CHOCOLATE PRODUCTION, NUTRIENTS AND HEALTH BENEFITS*

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ABSTRACT

Chocolate is defined as the final product formed by grinding the roasted cocoa beans with cocoa butter, and sugar and adding emulsifier and vanilla to this mixture. There are basically three types of chocolate: dark (bitter), milk and white. Dark chocolate consists of sugar, cocoa butter, and cocoa liquor. Milk chocolate consists of the same ingredients as dark chocolate but contains milk (milk powder). White chocolate, on the other hand, consists of sugar, cocoa butter and powdered milk, but no cocoa liquor. In this article dark chocolate production processes such as mixing and thinning, conching and tempering were investigated. Recent studies on nutrients and health benefits of chocolate were discussed as well.

***Key words**: Chocolate, Thinning, Conching, Tempering, Health benefits*

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INTRODUCTION

Chocolate is the product formed by grinding the roasted cocoa beans and mixing them with cocoa butter and sugar, and adding emulsifier and vanilla to this mixture. Although the production of chocolate from cocoa beans is an industrial process, the stage from harvesting the cocoa seed to obtaining the bean takes place with a natural fermentation in the producing countries. Cocoa tree belongs to *Theobroma cacao*. Cocoa beans are in melon-like fruits, and during fermentation, this pectinaceous pulp surrounding beans is broken down and partially separated from the beans. One fruit contains about 20-22 cocoa beans **[1]**. Fermentation consists of a natural, seven-day microbial fermentation of the pulp at high temperatures of up to 50°C **[2]**. Some of the compounds that give flavor to cocoa are formed during this fermentation. Reduction of the amount of pectin by physical or mechanical means can also lead to an improved fermentation in reduced time **[2]**. The traditional fermentation is a result of a set of reactions catalyzed by a succession of microorganisms (yeasts, lactic acid bacteria, and acetic acid bacteria) that inoculate cocoa pulp spontaneously **[3]**. Finally, the fermentation end products formed, such as ethanol, lactic acid, and acetic acid kill the beans and cause production of flavor precursors **[2]**. Additionally, free amino acids, peptides and the inversion of sugars such as sucrose and the subsequent formation of reducing sugars occur **[3, 4]**. Cocoa is produced in different parts of the world, for example in Central and South America (Brazil, Ecuador, Peru, Papua New Guinea, Dominican Republic, Colombia, Venezuela, and Mexico), Africa (Ghana, Ivory Coast, Nigeria and Cameroon) and Asia (Indonesia, Malaysia, New Guinea). Cocoa beans contain a large amount of fat. It contains 50-54% fat, 10-15% protein, 4-5% moisture, 1% theobromine and 0.44% caffeine **[5]**. Cocoa butter consists of triglycerides formed by linoleic, oleic, palmitic and stearic acids with glycerol **[1]**. In this

article, the stages of the dark chocolate production process, the nutritional characteristics and health benefits of chocolate are examined in detail.

Dark chocolate production

According to the Turkish Food Codex, Cocoa and Chocolate Products Notification **[6],** dark chocolate is defined as a product consisting of cocoa products and sugar, containing at least 18% cocoa butter, 14% non-fat cocoa solid, and 35% total dry cocoa solids. Chocolate production flow chart is shown in Figure 1 **[7].** Dark chocolate production consists of five stages: mixing, refining, conching, tempering and crystallization (Figure 1). Each step in the production of chocolate has its own importance. In order to achieve the desired quality in chocolate, it is important to choose the right parameters in the production process as well as to use quality raw materials. In the refining process, it is aimed to reach the desired particle size with a three- or five-cylinder system and thus to obtain the desired smooth texture in the final product. This process also affects the rheological and sensory properties of the final product. Conching is accomplished by mixing the chocolate components at elevated temperatures on average >40°C. Conching time and temperature affect the texture, flavor and viscosity of chocolate **[8].** The crystalline network formed by lipids in the crystallization step affects some of the important physical and functional characteristics of chocolate (eg texture, crunching and shine). Tempering affects some other quality properties such as color, hardness and shelf life **[9].**

Mixing and Refining

The first step in chocolate production is to mix components such as sugar, cocoa liquor and cocoa butter into a paste. Mixer is shown in Figure 2. This mixture, which is prepared with an oil content of 8-24%, is refined to a particle size of less than 30 microns using two- and five-cylinder refiners. Particle size significantly affects the rheological and sensory properties of the final product **[7].** If the

particle size is larger than 30 microns, chocolate causes a rough texture in the mouth, and if it is smaller than 30 microns, it causes a paste-like texture [10].

