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Dietary Intake of Tunisian Adult Population Aged from 19 To 65 in Cobalt

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Abstract

Dietary intake of Tunisian adult population in cobalt was assessed using Total Diet Study method. Research and quantification of cobalt was performed on 42 core food groups represented by 73 food samples. One core food group “spices” had a cobalt concentration (0.33 mg / kg) higher than the LOQ. The estimated average of mean daily intake in Cobalt for the Tunisian adult population ranged from 2.21 10^{-3} (LB) to 0.11 mg/kg bw/day (UB), the mean daily intake in 5th percentile ranged from 4.42 10^{-4} (LB) to 6.84 10^{-2} mg / kg bw/day (UB) and the in the 95th percentile ranged from 5.37 10^{-3} (LB) to 0.161 mg/kg bw /day (UB).

The estimated mean daily intake in Cobalt compared to body weight for the Tunisian adult population ranged from 2.95 10^{-5} at LB to 1.40 10^{-3} mg/kg bw/day at UB, at the 5th percentile it ranged from 5.90 10^{-6} in the LB to 9.12 10^{-4} mg/kg bw/day in the UB, and in the 95th percentile it ranged from 7.15 10^{-5} (LB) to 2.15 10^{-3} mg/kg bw/day (UB).

The mean daily intake in Cobalt represented 92 % (LB) to 4378 % (UB) the Minimum Nutritional Recommended value. At the 5th percentile the Cobalt intake represented 18 % (LB) to 2849 % (UB) of the Minimum Nutritional Recommended value.

The mean daily intake in cobalt relative to body weight for the Tunisian adult population varies from 2 % (LB) to 88 % (UB) percentage of the Safety Limit (SL). At the 95th percentile the mean daily intake in cobalt represented 4 % (LB) to 134 % (UB). The percentage of individuals with an intake higher than the LS ranged from 0 % (LB) to 28.40 % (UB).

The present findings indicate that the theoretical risk of insufficient cobalt intake and the theoretical risk of excessive Cobalt intake cannot be dismiss with certainty.

Keywords: Total Diet study; Cobalt; Dietary intake

Introduction

Cobalt is a natural element [1]. The earth's crust contains 0.0023 % cobalt [2]. It is usually associated with other metals such as copper, nickel, manganese and arsenic [2]. Cobalt is found in the form of cobalamin (vitamin B12), in animal products such as meat, fish, poultry, seafood, milk, cheese and eggs and in inorganic form in plants [3,4]. Vitamin B12 must be provided by ruminants to humans and species with a single gastric pouch because they are unable to produce vitamin B12 from cobalt [5,6]. Cobalt is absorbed by the oral and pulmonary routes. Absorption through intact skin is very low or nil [3]. Oral absorption of cobalt in humans depends on the form of the chemical element, its dose and the nutritional status of the person exposed to it. The absorption of cobalt by the gastrointestinal tract depends on the solubility of the element and the iron deficiency of the exposed person [7]. Cobalt could be cardiotoxic; indeed, cardiomyopathies have been observed in Belgium, the United States and Canada in beer drinkers with cobalt used as a foam-modifying agent [2]. There are other findings on adverse health effects related to cobalt; the repeated absorption of cobalt can also produce hypothyroidism and thyroid hyperplasia. Some cases of polycythemia have also been reported in cobalt-contaminated beer drinkers or exposed workers [3,8]. Cobalt may increase the risk of broncho-pulmonary cancer associated with exposure to hard metals (cobalt associated with tungsten carbide) [3,8]. In vivo and in vitro studies have shown that cobalt salts (dichloride or acetate) are capable of inducing genotoxic alterations such as DNA damage, gene mutations, micronucleus formation, chromosomal aberrations in humans oral (ANSES 2011, Health Canada, 2011). Cobalt deficiency has not been described apart from vitamin B12 deficiencies, of which it is one of the constituents (Basdevant, *et al.*, 2001) [9].

Methodology

Trace element selection

WHO offers a list of the main priority contaminants to be looked for during the TDS (WHO, 2002) [7] but not for nutrients and each country decides on its own priorities? The choice fell on trace element cobalt.

Selection of the core food list

The food list was derived from the food consumption database of a household survey carried out by the National Institute of Statistics (NIS, 2010). This survey was conducted with a sample of 6,500 households representative of the Tunisian population covering the entire geographic (governorate, delegation and district) and socio-economic distribution. There was also a stratification between communal (urban) and non-communal (rural) environments. The house hold samples were rotated (the same house hold was visited two times a day for one week). The observation period of food consumption for each household was of one week. Thus, the researcher analyzed the menu of each main meal (lunch and dinner) twice a day for 7 consecutive days. Each time the researcher would weigh the quantities of food intended to be consumed by the members of the household and which constituted the ingredients for preparing the meals. The researcher also noted the number of people present at that meal. After the meal, the left overs were also evaluated and quantified, including the amounts of food in each dish, in order to only record what had actually been consumed. During each visit, the nature and quantity of all other foods taken between meals were systematically recorded. However, any meals taken outside the household were not taken into account. Only snacks eaten outside were taken into consideration. If a person did not eat a certain meal at home, but did not eat elsewhere either, the portion would be adapted (coefficient that takes into account the "catch-up" during the following meal).Once processed, the consumption data obtained from the National Household Budget and Quality of Life Survey conducted by the National Institute of Statistics of Tunisia (NIS, 2010), enabled us to determine the average amount of food "as consumed".

