Ann. Anim. Sci., Vol. 15, No. 3 (2015) 799–810 *DOI: 10.1515/aoas-2015-0025*

DE GRUYTER
OPEN

IODINE CONCENTRATION IN POLISH CONSUMER MILK*

Bogdan Śliwiński[1], Franciszek Brzóska[1♦], Zbigniew Szybiński[2]

[1]Department of Animal Nutrition and Feed Science, National Research Institute of Animal Production, 32-083 Balice n. Kraków, Poland
[2]Department and Clinic of Endocrinology, Jagiellonian University, Collegium Medicum, Kopernika 17, 31-501 Kraków, Poland
♦Corresponding author: franciszek.brzoska@izoo.krakow.pl

Abstract

The aim of this study was monitoring the iodine concentration in Polish consumer milk in the years 2011–2012. The test material used in this study consisted of consumer UHT pasteurized milk with extended shelf life. Six randomly selected cartons of milk with different fat content (from 0.5% to 3.2%) were each purchased from large-sized stores located in 16 cities during the summer and in 13 cities during the cow's winter feeding period. In total, 167 milk samples were collected. During the summer season, the milk's iodine content averaged 143 µg iodine kg^{-1} and ranged from 103 to 196 µg iodine kg^{-1} (n=96 samples), with a standard deviation (SD) of ±31 and coefficient variability (CV) of 44%. During the winter season, the milk's iodine content averaged 183 µg iodine kg^{-1} and ranged from 141 to 236 µg iodine kg^{-1} (n=77 samples), with a standard deviation (SD) of ±5 and coefficient of variability (%) (CV) of 26%. Iodine levels in Polish consumer milk increased from the last monitoring (2007–2008) from 100 to 143 µg iodine kg^{-1} in the summer season, and from 147 to 183 µg iodine kg^{-1} in the winter season (increases of 47% and 24%, respectively).

Key words: Poland, iodine, consumer milk, region, season

Iodine is an essential element for proper thyroid function in both animals and humans (Anke et al., 1993; Schöne et al., 2009). Iodine deficiency in Europe remains a serious international public health problem (Vitti et al., 2001; Delange, 2002; WHO, 2004; Zimmermann and Andersson, 2012). The most popular model of iodine prophylaxis in Europe is based on iodization of salt; however, among 40 European countries, only 13 introduced obligatory iodization of salt. The Polish model of iodine prophylaxis contains the following elements: obligatory iodization of household salt (20–40 mg I/kg) based on the disposition of the Ministry of Health introduced in 1996, obligatory iodization of neonatal formula (10 µg/100 ml of milk), and additionally recommended pharmacotherapy 150 µg I/daily in pregnant and breastfeed-

*This study was supported by the Ministry of Science and Higher Education, Warsaw.

ing women (on a voluntary basis). The iodine content in milk depends on the iodine intake in feed rations for cows. In Poland, iodine monitoring was conducted in the southern regions of Poland the first time in the 1960s and 1970s. It was performed in areas where iodine deficiency in humans was most severe. Unpasteurized bulk milk was studied in the west and south part of Poland in the 1970s, and was found to contain only 20–40 µg iodine kg^{-1}, with considerable deviations (Ewy et al., 1962, 1966). In 1995, raw milk iodine levels in southern Poland were similar to those observed previously (Brzóska et al., 1998). Such milk iodine levels are characteristic of cows receiving iodine in basal diets and no dietary iodine supplements (Schöne and Rajkumar, 2009). The low iodine content of milk from Polish cows in the 1960s and 1970s was due to the fact that feeds were not supplemented with iodine and no iodine-based udder hygiene was applied. During that time, consumer milk was not pasteurized, and milk from the regions more abundant in iodine was not transported in Poland on the same scale as today because deep pasteurization technology was unavailable. Milk was distributed in glass bottles and delivered daily in the early morning to consumers. A study of the iodine content in domestic bulky feeds and cereal seeds of Poland showed that it was low in hay, silages and cereal grains (Strzetelski, 2005). Another monitoring of consumer milk in Poland was conducted in 2007–2008 and covered ultrahigh temperature (UHT) treated milk, the samples of which originated from large stores in 13 provincial cities of Poland. Iodine content ranged from 100 µg iodine kg^{-1} milk in summer to 147 µg iodine kg^{-1} milk in winter, which reflected the changes taking place in Poland with regard to the feeding of dairy cows, in particular the use of feed and mineral-vitamin mixtures containing iodine (Brzóska et al., 2009). Cattle farming and milk production are subject to market rules and change. Modern feeding systems for dairy cows are promoted with increasing consumption of commercially-manufactured compound feeds that contain iodine. Production of mineral-vitamin feeds has been developed based on technology transfer between European Union countries. Poland now has large manufacturing plants producing mineral-vitamin mixes and supplements for domestic animals and for foreign markets. Iodized salt blocks, to be fed to cows in small and large herds, began to be produced.