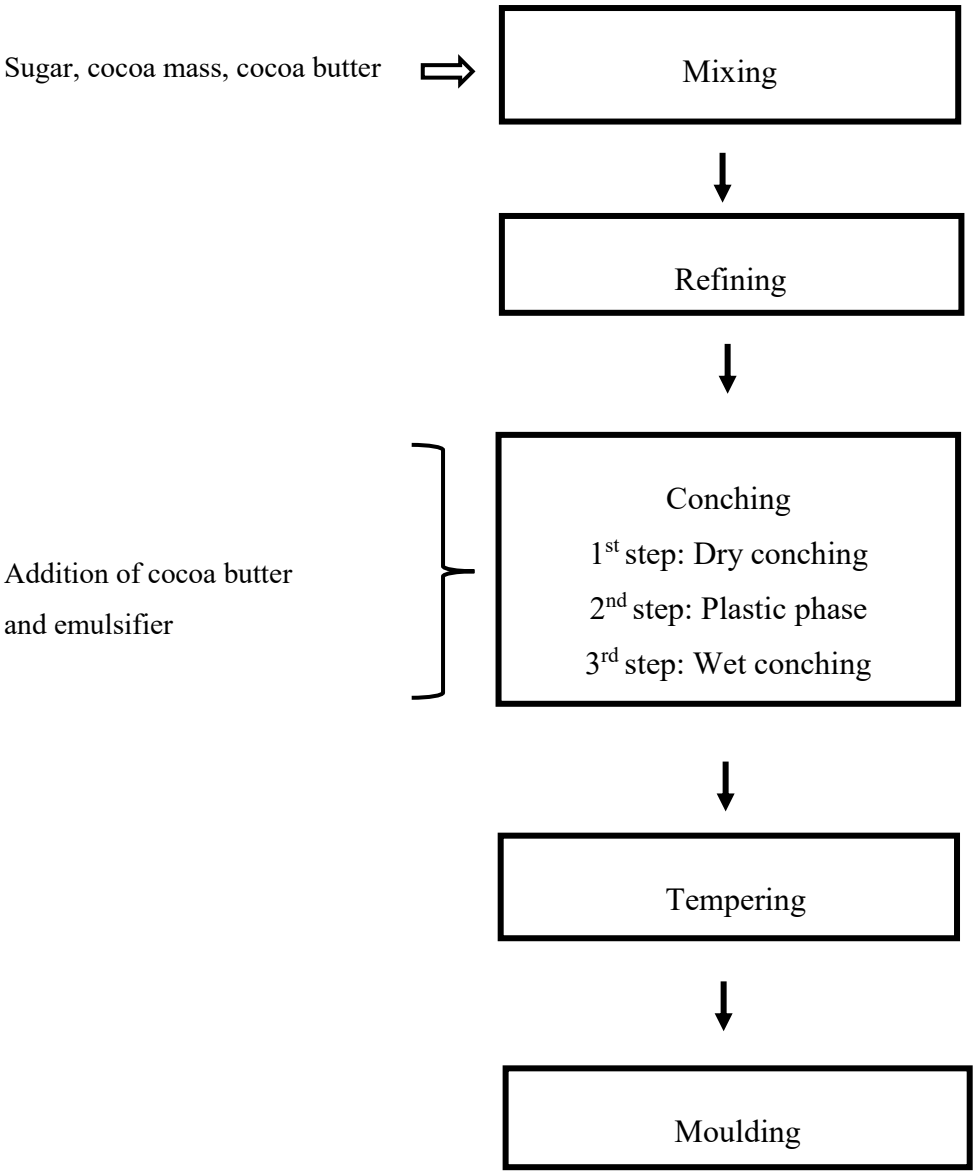

Figure 1. Chocolate production process **[7]**

Figure 2. Mixer

The five-cylinder (drum) refiner system consists of four vertically aligned hollow cylinders. Figure 3 shows the pilot scale refiner. The temperature control of these cylinders, which are held together by hydraulic pressure, is provided by the internal water flow. A thin layer of chocolate film is drawn into the accelerating drum and runs over the drum until it is separated by a scraper blade. The solid particles cut by the drum are coated with oil and form new surfaces and become active by absorbing volatile aroma compounds from cocoa components. Although the optimum particle size in dark chocolate varies according to the product and its composition, it should be as small as 35 microns. The refining process not only reduces particle size and prevents agglomeration, but also affects the dispersion of particles, each of which is coated with oil, throughout the continuous phase **[7].**

Figure 3. Pilot scale refiner

Conching

The refined mixture is subjected to conching, a process that contributes to the improvement of the taste, texture and viscosity of the final product **[7].** Conche is a scraper mixer that optimizes the flavor development of the final product and ensures that the chocolate mass becomes fluid. By mixing, the acidic flavors and moisture in the cocoa mass are reduced. Conching time is also important and plays an effective role on the texture, taste and quality characteristics of the final product **[10].** Conching time and temperature values vary depending on the type of chocolate. The average conching time in dark chocolate is 16-24 hours, and the temperature values can start from 70°C and increase up to 82°C. Cocoa butter and lecithin can be added towards the end of conching in order for the chocolate to reach the appropriate viscosity **[7].** In order to obtain a quality chocolate, it is required to go through three stages during conching: dry conching, plastic phase and wet conching. Figure 4 shows wet conching.

