CHOCOLATE AND COCOA

1. Introduction

The name *Theobroma cacao*, food of the gods, indicating both the legendary origin and the nourishing qualities of chocolate, was bestowed upon the cacao tree by Linnaeus in 1720. All cocoa and chocolate products are derived from the cocoa bean, the seed of the fruit of this tree. Spanish explorers to the New World encountered the use of cocoa beans among the Aztec of Mexico and the Maya of the Yucatan as an ingredient in preparing a chocolate flavored drink much prized by the ruling class. The cultivation of cocoa trees in Mexico was underway for at least 1000 years before the Spanish arrival based on Mayan pottery inscriptions. In the *True History of Chocolate*, credit is given to the even more ancient Olmec civilization in southern Mexico for the first domestication and use of cocoa (1).

The terms cocoa and cacao often are used interchangeably in the literature. Both terms describe various products from harvest through processing. In this article, the term cocoa will be used to describe products in general and the term cacao will be reserved for botanical contexts. Cocoa traders and brokers frequently use the term raw cocoa to distinguish unroasted cocoa beans from finished products; this term is used to report statistics for cocoa bean production and consumption.

2. Standards for Cocoa and Chocolate

In the United States, chocolate and cocoa are standardized by the U.S. Food and Drug Administration under the Federal Food, Drug, and Cosmetic Act. The current definitions and standards resulted from prolonged discussions between the U.S. chocolate industry and the Food and Drug Administration (FDA). These definitions and standards were originally published in the *Federal Register* of December 6, 1944. The current standards for chocolate and cocoa products can be found in the Code of Federal Regulations (CFR), Title 21, Part 163-Cacao Products.

The Food and Agricultural Organization (FAO) and the World Health Organization (WHO) jointly sponsor the Codex Alimentarius Commission, which conducts a program for developing worldwide food standards. The Codex Committee for Cocoa Products and Chocolate has developed standards for chocolate (Codex Standard 87-1981), and cocoa powders and dry cocoa–sugar mixtures (Codex Standard 105-1981). Currently, a proposed draft standard for cocoa and chocolate products is before Codex for review. As a member of the Codex Alimentarius Commission, the United States is obligated to consider all Codex standards for acceptance.

The FDA announced in the *Federal Register* of January 25, 1989 a proposal to amend the U.S. chocolate and cocoa standards of identity. These amendments were in response to a citizen petition submitted by the Chocolate Manufacturers Association (CMA) and to better align U.S. standards with Codex. The new standards published as a final rule in the *Federal Register* of May 21, 1993, allow for the use of nutritive carbohydrate sweeteners, neutralizing agents, and emulsifiers; reduce slightly the minimum milkfat content and eliminate the nonfat milk solids/milkfat ratios in certain cocoa products including milk chocolate; update the language and format of the standards; and provide for optional ingredient labeling requirements. FDA has also received a proposal to establish a new standard of identity for white chocolate. Comments regarding the proposal amendments are under review by FDA, and a final ruling is expected to be issued in the near future.

2.1. White Chocolate. There is no standard of identity published for white chocolate in Title 21, Part 163 of the CFR. FDA published a proposal to establish a standard of identity for white chocolate in the *Federal Register* of March 10, 1997. The proposal was in response to citizen petitions filed by Hershey Foods Corporation (December 1992) and CMA (March 1993) requesting that FDA issue a standard of identity for white chocolate. Current products labeled white chocolate are operating under a temporary marketing permit. The presence of a standard would eliminate confusion over the content of products that are customarily referred to as white chocolate. A standard for white chocolate would also promote regulatory harmonization among nations that have already adopted a standard.

White chocolate has been defined by the European Economic Community (EEC) Directive 75/155/EEC as free of coloring matter and consisting of cocoa butter (not $<20\%$); sucrose (not $>55\%$); milk or solids obtained by partially or totally dehydrated whole milk, skimmed milk, or cream (not $<14\%$); and butter or butter fat (not $< 3.5\%$). In the proposed U.S. standard, white chocolate contains not <20% cocoa butter, not <14% total milk solids, not <3.5% milk fat, and not >55% nutritive carbohydrate sweetener.

3. Cocoa Beans

The cocoa bean is the basic raw ingredient in the manufacture of all cocoa products. The beans are converted to chocolate liquor, the primary ingredient from which all chocolate and cocoa products are made. Figure 1 depicts the conversion of cocoa beans to chocolate liquor, and in turn to the chief chocolate and cocoa products manufactured in the United States, ie, cocoa powder, cocoa butter, and sweet and milk chocolate.

Significant amounts of cocoa beans are produced in ~30 different localities. These areas are confined to latitudes 20° north or south of the equator. Although cocoa trees thrive in this very hot climate, young trees require the shade of larger trees such as banana, coconut, and palm for protection.

New cocoa hybrids and selections have been developed in Malaysia and other countries that produce significantly higher yields in select soil and climate conditions. In addition, high density plantings have demonstrated higher and

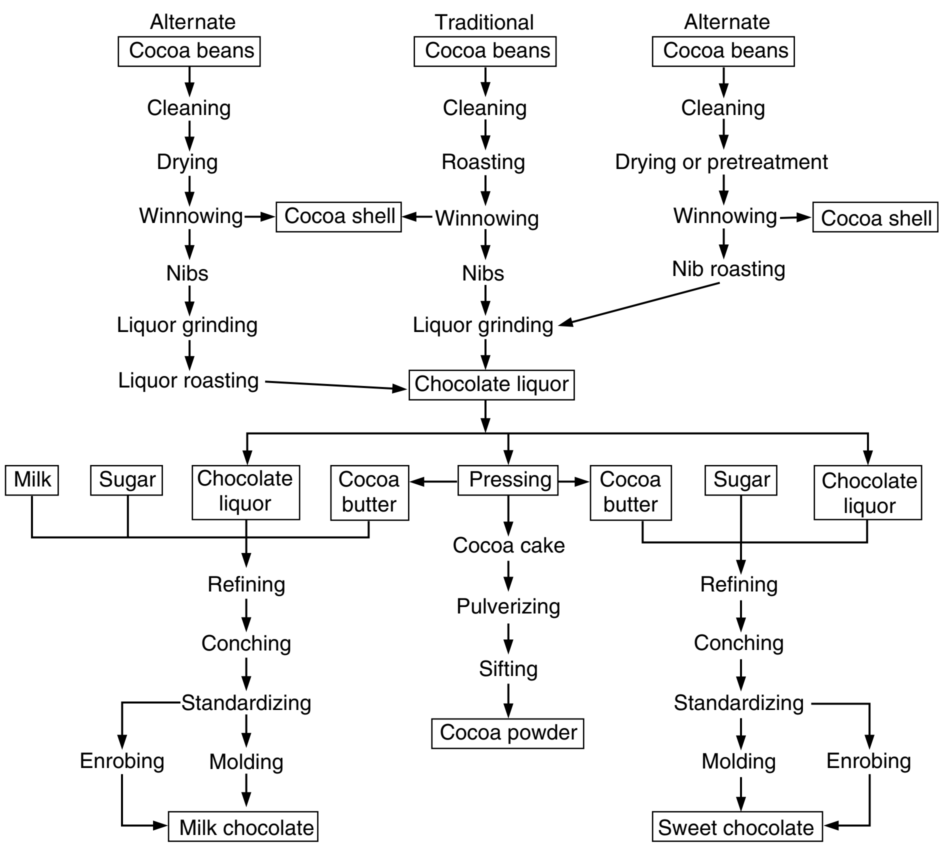

Fig. 1. Flow diagram of chocolate and cocoa production.

earlier yield in Malaysia and the Philippines. Low or no shade cocoa has also proven to increase yields. However, both high density and reduced shade cocoa production requires additional inputs of management and nutrition. Additional inputs to control pests and diseases also may be required.

