Elżbieta WIERZBICKA, Ph.D
Department of Human Nutrition, Institute of Human Nutrition Sciences
Warsaw University of Life Sciences (SGGW-WULS), Poland
Katedra Żywienia Człowieka, Instytut Nauk o Żywieniu Człowieka
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska

SWEETENERS AS SUGAR SUBSTITUTES IN FOOD INDUSTRY – ASSESSMENT OF DIETARY INTAKE OF INTENSE SWEETENERS IN CHILDREN AND ADOLESCENTS®

Substancje słodzące jako substytuty cukru w przemyśle spożywczym – ocena pobrania z dietą intensywnych substancji słodzących u dzieci i młodzieży®

Key words: sugar substitutes, non-nutritive sweeteners, low-calorie sweeteners, food additives, acceptable daily intake, ADI, safety evaluation, risk assessment.

Due to food industry offering a continuously expanding selection of products containing non-nutritive sweeteners (NNS) as sugar substitutes, the significance of studies referring to the assessment of the intake of NNS as part of one's diet in comparison to Acceptable Daily Intake (ADI) values is increasing, contributing to the monitoring and the assessment of food safety. The study was conducted in a group of 128 children and adolescents aged 7-16 years, from a randomly selected primary and secondary school within the area of the city of Warsaw. Based on a 3-day record of consumed products, meals and beverages and with the use of the Theoretical Maximum Daily Intake (TMDI) model, the intake of sweeteners was estimated and compared with the appropriate ADI values. In the studied group of children and adolescents, average (median) intake of the studied substances with the diet, calculated based on the real consumption of the sweeteners, did not exceed the established daily maximum intake, hence, the consumption of sweeteners from products containing sugar substitutes was on an acceptable level (all below ADI values). Due to a higher intake of sweeteners among adolescents aged 14-16 years, statistically significant for cyclamates and acesulfame K, this age group should be treated as a group that is vulnerable to higher intake, which may be linked with high consumption of flavoured non-alcoholic beverages, constituting the main source of intense sweeteners in their diet. It is necessary to continue studies to monitor changing use and the intake of sweeteners with the diet among children and adolescents.

Słowa kluczowe: substytuty cukru, nieodżywcze substancje słodzące, niskokaloryczne substancje słodzące, substancje dodatkowe, dopuszczalne dzienne pobranie, ADI, ocena bezpieczeństwa, ocena ryzyka.

Ze względu na stale poszerzającą się ofertę rynkowych produktów zawierających intensywne substancje słodzące jako substytuty cukru, badania związane z oceną pobrania ich z dietą w odniesieniu do dopuszczalnego dziennego pobrania (ADI) nabierają istotnego znaczenia, stanowiąc element monitorowania i oceny bezpieczeństwa żywności. Badania z tego zakresu przeprowadzono w grupie 128 dzieci i młodzieży w wieku 7-16 lat, z wylosowanej szkoły podstawowej i średniej z Warszawy. W oparciu o 3-dniowe bieżące notowanie spożytych produktów, potraw i napojów oraz model obliczeń teoretycznego najwyższego dziennego pobrania (TMD) I oszacowano pobranie substancji słodzących i porównano z odpowiednimi wartościami ADI. W badanej grupie dzieci i młodzieży średnie (mediana) pobranie z dietą substancji słodzących wyliczone na podstawie rzeczywistego spożycia tych produktów nie przekraczało ustalonego na podstawie badań toksykologicznych dopuszczalnego dziennego pobrania, a zatem pobranie substancji słodzących z produktów z zamiennikami cukru było na akceptowanym poziomie (wszystkie substancje poniżej ADI). Ze względu na stwierdzone znacznie większe spożycie substancji słodzących wśród młodzieży w wieku 14-16 lat, istotne w przypadku cyklaminianów i acesulfamu K, starszą młodzież szkolną należy wskazać jako grupę o potencjalnie większym ryzyku pobrania, co może być związane z dużym spożyciem aromatyzowanych napojów bezalkoholowych, będących głównym ich źródłem w diecie. W grupie dzieci i młodzieży niezbędne jest kontynuowanie badań monitoringowych z zakresu stosowania substancji słodzących oraz ich pobrania z całodzienną dietą.

Corresponding author – Adres do korespondencji: Elżbieta Wierzbicka, Department of Human Nutrition, Institute of Human Nutrition Sciences, University of Life Sciences (SGGW-WULS), 159c Nowoursynowska Street, 02-776 Warsaw, Poland. e-mail: elzbieta_wierzbicka@sggw.edu.pl

INTRODUCTION

Food additives play a significant role in the contemporary food industry. This statement refers also to sweeteners, in particular non-nutritive sweeteners (NNS). They are a functional class of food additives, typically used to replace sugars for the production of energy-reduced foodstuffs [6, 9, 11, 16, 40, 42, 43]. They provide a desired sweet taste without the addition of appreciable energy and can help maintain the palatability of products [4, 7, 16, 17, 33, 34]. These products may or may not be labelled as e.g. 'diet', 'light', 'sugar-free' or 'low-energy' and commonly contain one or more NNS as full or partial replacement of sugar. Some of these types of products are formulated such that they can be added directly to beverages such as tea and coffee, or used for cooking and baking [7, 16, 17, 33, 34, 40, 43].

The EFSA concluded that there is sufficient scientific information to support the claims that intense sweeteners, as sugar replacers, lead to a lower postprandial rise in blood sugar levels, if consumed in place of sugars [15, 16]. NNS is likely to be beneficial for most individuals from a diabetes management and dental point of view and can help maintain a healthy body weight through reducing sugar and energy intake, which is a public health priority [4, 11, 23, 26, 34, 42]. Desired taste constitutes the basic factor taken into account when choosing the sweet-tasting products. Actual levels of use of sweeteners depend on consumer preferences, the presence of any natural sugar as well as on the application of sweetener mixes, which is not rare, and sometimes necessary due to technological reasons [7, 17, 34, 43]. Children and adolescent's diets are far from optimal, being characterized by a high consumption of sweetened beverages, sweet bakery products, confectionary and dairy products and an excess of products high in sugar [2, 3, 37]. In particular, sugar intake among children has raised concern worldwide as it exceeds recommendations [23, 48].

The use of NNS is approved in Europe in a number of specific food categories according to the provisions of Regulation (EC) No 1333/2008 (European Commission 2008) as amended by Commission Regulation (EU) No 1129/2011 (European Commission 2011), and has to take place under strictly determined conditions. Maximum permitted levels (MPL) differ between sweeteners, reflecting the differences in sweetness intensity and represent maximum permitted value in each of the categories of food and beverages [18, 19]. Consumption of NNS is increasing worldwide [5, 24, 30, 32, 36, 39, 47, 49], with the most marked rise observed among children and adolescents [1, 8, 22, 24, 30–32, 41, 44, 50].

