Endocrinol Diabetes Nutr. 2020;67(6):383–393

Endocrinología, Diabetes y Nutrición

www.elsevier.es/endo

ORIGINAL ARTICLE

Iodine contents in conventional ultra-high temperature (UHT) processed cow milk: Changes over the year and regional differences. Implications for epidemiological studies on iodine nutritional status☆

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Received 8 May 2019; accepted 20 August 2019
Available online 29 August 2020

KEYWORDS
Iodine;
Conventional cow milk;
Ultra-High temperature (UHT) processed milk);
Iodine concentration in milk

Abstract
Background and objectives: Ultra-high temperature (UHT) processed cow milk is the milk most commonly consumed in Southwest Europe. The study objectives were: 1) to describe the pattern followed by iodine concentration (IC) in conventional UHT milk over the year, and 2) to find out any differences in IC in this type of milk depending on its geographical origin.
Material and methods: Bricks of conventional UHT cow milk of commercial brands available in food stores in Vitoria-Gasteiz (Araba/Álava), Basque Country (Spain) were bought for 12 consecutive months, and their ICs were measured using high performance liquid chromatography (HPLC).
Results: Median (P_{25}-P_{75}) IC in UHT milk (n = 489) was 190 (159–235) μg/L. IC in milk showed great changes over the year, reaching peak values between January and May (241 [201–272] μg/L), and minimal levels between July and November (162 [134–185] μg/L) (P < 0.0001). The IC of milk packed in Germany was significantly lower than that of milks packed in Spain and France, 119 (106–156) μg/L versus 189 (159–229) μg/L and 205 (176–243) μg/L respectively (p < 0.0001).

☆ Please cite this article as: Arrizabalaga JJ, Jalón M, Espada M, Cañas M, Latorre PM. Contenido de yodo de la leche convencional ultrapasteurizada (UHT) de vaca: Variaciones a lo largo del año y diferencias regionales. Implicaciones para los estudios epidemiológicos sobre el estado de nutrición de yodo. Endocrinol Diabetes Nutr. 2020;67:383–393.

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https://doi.org/10.1016/j.endien.2020.08.003

Conclusions: Conventional UHT cow milk is a very important nutritional source of iodine, but its IC is highly variable. Knowledge of the pattern followed by IC in milk over the year is of great interest for planning epidemiological studies on iodine nutritional status in schoolchildren and for interpretation of their results.

PALABRAS CLAVE
Yodo;
Leche convencional de vaca;
Leche ultrapasteurizada (leche UHT);
Concentración de yodo en la leche

Contenido de yodo de la leche convencional ultrapasteurizada (UHT) de vaca: Variaciones a lo largo del año y diferencias regionales. Implicaciones para los estudios epidemiológicos sobre el estado de nutrición de yodo

Resumen
Antecedentes y objetivos: La leche ultrapasteurizada (leche UHT) de vaca es la más consumida en el suroeste europeo. Los objetivos del estudio fueron: 1) describir el patrón que sigue la concentración de yodo (CY) en la leche convencional UHT de vaca a lo largo del año y 2) averiguar si existen diferencias en la CY en este tipo de leche según su procedencia geográfica.
Material y métodos: Se compraron *briks* de leche convencional UHT de vaca de marcas comerciales disponibles en los grandes establecimientos de alimentación de Vitoria-Gasteiz (Araba/Álava) durante 12 meses consecutivos y se determinó su CY mediante cromatografía líquida de alta resolución (HPLC).
Resultados: La mediana (P_{25}-P_{75}) de la CY en la leche (n = 489) fue de 190 (159-235) μg/L. La CY experimentó grandes variaciones a lo largo del año, alcanzando valores máximos entre enero y mayo, 241 (201-272) μg/L, y mínimos entre julio y noviembre, 162 (134-185) μg/L (p < 0,0001). La CY de la leche envasada en Alemania fue significativamente menor que la de las leches envasadas en España y en Francia, 119 (106-156) μg/L frente a 189 (159-229) μg/L y 205 (176-243) μg/L respectivamente (p < 0,0001).
Conclusiones: La leche convencional UHT de vaca es una fuente alimentaria muy importante de yodo, pero su CY es altamente variable. Conocer el patrón que sigue la CY en la leche a lo largo del año tiene mucho interés para la planificación de los estudios epidemiológicos sobre el estado de nutrición de yodo en escolares y para la interpretación de los resultados.

Introduction

Iodine is an essential nutrient for animal species[1] and an indispensable substrate for thyroid hormone synthesis, through which it exerts its most important biological effects.[1,2] Recent research has provided very valuable information on the role of iodine as an antioxidant in redox homeostasis and as an antibacterial, antiviral and antifungal agent.[2]

Iodine is an ultra-trace element in the terrestrial crust layer.[3,4] Most of this oligoelement is found in oceanic sediments (68%) and in continental sedimentary rocks (28%), while igneous and metamorphic rocks account for only 2.7% of the total.[4] Although iodine in the water of the seas and oceans accounts for only 0.8% of the total iodine in the terrestrial crust layer,[4] the iodine concentrations (ICs) in marine waters are relatively high, averaging approximately 60 μg/l.[3]