A cocoa tree produces its first crop in 3–4 years and a full crop after 6–7 years. A full grown tree can reach a height of 12–15 m but is normally trimmed to 5–6 m to permit easy harvest. Because of differences in climate the crop is not confined to one short season but may extend for several months. Indeed some areas have cocoa pods almost all year long with one or two minor peaks. Many areas have peak harvests; for example, in West Africa there is one large main crop (80% or more of total crop) from September to March and a small or medium-sized crop in May. Brazil on the other hand has two crops a year that are almost equal in size.

3.1. Fermentation (Curing). Prior to shipment from producing countries, most cocoa beans undergo a process known as curing, fermenting, or sweating. These terms are used rather loosely to describe a procedure in which seeds are removed from the pods, fermented, and dried. Some unfermented beans, particularly from Haiti and the Dominican Republic, are also used in the United States.

The age-old process of preparing cocoa beans for market involves specific steps that allegedly promote the activities of certain enzymes. Various methods of fermentation are used to the same end.

Fermentation plays a principal role in flavor development of beans by mechanisms that are not well understood (2). Because freshly harvested cocoa beans are covered with a white pulp rich in sugars, fermentation begins almost immediately upon exposure to air. The sugars are converted to alcohol, and finally to acetic acid, which drains off, freeing the cotyledon from the pulpy mass. The acetic acid and heat formed during fermentation penetrate the skin or shell, killing the germ and initiating chemical changes within the bean that play a significant role in the development of flavor and color. During this initial stage of fermentation, the beans acquire the ability to absorb moisture, which is necessary for many of the chemical reactions that follow.

3.2. Commercial Grades. Most cocoa beans imported into the United States are one of about a dozen commercial varieties that can be generally classified as Criollo or Forastero. Criollo beans have a light color, a mild, nutty flavor, and an odor somewhat like sour wine. Forastero beans have a strong, somewhat bitter flavor and various degrees of astringency. The Forastero varieties are more abundant and provide the basis for most chocolate and cocoa formulations. Table 1 shows the main varieties of cocoa beans imported into the United States. The varieties are usually named for the country or port of origin.

3.3. Bean Specifications. Cocoa beans vary widely in quality, necessitating a system of inspection and grading to ensure uniformity. Producing countries have always inspected beans for proper curing and drying as well as for insect and mold damage. Recently, a procedure for grading beans has been established at an international level. This ordinance, reached primarily through the efforts of FAO, has been adopted by Codex as the model ordinance for inspection and grading of beans. It classifies beans into two principal categories according to the fraction of moldy, slaty, flat, germinated, and insect-damaged beans (3).

Table 1. **Main Varieties of Cocoa Beans Imported into the United States**

Africa	South America	Pacific	West Indies
Ivory Coast	Bahia (Brazil)	Malaysia	Sanchez (Dominican Republic)
Accra (Ghana)	Arriba (Ecuador)	New Guinea	Grenada
Lagos	Venezuelan	Indonesia	Trinidad
Nigeria		Samoa	
Fernando Po			
Sierra Leone			

Cocoa beans are sometimes evaluated in the laboratory to distinguish and characterize flavors. Beans are roasted at a standardized temperature for a specific period of time, shelled, usually by hand, and ground or heated slightly to obtain chocolate liquor. The liquor's taste is evaluated by a panel of experts who characterize and record the particular flavor profile (3).

3.4. Blending. Most chocolate and cocoa products consist of blends of beans chosen for flavor and color characteristics. Cocoa beans may be blended before or after roasting, or nibs may be blended before grinding. In some cases, finished liquors are blended. Common, or basic beans, are usually African or Brazilian and constitute the bulk of most blends. More expensive flavor beans from Venezuela, Trinidad, Ecuador, etc, are added to impart specific characteristics. The blend is determined by the end use or type of product desired.

3.5. Production. Worldwide cocoa bean production has increased significantly over the past 10 years from $\sim$2.4 million t in the 1989–1990 crop year to $>$3.0 million t in 2000. The production share by country has also changed dramatically in the last 10 years. The big gainers were the Ivory Coast and Indonesia. The gains in Indonesia have helped to diversify production and partially shield the market from adverse weather-induced supply shocks. The biggest losers in production share have been Brazil and Malaysia. Table 2 lists production statistics for these countries (4).

3.6. Consumption. Worldwide cocoa bean consumption has increased over the past 10 years from $\sim$2.3 million t in the 1989–1990 crop year to almost 2.6 million t in 1999–2000 (4). Table 3 gives the annual tonnage of cocoa bean grind in leading countries. Total world cocoa grindings were 3.0 million t in 2000–2001 (4).

Table 2. **Production of Raw Cocoa Beans, 10^3t**

Region	1989–1990	1999–2000	2000–2001[a]
Ivory Coast	725	1409	1170
Brazil	348	123	152
Ghana	295	437	390
Malaysia	243	45	35
Nigeria	160	165	185
Indonesia	115	410	400
Other	521	472	480
Total	2407	3061	2812

[a] Forecasted data.

Table 3. **Grind of Raw Cocoa Bean, 10^3t**

Main cocoa grinding countries	1998–1999	1999–2000	2000–2001[a]
Netherlands	415	436	450
United States	406	439	438
Ivory Coast	225	235	265
Germany	197	215	227
Brazil	192	202	194
United Kingdom	167	168	162
France	124	142	145
Malaysia	105	115	115
Indonesia	75	85	75
Ghana	65	70	70
Russian Federation	47	60	70
Italy	73	64	65

[a] Estimated.

3.7. Marketing. Most of the cocoa beans and products imported into the United States are done so by New York and London trade houses. The New York Board of Trade is the parent company for the Sugar, Coffee, and Cocoa Exchange, which provides a mechanism by which both chocolate manufacturers and trade houses can hedge their cocoa bean transactions. Additional information on the functions of the Sugar, Coffee, and Cocoa Exchange can be found on internet websites at http://www.nybot.com or http://www.csce.com. (3) World bean prices have fallen from $1,640 per t in 1997–1998 to $1000 per t in 2001.

4. Chocolate Liquor

Chocolate liquor is the solid or semisolid food prepared by finely grinding the kernel or nib of the cocoa bean. It is also commonly called chocolate, unsweetened chocolate, baking chocolate, or cooking chocolate. In Europe chocolate, liquor is often called chocolate mass or cocoa mass.

4.1. Cleaning. Cocoa beans are imported in the United States in 70-kg bags. The beans can be processed almost immediately or stored for later use. They are usually fumigated prior to storage.

