Cocoa

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HEAVY METAL INDEX · INGREDIENT PROFILE October 2026

DOI 10.83376/hmi.ingredient.cocoa

CITE AS

Pendergrass, K. (2026). Cocoa. Heavy Metal Index. https://doi.org/10.83376/hmi.ingredient.cocoa

CORRESPONDENCE

Corrections are logged publicly on the article page, each with its date, the affected value, and the source that resolved it.

KEYWORDS

heavy metals, food safety, dietary exposure

PUBLICATION HISTORY

This revision 2026-10-22.

Abstract

Cadmium is the metal that sets cocoa apart, and it travels with the cocoa solids. In the US retail survey by Abt and colleagues, mean cadmium was 700 µg/kg in cocoa powder, 270 µg/kg in dark chocolate and 60 µg/kg in milk chocolate. In Japan, the median rose from 23 µg/kg in chocolate under 50% cocoa to 250 µg/kg at 80% or more. Lead, by contrast, is usually lower and is driven more by what happens to the bean after harvest than by where it grew.

1 | Cocoa overview

Growing origin is the strongest supported lever for cadmium. In industry bean testing compiled for a California settlement, median bean cadmium was 55-94 µg/kg for Nigeria, Côte d'Ivoire, Ghana, Cameroon and Brazil, a gainst 511 µg/kg for Ecuador, 542 µg/kg for Peru and 892 µg/kg for Venezuela.[3] The international cadmium assessment found the same pattern in cocoa powder, with a mean of 141 µg/kg in the mainly African cluster and 1,601 µg/kg in the mainly South and Central American cluster.[9] The low-cadmium origins are not lower in lead, so origin choice addresses one metal, not both.[3,10]

For a buyer, the supported priorities are lot results for cadmium with the cocoa-solids content stated, and cleaning and shelling controls for lead.[3,7] The EU limits cadmium at 0.10 to 0.80 mg/kg in chocolate according to cocoa content and at 0.60 mg/kg in cocoa powder, and the Codex Alimentarius standard sets 0.3 to 0.9 mg/kg for chocolate and 2.0 mg/kg for cocoa powder.[7,11] Chocolate supplied about 4% of dietary cadmium across European age groups and close to 10%, with other cocoa products, for school-age children; JECFA judged cocoa a minor contributor overall.[12,9]

2 | What counts as cocoa

Cocoa comes from the seeds of Theobroma cacao, dried which are fermented, cleaned and roasted, then separated into shell and nib.[10,13] Ground nibs form cocoa liquor, which is pressed into cocoa butter and a cake milled into cocoa powder; chocolate combines liquor, butter, sugar and, in milk chocolate, milk solids.[3,10]

These fractions behave differently for metals, so this page keeps them apart. In a pilot run on Bahia beans, cadmium was 60 µg/kg in the liquor and 111 µg/kg in the powder, while the cocoa butter was below the 1.5 µg/kg quantification limit.[10] Bean shells carry much of the lead: in industry testing the median shell lead was 341 µg/kg against 1.2 µg/kg in the separated nibs.[3]

The page covers beans and nibs, liquor, butter, natural and alkalised cocoa powder, sweetened drinking-chocolate powder sold as powder, and dark, milk and white chocolate. Foods that only contain cocoa, such as chocolate milk, cakes, cereals, spreads and filled or coated confectionery, are outside its scope, as is cocoa butter used as a skin-protectant drug.[5,14,15] Beans are usually reported on a dry-weight basis and products as sold, and the two are not converted into each other.[1,16]

3 | How metals reach cocoa

Cadmium enters the bean from the soil through the roots, and soil conditions explain much of the difference between farms.[6,21] A synthesis of studies across the cacao belt ranked total soil cadmium and soil pH as the strongest predictors of bean cadmium, and its model lowered bean cadmium from about 1.65 to 1.0-1.1 mg/kg as soil pH rose from 5 to about 7.[6] In Trinidad, nib cadmium tracked leaf cadmium closely (r = 0.79) but total soil cadmium only weakly (r = 0.35).[21]

Within the tree, cadmium reaching the nib travels mainly through the branches rather than from the leaves.[22] In a high-accumulating cultivar at the Trinidad genebank, nibs averaged 2,050 µg/kg, and in Peru two nearby Piura sites differed tenfold, at 7.12 and 0.72 mg/kg, with flood-plain soils transferring cadmium to beans about 3.5 times more readily.[23,22]