Due to the distribution of rocks and soil derived from them in the continental crust layer and the geochemistry of iodine and its cycle in the biosphere, animal species in extensive geographical settings of the planet were exposed until well into the second half of the 20th century to the harmful effects of iodine deficiency (ID) upon their growth and development, and their health. The disorders caused by ID have represented a huge public health problem worldwide, and in areas with extremely iodine-poor waters and soil, ID has been a very important obstacle to economic and social development.[5–7] Iodine deficiency produces a broad range of adverse effects upon the health of farm animals, and reduces poultry and livestock productivity. It causes endemic goiter and hypothyroidism in animals, reduces the reproductive capacity of poultry and livestock, decreases survival among their offspring, and results in a diminished production of eggs, milk, meat and wool.[8,9] However, the fortification of salt with iodine and the diffusion of the use of iodized salt, along with the supplementation of livestock feed with iodine and human and animal exposure to various adventitious sources of iodine has led to a radical change in the situation.

Since most surface waters and soils are poor in soluble iodine, and the amounts of the trace element transferred to terrestrial plants are very low, livestock feed needs to be supplemented with iodine in order to prevent ID.[9–12] Beyond protecting the health and improving the productivity of poultry and livestock, the use of appropriate amounts of supplementary iodine also allows new iodine-rich food sources to be made available to consumers.[10,11,13] As a result of iodine supplementation, the concentration of this micronutrient has increased in foods of animal origin, though the increase is much greater in eggs and milk than in meat from poultry and livestock, since iodine is concentrated by active transport in egg yolk and milk.[9,14,15] The milk of cows fed iodine supplements, and the dairy products prepared from it, are widely and frequently consumed, and thus have become important food sources of the micronutrient in many industrialized countries.[16,17]

However, the iodine concentration (IC) in cow's milk supplemented with the micronutrient does not remain constant throughout the year, but experiences significant variations, with higher ICs during the colder months and lower concentrations during the warmer months.[12,13,18–36] This phenomenon has been attributed mainly to variations in iodine intake by cows during the year, due to their greater dependence on compound feeds (supplemented with various nutrients, including iodine) during the cold months to cover their energy and nutrient requirements, resulting from a lesser availability of pasture and forage compared with in the warmer months.[10,12,18,21,22,26]

Ultra-high temperature (UHT) processed milk is obtained by applying a continuous heat flow at very high temperatures for very short periods of time in order to eliminate viable microorganisms or spores that may proliferate when the treated product is kept at room temperature in a sealed aseptic container. It can be stored at room temperature for several months when kept in the unopened container, and is the most widely sold milk in European countries such as Belgium, Spain, France and Portugal, where it accounts for over 90% of the milk consumed.[16]

In a scenario where the native iodine content of most foods is low, studying and monitoring IC in cow's milk represents basic knowledge in the fields of nutrition and public health. Given the lack of published studies on the iodine content in UHT cow's milk in Spain, we considered it appropriate to conduct a study with the following objectives: 1) to know the IC in the UHT cow's milk brands (corresponding to both conventional and organic production) available on the market; 2) to describe the pattern of IC in conventional UHT cow's milk during the 12 months of the year; and 3) to determine whether there are differences in IC in conventional UHT milk according to the geographical zone where it is packaged. The methodological aspects and results of the study on IC in UHT cow's milk formulas were published in 2015.[16] The present study describes and discusses the results of the other two research objectives mentioned above.

Material and methods

A longitudinal descriptive study was made of the IC in milk samples obtained from conventional UHT cow's milk containers purchased monthly from January to December 2008 in the large food distribution chains of Vitoria-Gasteiz (Araba/Álava)(the Basque Country, Spain).

Material

The containers with the commercial brands of conventional production UHT cow's milk were selected according to the following inclusion and exclusion criteria.

Inclusion criteria: 1) only brands packaged in tetra briks; 2) no more than two brands per geographic delimitation (province or historical territory of an Autonomous Community [in Spain], department of a region [in France] or administrative district of a federal state [in Germany]); and 3) the three varieties of milk based on their fat content, i.e., whole, semi-skimmed and skimmed milk, corresponding to each brand.

Exclusion criteria: milk subject to significant changes in composition (lactose-free or low-lactose milk and milk enriched with minerals and water-soluble vitamins, such as group B vitamins, iron or folic acid).

Based on the application of the above criteria, we selected 14 brands of conventional UHT cow's milk, and in a second phase, we arranged for the monthly collection of cartons of each variety of the selected brands of milk, making a total of 41 monthly containers (14 whole milk, 14 semi-skimmed milk and 13 skimmed milk [since no skimmed variety was distributed corresponding to one of the selected brands]).

The purchase of the milk was made in the third or fourth week of each month, and we recorded the code corresponding to the packaging plant of each of them, along with the preferred consumption date. The milk samples were stored frozen at −20 °C in polypropylene containers.

Methods

Iodine content was measured in the milk samples at the Regulatory Public Health Laboratory of the Department of Health of the Basque Government in Bilbao using reverse-phase high performance liquid chromatography (HPLC) with ion pair electrochemical detection with a silver electrode, according to official method 992.22 of the Association of Official Analytical Chemists International (AOAC International).[37] This method is applicable for the determination of iodides in liquid milk and in powdered milk.[37] Measurement range: from 20 μg/l to 200 μg/l. Limit of detection: 5 μg/l. Within- and between-series precision: 4.5% and 7.9%, respectively.

