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Iodine concentration in Polish milk — variations due to season and region

Stężenie jodu w mleku spożywczym w Polsce — zmienność zależna od pory roku i regionu

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Abstract

Introduction: Iodine concentration was studied in Polish consumer milk.
Material and methods: The milk originated from 13 provincial cities and 65 dairy cooperatives located in Poland.
Results: Milk iodine concentration in the winter season of 2007–2008 was 146.8 μg/L, with a standard deviation for the provinces of 27.9 μg/L and variation coefficient of 19.0% (n = 66 samples). Iodine concentration for provincial cities ranged from 76.3 to 192.0 μg/L. It was highest in the milk samples from the Lubelskie province (191.9 μg/L) and lowest in the milk samples from Podlasie (113.8 μg/L).
In the summer season, milk iodine concentration averaged 100.4 μg/L, with a standard deviation of 38.9 ìg/L and variation coefficient of 38.8% (n = 27 samples).
Conclusions: Iodine concentration for provincial cities ranged from 63.8 to 173.7 μg/L. Compared to the winter season, milk iodine concentration in the summer season was lower by an average of 25.2%, with a standard deviation of 4.3% (Kielce) to 52.2% (Wrocław).
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Key words: *milk, iodine concentration, region, season, variation*

Streszczenie

Wstęp: Badano stężenie jodu w mleku spożywczym w Polsce.
Materiał i metody: Mleko pochodziło z 13 miast wojewódzkich i 65 spółdzielni mleczarskich w Polsce.
Wyniki: Stężenie jodu w mleku w sezonie zimowym 2007/2008 roku wynosiła 146,8 μg/l, przy odchyleniu standardowym dla województw 27,9 μg/l i współczynniku zmienności 19,0% (n = 66 próbek). Zawartość jodu w mleku w miastach wojewódzkich wahała się od 76,3 do 192,0 μg/l. Największa była w próbkach mleka pochodzących z województwa lubelskiego (191,9 μg/l), a najmniejsza w próbkach mleka pochodzących z Podlasia (113,8 μg/l).
W sezonie letnim zawartość jodu w mleku wynosiła średnio 100,4 μg/l, z odchyleniem standardowym 38,9 μg/l i współczynnikiem zmienności 38,8% (n = 27 próbek).
Wnioski: Stężenie jodu w mleku z miast wojewódzkich wahała się od 63,8 do 173,7 μg/l. W porównaniu z sezonem zimowym, stężenie jodu w mleku w sezonie letnim była niższa średnio o 25,2%, z odchyleniem standardowym od 4,3% (Kielce) do 52,2% (Wrocław). **(Endokrynol Pol 2009; 60 (6): 449–454)**

Słowa kluczowe: *mleko, stężenie jodu, region, pory roku, zmiany*

Introduction

Iodine is a key trace element in the energy metabolism of mammals. By activating thyroid hormones, it affects foetal development, fertility, and many metabolic functions of adult organisms [1]. In many countries, prevention of thyroid disorders caused by iodine deficiency in the human diet is based on iodization of table salt [2–3]. The consumption of salt, including salt hidden in bread and animal products available in Poland, is considered high (approx. 10–11 g/day). Medical research has clearly established that such high salt consumption leads to arterial hypertension and cardiovascular diseases in humans [4, 5], as reflected in the World Health Organization (WHO) report on reducing salt intake [6]. Iodine deficiency in Europe is not severe, but efforts need to be made to increase iodine intake among the population [7].

Consumer milk and related products were examined in a search for alternative sources of iodine. Milk is a natural component of the human diet, rich in calcium

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and vitamins. It is commonly used in the feeding of infants, youth, and adults. Milk products such as kefir, yoghurt, and cottage cheese contain very little sodium, much protein and calcium, and are commonly used in the human diet.

The content of trace elements, including iodine in milk, may range widely from 20–30 μg/L for cows under extensive feeding systems to 200–300 μg/L for dairy cows that are fed balanced diets [1, 8–12]. Iodine in consumer milk comes from several sources: from natural iodine content of the feed and drinking water given to cows; from vitamin and mineral feed additives that enrich cow diets; and from veterinary drugs and udder and milking machine disinfectants [12].

Milk monitoring studies conducted in the late 1960s and early 1970s in south-western provinces of Poland revealed that the iodine content of cows' milk was very low at 20–40 μg/L [13–15]. Milk iodine studies repeated after 30 years in a similar region showed that milk iodine levels continued to be low [8]. The monitoring studies covered raw milk purchased by dairies from collection centres and processed into consumer milk and dairy products. In Poland, consumer milk intended for direct consumption as market milk has never been monitored, and recommended iodine levels in food products were based on German data (Kunachowicz, 2008 — oral report).