Lead mostly arrives on the outside of the bean after harvest, through soil and dust during fermentation, drying, transport and storage.[3,8] In a factory study, separated shells held 163 µg/kg lead and nibs 15.2 µg/kg, cleaning lowered whole-bean lead from 95.2 to 39.7 µg/kg, and dust collected from the cleaners carried 2,370-3,130 µg/kg.[3] The same investigation attributed about 70% of the lead in nibs to contact during bean breaking and winnowing.[3]

Aluminum and nickel follow the cocoa solids as well. German monitoring found a mean of 146 mg/kg aluminum in cocoa powder, and data compiled by a German state laboratory gave medians of 160 mg/kg in powder and 39 mg/kg in chocolate.[24,25]

4 | Which origins and products measured lower

For cadmium, West African beans are consistently the lowest measured.[3,9] Industry bean testing gave medians of 55 µg/kg for Nigeria, 60 µg/kg for Côte d'Ivoire, 70 µg/kg for Ghana and 90 µg/kg for Cameroon, against 2 46 µg/kg for the Dominican Republic, 359 µg/kg for Indonesia, 511 µg/kg for Ecuador and 542 µg/kg for Peru.[3] In the international assessment, cocoa powder averaged 141 µg/kg in the mainly African cluster, 609 µg/kg in Indonesia and 1,601 µg/kg in the mainly South and Central American cluster, and cocoa liquor showed the same order.[9] In the US retail survey, products of Latin American origin had higher cadmium than those of African origin after allowing for cocoa content.[1]

Within producing countries the range is wide, so a country name alone does not settle a lot. Peruvian regional bean means ran from 0.17 mg/kg in Cuzco to 1.78 mg/kg in Tumbes, although the authors found the regional differences not statistically significant.[16] A nationwide survey of 560 trees on 159 Ecuadorian farms in 2017 found cadmium in peeled, unfermented beans from 0.03 to 10.4 mg/kg dry weight, with a geometric mean of 0.55 mg/kg.[44] Ecuadorian province means ran from about 0.3 mg/kg in Napo to about 1.7 mg/kg in Guayas, and Brazilian beans averaged 60 µg/kg from Bahia but 129 µg/kg from Pará and 1,153 µg/kg in four Ecuadorian samples in the same study.[10,20] Genotype also matters: in Peru the native Chuncho type averaged 0.17 mg/kg against 0.90 mg/kg for CCN 51 and 1.80 mg/kg for spontaneous hybrids.[16]

For lead, the lowest results do not come from the low-cadmium origins. Industry bean medians for lead were 5-10 µg/kg for the Dominican Republic, Ecuador and Peru and 25 µg/kg for Côte d'Ivoire, Ghana, Nigeria and C ameroon.[3] In Brazil, the four Ecuadorian bean samples had the highest cadmium and the lowest lead in the study.[10] Because lead depends on post-harvest handling, the useful comparison for lead is between handling and cleaning practices, not between countries.[3]

Among products, milk and white chocolate are the lowest for both metals because they hold the least cocoa.[1,2,5] Milk chocolate averaged 60 µg/kg cadmium and 10 µg/kg lead in the US survey, against 270 and 30 µg/kg in dark chocolate and 700 and 110 µg/kg in cocoa powder, and white chocolate cadmium was near or below detection.[1,2,5] Organic labeling did not mean lower cadmium: certified-organic products averaged about 400 µg/kg more cadmium in a multi-year US analysis, and a German organic milk chocolate pool held 56 µg/kg against 16 µg/kg for the conventional pool.[26,17]

For nickel, which the EU has limited in chocolate and cocoa powder since July 2025, the supported comparison is between products rather than origins.[27] Milk chocolate measured 700-1,000 µg/kg in German and US total diet samples, against 2,800 µg/kg in dark chocolate and 10,600-11,050 µg/kg in cocoa powder.[14,17] The only origin data, from one Peruvian survey, put regional bean means between about 3.5 and 9.3 mg/kg, read from a figure and without detection limits, which is too weak to rank origins for nickel.[16]

Beans from Nigeria, Côte d'Ivoire, Ghana and Cameroon had median cadmium of 55-90 µg/kg in industry testing, a nd Brazilian beans 94 µg/kg.[3] Within Brazil, Bahia beans averaged 60 µg/kg, and within Peru, Cuzco beans averaged 0.17 mg/kg.[16,10] These are observed values for one metal; they do not make those origins lower in lead.[3]

Milk chocolate and white chocolate, because cadmium follows the nonfat cocoa solids.[1,2] In Japan, milk chocolate had a median of 23 µg/kg and dark chocolate 150 µg/kg, and white chocolate was near the detection limit.[2]