Statistical analysis

Since the IC values in milk did not exhibit a normal distribution, their measures of central tendency and dispersion were expressed as the median and interquartile range (IQR) (percentiles 25 and 75). After considering the sample sizes and checking normality and homoscedasticity conditions, nonparametric tests (the Mann-Whitney *U* test for the comparison of two medians and the Kruskal-Wallis test for the comparison of more than two medians) were used for analyzing differences in IC between the different comparator groups.

The data were processed and analyzed using MS Excel 2013 (Microsoft Corporation, Redmond, Washington, USA) and the SPSS version 25.0 statistical package for MS Windows (IBM Corp., Armonk, New York, USA). Statistical significance was considered for $p < 0.05$.

Results

Number of samples and preferred consumption date

A total of 489 samples of conventional UHT cow's milk were obtained from the 492 programmed samples. Three of the programmed samples could not be obtained due to a lack of stock of the required varieties at the time of collection. Table 1 shows the sales names, type of brand and location of the packaging plants of the studied milk samples. The mean available time from the date of purchase to the preferred consumption date ranged from 14 to 146 days, with a mean of 75.7 (22.8) days.

Changes in the iodine (iodide) content of conventional UHT cow's milk throughout the year

The median IC was 190 μg/l (159–235). There were no significant differences in IC among whole milk, semi-skimmed milk and skimmed milk ($p = 0.219$).

Fig. 1 shows that the IC in conventional UHT cow's milk was not constant throughout the year but showed considerable variations, reaching maximum values (over 200 μg/l) from January to May, minimum values (below 175 μg/l) from July to November, and intermediate values (between 175 μg/l and 200 μg/l) in June and December. The median IC in the samples for the January-May period ($n = 205$) was 241 μg/l (201—272), which was almost 50% higher than in the samples of the July-November period ($n = 203$), during which the median decreased to 162 μg/l (134185) ($p < 0.0001$). The median IC values in June ($n = 40$) and December ($n = 41$) were 192 μg/l (173–217) and 181 μg/l (151—202), respectively.

Differences in the iodine (iodide) content of conventional UHT cow's milk according to the geographical location of the packaging plants

As shown in Table 1, the location of the packaging plants of the selected conventional UHT cow's milk brands covered 12 zones located in three countries of the European Union: Germany (an administrative district of a federal state [Rhineland-Palatinate]), Spain (7 Autonomous Communities [Asturias, Cantabria, Castilla y León, Catalonia, Galicia, Madrid and the Basque Country] and France (4 regions [Aquitaine, Brittany, Midi-Pyrénées and Picardy]). A fourth country, Portugal, contributing only one of the milk samples (0.2%), is not counted. Excluding the sample from Portugal, 4.7% of the milk samples were packaged during the year in Germany, 73.8% in Spain, and 9.4% in France. The remaining 12.1% were samples corresponding to two white-label brands that were packaged some months of the year in plants located in Spain and the other months in plants located in France.

Iodine concentration proved significantly different depending on the country of the European Union where the milk packaging took place (Table 2). The median IC of the milk packaged in Germany, 119 μg/l, was much lower than that of the milk packaged in Spain and France, which reached 189 μg/l and 205 μg/l, respectively ($p < 0.0001$). The median ICs in whole milk ($n = 12$) and semi-skimmed milk ($n = 11$) packaged in Germany were 117 μg/l (101–156) and 125 μg/l (108–149), respectively. The median ICs in whole milk ($n = 120$), semi-skimmed milk ($n = 120$) and skimmed milk ($n = 120$) packaged in Spain were 187 μg/l (158–224), 189 μg/l (156–228) and 189 μg/l (163–232), respectively. Lastly, the median ICs in whole milk ($n = 12$), semi-skimmed milk ($n = 11$) and skimmed milk ($n = 23$) packaged in France were 201 μg/l (165–231), 189 μg/l (174–243) and 215 μg/l (188–251), respectively.

Iodine concentration also varied among the Spanish Autonomous Communities where milk packaging took place (Table 3). Specifically, the IC of milk packed in Galicia was significantly higher than that of milk packed in Asturias and the Basque Country. However, the IC in milk from Galicia proved very different depending on the province where it was packaged. In effect, the median IC of milk packaged in Lugo was higher than that of milk packaged in Coruña: 218 μg/l versus 169 μg/l ($p = 0.005$). In turn, the median IC of milk packaged in Coruña was comparable to that of milk packaged in Asturias and the Basque Country ($p = 0.539$).

Discussion

Iodine concentration in cow's milk depends on several factors, including the amount of iodine and iodine antagonists (derived from glucosinolates) present in feed components, the milk production method used (conventional or organic), the time of year (cold months or warm and hot months), and the use of iodinated antiseptics (iodophors) for udder hygiene and for the disinfection of milking machines and dairy industry equipment. The main conditioning factor, however, is the use of iodinated feed and supplements.[9–13,38] As regards the possible effect of ultra-pasteurization upon IC in milk, the iodine content was recently studied in 8 milk batches before and after UHT processing. This procedure was seen to induce no changes in milk IC.[35]

Mean iodine concentrations in milk were lower than 55 μg/l in most studies conducted in several European regions before the introduction of iodine prophylactic measures in livestock, with a predominance of levels between 10—40 μg/l.[11,32,39,40] Conventional cow's milk is produced under intensive livestock raising conditions, where nutritional additives (including iodine) are commonly used to preserve animal health. A broad diversity of agricultural and livestock practices, especially those related to the amounts of iodine used for feed supplementation and the utilization of iodophors, has led to significant regional differences in the IC in milk. The IC in conventional milk currently ranges from 100—300 μg/l[17] in most geographic areas in Europe in which studies have been made.

