Inorganic and Total Arsenic Contents in Rice-Based Foods for Children with Celiac Disease

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Abstract: Celiac disease is an autoimmune disease that affects the villi of the small intestine causing abdominal pain, gas, diarrhea, or bad absorption due to gluten intolerance. The only treatment for this disease consists of a lifelong gluten free diet; this is, celiac people cannot consume products containing gluten, such as wheat, barley, and rye, but they can use rice and corn. Thus, rice flour is mainly used for the manufacturing of the basic products of this population. Unfortunately, rice can contain high contents of total (t-As) and inorganic (i-As) arsenic. The current study demonstrated that products for celiac children with a high percentage of rice contained high concentrations of arsenic (256 and 128 μg kg^{-1}). The daily intake of i-As ranged from 0.61 to 0.78 μg kg^{-1} body weight (bw) in children up to 5 y of age; these values were below the maximum value established by the EFSA Panel (8.0 μg kg^{-1} bw per day), but it should be considered typical of populations with a high exposure to this pollutant. Finally, legislation is needed to improve the labeling of these special rice-based foods for celiac children; label should include information about percentage, geographical origin, and cultivar of the used rice.

Keywords: dietary exposure, food safety, gluten-free food, infant food

Practical Application: Companies manufacturing foods for celiac children should be aware that high iAs have been found and ask their rice suppliers to provide them with the safest rice (lowest i-As possible) for manufacturing of these special foods. Besides, manufacturers should include all available information on rice on the labels of their products.

Introduction

Celiac disease (CD) is a digestive illness that damages the mucous membrane of the small intestine and interferes with absorption of nutrients from food (NIDDK 2008; ESPGHAN 2012). This illness is caused by intolerance to gluten proteins from *Triticeae* cereals group: wheat (gliadine), rye (secaline), and barley (hordeine). The importance of the functional and clinical effects of this reduced nutrient absorption will depend on age and pathophysiological status of the patients (FACE 2001; AHRQ 2004; Polanco and Ribes 2010). Although this disease can occur at any age after the introduction of gluten-containing foods in the diet, it is mainly detected at 5 y of age or much later at 40s to 50s; the detection of the illness at the adolescence is uncommon (FACE 2001). However, the symptoms are more evident and intense at younger ages because of limited absorption capacity of remaining healthy intestine. The world prevalence of CD is estimated at 1%, although this prevalence may be much higher because a large proportion of cases remain undetected. In Spain the prevalence of CD is estimated at 1 out of 118 and 1 out of 389 in children and adults, respectively (Rodrigues and Jenkins 2006; Polanco 2008).

Currently, the only effective treatment for CD is lifelong adherence to a gluten-free diet as there is not specific drug treatment. This diet basically consists of eliminating all foods having wheat, rye, and barley (Rodrigues and Jenkins 2006; Polanco 2008). Despite these restrictions, people with CD can eat a well-balanced diet with a variety of gluten-free foods, including rice, maize, potato, soy, amaranth, quinoa, buckwheat, or bean flour instead of wheat flour (NIDDK 2008). Rice is especially used due in children and celiac foods due to its blandness, material properties, low allergen potential, and nutritional value (Meharg and others 2008). Rice is therefore essential for the manufacturing of commodities for celiac people and reaches high percentages in their formulations.

However, rice tends to accumulate arsenic (As) due to its cultivation under flooded conditions, where anaerobic soil conditions lead to high As availability to the plant (Signes and others 2008). In rice As content usually ranges from 100 to 400 μg kg^{-1} (Sun and others 2008; Meharg and others 2009). Juhasz and others (2006) estimated bioavailability for humans in the cooked rice in 33% for organic As (o-As) and 89% for the inorganic (i-As). Later Burló and others (2012), Carbonell-Barrachina and others (2012), and Hernández-Martínez and Navarro-Blasco (2013) reported that rice-based infant foods contain significant levels of As, and indicated that celiac products may also be contaminated.