5 | Processing, fermentation and shelling

Processing redistributes metals between fractions rather than removing them.[10] In the Bahia pilot run, about 59% of the cadmium stayed in the mill residue, 35% went to the liquor and 6% to the shell, and pressing sent all of the liquor's cadmium into the cake and none into the butter.[10] That is why cocoa powder, the defatted solids, is the most concentrated retail form, while cocoa butter is low.[10,9]

For lead, cleaning and shelling are the steps with measured effects.[3] Mechanical cleaning lowered whole-bean lead from 95.2 to 39.7 µg/kg, and adding a detergent and acid wash lowered it to 23.2 µg/kg.[3] After winnowing, the fine nib fractions carried up to 143 µg/kg lead against about 15-20 µg/kg in the coarse fractions, so screening out fines is a further lever.[3]

Fermentation has only small tested effects on cadmium. Adding Rhizobium japonicum to the fermenting mass lowered Trinitario bean cadmium from 0.36 to 0.29-0.30 mg/kg but barely changed Nacional beans (0.34-0.35 mg/kg).[28] A review notes that cadmium can move from nib to shell when fermentation drives nib pH below 5, which is a mechanism rather than a validated control.[8]

Very little cadmium: in the Brazilian pilot run, butter was below 1.5 µg/kg while the powder from the same batch held 111 µg/kg.[10] International data put the global median for cocoa butter at 20 µg/kg cadmium.[9]

6 | Mitigation from farm to factory

Controls for cocoa act at the farm, during post-harvest handling, in the factory and at lot acceptance.[13] The Codex code of practice recommends soil testing, liming toward pH 6 or above (for example 3 t/ha/year of dolomite), avoiding cadmium-rich fertilizers, applying zinc and using low-cadmium planting material, but it reports no measured effect sizes.[13]

The field evidence for cadmium is limited but measurable. In a Peruvian field trial, arbuscular mycorrhizal fungi lowered bean cadmium from 0.94 to 0.56 mg/kg, while biochar at 1-2% had smaller effects.[29] In a greenhouse trial, quinoa biochar at 2% cut seedling leaf cadmium by 15-54% depending on soil, but beans were not measured.[30] Compost changed soil cadmium fractions in Ecuador, but the bean results were not printed.[31]

Lead controls are about cleanliness after harvest: drying beans off the ground, cleaning, removing shells and dust, and keeping equipment free of lead.[3,13] Testing detects contamination and supports exclusion or blending, but it does not remove metals.[9,32]

Oñate et al. (2024) tested multicomponent Fe nanoparticles (MCNPs) applied to cadmium-contaminated cocoa soils and during fermentation of cocoa beans from three farms in Esmeraldas, Ecuador. Cadmium removal from beans was approximately 20% (CCN51 variety) and approximately 75% (Fino de Aroma variety) when MCNPs were applied at 0.112 kg/kg during on-site fermentation and 0.034 kg/kg in the laboratory (Table 2). Soil cadmium immobilization ranged from 5.2% to 35.5% depending on dose and soil type. This is a soil and bean treatment experiment, not finished-food survey data.[45]

Galvis et al. (2023) screened nine cacao rootstock genotypes for cadmium tolerance and accumulation in a pot experiment at 0, 6, and 12 mg·kg^{-1} soil cadmium over 90 days. Genotype EET62 accumulated approximately 14 times less cadmium in shoots than IMC67 at the highest exposure, and showed the lowest total cadmium per plant (0.30 mg compared to 2.53 mg for IMC67). PA150 also showed low shoot cadmium. This is a greenhouse rootstock screening study on juvenile plants, not finished-food data.[46]

Arce-Inga et al. (2022) isolated 138 bacterial strains from cacao rhizosphere soils in the Amazonas region of Peru, identifying four Bacillus sp. Strains tolerant to cadmium at concentrations up to 200 to 400 ppm in laboratory culture. The greenhouse trial on CCN-51 seedlings did not show a statistically significant reduction in plant cadmium under inoculation with these strains. This is a soil microbiology and bioremediation study, not finished-food data.[47]

7 | Trade-offs and limits of controls

Switching origin to reduce cadmium can leave lead unchanged or higher. West African beans had the lowest cadmium medians but lead medians of about 25 µg/kg, while Ecuadorian and Peruvian beans were higher in cadmium and lower in lead in the same industry testing.[3]

Soil amendments are not uniformly effective. A review found that gypsum, or lime with compost, lowered leaf cadmium but not bean cadmium in some trials, and that some liming materials increased uptake.[33] Biochar effects were not statistically significant in every soil tested.[30]

Blending dilutes a high-cadmium lot rather than removing cadmium, and a lower-cocoa recipe lowers cadmium per gram of chocolate but not per gram of cocoa.[2,32] Organic certification is not a cadmium control: certified-organic products measured higher in the US analysis.[26]