With reference to the assessment of the intake of additives, the EFSA Panel on Food Additives and Flavourings presented its recommendations to be applied when assessing the safety of food additives, including exposure assessment scenarios as part of this assessment. Both typical as well as maximum levels of use of an assessed substance may be in particular taken into consideration in exposure estimates. It enables the assessment of the intake of such substances as part of one's diet basing on maximum permitted levels of use taking into consideration the brand-loyal consumers [12, 14, 16]. Additionally, a programme for the re-evaluation of food additives that were already permitted in the European Union before 20 January 2009 has been set up under the Regulation (EU) No 257/2010 [20]. This regulation foresees that sweeteners are re-evaluated whenever necessary in light changing conditions of use and new scientific information, and a protocol is being implemented in order to draft the scientific opinions on the re-evaluations of sweeteners [16].

In connection with the increasingly widespread use of NNS, the significance of studies referring to the assessment of their intake as part of one's diet is increasing and it results from the need to ensure health safety of the consumed products. Research in this field is based on the comparison of doses to be used in different food products with the values of Acceptable Daily Intake (ADI) as well as verification whether it could be possible for the ADI value to be exceeded, assuming different values of their consumption [12, 14, 16, 21, 25, 43]. International food regulators and other health or scientific agencies, including the EFSA, are responsible for the establishment of ADI values [12, 14, 16, 21, 25].

The aim of the study was to analyze the daily diet of primary and secondary school students with reference to the use of NNS as well as to assess their intake compared to the respective ADI values.

SUBJECTS AND METHODS

The study was conducted in a group of 128 children and adolescents aged 7–16 (mean age 12.5±3.2 years), 68 girls and 60 boys living within the area of the city of Warsaw. Study inclusion criterion consisted in the fact of a given child being a student of a randomly selected primary or secondary school. The following age groups were included in the study in the period of September to November: 7–10 years old (32 participants), 11–13 years old (41 participants), 14–16 years old (55 participants). A survey questionnaire together with notes on all meals consumed during 3 days were prepared by the parents who had given their consent for their children to take part in food-related studies. Basing on the analysis of the daily food ration, the following product groups containing artificial sweeteners were studied: fruit beverages containing fruit juice, "cola" beverages, energy drinks, beverages based on mineral water (so called flavoured water), "ice tea" beverages, other carbonated or non-carbonated beverages with fruit flavor, yoghurt and milk desserts, sweets, table sweeteners as well as pastilles, lozenges, chewing gums. The presence of the studied sweeteners in the products was determined based on manufacturer's information included on the label of the consumed products.

Theoretical Maximum Daily Intake (TMDI) model was applied in order to assess daily intake of intense sweeteners [14, 16] and their content in the consumed products was assumed at the permitted maximum, specified in appropriate legal provisions in force [19]. For each study participant, daily intake of acesulfame K (E 950), aspartame (E 951), cyclamic acid and its salts (E 952), saccharin and its salts (E 954) as well as sucralose (E 955) was calculated. Intake assessment was performed on the group of consumers only, calculated per individual body mass of each study participant. Mean body mass in respective age groups was: 7-10 years old (26.1±6.2 kg); 11-13 years old (41.8±6.3 kg); 14-16 years old (62,8±8.2 kg). Estimated daily intake was compared to appropriate ADI for each substance. Results are reported as a percentage of the ADI (%ADI) for average (mean or median) and high-level consumers (95th percentile) for the population group examined in this study.

Statistical data analysis was performed with the use of the STATISTICA v.13.3 software. Chi^2 test was applied for qualitative variables. The Mann-Whitney nonparametric test was used in order to check the significance of differences for quantitative variables, thus verifying the hypotheses concerning the influence of age on the intake of the studied substances. The results were presented as mean with standard deviation (mean±SD) together with 95% confidence interval (CI) as well as 50th and 95th percentile of dietary intake. Significance level of ≤0.05 was assumed.

RESULTS

Dietary daily intake of artificial sweeteners, calculated according to the TMDI model based on the data obtained during a 3-day food record taking, is presented in Tables 1. and 2. The studies performed showed that the percentage of study participants consuming products containing artificial sweeteners was growing together with the increasing age of the children who took part in the study. The studied substances were consumed within their daily diet (Table 1) on the general level by ca. 48% of the children and adolescents surveyed, with statistically significantly more study participants in the oldest age group (71%) compared to younger respondents (on average 34%). It was stated that the biggest number of participants ate products containing acesulfame K (ca. 44% of all of those surveyed) and aspartame (40%), then cyclamates (ca. 19%), and the products with saccharin (14%) and sucralose (12%) were the least frequently consumed. In the group of older students, the presence of acesulfame K and aspartame was significantly more frequent than among younger children. The remaining studied substances were also more frequent in the diet of older respondents compared to younger ones; however, these differences did not represent statistical significance. In the studied group of children, the highest intake (mg/kg of body mass/day) expressed as median (Table 2) was recorded for cyclamates and sucralose, then aspartame and acesulfame K, and the lowest for saccharin. The menus of children from the oldest age group included significantly more cyclamates and acesulfame K than those of younger respondents.

In order to assess potential health risk, the calculated intake of artificial sweeteners with daily diet was expressed per kg of body mass (Table 2) as well as with reference to appropriate ADIs (Table 3). Mean (median) intake of the studied substances estimated based on the TMDI model posed no health risk, i.e. it was significantly below ADI values. The consumption of studied substances was at a safe level not exceeding the established ADI values. The highest mean intake was recorded for cyclamates (20% ADI) then for acesulfame K, saccharine and sucralose (ca. 10% of ADI respectively), and the lowest for aspartame (ca. 5% ADI). Intake values for 95th percentile did not exceed the ADI either. Diets of adolescents from the oldest age group contained significantly more acesulfame K (52% of ADI) and cyclamates (38% of ADI) compared to the diets of younger respondents. Taking into consideration the consumption at the level of the 95th percentile as the least favorable scenario, in the oldest age group, relatively high intake of acesulfame K (52% of ADI) and cyclamates (38% of ADI) was recorded. Also, in the group of children aged 11-13, the intake of cyclamates was at a relatively high level (35% of ADI).

