

The contribution of cacao consumption to the bioavailable dietary cadmium exposure in the Belgian population



Erik Smolders¹, Ruth Vanderschueren¹, Jasmien Doevenspeck¹, Lieselot Goethals¹, Mirjana Andjelkovic² and Nadia Waegeneers²

¹Division Soil and Water Management KU Leuven and ²Service Risk and Health Impact Assessment, Sciensano

New EU maximum limits for Cd (mg/kg)

COMMISSION REGULATION (EU) No 488/2014

of 12 May 2014

amending Regulation (EC) No 1881/2006 as regards maximum levels of cadmium in foodstuffs

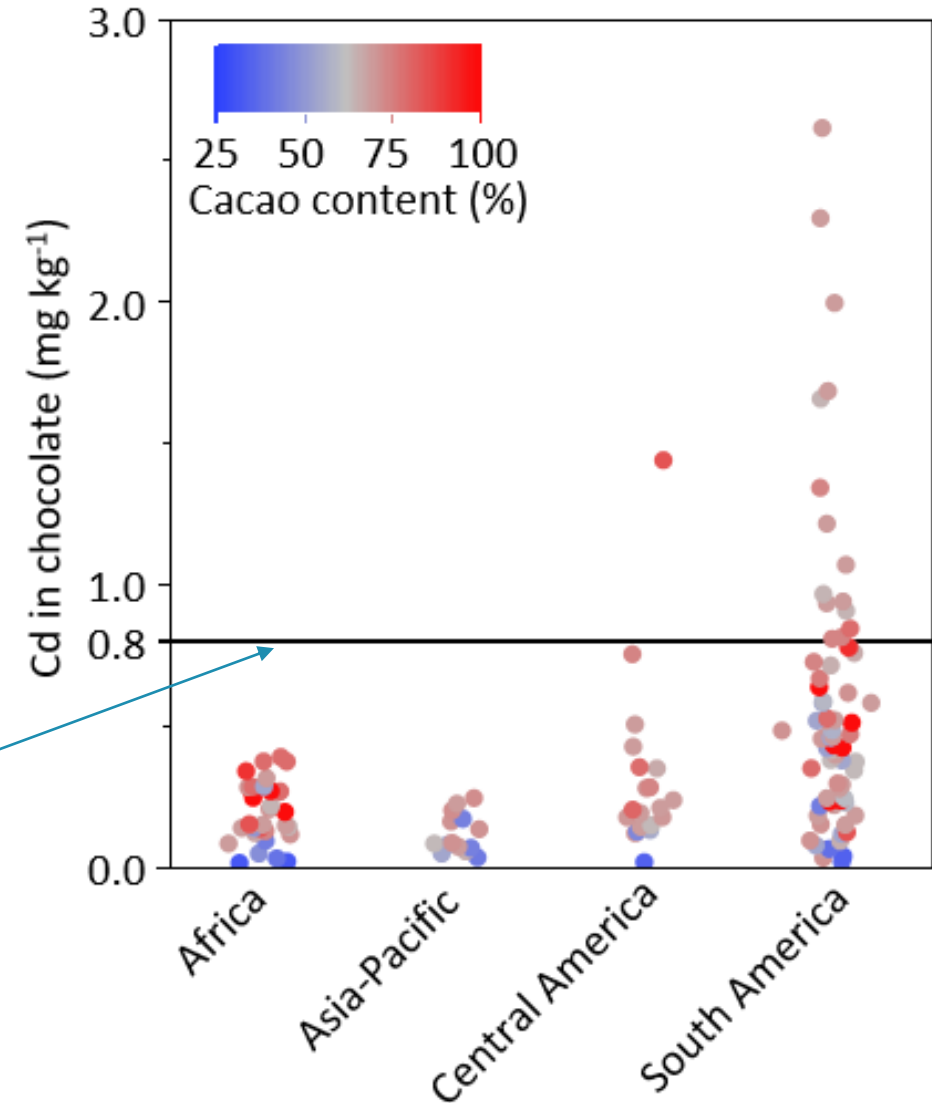
3.2.7	Specific cocoa and chocolate products as listed below ⁽⁴⁹⁾	
	— Milk chocolate with < 30 % total dry cocoa solids	0,10 as from 1 January 2019
	— Chocolate with < 50 % total dry cocoa solids; milk chocolate with ≥ 30 % total dry cocoa solids	0,30 as from 1 January 2019
	— Chocolate with ≥ 50 % total dry cocoa solids	0,80 as from 1 January 2019
	— Cocoa powder sold to the final consumer or as an ingredient in sweetened cocoa powder sold to the final consumer (drinking chocolate)	0,60 as from 1 January 2019

