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Dietary exposure of cadmium from milk products containing cocoa in children aged 1 to 5 years old, pregnant and lactating women

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Abstract

This study was conducted to evaluate the cadmium contamination level in milk products containing cocoa (chocolate flavour milk products), and its dietary exposure in vulnerable consumers, i.e. children aged one to five years old, pregnant and lactating women (PLW) in Indonesia. A total of 78 samples of milk products, which were registered in the Indonesian National Agency of Drug and Food Control (NADFC) and distributed in the Indonesian market, were analysed using Atomic Absorption Spectrophotometry Graphite Furnace (AAS-GF). Milk powder for children aged one to five years, UHT liquid milk, and condensed milk meet the NADFC regulation No. 5 of 2018. However, 63% of chocolate flavour PLW milk powder had Cd levels that exceeded the NADFC (maximum 10 µg/kg). Chocolate flavour milk has a higher Cd level than non-chocolate flavour milk products. The highest value of Cd exposure was in children aged three to five years old who consumed chocolate flavour milk powder, with an average value of 0.095 and P95 value of 0.151 µg/kg BW/day. However, based on the P95 exposure value, the contribution of Cd exposure for this product was only 18.12 and 42.27% to the PTMI-JECFA and TWI-EFSA values, therefore, it was not considered a risk of health problems. For PLW milk powder, although 63% of samples exceeded the NADFC regulation, the P95 value of Cd exposure was 1.41 and 3.29% to the PTMI and TWI value, therefore, it was also considered not to pose a risk of health problems.

1. Introduction

Cocoa powder is one of the raw materials used in food products, to give its natural brown colour and good taste. The use of cocoa powder in food products became a concern after the European Union issued commission regulation No. 448/2014 concerning the maximum limit of Cd in food products [Commission Regulation (EU) No 488/2014 (European Commission, 2014)]. Average dietary exposure to Cd in European countries is close to or nearly exceeds the tolerable weekly intake (TWI) of 2.5 mg/kg body weight (BW) (EC-448, 2014). In the latest Commission Regulation (EU) 2021/1323, there is no change in the Cd limit requirement for cocoa powder to be consumed, which is a maximum of 600 µg/kg (European Commission, 2021).

According to the International Agency for Research on Cancer (IARC), Cd and Cd compounds are classified as Group 1 (one), carcinogenic to humans (IARC, 2012). There is sufficient evidence for the carcinogenicity of Cd and Cd compounds in humans, indicated by the presence of lung, kidney, and prostate cancer due to exposure to Cd and Cd compounds (Siswanto *et al.*, 2014). Cd is a highly toxic non-essential heavy metal known for its detrimental effects on cell enzymatic systems, oxidative stress, and inducing nutritional deficiencies in plants (Purwanto, 2019). Cd exposure occurs from ingestion of contaminated food (such as crustaceans, offal, leafy vegetables, and rice from certain regions of Japan and China), or water (either from old water pipes or industrial pollution), which can cause adverse health effects in the long term (Godt *et al.*, 2006; Bernhoft, 2013; WHO, 2019). Cadmium is mostly found in fruits and vegetables due to the high rate of soil transfer to plants (Satarug *et al.*, 2010).

The high content of Cd in cocoa powder is caused by the origin of the cocoa beans used during the processing. The results showed that cocoa beans from Latin America, i.e. Central and South America, such as Peru, Honduras, and Ecuador, were known to contain high concentrations of Cd and exceeded the limit in

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Commission Regulation (EU) 2021/1323 (Chavez *et al.,* 2015; Arevalo-Gardini *et al*., 2017; Abt *et al*., 2018; Gramlich *et al*., 2018; Arguello *et al*., 2019; Romero-Estevez *et al.,* 2019). The high content of Cd in cocoa beans or processed cocoa products from Latin America is also known from the notification of rejection by European Union countries through the RASFF (rapid alert system for food and feed) portal. Based on these databases, from 2014 to 2021, there were seven notification alerts raised for the product category of cocoa and cocoa preparation. It was found that the origins of cocoa were from Ecuador, Colombia, Peru, and Venezuela (RASFF, 2020; RASFF, 2021). Ecuador experienced rejection twice, in 2014 (2460 µg/kg) and 2017 (1450 µg/kg).

