

ASSESSING EXPOSURE TO 3-MCPD FROM BAKERY PRODUCTS BASED ON MONITORING STUDIES UNDERTAKEN THROUGHOUT POLAND

Andrzej Starski, Małgorzata Jędra, Halina Gawarska, Jacek Postupolski*

Department of Food Safety, National Institute of Public Health-National Institute of Hygiene, Warsaw, Poland

ABSTRACT

Background. The compound 3-monochloropropano-1,2-diol, (3-MCPD) is a contaminant found in foodstuffs that arises during food processing and storage. Conditions conducive to the former are low pH and a high temperature and it can also be formed during manufacturing, ie. food processing. Those favouring the latter are dampness, raised temperatures, packaging conditions and storage duration. For the first time, high levels of 3-MCPD have been reported in soy sauces and hydrolysate products of vegetable protein manufactured through using acid hydrolysis. Animal studies on rats and mice have found that 3-MCPD is a carcinogen, however it is not genotoxic.

Objectives. To determine 3-MCPD levels in bakery products currently on the market and to estimate the resulting exposure to the those consumer groups most vulnerable. Results from a two year assessment of this contaminant are so presented.

Material and methods. Concentrations of 3-MCPD were measured in 244 samples of bakery foodstuff products found on the market which included; sponge cake, biscuits, cakes, crackers, breadsticks and rusks. Sampling was undertaken by the State Sanitary Inspectorate and analyses were performed by an accredited Gas Chromatography Mass Spectrometry (GC/MS) method. The exposure was assessed by comparing the accepted Tolerable Daily Intake (TDI) for 3-MCPD with the different conditions it occurred in, the consumption of 3-MCPD in the aforementioned foodstuffs and the various consumer groups.

Results. Levels of 3-MCPD that exceeded the limits of quantification in the studied foodstuffs were found in 91 out of 244 samples, (ie. 37.3%). These samples included 11 sponge cakes (11.3%), 27 biscuits (55.2%), 10 crackers (8.33%), 17 breadsticks (8.93%), 21 rusks (63.6%) and 5 cakes (3.13%). The highest numbers of samples containing more than 10 (≥ 10) $\mu\text{g}/\text{kg}$ of 3-MCPD were successively found in the following; breadsticks (79%), biscuits (75%), rusks (33%), crackers (33%), cakes (31%), biscuits (24%) and sponge cakes (4%). In 60 samples (24.6%), levels of 3-MCPD were higher than 10 $\mu\text{g}/\text{kg}$. It was estimated that the mean daily adult exposure to 3-MCPD is 0.008 - 0.013 $\mu\text{g}/\text{kg}$ body weight/day ie. 0.4 - 0.65% of the TDI, however at high exposures this became 6% of the TDI. In the children's group, the mean exposure was 0.022 - 0.036 $\mu\text{g}/\text{kg}$ body weight/day ie. 1.1 - 1.8% of the TDI whilst at high exposure it became 16.4% of the TDI.

Conclusions. The results demonstrated that sample levels of 3-MCPD in bakery products do not constitute a significant health risk to consumers.

Key words: 3-monochloropropan-1,2-diol, 3-MCPD, sponge cake, biscuits, bakery products, monitoring, exposure assessment

STRESZCZENIE

Wprowadzenie. 3-monochloropropano-1,2-diol (3-MCPD) jest zanieczyszczeniem chemicznym żywności powstającym w procesie jej wytwarzania i przechowywania. Na tworzenie się zanieczyszczenia mają wpływ: niskie pH, wysoka temperatura oraz proces technologiczny, natomiast podczas przechowywania: wilgoć, podwyższona temperatura, opakowania oraz okres przechowywania. Po raz pierwszy 3-MCPD w wysokich zawartościach stwierdzono w sosach sojowych i hydrolizatach białek roślinnych produkowanych metodą kwaśnej hydrolizy. Badania na szczurach i myszach wykazały, że 3-MCPD posiada działanie kancerogenne, nie jest natomiast substancją genotoksyczną.

Cel badań. Ocena zawartości 3-MCPD w wyrobach piekarskich znajdujących się w obrocie oraz oszacowanie narażenia konsumenta na to zanieczyszczenie. W pracy omówiono wyniki 2 letnich badań produktów piekarskich pochodzących z obrotu.