Codex Alimentarius Commission limits for Cd are 0.8 or 0.9 mg Cd/kg of chocolate, depending on the cocoa content.

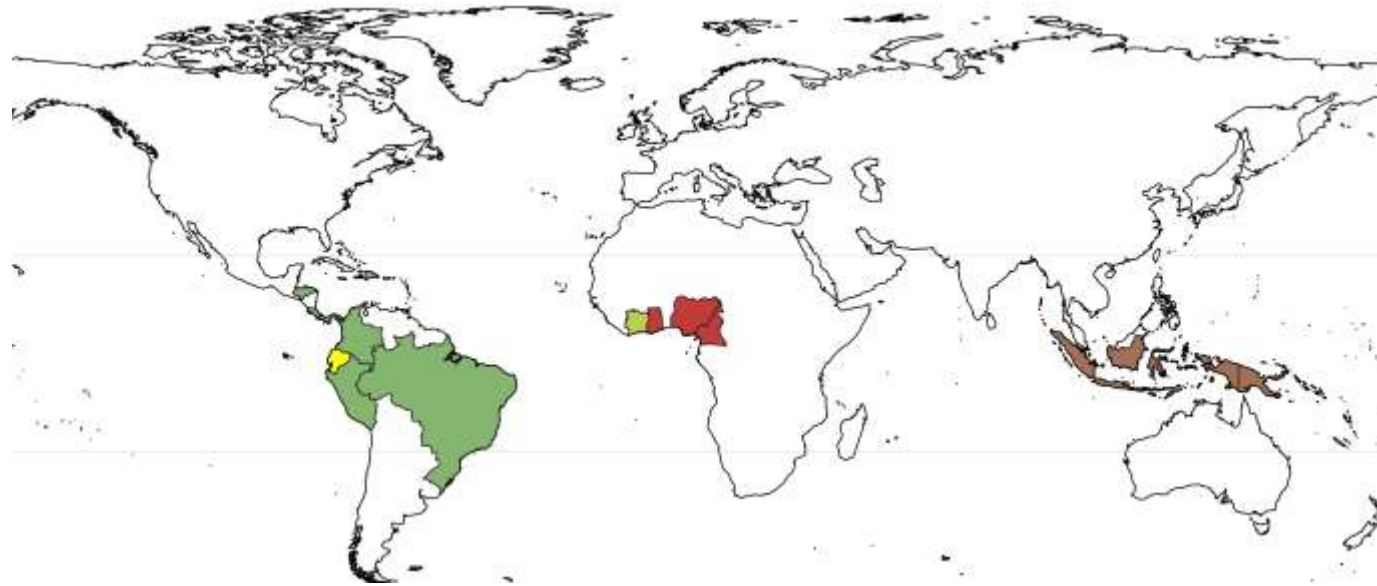
Cadmium is mainly an issue in Central and South America as suggested by data of single origin chocolates



EU limit in chocolate
 $0.80 \text{ mg Cd kg}^{-1}$
For $>50\%$ cacao
solids



Cadmium in cacao



Schwermetalle in Lebensmitteln

1. Mitteilung: Über den Gehalt an Cadmium in Rohkakao und in Kakao-Halb- und Fertigprodukten

Von G. Knezevic
(1979)