Inorganic As has been classified by the Intl. Agency for Research on Cancer (IARC) as group 1 carcinogenic; this classification was based on the induction of primary skin cancer as well as the induction of lung and urinary bladder cancer (IARC 2004). As for the tolerable intake of As, in 2009 the EFSA Panel on Contaminants in the Food Chain (EFSA 2009) indicated that the provisional tolerable weekly intake (PTWI) of 15 μg kg^{-1} established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) was no longer appropriate. The panel concluded that the overall range of $BMDL_{01}$ values of 0.3 to 8.0 μg kg^{-1} bw (body weight) per day should be used instead of a single reference point in the risk characterization of i-As.

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Summarizing celiac foods requires special attention with respect to their i-As content. The 4 objectives of this study were: (i) to determine the content of total As (t-As) and i-As in the main foods for children aged 1 to 5 with the CD (control samples without rice will be studied as control products), (ii) to estimate the contents of t-As and i-As in the rice used in the manufacture of these products, (iii) to estimate the dietary intake of i-As and to model and predict the health risks in children (1 to 5 y of age) as a result of their exposure to i-As from rice-based foods, and (iv) to give a series of recommendations about labeling and appropriate selection of rice cultivars and geographical sources to manufacturers, consumers, and authorities.

Material and Methods

Instrumentation

Determination of total As (t-As) was performed with a Unicam Model Solaar 969 atomic absorption spectrometer equipped with a continuous hydride generator Unicam Solaar VP90 (AAS-HG).

For As speciation analysis, a high-performance liquid chromatography system consisting of a Varian 9012 ternary pump (Varian, San Fernando, Calif., U.S.A.), a Rheodyne 7125 injector, and a 50 μL loop for sample introduction was used. Separations of As species were performed on a Hamilton PRP X-100 anion-exchange column (particle size: 10 μm, length: 250 mm; inner diameter: 4.1 mm; Hamilton, Reno, Nev., U.S.A.). A guard column packed with the same material (particle size: 12 to 20 μm; length: 25 mm; inner diameter: 2.3 mm) preceded the analytical column. Hydride generation of volatile arsines before the detection was performed adding online solutions of HCl and $NaBH_4$ by means of a Gilson Minipuls 3 peristaltic pump. The quantification of As was performed on a hydride generation system (PSA 10.044, PS Analytical, Kent, UK) using an atomic fluorescence spectrometer system (PSA 10.044 Excalibur, PS Analytical) equipped with a boosted-discharge hollow cathode lamp (Photron Pty. Ltd, Vic., Australia). The analogue signal output was connected to a computer equipped with chromatographic software (PS Analytical).

Other equipment used included a sand bath (Falc, Treviglio, Italy), model BS 70, a muffle furnace (Hobersal, Barcelona, Spain) model 12 PR/300 series 8B, a grinder (Moulinex, Valencia, Spain) with a maximum power of 180 W and a hot air oven (Selecta, Barcelona, Spain).

Reagents

Ultrapure deionized water (18 MΩ cm^{-1}) was used for the preparation of the reagents and standards. All glassware was treated with 10% (v/v) HNO_3 for 24 h and then rinsed 3 times with deionized water before use. All chemicals were of trace element grade. Commercial standards of $NaAsO_2$ (sodium metaarsenite) and $Na_2HAsO_4 \cdot 7H_2O$ (sodium hydrogen arsenate) were obtained from Panreac (Barcelona, Spain), while $CH_4AsNaO_3 \cdot 1.5H_2O$ (monosodium methylarsinate sesquihydrate, MMA) and $(CH_3)_2AsO(ONa) \cdot 3H_2O$ (monosodium dimethylarsinate trihydrate, DMA) were from Supelco (Bellefonte, Pa., U.S.A.) and Fluka (Buchs, Germany), respectively. Magnesium nitrate, $MgNO_3$ and MgO (Panreac, Barcelona, Spain) were used in the ashing solution and 65% (v/v) HNO_3 (Merck, Germany) during the digestion of samples for t-As. Hydrochloric acid, 37% (v/v) HCl (Merck, Germany), 99% pure IK (Rectapur, Leuven, Belgium), and 99% pure ascorbic acid (Panreac, Barcelona, Spain) were used to adjust pH and as reducing agents. For the generation of AsH_3, $NaBH_4$ (Panreac, Barcelona, Spain) solution was prepared by dissolving 1.4 g of $NaBH_4$ powder in 100 mL of 0.4% (m/v) NaOH solution and filtering through Whatman N° 42 paper; fresh $NaBH_4$ solutions were prepared daily. Finally, the 33% (v/v) H_2O_2 used for the speciation digestion was from Panreac (Barcelona, Spain).