In coordination with the Polish Council for the Control of Iodine Deficiency Disorders accredited to the WHO, studies were undertaken to determine the iodine content of consumer milk marketed by supermarket chains in provincial cities of Poland. The research hypothesis was that the iodine content of consumer milk in Poland is higher than in previous studies as a result of progress in the feeding of dairy cows over the last 10–20 years and changes that occurred in milk collection centres, the elimination of small farms with 1–3 cows, farms that use no iodinized feeds in cow nutrition, and farms without the milk refrigeration facilities required to maintain proper quality standards for processing into related products, including consumer milk.

The aim of the study was to determine the iodine content of consumer milk produced by dairy cooperatives in different regions of Poland in two seasons (winter season of 2007–2008 and summer season of 2008) and marketed by supermarket chains in provincial cities of Poland.

Material and methods

Milk samples were monitored in two seasons because of different cow diets and milk yield levels in these two periods. In the winter season of 2007–2008, 66 samples of carton milk were collected. Ninety percent was UHT milk with extended shelf life and 10% was bottled untreated milk for direct consumption. The milk came from hypermarket and supermarket chains located in the cities of Wrocław, Opole, Katowice, Rzeszów, Poznań, Zielona Góra, Łódź, Kielce, Lublin, Warszawa, Szczecin, Olsztyn, and Kraków. Three to eight samples (cartons) of consumer milk were collected from every retail outlet and it was ensured that each sample came from a different milk producer. The fat content of milk samples ranged from 0.5% to 3.2%.

In the summer season of 2008, monitoring was restricted to the most severely iodine-deficient areas described in the literature, and covered Wrocław, Opole, Katowice, Kraków, Rzeszów, and Kielce. A total of 27 consumer milk samples were collected.

The milk came from 65 Dairy Cooperatives and District Dairy Cooperatives located in different regions of Poland, mainly in Warmia and Mazury, Mazovia, Podlasie, Wielkopolska, Lubelskie province, Silesia, and Małopolska. The consumer milk was often marketed and sold in cities far removed from the region of origin. For example, milk from the District Dairy Cooperative in Łowicz was found in the supermarkets of Wrocław, Szczecin, Olsztyn, Kraków, and Poznań. Milk from the Mlekovita Dairy Cooperative in Wysokie Mazowieckie was sold in the supermarkets of Łódź, Szczecin, Lublin, Olsztyn, and Katowice. Consumer milk from the Mlekpol Dairy Cooperative in Grajewo was offered in the supermarkets of Szczecin, Olsztyn, Zielona Góra, Olsztyn, Kraków, and Warszawa. Supermarkets in Kielce sold milk imported from Olomouc (Czech Republic) and those in Katowice sold milk imported from Lyon (France). Winter milk was collected in November and December 2007 and in January, February, March, and April 2008. Summer milk was collected in August 2008.

Milk samples were transported on the day of purchase to the Main Laboratory of the National Research Institute of Animal Production in Aleksandrowice, preserved with penicillin, and frozen until analysis. The analyses were performed by dry alkaline mineralization and colorimetric measurements, using the iodine-catalyzed reduction of ceric ion by arsenous ion [16, 17].

The results obtained from the laboratory analysis were analysed statistically. Means for stem-and-leaf diagrams, standard deviation, coefficients of variation, and ranges of milk iodine were calculated [18].

Results

The iodine content of Polish consumer milk in the winter season of 2007–2008 is presented in Table I. The mean iodine content of milk from 66 samples was 146.8 μg/L, with a standard deviation for the provinces of 27.9 μg/L

Table I. *Iodine content of consumer milk in Poland's provincial cities — winter season 2007–2008*

Tabela I. *Zawartość jodu w mleku spożywczym w miastach wojewódzkich w Polsce — sezon zimowy 2007–2008*