The aim of the recent monitoring was to evaluate current iodine levels in Polish consumer milk offered in large-sized stores in most provincial cities, and to attempt to determine what part of iodine found in milk can supply iodine in the human diet. It was assumed that recent changes in cow husbandry, in particular the increasing number of cows in dairy herds and improvements in nutrition and udder hygiene, might have contributed to a further increase in milk iodine levels.

Material and methods

Collection of samples

The test material used in this study consisted of UHT pasteurized milk with extended shelf life. Six randomly selected cartons of milk with different fat content (from 0.5% to 3.2%) were each purchased from large-sized stores located in provincial cities of Poland (samples from cities). The samples of milk were purchased in 16 cities in the summer (Tables 1 and 3) and in 13 cities in the winter (Tables 2 and 4). Monitoring was conducted during the summer feeding season when 96 milk samples were collected in 2011, and during the winter feeding season when 77 samples of milk were collected in 2012. The consumer milk was produced in 7 regions of Poland: Podlasie, Łódź, Kuyavia-Pomerania, Wielkopolska, Mazovia, West Pomerania, and Lublin (samples from regions). The milk originated from 13 raw milk co-operative processors. The most distant regions of consumer milk producers are approx. 500–600 km apart. On the same or the next day, milk samples were transported to the Central Laboratory of the National Research Institute of Animal Production in Aleksandrowice near Kraków and analyzed for their iodine content.

Table 1. Milk iodine content during the 2011 summer season according to purchase location

Samples from city	No. of samples	Iodine content, μg kg^{-1} milk				
		mean	CV%	SD	min.	max.
Wrocław	6	155 cba	22.1	14.3	133	183
Bydgoszcz	6	158 cba	78.0	49.3	47	277
Lublin	6	140 cb	25.5	18.2	99	168
Gorzów Wielkopolski	6	160 cba	31.1	19.5	102	189
Warszawa	6	160 cba	25.2	15.8	118	189
Kraków	6	109 cb	27.2	24.9	91	155
Opole	6	126 cb	30.5	24.3	78	166
Rzeszów	6	123 cb	32.9	26.8	56	141
Siedlce	6	149 cba	26.8	18.0	125	187
Gdańsk	6	140 cb	29.4	21.0	108	187
Olsztyn	6	163 ba	18.2	11.2	136	184
Poznań	6	143 cba	27.8	19.4	100	179
Szczecin	6	196 a	92.9	47.4	116	335
Katowice	6	145 cba	19.4	13.4	124	173
Kielce	6	103 c	37.1	36.0	38	142
Łódź	6	123 cb	45.0	36.5	70	187
Mean	96	143				
SD		31				
CV%		44				
Range		103–196				

a, b, c – means with the same letters are not significantly different at $P<0.05$.
CV – coefficient of variation.
SD – standard deviation.

Milk analysis

Milk iodine levels were determined by catalytic-colorimetric method after mineralization in ammonium persulfate according to the method of Sandell and Kolthoff (1937), modified by Bobek and Kołczak (1960). This method uses the catalytic reaction of iodine for the reduction of ceric ion by arsenious ion.

Table 2. Milk iodine content during the 2011 summer season according to production region

Samples from region	No. of samples	Iodine content, μg kg^{-1} milk				
		mean	CV%	SD	min.	max.
Mazovia	3	91 c	31.4	34.4	56	116
Wielkopolska	4	167 abc	19.0	11.4	147	187
Łódź	21	146 bc	59.6	40.9	38	335
Podlasie	46	134 bc	36.4	27.1	70	293
West Pomerania	2	157 abc	7.8	5.0	151	162
Lublin	2	152 abc	22.6	14.9	136	168
Kuyavia-Pomerania	14	155 abc	25.6	16.5	112	208
Mean	92	143				
SD		31				
CV%		44				
Range		91–167				

For abbreviations see Table 1.

