acceptability score by consumers. However, roasting at temperature range from 90 to 110°C was acceptable by consumers in appearance, aroma, flavor, texture, and overall quality attributes.

This process develops the aromas and contributes to reducing acidity and astringency, reducing moisture content, deepening color, and facilitating shell removal [29]. Also, roasting is killing any organisms that exist on the bean, which appear in the fermentation process [18]. In this process, it has been found to decrease the flavanols and phenolic content of cocoa beans [37].

5.4.3 Grinding

The roasting method makes the shells of the cocoa brittle, so it is winnowed to remove the shells of the bean and only cocoa nibs pass through a series of sieves, and this method is called winnowing [29]. In the grinding process, the nibs are ground in a granite stone mill, which crushes the grain and releases the fat or cocoa butter [29]. Cocoa butter is the main ingredient of chocolate [19]. Chocolate consists of both cocoa solids and cocoa butter in almost the same ratio [18].

5.4.4 Coaching

This process is completed by conche machines. Moreover, this process is developing flavor, aerating, and emulsifying. The required time is 4–72 hours (depending on the desired results, and the machine type plays a major as well). The temperature is between 55 and 88°C (130 and 190 °F) and is controlled regarding the desired flavor and uniformity [29]. In this process, chocolate could lose almost 80% of volatile substances [19].

5.5 Types of chocolate

There are many types of chocolate that are different in ingredients and characteristics.

1. Dark chocolate, which contains the highest percentage of cocoa bean solids (up to 80% of the total weight) and cocoa butter compared with other varieties. This type is featured by the strong aroma of cocoa. Its quality depends on the percentage of cocoa. Most of the human benefits of health have been linked to consuming this type.

2. Another type is called Gianduja chocolate, which contains hazelnuts, cocoa, and sugar. Its color is brown.

3. Milk chocolate consists of cocoa butter, sugar, milk powder, lecithin, and cocoa of 20–25%. Its properties are including a bright appearance, an intense, persistent aroma, and a sweet taste with a slightly bitter accent of cocoa [2]. According to FDA Standards of chocolate identity, milk chocolate must include at least 10% chocolate liquor and 12% milk solids. Also, cocoa butter and milk are the only fat allowed in this type [39].

4. The last type is white chocolate, which contains cocoa butter, milk, and sugar with no cocoa solids. It is a sweet, pleasant taste [2]. To meet the FDA standards, this type must have at least 20% cocoa butter and 14% milk solids [39].

6. Food safety of chocolate

Food contamination is referring to food that is contaminated microbiologically, chemically, or physically. That can be done at any stage of food processing such as during storage or transportation [40]. Also, food allergies can be considered a contamination factor [41].

Food safety issues are considered a huge challenge in the health sector compared to those of malaria or tuberculosis [42]. As the person who consumes contaminated food gets food poisoning and starts the poisoning symptoms in hours, and it could need to visit a hospital, particularly the high-risk group, which includes older adults, pregnant women, infants, and young children, and people with chronic disease [43]. Food poisoning includes many common symptoms, which are upset stomach, stomach cramps, nausea, vomiting, diarrhea, and fever [44]. There are many foods that are linked to food poisoning, which are poultry, raw fruits and vegetables, fish and shellfish, rice, deli meats, unpasteurized dairy, and eggs [45]. Many cases of outbreaks of food poisoning in the United States have been linked to fruits and vegetables in 2018 [46].

6.1 Microbial contamination of food

Microbial contamination is the most common type of food contamination. It can be done if the food is contaminated by microorganisms such as bacteria, viruses, mold, fungi, and toxins. Many reasons lead to microbial contamination that including undercooking chicken, storing and preparing raw foods near to ready-to-eat food, and this leads to cross-contamination [41]. Also, the vectors of biological contamination include food handlers and that can be caused by aerosol droplets from coughing near the production line. Moreover, vectors include packaging materials, equipment, and tools used; an example of this is using the same cutting board and knife in raw food and ready-to-eat food. Contaminated water is also an important factor to cause microbial contamination. Furthermore, pests such as insects and rodents are factors of contamination [40]. Therefore, food hygiene practices must be implemented to prevent contamination that including personal hygiene, separating raw and ready-to-eat food at all stages of processing, washing raw fruits and vegetables, and pest control on the premise [41].