The consumption database is in g/week of food "as purchased" per household. The quantities "as purchased" have been converted into "edible parts" of food (by the application of yield coefficients) and then into amount of food "as consumed" (by applying cooking coefficients) (NINFT, 2007).The results of this survey make it possible to approximate the amounts of food "as consumed" rather than "as purchased" in grams per day and per person.

In order to be able to work on data corresponding to the equivalent of "individual consumption", the total consumption for each household has been converted into data equivalent for one adult. Each individual was assigned a "consumption coefficient" (adult equivalence factor (FAO/WHO/UNU, 2004)).

The amounts weighed are therefore related to the number of persons (individuals who actually consumed them). The results of this survey make it possible to approximate the amounts of food consumed (food "as consumed" rather than "as purchased") in grams per day and per person and to establish a list of foods to be analyzed representative of the Tunisian diet as described in Table 1.

Table 1: list of foods to be analyzed representative of the Tunisian diet

FOOD SUBGROUP	% CONSUMERS	MEAN DAILY CONSUMPTION (g/AE/day)	CONTRIBUTION TO TOTAL DIET (%)	*MAXIMUM DAILY CONSUMPTION (g/AE/day)*	*MEDIAN (P50) DAILY CONSUMPTION (g/AE/day)*	*SD (g/AE/day)*	*P 95 CONSUMERS*
							(g/AE/day)
wheat Couscous and traditional bread	83,74 %	315,13	10,86 %	3125,49	157,36	408,73	1168,57
wheat Couscous	13,83 %	62,27	2,15 %	2004,81	0	244,99	358,06
pasta	95,39 %	194,86	6,72 %	1286,65	169,32	136,49	431,49
Bread	94,90 %	246,19	8,48 %	714,29	246,13	140,43	495,55
pastries	66,75 %	31,08	1,07 %	681,82	11,105	60,89	121,45
Barley products	30,10 %	9,36	0,32 %	267,23	0	27,52	45,35
rice	20,39 %	18,87	0,65 %	375	0	45,52	110,75
sorghum	3,64 %	4,69	0,16 %	372,49	0	31,72	0
Dry legumes	84,22 %	28,25	0,97 %	186,34	18,515	29,92	83,08
Jute mallow	8,01 %	3,19	0,11 %	91,74	0	11,98	34,54
Solanaceous vegetable	97,33 %	50,3	1,73 %	202,74	39,24	39,22	135,18
Root and bulb legumes	98,79 %	41,04	1,41 %	250,88	32,97	32,52	100,37
potatoes	96,84 %	48,05	1,66 %	226,11	42,57	31,29	103,01
Vegetable Cucurbitaceous + green legumes+stems legumes+ brasissés legumes	80,58 %	37,78	1,30 %	310,75	26,055	43,18	124,72
Leafy vegetables	75,49 %	21,38	0,74 %	176,37	11,94	27,13	71,41
Industrial tomatoes	97,57 %	29,32	1,01 %	128,7	27,125	16,01	60,75
Industrial Harissa	18,93 %	0,9	0,03 %	21,84	0	2,67	6,16
Olive + pickles	22,09 %	1,83	0,06 %	40,58	0	5,16	11,37
Cucurbitaceous fruits	22,57 %	62,72	2,16 %	1926,12	0	167,72	384,05
Citrus	42,96 %	25,65	0,88 %	638,96	0	60,96	108,25
dates	11,65 %	3,35	0,12 %	83,24	0	11,75	25,08
Fruits stone + seeds	43,69 %	35,52	1,22 %	511,04	0	62,56	165,13
Other fruits	35,44 %	33,61	1,16 %	641,65	0	75,62	166,68
Meat of sheep and goats and cattle	56,80 %	15,9	0,55 %	131,93	7,81	22,5	63,83
Poultry meat	66,50 %	20,24	0,70 %	148,5	15,495	22,83	63,96
Chiken liver	3,16 %	0,54	0,02 %	50,33	0	3,84	0
Eggs	83,50 %	17,58	0,61 %	94,52	12,78	17,39	51,9
Fat fish	42,23 %	11,23	0,39 %	112,62	0	19,17	52,5
non fat fish	25,00 %	6,85	0,24 %	90,2	0	14,76	37,88
Whole milk	35,44 %	52,99	1,83 %	798,03	0	110,38	272,86
Semi-skimmed milk	69,66 %	138,95	4,79 %	1026,19	112,435	149,12	414,11
yoghurts	49,03 %	15,85	0,55 %	303,03	0	30,76	68,52
Melted cheese	20,63 %	0,91	0,03 %	24,24	0	2,45	6,25
sugar	97,33 %	32,23	1,11 %	181,48	26,935	24,48	72,83

Olive oil	68,20 %	16,11	0,56 %	123,88	5,96	21,96	65,63
Vegetable seed oil (palm + soja)	91,75 %	41,01	1,41 %	197,55	38,145	29,11	87,82
Margarin	30,83 %	2,29	0,08 %	28,81	0	4,75	12,17
the	75,49 %	101,98	3,51 %	818,72	77,78	114,08	313,01
coffee	72,57 %	69,87	2,41 %	525,63	41,395	82,45	230,49
Soft drinks	48,06 %	44,95	1,55 %	426,44	0	67,76	168,86
Spices	97,33 %	6,7	0,23 %	43,08	5,42	5,17	16,27
water	100,00 %	1 000	34,46 %	1000	1000	0	1000

Foods were classified into food subgroups based on 1) foods of the same category; 2) similar manufacturing methods; 3) a similar composition; and 4) similar cooking methods [10].