Table 3. Milk iodine content during the 2011–2012 winter season according to purchase location

Samples from city	No. of samples	Iodine content, μg kg^{-1} milk				
		mean	CV%	SD	min.	max.
Wrocław	6	185 abc	11.7	8.81	161	220
Lublin	6	180 abc	7.3	5.41	165	199
Gorzów Wielkopolski	6	168 bc	25.1	17.23	125	221
Warszawa	6	210 ab	24.8	21.21	161	297
Kraków	5	141 c	33.0	20.72	89	215
Opole	6	200 abc	21.6	17.64	155	267
Rzeszów	6	179 abc	18.7	13.61	117	210
Gdańsk	6	168 bc	14.4	9.88	145	215
Poznań	6	189 abc	12.8	9.86	158	224
Szczecin	6	182 abc	26.6	19.72	103	249
Katowice	6	236 a	41.1	39.56	175	430
Kielce	6	150 bc	28.1	17.13	76	193
Łódź	6	186 abc	13.0	9.85	149	211
Mean	77	183				
SD		5				
CV%		26				
Range		141–236				

For abbreviations see Table 1.

Statistical analysis

Statistical description and evaluation of results were performed by one-way analysis of variance with milk purchase location (cities) and milk production site (regions) as treatment factors. The results are expressed as means with standard deviation (SD), coefficient variability (CV%) and range (minimum and maximum). Analysis was performed using SAS software, but significant differences between means were determined with Duncan's tests.

Table 4. Milk iodine content during the 2011–2012 winter season according to production region

Samples from region	No. of samples	Iodine content, µg kg^{-1} milk				
		mean	CV%	SD	min.	max.
Mazovia	3	115 d	9.7	11.1	103	125
Wielkopolska	3	149 cd	35.9	53.4	89	192
Warmia and Mazury	1	158 cd	15.5	19.6	67	176
Łódź	19	175 bcd	21.0	36.7	76	224
Podlasie	35	175 bcd	12.5	21.9	132	206
West Pomerania	3	179 bcd	17.2	30.9	161	215
Kuyavia-Pomerania	11	241 bc	28.3	68.1	178	430
Mean	75	170				
SD		47				
CV%		26				
Range		115–241				

For abbreviations see Table 1.

Results

In both research seasons, consumer milk was produced in 13 dairy cooperatives and plants located in 7 regions of Poland. An analysis of milk purchase location and origin indicates that consumer milk transport routes in Poland intersect, which may result from marketing strategies. While raw milk is transported over distances of up to 100 km from dairy farms to milk processors, UHT consumer milk is transported over distances as large as 100–500 km and sold in regions where dairy farming is not widespread. During the summer season, milk iodine from cities averaged 143±31 µg iodine kg^{-1} and ranged from 103 to 196 µg iodine kg^{-1} (n=96 samples) (Table 1). During the winter season, milk iodine content from cities averaged 183±5 µg iodine kg^{-1} and ranged from 141 to 236 µg iodine kg^{-1} (n=77 samples) (Table 2). The average iodine content of milk was 28% higher in the winter compared to the summer season, except for two cases where the reverse situation occurred. Single samples of consumer milk that contained less than 50 µg iodine kg^{-1} were still marketed, mostly in southern Poland.

In summer, iodine content was highest in milk from the Wielkopolska milk co-operatives (167 µg iodine kg^{-1}) and lowest in milk from the Mazovia milk co-operatives (91 µg iodine kg^{-1}; Table 3). Iodine concentration in milk from the Mazovia region was significantly lower than from the other regions of Poland ($P \leq 0.05$). In the winter season, iodine content was highest in milk from the Kuyavia-Pomerania milk co-operatives (241 µg iodine kg^{-1}) and lowest in milk from the Mazovia milk co-operatives (115 µg kg^{-1}; Table 4). No significant differences were observed in iodine concentration in the regions, apart from Kuyavia-Pomerania and Mazovia ($P \leq 0.05$).

Discussion

Iodine in feeds, the cow's ration and milk

The iodine content of cow's milk depends on the level of dietary iodine supply. The iodine content of feed materials depends on the soil iodine content, which is assumed to be higher in alluvial soils and much lower in shallow soils on rocky substrate. Accordingly, the farther away from the sea and river deltas, the lower the iodine content of soil and fodder plants (Anke et al., 1993). The monitoring of Polish feedstuffs for iodine content showed that bulky feeds, including forages, silages and hay, contain an average of 112.8 mg iodine kg^{-1} DM compared to 48.5 mg iodine kg^{-1} DM for cereal grains (Strzetelski, 2005). The ration of a cow ingesting 18–24 kg DM a day, including approximately 60% bulky feeds, contains 4–6 mg iodine. This results in milk with a low iodine content of 20–40 µg iodine kg^{-1} (Brzóska et al., 1998; Ewy et al., 1962, 1966).