For a long period, it was referred to low-moisture foods, such as chocolate, as a safe product against microbial contamination because of their properties, as the water activity (aw) is below 0.6, which is not an active area for microbial growth. However, the early 1970s were linked to the first outbreaks of Salmonella to low-moisture products such as chocolate, oat cereals, peanut butter, and infant formula. Salmonella was the main pathogen of concern for all of those products [47]. Also, another study that was to identify the emerging hazards related to chocolate products between 2013 and 2018 has concluded that microbiological hazard is 16,49%, and it is the second hazard following chemicals in cocoa from Africa and South America as well [48]. According to the most recent data, it has been shown that a Salmonella outbreak in a brand of chocolate wafers from Poland between December 2020 and early April 2021affected 32 people as announced [49].

Moreover, many reasons cause biological contamination linked to chocolate products, for example, pathogenic microorganisms can be found because of using contaminated ingredients such as milk and sugar. Also, pathogens can be presented because of damage or soiled packaging material because of mishandling at the supplier level. Furthermore, it can be found in returned chocolate products because of mishandling in any area such as retail or during transportation [50].

6.2 Chemical contamination of food

Chemical contamination is any food contaminated by a chemical agent. For example, food is contaminated by cleaning agents and that can happen when using chemical cleaning during processing or when using chemical cleaning on tools and not cleaning well. Furthermore, there is natural chemical contamination such as toxins in some fish, such as methylmercury [51]. Also, contamination can happen in agriculture production when they spray fertilizers and pesticides close to food when it is growing. Therefore, it must be ensured that chemical agents are away from the food area. Always follow the manufacturers' instructions before using chemicals. Food must be covered when cleaning and dealt only with approved chemical suppliers [41].

There are many potential chemical contaminations related to chocolate that can happen at any stage of the food chain, which includes the existence of environmental contaminants such as pesticides above the allowance level, as well as presence of food additives in dark chocolate or heavy metals or addition of food additives, which are not permitted for use by government regulations [50].

This type of contamination, either industrial contaminants or pesticides, is most commonly related to chocolate products in Africa, South America, and Asia [48]. Another study proved that some cocoa products exceed the European Union and Chinese Maximum Contaminant Level regarding arsenic, cadmium, lead, and mercury, which could affect human health [52].

6.3 Physical contamination of food

Physical contamination of food is any food that contains a foreign object at any stage of the production process. That foreign substance causes health issues for consumers, such as broken teeth or choking [41]. There are many food products recalled every year because of physical contamination, which causes consumers health issues and costs less. There are many real examples from the Food and Drug Administration (FDA) 2016 product recall list such as "small metal shavings in apple coffee cakes, metal fragments in sugar used in Asian sauce, plastic mesh screen fragments in flour, and pieces of rubber in baby food" [53].

An example of physical contamination in almond processing is that, when the crop is ready for harvesting, the tree is shacked by a tractor machine, which leads to falling of almonds on the ground, which are left for many days to dry. Then, another machine sweeps them into rows so a harvester can pick them up with a series of belts. The almonds are cleaned by the machine and dumped into a bucket in the back of the truck. Then the truck is transferred to the industry to remove the shells and sticks and clean the product. The industry machines can be damaged and worn out, which could lead sometimes to the transfer of small pieces of that machinery into a package. This could include bolts and washers. Therefore, using technology in processing plants is an important role such as using X-rays and sensors and food metal detectors to identify any foreign substance to protect humans' health [53].

6.4 Allergenic contamination of food

Food allergies are an individual adverse reaction to some food. Food allergens are proteins that can be found in food in huge amounts [54]. Even a small amount of food is enough to impact a person who has a food allergy [41]. According to the Food Safety Authority of Ireland [55], there are 14 named allergens (**Table 2**).