The first step in the processing of cocoa beans is cleaning. Stones, metals, twigs, twine, and other foreign matter are usually removed by passing beans in a thin layer over a large vibrating screen cleaner. Large objects are retained as the beans fall through a lower screen. The second screen removes sand and dirt that have adhered to the beans. Strategically placed magnets are commonly used to remove small pieces of metal.

4.2. Roasting. The chocolate flavor familiar to the consumer is primarily developed during roasting, which promotes reactions among the latent flavor precursors in the bean. Good flavor depends on the variety of bean and the curing process used. The bacterial or enzymatic changes that occur during fermentation presumably set the stage for the production of good flavor precursors.

Although flavor precursors in the unroasted cocoa bean have no significant chocolate flavor themselves, they react to form highly flavored compounds. These flavor precursors include various chemical compounds such as proteins, amino acids, reducing sugars, tannins, organic acids, and many unidentified compounds.

The natural moisture of the cocoa bean combined with the heat of roasting cause many chemical reactions other than flavor changes. Some of these reactions remove unpleasant volatile acids and astringent compounds, partially breakdown sugars, modify tannins and other nonvolatile compounds with a reduction in bitterness, and convert proteins to amino acids that react with sugars to form flavor compounds, particularly pyrazines (5). There are ~400–500 compounds that have been identified from volatile and non-volatile fractions of chocolate that contribute to chocolate flavor, including hydrocarbons, alcohols, aldehydes, ketones, esters, amines, oxazoles, and sulfur compounds (6).

Roasting is essentially a cooking process developed by craftsmen who were guided by their senses of smell and taste and their knowledge of how beans of differing degrees of roast behaved in the subsequent processes. The ease and efficiency with which the processes of winnowing, grinding, pressing, and conching can be performed is affected by the degree of roast.

Roasting conditions can be adjusted to produce different flavors. Low, medium, full, and high roasts can be developed by varying time, temperature, and humidity in the roaster. Low roasts produce mild flavors and light color; high roasts produce strong flavors and dark color (7).

Roasters have evolved from the coke-fired rotary drum type to continuous feed roasters. It is traditional to roast cocoa beans with the shell still on. However, other methods of roasting include nib roasting, in which the shell is first removed by a rapid or moist heating step, and liquor roasting (Fig. 1). The newer nib and liquor roasters are designed to subject the cocoa to more uniform heat conditions in addition to minimizing the loss of cocoa butter to the shell. Nib and liquor roasters do not need the high temperatures necessary for whole bean roasting and, therefore, can be considered more energy efficient. Roasting times vary from ~30 to 60 min. Actual temperature of the bean in the roaster is difficult to measure but probably ranges from as low as 70°C to as high as 180°C.

4.3. Winnowing. Winnowing, often called cracking and fanning, is one of the most important operations in cocoa processing. It is a simple process that involves separating the nib, or kernel, from the inedible shell. Failure to remove shell results in lower quality cocoa and chocolate products, more wear on nib grinding machines, and lower efficiency in all subsequent operations.

Because complete separation of shell and nib is virtually impossible, various countries have established maximum allowable limits of shell by weight; U.S. manufacturers average from 0.05 to 1%. The cocoa shell legal limit is 1.75% in the United States.

The analysis of cocoa shell (8) is given in Table 4. In the United States, shells are often used as mulch or fertilizer for ornamental and edible plants, as animal feed, and as fuel for boilers.

4.4. Grinding. The final step in chocolate liquor production is the grinding of the kernel or nib of the cocoa bean. The nib is a cellular mass containing

Table 4. **Analyses of Cocoa Shell from Roasted Cocoa Beans**

Component	Shell, %
water	3.8
fat	3.4
ash	
total	8.1
water-soluble	3.5
water-insoluble	4.6
silica, etc	1.1
alkalinity (as K_2O)	2.6
chlorides	0.07
iron (as Fe_2O_3)	0.03
phosphoric acid (as P_2O_5)	0.8
copper	0.004
nitrogen	
total nitrogen	2.8
protein nitrogen	2.1
ammonia nitrogen	0.04
amide nitrogen	0.1
theobromine	1.3
caffeine	0.1
carbohydrates	
glucose	0.1
sucrose	0.0
starch (taka-diastase method)	2.8
pectins	8.0
fiber	18.6
cellulose	13.7
pentosans	7.1
mucilage and gums	9.0
tannins	
tannic acid (Lowenthal's method)	1.3
cocoa-purple and cocoa-brown	2.0
acids	
acetic (free)	0.1
citric	0.7
oxalic	0.32
extracts	
cold water	20.0
alcohol, 85%	10.0

~50–56% cocoa fat (cocoa butter). Grinding liberates the fat locked within the cell wall while producing temperatures as high as 110°C.

Nibs are usually ground while they are still warm from roasting. The original horizontal three-tier stone mills and vertical disk mills have been replaced by modern horizontal disk mills, which have much higher outputs and are capable of grinding nibs to much greater fineness. Two modern machines in particular account for a large percentage of liquor grinding. One uses a pin mill mounted over a roller refiner. The pin mill grinds the nibs to a coarse but fluid liquor. The liquor is delivered to a roll refiner that reduces the particle size to a very fine limit. The second type is a vertical or horizontal ball mill. Coarsely ground nib is fed to the base of a vertical cylinder, which contains small balls in separate compartments. A central spindle causes the balls to rotate at very high speeds, grinding the liquor between them and against the internal wall of the cylinder (9).

5. Cocoa Powder

Cocoa powder (cocoa) is prepared by pulverizing the remaining material after part of the fat (cocoa butter) is removed from chocolate liquor. The U.S. chocolate standards define three types of cocoas based on their fat content. These are breakfast, or high fat cocoa, containing not $<22\%$ fat; cocoa, or medium fat cocoa, containing $<22\%$ fat but $>10\%$; and low fat cocoa, containing $<10\%$ fat.

Cocoa powder production today is an important part of the cocoa and chocolate industry because of increased consumption of chocolate-flavored products. Cocoa powder is the basic flavoring ingredient in most chocolate-flavored cookies, biscuits, syrups, cakes, and ice cream. It is also used extensively in the production of confectionery coatings for candy bars.

5.1. Cocoa Powder Manufacture. When chocolate liquor is exposed to pressures of 34–41 MPa (5000–6000 psig) in a hydraulic press, and part of the fat (cocoa butter) is removed, cocoa cake (compressed powder) is produced. The original pot presses used in cocoa production had a series of pots mounted vertically one above the other. These have been supplanted by horizontal presses that have 4–24 pots mounted in a horizontal frame. The newer presses are capable of complete automation, and by careful selection of pressure, temperature, and time of pressing, cocoa cake of a specified fat content can be produced.

Cocoa powder is produced by grinding cocoa cake. Cocoa cake warm from the press breaks easily into large chunks but is difficult to grind into a fine powder. Cold, dry air removes the heat generated during most grinding operations. Because the finished cocoa powder still contains fat, great care must be taken to prevent the absorption of undesirable odors and flavors.

Commercial cocoa powders are produced for various specific uses and many cocoas are alkali treated, or Dutched, to produce distinctive colors and flavors. The alkali process can involve the treatment of nibs, chocolate liquor, or cocoa with a wide variety of alkalizing agents (10).