This constituted the basis for creating the food item list for the sampling plan. Overall, 42 core food groups were selected covering 97 % of the Tunisian diet.

Sample collection

After listing the most consumed foods, a purchase list and a sampling guide were prepared according to the previous final selection done. This resulted in 42 core food groups representative of the Tunisian diet (quantities, geographic type (regional or national) and seasonality (winter, summer)).Identification of food items to be purchased, their regional distribution and the most consumed brands of food was done according to surveys of the data provided by the various ministries in relation with food control, inter-professional groups (UTICA), inter-professional groups of red meat and milk, poultry and rabbit and distributors.

The investigation about the Tunisian food market production and distribution concerned the entire food chain, from production to final consumption. The data collected enabled us to create a database for each core food category (canned goods, pasta, milk and dairy, poultry and egg products, fish, oil and fats, confectionery, biscuits, water, beverages, sugar and salt) and the identify the geographic zone of the purchase.

The 42 selected core food groups were divided into28 national core food groups including processed and imported food. Samples of these core food groups were purchased at the wholesale market in Tunis (Bir El Kassaa) which centralizes imports from abroad and unprocessed products from many of the country's governorates. Some samples were purchased from local markets and specific sales outlets for certain foods such as pastries, poultry, etc.

14 regional food groups: these are raw foods produced in different ways and in different environments according to the region (meat, fruits and vegetables) which may have variable levels of contamination. The purchases were made in several places such as the wholesale market in each of the 3 regions chosen for fresh products (if a products was missing, it was purchased at a municipal and/or a weekly market) while other products were acquired at local shops (fresh milk, vegetables, spicy fish, etc.).

Each of the 42core food group samples was, as described in Table 2,a composite sample composed by a weighted proportion of foods according to the respective average amounts of consumption as described in Table 1(e.g. dry legumes are composed of 43.66 % dry beans, 43.7 % chickpeas and 12.65 % lentils) (EFSA,2011) [8].

Analytical method

The analysis of cobalt was carried out in WEJ Contaminants GmbH (Hamburg), accredited (DIN EN ISO 17025) by the German Accreditation Council.

The cobalt content in the different food groups (fresh fruits and vegetables, cereals, milk and derivatives, meat and derivatives, spices….) and in drinks (including water)was determined by Inductively Coupled Plasma / Atomic Emission Spectrometry (ICP-AES) and inductively Coupled Plasma / Mass Spectrometry (ICP-MS) and this according to the food matrix. The LOD varies from 0.03 to 0.07 mg/Kg and the LOQ varies from 0.1 to 0.2 mg/Kg.

The analytical methods include the following steps: 1st step: Pre-treatment:- Preparation of solid samples for testing (vegetables and fruits, cereal products and derivatives, powdered sugar, spices, meats, fish, eggs, oils and margarines) by homogenization of the sample according to the 'EN 13804-2002, followed by grinding, homogenization, weighing and placing in a capsule.- Preparation of liquid samples for testing (tap water, milk, carbonated drink) by homogenizing the sample according to EN 13804-2002, followed by weighing and placing in a capsule. 2nd step: Wet mineralization- Hot acid mineralization in the heating block: the sample (solid or liquid) is digested in the presence of concentrated acid (nitric acid), then it is heated at 90 ° C for three hours. For the solid sample, additional heating is done for 4 hours at 160 ° C to obtain a liquid sample. 3rd step: Dosage. The determination of cobalt.

Exposure estimation and treatment of censored data

The processing of censored data (<LOD or between LOD and LOQ) was done according to the recommendations of the International Program on Chemical Safety (IPCS / Gems / Food, 1995). This proposed treatment method for censored data has the advantage of taking into account the effect of censorship as a function of the proportion of quantified results and thus of controlling the uncertainties arising from the analytical limits in the exposure values with lower bound, middle bound and upper bound scenarios. It is the proportion of <LOD (undetected) data that determines the choice of scenario and the values that are assigned to un-quantified data. Ifthe proportion of results was over60 %, the lower bound (the concentration of non-quantified analytes set to the zero) and upper bound (the concentration of non-quantified analytes set to the limit of detection) scenarios were used. If the results were £ 60 % (the concentration of non-quantified analytes set to half the limit of the quantification) the middle bound scenario was used. For results between LOD and LOQ, it is also the proportion of <LOD (undetected) data that determines the choice of scenario. If this proportion is between 60 % and 80 % or higher, then the lower bound and upper bound scenarios are used. In the lower bound case the consumption is multiplied by the LOD value and in the upper bound case the consumption is multiplied by the LOQ value. If the proportion of the results is <60 % then the middle bound scenario is chosen. The results between LOD and LOQ are multiplied by 1/2 LOQ.