Allergic food contamination can happen when food from the list of food allergies enters or contacts another food. An example of this is using the same container to store pasta that is already selected to store peanuts. Therefore, it must be ensured to

	Food allergen products
1	Cereals containing gluten such as wheat
2	Crustaceans and products thereof
3	Eggs and products thereof
4	Fish and products thereof
5	Peanuts and products thereof
6	Soybeans and products thereof
7	Milk and products thereof
8	Nuts, which are almonds, hazelnuts, walnuts, cashews, pecan nuts, Brazil nuts, pistachio nuts, macadamia or Queensland nuts, and products thereof
9	Celery and products thereof
10	Mustard and products thereof
11	Sesame seeds and products thereof
12	Sulfur dioxide and sulfites at concentrations of more than 10 mg/kg
13	Lupin and products thereof
14	Molluscs and products thereof

Table 2.
Food allergies products.

deal only with approved suppliers who take critical control of allergenic contamination. Always separate tools, equipment, and clothes that are used for allergenic foods from other foods. Separate allergen in storage from other foods. Cleaning must be implemented properly in the area after the use of one of the 14 allergen products.

Many food safety concerns can be avoided when implementing an effective prerequisite program that includes cleaning and sanitation, staff training, maintenance, chemical control, waste management, and storage and transportation [56]. Hygiene must be implemented in the chocolate industry to provide safe products to protect consumers [57].

It should provide maintenance of food equipment and infrastructure; this can be done by regularly auditing all equipment used in the chocolate factory and fixing any problem, which could post hygiene issues and food safety. Also, hygiene must be maintained during maintenance and the equipment cleaned after that and sanitized before using it again, and the product carefully protected from any foreign body. For the infrastructure part, it should follow a regular check to protect the production area from any issues such as soil and dust to keep the environment safe and hygiene. Any repair must be done outside of production periods, but if that is not possible, a separation wall must be set to protect the production area [57].

Also, it must follow cleaning and disinfecting daily in the industry and removing any undesirable substances such as residues and foreign bodies, which could affect the hygiene of products or equipment. Also, it must separate chemical agents apart from food products to prevent cross-contamination, and all storage should be cleaned regularly [57].

In general, food industries, particularly the chocolate industry attracts insects and rodents through the odors as this place is seen as a great environment for insects because of the presence of food and water and shelter. Therefore, pest control must be implemented effectively, and auditing inspection should be followed regularly and correct any failure related to that. Moreover, it must protect the chocolate production from any contamination, so it should set rules for staff working and visitors

such as regularly washing their hands and wearing gloves, mouth masks, hairnets, and clean disinfected clothing [57]. Regarding peanuts and other nuts, they should be segregated as much as possible. It should clean any machine correctly during changing from nut products to other products and must refer to the label that this industry is processing nuts. A further step that should be implemented is using a metal detector to ensure that the product is free from any foreign body such as plastic or other [58].

Furthermore, applying a Hazard Analytical Critical Control Point is required to prevent any type of contamination as this system is to reduce or prevent any risks early before it happens [56]. A Critical Control Point (CCP) is referred to as a step that can be applied, and it is a necessity to prevent or reduce food safety hazards. Most steps include a heating, cooking, or cooling stage. Examples of critical control points in chocolate production include roasting cocoa at temperatures between 105°C and 120°C and at specific times to eliminate pathogens. The further step is metal detection.

Also, there are many control points in chocolate production, for example:

- Receiving, which is required visual inspection, and use of chemical-free materials
- Splitting; use sanitized equipment and personal hygiene.
- The fermentation that is required visual inspection, and regular maintenance of fermentation tanks.
- Drying, which needs visual inspection, observation of time, and temperature.
- Roasting is very important to follow the correct time and temperature to kill pathogens.
- Grinding required also visual inspection and sanitization of equipment.
- Coaching that includes visual inspection and proper maintenance of equipment.
- Tempering—visual inspection, sanitized equipment
- Molding—ensure molds are clean.
- Packing—metal detection, food-grade inks, appropriate packaging materials, correct labeling [59].

7. Conclusions

In conclusion, cocoa is an important product globally as it provides many health benefits for people such as reducing the risk of heart disease, reducing blood pressure, and working as an anti-inflammatory substance. However, consuming too much could lead to many negative impacts on human health such as diabetes or overactivation for children because of the presence of caffeine and weak bone for elderly people, subsequently should avoid eating a lot of chocolate. Also, more research is needed to establish more health benefits. Chocolate is considered a low-risk product, but there are many contaminants linked to it, which could cause many

health issues; therefore, good hygiene practices and the HACCP system should be followed to provide safe products.

Conflict of interest

The authors declare no conflict of interest.

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