Cocoa powders not treated with alkali are known as cocoa or natural cocoa. Natural cocoa has a pH of $\sim$4.8–5.8 depending on the type of cocoa beans used. Alkali processed cocoa ranges in pH from about 6 to as high as 8.5.

6. Cocoa Butter

Cocoa butter is the common name given to the fat obtained by subjecting chocolate liquor to hydraulic pressure. It is the main carrier and suspending medium for cocoa particles in chocolate liquor and for sugar and other ingredients in sweet and milk chocolate.

The FDA has not legally defined cocoa butter, and no standard exists for this product under the U.S. Chocolate Standards. For the purpose of enforcement, the FDA defines cocoa butter as the edible fat obtained from cocoa beans either before or after roasting. Cocoa butter as defined in the *U.S. Pharmacopeia* is the fat obtained from the roasted seed of *Theobroma cacao Linne*.

The Codex Committee on Cocoa Products and Chocolate defines cocoa butter as the fat obtained from cocoa beans with the following characteristics (11):

(1) Free fatty acid content (expressed as oleic acid) not >1.75% m/m.
(2) Unsaponifiable matter not >0.7% m/m, except in the case of press cocoa butter which shall not be >0.35% m/m.

Press cocoa butter is defined as fat obtained by pressure from cocoa nib or chocolate liquor. In the United States, this is often referred to as prime pure cocoa butter. Expeller cocoa butter is defined as the fat prepared by the expeller process. In this process, cocoa butter is obtained directly from whole beans by pressing in a cage press. Expeller butter usually has a stronger flavor and darker color than prime cocoa butter and is filtered with carbon or otherwise treated prior to use. Solvent extracted cocoa butter is cocoa butter obtained from beans, nibs, liquor, cake, or fines by solvent extraction (qv), usually with hexane. Refined cocoa butter is any of the above cocoa butters that has been treated to remove impurities or undesirable odors and flavors.

6.1. Composition and Properties. Cocoa butter is a unique fat with specific melting characteristics. It is a solid at room temperature (20°C), starts to soften ~30°C, and melts completely just below body temperature. Its distinct melting characteristic makes cocoa butter the preferred fat for chocolate products.

Cocoa butter is composed mainly of glycerides of stearic, palmitic, and oleic fatty acids (see FATS AND FATTY OILS). The triglyceride structure of cocoa butter has been determined (12,13) and is as follows:

tri-saturated, 3%;
mono-unsaturated (oleo-distearin), 22%;
oleo-palmitostearin, 57%;
oleo-dipalmitin, 4%;
di-unsaturated (stearo-diolein), 6%;
palmito-diolein, 7%;
tri-unsaturated, tri-olein, 1%.

Although there are actually six crystalline forms of cocoa butter, four basic forms are generally recognized as alpha, beta, beta prime, and gamma. The γ (gamma) form, the least stable, has a melting point of 17°C. It changes rapidly to the α (alpha) form that melts at 21–24°C. At normal room temperature the β' (beta prime) form changes to the β (beta) form, melting at 27–29°C, and finally, the β form is reached. It is the most stable form with a melting point of 34–35°C (14).

Since cocoa butter is a natural fat, derived from different varieties of cocoa beans, no single set of specifications or chemical characteristics can apply. Codex previously defined the physical and chemical parameters of the various types of cocoa butter (15) (Table 5). However, the Codex Committee recently simplified

Table 5. **Properties and Composition of Cocoa Butter**[a]

Characteristic	Press cocoa butter	Expeller cocoa butter	Refined cocoa butter
refractive index n_D^{40}, °C	1.456–1.458	1.453–1.459	1.453–1.462
melting behavior			
slip point, °C	30–40	30–34	30–34
clear melting point, °C	31–35	31–35	31–35
free fatty acids			
mol% oleic acid	0.5–1.75	0.5–1.75	0–1.75
saponification value			
mg KOH/g fat	192–196	192–196	192–196
iodine value, Wijs	33.8–39.5	35.6–44.6	35.7–41.0
unsaponifiable matter			
petroleum ether % m/m	not > 0.35%	not > 0.40%	not > 0.50%

[a] Contaminants not to exceed 0.5 mg/kg of arsenic, 0.4 mg/kg of copper, 0.5 mg/kg of lead, and 2.0 mg/kg of iron (16).

the standard for cocoa butter and no longer distinguishes between the various types (11).

6.2. Substitutes and Equivalents. In the past 25 years, many fats have been developed to replace part or all of the added cocoa butter in chocolate-flavored products. These fats fall into two basic categories commonly known as cocoa butter substitutes and cocoa butter equivalents. Neither can be used in the United States in standardized chocolate products. However, EU regulations allow for the use of specified vegetable fats in standardized chocolate as long as labeling requirements are met. In conformity with EU regulations only the following vegetable fats may be used in chocolate: illipe, palm oil, sal, shea, kokum gurgi, and mango kernel. However, the regulations allow for an exception—the use of coconut oil in chocolate used for the manufacture of ice cream and similar frozen products.

Cocoa butter substitutes of all types enjoy widespread use in the United States chocolate-flavored products. Cocoa butter equivalents are not widely used because of their higher price and limited supply.

Cocoa butter substitutes do not chemically resemble cocoa butter and are compatible with cocoa butter only within specified limits. Cocoa butter equivalents are chemically similar to cocoa butter and can replace cocoa butter in any proportion without deleterious physical effects (16,17).

Cocoa butter substitutes and equivalents differ greatly with respect to their method of manufacture, source of fats, and functionality; they are produced by several physical and chemical processes (18,19). Cocoa butter substitutes are produced from lauric acid fats such as coconut, palm, and palm kernel oils by fractionation and hydrogenation; from domestic fats such as soy, corn, and cotton seed oils by selective hydrogenation; or from palm kernel stearines by fractionation. Cocoa butter equivalents can be produced from palm kernel oil and other specialty fats such as shea and illipe by fractional crystallization; from glycerol and selected fatty acids by direct chemical synthesis; from edible beef tallow by acetone crystallization; or from domestic fats such as soy and cotton seed by enzymatic interesterification.

7. Sweet and Milk Chocolate

Most chocolate consumed in the United States is consumed in the form of milk chocolate and sweet chocolate. Sweet chocolate is chocolate liquor to which sugar and cocoa butter have been added. Milk chocolate contains these same ingredients and milk or milk solids (Fig. 2).

U.S. definitions and standards for chocolate are quite specific (20). Sweet chocolate must contain at least 15% chocolate liquor by weight and must be sweetened with a nutritive carbohydrate sweetener. Semisweet chocolate or bittersweet chocolate, though often referred to as sweet chocolate, must contain a minimum of 35% chocolate liquor. These products, sweet chocolate and semisweet chocolate, or bittersweet chocolate, are often simply called chocolate or dark chocolate to distinguish them from milk chocolate. Table 6 gives some typical formulations for sweet chocolates (6).

Sweet chocolate can contain milk or milk solids (up to 12% max), nuts, coffee, honey, malt, salt, vanillin, and other spices and flavors as well as a number of specified emulsifiers. Many different kinds of chocolate can be produced by careful selection of bean blends, controlled roasting temperatures, and varying amounts of ingredients and flavors (21).

