APPENDIX

10 Nutritional Properties of Cocoa

Robert Rucker

Relative to other seeds, the nutritive value of cacao may be viewed as very good to excellent based on its overall composition. Indeed, its ability to serve as a relatively complete food in part provides rationale as to why cocoa evolved as a substantial component of the diets in southern Mexico and Central and South America [1].

The cacao fruit or pod is melon-shaped (12–30 cm long and 8–12 cm wide) with an average weight of 400–600 g. Each pod usually contains 30–40 seeds or beans imbedded in a white pulp that is sweet when the pods are fresh. The seeds have a reddish brown external color and a dark brown interior owing to their rich polyphenolic content. The pulp is aromatic and mucilaginous, composed of spongy parenchymatous cells that contain a sap rich in carbohydrates. The beans and pulp together amount to about one-third to one-half the total weight of the pod (125–200 g). Although it takes 20 or more pods to harvest 1 kilogram of processed commercial cocoa powder, from a food perspective the beans and pulp from a single pod are sufficient to provide half the daily need of a small person (450–700 calories).

With regard to cocoa powder, 100 hundred grams (about $\frac{1}{4}$ pound) can provide 10–20 percent of the energy needs of a young adult [2] and contribute substantial amounts of a person's vitamin and mineral needs (Table A10.1) [3].

Cacao seeds contain about 40–50 percent fat and 14–18 percent protein depending on the time of harvest. Although cocoa is not an optimal vitamin source as a single food, on a per unit energy basis (e.g., expressed as an amount per calories), cocoa is adequate. As a single source of food, however, cocoa is an excellent source of essential minerals. For example, 50–100 grams of processed cocoa powder can easily meet the daily human needs of most of the essential so-called trace minerals or elements (Table A10.1). Regarding protein, its content in cacao is adequate on a caloric or energy basis, but the quality of the protein is somewhat marginal because the concentration of two essential amino acids, methionine and cysteine, is too low to meet independently human requirements (see section regarding Protein and Amino Acids and Fig. A10.1).

Lipids

The fat in cocoa (cocoa butter) is neutral in flavor. Of the caloric content in typical whole beans, about 50–60 percent comes from cocoa butter. The fatty acids that predominate the triacylglycerol (triglyceride) fraction of cocoa butter are oleic, palmitic, and stearic acids (>90 percent) in combination with several polyunsaturated fatty acids, mostly arachidonic and linolinic acids (5–10 percent). Although concern has been expressed about the high saturated fat content of cocoa butter, the usual health assumptions made regarding saturated fats

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Table A10.1 **Nutritional Properties of Cocoa: Cocoa as a Food Source**[a]

Nutrient or Component RDA[b]	Amount per 100 grams (Dry Powder)	Percentage of U.S. (grams per 100 grams Dry Powder)
Food energy	225–325 kcal (1000–1500 kJ)	See text
Protein (g)	18–19	See text
Fat (g)	20–25	See text
Carbohydrate (g)	45–55	See text
Fiber (g)	25–35	
Digestible (g)	10–20	
Simple sugars (g)	1–2	
Ash (minerals) (g):	5–6	
Calcium	100–180 mg	10–20
Phosphorus	750–1000 mg	100
Iron	10–15 mg	60–80
Magnesium	500–600 mg	100
Copper	4–6 mg	100
Zinc	5–10 mg	80–100
Potassium	1500–2000 mg	100
Manganese	3–5 mg	100
Selenium	15–20 µg	~40
Vitamins		
Vitamin A equivalents	10–20 RE (µg)	<1
Vitamin E	0.1–0.2 mg as αTE	<5
Vitamin K1	2.5 µg	<5
Vitamin B1, thiamin	0.1 mg	<10
Vitamin B2, riboflavin	0.2–0.3 mg	<20
Niacin	2–4 mg	<20
Vitamin B6, pyridoxine	0.1–0.2 mg	<10
Folate, total	32–40 mcg	10
Pantothenate	0.2–0.4 mg	<10
Other		
Polyphenols	7–18 g	
Theobromine	2–3 g	
Caffeine	0.1 g	
Cholesterol	0	

[a]Based on a composite of compositions for cocoa dry powder [3].
[b]Based on the needs of a small adult [2].