DISCUSSION

The presence of intense sweeteners in the usual diet of the children and adolescents surveyed did not pose a health risk as the estimated intake in all age groups was below ADI values. Paying particular attention to children and adolescents as groups particularly vulnerable to higher intake of artificial sweeteners with their daily diet constituted the subject of

Table 1. Study population by age group and percentage of subjects (%) consuming products containing intense sweeteners on a daily diet

Tabela 1. Badana grupa osób z uwzględnieniem kategorii wiekowych oraz odsetek osób (%) spożywających produkty zawierające poszczególne substancje słodzące z całodzienną dietą

Sweetener	Total	7-10 years	11–13 years	14–16 years	p*
Occurrence of intense sweeteners in daily diet (total)	47.5	31.8^a	36.7^a	71.3^b	0.0032
Acesulfame K (E 950)	44.3	27.6^a	34.8^a	67.9^b	0.0114
Aspartame (E 950)	40,1	21.9^a	29.9^a	65,2^b	0.0035
Cyclamate (E 952)	19.3	10.5	17.6	26.9	NS
Saccharin (E 954)	13.8	7.4	13.2	20.5	NS
Sucralose (E 955)	11.7	7.4	10.5	17.2	NS

*p-values for differences between subgroups were calculated with Chi-square test for categorical variables; NS – not significant.

Source: The own study

Źródło: Badania własne

Table 2. Daily intake of intense sweeteners (mg/kg bw per day) by consumers only groups evaluated with use of the TMDI model

Table 2. Dzienne pobranie z dietą intensywnych substancji słodzących (mg/kg mc/dzień) w badanych grupach osób oszacowane z zastosowaniem modelu TMDI

Sweetener	Total	7-10 years	11–13 years	14–16 years	P*
Acesulfame K					
Mean ± SD 95% CI	0.79 ± 1.09 0.44 – 1.18	0.36 ± 0.15 0.25 – 0.52	0.52 ± 0.46 0.12 – 0.89	1.95 ± 1.25 0.69 – 2.38	0,032
Median (P50) P95	1.02 3.92	0.29[a] 0.95	0.39[a] 1.95	3.56[b] 5.45	
Aspartame					
Mean ± SD 95% CI Median (P50) P95	2.15 ± 1.49 1.25 – 2.47 1.35 7.25	1.42 ± 0.54 0.89 – 2.01 1.59 5.96	1.24 ± 0.45 0.56 – 1.95 1.75 7.99	2.99 ± 2.14 1.12 – 4.25 3.95 10.45	NS
Cyclamate					
Mean ± SD 95% CI Median (P50) P95	1.39 ± 0.72 0.99 – 1.75 1.34 3.25	0.85 ± 0.45 0.21 – 1.93 0.99[a] 2.49	1.25 ± 0.55 0.59 – 1.95 1.26[a] 3.25	2.05 ± 0.56 1.02– 2.55 1.62[b] 3.95	0,046
Saccharin					
Mean ± SD 95% CI Median (P50) P95	0.52 ± 0..25 0.39 – 0.65 0.49 1.27	0.35 ± 0.12 0.24 – 0.82 0.21 0.65	0.49 ± 0.15 0.35 – 0.73 0.38 0.92	0.62 ± 0.24 0.41 – 0.98 0.59 1.24	NS
Sucralose					
Mean ± SD 95% CI Median (P50) P95	1.49 ± 0.45 1.15 – 1.84 1.29 3.05	0.96 ± 0.15 0.43 – 2.42 0.96 1.92	1.58 ± 0.25 0.92 – 2.43 1.52 2.15	1.62 ± 0.59 0.99 – 2.62 1.75 3.04	NS

TMDI – Theoretical Maximum Daily Intake; *p-values for differences between subgroups were calculated with Mann-Whitney U test. Median with different letter scripts differed significantly at p≤0.05; NS – not significant.

Source: The own study

Źródło: Badania własne

Table 3. Daily intake of artificial sweeteners (expressed as % ADI) by consumers only groups evaluated with use of the TMDI model

Tabela 3. Dzienne pobranie z dietą intensywnych substancji słodzących (wyrażone jako %ADI) w badanych grupach osób oszacowane z zastosowaniem modelu TMDI

Sweetener	Total	7-10 years	11–13 years	14–16 years	p*
Acesulfame K (ADI – 9 mg/kg bw per day)					
x ± SD 95% CI Median (P50) P95	8.56 ± 10.4 4.93 – 13.5 3.15 36.5	3.85 ± 1.92 2.25 – 5.43 3.14[a] 6.99	5.12 ± 4.20 0.97 – 8.95 3.92[a] 9.85	12.6 ± 10.5 5.82 – 19.7 8.01[b] 52.4	0,028
Aspartame (ADI – 40 mg/kg bw per day)					
x ± SD 95% CI Median (P50) P95	4.63 ± 4.24 2.98 – 6.43 4.12 17.2	3.92 ± 1.35 2.28 – 5.02 3.87 7.32	4.12 ± 2.06 2.26 – 5.83 4.28 6.74	5.98 ± 5.62 2.81 – 8.45 4.66 25.9	NS

Sweetener	Total	7-10 years	11–13 years	14–16 years	p*
Cyklamate (ADI – 7 mg/kg bw per day)					
x ± SD 95% CI Median (P50) P95	19.8 ± 9.7 14.1 – 25.4 18.9 35.6	11,9 ± 5,94 2.72 – 26.9 14.2 27.9	17,5 ± 7,4 8.25 ± 26.9 18.6[a] 34.5	25,2 ± 11,2 14.2 – 33.7 27.2[b] 37.8	0,037
Saccharin (ADI – 5 mg/kg bw per day)					
x ± SD 95% CI Median (P50) P95	9.05 ± 4.15 7.45 – 12.6 6.25 19.8	5.82 ± 0.97 3.12 – 14.6 5.81 12.3	8.87 ± 2.72 4.58 – 13.2 6.52 17.5	12.1 ± 4.30 7.45 – 16.6 11.9 24.1	NS
Sucralose (ADI – 15 mg/kg bw per day)					
x ± SD 95% CI Median (P50) P95	9.65 ± 2.92 7.42 – 11.9 9.35 18.6	6.78 ± 1.12 3.52 – 16.8 6.72 9.5	10.8 ± 1.92 5.74 – 15.3 9.99 11.8	11.5 ± 3.68 5.95 – 15.2 11.6 19.9	NS

ADI – Acceptable Daily Intake (mg/kg body weight per day); TMDI – Theoretical Maximum Daily Intake; *p-values for differences between subgroups were calculated with Mann-Whitney U test. Median with different letter scripts differed significantly at $p \leq 0.05$; NS - not significant.

Source: The own study

Źródło: Badania własne

numerous scientific studies [1, 8, 22, 31, 41, 44, 50]. Higher intake of these substances was reported in the studies reported to children with diabetes [28]. Also, the respondents representing particular food-related behaviors and on special diets were found to consume more substances of this kind with their daily food ration. Intake assessment is of particular importance in the group of children and teenagers for whom the consumption per kilogram of body mass is higher than for adults [3, 20, 41, 44]. In Swedish studies [28], assuming the least favorable intake scenario in the group of children, exceeded ADI was reported for cyclamates and saccharine. In the present study, the intake estimated for them was significantly lower.