The most popular chocolate in the United States is milk chocolate. The U.S. Chocolate Standards state that milk chocolate shall contain no <3.39 wt% of milk fat and not <12 wt% of milk solids. Milk chocolate can contain spices, natural

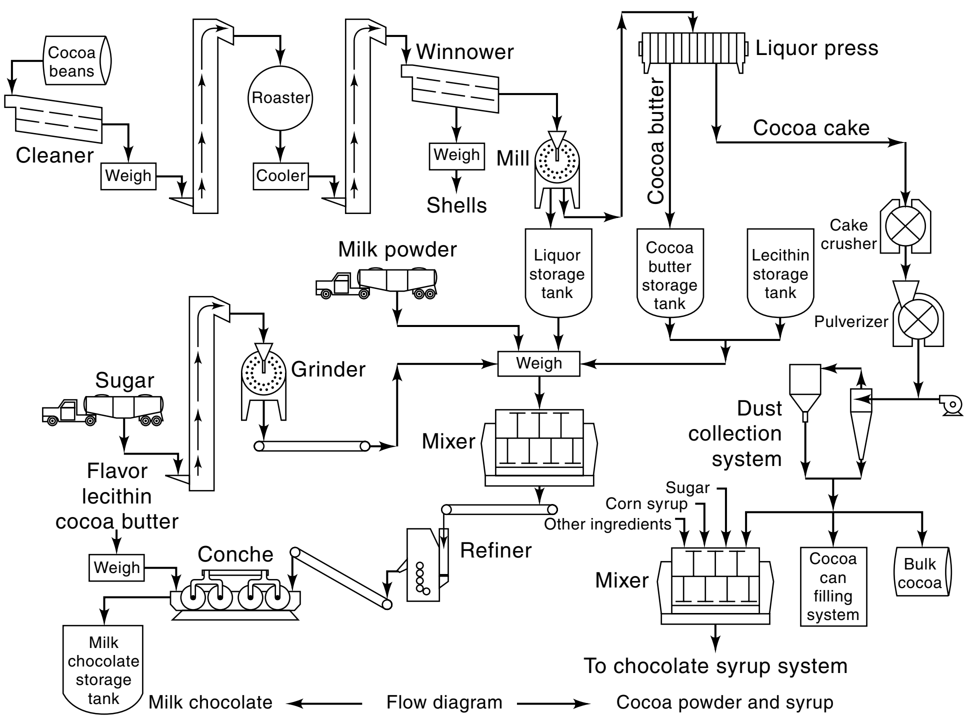

Fig. 2. Process flow diagram for milk chocolate, chocolate syrup, and cocoa powder.

Table 6. **Typical Forumulations for Sweet (Dark) Chocolates**

	Formulation, %		
Ingredient	1	2	3
chocolate liquor	15.0	35.0	70.0
sugar	60.0	50.4	29.9
added cocoa butter	23.8	14.2	
lecithin	0.3	0.3	
vanillin	0.9	0.1	0.1
Total fat	*32.0*	*33.0*	*37.1*

and artificial flavorings, ground whole nut meats, dried malted cereal extract and other seasonings that do not impart a flavor that imitates the flavor of chocolate, milk, or butter. In addition, chocolate liquor content must not be $<10\%$ by weight. Some typical formulations of milk chocolate and some compositional values are shown in Table 7 (6).

7.1. Production. The main difference in the production of sweet and milk chocolate is that in the production of milk chocolate, water must be removed from the milk. Many milk chocolate producers in the United States use spray-dried milk powder. Others condense fresh whole milk with sugar, and either dry it, producing milk crumb, or blend it with chocolate liquor and then dry it, producing milk chocolate crumb. These crumbs are mixed with additional chocolate liquor, sugar, and cocoa butter later in the process (22). Milk chocolates made from crumb typically have a more caramelized milk flavor than those made from spray- or drum-dried milk powder.

7.2. Mixing. The first step in chocolate processing is the weighing and mixing of ingredients which is usually a fully automated process carried out in a batch or continuous processing system. In batch processing, all the ingredients for one batch are automatically weighed into a mixer and mixed for a specific period of time. The mixture is conveyed to storage hoppers directly above the refiners. In the continuous method, ingredients are metered into a continuous kneader, which produces a constant supply to the refiners (23). The continuous process requires very accurate metering and rigid quality control procedures for all raw materials.

Table 7. **Typical Formulations for Milk Chocolate**

	Formulation, %		
Ingredient	1	2	3
chocolate liquor	11.0	12.0	12.0
dry whole milk	13.0	15.0	20.0
sugar	54.6	51.0	45.0
added cocoa butter	21.0	21.6	22.6
lecithin	0.3	0.3	0.3
vanillin	0.1	0.1	0.1
Total Fat	*30.9*	*32.6*	*35.0*

7.3. Refining. The next stage in chocolate processing is a fine grinding in which a coarse paste from the mixer is passed between steel rollers and converted to a drier powdery mass. Refining breaks up crystalline sugar, fibrous cocoa matter, and milk solids.

Tremendous advances have been made in the design and efficiency of roll refiners. The methods currently used for casting the rolls have resulted in machines capable of very high output and consistent performance. The efficiency of the newer refiners has also been improved by hydraulic control of the pressure between the rolls and thermostatic control of cooling water to the rolls.

Modern 5-roll refiners with 2-m wide rollers can process up to 2200 kg of paste per hour. The actual output is dependent on the desired particle size.

Particle size is extremely important to the overall quality of sweet and milk chocolate. Hence, the refining process, that controls particle size is critical. Fine chocolates usually have no particles >25 or 30 μm, which is normally accomplished by passing the paste through refiners more than once. However, smooth chocolates can be produced with only a single pass through the refiners if the ingredients are ground prior to mixing. Particle size has a significant effect on both texture and flavor of the finished chocolate.

7.4. Conching. After refining, chocolate is subjected to conching, a step critical to the flavor and texture development of high quality chocolates. Conching is a mixing–kneading process allowing moisture and volatile components to escape while smoothing the chocolate paste. It is one of the less satisfactorily explained parts of the chocolate making process and can embrace a wide range of phenomena, ranging from the relatively simple process of reliquefaction of a newly refined chocolate paste to complex and often controversial processes of flavor development, gloss development, agglomerate reduction, viscosity reduction, and modification of the melting quality.

The name conche derives from the seashell shape of the first really effective conching machine, which consisted of a tank with curved ends and a granite bed on which the chocolate paste from the refiners was slowly pushed back and forth by a granite roller. This longitudinal conche, the development of which is commonly attributed to Rodolph Lindt of Switzerland in 1879, is still used and many experts consider it best for developing subtle flavors.

Several other kinds of conches also are used today. The popular rotary conche can handle chocolate paste in a dry stage direct from the refiners (24). The recently developed continuous conche actually liquifies and conches in several stages and can produce up to 3600 kg of chocolate per hour in a floor area of only 34 m^2.

Conching temperatures range from 55–85°C for sweet chocolate and from 45–55°C for milk chocolate. Higher temperatures are used for milk chocolate if caramel or butterscotch flavors are desired (25).

Conching time varies from a few hours to many days and many chocolates receive no conching. Nonconched chocolate is usually reserved for inexpensive candies, cookies, and ice cream. In most operations, high quality chocolate receives extensive conching for as long as 120 h.