Indonesia is the third-largest cocoa bean-producing country in the world (16.5%) after Ivory Coast (38.1%) and Ghana (17%) (FAO, 2021). The regulation for cocoa powder currently used in Indonesia is INS for cocoa powder No. 3747: 2013 (maximal 1000 µg/kg) and the NADFC regulation No. 5 of 2018 (maximal 850 µg/kg) (INS, 2013; NADFC, 2018). In the cocoa powder processing industry, apart from using cocoa beans from Indonesia, cocoa beans from Latin America, Africa, and other Asian countries are also used. The top three exporters of cocoa beans to Indonesia from 2015 to 2019, were Malaysia (21,93%), Ivory Coast (17.70% and Ecuador (16.23%) (Pusdatin, 2020). From 2002 to 2018, total milk consumption at the household level in Indonesia tended to increase by 6.57% per year or by 2.02 kg/capita (Pusdatin, 2019). Thus, with the existence of cocoa bean imports from Latin American countries, the high potential levels of Cd in cocoa beans from these countries, and increasing consumption of dairy products, indicate the potential risk of exposure to Cd in the Indonesian population who consume products that use cocoa powder, especially for vulnerable consumers, such as children under 5 years old and pregnant and lactating women (PLW). Furthermore, there is a significant change in the requirements of the Cd limit for PLW speciality drinks (including PLW milk powder), i.e. from 200 to 10 µg/kg (NADFC, 2018).

Exposure study of Cd can be carried out quantitatively using a deterministic approach/point estimate (WHO, 2006). The value of Cd heavy metal toxicity as a contaminant is indicated by the provisional tolerable monthly intake (PTMI) value (JECFA, 2011). The risk of heavy metal exposure is considered high or unsafe if the risk assessment value is more than 100% PTMI. Studies on the risk of exposure to Cd from dairy products containing cocoa powder in Indonesia, until now, are still underreported. This study aimed to obtain the prevalence and level of Cd contamination and estimate Cd exposure among children aged one to five years old and PLW consumers throughout Indonesia who consume milk products containing cocoa so that an overview of the level of health risk can be obtained.

2. Materials and methods

2.1 Sample collection and preparation

A sampling of milk products was carried out using a non-random sampling method (purposive sampling), i.e., based on well-known brands registered in NADFC and distributed in the Indonesian market. A total of 78 samples of milk products have been collected from three supermarkets in different locations, i.e., Jatiasih (Bekasi), Tambun (Bekasi), and East Jakarta (DKI Jakarta). These samples consisted of five different milk categories, i.e., milk powder for children aged one to three years old (n = 9), milk powder for children aged three to five years old (n = 15), UHT liquid milk (n = 12), condensed milk (n = 12), and PLW milk powder (n = 30). Of these 78 samples, 63 samples were milk products that contained cocoa powder or chocolate flavour milk products (marked as chocolate milk products) and 15 samples (three samples per category) were milk products that did not contain cocoa powder or non-chocolate flavour milk (marked as non-chocolate milk product). In each brand collected for analysis, three different production codes were taken. For each production code, three samples were taken and then composited. If the number of products in the supermarket was less than 25 packages, then one sample was taken and not composited [Commission Regulation (EU) No 836/2011 (European Commission, 2011)]. Milk product samples were given a sample code to maintain the confidentiality of the sample during testing at the BBIA laboratory, Bogor.

Cocoa powder was collected using a non-random sampling method (purposive sampling), i.e., based on the cocoa powder used for the dairy industry that was produced by PT. XYZ manufacturer. There are two types of processing in cocoa powder processing, namely natural (without any alkalization process) and with an alkalization process. Cocoa powder from the alkalization process, i.e., low alkalized (LA), medium alkalized (MA), and high alkalized (HA). In this study, three different production codes (n = 9) were taken for each type of cocoa powder. The information regards the amount (as a percentage) and composition of cocoa beans used in the PT. XYZ manufacturer during the cocoa processing was also collected. Cocoa powder samples were given a sample code to maintain the confidentiality of the sample during testing at the BBIA laboratory, Bogor.

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2.2 Determination of cadmium levels in cocoa powder and milk products

The analysis of cadmium content was conducted in the Laboratory of the Central Agro-Industry (BBIA) Bogor. The cadmium standard, HCl, and HNO_3 concentrate reagents that were used in the analysis were from Merck (Darmstadt, Germany). The testing of Cd levels in milk powder referred to the AOAC Official Method 999.11 (AOAC, 2000), using graphite furnace atomic absorption spectrophotometry (AAS-GF) from Agilent Technologies type 200 Series AA and GTA 120 Graphite Tube Atomizer (Agilent, USA), with a detection limit of 0.023 µg/kg. The testing of Cd levels in cocoa powder refers to the Indonesian National Standard (INS) method of cocoa powder no. 3747 (INS, 2013), using flame atomic absorption spectrophotometry (AAS-flame) type AAS280FS (Varian, USA), with a detection limit of 12 µg/kg. The concentration of Cd in cocoa powder and milk products samples was obtained by plotting the standard curve against the samples whose levels were detected. The determination of the Cd content in each sample was carried out in duplicate.

2.3 Study of chocolate and non-chocolate flavour milk products consumption

Consumption data is calculated based on the report of the total diet study of individual food consumption survey (IFCS) in 2014, obtained from the Laboratory of Data Management of Research and Development Agency of the Ministry of Health of the Indonesian government in August 2021. The study of the consumption of milk products was carried out using respondent profile data and milk consumption data from the Indonesian population. This report is the result of an analysis of food consumption data collected from 145,360 respondents throughout Indonesia conducted by the Indonesian Ministry of Health (Siswanto *et al.*, 2014). Based on processing data using Microsoft Excel 2010 (Microsoft Co. USA), information on respondent profiles such as age, body weight, and consumption levels for milk products was obtained. These data were separated for chocolate flavour and non-chocolate flavour milk products. The consumption level was in unit g/individual/day.