An important part of the cow's ration containing energy and protein is formed by compound feeds. Their amount for the lactation and dry periods depends on milk output and ranges widely from 0.5 to 2.0 mg per year. In addition to protein and energy, compound feeds are formulated to contain mineral elements, including iodine. There are discrepancies between nutritional recommendations and the actual diets of cows. Animal feeding guidelines recommend adding 100–600 µg iodine kg^{-1} of ration DM in relation to cow's milk yields (GfE, 2001; NRC, 2001), which translates into a maximum of 15 mg iodine/day. EU feed regulations authorize a maximum level of 5 mg iodine kg^{-1} feed (EU, 2003, 2005) which, with a daily yield of 30 kg of milk, translated into a consumption of 6–8 kg compound feed containing 30–40 mg of iodine. In 2013, the EFSA Panel on Additives and Products or Substances Used in Animal Feed recommended 2 mg iodine kg^{-1} DM as the maximum iodine content in the rations for dairy cows and minor dairy ruminants (EFSA, 2013). A more current study made in Germany, with iodine estimation in milk samples by inductively coupled plasma-mass spectrometry, has shown that an intake of 3, 17 and 68 mg iodine/cow d^{-1} resulted in the milk iodine concentration of 101, 343 and 1215 µg kg^{-1}, respectively (Schöne et al., 2009). Dairy cattle with a top milk yield of 40 kg/day should consume approx. 24 kg DM, including 48 mg iodine/day. Approximately 60% of Poland's milk production is based on herds with less than 20 cows; 40% of milk is produced by farmers keeping more than 100 cows. The average consumption of commercially manufactured compound feeds per cow is low and does not exceed 0.5 Mg/year in small farms, and 1–2 Mg/cow in the farms with more than 100 cows. Salt licks containing 100 mg iodine kg^{-1} salt are also produced. Annual production is approx. 1,000 thousand blocks, each weighing 10 kg, but only a small amount of salt licks are iodized. Approx. 30% of this production is exported.

Iodine content in milk in the seasons

Studies on the iodine content of consumer milk in Poland in the years 2007–2008 showed a level of approx. 100 µg in summer and 140 µg iodine kg^{-1} milk in winter (Brzóska et al., 2009). This suggests that iodine intake by cows has increased over the last few years. There is a proportional relationship between iodine intake by cows and milk iodine content. Research has shown that iodine in the form of potassium iodide, fed to cows at 5.8 to 58.3 mg iodine/day, increased the iodine content of milk from 20.6 to 217.0 μg iodine kg^{-1} (Brzóska et al., 2000). Further studies have shown that giving cows salt licks containing 300 mg iodine kg^{-1} increases milk's iodine content to 102.9 μg iodine kg^{-1}, while simultaneous administration of salt licks and a mineral mixture containing 300 mg iodine kg^{-1} results in 181.2 μg iodine kg^{-1} of milk (Brzóska et al., 2001 a, 2001 b; Wiewióra et al., 2004). The estimated intake of salt licks was 65 g salt/cow/day. The studies did not show any negative effects of dietary iodine levels on milk yield and on the composition and technological characteristics of milk such as fat and protein content, acidity, density and renneting time (Brzóska et al., 2000, 2003, 2001 a, b; Wiewióra et al., 2004). The fact that milk iodine content is higher in winter than in summer remains unexplained, but is related to the stage of lactation. In the summer season cows are generally calved in early spring, produce more milk and often start to graze pasture. In the winter season diets are based on grass silages and maize silages in large farms, and partly on hay in small farms, while the cows are in the second half of gestation. It is difficult to decide which of these factors explains the differences in milk iodine levels. A similar pattern was reported in an American study, in which milk iodine content was distinctly higher in the winter than in the summer period (Pennington, 1990). It can be assumed that with constant dietary iodine supply, cows in the first trimester of lactation, during the spring-summer period, are characterized by a higher milk yield, which could make the milk more dilute. It is difficult to determine if the iodine level in cow's milk depends on hormonal activity related to the lactation period and advancing pregnancy during the summer period. It can be speculated that the developing fetus and its nervous system absorb most of the iodine available in the cow's body, thus reducing its content in the milk. This question will remain hypothetical and speculative until appropriate research has been carried out. Research in Finland with dairy cow herds showed that iodine supplementation of feeds reduces irregular estrous incidence (Lamberg, 1986), but in pregnant animals iodine deficiency may lead to abnormal fetal development or even damage the fetus (Schöne and Rajkumar, 2009).