Flavors, emulsifiers, or cocoa butter are often added during conching. The flavoring materials most commonly added in the United States are vanillin, a vanillalike artificial flavor, and natural vanilla (26) (see FLAVORS AND SPICES). Cocoa butter is added to adjust viscosity for subsequent processing.

Several chemical changes occur during conching including a rise in pH and a decline in moisture as volatile acids (acetic) and water are driven off. These chemical changes have a mellowing effect on the chocolate (27).

7.5. Standardizing. In standardizing or finishing, emulsifiers and cocoa butter are added to the chocolate to adjust viscosity to final specifications.

Lecithin (qv), a natural phospholipid possessing both hydrophilic and hydrophobic properties, is the most common emulsifier in the chocolate industry (6). The hydrophilic groups of the lecithin molecules attach themselves to the water, sugar, and cocoa solids present in chocolate. The hydrophobic groups attach themselves to the cocoa butter and other fats such as milk fat. This reduces both the surface tension, between cocoa butter and the other materials present, and the viscosity. Less cocoa butter is then needed to adjust the final viscosity of the chocolate.

The amount of lecithin required falls within a narrow range of $\sim$0.2–0.6% (28). It can have a substantial effect on the amount of cocoa butter used, reducing the final fat content of chocolate by as much as 5%. Because cocoa butter is usually the most costly ingredient in the formulation of chocolate, the savings to a large manufacturer can be substantial.

Lecithin is usually introduced in the standardizing stage but can be added earlier in the process. Some lecithin is often added during mixing or conching. The addition at this point has the added advantage of reducing the energy necessary to pump the product to subsequent operations since the product viscosity is reduced.

Chocolate does not behave as a true liquid owing to the presence of cocoa particles and the viscosity control of chocolate is quite complicated. This non-Newtonian behavior has been described (29). When the square root of the rate of shear is plotted against the square root of shear stress for chocolate, a straight line is produced. With this Casson relationship method (30) two values are obtained, Casson viscosity and Casson yield value, which describe the flow of chocolate. The chocolate industry was slow in adopting the Casson relationship but this method now prevails over the simpler MacMichael viscometer. Instruments such as the Carri-Med Rheometer and the Brookfield and Haake Viscometers are now replacing the MacMichael.

At this stage of manufacture, chocolate may be stored for future use in bulk liquid form if usage is expected to be within 1–2 weeks, or at 43–50°C in a hot water jacketed agitated tank or in solid block form where it can be stored for as long as 6–12 months. Blocks typically weigh between 3 and 30 kg. Storage conditions for block chocolate should be cool and dry, ie, 7–18°C and 40–45% relative humidity. If chocolate has been stored in block form, it can be remelted to temperatures up to 50°C and then processed in the same manner as freshly made liquid chocolate.

At this stage, the chocolate is ready for forming into its final shape after it is tempered. The two most common forms are molding or enrobing.

7.6. Tempering. The state, or physical structure, of the fat base in which sugar, cocoa, and milk solids are suspended is critical to the overall quality and stability of chocolate. Production of a stable fat base is complicated because the cocoa butter in solidified chocolate exists in several polymorphic forms.

Tempering is the process of inducing satisfactory crystal nucleation of the liquid fat in chocolate.

Nucleation tempering of the still molten fat is necessary because the cocoa butter, if left to itself, can solidify in a number of different physical forms, ie, into an unstable form if cooled rapidly, or into an equally unacceptable super stable form if cooled too slowly, as commonly happens when a chocolate turns gray or white after being left in the sun. The coarse white fat crystals that can form in the slowly cooled center of a very thick piece of chocolate are similarly in a super stable form known in the industry as fat bloom.

Control of the polymorphic forms in cocoa butter is further complicated by the presence of other fats such as milk fat. The fat in a chocolate can be likened to the mortar between the bricks in a mason's wall. The solid particles in a well-conched chocolate bed down better than the solids in a coarsely refined and poorly mixed one (31).

A stable crystalline form for chocolate depends primarily on the method used to cool the fat present in the liquid chocolate. To avoid the grainy texture and poor color and appearance of improperly cooled chocolate, the chocolate must be tempered or cooled down so as to form cocoa butter seed crystals (32). This can be accomplished by cooling the warm (44–50°C) liquid chocolate in a water jacketed tank, which has a slowly rotating scraper or mixer. As the chocolate cools, the fat begins to solidify and form seed crystals. Cooling is continued to $\sim$26–29°C, during which time the chocolate becomes more viscous. If not further processed quickly, the chocolate will become too thick to process.

In another method of tempering, solid chocolate shavings are added as seed crystals to liquid chocolate at 32–33°C. This is a particularly good technique for a small confectionery manufacturer who does not produce his own chocolate. However, the shavings are sometimes difficult to disperse and may cause lumps in the finished product (21). Most companies use continuous thin-film heat exchangers for the tempering process.

7.7. Molding. The liquid tempered chocolate is deposited into a metal or plastic (polycarbonate) mold in the shape of the final product. There are three basic types of molding: solid (or block), shell, and hollow.

Solid chocolate, eg, Hershey's Milk Chocolate Bar, is the most common molding. The chocolate, either milk or dark, is deposited into a mold and the mold passes through a cooling tunnel with a residence time in the tunnel of $\sim$25 min. When the molds emerge from the tunnel, the chocolate is solidified. In addition to solidifying, the chocolate also contracts if it is correctly tempered, thus facilitating the removal of the bar from the mold. The demolded bar is then wrapped and packaged for shipment to the consumer.

Shell molding is a process by which a liquid or soft center is incorporated inside a chocolate shell. Modern equipment codeposits both the center filling and the chocolate shell in one step. The old method, and still the most common, is to form a hollow shell of chocolate in the mold followed by a short cooling tunnel. A filling is then deposited into the shell and sometimes followed by further cooling. A layer of chocolate then is deposited on top of the filling; this layer welds itself to the originally formed shell thus completely encapsulating the filling. The molds are cooled for a third and final time after which the pieces can be removed and wrapped.

Hollow molding as the name implies is a molded product with a hollow center such as Easter eggs, bunny rabbits, and Santa Claus. The molds used in hollow molding are divided in two halves and connected by a hinge. Chocolate is deposited into one-half of the mold. The mold is then closed and rotated so that the liquid chocolate completely coats the inside surface of the mold. After cooling the molds are opened and the piece removed.

7.8. Enrobing. A preformed center such as nougat, fondant, fudge, cookies, etc, is placed on a conveyor belt and passed through a curtain of liquid tempered chocolate. The weight and thickness of the coating adhering to the center is controlled by an air curtain and vibration mechanism located immediately after the chocolate curtain. The now chocolate-coated centers pass into a cooling tunnel with a dwell time between 5 and 10 min. Upon emergence from the cooling tunnel the chocolate-coated pieces are ready for wrapping and packing.