The cobalt intake was estimated by multiplying the food consumption data for the food group by the cobalt content data for that food group. It is expressed in the usual unit of measurement of the element, that is, in milligrams per kilogram of body weight per day (mg/kg bw/day). The total intake of cobalt is the sum of the cobalt intake in all the aggregated food groups analyzed.

The total intake of cobalt was calculated using the following equation:

$$E_{ik} = \sum_{a=1}^{n} \frac{C_{i,a} \times T_k}{pc_i}$$

- $\mathbf{E_{ik}}$ is the total daily intake of the equivalent adult “i” to pesticide “k” (mg/kg bw/day),

- $\mathbf{C_i}$ is the average daily consumption of food “a” by the equivalent adult (one person) “i” (kg/day),

- $\mathbf{T_k}$ is the mean content of cobalt “**k**” in food “**a**” (mg/kg),- $\mathbf{pc_i}$ is the body weight of the equivalent adult “**i**” (kg).

- **n** is the total number of foods consumed by the equivalent adult (*one person*) “**i**”

In this study, the total daily intake is expressed as the average total daily intake and the 95th percentile (P95) of daily intake. The average contribution of each food group is expressed as a percentage of the total daily intake.

Results and discussion

Characterization of the danger

WHO considered vitamin B12 rather than cobalt and have only recommended intake for vitamin B12 without setting minimum intakes [11,12]. The risks associated with a high cobalt intake were reviewed by WHO (WHO / FAO, 2004) and the European Food Safety Authority [13] who ultimately decided to take no position and set no maximum value of intake. ANSES, based on the small number of studies available orally, determined a range for a TDI (Tolerable Daily Intake) for the toxic effects of cobalt fixed between 1.6 and 8 µg / kg bw / day without being able to exclude the possibility of toxic effects without threshold [4].

For this study, the nutritional values used as a reference value for the assessment of the adequacy of cobalt intake for the Tunisian adult population are:

- the WHO Minimum Nutritional value Recommended (2.4 µg / d for the 19 to over 65 years of age) because of the absence of Minimum Nutritional requirement value (WHO / FAO, 2004) and

- As the VTR (toxicological reference value) the lower limit of the TDI (Tolerable Daily Intake) of the interval for toxic effects determined by ANSES which is 1.6 µg / kg bw / day [4].

Exposure assessment

The scenarios used for estimating the cobalt intake of the Tunisian population are the Lower and Upper Bound scenario because the proportion of result <LOD is greater than 60 %. The mean daily intake in cobalt estimated for the Tunisian adult population varies from 2.21 10^{-3} (LB) to 0.11 mg / day / eq ad (UB), the mean daily intake on the 5th percentile varies from 4.42 10^{-4} (LB) to 6.84 10^{-2} mg / d / eq ad (UB) and the 95th percentile daily intake ranged from 5.37 10^{-3} (LB) to 0.161 mg / d / eq ad (UB) (Table 2).

The estimated mean daily intake for cobalt compared to body weight ranged from 2.95 10^{-5} (LB) to 1.40 10^{-3} mg / kg bw / day (UB), the mean daily intake compared to body weight in the 5th percentile for the Tunisian population ranged from 5.90 10^{-6} (LB) to 9.12 10^{-4} mg / kg bw / day (UB) (Table 3).

Table 2: Estimated Cobalt intakes of the Tunisian population in mg / d / (Lower Bound- Upper Bound)