Iodine content in milk in the regions

The present study confirmed that the iodine content of consumer milk varies according to the region of Poland. In the summer season, iodine content was highest in milk from the Wielkopolska region and lowest in milk from the Mazovia region (Table 2). In the winter season, iodine content was highest in milk from the Kuyavia-Pomerania region and lowest in milk from the Mazovia region (Table 3).

This may be due to the differences in the size of dairy herds in these regions and the cow's feeding. None of the purchased and randomly chosen samples of milk was produced in the regions of Silesia, Małopolska, Kielce and Podkarpacie. This means that milk from these regions, mostly from small dairy farms keeping up to 6 cows, is sold to cooperatives supplying the smaller cities, and can also be collected and transported to neighboring provinces as the raw material for milk processing. Our results clearly indicate that the awareness of dairy farmers about correct nutrition, including the use of mineral feed supplements, is higher for larger herds in Wielkopolska and

Kuyavia-Pomerania than in the other regions. The iodine concentration in milk from the Mazovia region was lower than from the other regions, as indicated by the results of the smallest cow farm in this region in comparison to, e.g. the Podlasie region, the largest milk producer in Poland (Table 1).

Iodine in milk and human nutrition

The iodine concentration in consumer milk has implications for human nutrition and for deriving recommendations for optimal dairy cow feeding. The German, Austrian and Swiss Nutrition Societies (DACH, 2008) consider 500 µg iodine d^{-1} as the upper limit of iodine intake by humans. Experts from the WHO (WHO, UNICEF, ICCIDD, 2001) specified 1,000 µg iodine d^{-1}, but the US Food and Nutrition Board defined 1,100 µg iodine d^{-1} as the upper limit of iodine intake by humans (US Food and Nutrition Board, 2002). The fear of exceeding this limit led the European Food Safety Authority to reduce the concentration of iodine in compound feeds from 10 to 5 mg iodine kg^{-1}, but presently it is defined as 2 mg kg^{-1} DM of the cow's daily ration (EFSA, 2013; EU, 2003, 2005; Schöne et al., 2003). Studies performed in the late 1980s showed that the mean iodine content of fluid milk in the USA ranged from 160 to 340 µg iodine kg^{-1} with strong regional and seasonal variations (Pennington, 1990). In Great Britain, milk and milk products are considered the principal sources of iodine for humans. The mean iodine content of British consumer milk ranged from 130 to 200 µg iodine kg^{-1} (Lee et al., 1994). Milk and eggs are the main sources of iodine for the inhabitants of Finland. It is assumed that just 20% of iodine intake in Finland is from iodized salt (Lamberg, 1986). In Norway, milk iodine content averaged 88 µg iodine kg^{-1} in the summer and 232 µg iodine kg^{-1} in the winter period. It was estimated that 0.4 liters of milk satisfied 25% and 60% of the human requirement for iodine in the summer and winter, respectively (Dahl et al., 2003). Studies performed in Ireland in 1992–1995 with 69 samples of unpasteurized milk collected from bulk tanks showed a mean iodine content of 139 (range 2–435) µg iodine kg^{-1} (Rogers, 1999). Based on studies conducted in Germany, it is estimated that 37% of iodine in women's diets comes from milk and milk products, but iodine deficiency is still prevalent (Jahreis et al., 2001). Iodine deficiency affects all parts of Germany and is particularly acute in the mountain regions (Anke et al., 1993). In their considerations of how to meet the nutritional requirements of German inhabitants for iodine, Groppel and Hötzel (1993) considered milk, and products thereof, as well as marine fish as the main sources of iodine. A study of 28 Bavarian dairies showed that 368 samples of milk before pasteurization contained an average of 115 (26–298) µg iodine kg^{-1} milk (Preiss et al., 1997). A study performed in Thuringia with 61 milk samples revealed that they contained 111 (15–290) µg iodine kg^{-1} milk (Bader et al., 2005). Monitoring studies of milk iodine concentration indicate a range of 100–200 µg iodine kg^{-1} milk in Germany (Schöne et al., 2009). The high iodine content of milk in the USA and Great Britain is attributed to iodine in feedstuffs as well as the widespread use of iodine-based disinfectants for teat dipping and disinfection of milking equipment (Berg and Padgitt, 1985).