The Cd content in semi-bitter chocolates, if exclusively manufactured from common consumption brands, is below 0.2 mg/kg, the same being true for special bitter chocolates. **If and when semi-bitter and special bitter chocolates are exclusively made from high-quality origin grades, a somewhat higher Cd content must be expected.**

Food Additives and Contaminants, 2003, Vol. 20, No. 4, 343-352

Concentrations and bioavailability of cadmium and lead in cocoa powder and related products

S. Mounicou†, J. Szpunar†, D. Andrey‡, C. Blake‡ and R. Lobinski†*††

Introduc

D. Bertoldi et al. / Food Control 65 (2016) 46–53

49

Table 2

Content (mean ± standard deviation) of mineral elements in cocoa beans of different origin. K, P, Mg and Ca are expressed in g/kg, Al, Fe, Zn, Rb, Mn, B, Cu, Na, Sr, Ba, Ni, Ti and Cr are expressed in mg/kg whereas the other elements are expressed in µg/kg.

Element	DL ^a	West Africa (N = 21)	East Africa (N = 8)	Asia (N = 8)	South America (N = 14)	Central America (N = 10)
Cd	0.1	92.6 ± 41.8 ^c	508 ± 587 ^{ab}	328 ± 176 ^b	1388 ± 1089 ^a	544 ± 302 ^{ab}

Cadmium limits in various compartments...same information, different risk assessment

Body burden Urinary threshold	$\mu\text{g Cd g}^{-1}$ creatinine	2.0 ^a	Effect level (ECB, 2007)
		3.9 ^b	Effect level (EFSA, 2009b)
		5.2	Effect level (WHO/FAO/JECFA, 2011)
Diet Tolerable daily intake for 70 kg adult	$\mu\text{g Cd day}^{-1}$	25	EFSA opinion ^c (EFSA, 2009b)
		58	WHO/FAO/JECFA (2011) ^d
		70	WHO 1989–2009* (WHO, 1989)
Food limits (fresh wt. basis) Wheat grain	mg Cd kg^{-1}	0.10	China: GB 2762-2017 (CFDA, 2017)
		0.20	Codex Alimentarius (FAO, 2015)
		0.20	EC No. 1881/2006 (EU, 2006)

Chocolate consumption contributes to Cd exposure in the diet

Daily dietary Cd intake in EU, not including chocolate is 10-15 $\mu\text{g}/\text{day}$

Daily chocolate portion of 20 g, dark chocolate at the limit of 0.8 $\mu\text{g}/\text{g}$ or $20 \times 0.8 = 16 \mu\text{g Cd}/\text{day}$

Sum is 10-15 + 16 $\mu\text{g Cd}/\text{day}$ or 26-31 $\mu\text{g Cd}/\text{day}$ > EFSA PTDI of 25 $\mu\text{g}/\text{day}$

Concerns with current Cd exposure assessments

1. National dietary data (Food Frequency Questionnaires) suggests lower chocolate consumption than industry based consumptions

Country	#participants	Daily chocolate consumption (g/day)	Source
BE, 2nd. BNFC	3146	15	EFSA 2021
BE, industry		28	ICCO 2021
FR, INCA3	4396	7.5	EFSA 2021
FR, industry		19	ICCO 2021
DE, NNS2	13926	9	EFSA 2021
DE, industry		30	ICCO 2021

2. The number of different chocolate products that have been analysed for Cd is small, e.g. only 10 in Belgian dietary study of Vromman et al. 2010

3. Is Cd in cacao products equally bioavailable as Cd in main food groups that contribute to dietary Cd exposure, e.g. wheat, rice and potatoes?