2.4 Estimated cadmium exposure

Assessment of Cd exposure was estimated using a deterministic approach. Values used in calculating exposure values are based on the mean, 50th percentile (P50), 75th percentile (P75), and 95th percentile (P95). Estimation of exposure per day (estimated daily intake/EDI) in units of µg/kg BW/day was obtained by multiplying the average Cd concentrations in the products tested, with consumption data, and dividing by the weight of the population. The respondent's body weight was obtained from IFCS data (Siswanto *et al.*, 2014). The estimation of Cd exposure for one week was calculated by multiplying the value of exposure per day by seven, while the estimation for one month was calculated by multiplying the value of exposure per day by 30. The estimation of Cd exposure can be calculated based on the following equation:

$$\text{Cd exposure per day } (\mu g/kg\ BW/day) = \frac{\text{consumptions}\left(\frac{g}{day}\right) \times \text{Conc. of Cd}\left(\frac{\mu g}{kg}\right)}{\text{body weight (kg)}}$$

2.5 Cadmium risk characterization

Cadmium is categorized as a contaminant that accumulates in the body, thus the health-based guidance value (HBGV) used by the joint FAO/WHO expert committee of food additive (JECFA) is a PTMI value, i.e., 25 µg/kg BW/month (JECFA, 2011). Risk characterization of Cd was carried out by comparing the exposure value with PTMI. Risk to PTMI value was obtained by dividing the monthly Cd exposure value by 25 and multiplying by 100. In this study, apart from being calculated based on JECFA, risk characterization was also calculated based on the HBGV by the EFSA Panel for Contaminants in the Food Chain (CONTAM Panel), i.e., as a TWI value, 2.5 µg/kg BW/month (EFSA, 2011). Risk to TWI value was obtained by dividing the weekly Cd exposure by 2.5 and multiplying by 100. The risk to health due to the Cd exposure is indicated if the risk value obtained (as the risk to PTMI or TWI value) is more than 100, and conversely, if the risk value obtained less than 100, it indicates there is no health risk in the population (IARC 2012).

In this study, the calculation of risk characterization of PLW milk powder was also carried out with the scenarios: (1) scenario A: the highest consumption based on the serving suggestion (stated on the packaging label), the lowest bodyweight, and the highest Cd level, and (2) scenario B: the highest consumption P95, the lowest bodyweight, and the highest Cd levels. The lowest body weight of each group of respondents was calculated based on the IFCS 2014 report (Siswanto *et al.*, 2014) and the Cd level was from each milk product based on analysis results in this study.

3. Results and discussion

3.1 Cadmium levels in cocoa powder

The test results of cocoa powder (n = 9) using AAS, with a detection limit of 12 µg/kg are shown in Table 1. Results showed that all samples met the requirements Cd limit in NADFC regulation No. 5 of 2018, but the Cd levels in the LA samples were close to the upper limit of

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Table 1. Contamination level of Cd (µg/kg) in cocoa powder PT. XYZ.

Cocoa powder sample	Cd concentration (µg/kg)		Cocoa beans compositions used in PT. XYZ manufacturer
	Mean±SD	Range	
LA	760.7±33.1	722.5 – 781.5	25% Ecuador + 15% Congo + 60% Indonesia
MA	293.3±9.5	284.8 – 303.5	20% Nigeria + 40% Cameroon + 40% Indonesia
HA	385.6±95.9	319.8 – 494.8	30% Ivory Coast + 15% Nigeria + 20% Ecuador + 15% Cameroon + 20% Indonesia

850 µg/kg, where the range of Cd was 722.5 – 781.5 µg/kg. Based on the composition of cocoa beans used in LA, PT XYZ manufacturers used cocoa beans from Ecuador and Indonesia which are larger in number (25 and 60%), compared to the MA and HA types. This is aligned with the results of research conducted by Bertoldi *et al.* (2016), which reported cocoa beans from South and Central America had higher levels of Cd by 1388 and 544 µg/kg. The study reported by Ristanti *et al.* (2016) in cocoa beans from West Sulawesi, Indonesia, showed similar results, i.e., Cd levels are found up to 746.8 µg/kg.