Table 1–Total (t-As) and inorganic arsenic (i-As) contents in Spanish foods for children with the celiac disease.

Group	Sample code	Rice (%)	t-As (μg kg^{-1})	i-As (μg kg^{-1})
CONTROL SAMPLES				
1. Pasta	Control 1	0	nd[a]	nd
2. Bread	Control 2	0	nd	nd
3. Breakfast cereals	Control 3	0	nd	nd
4. Chocolate wafers	Control 4	0	nd	nd
5. Biscuits	Control 5	0	nd	nd
RICE-BASED SAMPLES				
1. Pasta				
	1A	35.0	46.3 de[b]	30.9 c
	1B	90.0	256 a	128 a
	1C	93.4	128 c	75.3 b
	1D	95.0	202 b	135 a
2. Bread				
	2A	30.0	71.6 d	34.1 c
	2B	30.0	62.0 d	34.4 c
3. Breakfast cereals				
	3A	75.0	136 c	124 a
4. Chocolate wafers				
	4A	5.0	nd f	nd e
5. Biscuits				
	5A	10.0	16.8 e	12.0 d
	5B	15.0	28.1 e	14.8 d
	5C	15.0	31.8 e	35.3 c
LOQ (μg kg^{-1})			6	6
CRM (%)			101	98

[a]nd = below LOQ (limit of quantification determined as 3 times the standard deviation of the blanks, limit of detection [LOD], multiplied by the proper dilution factor).
[b]Values followed by different letters, in the same column, were significantly different ($P < 0.05$), according to the Tukey's test.

Sample preparation

In this study, samples from 5 foods groups were analyzed: pasta, bread, breakfast cereals, chocolate wafers, and biscuits. All products were purchased (in triplicate) in national supermarket chains from the provinces of Alicante and Murcia (Spain) and were analyzed for t-As and i-As contents. The products under analysis were: 5 pasta samples, 3 bread samples, 2 breakfast cereals with chocolate, 2 chocolate wafers, and 4 biscuits, making a total of 16 products (in triplicate).

All products were targeted for children above 1 y of age and suffering from the CD. For each group, there was a control product containing no rice; in most of the cases, this ingredient was replaced by corn. Products within each group had rice percentages ranging from 5% to 95% rice in their formula (Table 1).

Total arsenic (t-As)

All samples were analyzed for t-As by Hydride Generation Atomic Absorption Spectrometry (HG-AAS). A 0.5 g (pasta) or 1 g portion (other products) of dried, ground, and homogenized sample was weighed and digested using the method first described by Muñoz and others (2000) and later slightly modified by Burló and others (2012). Calibration standards of $NaAsO_2$ [As(III)] were prepared using the same HCl concentration of the samples and certified materials. The instrumental conditions used for the hydride generation were: reducing agent: 1.4% (m/v) $NaBH_4$ in

0.4% (m/v) NaOH at a flow of 5 mL min^{-1}; HCl solution: 10% (v/v) at 10 mL min^{-1}; carrier gas: argon, at 250 mL min^{-1}; while the conditions for the atomic absorption spectrometer were: wavelength: 193.7 nm; spectral bandpass: 0.5 nm; intensity of the hollow cathode lamp 8 mA; air/acetylene flame.

In each analytical batch, at least one reagents blank and one internationally certified reference material (CRM) were included to assess precision and accuracy for chemical analysis. The CRM (rice flour, NIST SRM 1568a) used for testing this analytical method was provided by CYMIT Química S.L. (Barcelona, Spain) and produced by the US Natl. Inst. of Standards and Technology. The quantified t-As content in this CRM was 293 ± 9 μg kg^{-1}, while the certified value was 290 ± 30 μg kg^{-1}.