Material i metody. Analizie chemicznej pod kątem zawartości 3-MCPD poddano 244 próbki wyrobów piekarskich: biszkopty, herbatniki, ciastka, krakersy, paluszki i suchary. Próbkę do badań były pobierane z obrotu przez pracowników Państwowej Inspekcji Sanitarnej. Zawartość zanieczyszczenia analizowano akredytowanymi metodami chromatografii gazowej sprzężonej ze spektrometrią mas (GC/MS). Oceny narażenia dokonano porównując wartości pobrania z TDI ustalonym dla 3-MCPD, przyjęto scenariusze obejmujące zróżnicowane występowanie zanieczyszczenia, spożycie omawianych środków spożywczych oraz grupy konsumentów.

* **Corresponding author:** Andrzej Starski, Department of Food Safety, National Institute of Public Health-National Institute of Hygiene, Chocimska Street 24, 00-791 Warsaw, Poland, phone +48 22 54 21 383, fax: +48 22 54 21 225, e-mail: astarski@pzh.gov.pl

Wyniki. Zawartość 3-MCPD w badanych produktach spożywczych powyżej granicy oznaczalności stwierdzono w 91 z 244 próbek (37,3%), w tym w 11,3% próbek biszkoptów (11), 55,2% herbatników (27), 83,3% sucharów (10), 89,5% paluszków (17), 63,6% krakersów (21) oraz w 31,3% ciastek różnych (5). Największą liczbę próbek o zawartości 3-MCPD powyżej 10 µg/kg (≥ 10) stwierdzano kolejno w: paluszkach (79%), sucharach (75%), krakersach (33%), ciastkach (31%), herbatnikach (24%) i biszkoptach (4%). Ogółem w przypadku 60 próbek (24,6% badanej populacji) poziom zanieczyszczenia wynosił powyżej 10 µg/kg. Oszacowane średnie narażenie na 3-MCPD w grupie dorosłych wynosiło 0,008-0,013 µg/kg m.c./dzień tj. 0,4-0,65% wartości Tolerowanego Dziennego Pobrania (Tolerable Daily Intake, TDI), natomiast narażenie wysokie 6,1% wartości TDI. W grupie dzieci średnie narażenie wynosiło 0,022-0,036 µg/kg m.c./dzień tj. 1,1-1,8% wartości TDI, a w przypadku wysokiego narażenia do 16,4% TDI.

Wnioski. Na podstawie uzyskanych wyników stwierdzono, że zawartości 3-MCPD w badanych wyrobach piekarskich nie stanowią istotnego zagrożenia dla zdrowia konsumenta.

Słowa kluczowe: 3-monochloropropano-1,2-diol, 3-MCPD, biszkopty, herbatniki, wyroby piekarskie, monitoring, szacowanie narażenia

INTRODUCTION

3-MCPD is one of the chemical contaminants arising during food processing and storage. In the 1980s it was found that small amounts of chloropropanol compounds can be formed during acid hydrolysis of vegetable protein. These being; 3-MCPD, 2-chloropropano-1,3-diol (2-MCPD), 1,3-dichloropropan-2-ol (1,3-DCP) and 2,3-dichloropropanol (2,3-DCP), of which the former is the most widely found. The mechanism of its formation was also discovered [2, 7, 15, 17]. Since then 3-MCPD had been detected in other foodstuffs and food ingredients, in particular those containing fats and sodium chloride that had previously undergone thermal treatment [3, 6, 7, 9, 10]. This compound arises by nucleophilic substitution of the chloride ion to glycerol or glycidol. Under alkaline conditions 3-MCPD can eliminate the chloride anion from the conjugate thus forming toxic forms of glycidol and then glycerol. 3-MCPD is well soluble in water and ethanol but is unstable under alkaline conditions.