8. Theobromine and Caffeine

Chocolate and cocoa products, like coffee, tea, and cola beverages, contain alkaloids (qv) (1). The predominant alkaloid in cocoa and chocolate products is theobromine [83-67-0], though caffeine [58-08-2] is also present in smaller amounts. Concentrations of both alkaloids vary depending on the origin of the beans. Published values for the theobromine and caffeine content of chocolate vary widely because of natural differences in cocoa beans and differences in analytical methodology. This latter problem was alleviated by the introduction of high pressure liquid chromatography (HPLC), which has greatly improved the accuracy of analyses. HPLC values for theobromine and caffeine in a number of chocolate liquor samples have been published (33) (Table 8). Of the 12 varieties tested, the ratio of theobromine to caffeine varied widely from 2.5:1 for New Guinea liquor to 23.2:1

Table 8. **Variations in Theobromine and Caffeine Content of Various Chocolate Liquors**

Country of origin	Theobromine, %	Caffeine %	Total Alkaloid %	Theobromine/caffeine ratio
New Guinea	0.818	0.329	1.15	2.49:1
New Guinea	0.926	0.330	1.26	2.81:1
Malaysia	1.050	0.252	1.30	4.17:1
Malaysia	1.010	0.228	1.24	4.43:1
Bahia	1.210	0.183	1.39	6.61:1
Main Lagos	1.730	0.159	1.89	10.90:1
Light Lagos	1.230	0.137	1.37	8.98:1
Sanchez	1.570	0.177	1.75	8.87:1
Sanchez (small)	1.250	0.261	1.51	4.79:1
Fernando Po	1.470	0.064	1.53	23.00:1
Tabascan	1.410	0.113	1.52	12.50:1
Trinidad	1.240	0.233	1.47	5.32:1
average	1.240	0.206	1.45	7.91:1
maximum	1.730	0.330	1.89	23.00:1
minimum	0.818	0.064	1.15	2.49:1

Table 9. **Theobromine and Caffeine Content of Finished Chocolate Products**

Product	Theobromine, %	Caffeine, %
baking chocolate	1.386	0.164
chocolate flavored syrup	0.242	0.019
cocoa, 15% fat	2.598	0.247
dark sweet chocolate	0.474	0.076
milk chocolate	0.197	0.022

for that obtained from Fernando Po. Total alkaloid content, however, remained fairly constant, ranging from 1.15 to 1.89%.

The theobromine and caffeine contents of several finished chocolate products as determined by HPLC at Hershey's laboratories are presented in Table 9.

9. Nutritional Properties of Chocolate Products

Chocolate and cocoa products supply proteins, fats, carbohydrates, vitamins, and minerals. The Chocolate Manufacturers Association of the United States (Vienna, Virginia) completed a nutritional analysis from 1973 to 1976 of a wide variety of chocolate and cocoa products representative of those generally consumed in the United States. Complete nutritional data for the various products analyzed are given in Tables 10–14 for analyses conducted by Philip Keeney's laboratory at Pennsylvania State University, and in Table 15 for analyses done at South Dakota State University. Where possible, data on more than one sample of a given variety or type of product are presented.

9.1. Polyphenols. Chocolate and cocoa have been shown to be a rich source of antioxidant polyphenols. Flavonoids, a major subgroup, have been associated with the development of color and flavor. Flavonoids found in cocoa beans include epicatechin, catechin, and oligomers.

In fact, dark chocolate and cocoa were shown to contain more polyphenols on a dry defatted basis than 23 fruits, vegetables, and beverages (34). Data is growing indicating that polyphenols in the diet can help maintain cardiovascular health. Incorporating chocolate and cocoa in a diet that is rich in other food sources of antioxidants could reduce the risk of cardiovascular disease (35).

10. Economic Aspects

Chocolate consumption on a global basis was ~ $41 billion in 2000. In the United States, Hershey, Mars, and Nestlé control about 70% of the market. For Europe, Nestlé (including Rowntree), Mars, Kraft-Jacob Suchard (Philip Morris), Cadbury, and Ferrero control >70% of the chocolate trade. In Japan, Lotte, Meiji, Fujiya, Morinaga, and Ezaki Glico sell 88% of the chocolate. The reported

Table 10. **Amino Acid Content of Cocoa and Chocolate Products, mg/g**

		Chocolate liquor[a]		Cocoa[b]			Milk chocolate	
	Whole beans[c]	Natural	Dutch	Natural	Dutch	Sweet chocolate[d]	12% MS[e]	20% MS[f]
tryptophan	1.2	1.3				0.6		
threonine	3.5	3.9	3.6	7.7	8.0	1.5	1.8	2.8
isoleucine	3.3	3.8	4.0	7.0	7.4	1.4	2.2	3.5
leucine	5.3	6.0	6.3	11.5	11.3	2.3	3.8	6.1
lysine	4.8	5.1	5.1	8.7	8.3	1.9	2.4	3.9
methionine	0.7	1.1	0.9	2.0	1.7	0.4	0.9	1.4
cystine	1.4	1.1	1.0	2.1	2.1	0.4	0.3	0.4
phenylalanine	4.1	4.9	5.3	9.9	9.7	1.7	2.2	3.6
tyrosine	2.6	3.5	3.6	7.8	8.0	1.2	1.9	3.0
valine	5.1	5.8	6.3	11.1	10.9	2.1	2.7	4.3
arginine	5.0	5.3	5.1	11.3	11.3	1.9	1.2	1.9
histidine	1.6	1.7	1.7	3.4	3.0	0.6	0.7	1.0
alanine	3.8	4.3	4.1	8.7	8.4	1.5	1.4	2.3
aspartic acid	9.2	10.0	9.8	19.1	18.3	3.9	3.5	5.5
glutamic acid	12.8	14.1	14.1	28.0	26.2	5.7	8.5	13.7
glycine	4.0	4.4	4.5	8.3	8.5	1.6	1.0	1.6
proline	3.4	3.7	3.9	7.6	7.5	1.4	3.4	5.5
serine	3.7	4.1	4.0	6.8	8.2	1.5	1.9	3.0
Total AA recovered[g]	*75.5*	*84.1*	*83.3*	*162.0*	*158.8*	*31.6*	*39.8*	*63.4*

[a] Chocolate liquor = 55% fat.
[b] Cocoa = 13% fat.
[c] Whole beans = 48% fat, 5% moisture, 10% shell.
[d] Sweet chocolate = 35% chocolate liquor, 35% total fat.
[e] 12% MS milk chocolate = 12% whole milk solids, 10% liquor, 32% total fat.
[f] 20% MS milk chocolate = 20% whole milk solids, 13% liquor, 33% total fat.
[g] Total AA recovered = sum of individual amino acids (qv).