Official method 992.22 of the AOAC International allows for the recovery of 87% of the total iodine content in liquid milk.[37] Taking into consideration that the median iodide concentration of the selected conventional UHT milk brands was 190 μg/l, the total iodine content of these brands is approximately 218 μg/l. A glass of conventional UHT milk (200—250 ml) packaged in Spain or France contains about 50 μg of iodine.

In a study conducted in the same year as our own, Soriguer et al. analyzed IC in 362 samples of cow's milk

Table 1 Sales specification, type of brand and location of the conventional UHT cow's milk packaging plants.

Sales specification	Type of brand	Location of the packaging plants[a]	
		Region (zone)	Country
Aloña whole	White (Eroski)	Basque Country (Gipuzkoa)	Spain
Aloña semi-skimmed	White (Eroski)	Basque Country (Gipuzkoa)	Spain
Aloña skimmed	White (Eroski)	Basque Country (Gipuzkoa)	Spain
Bomilk whole	White (Eroski)	Galicia (Coruña, Lugo) and Aquitaine (Pyrénées Atlantiques)	Spain and France
Bomilk semi-skimmed	White (Eroski)	Galicia (Lugo) and Aquitaine (Pyrénées Atlantiques)	Spain and France
Bomilk skimmed	White (Eroski)	Galicia (Lugo) and Aquitaine (Pyrénées Atlantiques)	Spain and France
Carrefour whole	White (Carrefour)	Galicia (Lugo)	Spain
Carrefour semi-skimmed	White (Carrefour)	Galicia (Lugo)	Spain
Carrefour skimmed	White (Carrefour)	Galicia (Lugo)	Spain
Celta whole	Manufacturer	Castilla-León (Ávila) and Galicia (Coruña, Lugo)	Spain
Celta semi-skimmed	Manufacturer	Castilla-León (Ávila) and Galicia (Coruña, Lugo)	Spain
Celta skimmed	Manufacturer	Castilla-León (Ávila) and Galicia (Coruña, Lugo)	Spain
Central Lechera Asturiana whole	Manufacturer	Asturias, Catalonia (Girona) and Galicia (Lugo)	Spain
Central Lechera Asturiana semi-skimmed	Manufacturer	Asturias, Catalonia (Girona) and Galicia (Lugo)	Spain
Central Lechera Asturiana skimmed	Manufacturer	Asturias, Catalonia (Girona) and Galicia (Lugo)	Spain
Délisse whole	White (E. Leclerc)	Aquitaine (Pyrénées Atlantiques), Brittany (Ille and Vilaine) and Midi-Pyrénées (Tarn and Garona)	France
Délisse semi-skimmed	White (E. Leclerc)	Aquitaine (Pyrénées Atlantiques), Brittany (Ille and Vilaine) and Midi-Pyrénées (Tarn and Garona) and Picardy (Oise)	France
Délisse skimmed	White (E. Leclerc)	Aquitaine (Pyrénées Atlantiques), Brittany (Ille and Vilaine) and Midi-Pyrénées (Tarn and Garona)	France
Dia whole	White (Dia)	Galicia (Lugo) and Aquitaine (Pyrénées Atlantiques)	Spain and France
Dia semi-skimmed	White (Dia)	Castilla-León (Valladolid), Galicia (Coruña, Lugo), Madrid and Aquitaine (Pyrénées Atlantiques)	Spain and France
Dia skimmed	White (Dia)	Aquitaine (Pyrénées Atlantiques)	France
El Corte Inglés whole	White (Corte Inglés)	Asturias	Spain
El Corte Inglés semi-skimmed	White (Corte Inglés)	Asturias	Spain
El Corte Inglés skimmed	White (Corte Inglés)	Asturias	Spain
Eroski whole	White (Eroski)	Cantabria and Galicia (Coruña)	Spain
Eroski semi-skimmed	White (Eroski)	Cantabria and Galicia (Coruña)	Spain
Eroski skimmed	White (Eroski)	Cantabria and Galicia (Coruña)	Spain
Kaiku whole	Manufacturer	Basque Country (Gipuzkoa)	Spain
Kaiku semi-skimmed	Manufacturer	Basque Country (Gipuzkoa)	Spain
Kaiku skimmed	Manufacturer	Basque Country (Gipuzkoa)	Spain

Table 1 (*Continued*)