Various studies have found that 3-MCPD is toxic [1, 8, 12, 15, 17], and after being absorbed by the digestive system it enters the circulation and passes the blood brain barrier and blood testes barrier. Chronic toxicity experiments on rats have demonstrated toxicity to the kidney, central nervous system (CNS) and endocrine system. *In vitro* tests also demonstrate that 3-MCPD is mutagenic. *In vivo* studies performed on rats and *Drosophila melanogaster* showed that 3-MCPD is potentially genotoxic. Long-term studies on rats indicate that the increased number of tumours is not because of genotoxicity, but most likely due to chronic endocrine disorders, (tumours in the mammary glands and testes having been observed), or that cytotoxicity is maintained or a hyperplasia of the kidneys (tumours). 3-MCPD induces tumour formation by mechanisms other than genotoxicity. The enantiomers of 3-MCPD also possess different toxicities.

In May 2001, the EC's Scientific Committee on Food (SCF) assessed the scientific evidence on 3-MCPD obtained from long term studies on rats and determined that the lowest observable adverse effect level (LOAEL) was a dose of 1.1 mg/kg body weight/day. The compound was also recognised to be a non-genotoxic carcinogen. In performing its assessment, the uncertainty factor was taken as 500 in order to set the TDI level of 2 µg/kg body weight/day. This high value adopted for the uncertainty factor, instead of the often used 100 level, was because of the lack of a statistically significant difference between the NOAEL (no observed adverse effect level) and LOAEL as well as lack of toxicological evidence on 3-MCPD affecting foetal differentiation and development. A scientific co-operation study undertaken by the EC (SCOOP) in EU member states, collected and analysed 3-MCPD from 3600 foodstuff samples [3]. Many of these consisted of soy sauce where 3-MCPD levels were significantly higher than in other foodstuffs at 9100 µg/kg. Other samples analysed for 3-MCPD included sauces, soups, spices, salads and vegetable protein products made up of hydrolysed vegetable protein (HVG). 3-MCPD was detected in 45% samples above the limit of quantification (LOQ) with a mean value of 252 µg/kg.

Foodstuffs that contain low amounts of 3-MCPD include vegetable and animal fats, meat and its products, fish, cereals, bakery products, fruit and vegetables where mean levels range from 35 to 95 µg/kg. Within this group, the highest levels are seen in pasta and dumplings of up to 945 µg/kg, whereas the lowest ones are in dairy products, beverages and confectionery (including cocoa and drinking chocolate). Over 90% of the aforementioned foodstuffs had 3-MCPD levels below the LOQ of the analytical methods used [3].

Although 3-MCPD levels are low in cereal products, the dietary consumption of these foodstuffs in Poland is relatively high and thus may contribute significantly to the total 3-MCPD intake. Conditions that favour

3-MCPD formation in bakery products are baking temperatures above 200°C, low pH, presence of fats (acylglycerols) as well as food additives such as diacetyl-tartaric acid and mono and diglyceride fatty acids [7, 9, 17]. However, pHs exceeding 6 and the presence of carbohydrates inhibit 3-MCPD formation.

Bakery products such as sponge cake, biscuits rusks and biscuits are frequently featured in the diet of young children, those of advanced age and persons suffering illnesses. It is therefore important that 3-MCPD be estimated in these products to determine the exposure in such vulnerable groups. The current study presents 3-MCPD measurements undertaken in selected bakery products from which exposure to this compound was assessed in Polish consumers.

MATERIAL AND METHODS

The bakery products available on the market were sampled by the State Sanitary Inspectorate (SSI) throughout Poland during 2008-9. These included sponge cake, biscuits, cakes, crackers, breadsticks and rusks. A total of 244 samples were taken of which 228 were of domestic manufacture whilst 50 samples came from abroad (ie. Italy, Germany, Czech Republic, Belgium, Spain and Croatia). A breakdown of numbers according to category showed the following; sponge cake 97, biscuits 67, rusks 12, breadsticks 19, crackers 33 and cakes 16.

Analysis of 3-MCPD in samples was performed by accredited laboratories of the SSI using a method compliant with the PN-EN 14573:2005 standard [11]. Samples were first homogenised in a sodium chloride solution and the mixture, as the mobile phase, was absorbed onto an Extrelut column (Merck, Silica Earth). Extraction was achieved by first eluting off the initial components with a hydrophobic mixture of hexane and diethyl ether. The 3-MCPD was then eluted with ethyl acetate. The purified extract was subjected to acetylation using N-heptafluorobutyrylimidazole (HFBI - from Sig-

ma) to form a 3-MCPD derivative to which a deuterated internal standard (IS) was added; d_5 -3-MCPD ready for GC/MS analysis. The principal ions monitored were $m/z = 253$ for 3-MCPD and $m/z = 257$ for the IS, with other 3-MCPD ions also measured for confirmation; $m/z = 453, 291, 289$ and 275 .