Prevention of iodine deficiency in humans through high milk iodine levels may be seen in the case of radioactive contamination following a nuclear reactor accident, when radioactive iodine isotope ^{131}I is released into the atmosphere. Unlike iodine deficiency, saturation of the animal and human thyroid with dietary iodine prevents the absorption of radioactive iodine in the body. Medical research provides compelling evidence that both long-term iodine deficiency and excess can be goitrogenic to humans (Philips et al., 1988). Excessive dietary iodine intake may induce the 'Wolff-Chaikoff' effect, characterized by inhibition of iodine uptake by the thyroid and inhibition of hormonogenesis. A newsletter of the International Council for the Control of Iodine Deficiency Disorders (WHO, 1995) reports that concern about the development of iodine-induced thyrotoxicosis should not be regarded as a contraindication to programs of iodine supplementation of salt, feed and consumer milk in view of the enormous benefits of this element for the correction of iodine deficiency in the entire human population. According to Szybiński (1997, 2012), these include improvements in biological living conditions of children, children's learning, women's health, and economic aspects of productive life. Sporadic cases of iodine allergy are far out of proportion to the benefits of using iodine to maintain normal thyroid function, for both individuals and whole societies. This issue is of special importance in Poland, considering the need to reduce salt intake and cardiovascular diseases caused by excessive salt consumption. In opposition to iodization of household salt as iodine disorders prophylaxis is the recommendation by the World Health Organization that salt consumption is a risk factor for hypertension, atherosclerosis, myocardial infarction, stroke, and select cancers, and should be restricted (WHO, 2007; Szybiński et al., 2010). Milk with 100–200 μg nutritional iodine kg^{-1} should be an important diet component, and a new element of human iodine disorders prophylaxis in the European Union. Results of the present monitoring indicate that Poland has gone from a country with low milk iodine levels in the 1960s–1990s to a country with medium and high milk iodine levels, similar to those in Germany, Great Britain, Finland and the USA. This calls for a new look at the recommendations for dietary iodine intake by different groups of the Polish population.

In addition to economic activity, milk producers and processors fulfil an important social function of which they may still be unaware. Apart from commercial production of basic food products such as milk and, indirectly, butter, cheese and other dairy products, they have an influence on their quality, including the health quality of the milk produced. The iodized salt licks produced by the Kłodawa Salt Mine and the mineral feed additives that contain iodine contribute to improving the health quality of milk in Poland and reduce the incidence of thyroid disorders. Iodized feeds, mineral-vitamin mixtures and salt licks should be a permanent part of the feed ration for cows and dairy cattle. Although salt licks are a feed supplement that do not increase the milk yields of cows in a noticeable and radical way, they help maintain ionic balance and good health levels in the cow, while supplementation of the diet with iodine also contributes to improvements in fertility and helps to obtain milk with enhanced healthfulness. The present findings show that due to its high iodine content, ranging widely from 50 to 300 μg iodine kg^{-1}, consumer milk in Poland can be either the main or a supplemental source of dietary iodine, which depends exclusively on the amount of milk and milk products consumed. We believe that milk packaging labels should contain information about iodine concentration.

The present monitoring showed that out of 96 samples of consumer milk available in the summer, this information was provided on milk for children, produced by one dairy cooperative only. This currently high concentration of iodine in cow's milk in Poland is especially important when the first published data revealed diminishing daily household salt consumption by around 25% (Jarosz et al., 2011). It means that the current model of iodine prophylaxis, still based on iodization of household salt, may be less effective. The increase of iodine content in consumer milk in Poland during the last 20–30 years is very important for the whole population, in particular for schoolchildren, pregnant women, newborn babies, and breastfeeding women.

Conclusions

Considering the current recommended iodine intake of 60 μg for children, 100 μg for teenagers and 150 μg iodine d^{-1} for adults, 0.20 liters of UHT milk meets approximately 48%, 29% and 19% of the iodine requirement in the summer and 62%, 37% and 25% of the iodine requirement in the winter, respectively. Regional variations of up to 30% are possible, with a higher iodine content in consumer milk from Kuyavia-Pomerania and Wielkopolska, and a lower content in consumer milk originating from Mazovia and Podlasie. Considering the range of iodine concentration in consumer milk in Poland, milk containers should provide information about iodine concentration.

Anknowledgements

The authors wish to ancknowledge the technical assistance of Mrs. Dorota Garcarz for the iodine analysis.

References

Anke M., Groppel B., Bauch K.H. (1993). Iodine in the food chain. In: Iodine deficiency in Europe, Delange F. (ed.). Plenum Press, New York, USA, pp. 151–157.