FOOD SUBGROUP	**MEAN DAILY CONSUMPTION (g/j)**	**CONSUMPTION at P95 (g/j)**	**% consumers**	TMDI LB (mg /j / eq ad)	Intake / TMDI LB	Intake at P95 LB (mg /j / eq ad)	Apport au P5 LB (mg /j / eq ad)	MDI UB (mg /j / eq ad)	Intake / TMDI UB	Intake At P95 UB (mg /j / eq ad)	Intake At P5 UB (mg /j /eq ad)
Citrus	25,65	108,25	42,96 %	0	0 %	0	0	$1,80.10^{-3}$	1,71	$7,58.10^{-3}$	0
other fruits	33,61	166,68	35,44 %	0	0 %	0	0	$1,01.10^{-3}$	0,96	5.10^{-3}	0
Soft drink	44,95	168,86	48,06 %	0	0 %	0	0	$1,35.10^{-3}$	1,28	$5,07.10^{-3}$	0
Coffzz	69,87	230,49	72,57 %	0	0 %	0	0	$2, .10^{-3}$	1,99	$6,91.10^{-3}$	0
Industriel canned tomatoes	29,32	60,75	97,57 %	0	0 %	0	0	$8,8.10^{-4}$	0,84	$1,82.10^{-3}$	$2,74.10^{-4}$
Corète	3,19	34,54	8,01 %	0	0 %	0	0	$6,38.10^{-4}$	0,61	$6,91.10^{-3}$	0
Whole wheat couscoust	62,27	358,06	13,83 %	0	0 %	0	0	$1,87.10^{-3}$	1,78	$1,07.10^{-2}$	0
Wheat couscous and artisanal bread	315,13	1168,57	83,74 %	0	0 %	0	0	$9,45.10^{-3}$	9,00	$3,51.10^{-2}$	0
Dates	3,35	25,08	11,65 %	0	0 %	0	0	10^{-4}	0,10	$7,52.10^{-4}$	0
Water	1000,00	1000,00	100,00 %	0	0 %	0	0	3.10^{-2}	28,55	3.10^{-2}	0,03
Spices	6,70	16,27	97,33 %	$2,21.10^{-3}$	100 %	$5,37.10^{-3}$	$4,42.10^{-4}$	$2,21.10^{-3}$	2,10	$5,37.10^{-3}$	$4,42.10^{-4}$
Sorghum	4,69	0	3,64 %	0	0 %	0	0	$4,69.10^{-4}$	0,45	0	0
Chicken liver	0,54	0	3,16 %	0	0 %	0	0	$1,63.10^{-5}$	0,02	0	0
Melted cheese	0,91	6,25	20,63 %	0	0 %	0	0	$6,37.10^{-5}$	0,06	$4,37.10^{-4}$	0
Cucurbit fruits	62,72	384,05	22,57 %	0	0 %	0	0	$4,39.10^{-3}$	4,18	$2,69.10^{-3}$	0
Stone and seeds fruits	35,52	165,13	43,69 %	0	0 %	0	0	$2,49.10^{-3}$	2,37	$1,16 .10^{-2}$	0
Harissa	0,90	6,16	18,93 %	0	0 %	0	0	$6,29\ 10^{-5}$	0,06	$4,31.10^{-4}$	0
Vegetable oil	41,01	87,82	91,75 %	0	0 %	0	0	$1,23.10^{-3}$	1,17	$2,63.10^{-3}$	0
Olive oil	16,11	65,63	68,20 %	0	0 %	0	0	$4,83.10^{-4}$	0,46	$1,97.10^{-3}$	0
Whole milk	52,99	272,86	35,44 %	0	0 %	0	0	$1,59.10^{-3}$	1,51	$8,19.10^{-3}$	0
Semi-skimmed milk	138,95	414,11	69,66 %	0	0 %	0	0	$4,17.10^{-3}$	3,97	$1,24.10^{-2}$	0
Leafy vegetables	21,38	71,41	75,49 %	0	0 %	0	0	$6,41.10^{-4}$	0,61	$2,14.10^{-3}$	0
Cucurbitaceae fruit vegetables + brassicas + stems + Green legumes	37,78	124,72	80,58 %	0	0	0	0	$1,13.10^{-3}$	1,08	$3,74.10^{-3}$	0
Solanaceous vegetables	50,30	135,18	97,33 %	0	0	0	0	$5,03.10^{-3}$	4,79	$1,35\ 10^{-2}$	$4,2.10^{-4}$
Root vegetables + bulbs	41,04	100,37	98,79 %	0	0	0	0	$1,23.10^{-3}$	1,17	$3,01.10^{-3}$	$2,14.10^{-4}$
Dry legumes	28,25	83,08	84,22 %	0	0	0	0	$2,82.10^{-3}$	2,69	$8,31.10^{-3}$	0
Margarin	2,29	12,17	30,83 %	0	0	0	0	$6,87.10^{-5}$	0,07	$3,65.10^{-4}$	0
eggs	17,58	51,90	83,50 %	0	0	0	0	$5,28.10^{-4}$	0,50	$1,56.10^{-3}$	0
Canned olives + variants	1,83	11,37	22,09 %	0	0	0	0	$5,50.10^{-5}$	0,05	$3,41.10^{-4}$	0
Bread	246,19	495,55	94,90 %	0	0	0	0	$7,39.10^{-3}$	7,03	$1,49.10^{-2}$	$8,58.10^{-6}$
Pasta	194,86	431,49	95,39 %	0	0	0	0	$5,85.10^{-3}$	5,56	$1,29.10^{-2}$	$6,66.10^{-4}$
Fish	31,08	121,45	66,75 %	0	0	0	0	$9,32.10^{-4}$	0,89	$3,64.10^{-3}$	0

fatty fish	11,23	52,50	42,23 %	0	0	0	0	$1,12.10^{-3}$	1,07	$5,25.10^{-3}$	0
Non fatty fish	6,85	37,88	25,00 %	0	0	0	0	$6,85.10^{-4}$	0,65	$3,79.10^{-3}$	0
Potatoes	48,05	103,01	96,84 %	0	0	0	0	$3,36.10^{-3}$	3,20	$7,21.10^{-3}$	$6,79.10^{-4}$
Barley products	9,36	45,35	30,10 %	0	0	0	0	$2,81.10^{-4}$	0,27	$1,36.10^{-3}$	0
Rice	18,87	110,75	20,39 %	0	0	0	0	$5,66.10^{-4}$	0,54	$3,32.10^{-3}$	0
Sugar	32,23	72,83	97,33 %	0	0	0	0	$9,67\ 10^{-4}$	0,92	$2,18.10^{-3}$	$1,11.10^{-4}$
Tea	101,98	313,01	75,49 %	0	0	0	0	$3,06.10^{-4}$	2,91	$9,39.10^{-3}$	0
Sheep, goat and bovine meat	15,90	63,83	56,80 %	0	0	0	0	$4,77.10^{-4}$	0,45	$1,91.10^{-3}$	0
Poultry meat	20,24	63,96	66,50 %	0	0	0	0	$1,42.10^{-3}$	1,35	$4,48.10^{-3}$	0
Yogurt	15,85	68,52	49,03 %	0	0	0	0	$1,11.10^{-3}$	1,06	$4,8.10^{-3}$	0
Total	**2901,51**	**4178,76**		**$2,21.10^{-3}$**	**100**	**$5,37.10^{-3}$**	**$4,4.10^{-4}$**	**0,11**	**100**	**0.16**	**0.068**