Goal: to refine the Cd exposure assessment via consumption of all cacao containing products

- Food Frequency Questionnaire on most dominant cacao containing products
- Analyses of most dominant cacao containing products
- Analysis of bioaccessible fractions of Cd in these products

Methods

- Online 24h recalls of consumption of Belgian population. May-June 2021 (n=1467) and October-December 2021 (n=588). 1750 different cacao products (type&brands) entered
- Analyses of 349 different containing products for Cd,
- Analysis of bioaccessible fractions of Cd in these products (Brodkorb et al. 2019)

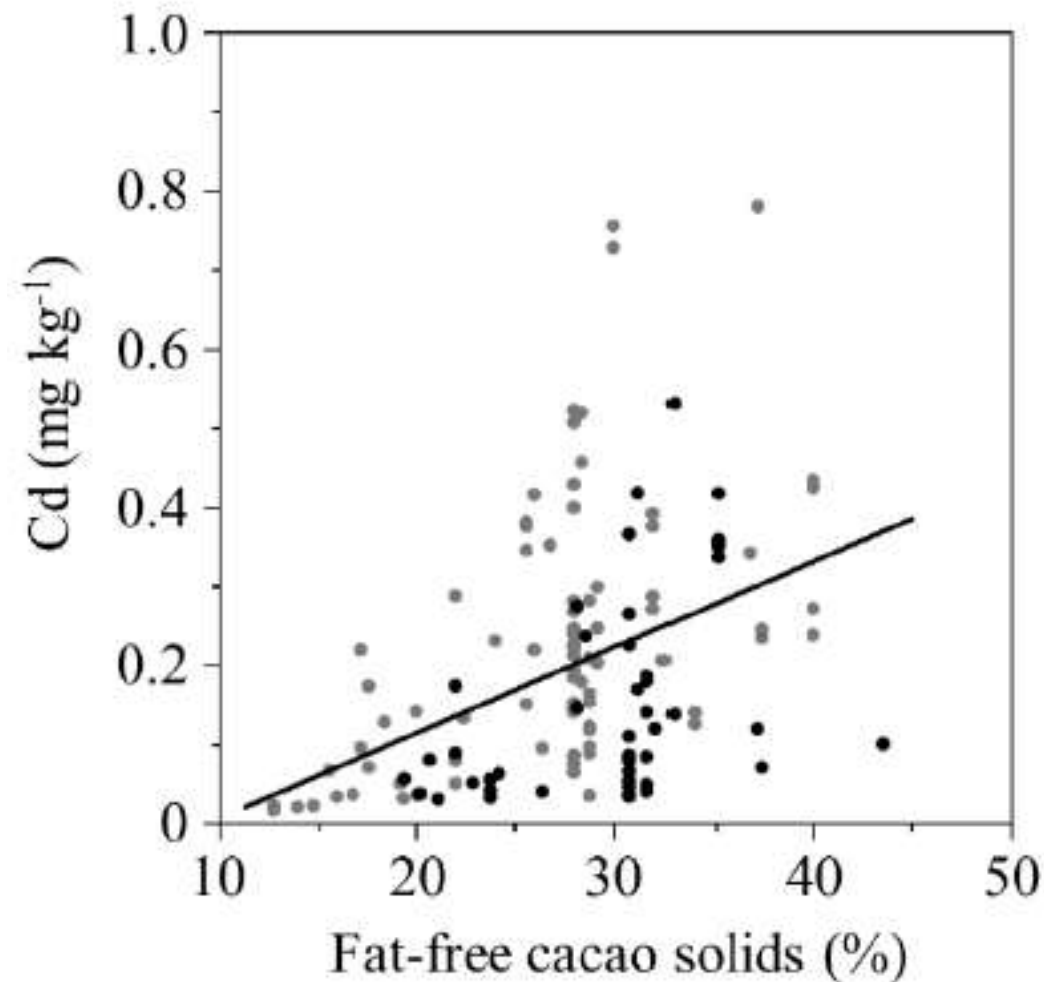
Selected description of participants (n=1467, average age = 36 years)

Characteristic	Response	Fraction of participants (%)
Gender	Male	34
	Female	66
Nationality	Belgian	96
	Other/unknown	4
Weight status ⁽¹⁾	Underweight	3
	Normal	63
	Overweight	23
	Obese	9
	Morbidly obese	<1
Food preference	Omnivore	81
	Vegan/vegetarian	19

The selection biases in the survey cohort for the parameters sex, prevalence of a vegetarian/vegan diet, BMI and education level can thus be considered as non-differential biases and were not expected to affect the conclusions of this study.