While assessing the intake of intense sweeteners in diet it is necessary to pay particular attention to eating habits of children and adolescents in the field of consumption of flavoured non-alcoholic beverages. Research points to the relatively high level of consumption of these beverages, constituting an important source of cyclamates and saccharine as well as acesulfame K and aspartame, and in recent years also sucralose. It can be concluded from the abovementioned studies that beverages of this kind constituted main source of intake of intense sweeteners. Similarly to the observations within the present study, the highest intake expressed as %ADI was also attributed to cyclamates and acesulfame K [1, 22, 27, 31, 44, 50].

Due to their level of sweetness achieved already at low concentration, the use of artificial sweeteners enables the production of "light" food products with energetic value lowered by 30% compared to their traditional counterparts. The offer of products of this kind available on the market is developing within a relatively wide range. Due to their rather low price, artificial sweeteners are used in food industry to replace sugar, in particular in the production of non-alcoholic beverages [4, 7, 9, 17, 43]. Reduced energy value and preserved sweet taste together with no increase in blood glucose are the advantages of these substances for persons suffering from diabetes or those who want to reduce their body mass. A reduction of the energy density of the available foods by changing their production technology is an important component of prevention efforts [11, 15, 26, 33–35]. The recent position of the Polish Society of Obesity Research and Diabetes Poland confirms the safety of low-calorie sweetener use in food products and recommends substituting sugar with these low-calorie sweeteners by overweight and obese subjects, particularly if impaired fasting glucose, impaired glucose tolerance, or diabetes type 2 is also present. Additionally, the position stressed that the consumption of food products with a reduced energy value due to their low-calorie sweetener content cannot be the only modification – other changes to the diet are also necessary [38].

Permitted food additives are safe for the society in general, but for those suffering from individual hypersensitivity their consumption may lead to undesirable reactions [10, 29]. It may be connected with the risk of the occurrence of non-toxic symptoms of the reaction of the body, not related to the dose of the substance, but depending on individual sensitivity and the reaction to a given substance treated as atypical for the healthy population, described as reactions connected with hypersensitivity. This problem was studied in pediatric practice. Development mechanisms of hypersensitivity to some additives have not been fully studied and the symptoms may vary. They may represent immunological character, but significantly more frequently they are not connected with this mechanism. Due to their complex characteristics, hypersensitivities of this kind are relatively hard to be diagnosed and the recommended method is the placebo-controlled double blind challenge test [29].

Non-nutritive sweeteners are generally associated with their perceived health benefits although there are ongoing debates regarding their benefits for obesity and weight-related diabetes alongside concerns for their safety [10, 41, 44, 45, 46, 50]. In the recent years, the most doubts connected with the use of artificial sweeteners refer to aspartame. The metabolism of this substance, being the aspartyl-phenylalanine methyl ester, takes place by hydrolysis to aspartic acid and phenylalanine methyl ester, which is then decomposed into phenylalanine and methanol. With reference to this fact, institutions assessing food additives presented their opinions about this substance. Joint Expert Committee on Food Additives and Contaminants (JECFA) as well as EFSA confirmed the safety of aspartame as well as current ADI [13].

Assessing the intake of artificial sweeteners, with particular attention paid to children and adolescents as a group particularly vulnerable to higher intake, constituted the subject of numerous scientific studies [1, 8, 22, 44, 50]. Results similar to those presented herein were obtained in foreign studies, in which higher intake of artificial sweeteners was observed among children and adolescents compared to older population groups [5, 24, 30, 36, 39, 47, 49]. Swedish studies [28] presented excessive intake for cyclamates and saccharine, for which the intake estimated in the present study was significantly lower. The assessment of eating habits of primary and secondary school students from the quantitative and qualitative perspective points to frequent and relatively high consumption of flavored non-alcoholic drinks. It was stated in numerous studies [27, 31, 36, 39] that beverages of this kind constituted the main source of artificial sweeteners consumed. Likewise, a recent study of the dietary exposure of sweeteners which are most used globally showed that overall intakes remained within ADI guidance and ongoing monitoring was also advised in response to global dietary recommendation to lower sugar intake [6, 20, 21, 32, 42].

SUMMARY

Due to food industry offering a continuously expanding selection of products containing intense sweeteners, the significance of studies referring to the assessment of the intake of sweeteners as part of one's diet in comparison to Acceptable Daily Intake (ADI) values is increasing, contributing to the monitoring and the assessment of food safety. The mean daily intake of the analyzed intense sweeteners assessed with reference to ADI did not present safety concerns of the studied population groups. For each of these sweeteners the estimated daily intake was less than the ADI. Due to significantly higher intake of artificial additives observed among adolescents aged 14-16, significant for acesulfame K and cyclamates, this age group should be treated as potentially more vulnerable, which may be connected with high consumption of flavoured non-alcoholic beverages, constituting their main source in diet. It is necessary for the studies to be continued, in particular among children and adolescents, as in these groups the dietary intake may be higher due to relatively higher intake of these substances per body mass unit. All intense sweeteners as well as other food additives permitted for use within the European Union are subject to the rigorous EFSA assessment. As part of these evaluations, evidence from scientific research is studied in detail. Sweeteners as sugar substitutes are useful as they allow consumers to choose a wide variety of food and beverages with different energy density levels, as part of a balanced diet.

PODSUMOWANIE

Ze względu na stale zwiększającą się ofertę rynkowych produktów zawierających intensywne substancje słodzące, badania związane z oceną ich pobrania z dietą w odniesieniu do dopuszczalnego dziennego pobrania Acceptable Daily Intake (ADI) nabierają istotnego znaczenia, stanowiąc element monitorowania i oceny bezpieczeństwa żywności. Na podstawie przeprowadzonych badań w grupie dzieci i młodzieży stwierdzono, że średnie dzienne spożycie intensywnych substancji słodzących oceniane w odniesieniu do ADI nie budziło obaw o bezpieczeństwo. Dla każdej z badanych substancji szacowane pobranie było mniejsze niż wartości ADI. Ze względu na stwierdzone znacznie większe ich pobranie wśród młodzieży w wieku 14–16 lat, istotne w przypadku acesulfamu K i cyklaminianów, starszą młodzież szkolną należy traktować jako grupę o potencjalnie większym ryzyku pobrania, co może być związane z dużym spożyciem aromatyzowanych napojów bezalkoholowych, będących głównym ich źródłem w diecie. Niezbędne jest kontynuowanie badań monitoringowych, szczególnie w grupie dzieci i młodzieży, u których spożycie tych substancji może być większe z powodu stosunkowo większego ich pobrania na jednostkę masy ciała. Wszystkie intensywne substancje słodzące, podobnie jak i inne dodatki do żywności dopuszczone do stosowania w Unii Europejskiej, podlegają rygorystycznym ocenom EFSA. W ramach tych ocen bardzo szczegółowo analizowane są wyniki pochodzące z badań naukowych. Substancje słodzące stosowane jako substytuty cukru dają konsumentom możliwość wyboru żywności i napojów o różnym poziomie wartości energetycznej, co może być ważnym elementem zbilansowanej diety.