Mixing cocoa beans is a good strategy to reduce Cd levels in cocoa powder (Vanderschueren *et al.*, 2021). In this study, cocoa powder MA has the lowest Cd concentration, with a Cd range was 284.8 – 303.5 µg/kg, and the composition of cocoa beans blending that was used by PT. XYZ manufacturer during cocoa processing was 60% from Africa, 40% from Indonesia, and did not use beans from the American continent. Ferreira de Oliveira *et al.* (2020) also reported the use of cocoa beans from different regions during the processing of cocoa beans can be an alternative to reduce Cd levels in the final product consumed. The occurrence of Cd was mainly in the non-lipid fraction of cocoa beans, i.e., cocoa powder, since at the pressing stage of the cocoa nibs (resulting from the cocoa beans grinding step), Cd would accumulate in cocoa liquor and would be converted into cocoa powder, while the cocoa butter and pressing residue were not contaminated by Cd (Ferreira de Oliveira *et al.*, 2020). Abt and Robin (2020) also reported that two factors affecting the Cd levels were the percentage of cocoa content in the product and the country of origin of the cocoa beans being used. Based on this study, the producers of cocoa powder need to implement a good strategy for cocoa bean blending during cocoa processing to achieve regulatory requirements for Cd content.

3.2 Cadmium levels in milk products

The test results as shown in Table 2 for samples of milk products (n = 78) by the AAS-GF method. Results showed that all milk products contain Cd, and met the Cd limit regulation, except for PLW milk powder. There are 17 of 27 samples (63%) of PLW chocolate flavour milk powder, having Cd levels exceeding the requirements of NADFC regulation No. 5 of 2018. Based on the mean value, the PLW chocolate flavour that meet the NADFC requirements were products with codes SI-03 and SI-05 (Figure 1).

In this study, although non-chocolate flavour milk products were only 15 samples (derived from five types

Table 2. Prevalence and contamination levels of Cd (µg/kg) in milk products.

Sample name	No. of sample	Range of cocoa composition (%)	Range (µg/kg)	Mean±SD (µg/kg)	NADFC (µg/kg)	No. exceeded NADFC (%)
Milk powder for children aged 1 - 3 years old						
Non-chocolate	3	0	1.53 – 2.33	1.82±0.45	10*	0
Chocolate	6	NA – 2.7	1.40 – 3.31	2.55±0.65	10*	0
Milk powder for children aged 3 - 5 years old						
Non-chocolate	3	0	1.22 – 1.73	1.54±0.28	50*	0
Chocolate	12	NA – 4.5	2.40 – 5.45	3.36±0.73	50*	0
UHT liquid milk						
Non-chocolate	3	0	1.02 – 1.56	1.33±0.28	50*	0
Chocolate	9	NA – 0.7	0.73 – 1.67	1.17±0.35	50*	0
Condensed milk						
Non-chocolate	3	0	1.11 – 1.96	1.61±0.44	50*	0
Chocolate	9	NA – 3.0	1.58 – 6.42	3.73±1.33	50*	0
PLW milk powder						
Non-chocolate	3	0	0,78 – 1.96	1.28±0.61	10	0
Chocolate	27	NA – 7.1	4.60 – 30.51	12.78±6.87	10	17/27 (63%)
Total samples	78					

NA: Not available, the percentage of cocoa powder composition was not stated on the packaging label.
*As per product consumed.

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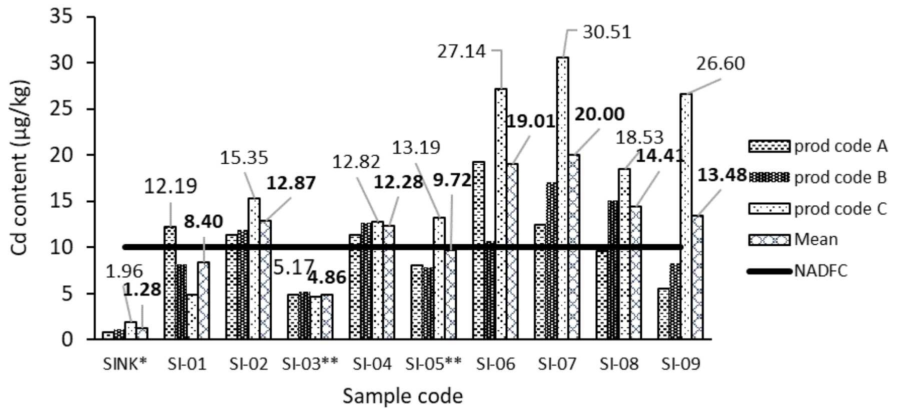

Figure 1. Contamination levels of Cd (µg/kg) in PLW milk powder compared to the NADFC regulation (maximum 10 µg/kg), and cocoa powder composition (%) in the product. *Milk product did not contain cacao powder, **No information of cocoa powder composition (as in percentage) in the packaging label of the product.

of samples, each from three different production codes), it showed that these samples gave a tendency for lower Cd levels than the chocolate flavour milk products (comparison between the same category). The maximum Cd level obtained was 2.33 µg/kg, i.e., non-chocolate flavour milk powder for children aged one to three years. However, the UHT liquid milk product gives no different results between products containing cocoa powder and those that do not contain cocoa powder. The range of Cd levels in non-chocolate flavour UHT liquid milk was 1.02 – 1.56 µg/kg, not much different from that in chocolate flavour UHT liquid milk, which was 0.73 – 1.67 µg/kg. Based on the information on the packaging label, the composition of cocoa powder was 0.7%, and this was only available on one sample, the other products did not have the information for the percentage of cocoa powder used. The more visible result related to higher Cd levels in chocolate flavour milk products is by looking at the Cd levels in PLW milk powder in this study. The cocoa powder composition in PLW milk powder is higher than in the other milk category. Results showed (Table 2) that the range of Cd levels in chocolate flavour PLW milk powder with a composition up to 7.1% was higher (4.60 to 30.51 µg/kg) compared to the non-chocolate flavoured (0.78 to 1.96 µg/kg).