Average Cd concentration and fat-free cacao solids content of the 1750 different cacao products of which 349 were sampled on the market and analysed. Averages followed by different characters indicate significant differences among rows based on Tukey's Honestly significant difference test (P-value < 0.05).

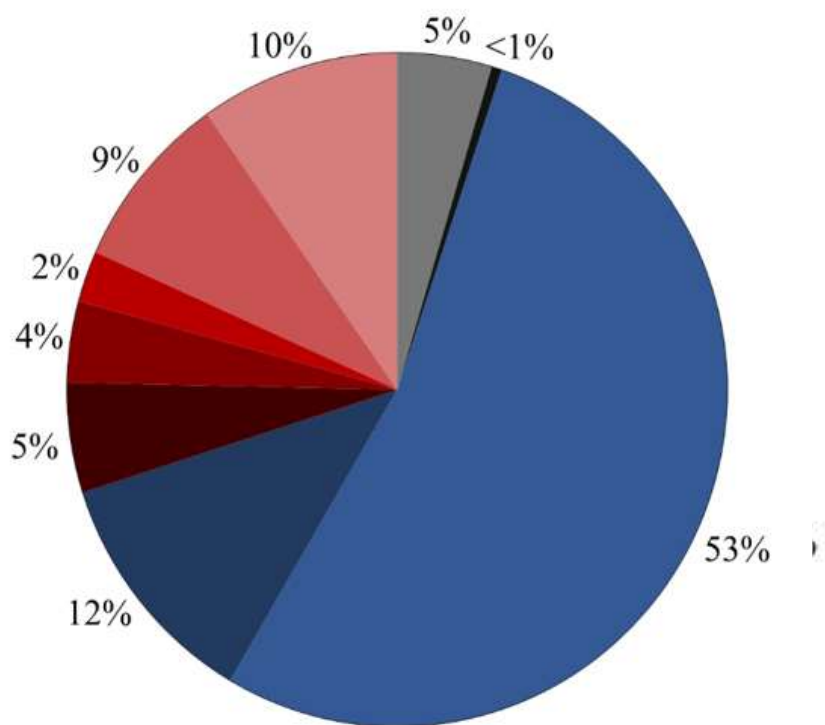
Category	Subcategories	N total reported (measured)	Subset of measured products	
			Cd (mg kg ⁻¹)	Fat-free cacao solids (%)
Cacao ingredients	Cacao powder, cacao nibs	22 (9)	0.19 A	82 A
Chocolate and chocolate products	Chocolate bars with and without filling, pralines, chocolate figurines and easter eggs, chocolate pellets, chocolate sprinkles, chocolate spreads	865 (178)	0.07 B	12 B
Desserts	Ice cream, chocolate mousse, chocolate pudding, chocolate sauce, cream cheese with chocolate, other desserts	137 (25)	0.01 BC	1 C
Drinks	Chocolate milk, coffee with cacao, powdered drinking chocolate	62 (12)	0.02 BC	7 BC
Baked goods and pastries	Cakes, brownies, donuts, pastries, pies, other baked goods	205 (26)	0.011 BC	2 C
Breakfast cereals	Muesli/granola, other breakfast cereals	107 (23)	0.03 BC	2 C
Snacks	Fruits/nuts covered with chocolate, candy, candy bars, cereal bars, cookies, other snacks	352 (76)	0.02 C	2 C
All		1750 (349)	0.05	9