Sales specification	Type of brand	Location of the packaging plants[a]	
		Region (zone)	Country
Milbona whole	White (Lidl)	Rhineland-Palatinate (Eifelkreis Bitburg-Prüm)	Germany
Milbona semi-skimmed	White (Lidl)	Rhineland-Palatinate (Eifelkreis Bitburg-Prüm)	Germany
Pascual whole	Manufacturer	Castilla-León (Burgos), Catalonia (Barcelona) and Galicia (Lugo)	Spain
Pascual semi-skimmed	Manufacturer	Castilla-León (Burgos), Catalonia (Barcelona) and Galicia (Lugo)	Spain
Pascual skimmed	Manufacturer	Catalonia (Barcelona) and Galicia (Lugo)	Spain
Président whole	Manufacturer	Galicia (Lugo)	Spain
Président semi-skimmed	Manufacturer	Galicia (Lugo)	Spain
Président skimmed	Manufacturer	Galicia (Lugo)	Spain
Ram whole	Manufacturer	Galicia (Coruña)	Spain
Ram semi-skimmed	Manufacturer	Galicia (Coruña)	Spain
Ram skimmed	Manufacturer	Galicia (Coruña)	Spain

UHT milk: ultra-high temperature processed milk.

[a] The packaging of each variety of milk (whole, semi-skimmed or skimmed) took place in the course of the year in plants located in a single European autonomous community or region (in Asturias, Galicia, the Basque Country or Eifelkreis Bitburg-Prüm), or in plants located in two or more European autonomous communities or regions (in Asturias, Cantabria, Castilla y León, Catalonia, Galicia, Madrid, Aquitaine, Brittany, Midi-Pyrénées or Picardy, the specific location varying over the year).

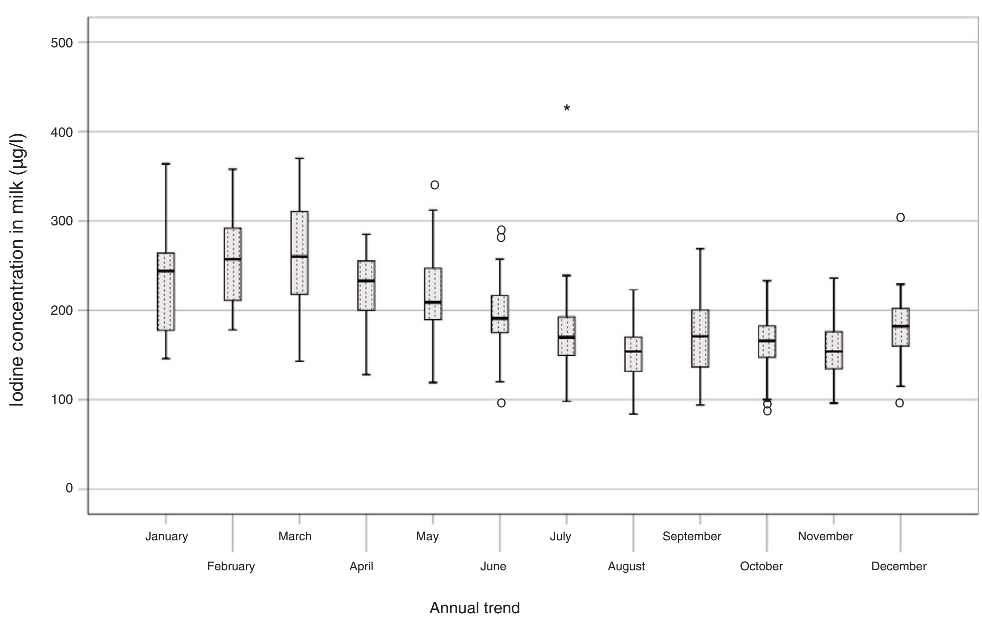

Fig. 1 Variations in iodine (iodide) concentration in conventional UHT cow's milk throughout the year.

corresponding to 47 brand names purchased in Andalusia, Asturias, Catalonia, Galicia, Valencia and the Basque Country, and recorded a mean IC of 259 (± 58) µg/l.[30] In addition to differences due to the use of different brands of milk and the application of a different laboratory technique for sample analysis (a modified method of Benotti and Benotti), it is likely that a significant part of the observed differences in IC between the aforementioned study and our own is attributable to the different protocols used to collect the milk samples (number of samples at each time of year). In this regard, Soriguer et al. collected milk samples 7 times during the year, and 80.1% of the samples corresponded to the period between February and June, during which IC was highest in their study. In our case, the selected conventional

Table 2 Iodine concentration in conventional UHT cow's milk according to the country of the European Union where packaging was carried out.

Location of the packaging plants[a]		Iodine (iodide) concentration (μg/l)			
Country	Region	n	P_{25}	P_{50}	P_{75}
Germany	Rhineland-Palatinate	23	106	119*	156
Spain	Asturias, Cantabria, Castilla y León, Catalonia, Galicia and the Basque Country	360	159	189*	229
France	Aquitaine, Brittany, Midi-Pyrénées and Picardy	46	176	205*	243
Spain and France	Galicia, Castilla-León, Madrid and Aquitaine	59	184	210*	276

UHT milk: ultra-high temperature processed milk.
[a] All packaging of each variety of milk was carried out in the course of the year in plants located in a single country (Germany, Spain or France) or in plants located in two countries (Spain and France) (in some months packaging took place in Spain [Galicia, Castilla y León or Madrid] and in other months in France [Aquitaine]).
* $p < 0.0001$.

Table 3 Iodine concentration in conventional UHT cow's milk according to the Spanish autonomous communities (ACs) where packaging was carried out.