The results of the Cd levels in the UHT sample in this study are lower when compared to the results of Akhtar *et al.* (2015). The Cd level in UHT milk and fresh milk in Multan, Pakistan was in the range of 1.5 to 62.1 µg/L (Akhtar *et al.* 2015). Unfortunately, the flavour information of the UHT milk was unknown. Higher results of Cd levels were also shown in the research by Alexander and Rohman (2019), which conducted testing on various brands of milk marketed around Yogyakarta, Indonesia. Results were reported in the range of 238.0 to 337.4 µg/L, with the ICP-AES method and a detection limit of 4.7 µg/L. Unfortunately, the types of milk products and the flavour of milk products being analysed were also not informed. Results from a study by Tonekaboni *et al.* (2019) in fresh and pasteurization milk samples in East Iran, showed slightly higher Cd levels compared to the results of non-chocolate flavour in this study. The mean results of these samples (in range) respectively were 3.2 to 9.2 µg/kg, and 3.9 to 7.9 µg/kg, the method used was AAS-GF and no flavour information. Yu *et al.* (2015) reported a similar result for fermented, sterilization, and modified milk samples taken in Jiangxi, China. The method used was ICP-MS and the result was between 1.9±1.1 to 4.1±4.7 µg/kg, but, unfortunately, the flavour information of the products was unknown. Evgenakis *et al.* (2018) reported the Cd levels on chocolate milk products, and results showed the same pattern as this study, although the type of the milk, which was obtained from the local supermarket in Thessaloniki, Greece, was different, i.e., semi-skimmed and skimmed milk. The cadmium levels in chocolate flavour reported an average value of 1.81 to 5.96 µg/kg. This Cd level was higher than non-chocolate semi-skimmed and skimmed milk (<LOD (0.260) up to 0.484 µg/kg).

In the research conducted by Abt *et al.* (2020), factors that affected the Cd content in the product containing cacao were the percentage of cocoa content in the product and the country of origin of the cocoa beans being used in cocoa processing. However, results in this study (Figure 1) showed that PLW milk powder code SI-09 with a composition of 2.0% cocoa powder, has a Cd content of up to 26.60 µg/kg. Whereas the PLW milk powder code SI-01, with a composition of 7.1% cocoa powder, has a lower Cd content of 12.19 µg/kg. The weak correlation was also indicated by the Pearson correlation coefficient value (obtained from calculations in the Microsoft Excel 2019 program) i.e. 0.246 and based on the Spearman equation i.e. 0.252 (Spearman Rank Correlation Coefficient, 2008). This weak correlation was caused by the inconsistency of Cd level in samples although coming from the same brand. There were seven samples, i.e. codes SI-01, SI-02, SI-05, SI-

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06, SI-07, SI-08, and SI-09 which have inconsistent Cd levels in each of their production codes (A, B, and C). This indicates the milk product manufacturer has not optimally monitored the Cd content in the cocoa powder used in their production. Of nine samples of chocolate flavour PLW milk powder, there was only one sample (code SI-03) had a Cd level below 10 µg/kg, met NADFC requirements, and consistent results showed a low standard deviation (0.29 µg/kg). Although the Cd level is low, the percentage composition of cocoa powder in this product was not mentioned on the packaging label, the same as code SI-05. Therefore, both samples were not included in the correlation calculation.

The Cd content in milk products also can be calculated theoretically. In the PLW milk product that has an issue with high levels of cadmium, if the upper limit of cocoa powder based on NADFC is 850 µg/kg (NADFC, 2018), and in this study, it is known that the highest composition of cocoa powder in PLW milk powder is 7.1%, then, theoretically the Cd content in milk products will exceed the NADFC requirement for PLW product (maximum 10 µg/kg), i.e., 60.35 µg/kg. To meet the NADFC requirements for PLW milk powder, if using cocoa powder with a Cd content within the upper limit of 850 µg/kg, then the percentage of cocoa powder used should be less than 1.175%.