Table 11. **Composition of Cocoa Beans and Their Products, Whole Weight Basis in %**

	Total solids	Total protein[a]	Cocoa protein[b,c]	Fat	Ash	Total carbohydrates[d]
whole cocoa beans						
Ghana	92.9	10.1	10.1	47.8	2.7	30.3
	94.0	9.8	9.8	51.6	2.6	28.0
	94.5	10.2	10.2	46.4	2.9	33.0
	94.7	10.3	10.3	46.3	3.1	33.0
Bahia	94.0	10.0	10.0	49.3	2.7	30.0
	94.1	10.2	10.2	48.6	2.7	30.6
	95.1	10.2	10.2	48.2	2.7	32.0
	94.9	10.2	10.2	48.4	2.7	31.6
chocolate liquor						
natural	98.4	9.4	9.4	56.2	2.4	28.5
	98.5	10.2	10.2	55.1	2.6	28.6
	98.9	10.1	10.1	57.0	2.4	27.4
	98.5	9.2	9.2	55.4	3.8	28.5
Dutch	98.6	9.2	9.2	55.4	3.8	28.5
	99.2	9.4	9.4	56.0	3.8	28.1
cocoa						
natural	96.3	18.4	18.4	12.8	4.6	56.9
	96.2	18.4	18.4	16.4	4.8	52.9
	97.4	19.8	19.8	12.7	4.5	56.5
Dutch	97.1	17.5	17.5	12.0	8.3	55.9
	97.4	18.3	18.3	14.3	7.4	53.7
sweet chocolate						
	99.6	3.4	3.4	35.1	1.0	59.4
	99.3	3.8	3.8	36.5	1.0	57.3
	99.5	3.6	3.6	35.0	1.0	59.2
milk chocolate						
12%	99.2	4.2	1.0(3.2)	34.7	0.9	59.2
whole milk solids						
	99.5	4.3	1.1(3.1)	30.2	1.0	63.8
	99.6	4.5	1.1(3.4)	32.3	0.9	61.6
	99.5	4.0	1.4(2.6)	29.6	1.0	64.6
20%	98.8	6.6	1.3(5.2)	34.4	1.5	56.1
wholw milk solids						
	99.5	6.5	1.2(5.2)	33.1	1.4	58.3
	99.4	6.8	1.4(5.4)	30.5	1.5	60.4

[a] Total protein = milk protein + cocoa protein.
[b] Cocoa protein = (total nitrogen − milk nitrogen) × 4.7
[c] Milk protein = milk nitrogen × 6.38 appears in parentheses.
[d] Total carbohydrate by difference using cocoa nitrogen × 5.63.

international average for chocolate consumption was 14.2 lb per capita. Per capita chocolate consumption for some leading countries include:

Switzerland	23.11 lb
Germany	22.03 lb
Austria	20.57 lb
Ireland	18.81 lb
Norway	18.74 lb
United States	11.93 lb

Table 12. **Vitamin Content of Various Samples of Cocoa Beans and Chocolate Products,[a] Whole Weight Basis, mg/100 g**

Samples	B_1	B_2	Pantothenic acid	Niacin	B_6
whole cocoa beans					
Ghana	0.21	0.16	0.24	0.19	0.22
	0.17	0.18	0.35	1.07	0.21
	0.19	0.18	0.57	0.91	0.18
	0.16	0.15	0.32	0.52	0.01
Bahia	0.14	0.18	0.34	0.46	0.61
	0.17	0.18	0.35	1.13	0.16
	0.13	0.27	0.61	1.00	0.16
	0.16	0.16	0.38	0.81	0.09
chocolate liquor	0.08	0.17	0.20	0.88	0.09
	0.11	0.16	0.27	1.02	0.20
	0.08	0.15	0.17	1.01	0.16
	0.05	0.11	0.15	0.29	0.02
cocoa	0.05	0.19	0.33	1.34	0.17
	0.13	0.23	0.35	1.53	0.17
	0.15	0.22	0.32	1.37	0.24
milk chocolate	0.07	0.10	0.37	0.14	0.02
	0.11	0.24	0.37	0.38	0.02
	0.07	0.16	0.45	0.21	0.07
	0.10	0.25	0.61	0.24	0.08
	0.15	0.33	0.32	1.11	0.20

[a] Vitamin A and C, negligible amounts present.

The leading chocolate companies continue to pursue a global confectionery business strategy with an increase in the early 1990s of confectionery business activity in the Eastern Bloc countries, Russia, China, and South America. Generally as per capita income increases, chocolate consumption increases, and sugar consumption decreases. Consumer demographics, the declining child population, and the increase in consumer awareness of health issues play important roles in the economics of chocolate consumption. Chocolate confectionery busi-

Table 13. **Tocopherols of Chocolate of Cocoa Beans and Chocolate Products, mg/100 g**

	Total tocopherol	Alpha tocopherol
Bahia-Ghana beans	10.3	1.0
liquor, natural	10.9	1.1
liquor, Dutch	10.0	0.8
cocoa butter, natural	19.2	1.2
cocoa butter, Dutch	18.7	1.1
cocoa, natural	2.3	0.2
cocoa, Dutch	2.2	0.2
dark chocolate	6.0	0.7
milk chocolate, 12% milk	5.6	0.7
milk chocolate, 20% milk	6.3	0.7

Table 14. **Fatty Acid Composition of Raw Cocoa Beans and Cocoa Butter**[a]

	Fatty acid[b], mol %					
	14:0	16:0	18:0	18:1	18:2	20:0
cocoa beans						
Ghana	0.16	28.31	34.30	34.68	2.55	
	0.53	30.20	31.88	33.55	3.85	
	0.19	31.72	32.57	32.82	2.70	
	0.23	31.50	32.39	33.06	2.82	
Bahia	0.15	29.29	31.70	35.24	3.62	
	0.12	26.68	32.06	37.90	3.24	
	0.25	33.99	28.80	33.62	3.34	
	0.19	30.91	30.37	35.22	3.31	
natural cocoa butter	0.15	27.08	32.64	35.61	3.63	0.89
	0.19	27.68	32.64	35.03	3.63	0.83
	0.14	28.42	32.55	34.71	3.23	0.95
	0.14	27.29	32.41	35.36	3.70	1.10
Dutch cocoa butter	0.16	27.23	32.69	35.54	3.31	1.07
	0.15	26.63	34.24	34.68	3.52	0.78
	0.15	26.47	33.53	35.45	3.40	1.00

[a] Calculated from peak areas of the gas chromatograms.
[b] Fatty acid is designated by chain length followed by sites of unsaturation.

ness trends include product down-sizing leading to snack size finger foods, increased emphasis on specialty chocolates with concentration on dessert chocolates, chocolate with high liquor content, organic chocolate, chocolate made with cocoa beans from a specific origin, and chocolate brand equity spread into beverages, baked goods, frozen novelties, and even sugar confections.

Table 15. **Mineral Element Content**[a] **of Cocoa and Chocolate Products, mg/100 g**

Product	Ca	Fe	Mg	P[b]	K	Na	Zn	Cu	Mn
raw Accra nibs	59.56	2.50	232.15	385.33	626.70	11.98	3.543	1.930	1.600
raw Bahia nibs	52.73	2.45	229.11	383.33	622.55	13.55	3.423	1.940	2.060
natural cocoa	115.93	11.34	488.51	7716.66	1448.56	20.12	6.306	3.620	3.770
Dutch cocoa	111.41	15.52	475.98	7276.00	2508.58	81.14	6.370	3.610	3.750
chocolate liquor	59.39	5.61	265.23	3996.66	679.61	18.89	3.530	2.050	1.850
12% milk	106.41	1.23	45.56	159.00	156.64	80.09	0.773	1.020	0.282
chocolate 20% milk	174.00	1.40	52.26	207.96	346.33	115.40	1.240	0.126	0.139
chocolate dark chocolate	26.33	2.34	93.70	142.90	302.53	18.63	1.500	0.432	0.345

[a] Mean values from duplicate analyses of each of three samples by atomic absorption spectrophotometry.
[b] Total phosphorus–;ash below 550°C (AOAC procedure).

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