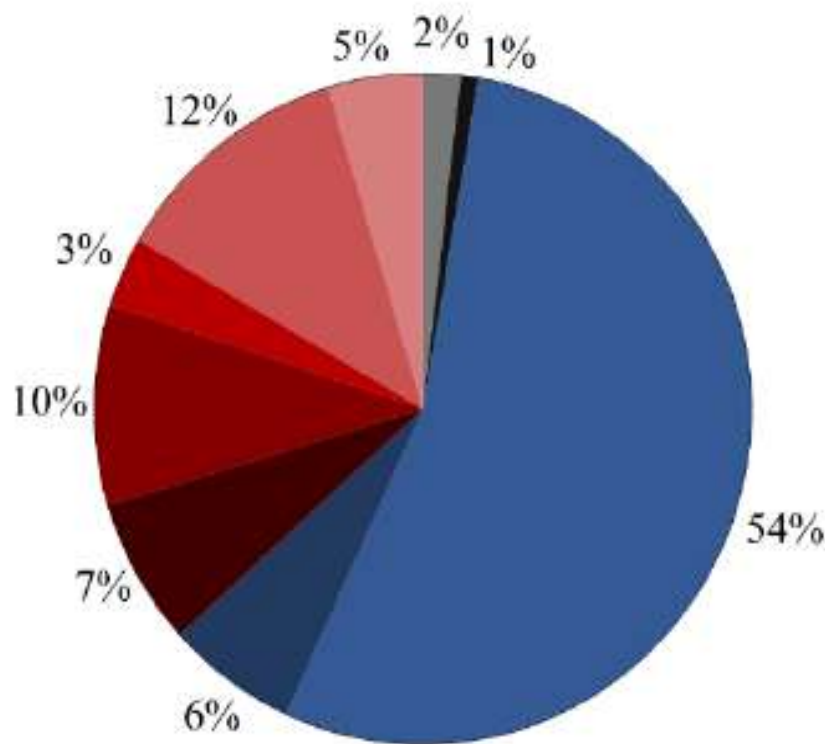
Correlation between the measured Cd concentration and the fat-free cacao solids content in dark chocolate bars analyzed in this work (black symbols, N = 49) and in a previous origin chocolate survey [grey symbols, N = 83 (Vanderschueren et al. 2019)]. That relation between fat-free cacao solids and Cd content was used to estimate the Cd content of other dark chocolate products in the present study.

“hidden chocolate” contributes. Chocolate bars and pralines represent only 53 % (54%) of consumption of fat free cacao solids (Cd exposure) of all cacao products