Provincial city	No. of samples (n)	Iodine content (µg/L of milk)				
		Mean	SD	CV%	Min.	Max.
Wrocław	6	149.9	34.0	22.8	96.5	202.7
Opole	3	112.6	13.6	12.1	97.0	122.3
Katowice	4	161.7	30.8	19.0	127.0	197.7
Kraków	5	76.3	43.7	57.3	31.8	135.8
Rzeszów	5	130.0	48.6	37.4	67.3	193.1
Zielona Góra	6	163.9	93.1	56.8	79.8	335.4
Poznań	4	192.0	62.4	32.5	117.0	263.5
Łódź	3	161.6	65.1	40.3	103.0	201.4
Kielce	4	181.6	143.2	78.9	102.9	201.4
Lublin	7	152.8	52.6	35.0	82.0	230.4
Warszawa	5	146.5	38.0	25.9	99.5	194.7
Szczecin	6	139.4	57.5	44.1	88.9	234.6
Olsztyn	8	139.9	42.7	30.5	96.3	206.3
Mean	66	146.8				
SD		27.9				
CV%		19.0				
Range		76.3–192.0				

Table II. *Iodine content of consumer milk by region — winter season 2007–2008*

Tabela II. *Zawartość jodu w mleku spożywczym w poszczególnych regionach Polski — sezon zimowy 2007–2008*

Region	No. of samples (n)	Iodine content (µg/L of milk)				
		Mean	SD	CV%	Min.	Max.
Warmia and Mazury	6	136.7	15.7	11.5	82.0	201.4
Mazovia	10	128.2	12.2	9.5	96.5	194.7
Podlasie	16	113.8	10.0	9.7	67.3	193.7
Wielkopolska	25	163.9	17.7	10.8	85.8	335.4
Lubelskie	4	191.9	22.4	11.7	154.6	230.4
Silesia and Małopolska	3	118.8	16.4	13.8	41.0	193.1
Mean	64	142.2				
SD		15.9				
CV%		11.2				
Range		113.8–191.9				

and variation coefficient of 19.0%. Iodine concentration for provincial cities ranged from 76.3 to 192.0 µg/L. Milk iodine content in particular provinces was similar, except in Kraków where it was the lowest of all cities. There were large differences in standard deviation for individual provincial cities, ranging from 13.6 (Opole) to 143.2 µg/L (Kielce). The coefficient of variation ranged from 12.1% (Opole) to 78.9% (Kielce). The lowest milk iodine concentration was found in a milk sample from Kraków (31.8 µg/L) and the highest in Zielona Góra (335.4 µg/L).

Table II gives the iodine content for 64 Polish milk samples, without the two foreign samples, according to the region in which they were produced in the winter season of 2007–2008. The area of Poland was divided into 6 regions with regard to dairy plants whose products were analysed for iodine content, including

Table III. *Iodine content of consumer milk in Poland's provincial cities — summer season 2008*

Tabela III. *Zawartość jodu w mleku spożywczym w miastach wojewódzkich w Polsce — sezon letni 2008*

Provincial city	No. of samples (n)	Iodine content (µg/L of milk)				
		Mean	SD	CV%	Min.	Max.
Wrocław	5	71.7	27.2	38.0	29.8	96.0
Opole	4	95.7	10.8	11.2	82.8	108.4
Katowice	4	98.0	15.2	15.5	77.8	111.9
Kraków	5	63.8	16.8	26.3	36.1	74.9
Kielce	4	173.7	145.8	83.9	43.6	380.8
Rzeszów	5	99.3	20.2	20.3	74.1	123.4
Mean	27	100.4				
SD		38.9				
CV%		38.8				
Range		63.8–173.7				

Table IV. *Iodine content of consumer milk by region — summer season 2008*

Tabela IV. *Zawartość jodu w mleku spożywczym w poszczególnych regionach Polski — sezon letni 2008*

Region	No. of samples (n)	Iodine content (µg/L of milk)				
		Mean	SD	CV%	Min.	Max.
Warmia and Mazury	11	89.3	8.7	11.0	29.8	111.9
Mazovia	4	82.9	8.5	11.7	60.5	80.0
Wielkopolska	9	142.6	17.1	12.9	74.9	380.8
Silesia and Małopolska	3	86.6	8.1	10.2	36.1	123.4
Mean	27	100.4				
SD		10.9				
CV%		12.0				
Range		86.6–142.6				

Warmia and Mazury, Podlasie, Mazovia, Wielkopolska, Lubelskie province, Silesia, and Małopolska. The highest iodine concentration was found in the milk samples from the Lubelskie province (191.9 µg/L) and lowest in the milk samples from Podlasie (113.8 µg/L). In the winter, the iodine content ranged widely from 41.0 µg/L (Silesia and Małopolska) to 335.4 µg/L (Wielkopolska).