REFERENCES

[1] **ARCELLA D., C. LE DONNE, R. PICCINELLI, C. LECLERCQ. 2004.** "Dietary estimated intake of intense sweeteners by Italian teenagers. Present levels and projections derived from the INRAN-RM-2001 food survey". Food and Chemical Toxicology 42 (4): 677–685.

REFERENCES

[1] **ARCELLA D., C. LE DONNE, R. PICCINELLI, C. LECLERCQ. 2004.** "Dietary estimated intake of intense sweeteners by Italian teenagers. Present levels and projections derived from the INRAN-RM-2001 food survey". Food and Chemical Toxicology 42 (4): 677–685.

[2] **AZAÏS-BRAESCO V., D. SLUIK, M. MAILLOT, F. KOK, L. A. MORENO. 2017.** "A review of total & added sugar intakes and dietary sources in Europe". Nutrition Journal 16:6.

[3] **BAILEY R.L., V.L. FULGONI, A.E. COWAN, P.C. GAINE. 2018**. "Sources of added sugars in young children, adolescents, and adults with low and high intakes of added sugars". Nutrients 10(1): 102.

[4] **BELC N., I. SMEU, A. MACRI, D. VALLAURI K. FLYNN. 2019**. "Reformulating foods to meet current scientific knowledge about salt, sugar and fats". Trends in Food Science & Technology 84: 25–28.

[5] **BUFFINI M., S. GOSCINNY, J. VAN LOCO, A.P. NUGENT, J. WALTON, A. FLYNN, M.J. GIBNEY, B.A. MCNULTY. 2018.** "Dietary intakes of six intense sweeteners by Irish adults". Food Additives and Contaminants Part A 35 (3): 425–438.

[6] **CAROCHO M., P. MORALES, I.C.F.R. FERREIRA. 2017.** "Sweeteners as food additives in the **XXI century: a review** of what is known, and what is to come." Food and Chemical Toxicology 107:302–317.

[7] **CHATTOPADHYAY S., U. RAYCHAUDHURI, R.J. CHAKRABORTY. 2014.** "Artificial sweeteners - a review." Journal of Food Science and Technology 51: 611–21.

[8] **DANIKA MARTYN M., A.P. NUGENT, B.A. MCNULTY, E. O'REILLY, C. TLUSTOS, J. WALTON, A. FLYNN, M. J. GIBNEY. 2016.** "Dietary intake of four artificial sweeteners by Irish pre-school children". Food Additives & Contaminants: Part A 33(4): 592–602.

[9] **DI MONACO R., N.A. MIELE, E.K. CABISIDAN, S. CAVELLA. 2018.** "Strategies to reduce sugars in food." Current Opinion in Food Science 19:92-97.

[10] **DURÁN AGÜERO S., L. ANGARITA DÁVILA, M.C. ESCOBAR CONTRERAS, D. ROJAS GÓMEZ, J. DE ASSIS COSTA. 2018.** "Noncaloric Sweeteners in Children: A Controversial Theme". BioMed Research International 2018: 4806534.

[11] **EDWARDS C.H., M. ROSSI,C.P. CORPE, P.J. BUTTERWORTH, P.R. ELLIS. 2016.** "The role of sugars and sweeteners in food, diet and health: Alternatives for the future." Trends in Food Science and Technology 56: 158–166.

[12] **EFSA 2012.** "Panel on Food Additives and Nutrient Sources added to Food. Scientific opinion. Guidance for submission for food additive evaluations." EFSA Journal 10: 2760.

[13] **EFSA 2013.** "Scientific Opinion on the re-evaluation of aspartame (E 951) as a food additive." EFSA Journal 11(12): 3496.

[14] **EFSA 2014.** "Panel on Food Additives and Nutrient Sources Added to Food), 2014. Statement on a conceptual framework for the risk assessment of certain food additives re-evaluated under Commission Regulation (EU) No 257/2010." EFSA Journal 12(6): 3697.

[2] **AZAIS-BRAESCO V., D. SLUIK, M. MAILLOT, F. KOK, L. A. MORENO. 2017.** "A review of total & added sugar intakes and dietary sources in Europe". Nutrition Journal 16: 6.

[3] **BAILEY R.L., V.L. FULGONI, A.E. COWAN, P.C. GAINE. 2018.** "Sources of added sugars in young children, adolescents, and adults with low and high intakes of added sugars". Nutrients 10(1): 102.

[4] **BELC N., I. SMEU, A. MACRI, D. VALLAURI K. FLYNN. 2019.** "Reformulating foods to meet current scientific knowledge about salt, sugar and fats". Trends in Food Science & Technology 84: 25–28.

[5] **BUFFINI M., S. GOSCINNY, J. VAN LOCO, A.P. NUGENT, J. WALTON, A. FLYNN, M.J. GIBNEY, B.A. MCNULTY. 2018.** "Dietary intakes of six intense sweeteners by Irish adults". Food Additives and Contaminants Part A 35 (3): 425–438.

[6] **CAROCHO M., P. MORALES, I.C.F.R. FERREIRA. 2017.** "Sweeteners as food additives in the XXI century: a review of what is known, and what is to come." Food and Chemical Toxicology 107:302-317.

[7] **CHATTOPADHYAY S., U. RAYCHAUDHURI, R.J. CHAKRABORTY. 2014.** "Artificial sweeteners – a review." Journal of Food Science and Technology 51: 611–21.

[8] **DANIKA MARTYN M., A.P. NUGENT, B.A. MCNULTY, E. O'REILLY, C. TLUSTOS, J. WALTON, A. FLYNN, M. J. GIBNEY. 2016.** "Dietary intake of four artificial sweeteners by Irish pre-school children". Food Additives & Contaminants: Part A 33(4): 592–602.

[9] **DI MONACO R., N.A. MIELE, E.K. CABISIDAN, S. CAVELLA. 2018.** "Strategies to reduce sugars in food." Current Opinion in Food Science 19: 92–97.

[10] **DURAN AGUERO S., L. ANGARITA DAVILA, M.C. ESCOBAR CONTRERAS, D. ROJAS GOMEZ, J. DE ASSIS COSTA. 2018.** "Noncaloric Sweeteners in Children: A Controversial Theme". BioMed Research International 2018: 4806534.

[11] **EDWARDS C.H., M. ROSSI,C.P. CORPE, P.J. BUTTERWORTH, P.R. ELLIS. 2016.** "The role of sugars and sweeteners in food, diet and health: Alternatives for the future." Trends in Food Science and Technology 56: 158–166.