Fraction of total consumed fat-free cacao solids



Fraction of total consumed Cd from cacao-containing products



Cocoa ingredients

■ Cocoa powder

■ Cacao nibs

Chocolate and chocolate products

■ Chocolate bars and pralines

■ Chocolate spreads

Other product categories

■ Baked goods and pastries

■ Cereals

■ Desserts

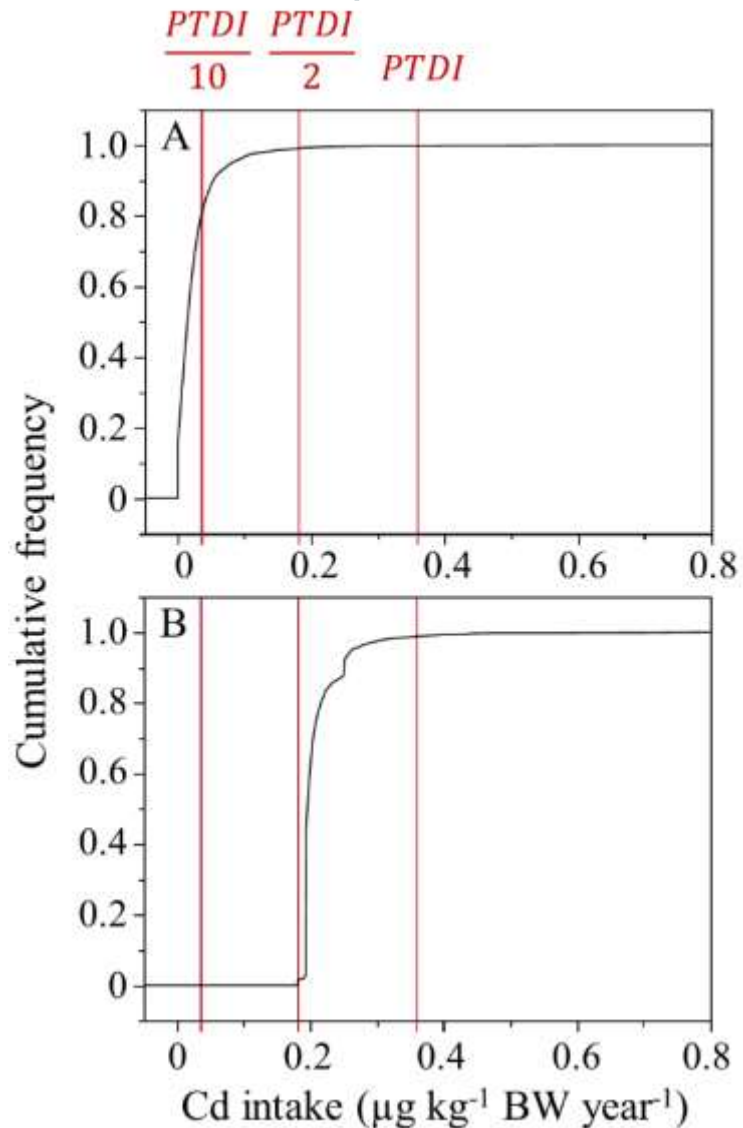
■ Snacks

■ Drinks

Chocolate consumption: well above earlier dietary estimates...but close to industry estimates

Study	N	Chocolate consumption (g day ⁻¹)		Average Cd intake	
		Average (± stdev)	95 th percentile	Total diet (µg kg ⁻¹ BW day ⁻¹)	Contribution of chocolate (%)
This work	2055	28 (± 38)	100	0.21 (± 0.04) ⁽²⁾	7-9%
Dietary Cd survey and statistics based on the first Belgian National Food Consumption survey (Vromman et al. 2010)	1234	14		0.14	3.6
Statistics based on the 2nd Belgian National Food Consumption survey (EFSA 2021)	3146	15 (± 25)			
ICCO (ICCO 2012)		24 (± 4)			

Five survey entries (0.2% of all entries) exceeded the TDI established by EFSA (2011) based solely on the consumption of cacao-containing products,



Cumulative frequency distribution of the total cacao-related Cd intake (all consumed products included)

The total dietary Cd intake estimated based on the EFSA exposure data for the Belgian population

The cadmium bioaccessibility decreases with increasing fat-free cacao solids content and is up to factor 5 lower in cacao products compared to wheat flour

Sample	Fat-free cacao solids (%)	Initial Cd content (mg kg ⁻¹)	Cd bioaccessibility (%)
Wheat flour 1	/	0.023	71 ± 15
Wheat flour 2	/	0.021	66 ± 5
Milk chocolate	3.2	0.019	60 ± 13
Dark chocolate 1	21.8	0.045	37 ± 9
Dark chocolate 2	26	0.236	36 ± 7
Dark chocolate 3	28.8	1.112	32 ± 2
Cacao powder	88	0.403	12 ± 1

In a nutshell...

- Both the average chocolate consumption (28 g day⁻¹) and the relative contribution of chocolate to the total dietary Cd exposure (7–9%) were higher than previously estimated for the Belgian population
- The Cd bioaccessibility in chocolate products was a factor 5 (cacao powder) and 2 (dark chocolate) lower compared to wheat flour
- This study suggests that Cd intake from cacao consumption has been underestimated because of hidden cacao in non-chocolate food categories but, in contrast, may have overestimated the true exposure because of lower bioavailability compared to the main foodstuffs contributing to Cd exposure