The iodine content of consumer milk in the summer season of 2008 is given in Table III. The mean iodine content of milk from 27 samples was 100.4 µg/L, with a standard deviation of 38.9 µg/L and variation coefficient of 38.8%. The iodine content for provincial cities ranged from 63.8 to 173.7 µg/L. Disproportions in the milk iodine content between the provincial cities were higher in summer than in winter. The lowest iodine content was again found in Kraków and the highest in Kielce. In all cities, milk iodine content in the summer season was lower than that in the winter season by an average of 25.2%, with standard deviations ranging from 4.3% (Kielce) to 52.2% (Wrocław). The highest milk iodine content in the summer was found in Wielkopolska, with the highest standard deviation and range of milk iodine content. In the other three regions, the milk iodine content was similar (Table IV).

Discussion

The monitoring of cow's milk for iodine content was performed both in selected European countries and in the United States. Raw milk supplied to dairy plants and retail milk were analysed. Milk iodine content reflects iodine levels in milk from different suppliers and different regions of Poland. Cows' milk iodine content depends on many factors, mainly the supply of dietary iodine in cow diets. Iodine is ingested in basal feed such as pasture forage, silage, hay, and feed mixtures. It is also ingested in drinking water and inhaled from the air. The amount of iodine ingested that way is just 4–6 mg I/day, which forms around 5% of the cow's daily iodine requirement [9]. It was found that iodine intake should be around 40–50 mg I/day to ensure around 100–200 μg I per litre of milk [9, 10]. The earlier cow iodine requirement was set at 0.5 mg/kg of diet dry matter, which corresponded to 9–11 mg I/day [19, 20]. Research in Ireland has shown that the cow's iodine requirement was too low and failed to meet the animal's nutritional requirement. A study of 50 herds with 33 to 293 cows demonstrated that 38% of the herds had low iodine status in the spring and 70% had low iodine status in the autumn [21]. Considering the considerable increases in milk yields of cows and the growing importance of iodine in milk and the human diet, cow iodine requirements were recently increased in Ireland to 50–60 mg I/day during lactation. This amount falls to around 12 mg I/day after around 300 days of lactation, during the dry period, and during the milking interval [22–23]. For this iodine intake, milk iodine content increases to 150–200 μg/L, with iodine intake by consumers from a 200 ml glass of milk being 30–40 μg, which accounts for 20–30% of the daily adult iodine requirement. Iodine is ingested by cows mainly in feed mixtures or feed additives, including mineral and vitamin mixtures, and in iodized salt licks. Cows' milk iodine content depends on the awareness of cow breeders, the economic conditions of farms, and the amount of iodine-treated feed additives given to cows. Iodine in milk may also originate from iodophor preparations used to disinfect udders and milking machines. They have been used in Poland recently on a small scale for fear of inhibiting microbiological processes during fermentation of yoghurts and kefirs and the production of mature cheese. The iodine content of mineral and vitamin mixtures averages at 100 mg/kg, and the recommended ration of mineral mixture for a cow is 100–200 g/day. This means that iodine intake from the mineral mixture may range from 10 to 20 mg/day. The acceptable iodine content of feed mixtures for cows was set by feed law regulations at 5 mg I/kg, which means that for a daily intake of 6–7 kg of this high-energy and high-protein feed, a cow ingests 30–35 mg I/day. Miller et al. [24] found that 70–90% of dietary iodine is absorbed directly from cattle forestomachs, 30% is excreted in faeces, and 40% is excreted in urine. The same authors also showed that 8% of ingested iodine is excreted in milk. Other studies in Poland have demonstrated that the amount of iodine excreted in cows' milk ranged from 2 to 4% of iodine ingested [25, 11]. Iodine absorption from the diet decreases in the presence of goitrogenic substances found in rapeseed feeds [26]. It also depends on the chemical form of iodine [9, 26–27].

Monitoring studies of the iodine content of fluid milk published in the USA showed that iodine content averaged 230 μg I per litre of milk, with a standard deviation of 90 μg and variation coefficient of 39% [28]. Considering the large distances between different US regions, milk iodine levels varied within wide limits according to region and season. Fluid milk iodine content was 270 μg/L milk in the summer season and 190 μg/L milk in the winter season. This may be due to the differing milk yields of cows over the year, with constant iodine supply. Because most cows in a moderate climate zone calve in the winter-spring season (February––April), the highest milk yield occurs during the summer, with a decrease in milk yield in the autumn and winter months. Milk obtained in the summer season is lower in trace elements such as iodine. During the period 1965/70–1980, the iodine content of milk in the USA increased by 300–500%, after the introduction of iodine-supplemented cow diets and the use of iodine preparations for udder and milking machine sanitation [29]. In view of the high iodine content of milk, the US dairy industry suggested 500 μg I/L of milk as the maximum level in drinking milk. It is assumed that iodine found in US milk accounts for 20–30% of the requirement for youth and adults and 59% for infants [28].