Arsenic speciation

Speciation extraction procedure followed that first described in Zhu and others (2008) and later by Carbonell-Barrachina and others (2012). Around 0.2 g of dried, ground, and homogenized samples was accurately weighed out into a 50 mL polypropylene digest tube and 10 mL of 1% (v/v) HNO_3 were added to steep overnight. Then samples were extracted in a microwave oven (Milestone, model Start D, Sorisole, Italy). The temperature was raised, first to 55 °C, and held for 10 min, and then at 75 °C, and held for 10 min. Finally, the temperature was taken up to 95 °C and maintained for 30 min. Samples were cooled to room temperature and approximately 2 mL samples were centrifuged at 12000 g for 15 min. The supernatant was filtered through 0.45 μm filter (Millipore) and 900 μL were mixed with 100 μL of H_2O_2 and left overnight at 4 °C. Then samples were kept at 4 °C until analysis. Quality controls of CRM and blanks were run with each extract batch.

Retention time for the As species was determined using a species mix comprising standards of 10 to 50 mg/L arsenite, arsenate, MMA, and DMA. Inorganic arsenic (i-As) was quantified as the sum of arsenite and arsenate species. Recovery of t-As (sum of all As species) in NIST rice flour CRM was 280 ± 7 μg kg^{-1} compared to a certified value of 290 ± 30 μg kg^{-1}. No rice CRM certified speciation is available; however, results (i-As 97 ± 6 μg kg^{-1} and o-As 187 ± 7 μg kg^{-1}) were in good agreement with those previously reported by Raab and others (2009) i-As 99 μg kg^{-1} and o-As mg kg^{-1} 185 μg kg^{-1} and Carbonell-Barrachina and others (2012) i-As 95 μg kg^{-1} and o-As mg kg^{-1} 182 μg kg^{-1}.

Statistical analyses

All data were subjected to analysis of variance (ANOVA) and the Tukey's least-significant difference multicomparison test to determine significant differences among samples (food type). The statistical analyses were performed using IBM SPSS Statistics 21.0 (IBM Corp., Armonk, N.Y., U.S.A.).

Results and Discussion

Total (t-As) and inorganic (i-As) arsenic in control and rice-based samples

The first important result of this study is the statement that all control samples (without rice in their composition) did not contain measurable amounts of As, neither i-As nor o-As (Table 1). These control products were based on corn flour and potato starch. Consequently, it can be concluded that foods for CD children based on cereals others than rice (basically corn-based) are arsenic-free. These results agreed with the study by Matos-Reyes and others (2010), who reported that As content in corn flour was below the detection limit of their analytical equipment, 0.5 μg kg^{-1}.

On the other hand, the content of As in rice-based foods for CD children (Table 1), the highest values were found in samples 1B, 1D, 3 A and 1C: 256, 202, 136, and 128 μg t-As kg^{-1} and 153, 131, 88.4, and 74.2 μg i-As kg^{-1}, respectively. These high values of As contents seemed related to high percentages of rice; rice percentages for these samples were 95%, 90%, 75%, and 93.4%, respectively. Figure 1 shows positive relationships among the rice percentage used in the manufacturing of foods and the contents of