Location of the packaging plants[a]	Iodine (iodide) concentration (μg/l)			
	n	P_{25}	P_{50}	P_{75}
Asturias	36	158	180 †	204
Galicia	108	171	214.5 †	256
Basque Country	72	153	169.5 †	195
In 2 or more ACs (Asturias, Cantabria, Castilla y León, Catalonia, Galicia)	144	160	191 †	234

UHT milk: ultra-high temperature processed milk.
*$p < 0.0001$.
[a] All packaging of a given variety of milk (whole, semi-skimmed or skimmed) took place in the course of the year in plants located in a single autonomous community (in Asturias, Galicia or the Basque Country) or in plants located in two or more autonomous communities (in Asturias, Cantabria, Castilla y León, Catalonia and Galicia, the specific location varying over the year).

UHT milk containers were purchased every month of the year in order to determine the mean weighted iodine content throughout the year.

As part of a study on iodine in the total diet in Catalonia conducted by the *Agència Catalana de Seguretat Alimentària* (Catalan Food Safety Agency [ACSA]),[41] 144 cartons of conventional UHT cow's milk were purchased in July 2015 for analysis of their iodine content (3 individual cartons of each of the milk varieties according to fat content [whole, semi-skimmed and skimmed milk], corresponding to 16 brands). In its report, the ACSA did not specify the geographical location of the plants where the milk brands selected for the study were packaged. Inductively coupled plasma-mass spectrometry (ICP-MS) was used to analyze IC. The median IC value in July was 157 μg/l (137–170). In Catalonia, no information is available on the IC values throughout the year in conventional UHT milk.

There is ample scientific documentation on the changes experienced by IC during the cold and warm months in the milk of cows supplemented with iodine.[12,13,18–36] However, very few publications offer data on the IC in cow's milk over a period of at least 12 consecutive months,[18,20,23,29,35,36] and none of them provide information on the IC in UHT milk ready for sale in food stores. These are studies in which milk was collected from dairy farms or cooperatives (raw milk) and from dairy businesses (pasteurized milk and UHT milk) very shortly after being produced by the cows.[18,20,23,29,35,36] The ICs were higher from November to April[18,20,23] or May,[35,36] and lower from May[18,20,23] or June[35,36] to October. These differences in IC were probably due to two factors: variations in the start and end of the cow stabling and feeding periods of cows in in-door and open spaces, which depend on the climatic conditions of each geographic area[21], and the calving patterns, which determine at what time of year the nutritional formulations characteristic of pregnancy and lactation are applied to the cows.[12,36] For example, more calves are born in Switzerland from November to January,[12] but most calves in Ireland and the United Kingdom are born from February to April.[36]

There may be a long time delay between the date of UHT heat treatment of milk and the date of purchase on the retail market, since this is a product with a long shelf life (several months). Conventional UHT milk purchased from the Vitoria-Gasteiz retail market also exhibited two different periods regarding IC in the course of the year, though the start and end of the periods with the highest ICs, and the start and end of the periods with the lowest ICs occurred between one and two months later than those reported in the literature for freshly produced conventional cow's milk.

The milk with the lowest IC was packaged in the Eifelkreis Bitburg-Prüm district of the federal state of Rhineland-Palatinate, in Germany. The IC of the milk from this region, 119 μg/l, was quite similar to that found in studies conducted with different sampling systems and analytical methods in other federal states in Germany.[23,31,42] During one year, Preiss et al. collected a total of 370 samples of milk produced in Bavaria.[23] There is no information as to whether this was conventional or organic milk. The mean iodine content was found to be 115 μg/l (test method: gas chromatography). Johner et al. in turn studied IC in 112 milk samples (84 conventional and 28 organic) purchased from the same supermarkets in the Dortmund region, in North Rhine-Westphalia, from 2004 to 2010.[31] The mean iodine content was 98 (± 34) μg/l, and the IC in conventional milk was significantly higher than in organic milk: 112 (± 23) μg/l versus 58 (± 28) μg/l (test method: Sandell-Kolthoff). Köhler et al. studied IC in 135 milk containers (73 corresponding to conventional production and 62 to organic production) purchased in the federal state of Thuringia in the same supermarkets and grocery stores, from 2007 to 2011.[42] The mean iodine content was 122 (± 36.8) μg/l, and IC was significantly higher in conventional milk than in organic milk: 143 μg/l versus 92 μg/l (test method: ICP-MS).

Few studies have been published on IC in conventional UHT milk produced in France, and the current information available in this regard is very limited and incomplete. The iodide contents found by our working group in conventional UHT milk samples from packaging plants located in France were higher than those found in the food nutritional composition table prepared by the *Agence Nationale de Sécurité Sanitaire de l'Alimentation, l'Environnement et du Travail* (ANSES) and the *Centre Informatique sur la Qualité des Aliments* (CIQUAL).[43] The mean ICs in the most recent version of these tables are ''less than 20 μg/100 g'' in whole UHT milk (minimum 12.5; maximum 37.1), ''12.1 μg/100 g'' in semi-skimmed UHT milk (minimum 2; maximum 27.2), and ''13.5 μg/100 g'' in skimmed UHT milk (minimum 2; maximum 27). In our study, the iodide levels in whole (n = 12), semi-skimmed (n = 11) and skimmed milk (n = 23) were 201 μg/l (minimum 113; maximum 291), 189 μg/l (minimum 107; maximum 275), and 215 μg/l (minimum 94; maximum 287), respectively. Equivalence between grams and milliliters of milk: 1 g of milk = 0.969 mL of milk.