3.2 Milk products consumption rate in Indonesia

3.2.1 Respondents of IFCS 2014

Based on the results of the IFCS 2014, the number of respondents for children aged one to three years old was 5,463 people, with an average weight of 11.20 kg, and a range of 4.50 to 20.90 kg. The number of respondents for children aged three to five years was 5,106 people with an average weight of 15.49 kg, and a range of 6.90 to 39.60 kg, while for the PLW group with an age range of 16 – 44 years, the number of respondents was 342 people, with an average weight of 57.44 kg, and a range of 36.20 to 95.60 kg. During data processing, for the age group of three to five years, the lowest weight data was 4.00 kg and the highest was 75.00 kg. However, these two data are not included in the calculation of weight processing, considering that based on the Minister of Health Regulation No. 2 of 2020 concerning the anthropometric standard of children, the threshold value (Z-score) in the category of very low body weight for boys aged three years (36 months) is 10.0 kg, while for girls it is 9.6 kg. The threshold value (Z-score) for the risk of being overweight is 20.7 kg for boys and 20.9 kg for girls (MoH 2020).

3.2.2 Consumption rate

Based on the consumption data of the IFCS 2014 report as shown in Table 3, the highest consumption rate as an average value was UHT liquid milk (up to 139.37 g/individual/day), then followed by condensed milk, PLW milk powder, milk powder for children aged three to five years old, and milk powder for children aged one to three years old (25.83 g/individual/day). Based on the IFCS report 2014 (Siswanto *et al.* 2014), the average consumption of milk products for the aged group of 0 – 59 months was 22.7 g/individual per day. The consumption rate for chocolate flavour milk products was higher than for non-chocolate flavour, except for condensed milk and PLW milk powder (Table 3). The level of consumption of chocolate flavour UHT liquid in children aged one to three years old was 1.36-fold higher

Table 3. Data consumption of milk product.

Sample name	Age (year)	Number of respondents	Consumption level (g/individual/day)			
			Mean	P50	P75	P95
Milk powder for children aged 1 - 3 years old						
Non- chocolate	1 – 3	3701	25.83	24	30	48
Chocolate		426	26.39	24.5	30	47
Milk powder for children aged 3 - 5 years old						
Non- chocolate	3 – 5	2316	26.5	25	30	49
Chocolate		640	28.31	27	30	45
UHT liquid milk						
Non- chocolate	1 – 3	122	99.36	107.5	125	190
Chocolate		208	135.15	125	190	250
Non- chocolate	3 – 5	277	111.86	120	180	250
Chocolate		455	139.37	125	200	250
Condensed milk						
Non- chocolate	1 – 3	842	29.9	30	40	50
Chocolate		76	26.06	21	40	46.5
Non- chocolate	3 – 5	1343	30.47	30	40	50
Chocolate		220	31.8	30	40	52.6
PLW milk powder						
Non- chocolate	16 – 44	267	32.02	30	37.5	60
Chocolate		75	28.31	30	30.5	45

than non-chocolate flavoured, while in the aged three to five years old was 1.24-fold. The average consumption of condensed milk reached 1.04-fold compared to non-chocolate flavour. The average consumption of PLW chocolate flavour was 0.9-fold lower compared to non-chocolate flavour. The highest consumption as P95 reaches up to 250 g/individual/day (chocolate flavour UHT liquid milk).

3.3 Cadmium exposure rate of milk products

Exposure of Cd from the consumption of milk products to vulnerable customers, i.e., children aged one to five years old and PLW consumers in the Indonesian population is presented in Table 4. The average Cd for daily exposure in chocolate flavour milk products was seen to be higher than in non-chocolate products. The order of the average daily Cd exposure from the highest is (1) milk powder for children aged three to five years old; (2) milk powder for children aged one to three years old; (3) UHT liquid milk; (4) condensed milk; and (5) PLW milk powder. The highest average Cd exposure reached 0.095 µg/kg BW/per day (chocolate flavour milk powder for children aged three to five years old), and this was 2.3-fold higher than the non-chocolate flavour milk. In PLW milk products, the average and P95 of Cd exposure reach up to 0.007 and 0.012 µg/kg BW/day. Although the consumption level of PLW chocolate flavour is 0.9-fold lower than non-chocolate, the exposure value of mean and P95 were 7.0 and 12.0-fold higher than non-chocolate flavour. Thus, there is a tendency for the presence of cocoa powder to provide higher Cd exposure and increase the risk of Cd exposure in these consumers.

In line with this study, the exposure data in the study conducted by Evgenakis *et al.* (2018) also showed the same pattern. The study showed that semi-skimmed and skimmed milk has a lower Cd exposure than chocolate semi-skimmed and skimmed milk. The approximate value of the EDI for semi-skimmed and skimmed milk was 0.002 µg/kg BW/day, while the range of exposure value of the consumption of chocolate semi-skimmed and skimmed milk was 0.006 to 0.020 µg/kg BW/day.