In the dry conching stage, the chocolate is in powder form and the moisture content is high. Too much moisture affects the fluidity of the product negatively. Since the surface of the chocolate powders is not completely covered with oil during the dry conching stage, this stage is very important to reduce the moisture

in the final product. At this stage, a chocolate with lower moisture content is produced by rapid heating and mixing of the powder. As the temperature rises,

Figure 4. Wet conching

the cocoa butter in the chocolate powder begins to melt and the particles stick together to form a paste-like structure. This stage constitutes the plastic phase of conching. Finally, oil and emulsifiers are added during the wet conching stage, ensuring that the chocolate has the right flow properties for the downstream processing steps **[11].**

Tempering

Cocoa butter may exhibit a series of crystallizations in polymorphic form as a function of triglyceride composition. The fatty acid composition affects the solidification of the oil and various physical crystallization conditions. Cocoa

butter has 6 polymorphic structures, they are expressed with Roman numerals from I to VI. The three basic polymorphic structures are α, β, β′. Form V (also called the β form) is the most desirable polymorphic form for a well-tempered chocolate, providing the desired brittleness and gloss in the product while also increasing its resistance to oil blooming **[12].** Tempering is very important for chocolate to be in a suitable polymorphic form and affects quality characteristics such as colour, hardness and shelf life. The tempermeter is shown in Figure 5. Tempering can take place in four basic steps. First, it is complete melting at 50°C, cooling to the crystallization point at 32°C, crystallization at 27°C, and transformation of all unstable crystals at 29–31°C **[12].**

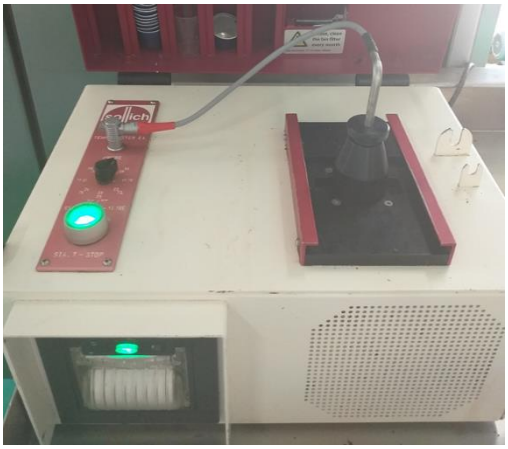

Figure 5. Tempermeter

Well-tempered chocolate should have good shape, colour, gloss properties and more stability, longer shelf life and harder properties. The reason why the tempering process differs in milk chocolate from dark chocolate is due to the different effects of milk fat in milk chocolate on crystal formation. In addition, the eutectic effect of milk fat has both an inhibiting effect on flowering and a softer texture and lower tempering temperature due to its lower melting point **[12].**

Nutrients and Health Benefits of Chocolate

The key ingredients in a chocolate formulation are; cocoa mass, cocoa butter, sugar and lecithin as emulsifier. However, the assortment in chocolate is the result of incorporating other ingredients such as nuts, dried fruits or cereals into formulations. The main categories of commercial chocolate are dark, milk and white chocolate, which differ in cocoa mass, milk fat and cocoa butter content **[13].** Typical nutritional values for different chocolate varieties are given in Table 1 **[11].** Chocolate and chocolate products, which have high energy and nutritional value, have an energy value of more than 3000 kcal/kg. Much of this high energy value comes from fat and carbohydrates. The most energy-rich component of chocolate is cocoa butter. Cocoa butter contains about 34% stearic acid, 34% oleic acid, 27% palmitic acid, all three of which are saturated fatty acids. Stearic acid has little effect on cholesterol levels. Oleic acid has a lowering or neutral effect on cholesterol levels. Palmitic acid, on the other hand, has moderate cholesterol-raising properties. Unsaturated fatty acids make up the rest of the cocoa butter, and cocoa butter contains almost no trans fatty acids **[11].** Chocolate also contains minerals, especially potassium, magnesium, copper and iron **[13].**