The information available on IC in conventional UHT milk produced in Spanish geographical areas is very limited. A study conducted in northwest Spain on the concentration of essential trace elements and toxic elements in organic and conventional milk also examined the iodine content in conventional UHT milk corresponding to 5 brands produced in this region and purchased during the winter.[44] The mean IC was seen to be 265 μg/l (test method: ICP-MS). Although this result must be viewed with great caution because of the small number of samples analyzed, it is quite close to the value recorded by our own group. In our case, the median iodide concentration in conventional UHT milk packaged in Asturias and Galicia in winter (n = 36) was 245 μg/l (210–280).

Implications for epidemiological studies on iodine nutritional status in schoolchildren and pregnant women

The most useful indicator for estimating iodine nutritional status in populations is the median urinary IC (mUIC).[45,46] The consumption of conventional cow's milk is the only known factor that may be associated with changes in urinary iodine excretion in the course of the year (greater IC in urine in winter than in summer) in children and, to a lesser extent, in adults.[18,47–50] Seasonal variation in urinary iodine excretion has also recently been reported in pregnant women.[51,52]

The time sequence of the variations in IC during the year in conventional UHT milk in our study may in part explain the major changes in urinary IC observed over the year in the schoolchildren (6–14 years of age) who participated in the ''2005 Nutrition Survey: Dietary habits and health status of the Basque population aged 4–18 years'', conducted in the Basque Country by the Public Health Department of the Basque Government.[53] Casual urine samples (n = 657) to assess the iodine nutritional status of the population were collected over 12 months from 1 March 2004 to 28 February 2005, and measurements of IC in urine were performed using high-performance liquid chromatography with electrochemical detection. The mUIC during the period of maximum IC in urine (November-January; n = 133) was 75% higher than the mUIC during the period of minimum IC in urine (June-September; n = 170): 217 μg/l versus 124 μg/l. These variations in urinary IC during the year also reflected variable iodine intake during the year, and the annual pattern of urinary iodine excretion suggests that the consumption of milk from cows fed with iodinated feed and of iodine-rich dairy products prepared with this milk was the main factor responsible for the observed phenomenon.

Fig. 2 shows the changes in IC in conventional UHT cow's milk and urine in schoolchildren from the Basque Country over 12 months, stratified into four trimesters. Grouping the urinary ICs by trimester facilitates the reaching of sample sizes that allow for the estimation of iodine nutritional status in each stratum with a precision of ± 10% within a 95% confidence interval (95%CI).[54]

There was an advance in the start of the seasons of greater and lower ICs in the urine of schoolchildren as compared to UHT milk. The start of the season of higher IC in the urine of schoolchildren occurred in November, while in conventional UHT milk it occurred later (in December-January). The start of the season of lower IC in the urine of schoolchildren occurred in June, while in conventional UHT milk it occurred somewhat later (in June-July). Part of the advance in the time sequence of the variations in the urinary ICs of schoolchildren versus those seen in UHT milk could have been due to the effects of yoghurt consumption upon IC in