Bader N., Möller U., Franke K., Jahreis G. (2005). Tendency of increasing iodine content in human milk and cow's milk. Exp. Clin. Endocrinol. Diabetes, 113: 8–12.

Berg J.N., Padgitt D. (1985). Iodine concentration in milk from iodophor teat dips. J. Dairy Sci., 68: 457–461.

Bobek S., Kołczak T. (1960). Adaptation of the alkaline method of iodine determination in tissues, milk, urine and water and in green parts of plants. Endocrinol. Pol., 15: 181–186.

Brzóska F., Bobek S., Kamiński J., Pyska H. (1998). Iodine concentration of cow's milk in south part of Poland after 30 years (in Polish). Rocz. Nauk. Zoot., 25: 63–71.

Brzóska F., Pyska H., Brzóska B., Wiewióra W. (2000). Effect of iodine in daily ration on iodine content in milk and iodine status of dairy cows. Rocz. Nauk. Zoot.– Ann. Anim. Sci., 27: 103–116.

Brzóska F., Łojewska A., Brzóska B., Zyzak W. (2001 a). Salt licks with micronutrients in dairy cow's feeding. Ann. Warsaw. Agr. Univ., Anim. Sci., Special Number, pp. 318–325.

Brzóska F., Łojewska A., Brzóska B., Zyzak W. (2001 b). The effect of salt licks with microelements on their level in cow's blood serum and cow's milk (in Polish). Rocz. Nauk. Zoot., 28: 83–92.

Brzóska F., Pietras M., Brzóska B. (2003). Effect of licks and mineral mixtures with iodine on cows yield, iodine content of milk, milk nutrients and blood constituents. Ann. Anim. Sci., 3: 55–66.

Brzóska F., Szybiński Z., Śliwiński B. (2009). Iodine concentration in Polish milk – variations due to season and region. Endokrynol. Pol., 60: 449–454.

DACH (2008). Referenzverte für die Nährstoffzufuhr. 1. Aufl., 3. Korr. Nachdruck. Umschau Brans GmbH Verlagsgesellschaft. Frankfurt/M., pp. 179–184.

Dahl L., Opsahl J.A., Meltzer H.M., Julshamm K. (2003). Iodine concentration in Norwegian milk and dairy products. Brit. J. Nutr., 90: 679–685.

Delange F. (2002). Iodine deficiency in Europe and its consequences: an update. Eur. J. Nucl. Med. Mol. Imaging., 29, Suppl. 2: S404–S416.

EFSA (2013). Opinion of the safety and efficacy of iodine compounds (E2) as feed additives: calcium iodate anhydrous, based on a dossier submitted by Calibre Europe SPRL/BVBA. EFSA Journal, 11: 3100–3134.

EU (2003). EU-European Union. Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition. OJEU, 46, L268/29--L268/43.

EU (2005). EU-European Union. Regulation (EC) No 1459/2005 of the European Parliament and of the Council of 8 September 2005 amending the conditions for authorization of a number of feed additives belonging to the group of trace elements. OJEU, 48, L233/8-L233/10.

Ewy Z., Bobek S., Kamiński J. (1962). Investigation of iodine deficiency of animals in Kraków voivodeship (in Polish). Rocz. Nauk Roln., 79, B-3: 311–334.

Ewy Z., Bobek S., Kamiński J. (1966). Concentration of iodine in water and milk of Katowice region (in Polish). Rocz. Nauk Roln., 88, B-2: 131–136.

GfE (2001). GfE-Gesellschaft für Ernährungsphysiologie. Empfehlungen zur Energie- und Nährstoffversorgung der Milchkühe und Aufzuchtrinder. Nr. 8. DLG-Verlag, Frankfurt/M. pp. 89–104.

Groppel B., Hötzel D. (1993). Iodine deficiency with particular reference to Germany. Proc. 8th Int. Symp. on "Trace Elements in Man and Animals-TEMA 8", pp. 1028–1031.

Jahreis G., Hausmann W., Kiessling G., Franke K., Leiterer M. (2001). Bioavailability of iodine from normal diets rich in dairy products – results of balance studies in women. Exp. Clin. Endocrinol. Diabetes, 109: 3, 163–167.

Jarosz M., Sekuła W., Rychlik E., Ołtarzewski M. (2011). Salt consumption and cardiovascular diseases and gastric cancer in Poland (in Polish). Żyw. Człow. Metab., 38: 297–406.