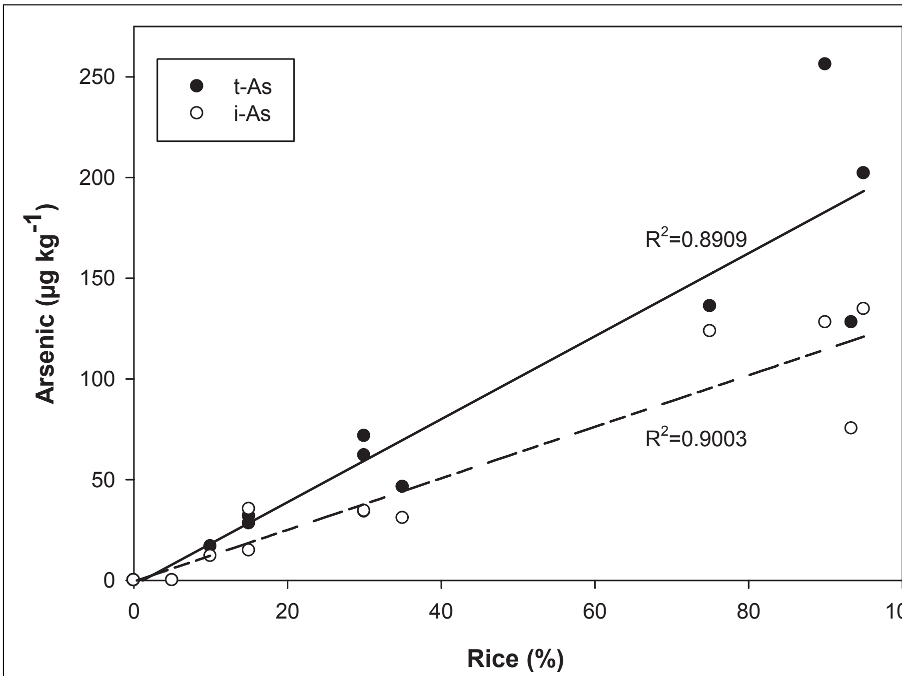

Figure 1–Relationship between total (t-As) and inorganic arsenic (i-As) and rice percentage in samples of Spanish rice-based foods for children with the celiac disease.

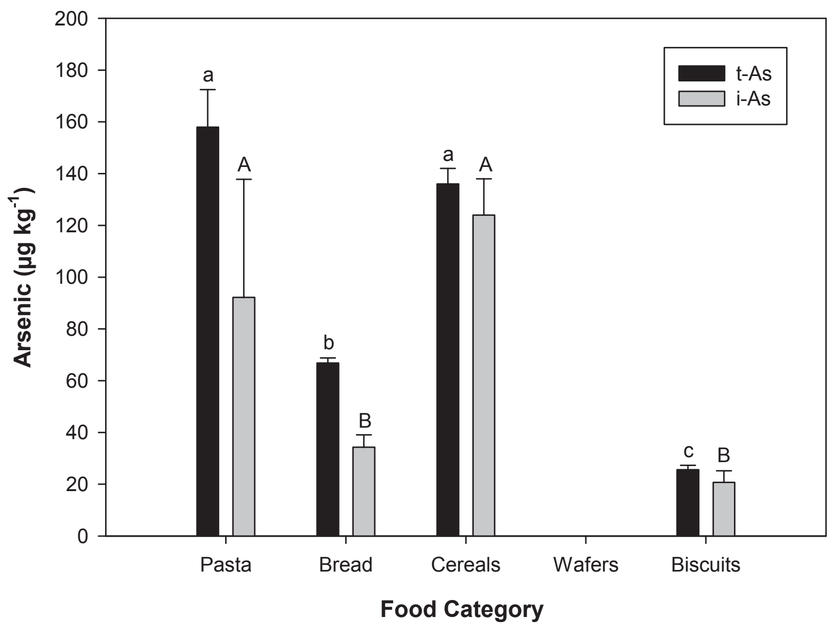

Figure 2–Mean of total (t-As) and inorganic arsenic (i-As) contents in the 5 categories of Spanish rice-based foods for children with the celiac disease. Values followed by different letters, in the arsenic type [t-As: small letters or i-As: capital letters], were significantly different ($P < 0.05$), according to the Tukey's test.

t-As ($R^2 = 0.8909$) and i-As ($R^2 = 0.9003$) in it. These positive relationships mean that the higher the rice percentage the higher the t-As and i-As in the sample. A similar positive relationship was reported by Burló and others (2012) and Carbonell-Barrachina and others (2012) in rice-based infant foods from Spain, the United Kingdom, China, and the USA.

Figure 2 represents the mean values for the contents of t-As and i-As in the 5 categories of foods for children with CD. As expected after seen the rice percentage in Figure 1, the groups with the highest t-As and i-As were pasta and breakfast cereals, with mean values of 158 ± 15 and 136 ± 6 μg t-As kg^{-1} and 92.2 and 124 μg i-As kg^{-1}, respectively. As can be seen the breakfast cereals were characterized by a high ratio of i-As/t-As, with a value of 0.91.

On the other hand, the chocolate wafers contained no measurable As without any doubt because of the low percentage of rice used in their manufacturing (5%). Bread and biscuits samples presented intermediate contents of both t-As and i-As.