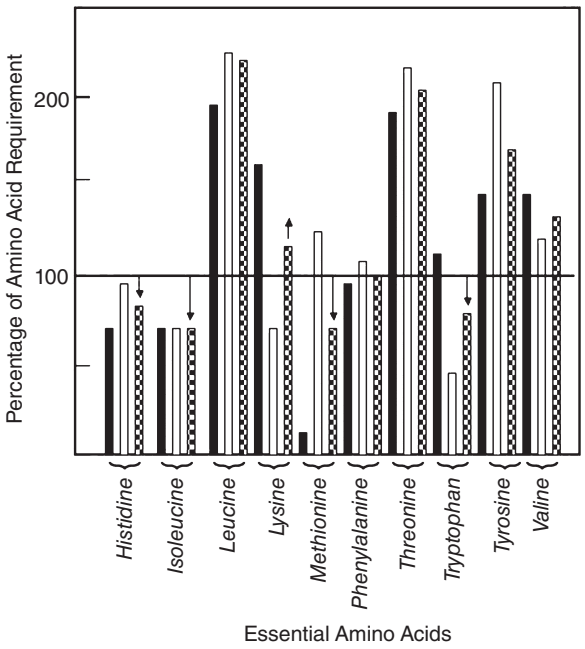

FIGURE A10.1. Amino acid requirements, cocoa and corn protein isolates and their combination. The ability of cocoa (solid bar), corn (open bar), or a combination (50:50 mixture, checkered bar) to meet human amino acid requirements is represented when fed these protein or the combination is fed at the equivalent of 25 grams of protein (i.e., about an ounce). The requirement for each amino acid is arbitrarily set at 100 percent [2]. By complementing corn protein, cocoa improves biological quality so that the requirement for lysine is met and the requirement for tryptophan is almost met. By complementing cocoa protein, corn improves biological quality so that the requirements for histidine and methionine are almost met. Either corn or cocoa when consumed at the equivalent of 25 grams of protein contain sufficient isoleucine to meet ~75 percent of the requirement.

may not apply to cocoa. The lipids in cocoa butter, for example, are not as efficiently or as rapidly absorbed as those in other vegetable fat because of the rather complex molecular configuration of these fatty acids in cocoa triglycerides, which slows the time for overall metabolism and, in particular, slows intestinal absorption [4, 5].

With respect to the consumption of cocoa butter and its effects on serum lipids, the slower rate of absorption of the triacylglycerides in cocoa butter and the high polyphenolic content in cocoa actually have a salutary effect. In humans fed cocoa, plasma LDL cholesterol, oxidized LDL (so-called bad cholesterol components), and apo B (an important lipoprotein polypeptide critical to LDL function) are decreased, while plasma HDL cholesterol (so-called good cholesterol) is increased [6–8].

Protein and Amino Acids

The protein content in cocoa beans is typical of many seeds but, as noted previously, protein quality—based on the distribution of certain essential amino acids—is relatively poor [3, 9]. Compared to a typical reference protein, for example, egg white, whose biological value and chemical score of 100 serves as a comparative baseline, the chemical score for cocoa protein is less than 25, due to the low amount of methionine, an

essential amino acid needed to make a "complete" protein. The chemical score is a method for rating proteins based on their chemical composition (more specifically the essential amino acid levels relative to a chosen reference). To determine the chemical score, a protein is picked as a reference and other proteins are rated relative to that reference protein. Typically, egg protein is used with the assumption that the amino acid profile of egg is the ideal for humans; that is, the essential amino acid requirements will be met when fed at the amount needed to meet the protein requirement [10].