[12] **EFSA 2012.** "Panel on Food Additives and Nutrient Sources added to Food. Scientific opinion. Guidance for submission for food additive evaluations." EFSA Journal 10: 2760.

[13] **EFSA 2013.** "Scientific Opinion on the re-evaluation of aspartame (E 951) as a food additive." EFSA Journal 11(12): 3496.

[14] **EFSA 2014.** "Panel on Food Additives and Nutrient Sources Added to Food), 2014. Statement on a conceptual framework for the risk assessment of certain food additives re-evaluated under Commission Regulation (EU) No 257/2010." EFSA Journal 12(6): 3697.

[15] **EFSA 2011.** "European Food Safety Authority." Scientific opinion on the substantiation of health claims related to intense sweeteners and contribution to the maintenance or achievement of a normal body weight (ID 1136, 1444, 4299), reduction of post-prandial glycaemic responses (ID 4298), maintenance of normal blood glucose concentrations (ID 1221, 4298), and maintenance of tooth mineralisation by decreasing tooth demineralisation (ID 1134, 1167, 1283) pursuant to Article 13(1) of Regulation (EC) No 1924/20061. EFSA Journal 9(6): 2229.

[16] **EFSA 2021.** "European Food Safety Authority." webpage for "Sweeteners". https://www.efsa.europa.eu/en/topics/topic/sweeteners (accessed May 2021).

[17] **ERICKSON S., J. CARR. 2020.** "The technological challenges of reducing the sugar content of foods." Nutrition Bulletin 45: 309–314.

[18] **EUROPEAN COMMISSION 2008.** "Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives." Official Journal of the European Union L 345: 16–33.

[19] **EUROPEAN COMMISSION 2011.** "Regulation (EU) No. 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) No. 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives." Official Journal of the European Union L 295:1–177.

[20] **EUROPEAN COMMISSION 2010.** "Regulation (EU) No 257/2010 0f 25 March 2010 setting up a programme for the re-evaluation of approved food additives in accordance with Regulation (EC) No 1333/2008 of the European Parliament and of the Council on food additives." Official Journal of the European Union L 80/19.

[21] **FITCH S.E., L.E. PAYNE, J.L. VAN DE LIGT, C. DOEPKER, D. HANDU, S.M. COHEN, D. WIKOFF. 2021.** "Use of acceptable daily intake (ADI) as a health-based benchmark in nutrition research studies that consider the safety of low-calorie sweeteners (LCS): a systematic map". BMC Public Health 21(1): 1–11.

[22] **GARAVAGLIA M.B., V.R. GARCIA, M.M.E. ZAPATA. 2018.** "Non-nutritive sweeteners: children and adolescent consumption and food sources". Archivos Argentinos de Pediatría 116(3): 186–191.

[23] **GIBSON S, M. ASHWELL, J. ARTHUR, L., BAGLEY A., LENNOX, P.J., ROGERS, S. STANNER. 2017.** "What can the food and drink industry do to help achieve the 5% free sugars goal?" Perspectives in Public Health 137(4):237-247.

[24] **GRECH A., C.O. KAM, L. GEMMING, A. RANGAN. 2018.** "Diet-quality and socio-demographic factors associated with non-nutritive sweetener use in the Australian population" Nutrients 10(7): 833.

[25] **HABER L.T, M.L. DOURSON, B.C. ALLEN, R.C. HERTZBERG, A. PARKER, M.J. VINCENT, A. MAIER, A.R. BOOBIS. 2018.** "Benchmark

[15] **EFSA 2011.** "European Food Safety Authority." Scientific opinion on the substantiation of health claims related to intense sweeteners and contribution to the maintenance or achievement of a normal body weight (ID 1136, 1444, 4299), reduction of post-prandial glycaemic responses (ID 4298), maintenance of normal blood glucose concentrations (ID 1221, 4298), and maintenance of tooth mineralisation by decreasing tooth demineralisation (ID 1134, 1167, 1283) pursuant to Article 13(1) of Regulation (EC) No 1924/20061. EFSA Journal 9(6): 2229.

[16] **EFSA 2021.** "European Food Safety Authority." webpage for "Sweeteners". https://www.efsa.europa.eu/en/topics/topic/sweeteners (accessed May 2021).

[17] **ERICKSON S., J. CARR. 2020.** "The technological challenges of reducing the sugar content of foods." Nutrition Bulletin 45: 309–314.

[18] **EUROPEAN COMMISSION 2008.** "Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives." Official Journal of the European Union L 345: 16–33.

[19] **EUROPEAN COMMISSION 2011.** "Regulation (EU) No. 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) No. 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives." Official Journal of the European Union L 295: 1–177.

[20] **EUROPEAN COMMISSION 2010.** "Regulation (EU) No 257/2010 0f 25 March 2010 setting up a programme for the re-evaluation of approved food additives in accordance with Regulation (EC) No 1333/2008 of the European Parliament and of the Council on food additives." Official Journal of the European Union L 80/19.

[21] **FITCH S.E., L.E. PAYNE, J.L. VAN DE LIGT, C. DOEPKER, D. HANDU, S.M. COHEN, D. WIKOFF. 2021.** "Use of acceptable daily intake (ADI) as a health-based benchmark in nutrition research studies that consider the safety of low-calorie sweeteners (LCS): a systematic map". BMC Public Health 21(1): 1–11.

[22] **GARAVAGLIA M.B., V.R. GARCIA, M.M.E. ZAPATA. 2018.** "Non-nutritive sweeteners: children and adolescent consumption and food sources". Archivos Argentinos de Pediatria 116(3): 186–191.

[23] **GIBSON S, M. ASHWELL, J. ARTHUR, L., BAGLEY A., LENNOX, P.J., ROGERS, S. STANNER. 2017.** "What can the food and drink industry do to help achieve the 5% free sugars goal?" Perspectives in Public Health 137(4): 237–247.

[24] **GRECH A., C.O. KAM, L. GEMMING, A. RANGAN. 2018.** "Diet-quality and socio-demographic factors associated with non-nutritive sweetener use in the Australian population" Nutrients 10(7): 833.

[25] **HABER L.T, M.L. DOURSON, B.C. ALLEN, R.C. HERTZBERG, A. PARKER, M.J. VINCENT, A. MAIER, A.R. BOOBIS. 2018.** "Benchmark

dose (BMD) modeling: current practice, issues, and challenges." Critical Reviews in Toxicology 48: 387–415.

[26] **HASHEM K. M., F.J. HE, G.A. MACGREGOR. 2019.** "Effects of product reformulation on sugar intake and health – A systematic review and meta-analysis. Nutrition Reviews" 77(3): 181–196.

[27] **HUIZINGA O., M. HUBERT. 2017.** "The content of caloric and non-caloric sweeteners in soft drinks in Germany". Obesity Medicine 6: 11–14.