3.4 Risk of exposure to cadmium in milk products

Toxicity values for Cd were previously expressed as a weekly intake (PTWI) of 7 µg/kg body weight (BW). Given the long half-life of cadmium, daily food consumption has a small or even negligible effect on overall exposure, long or short-term risk assessment should be assessed over months (JECFA, 2011). Therefore, according to JECFA, the health-based guidance value (HBGV) for Cd should be assessed for at least 1 month (as PTMI, 25 µg/kg body weight) and the previous PTWI value was withdrawn (JECFA, 2011). In contrast to JECFA, the EFSA panel for contaminants in the food chain sets a TWI value of 2.5 µg/kg BW (EFSA, 2011). In this study, the risk of Cd exposure from milk products consumed by children aged one to five years and PLW was calculated for both values (PTMI and TWI) and presented in Table 4. The risk of Cd exposure in chocolate flavour milk products was seen to be higher than in non-chocolate flavour. Based on the

Table 4. Cadmium exposure and risk of milk products.

Sample name	Age (years)	Cd exposure (µg/kg BW/day)				Risk of Cd exposure (%)			
						PTMI		TWI	
		Mean	P50	P75	P95	Mean	P95	Mean	P95
Milk powder for children aged 1 - 3 years old									
Non-chocolate	1 - 3	0.047	0.044	0.054	0.087	5.63	10.46	13.14	24.41
Chocolate		0.067	0.063	0.077	0.12	8.09	14.41	18.88	33.62
Milk powder for children aged 3 - 5 years old									
Non-chocolate	3 - 5	0.041	0.039	0.046	0.076	4.9	9.07	11.44	21.16
Chocolate		0.095	0.091	0.101	0.151	**11.40***	**18.12***	**26.60***	**42.27***
UHT liquid milk									
Non-chocolate	1 – 3	0.012	0.013	0.016	0.027	1.44	3.18	3.37	7.43
Chocolate		0.014	0.013	0.019	0.027	1.71	3.24	3.99	7.57
Non-chocolate	3 - 5	0.01	0.009	0.013	0.022	1.17	2.68	2.73	6.25
Chocolate		0.011	0.011	0.014	0.02	1.29	2.44	3.02	5.7
Condensed milk									
Non-chocolate	1 - 3	0.004	0.004	0.006	0.008	0.53	0.93	1.23	2.18
Chocolate		0.009	0.009	0.011	0.017	1.05	1.99	2.46	4.65
Non-chocolate	3 - 5	0.003	0.003	0.004	0.006	0.4	0.7	0.93	1.63
Chocolate		0.008	0.008	0.01	0.016	1	1.91	2.33	4.45
PLW milk powder									
Non-chocolate	16 - 44	0.001	0.001	0.001	0.001	0.09	0.16	0.21	0.37
Chocolate		0.007	0.006	0.008	0.012	0.79	1.41	1.84	3.29

Bold figures indicate the highest value of Cd exposure risk (%) for Mean and P95 of PTMI and TWI in milk products.

higher risk exposure, as P95 value, the order of the risk to PTMI and TWI values from the highest is milk powder for children aged three to five years old (18.12 and 42.27%), milk powder for children aged one to three years old (14.41 and 33.62%), UHT liquid milk (3.24 and 7.57%), condensed milk (1.99 and 4.65%), and PLW milk powder (1.41 and 3.29%). All of these values came from chocolate flavour milk products. Results showed the group of children aged one to five years is vulnerable to Cd exposure through the consumption of milk products containing cocoa. However, the risk value for average and P95 value in these milk products are below 100% (the highest percentage showing 42.27%). This indicates that there is a tendency not to cause health problems by consuming milk products in children aged one to five years old and PLW consumers in Indonesia. Based on the study of Evgenakis *et al.* (2018), if the Cd exposure value is calculated against the PTMI value, then a value of 2.4% is obtained (less than 100% PTMI value), which indicates there is no significant exposure that potential to pose health risks.

3.5 Risk scenario of cadmium exposure based on serving suggestion (A scenario)

The serving suggestion listed on the packaging label was intended to fulfil the nutrition of PLW. The health risk of Cd exposure also can be evaluated as the highest risk, based on the serving suggestion. The purpose of this risk scenario is to fulfil the nutrition for children aged one to five years old and PLW, but the safety of the food products can be guaranteed. Data needed for this evaluation were the highest consumption in the serving suggestion, the highest Cd concentration in each product, and the minimal value of body weight based on the IFCS Report 2014. Results in Table 5 show that chocolate flavour milk products have a higher risk compared to non-chocolate flavour. The Cd exposure of these products with the scenario reaches up to 0.082, 0.063, and 0.084 µg/kg BW/day, respectively. Thus, the risk to PTMI and TWI values respectively for PLW chocolate were 9.80 and 22.86%; 7.58 and 17.69%; and 10.11 and 23.60%, where these values are below 100%. This indicates that there is a tendency not to pose health problems for children aged one to five years old and PLW consumers.

Based on this risk assessment, there were 63% of chocolate flavour PLW milk products did not meet the NADFC regulation (NADFC, 2018), but, since the risk value below 100%, therefore, this standard is very stringent for PLW milk powder contributed to very low of Cd exposure/ risk. Recommendations for the Cd limit are given for a maximum of 10 µg/kg but calculated as a product consumed. This requirement also has been implemented in the food category infant, follow-on, and growth formulas (NADFC, 2018; NADFC, 2019).