8 | Testing cocoa for metals

A useful cocoa test states the form, the basis and the cocoa-solids content, because the EU and Codex limits are set by cocoa-solids class.[7,11] Beans are usually reported on a dry-weight basis and products as sold; Singapore's cocoa-powder limits are even set on a dry, fat-free basis.[16,34]

Detection limits must sit well below the relevant limit. FDA's reporting limits were 3 µg/kg for cadmium and 10 µg/kg for lead in cocoa powder, while some monitoring submissions used limits of 40 µg/kg or more for cadmium in powder, which hides much of the lower range.[5,14] Several surveys reported no detection limit, reference material or recovery check, and two were held here because their values could not be reconciled with their own methods.[18,19]

Arsenic and mercury in cocoa are reported almost entirely as totals.[5,35] Inorganic arsenic in European monitoring of chocolate and cocoa powder was mostly below about 20 µg/kg, and no source measured methylmercury or hexavalent chromium in cocoa.[5]

Some very high values come from products that are mostly not cocoa or from methods that cannot support them. A Lahore survey converted digest results with inconsistent factors and included many compound confections without cocoa, and an Abuja survey reported chromium 30-40 times the limit it cited while concluding compliance.[18,19]

9 | Buying and verifying cocoa

Ask for lot-specific cadmium results with the cocoa-solids content, and compare them with the limit for the destination market.[7,11] The EU sets cadmium at 0.10 mg/kg for milk chocolate under 30% cocoa solids, 0.30 mg/kg for chocolate under 50%, 0.80 mg/kg for chocolate at 50% or more and 0.60 mg/kg for consumer cocoa powder.[7] Codex and Hong Kong set 0.3, 0.7, 0.8 and 0.9 mg/kg across the same cocoa-content bands and 2.0 mg/kg for cocoa powder, and Australia and New Zealand set 0.5 mg/kg for chocolate and cocoa products.[11,36,37]

Other markets also limit lead and arsenic. MERCOSUR sets lead at 0.2-0.5 mg/kg and arsenic at 0.2-0.5 mg/kg for cocoa paste and chocolates, China sets lead and total arsenic at 0.5 mg/kg for cocoa products and chocolate, and the EU has applied nickel limits of 2.5-15 mg/kg since July 2025.[27,38,39]

For cadmium, record the bean origin and request bean-lot results, since origin is the strongest predictor but varies within countries.[3,16] Buyers have used bean acceptance thresholds of about 0.5-1.1 mg/kg to meet the chocolate limits.[32] For lead, specify cleaning, shell and dust removal and request finished-lot results, because lead depends on handling rather than origin.[3]

10 | Exposure from cocoa and chocolate

Cocoa is a modest but real source of dietary cadmium.[12,9] EFSA found that chocolate products supplied 4.3% of cadmium exposure across European age groups, and close to 10% for school-age children when cocoa beans and products are added.[12] JECFA put cocoa products at 0.1-9.4% of cadmium exposure across national and regional diets and concluded they are not a major contributor; applying the Codex limits lowered total exposure by 0.7% on average.[9]

Chocolate matters more for nickel. EFSA found that sugar and confectionery, driven mainly by chocolate, supplied up to 31% of adolescents' nickel exposure, and cocoa beverages, with soft drinks, were the main b everage contributors for toddlers.[40]

Concentration is not intake: a small serving of dark chocolate can add more cadmium than a larger serving of milk chocolate.[1,2] Australian milk chocolate averaged 15 µg/kg cadmium and 6 µg/kg lead in the 25th total diet study, near the low end of retail chocolate.[41]

11 | Evidence review and remaining gaps

This assessment covers every source record in the HMI library that is tagged to cocoa or mentions cocoa, cacao or chocolate, plus every matching row in WHO GEMS/Food, the FDA Total Diet Study and other indexed datasets, each with a recorded decision based on its content. Two retail surveys are held in full and individual values from several others are held because they could not be reconciled with their own methods or figures.[18,19,20]

The remaining gaps are mostly unpublished data. Per-farm bean results behind the Ecuadorian compost trial and the Peruvian national map, per-product values behind the multi-year US analysis, and EFSA's 2020 nickel annex w ere not available in the library.[23,26,40,31]

References identify the sources used in these answers. The Sources index preserves additional discovery links; inclusion there does not mean a source has been reviewed for this assessment. Corrections, completed searches, new direct evidence and changes in requirements should reopen the relevant answer.