This method conformed to analytical criteria for measuring 3-MCDP defined in EC Regulation No 333/2007 [13], with a limit of detection (LOD) $\leq 5 \mu\text{g}/\text{kg}$ and a LOQ of $\leq 10 \mu\text{g}/\text{kg}$. Two approaches were adopted for calculating results below the LOD or LOQ. In those results below the LOQ the actual LOQ value was taken (ie. termed upper band; UB), whilst for those that were below the LOQ a zero value was assigned (lower band; LB). Subsequent calculations took into account the LOD and LOQ values reported by each participating laboratory.

RESULTS AND DISCUSSION

3-MCPD was detected in 242 samples (99.2%) of the studied foodstuffs. The highest levels were recorded in rusks and crackers whereas the lowest ones were in biscuits and sponge cakes. Amounts of 3-MCPD above the LOQ were found in 91 samples (37.3%), of which 11 were sponge cake (11.3%), 27 biscuits (55.2%), 10 rusks (83.3%), 17 breadsticks (89.5%), 21 crackers (63.6%) and 5 cakes (31.3%). Levels of 3-MCPD varied between the LOQ to $81.2 \mu\text{g}/\text{kg}$ in one sample of crackers taken. The LOQ values varied according to the reporting laboratory and were dependent on the sample matrix, ranging from 3.8 to $10.0 \mu\text{g}/\text{kg}$. Levels of 3-MCPD in samples coming from other EU countries were not significantly different to home products. Earlier studies reported by this group on bakery products such as rusks and toast demonstrated relatively higher mean levels of 3-MCPD ($26.5 \mu\text{g}/\text{kg}$) compared to bread ($18.6 \mu\text{g}/\text{kg}$) [6]. Table 2 presents the measured 3-MCPD values found in each foodstuff category including, as appropriate, the upper band or lower band

Table 1. Results of monitoring study on 3-MCPD occurrence in selected bakery wares

Bakery ware group	Number of samples (n)	Average level of 3-MCPD* $\mu\text{g}/\text{kg}$	3-MCPD level					Maximum $\mu\text{g}/\text{kg}$
			P10	P25	median	P75	P90	
All products	244	6.7-10.9	0-5.0	0-5.6	0-6.0	9.5-10.0	22.7	81.2
biscuits (soft)	97	1.2-6.5	0-5.0	0-5.6	0-5.6	0-6.0	4.7-10.0	35.5
biscuits (hard)	67	5.7-9.7	0-5.0	0-6.0	0-8.3	9.2-10.0	16.4	43.4
rusks	12	35.2-36.2	0.8-6.2	22.0	34.5	45.5	70.1	81.2
sticks	19	17.7-18.4	5.8-7.0	10.3	16.7	26.6	33.0	34.7
crackers	33	9.6-11.8	0-5.2	0-6.0	7.9-8.2	12.4	21.3	55.5
cakes	16	8.3-12.1	0-5.0	0-5.0	0-5.5	15.2	21.2	58.8

* the values expressed as range correspond to assumed approach: lower bound (LB) and upper bound (UB)

values previously determined. Figure 1 represents a box chart for the upper band approach where the P25-P50 and P50-P75 ranges are shown as well as the P90 and average values.

In making comparisons, analytical data was binned in the following groups; $<10 \mu\text{g}/\text{kg}$, ≥ 10 to $<20 \mu\text{g}/\text{kg}$, ≥ 20 to $<50 \mu\text{g}/\text{kg}$ and $\geq 50 \mu\text{g}/\text{kg}$; Figure 2. Numbers of samples containing 3-MCPD levels greater than 10

with bread whose consumption is high compared to snacking products.