For additional comparisons, the biological values and chemical scores for two relative "good" protein sources, soybean protein isolate and casein, are 65 and 50, respectively. The scores of 65 and 50 mean that when one of them is consumed as the sole source of protein, there is one essential amino acid whose content relative to the requirement is only 50–65 percent. However, many types of proteins are consumed through the course of a day. Cocoa was often coconsumed with corn, a very common practice in Central America and Mexico.

When proteins are consumed together, the chemical score of the mixture can markedly improve along with the biological quality depending on the relative distribution of different proteins in these two sources. When an improvement is achieved, the proteins are designated as complementary. Cocoa and maize are complementary in that the amino acid content of the mixture is improved. For example, methionine is higher in corn and the amino acid composition of cocoa improves the low lysine and tryptophan content of corn (Fig. A10.1). When human diets are sufficient in calories, the protein requirement needed to maintain positive nitrogen balance in a human is about 0.8 g per kg of body weight or 12–16 percent of total daily calories. Accordingly, with the appropriate complementation brought about by consuming cocoa and corn in combination, as little as $\frac{3}{4}$ ounces (about 25 grams) of crude protein from a 50:50 mix of cocoa powder and corn protein almost meets a person's essential amino acid needs.

Carbohydrate

Freshly harvested cocoa beans contain about 12–14 percent potentially digestible carbohydrate and considerable quantities of nondigestible carbohydrate or fiber. In fresh pulp there is sufficient simple sugar to have a sweet taste. The pulp also contains pentosans (2–3 percent), citric acid (1–2 percent), and salts (8–10 percent), mainly potassium complexes. However, after six or more days of bacterial fermentation, as per the traditional method of processing cacao beans, the digestible carbohydrate content and composition of the cocoa pod (pulp and beans) is altered significantly [11]. During this process the pulp is digested and a number of complex products are produced, among them various short-chain sugars and ketoacids, and eventually acetic acid and alcohol. The fermentation process also reduces the carbohydrate content of beans to 5–6 percent, owing to the production of fermentation products. In this regard, it is important to note that cacao beans may be prepared by simply drying them or curing them by fermentation, often referred to as "sweating," because of the heat and moisture produced. Drying usually produces a product that is more bitter than that prepared by "sweating" or extensive fermentation.

Vitamins and Minerals

Expressed as amounts per kilocalorie or other units of food-derived energy, cocoa is an excellent source of most essential minerals, especially calcium, copper, iron, manganese, magnesium, phosphorus, potassium, and zinc. For copper, iron, and magnesium, the human requirement on a caloric basis is often exceeded severalfold [2].

Although cocoa is not high in certain vitamins, when consumed with maize and with condiments and spices, especially pigmented fruits and vegetables, these complementary additions provide vitamins whose amounts are missing in cocoa. Noteworthy, the cacao shell has been reported to contain 20–30 International Units of vitamin D_2 (ergocalciferol) per gram or 300 International Units per gram of extractable fat. Consequently, by-products of cocoa—such as the shells—have been used successfully as components of animal feeds [12–15] to achieve maximal rates of growth or milk production.

Other Components

Some of the health effects of the other components in cocoa have been discussed in considerable detail elsewhere [16]. The amounts of nonnutritive compounds (only in the sense that they do not provide energy or may be classed as traditional vitamin) contained in 100 grams of cocoa powder are significant and may account for 20 percent of powder weight: polyphenolics, 7–18 grams (mostly anthocyanidins, proanthocyanins, and other catechin derivatives); theobromine, 2–3 grams; and caffeine, 0.1 gram per 100 g of powder.

Conclusion

For hundreds of years, chocolate in its many forms has been used as a food component. According to legend, the Mexican god Quetzalcoatl left the cocoa tree for the people, that is, as "the food of the gods." As a bean or seed, it is clearly superior to most beans from a

nutritional perspective. It is almost a complete food when the nutrient content is expressed per food Calorie. With appropriate complementation, cocoa is capable of serving as the central part of even a simple diet.

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