The ratio i-As/t-As presented a mean value of 0.67 ± 0.06, a median of 0.63 and ranged between 0.48 and 1.11. These values agree quite well with those reported by Carbonell-Barrachina and others (2012) in Spanish infant foods based on rice; the values found by these researchers ranged 0.36 and 0.89, with a mean of 0.64. In this same study, it was reported that the ratio i-As/t-As ha mean values of 0.76, 0.55, 0.71, and 0.53 for rice-based infant foods from China, the USA, the United Kingdom, and Spain, respectively. Sun and others (2009) found high values of the ratio i-As/t-As, mean of 0.81 rice products, such as breakfast cereals, rice crackers, and Japanese rice condiments.

Regarding the o-As species, DMA was predominant and represented approximately 80% of the total o-As content. Signes-Pastor and others (2012) reported that all As present in rice from West Bengal (India) was present as DMA; no measurable MMA was found. Similarly Meharg and others (2008) reported that all o-As was present as DMA in baby rice.

It can be concluded that the content of i-As followed the order: pasta > cereals > bread > biscuits > wafers, and that these contents were positively correlated with the important of rice in the product formulation.

Table 2–Estimation of total (t-As) and inorganic arsenic (i-As) contents in rice used as ingredient for Spanish foods for children with the celiac disease.

Group	Sample	Rice (%)	t-As (μg kg^{-1})	i-As (μg kg^{-1})
1	1A	35.0	132 d[a]	82.6 c
	1B	90.0	285 a	170 a
	1C	93,4	137 d	79.4 c
	1D	95.0	213 bc	138 b
2	2A	30.0	239 ab	138 b
	2B	30.0	207 bc	120 b
3	3A	75.0	182 c	118 b
4	4A	5.0	0 e	0 d
5	5A	10.0	168 cd	117 b
	5B	15.0	187 c	140 b
	5C	15.0	225 b	135 b

[a]Values followed by different letters, in the same column, were significantly different ($P < 0.05$), according to the Tukey's test.

Total (t-As) and inorganic (i-As) arsenic in rice

Only few of the rice percentages used in this study were included in the labeling of the products. To gather this information, e-mails were sent and telephone calls were made to the manufacturers and the gathered information is listed in Table 2. Considering that all As is coming from rice and the rice percentage of the commercial foods for celiac children, the t-As and i-As contents of the raw material rice was estimated (Table 2). t-As contents ranged from 132 to 285 μg kg^{-1} (mean of 180 ± 22 μg kg^{-1}) while i-As contents ranged from 79.4 to 140 μg kg^{-1} (mean of 113 ± 14 μg kg^{-1}). The highest t-As values were those of samples 1B, 2A, 5C, and 1D, with concentrations of 285, 239, 225, and 213 μg kg^{-1}, respectively. Similarly the highest i-As values were found in samples 1B, 5B, 1D, and 2A samples, with concentrations of 170, 140, 138, and 138 μg kg^{-1}, respectively. The samples of Spanish rice included in the EFSA (2009) document presented mean values

Table 3–Weekly intake estimation of total (t-As) and inorganic (i-As) in children of 2 to 5 y of age.