First of all, the current study can be compared with the aforementioned SCOOP study [3]. The UK, France and Sweden reported findings from 337 samples of bakery products of which 164 (48.7%) had 3-MCPD levels less than $10 \mu\text{g}/\text{kg}$. This proportion is twice greater than in the presented study. 3-MCPD was detected

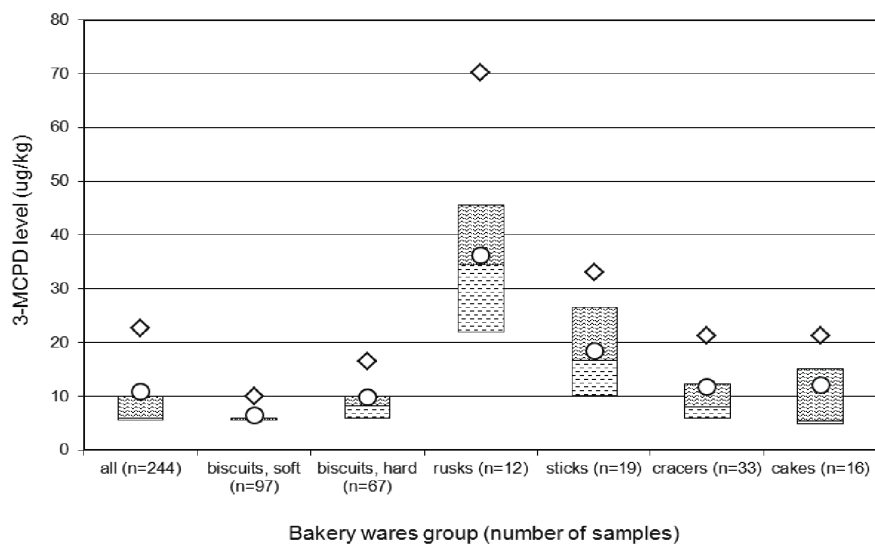


Figure 1. Amounts of 3-MCPD in specific groups of bakery wares

$\mu\text{g}/\text{kg}$ were found in the following foodstuff categories; breadsticks (79%), rusks (75%), crackers (33%), cakes (31%), biscuits (24%) and only 4% of sponge cakes. Overall, there were 60 samples (24.6% of total) showing 3-MCPD levels above $10 \mu\text{g}/\text{kg}$.

It is important to compare the presented results with other like studies on similar foodstuffs. A common approach when assessing 3-MCPD levels an human exposure is to include all bakery products together

in the following foodstuffs; 34.5% sponge cakes (over 7 times higher), 93% crackers (3 times higher) and 37% cakes (similar results).

The highest number of products containing 3-MCPD (87%) were crackers with a maximum amount detected of $130 \mu\text{g}/\text{kg}$. The mean level of 3-MCPD found in all the studied foodstuffs was $20 \mu\text{g}/\text{kg}$ and in no group did this ever exceed a mean of $30 \mu\text{g}/\text{kg}$; these findings were almost double those in the presented study despite

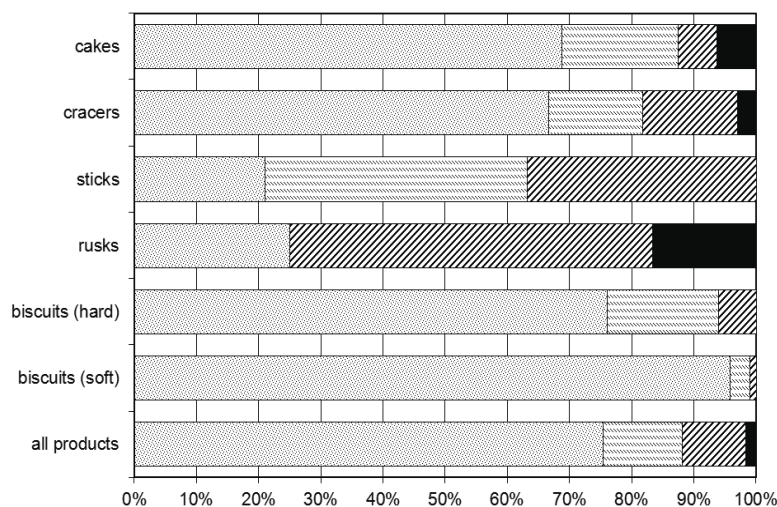


Figure 2. Percent of sample in selected group of bakery wares in relation to ranges of 3-MCPD contamination ($\mu\text{g}/\text{kg}$)

the presence of foodstuffs such as rusks and breadsticks which were absent from the SCOOP study report. Such higher results may have arisen because in the year 2000 there were less advanced systems in place for limiting the formation of 3-MCPD in foodstuffs during manufacture compared to the time when the presented study was conducted ie. 2008-9. Furthermore, analytical methods have since improved with now lower LOQs.