Table 1. Nutrition values for 100 g chocolate **[11].**

	Dark	Milk	White
Energy (kcal)	530	518	553
Protein (gr)	5	7	9
Carbohydrate (gr)	55	57	58
Fat (gr)	32	33	33
Calcium (mg)	32	224	272
Magnesium (mg)	90	59	27
Iron (mg)	3	2	0.2

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While most of the carbohydrates in chocolate come from sucrose, there are also small amounts of different carbohydrates in the dietary fibers found in cocoa. The type and amount of carbohydrates are important because of their effect on the glycemic index. The glycemic index is defined as the measure of the increase in blood glucose that occurs within two hours of consuming 50 grams of carbohydrates. Starchy products such as bread and potatoes are easily digested, causing a rapid rise in blood sugar. Conversely, since the amount of fat in foods slows the absorption of carbohydrates, the high fat content in chocolate causes blood sugar to rise more slowly, thus lowering the glycemic index **[11].**

The Aztecs and Mayans for many years enjoyed the use of cocoa beverages as beneficial for health. They believed cocoa products had therapeutic effects on diseases, as well. In recent years, scientific interest in the benefits of cocoa and chocolate products has increased again, especially in terms of reducing the risk of cardiovascular disease. Indeed, the positive effect of fat in the chocolate on cardiovascular diseases has been well documented **[14].** Recent research with a class of polyphenols and more specifically flavanols is relevant. Cocoa contains

epicatechin, catechin and procyanidin flavonols. It contains, polyphenols called tannins that contribute to chocolate's color and flavor. These tannins have been found to have anti-bacterial and anti-enzymatic activity. It reduces the formation of plaque on the teeth and prevents the formation of acid. Polyphenols are active compounds found found in a wide variety of foods, such as vegetables, fruits, tea, coffee, and red wine. Since dark chocolate contains more cocoa, the amount of polyphenols is higher than milky chocolate **[11].** Ten grams of dark chocolate contains approximately 120-150 mg of polyphenols **[12].**

It has been stated that cocoa flavonols can limit the progression of cardiovascular diseases by their anti-blood clotting, anti-inflammatory and antioxidant activities **[10, 11].** Flavanols can affect the reactivity of platelets and prevent blood clotting by reducing their tendency to agglomerate. In addition, flavonols have been observed to suppress some inflammatory reagents and increase anti-inflammatory nitric oxide. Studies have shown that cocoa and chocolate products cause an improvement in blood pressure and blood flow due to their effects on nitric oxide **[11].** In addition, regular consumption of dark chocolate has a protective effect against cardiovascular diseases in healthy individuals by reducing oxidative stress, decreasing arterial pressure and improving endothelial function **[11, 12].** There is the possibility that the inclusion of bioactive compounds found in chocolate in the diet may improve coronary circulation and ultimately reduce stroke and cardiovascular diseases. In a study by Fernández-Murga **[14]** and Fanton et al **[15],** the relationship between chocolate consumption and cardiovascular disease risk was investigated. It has been determined that chocolate consumption (<100 g/week) can reduce the risk of cardiovascular disease. However, it has been reported that excessive consumption of chocolate may cause adverse effects due to high sugar consumption, and approximately 45 g/week of chocolate is an appropriate dose **[10].**

Flavonols have an antioxidant effect against life-threatening diseases such as cancer, which helps prevent damage caused by free radicals in the body. It has been stated that the antioxidant activity produced by the consumption of dark chocolate, which is rich in flavonols, is higher than that of other antioxidant-rich foods and beverages such as green tea, red wine, blueberries and garlic **[10]**. Methylxanthines are a group of chemicals found in more than 60 plant varieties. Caffeine and theobromine compounds are found in significant amounts as methylxanthine in chocolate. It has been determined that caffeine stimulates the central nervous system. Cocoa also contains many other active compounds such as phenylethylamine, anandamide and tryptophan, all of which are thought to induce cravings for chocolate **[11].**

Chocolate consumption has positive physiological effects as well as psychological effects. Chocolate consumption can create an antidepressant effect by supporting the production of the neurotransmitter serotonin **[16].** In a study conducted with thirteen thousand six hundred and twenty-six (13.626) adults, the relationship between chocolate consumption and depression symptoms were evaluated and it was determined that dark chocolate consumption reduced the incidence of clinically depressive symptoms **[17]**. Also, another study showed that chocolate has a psychoactive property on improving stress and mood. In a study of three different types of chocolate (40g dark chocolate, 40g milk chocolate, 40g white chocolate) over two weeks, students who consumed dark or milk chocolate had reduced stress levels **[18]**. In a study conducted with 26 individuals who consumed 25 g of high polyphenol dark chocolate every day for 4 weeks, their mood and salivary cortisol levels were examined and a decrease in total daily cortisol, morning cortisol and cortisol/cortisone ratio was observed **[19].**

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