Table 3: Estimated Cobalt intakes of the Tunisian population compared to body weight in mg/ d / eq ad (Lower Bound- Upper Bound)

FOOD SUBGROUP	**MEAN DAILY CONSUMPTION (g/j)**	**CONSUMPTION at P95 (g/j)**	**% consumers**	TMDI LB (mg/ Kg bw/d)	Intake / TMDI LB	Intake at P95 LB (mg/ Kg bw/d)	Apport au P5 LB (mg/ Kg bw/d)	MDI UB (mg/ Kg bw/d)	Intake / TMDI UB	Intake At P95 UB (mg/ Kg bw/d)	Intake At P5 UB ((mg/ Kg bw/d)
Citrus	25,65	108,25	42,96 %	0	0 %	0	0	$2,39.10^{-5}$	1,71	$1,01.10^{-4}$	0
other fruits	33,61	166,68	35,44 %	0	0 %	0	0	$1,34.10^{-5}$	0,96	$6,67.10^{-5}$	0
Soft drink	44,95	168,86	48,06 %	0	0 %	0	0	$1,80.10^{-5}$	1,28	$6,75.10^{-5}$	0
Coffzz	69,87	230,49	72,57 %	0	0 %	0	0	$2,79.10^{-5}$	1,99	$9,22.10^{-5}$	0
Industriel canned tomatoes	29,32	60,75	97,57 %	0	0 %	0	0	$1,17.10^{-5}$	0,84	$2,43.10^{-5}$	$3,65.10^{-6}$
Corète	3,19	34,54	8,01 %	0	0 %	0	0	$8,51.10^{-6}$	0,61	$9,21.10^{-5}$	0
Whole wheat couscoust	62,27	358,06	13,83 %	0	0 %	0	0	$2,49.10^{-5}$	1,78	$1,43.10^{-4}$	0
Wheat couscous and artisanal bread	315,13	1168,57	83,74 %	0	0 %	0	0	$1,26.10^{-4}$	9,00	$4,67.10^{-4}$	0
Dates	3,35	25,08	11,65 %	0	0 %	0	0	$1,34.10^{-6}$	0,10	1.10^{-5}	0
Water	1000,00	1000,00	100,00 %	0	0 %	0	0	4.10^{-4}	28,55 %	4.10^{-4}	4.10^{-4}
Spices	6,70	16,27	97,33 %	$2,95.10^{-5}$	100 %	$7,16.10^{-5}$	$5,90.10^{-6}$	$2,95.10^{-5}$	2,10 %	$7,16.10^{-5}$	$5,9.10^{-6}$
Sorghum	4,69	0	3,64 %	0	0 %	0	0	$6,26.10^{-6}$	0,45 %	0	0
Chicken liver	0,54	0	3,16 %	0	0 %	0	0	$2,17.10^{-7}$	0,02 %	0	0
Melted cheese	0,91	6,25	20,63 %	0	0 %	0	0	$8,49.10^{-7}$	0,06 %	$5,83.10^{-6}$	0
Cucurbit fruits	62,72	384,05	22,57 %	0	0 %	0	0	$5,85.10^{-5}$	4,18 %	$3,58.10^{-4}$	0
Stone and seeds fruits	35,52	165,13	43,69 %	0	0 %	0	0	$3,31.10^{-5}$	2,37 %	$1,54.10^{-4}$	0
Harissa	0,90	6,16	18,93 %	0	0 %	0	0	$8,38.10^{-7}$	0,06 %	$5,75.10^{-6}$	0
Vegetable oil	41,01	87,82	91,75 %	0	0 %	0	0	$1,64.10^{-5}$	1,17 %	$3,51.10^{5}$	0
Olive oil	16,11	65,63	68,20 %	0	0 %	0	0	$6,45.10^{-6}$	0,46 %	$2,63.10^{-5}$	0
Whole milk	52,99	272,86	35,44 %	0	0 %	0	0	$2,12.10^{-5}$	1,51 %	$1,09.10^{-4}$	0
Semi-skimmed milk	138,95	414,11	69,66 %	0	0 %	0	0	$5,56.10^{-5}$	3,97 %	$1,66.10^{-4}$	0
Leafy vegetables	21,38	71,41	75,49 %	0	0 %	0	0	$8,55.10^{-6}$	0,61 %	$2,86.10^{-5}$	0