12 | Cocoa FAQs

Cadmium is the metal found at levels that matter most, followed by lead; cocoa is also high in nickel and aluminum.[1,4,24] Arsenic and mercury are usually low or below detection.[5,14]

Cadmium is taken up from the soil by the roots and is highest where soils are rich in cadmium and acidic.[6,23] Lead mostly settles on the bean shell from soil and dust after harvest.[3]

Not in the available evidence: in a multi-year US analysis, certified-organic products averaged about 400 µg/kg more cadmium and 20 µg/kg more lead.[26] A German organic milk chocolate pool also had more cadmium than the conventional pool (56 against 16 µg/kg), though that is one pool each.[17]

Milk and white chocolate, because they contain the least cocoa solids.[1,2] In the US survey, milk chocolate averaged 60 µg/kg cadmium against 270 µg/kg in dark chocolate and 700 µg/kg in cocoa powder.[1]

West African beans measured lowest, with medians of 55-90 µg/kg for Nigeria, Côte d'Ivoire, Ghana and C ameroon, against 511-892 µg/kg for Ecuador, Peru and Venezuela.[3] Ranges within countries are wide, and these origins are not lower in lead.[3,16]

Yes: cocoa powder is the most concentrated retail form because it is defatted cocoa solids.[10] US cocoa powder averaged 700 µg/kg cadmium and 110 µg/kg lead, against 270 and 30 µg/kg in dark chocolate.[1]

Chocolate is a modest source of dietary cadmium, supplying about 4% of European exposure and close to 10% for school-age children.[12] JECFA concluded cocoa products are not a major contributor to cadmium exposure, but they matter more for nickel in children and adolescents.[9,40]

Yes: the EU limits cadmium at 0.10-0.80 mg/kg in chocolate by cocoa content and 0.60 mg/kg in cocoa powder, and has limited nickel since July 2025.[7,27] Codex sets cadmium at 0.3-0.9 mg/kg for chocolate and 2.0 mg/kg for cocoa powder, and MERCOSUR and China also limit lead.[11,38,39]

Cleaning and shelling lower lead: cleaning cut whole-bean lead from 95.2 to 23.2-39.7 µg/kg in one factory study.[3] Processing does not remove cadmium; it moves it into the cocoa solids, so powder ends up more concentrated than liquor.[10]

For European school-age children, chocolate and cocoa products together supplied close to 10% of cadmium exposure.[12] Chocolate also drove up to 31% of adolescents' nickel exposure.[40]

Cadmium sits in the nonfat cocoa solids, so it rises with cocoa content.[10] In Japan, the median rose from 23 µg/kg below 50% cocoa to 250 µg/kg at 80% or more.[2]

Mostly not: lead is concentrated on the shell and in dust, and one investigation attributed about 70% of nib lead to contact during bean breaking and winnowing.[3] Industry shell lead had a median of 341 µg/kg against 1.2 µg/kg in nibs.[3]

In a US analysis of products bought in 2014-2022, lead was lower in the 2019 and 2022 cohorts than in 2014, and cadmium was lower in 2022.[26] The cohorts were different products chosen by popularity, so this is not a market-wide trend.[26]

Yes, at levels high for food: about 9,500 µg/kg in cocoa beans and products and 3,800 µg/kg in chocolate in European monitoring.[4] The EU has limited nickel since July 2025 at 2.5-7.0 mg/kg in chocolate and 15 mg/kg in cocoa powder.[27]

Usually little: FDA cocoa powder held 29 µg/kg total arsenic and 15 µg/kg mercury, and most European inorganic-arsenic results were below about 20 µg/kg.[5,14] A US analysis reported a median of 50 µg/kg total arsenic in dark chocolate and cocoa products.[26]

Not clearly: Brazilian bean-to-bar dark chocolates averaged 78 µg/kg cadmium and 13 µg/kg lead, and bean-to-bar milk chocolates 25 and 12 µg/kg, in the same range as the few conventional bars tested alongside them.[42] Artisanal Colombian single-farm bars made from high-cadmium beans averaged 1,100 µg/kg cadmium.[43]

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STATUS AND LICENCE

Editorially reviewed in-house; no external peer review has been completed on this ingredient profile. Published as an institutional technical report with its review state tracked on the article page. Released under CC BY 4.0.

COMPETING INTERESTS

The Heavy Metal Index reports what the peer-reviewed and regulatory literature supports. It is operated separately from any certification program, does not evaluate or endorse brands, and does not use certification thresholds as evidence for the statements made here.

DATA AVAILABILITY

Every source behind this ingredient profile is listed with its own source record at https://heavymetalindex.com/ingredients/cocoa#sources.

PUBLICATION HISTORY

This revision 2026-10-22. The full dated record is maintained at https://heavymetalindex.com/ingredients/cocoa.