Cotemporaneous with the current work, a UK monitoring study was performed on foodstuffs which included measuring 3-MCPD [4, 5]. During 2008-9, 15 samples of cakes and crackers were analysed, showing a mean value of 456 µg/kg (range 50-1538 µg/kg) in 2008 and mean of 329 µg/kg in 2009 (range 30-902 µg/kg). These much higher values may be due to crispy bread and gingerbread cake being included.

The relevant legislation currently in force (ie. EC Regulation No 1881/2006 with amendments) [14] defines the maximum levels for food contaminants, that includes 3-MCPD but only in soy sauces and hydrolysed vegetable protein. Taking into account the 3-MCPD contamination found in the 244 bakery products assessed by the current study, it was found that the 50 µg/kg dry mass level was exceeded in only 4 cases.

The levels of 3-MCPD so determined, were sufficient to enable consumer exposure to be estimated and compared to the TDI and for other estimations to be made on vulnerable consumer groups consisting of children and the elderly. Using available dietary data in Poland, biscuits were consumed at respectively 30.1 g and 21.0 g daily for boys and girls aged 1-3 years and respectively 53.1 g and 39.6 g daily for those aged

4-6 years. Bearing in mind the mean 3-MCPD content that was herein found in biscuits (ie. 5.7 to 9.7 µg/kg; LB:UB) the daily exposure (UB), as in the previously defined age group for boys, was respectively 0.292 µg and 0.515 µg; for girls this corresponded to 0.204 µg and 0.384 µg. In the group of 4 year old boys of body weight 18 kg [16], the intake is 0.029 µg/kg body weight/day which represents 1.45% of the TDI (ie. at 2 µg/kg body mass/day). The maximum level of 3-MCPD found in biscuits was 43.4 µg/kg which was equivalent to an intake 0.128 µg/kg body weight/day forming 6.4% of the TDI. The highest daily consumption of biscuits was 98.7 g in boys aged 16-18 years, (of 64 kg mean body weight). The calculated intake for this age group, (mean UB value) was 0.957 µg equivalent to 0.015 µg/kg body mass/day (0.75% TDI).

The exposure was also estimated from the SCOOP consumption data [3] that allows estimated exposure values for the aforementioned foodstuffs to be also estimated in other EU countries. In Poland, contaminant levels in foodstuffs were determined by a monitoring programme of which the presented study formed a part thereof. The estimation used population consumption values that included those at average/mean and high consumption levels (P95) and likewise for contaminants at an average and high consumption (P90). Calculations assumed a 20 kg body mass for children and 60 kg for adults. Results are shown in Table 2.

The average exposures so determined for adults were lower compared to corresponding results estimated in France and Netherlands, whilst the high exposure values were similar. The French studies showed that the highest

Table 2. Estimation of consumer exposure on 3-MCPD derived from selected bakery wares

Consumption g/day	3-MCPD occurrence ^(c)	Exposure ^(c)		% TDI ^(c)
	µg/kg	µg/person	µg/ kg b.w.	
Group: adults				
average consumption ^(a) average: 69.5	average: 6.7-10.9 P90: 22.7	0.466-0.758 1.578	0.008-0.013 0.026	0.4-0.65 1.3
average consumption ^(a) maximum: 112.3	average: 6.7-10.9 P90: 22.7	0.752-1.224 2.549	0.013-0.020 0.042	0.65-1.0 2.1
consumption level P95 ^(a) average: 195.6	average: 6.7-10.9 P90: 22.7	1.311-2.132 4.440	0.022-0.036 0.074	1.1-1.8 3.7
consumption level P95 ^(a) maximum: 319.1	average: 6.7-10.9 P90: 22.7	2.138-3.478 7.244	0.036-0.058 0.121	1.8-2.9 6.1
Group: children				
average consumption ^(b) average: 65.6	average: 6.7-10.9 P90: 22.7	0.440-0.715 1.489	0.022-0.036 0.074	1.1-1.8 3.7
average consumption ^(b) maximum: 104.3	average: 6.7-10.9 P90: 22.7	0.699-1.137 2.368	0.035-0.057 0.118	1.75-2.85 5.9
consumption level P95 ^(b) average: 181.9	average: 6.7-10.9 P90: 22.7	1.219-1.983 4.129	0.061-0.099 0.206	3.1-4.95 10.3
consumption level P95 ^(b) maximum: 288.7	average: 6.7-10.9 P90: 22.7	1.934-3.147 6.553	0.097-0.157 0.328	4.85-7.85 16.4