		Children of 2 to 3 y			Children of 3 to 5 y		
Day	**Rice-based sample**	**Amount (g)**	**t-As (μg)**	**i-As (μg)**	**Amount (g)**	**t-As (μg)**	**i-As (μg)**
BREAKFAST							
Monday	Biscuits	25	0.84	0.51	35	1.20	0.71
Tuesday	Cereals	20	2.70	1.77	30	4.10	2.65
Wednesday	Baguette bread	25	1.80	1.03	50	3.60	2.08
Thursday	Cereals	20	2.70	1.77	30	4.10	2.65
Friday	Biscuits	25	0.84	0.51	35	1.20	0.71
Saturday	Baguette bread	25	1.80	1.03	50	3.60	2.08
Sunday	Cereals	20	2.70	1.77	30	4.10	2.65
Mean As intake (μg)			1.91	1.20		3.13	1.93
SNACK							
Monday	Sandwich bread	40	2.50	1.44	60	3.70	2.15
Tuesday	Sandwich bread	40	2.50	1.44	60	3.70	2.15
Wednesday	Biscuits	15	0.50	0.30	20	0.70	0.41
Thursday	Sandwich bread	40	2.50	1.44	60	3.70	2.15
Friday	Sandwich bread	40	25.0	1.44	60	3.70	2.15
Saturday	Biscuits	15	0.50	0.30	20	0.70	0.41
Sunday	Sandwich bread	20	1.30	1.44	30	1.90	2.15
Mean As intake (μg)			4.97	1.11		2.59	1.65
LUNCH							
Monday	Pasta	50	13.0	7.65	60	15	9.18
Tuesday	Baguette bread	20	1.20	0.83	30	1.9	1.25
Wednesday	Rice	50	9.00	5.40	60	11	6.48
Thursday	Baguette bread	20	1.20	0.83	30	1.9	1.25
Friday	Pasta	50	13.0	7.65	60	15	9.18
Saturday	Baguette bread	20	1.20	0.83	30	1.9	1.25
Sunday	Baguette bread	20	1.20	0.83	30	1.9	1.25
Mean As intake (μg)			5.69	3.43		6.94	4.26
SNACK							
Monday	–	–	–		–	–	–
Tuesday	Biscuits	15	0.50	0.30	20	0.70	0.41
Wednesday	Sandwich bread	40	2.90	1.44	40	2.90	1.44
Thursday	Biscuits	15	0.50	0.30	20	0.70	0.41
Friday	–	–	–		–	–	–
Saturday	Sandwich bread	40	2.90	1.44	40	2.90	1.44
Sunday	–	–	–		–	–	
Mean As intake (μg)			1.70	0.87		1.80	0.93
DINNER							
Monday	Baguette bread	20	1.20	0.83	20	1.20	0.83
Tuesday	Rice	20	3.60	2.16	30	5.40	3.24
Wednesday	Baguette bread	20	1.20	0.83	20	1.20	0.83
Thursday	Baguette bread	20	1.20	0.83	20	1.20	0.83
Friday	Baguette bread	20	1.20	0.83	20	1.20	0.83
Saturday	Baguette bread	20	1.20	0.83	20	1.20	0.83
Sunday	Pasta	40	10.0	6.12	50	13.0	7.65
Mean As intake (μg)			2.80	1.78		3.49	2.15
Daily As intake (μg)			17.1	8.39		17.9	10.92
Daily As intake (μg kg^{-1} bw), percentile 5%			1.71	0.84		1.28	0.78
Daily As intake (μg kg^{-1} bw), percentile 50%			1.22	0.60		1.00	0.61

of 189 μg t-As kg^{-1} and 113 μg t-As kg^{-1} and averaged about 70 samples. More recently Burló and others (2012) studied the t-As content in 20 samples of rice marketed in Spain and found values ranging from 102 up to 351 μg kg^{-1}, with a mean value of 186 $\pm$ 15 μg t-As kg^{-1}. During 2013, Sommella and others (2013) reported values of t-As in Italian rice samples, ranging from 90 to 280 μg t-As kg^{-1}.

Therefore, the estimated t-As content of the rice used to manufacture foods for children with the CD agreed very well with those published previously in Spanish (Burló and others 2012) and Italian (Sommella and others 2013) rice. This agreement may indicate that Spanish or European rice could have been used in the manufacture of this type of delicate and special foods.

Some authors have indicated that brown rice has much higher concentrations of t-As and i-As than white rice, because As is predominantly accumulated in rice bran (Williams and others 2007; Sun and others 2008). Considering the values listed in Table 2, it seems improbable that brown rice was used as ingredient of celiac foods. Without any doubt the use of white rice and flour in the food industry, especially in products aimed for infant and people highly depended on rice, is one of the best solutions to reduce As exposure.

At present, there is an intense discussion within the As research community and the legislative institutions about the maximum values of t-As and/or i-As that should be established in rice and rice-based products. The most frequently mentioned values are 300 μg kg^{-1} and 200 μg kg^{-1} for t-As and i-As, respectively. If this was the current legal thresholds, all samples under analysis will be fully acceptable and only the sample of pasta 1B will be close to these limits, but still well below them.