Cucurbitaceae fruit vegetables + brassicas + stems + Green legumes	37,78	124,72	80,58 %	0	0 %	0	0	$1,51.10^{-5}$	1,08	$4,99.10^{-5}$	0
Solanaceous vegetables	50,30	135,18	97,33 %	0	0 %	0	0	$6,71.10^{-5}$	4,79	$1,80.10^{-4}$	$5,60.10^{-6}$
Root vegetables + bulbs	41,04	100,37	98,79 %	0	0 %	0	0	$1,64.10^{-5}$	1,17	$4,01.10^{-5}$	$2,86.10^{-6}$
Dry legumes	28,25	83,08	84,22 %	0	0 %	0	0	$3,77.10^{-5}$	2,69	$1,11\ 10^{-4}$	0
Margarin	2,29	12,17	30,83 %	0	0 %	0	0	$9,16.10^{-7}$	0,07	$4,87\ 10^{-6}$	0
eggs	17,58	51,90	83,50 %	0	0 %	0	0	$7,03.10^{-6}$	0,50	$2,08.10^{-5}$	0
Canned olives + variants	1,83	11,37	22,09 %	0	0 %	0	0	$7,34.10^{-7}$	0,05	$4,55.10^{-6}$	0
Bread	246,19	495,55	94,90 %	0	0 %	0	0	$9,85.10^{-5}$	7,03	$1,98.10^{-4}$	$1,144.10^{-6}$
Pasta	194,86	431,49	95,39 %	0	0 %	0	0	$7,79.10^{-5}$	5,56	$1,73.10^{-4}$	0,000008886
Fish	31,08	121,45	66,75 %	0	0 %	0	0	$1,24.10^{-5}$	0,89	$4,86.10^{-5}$	0
fatty fish	11,23	52,50	42,23 %	0	0 %	0	0	$1,50.10^{-5}$	1,07	7.10^{-5}	0
Non fatty fish	6,85	37,88	25,00 %	0	0 %	0	0	$9,14.10^{-6}$	0,65	$5,05.10^{-5}$	0
Potatoes	48,05	103,01	96,84 %	0	0 %	0	0	$4,48.10^{-5}$	3,20	$9,61.10^{-5}$	$9,05.10^{-6}$
Barley products	9,36	45,35	30,10 %	0	0 %	0	0	$3,75\ 10^{-6}$	0,27	$1,81.10^{-5}$	0
Rice	18,87	110,75	20,39 %	0	0 %	0	0	$7,55\ 10^{-6}$	0,54	$4,43.10^{-5}$	0
Sugar	32,23	72,83	97,33 %	0	0 %	0	0	$1,29.10^{-5}$	0,92	$2,91.10^{-5}$	$1,47.10^{-6}$
Tea	101,98	313,01	75,49 %	0	0 %	0	0	$4,08.10^{-5}$	2,91	$1,25\ 10^{-4}$	0
Sheep, goat and bovine meat	15,90	63,83	56,80 %	0	0 %	0	0	$6,36.10^{-6}$	0,45	$2,55.10^{-5}$	0
Poultry meat	20,24	63,96	66,50 %	0	0 %	0	0	$1,89.10^{-5}$	1,35	$5,97.10^{-5}$	0
Yogurt	15,85	68,52	49,03 %	0	0 %	0	0	$1,48.10^{-5}$	1,06	$6,4.10^{-5}$	0
Total	2901,51	4178,76		$2,95.10^{-5}$	100 %	$7,16.10^{-5}$	$5,9.10^{-6}$	$1,4.10^{-3}$	1	$2,15.10^{-3}$	$9,12.10^{-4}$

The main contributors to total mean daily intake in cobalt are tap water (28.55 %), wheat couscous and home-made bread (9 %) and bread (7.03 %).

Risk Characterization

The estimated mean daily intake in cobalt for the Tunisian adult population varies from 92 % at LB to 4378 % at UB of the Minimum nutritional value recommended by WHO. The daily cobalt Intake at the 5th percentile represent 18 % at LB and 2849 % at UB of the Minimum nutritional recommended by WHO.

The mean daily intake in cobalt compared to body weight for the Tunisian adult population represents 1.84 % at LB and 87.57 % at UB percentage of the lower bound of the safety limit (LS) recommended by ANSES. The daily intake of cobalt at the 95th percentile represents 4.47 % at LB and 134.19 % at UB percentage of the lower bound of the LS

The percentage of individuals who have a maximum daily intake in cobalt relative to the body weight more than the lower bound of the LS varies from 0 % at LB to 28.40 % at UB.

Conclusion

In the present study cobalt was quantified in a single core food group (spices) while in the French TDS (ANSES, 2011) and in the Swedish TDS [15], cobalt was quantified in all most foods analyzed. This difference of finding was because of the differences in analytical limits adopted in the search and quantification of cobalt for example in the French TDS (ANSES, 2011) the LOQ adopted was 0.0002 mg / kg which is a hundred times lower than that of the present study.

In the present study, spices represent the only source food identified of cobalt that stands out from other TDSs, which report the highest levels in other food categories such as chocolate and butter such as in the French TDS [4].

The estimated mean daily intake in cobalt for the Tunisian adult population ranged from 2.21 10-3 to 0.11 mg / d / EqAd wich is below that estimated in the US TDS [16] (14 µg / d) in the lower bound scenario but in the upper Bound scenarios the estimated mean daily intake in cobalt for the Tunisian adult population generally covers the Minimum nutritional value recommended by the WHO (92 % to 4378 % of this BNR) [17-22].