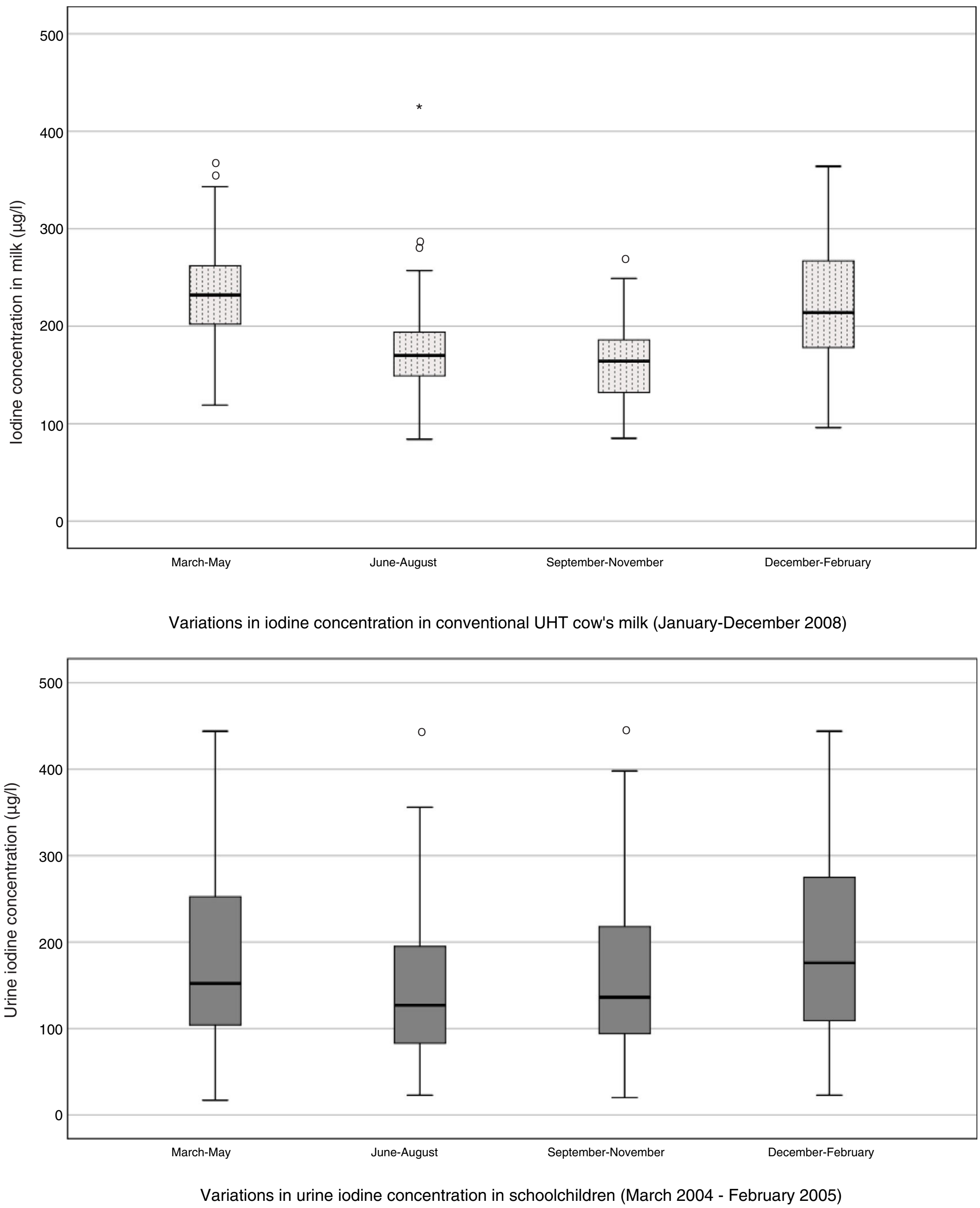

Fig. 2 Variations in iodine (iodide) concentration in conventional UHT cow's milk and urine in schoolchildren aged 6-14 years from the Basque Country.

urine. Yogurt is made from pasteurized milk and should be consumed on dates quite close to those of milk production. By contrast, the consumption of UHT milk may take place quite some time after the milk has been produced by the cows, and its effect upon IC in the urine of schoolchildren therefore may be considerably delayed as compared to that of yoghurt. Children aged 6–14 years in the Basque Country consume a daily average of 483 (± 184) g of milk and dairy products, particularly milk, 307 (± 161) g/day, and yogurt, 118 (± 99) g/day.[53]

The mUIC in spring among the schoolchildren from the Basque Country, 152 µg/l, is very close to the year-round mUIC of 147 µg/l. While awaiting confirmation of this finding from elsewhere, it seems reasonable for the collection of casual urine samples in epidemiological studies on iodine nutritional status in schoolchildren living in areas where conventional UHT milk is the most widely consumed milk to be conducted during the spring. This approach is not applicable to the other population group in which epidemiological studies on iodine nutritional status are particularly indicated (i.e., pregnant women), because the recruitment of participants in healthcare centers with pregnancy monitoring programs is usually made throughout the year.

A very important challenge for the future is to make milk as stable as possible as a food source of iodine. In order to reduce variations in milk iodine intake, it is particularly necessary to carefully control iodine intake in cows. It is also important to control the use of iodine-containing disinfectants used for udder hygiene and the disinfection of milking machines and dairy industry equipment. The best option in this regard is to replace such products with iodine-free antiseptics.[12,18,35,38] The amount of supplemental iodine should be sufficient to counteract the effects of iodine antagonizing substances contained in feed and pasture. While it is essential for cows to consume the necessary amounts of iodine regularly throughout the year, it is no simple matter to ensure that ICs remain stable in conventional milk when cows alternate in-door stabling and feeding during the cold months and open spaces on a grazing basis during the warm and hot months. The most critical season for cows to consume the required amounts of iodine is during the open grazing (pasture) period, though it is difficult to control their diet closely during that time. In order to optimise the intake of complementary feeding during the grazing season, it is essential to carefully plan the timing of the stabling of the cows for milking and to provide them with the required complementary feed.

Conclusions

The regular UHT cow's milk available in our food stores mostly comes from packaging plants in France and, especially, in Spain. This is a very important dietary source of iodine: a glass of conventional UHT milk (200—250 ml) packaged in Spain or France contains about 50 μg of iodine. However, the iodine content of conventional UHT cow's milk varies greatly throughout the year.

Knowing the profile of IC in milk during the year is of great interest for planning epidemiological studies on iodine nutritional status and for interpreting the results obtained. Casual urine samples in epidemiological studies on iodine nutritional status among schoolchildren living in geographical areas where conventional UHT milk is the most widely consumed milk should be collected in spring, because this is the season of the year when the mUIC in schoolchildren virtually coincides with the mUIC of the whole year.

Financial support

This study was fully funded through Research Projects Aids Program of the Obra Social (Gizarte Ekintza) of Caja Vital/Vital Kutxa-Kutxabank (Project VITAL07-003, S̈easonal fluctuations of iodine concentration in cow's milk).̈

Conflicts of interest

None.

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