[28] **ILBÄCK N.G., M. ALZIN, S. JAHRL. 2003.** "Estimated intake of the artificial sweeteners acesulfame K, aspartame, cyclamate and saccharin in a group of Swedish diabetics". Food Additives and Contaminants 20(2): 99–114.

[29] **KANTOR M.A. 2002.** "Adverse reaction to food additives". (In): Watson D. H (ed.) "Food chemical safety". Volume 2: Additives, Woodhead Publishing Ltd: 145–170.

[30] **LE DONNE C., L. MISTURA, S. GOSCINNY, S. JANVIER, K. CUYPERS, L. D'ADDEZIO, S. SETTE, G. CATASTA, M. FERRARI, R. PICCINELLI, J VAN LOCO, A. TURRINI. 2017.** "Assessment of dietary intake of 10 intense sweeteners by the Italian population". Food and Chemical Toxicology 102: 186–197.

[31] **LINO C., I. COSTA, A. PENA, R. FERREIRA, S.M. CARDOSO. 2018.** "Estimated intake of the sweeteners, acesulfame-K and aspartame, from soft drinks, soft drinks based on mineral waters and nectars for a group of Portuguese teenage students". Food Additives and Contaminants Part A 25(11): 1291–1296.

[32] **MARTYN D., M. DARCH, A. ROBERTS, H.Y. LEE, T. YAQIONG TIAN, N. KABURAGI, P. BELMAR. 2018.** "Low-/No-Calorie Sweeteners." A Review of Global Intakes. Nutrients 10: 357.

[33] **MOORADIAN A.D., M. SMITH, M. TOKUDA. 2017.** "The role of artificial and natural sweeteners in reducing the consumption of table sugar: A narrative review." Clinical Nutrition ESPEN 18: 1–8.

[34] **MORA M.R., R. DANDO. 2021.** "The sensory properties and metabolic impact of natural and synthetic sweeteners." Comprehensive Reviews in Food Science and Food Safety 20: 1554–1583.

[35] **MYSZKOWSKA-RYCIAK J., A. HARTON, D. GAJEWSKA, S. BAWA. 2010.** „Środki słodzące w profilaktyce i leczeniu otyłości." Kosmos – Problemy Nauk Biologicznych 59: 365–37.

[36] **NUNN R., L. YOUNG, C. MHURCHU. 2021.** "Prevalence and Types of Non-Nutritive Sweeteners in the New Zealand Food Supply, 2013 and 2019". Nutrients 13(9): 3228.

[37] **PERRAR I., S. SCHMITTING, K.W. DELLA CORTE, A.E. BUYKEN, U. ALEXY. 2020.** "Age and time trends in sugar intake among children and adolescents: Results from the DONALD study". European Journal of Nutrition 59(3): 1043–1054.

dose (BMD) modeling: current practice, issues, and challenges." Critical Reviews in Toxicology 48: 387–415.

[26] **HASHEM K. M., F.J. HE, G.A. MACGREGOR. 2019.** "Effects of product reformulation on sugar intake and health – A systematic review and meta-analysis. Nutrition Reviews" 77(3): 181–196.

[27] **HUIZINGA O., M. HUBERT. 2017.** "The content of caloric and non-caloric sweeteners in soft drinks in Germany". Obesity Medicine 6: 11–14.

[28] **ILBACK N.G., M. ALZIN, S. JAHRL. 2003**. "Estimated intake of the artificial sweeteners acesulfame K, aspartame, cyclamate and saccharin in a group of Swedish diabetics". Food Additives and Contaminants 20(2): 99–114.

[29] **KANTOR M.A. 2002.** "Adverse reaction to food additives". (In): Watson D. H (ed.) "Food chemical safety". Volume 2: Additives, Woodhead Publishing Ltd: 145–170.

[30] **LE DONNE C., L. MISTURA, S. GOSCINNY, S. JANVIER, K. CUYPERS, L. D'ADDEZIO, S. SETTE, G. CATASTA, M. FERRARI, R. PICCINELLI, J VAN LOCO, A. TURRINI. 2017.** "Assessment of dietary intake of 10 intense sweeteners by the Italian population". Food and Chemical Toxicology 102: 186–197.

[31] **LINO C., I. COSTA, A. PENA, R. FERREIRA, S.M. CARDOSO. 2018.** "Estimated intake of the sweeteners, acesulfame-K and aspartame, from soft drinks, soft drinks based on mineral waters and nectars for a group of Portuguese teenage students". Food Additives and Contaminants Part A 25(11): 1291–1296.

[32] **MARTYN D., M. DARCH, A. ROBERTS, H.Y. LEE, T. YAQIONG TIAN, N. KABURAGI, P. BELMAR. 2018.** "Low-/No-Calorie Sweeteners." A Review of Global Intakes. Nutrients 10: 357.

[33] **MOORADIAN A.D., M. SMITH, M. TOKUDA. 2017.** "The role of artificial and natural sweeteners in reducing the consumption of table sugar: A narrative review." Clinical Nutrition ESPEN 18: 1–8.

[34] **MORA M.R., R. DANDO. 2021.** "The sensory properties and metabolic impact of natural and synthetic sweeteners." Comprehensive Reviews in Food Science and Food Safety 20: 1554–1583.

[35] **MYSZKOWSKA-RYCIAK J., A. HARTON, D. GAJEWSKA, S. BAWA. 2010.** „Srodki slodzace w profilaktyce i leczeniu otylosci." Kosmos – Problemy Nauk Biologicznych 59: 365–37.

[36] **NUNN R., L. YOUNG, C. MHURCHU. 2021.** "Prevalence and Types of Non-Nutritive Sweeteners in the New Zealand Food Supply, 2013 and 2019". Nutrients 13(9): 3228.

[37] **PERRAR I., S. SCHMITTING, K.W. DELLA CORTE, A.E. BUYKEN, U. ALEXY. 2020.** "Age and time trends in sugar intake among children and adolescents: Results from the DONALD study". European Journal of Nutrition 59(3): 1043–1054.

[38] **POSITION. 2021.** "Position of the Polish Society of Obesity Research and Diabetes Poland on the use of low-calorie sweeteners". [In:] 2021 Guidelines on the management of patients with diabetes. A position of Diabetes Poland. Clinical Diabetology 10(1): 102–103.

[39] **REDRUELLO-REQUEJO M., M. GONZÁLEZ-RODRÍGUEZ, M.D.L. SAMANIEGO-VAESKEN, A. MONTERO-BRAVO, T. PARTEARROYO, G. VARELA-MOREIRAS. 2021.** "Low- and no-calorie sweetener (LNCS) consumption patterns amongst the Spanish adult population". Nutrients: 13: 1845.

[40] **RUSSELL C., C. GRIMES, P. BAKER, K. SIEVERT, M. LAWRENCE. 2020.** "The drivers, trends and dietary impacts of non-nutritive sweeteners in the food supply: A narrative review." Nutrition Research Reviews 1: 24.