Against this, the Intake on the 5th percentile does not cover this BNR in the LB (18.43 %), thus not allowing us to eliminate the possibility of inadequate intake for at-risk populations or populations with inadequate diets.

The mean daily intake estimated in cobalt compared to body weight for the Tunisian adult population is significantly lower than that of the French TDS (ANSES, 2011) in the minimalist scenario (LB).

The overestimation of the maximalist scenario (UB) increases the estimated intake in cobalt. Therefore, the maximalist scenario increases the theoretical estimated intake in cobalt compared to the body weight for the Tunisian adult population, bringing the maximum daily intake almost to 88 % of the adopted LS and beyond this LS (134 %) in the 95th percentile. In view of the particularly high LOQ adopted of the present study which significantly increases the intake the risk of excess cobalt could be ruled out with certainty.

These conclusions, however, should be confirmed by another study with analytical limits lower that detect the presence of cobalt in food more precisely and permit a more realistic assessment of cobalt intake.

References

1. Gál, J, Hursthouse A, Tatner P, Stewart F, Welton R (2008) Cobalt and secondary poisoning in the terrestrial food chain: Data review and research gaps to support risk assessment. Environ Int 34: 821-838.

2. INERIS (2002) Meta Mercure. Final report. Fabrice Marlière - Nathalie Bocquet - Maxime Rouez. Central Air Quality Surveillance Laboratory. INERIS.

3. INVS (2011) Exposure of the French population to chemicals in the environment. Vol 1. General presentation of the study, Metaxes and Metalloids. Sanitary Ware Institute.

4. ANSES (2011) French Total Nutrition Study 2, Tome 2, Inorganic Contaminants; minéraux; persistent organic pollutants; mycotoxins; phyto-estrogens. Notice of the Anses. Expertise report. National Food, Environment and Labor Health Safety Agency.

5. WHO (1973) Oligo-elements in human nutrition: Report of a Committee of Experts of the OMS. Technical Report Series Number 532. World Health Organization (WHO).

6. EFSA (2009) Scientific Opinion on the use of cobalt compounds as additives in animal nutrition. European Food Safety Authority (EFSA). 7: 1383.

7. WHO (2002) GEMS/Food Total Diet Studies, Report of the 2nd International Workshop on Total Diet Studies Brisbane, Australia, February 2002.

8. EFSA (2011) JOINT GUIDANCE OF EFSA, FAO AND WHO Towards a harmonised Total Diet Study approach: a guidance document1 European Food Safety Authority (EFSA).

9. Basdevant A, Laville M, Lerebours E (2001) Adult Clinical Nutrition Treaty. medical science.

10. NINFT (2007) Composition table of Tunisian foods. National Institute of Nutrition and Food Technology. Edition 2007.

11. FAO/OMS (2004). Vitamin and mineral requirement in human nutrition. Second edition. World Health Organization and Food and Agriculture Organization of the United Nations.

12. NHMRC (2006) Nutrient Reference Values for Australia and New Zealand Including Recommended Dietary Intakes. Department of Health and Ageing. National Health and Medical Research Council. Australia and New Zealand. 2006.

13. EFSA (2006) Tolerable upper intake levels for vitamins and minerals. Scientific Committee on Food Scientific Panel on Dietetic Products, Nutrition and Allergies. European Food Safety Authority (EFSA).

14. Iyengara GV, Wolfe WR, Tanner JT, Morris ER (2000) Content of minor and trace elements, and organic nutrients in representative mixed total diet composites from the USA. The Science of the Total Environnent 256: 215-26.

15. Becker W, Jorhem L, Sundstrom B, Petersson Grawe K (2011) Contents of mineral elements in Swedish market basket diet 9.

16. ANCSEP (2006) Report of the study on contamination of the food chain by pesticide residues. National Agency for Sanitary and Environmental Product Control (ANCSEP) 46.

17. EFSA (2011) Joint Guidance of EFSA, FAO AND WHO Towards a harmonised Total Diet Study approach: a guidance document1 European Food Safety Authority (EFSA).

18. FAO/WHO/UNU (2004) Human energy requirements Report of a Joint FAO/WHO/UNU Expert Consultation Rome. United Nations University World Health Organization Food and Agriculture Organization of the United Nations Rome.

18. NIS (2010) National Survey of Household Budget, Consumption and Standard of Living by the National Institute of Statistics (NIS).

19. OMS/FAO (2004) Vitamin and mineral requirements in human nutrition: report of a joint FAO/WHO expert consultation. World Health Organization and Food and Agriculture Organization of the United Nations.

20. Santé Canada (2011) Preliminary evaluation for the Challenge concerning the cobalt (Elemental Cobalt) Registration number of the Chemical Abstracts Service 7440-48-4 dichlorure of cobalt Registration number of the Chemical Abstracts Service 7646-79-9 Cobalt sulphate Registration number of the Chemical Abstracts Service 10124 -43-3 sulfuric acid, cobalt cell Chemical Abstracts Service Register Number 10393: 49-4.

21. Health Canada (2017).

22. INRS (2000) Cobalt et composés minéraux. Fiche toxicologique N°128.