Estimation of As intake in celiac children

The toxicology of As is independent of source once it crosses the gut membrane. All indications are that the bioavailability of i-As from rice is high, in the order of 90% (Juhasz and others 2006; Signes-Pastor and others 2012). Therefore, it will be considered that i-As from rice-based foodstuffs will be as toxic to children as that coming from other sources, such as drinking water.

After determining the contents of t-As and i-As in rice-based food for celiac children, it seemed desirable to estimate whether the weekly intake could represent a significant risk for celiac children aged 2 to 5 y old. The weight information as affected by the children age was obtained from Generalitat Valenciana (2012). CD is a cause of growth retardation in which the child stops progressing at the expected pace (NIDDK 2008). Therefore, in this study low weight percentiles were used: (i) 10 and 14 kg corresponding to the percentile 5 and 50 for children of 2 to 3 y, and (ii) 14 and 18 kg corresponding to the percentiles 5 and 50 for children of 4 to 5 y (WHO 2013).

A menu containing the foods analyzed in the present study has been designed according to the needs of children aged 2 to 5 y and it is presented in Table 3. The amounts of foods included in this menu have been chosen according to the children's needs (AESAN 2010). For the estimation of the As intake, the worst possible scenario was considered; this is, for each type of foods the highest possible t-As and i-As values were considered.

The CONTAM Panel of EFSA (2009) modeled the dose-response data from key epidemiologic studies and selected a benchmark response of 1% extra risk. The lowest $BMDL_{01}$ values were for lung cancer and this EFSA Panel concluded that the overall range of $BMDL_{01}$ values of 0.3 to 8.0 μg kg^{-1} bw per day should be used instead of a single reference point in the risk characterization of i-As. The estimated dietary exposures to i-As of Spanish children suffering from the CD ranged from 0.60 and 0.84 μg (kg^{-1} d^{-1}) and from 0.61 and 0.78 μg (kg^{-1} d^{-1}) in children aged 2 to 3 and 3 to 5 y old. The European Food Safety Authority (EFSA) in 2009 reported that the exposure levels in a normal consumer ranged from 0.13 to 0.56 μg (kg^{-1} d^{-1}) while the exposure level in consumers highly exposed to i-As ranged from 0.37 to 1.22 μg (kg^{-1} d^{-1}). Consequently, the experimental levels reported in this study completely agreed with these EFSA ranges, and were typical of a highly exposed to i-As group. In this particular case, the situation is worse because there are no many options for the restricted diet of children with the CD. Besides at these young ages, it has been reported that the human organism is very susceptible to the toxic effects of i-As (Rahman and others 2009).

Besides, it must be remembered that there could be some other sources of both t-As and i-As that have not been considered in this study and that might increase the exposure to this metalloid. It has been demonstrated that eating rice or rice-based products leads to increased exposure to As as proven by the analysis of human urine (Cascio and others 2011), and it should be mentioned as well that there are recent indications that biotransformations among As species occurring in the colon may induce an additional health risk (Sun and others 2012; Alava and others 2013). Finally, it can also happen that because celiac children have altered the mucous membrane of the small intestine and therefore their capacity to absorb nutrients, it is also possible that their capacity to absorb i-As and/or t-As could also be restricted.

Conclusions

There was a positive correlation between rice and As in rice-based products for celiac children; this is, the greater the percentage of rice used in the formulation of the product, the higher the content of As. Gluten-free products, which do not contain rice in their formulations, do not contain As above the detection limit. The highest values found were 256 and 128 μg kg^{-1} in t-As and i-As, respectively, and corresponded to pasta samples. The daily i-As intake from the studied rice-based products ranged from 0.61 to 0.78 μg kg^{-1} bw and it was within the $BMDL_{01}$ considered safe by the EFSA Panel (0.3 to 8.0 μg kg^{-1} bw per day). Therefore there is no serious and immediate risk to the health of children between 2 and 5 y suffering from the CD. However, these values could be considered as deserving attention because the exposure of celiac people to i-As from rice-based products will start with the detection of their illness and will last all their life. Besides, the addition of other foods to the diet can increase the intake of this contaminant to higher levels.

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