[41] **SAMUEL DURÁN A., L. ANGARITA DÁVILA, M.C. ESCOBAR CONTRERAS, D. ROJAS GÓMEZ, J. DE ASSIS COSTA. 2018.** "Noncaloric Sweeteners in Children: A Controversial Theme". BioMed Research International: 1–7.

[42] **STANNER S.A., A. SPIRO. 2020.** "Public health rationale for reducing sugar: Strategies and challenges." Nutrition Bulletin 45: 253–270.

[43] **ŚWIĄDER K., B. WASZKIEWICZ-ROBAK, F. ŚWIDERSKI. 2011.** „Substancje intensywnie słodzące – korzyści i zagrożenia". Problemy Higieny i Epidemiologii 92(3): 392–396.

[44] **SYLVETSKY A.C., Y. JIN, E.J. CLARK, J.A. WELSH, K.I. ROTHER, S.A. TALEGAWKAR. 2017.** "Consumption of low-calorie sweeteners among children and adults in the United States". Journal of the Academy of Nutrition and Dietetics 117(3): 441–448.

[45] **TOEWS I., S. LOHNER, D.K. DE GAUDRY, H. SOMMER, J.J. MEERPOHL. 2019.** "Association between intake of non-sugar sweeteners and health outcomes: Systematic review and meta-analyses of randomised and non-randomised controlled trials and observational studies". BMJ 364, k4718.

[46] **TURNER A., M. VEYSEY, S. KEELY, C.J. SCARLETT, M. LUCOCK, E.L. BECKETT. 2020.** "Intense Sweeteners, Taste Receptors and the Gut Microbiome: A Metabolic Health Perspective. International Journal of Environmental Research and Public Health"17(11): 4094.

[47] **VIN K., A. CONNOLLY, T. MCCAFFREY, A. MCKEVITT, C. O'MAHONY, M. PRIETO, D. TENNANT, A. HEARTY, J.L. VOLATIER. 2013.** "Estimation of the dietary intake of 13 priority additives in France, Italy, the UK and Ireland as part of the FACET project". Food Additives and Contaminants Part A, 30(12): 2050–2080.

[48] **World Health Organization (WHO). 2015.** "Guideline: Sugars intake for adults and children". Geneva: World Health Organization. https://www.who.int/publications/i/item/9789241549028

[38] **POSITION. 2021.** "Position of the Polish Society of Obesity Research and Diabetes Poland on the use of low-calorie sweeteners". [In:] 2021 Guidelines on the management of patients with diabetes. A position of Diabetes Poland. Clinical Diabetology 10(1): 102–103.

[39] **REDRUELLO-REQUEJO M., M. GONZALEZ-RODRIGUEZ, M.D.L. SAMANIEGO-VAESKEN, A. MONTERO-BRAVO, T. PARTEARROYO, G. VARELA-MOREIRAS. 2021.** "Low- and no-calorie sweetener (LNCS) consumption patterns amongst the Spanish adult population". Nutrients: 13: 1845.

[40] **RUSSELL C., C. GRIMES, P. BAKER, K. SIEVERT, M. LAWRENCE. 2020.** "The drivers, trends and dietary impacts of non-nutritive sweeteners in the food supply: A narrative review." Nutrition Research Reviews 1:24.

[41] **SAMUEL DURAN A., L. ANGARITA DAVILA, M.C. ESCOBAR CONTRERAS, D. ROJAS GOMEZ, J. DE ASSIS COSTA. 2018.** "Noncaloric Sweeteners in Children: A Controversial Theme". BioMed Research International: 1–7.

[42] **STANNER S.A., A. SPIRO. 2020.** "Public health rationale for reducing sugar: Strategies and challenges." Nutrition Bulletin 45: 253-270.

[43] **SWIADER K., B. WASZKIEWICZ-ROBAK, F. SWIDERSKI. 2011.** „Substancje intensywnie slodzace - korzysci i zagrozenia". Problemy Higieny i Epidemiologii 92(3): 392–396.

[44] **SYLVETSKY A.C., Y. JIN, E.J. CLARK, J.A. WELSH, K.I. ROTHER, S.A. TALEGAWKAR. 2017.** "Consumption of low-calorie sweeteners among children and adults in the United States". Journal of the Academy of Nutrition and Dietetics 117(3): 441–448.

[45] **TOEWS I., S. LOHNER, D.K. DE GAUDRY, H. SOMMER, J.J. MEERPOHL. 2019.** "Association between intake of non-sugar sweeteners and health outcomes: Systematic review and meta-analyses of randomised and non-randomised controlled trials and observational studies". BMJ 364, k4718.

[46] **TURNER A., M. VEYSEY, S. KEELY, C.J. SCARLETT, M. LUCOCK, E.L. BECKETT. 2020.** "Intense Sweeteners, Taste Receptors and the Gut Microbiome: A Metabolic Health Perspective. International Journal of Environmental Research and Public Health"17(11): 4094.

[47] **VIN K., A. CONNOLLY, T. MCCAFFREY, A. MCKEVITT, C. O'MAHONY, M. PRIETO, D. TENNANT, A. HEARTY, J.L. VOLATIER. 2013.** "Estimation of the dietary intake of 13 priority additives in France, Italy, the UK and Ireland as part of the FACET project". Food Additives and Contaminants Part A, 30(12): 2050–2080.

[48] **World Health Organization (WHO). 2015.** "Guideline: Sugars intake for adults and children". Geneva: World Health Organization. https://www.who.int/publications/i/item/9789241549028

[49] **WANG Y., L. CHENGGUO, L. DENGKUN, Y. HUAMEI, L. XIAOCHENG, J. DI, X.WEI, G. BAOFU. 2021.** "Estimated assessment of dietary exposure to artificial sweeteners from processed food in Nanjing, China". Food Additives & Contaminants Part A 38:7, 1105–1117.

[50] **YOUNG J., E.M. CONWAY, K.I. ROTHER, A.C. SYLVETSKY. 2019.** "Low-calorie sweetener use, weight, and metabolic health among children: A mini-review". Pediatric Obesity 14(8): e12521.

[49] **WANG Y., L. CHENGGUO, L. DENGKUN, Y. HUAMEI, L. XIAOCHENG, J. DI, X.WEI, G. BAOFU. 2021.** "Estimated assessment of dietary exposure to artificial sweeteners from processed food in Nanjing, China". Food Additives & Contaminants Part A 38:7, 1105–1117.

[50] **YOUNG J., E.M. CONWAY, K.I. ROTHER, A.C. SYLVETSKY. 2019.** "Low-calorie sweetener use, weight, and metabolic health among children: A mini-review". Pediatric Obesity 14(8): e12521.