3.6 Risk scenario of cadmium exposure based on the highest consumption P95 (B scenario)

Results in Table 6 showed that chocolate flavour condensed milk consumed by children aged three to five years old provides the highest PTMI and TWI risk values compared to other milk products, i.e. 11.13 and 25.98%, respectively. The order of PTMI and TWI risk values from the highest to the lowest is UHT milk, condensed milk, PLW milk powder, milk powder for children aged three to five years old, and powdered milk for aged one to three years old. Table 6 also shows that milk products containing cocoa powder have a higher risk. This is caused by the higher Cd level in chocolate flavour milk products, as well as the higher amount of consumption. However, since the risk of PTMI and TWI values are still below 100%, it is considered not to pose a health risk to children aged one to five years old and PLW who consume these types of milk products.

3.7 Research limitations

This study has limitations i.e., (1) the number of non -chocolate milk samples being analysed was only three samples per milk category, but the total samples were 15 and came from different production codes; (2) the low number of PLW respondents, thus need sampling and/or

Table 5. Cadmium exposure risk scenario based on serving suggestions (A scenario).

Sample name	Highest serving suggestion			The highest conc. of Cd (µg/kg)	Lowest body weight (kg)	Cd exposure (µg/kg BW/day)	Risk (%)	
	Serving (g)	Frequency*	Consumption (g)				PTMI	TWI
Milk powder for children aged 1 – 3 years old								
Non-chocolate	35	2	70	2.33	4.5	0.036	4.35	10.15
Chocolate	37	3	111	3.31	4.5	0.082	9.80	22.86
Milk powder for children aged 3 – 5 years old								
Non-chocolate	35	2	70	1.73	6.9	0.018	2.11	4.91
Chocolate	40	2	80	5.45	6.9	0.063	7.58	17.69
PLW milk powder								
Non-chocolate	45	2	90	1.96	36.2	0.005	0.59	1.37
Chocolate	50	2	100	30.51	36.2	0.084	10.11	23.6

*Frequency information in the packaging label of the product was only available for milk product category: children aged 1 -3 years old, 3 – 5 years old, Pregnant and Lactating Women (PLW).

Table 6. Cadmium exposure risk scenario based on P95 consumption, lowest bodyweight, and highest Cd levels (B scenario).

Sample name	Highest consumption (P95)*	The highest conc. of Cd (μg/kg)	Lowest bodyweight (kg)	Cd exposure (μg/kg BW/day)	Risk (%) PTMI	TWI
Milk powder for children aged 1 – 3 years old						
Non-chocolate	48	2.33	4.5	0.025	2.98	6.96
Chocolate	47	3.31	4.5	0.035	4.15	9.68
Milk powder for children aged 3 – 5 years old						
Non-chocolate	49	1.73	6.9	0.012	1.47	3.44
Chocolate	45	5.45	6.9	0.036	4.27	9.95
UHT liquid milk, consumed by children aged 1 – 3 years old						
Non-chocolate	190	1.56	4.5	0.066	7.90	18.44
Chocolate	250	1.67	4.5	0.093	11.13	25.98
UHT liquid milk, consumed by children aged 3 – 5 years old						
Non-chocolate	250	1.56	6.9	0.057	6.78	15.83
Chocolate	250	1.67	6.9	0.061	7.26	16.94
Condensed milk, consumed by children aged 1 – 3 years old						
Non-chocolate	50	1.96	4.5	0.022	2.61	6.10
Chocolate	190	6.42	4.5	0.066	7.96	18.58
Condensed milk, consumed by children aged 3 – 5 years old						
Non-chocolate	50	1.96	6.9	0.07	8.35	19.48
Chocolate	200	6.42	6.9	0.049	5.87	13.70
PLW milk powder						
Non-chocolate	60	1.96	36.2	0.003	0.39	0.91
Chocolate	45	30.51	36.2	0.038	4.55	10.62

*Based on P95 consumption data in Table 3.

food consumption survey to gather more data and respondent in the future.

4. Conclusion

Milk products that did not meet the NADFC regulation were PLW milk powder, and there were 63% of chocolate flavour PLW milk powder exceeded the regulation (more than 10 μg/kg). Chocolate flavour milk products have a higher Cd level than non-chocolate flavour. The presence of cocoa powder in milk products used in cocoa powder processing increases the risk of Cd exposure. The highest Cd exposure calculated as P95 was found in chocolate flavour milk powder for children aged three to five years old, with risk values compared to PTMI-JECFA and TWI-EFSA reaching 18.12 and 42.27%. Based on A and B scenarios, the highest risk value for PTMI-JECFA and TWI-EFSA was 11.13 and 25.98%. These values were below 100%, therefore it was considered not to pose a risk of health problems. The results of this study are expected to be beneficial in the consideration of the policy requirements for heavy metal contamination of Cd in cocoa powder and milk products.

Conflict of interest

The authors declare no conflict of interest.

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