Lamberg B.A. (1986). Endemic goitre in Finland and changes during 30 years of iodine prophylaxis. Endocrinol. Exp., 20: 35–47.

Lee S.M., Lewis J., Buss D.H., Holcombe G.D., Lawrence P.R. (1994). Iodine in British foods and diets. Br. J. Nutr., 72: 435–446.

NRC (2001). Nutrient requirements of dairy cattle. 7th revised ed. Washington, DC: National Academic Press, pp. 266–267.

Pennington J.A.T. (1990). Iodine concentrations in US milk: variation due to time, season and region. J. Dairy Sci., 73: 3421–3427.

Philips D.I., Nelson M., Barker D.J., Morris J.A., Wood T.J. (1988). Iodine in milk and the incidence of thyrotoxicosis in England. Clin. Endocrinol. (Oxf.), 28: 61–66.

Preiss U., Alfaro Santos C., Spitzer A., Wallnöfer P.R. (1997). Iodine content of Bavarian consumer milk. Z. Ernährungswiss., 36: 220–224.

Rogers P.A.M. (1999). Iodine supplementation of cattle. Teagasc, Grange Research Centre, Dunsany, Co. Meath. End of Project Report, No. 4381.

Sandell E.B., Kolthoff I.M. (1937). Microdetermination of iodine by a catalytic method. Microchim. Act., 1: 9–25.

Schöne F., Leiterer M., Hartung H., Kinast C., Greiling A., Böhm U., Jahreis G. (2003). Trace elements and further nutrition-related constituents of milk and cheese. Milchwissenschaft, 58: 486–490.

Schöne F., Rajkumar R. (2009). Iodine in Farm Animals. In: Comprehensive Handbook of Iodine, V.R. Preedy, G.N. Burrow, R. Watson (eds). Oxford, Academic Press, pp. 151–170.

Schöne F., Leiterer M., Lebzien P., Bemmann D., Spolders M., Flachowsky G. (2009). Iodine concentration of milk in a dose-response study with dairy cows and implication for consumer iodine intake. J. Trace Elem. Med. Biol., 23: 84–92.

Strzetelski P. (2005). Iodine content of green fodder and cereal crops in Poland. Ann. Anim. Sci., 5: 171–180.
Szybiński Z. (1997). New model of iodine prophylaxis of Poland (in Poland). Pol. J. Endocrinol., 48: 7– 16.
Szybiński Z. (2012). Work of the Polish Council for Control of Iodine Deficiency Disorders and the model of iodine prophylaxis in Poland. Pol. J. Endocrinol., 63: 156–160.
Szybiński Z., Jarosz M., Hubalewska-Dydejczyk A., Stolarz-Skrzypek K., Kawecka-Jaszcz K., Traczyk I., Stoś K. (2010). Iodine-deficiency prophylaxis and the restriction of salt consumption – a 21st century challenge. Pol. J. Endocrinol., 61: 135–140.
US Food and Nutrition Board IOM (2002). Dietary reference intakes for vitamin A, vitamin K, boron, chromium, nickel, silicon, vanadium, and zinc. Washington, DC, National Academy Press, pp. 258–289.
Vitti P., Rago T., Aghini-Lombardi F., Pinchera A. (2001). Iodine deficiency disorders in Europe. Public Health Nutr., 4: 529–535.
WHO (1995). ICCIDD Statement on Iodine Induced Thyrotoxicosis (Jodbasedow) (in Polish). IDD Newsletter, November, No. 55.
WHO, UNICEF, ICCIDD (2001). Assessment of the iodine deficiency disorders and monitoring their elimination. Geneva, WHO publ., WHO/NHD/01.1., pp. 1–107.
WHO (2004). Iodine status worldwide. WHO Global Database on Iodine Deficiency. WHO Geneva.
WHO (2007). WHO Forum and Technical Meeting on Reducing Salt Intake in Population. Paris, France, October, WHO 2006. Report of a WHO Expert Consultation Salt as a Vehicle for Fortification, Luxembourg, 21–22.03.2007, 5.
Wiewióra W., Brzóska F., Brzóska B., Pietras M. (2004). Iodine and selenium concentration in cow milk and plasma and its relations to milk yield, mineral content and selected metabolic parameters. Ann. Anim. Sci., 4: 79–90.
Zimmermann M.B., Andersson M. (2012). Update on iodine status worldwide. Thyroid, 19: 382–387.

Received: 4 XI 2014
Accepted: 13 II 2015