(a) in accordance to consumption study in France, Germany, Ireland, Netherlands, Sweden and United Kingdom [3]

(b) in accordance to consumption study in France, Germany, Netherlands, and United Kingdom [3]

(c) the values in range correspond to assumed approach: lower bound (LB) and upper bound (UB)

foodstuff consumption of the aforementioned categories was 112 g/day and that the P95 value was even as high as 319 g/day; this being similar to the Dutch findings. Corresponding exposures for mean consumption and contamination were respectively 0.039 - 0.042 µg/kg body weight/day and 0.031 - 0.035 µg/kg body weight/day, whereas those for high exposures (P95 occurrence and consumption) were respectively 0.106 - 0.117 µg/kg body weight/day and 0.082 - 0.093 µg/kg body weight/day. Studies from Germany, which had the lowest consumption levels, yielded respective exposures of 0.006 µg/kg body weight/day and 0.017 - 0.02 µg/kg body weight/day. Using results obtained for Poland to estimate those in Germany can be justified by having similar diets according to the GEMS/FAO cluster diet (Global Environment Monitoring System/ Food and Agriculture Organization).

The highest consumptions in child subjects were noted in France and Netherlands (the former with a mean of 104 g/day and P95 of 289 g/day). Exposure to average consumption in France was 0.072 - 0.08 µg/kg body weight/day and 0.044 - 0.051 µg/kg body weight/day in Netherlands, whereas the respective values for the consumer group with high exposures were 0.193 - 0.216 µg/kg body weight/day and 0.124 - 0.141 µg/kg body weight/day. Polish estimates of exposure are similar to the German ones i.e. 0.024 - 0.028 µg/kg body weight/day for the group of 4 yearolds and were also lower than the ones mentioned above. However the estimates for high exposure were similar within this subject group.

Within the EU, the daily intake of 3-MCPD from all sources was assessed as being significantly less than the TDI [15]. The highest levels were observed in Netherlands at 1.38 µg/kg body mass/day whose foodstuff source were various types of sauces. The highest dietary intake of 3-MCPD was from soy sauce being consumed only in Netherlands and Finland. However, in other countries the main foodstuff sources of 3-MCPD were bread, pasta, meat and beer due to the high consumption of these products. The estimated daily intakes of 3-MCPD in European children, (from Germany, France and Netherlands), were higher than in adults and due the consumption of bread, dumplings and cakes. It was also seen that high soy sauce consumption by children, (at the 95 percentile of consumption) may result in high 3-MCPD intakes for 4 yearolds at levels of 1.7 µg/kg body weight/day, constituting 85% of the TDI.

CONCLUSIONS

1. Foodstuffs available on the Polish domestic market had lower levels of 3-MCPD compared with other EU countries. Rusks, breadsticks, crackers and cakes had the highest content followed next by sponge cake and biscuits. Contaminant levels found in the-

se foodstuff categories were proportional to those determined in other EU countries.

2. The estimated mean exposure in adults was 0.008 - 0.013 µg/kg body weight/day representing 0.4 - 0.65% of the TDI (set at 2 µg/kg body weight/day), however this was 0.121 µg/kg body weight/day at high exposure, (i.e. 6.1% of the TDI. The former exposure does not constitute a significant threat to health.
3. The levels of 3-MCPD found in bakery products do not represent a significant health threat to consumers. In children the mean exposure was 0.022 - 0.036 µg/kg body weight/day forming 1.1 - 1.8% of the TDI, however the high exposure can even be as high as 0.328 µg/kg body weight/day, i.e. 16.4% of the TDI.

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Conflict of interest

The authors declare no conflict of interest.

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