Studies of consumer milk have shown considerable differences according to country, region, and feeding intensity of dairy cows. The iodine content of Norwegian milk was 88 μg I/L (range 63 to 122 μg/L) in the summer and 232 μg I/L (range 103 to 272 μg/L) in the winter [30]. The authors stated that milk and milk products account for 25% of the iodine requirement for Norwegians in summer and for over 60% in winter. The iodine content of milk in Great Britain, based on monitoring of 30 regions performed in 1990 and 1991, was 150 (range 40 to 310) μg/L compared to 230 μg/L in 1977—1979 [31]. In view of the high iodine content of milk in Great Britain, it was recommended that table salt should be iodized with extra care and iodine intake levels by consumers should be monitored on a regular basis [32]. Monitoring of iodine levels in raw milk purchased by 28 Bavarian dairy plants showed a content of 115 μg I/L (from less than 100 μg I/L in South Bavaria to over 150 μ I/L in North Bavaria) [33]. Monitoring of the iodine content of milk in Ireland showed that it averaged 139 μg I/L (range 2 to 435 μg I/L) [23]. A study of milk iodine content in Finland showed 280 μg I/L in summer and 400 μg I/L in winter [34]. Since 1950, iodine intake in Finland increased 4-5-fold when endemic goitre was prevalent among the population. About 50% of iodine intake was estimated to come from dairy products, with a decrease in salt consumption from 7–8 to below 4 g per day per person [35].

The monitoring of Polish milk iodine content performed in 2007–2008 showed that consumer milk sold in supermarket chains comes from major Polish milk producers located in the most important milk regions of Warmia and Mazury, Podlasie, Mazowsze, Wielkopolska, Lubelskie province, and to a lesser extent from Silesia and Małopolska. Because of the milk preservation technology used, it is transported over distances of 300–400 km and sold in distant provincial cities. The routes of consumer milk transportation intersect. Milk iodine levels approximate 150 μg I/L in winter and 100 μg I/L in summer, which is not considerably different from iodine milk levels in Germany, France, or Finland although some regional differences have emerged. In winter, 7 milk samples were found to contain over 200 μg I/L, 18 samples 151–200 μg I/L, 25 samples 101–150 μg I/L, 14 samples 51–100 μg I/L, and 2 samples less than 50 μg I/L. Milk produced in the Silesia and Małopolska regions had the lowest iodine content, and milk from the Wielkopolska region the highest. Milk iodine levels in Kielce and Katowice were distorted by the presence of milk imported from the Czech Republic and France, which was very high in iodine at over 300 μg I/L. The high iodine content of milk from the Wielkopolska region may be due to the fact that most of this milk comes from large farms (by Polish standards) of 100–300 cows. In the feeding of cows, these farms usually use feed mixtures enriched in minerals, including iodine, but may also use vitamin and mineral mixtures and salt licks. The opposite situation exists in Małopolska and Silesia, which are dominated by small milk producers who keep several to dozens of cows and generally use no iodine-supplemented feed mixtures in cow nutrition. Few producers use mineral and vitamin mixtures and salt licks. In these regions, the iodine supply of cows may improve through the promotion of efficient cow feeding methods involving the enrichment of cow diets with components absent from basal feeds that are found in feed mixtures and mineral feeds, including salt licks.

Conclusions

Iodine levels in Polish consumer milk show that with a daily intake of 200 ml milk, this amount accounts for 20–30% of the requirement in youths and 13–20% in adults.

A slow but regular increase in the size of dairy cattle herds in Poland will improve the mineral feeding of cows and continue to increase the iodine content of consumer milk.

We pin our hopes for increased milk iodine content on the campaign started in 2008 to iodize salt licks produced at the Kłodawa Salt Mine, which previously contained no iodine supplements.

References

1. Bobek S. Iodine prophylaxis in animals. Med Wet 1998; 54: 80–86.
2. Szybiński Z, Żarnecki A. Prevalence of goiter, iodine deficiency, and iodine prophylaxis in Poland. The result of a national wide study. Endokrynol Pol 1993; 44: 373–388.
3. Szybiński Z, Lewiński A. National programme for the elimination of iodine deficiency disorders in Poland (1999–2003). Pol J Endocrynol 1998; 49 (Suppl. 1): 203–213.
4. Law MR, Frost CD, Wald NJ. By how much does dietary salt reduction lower blood pressure? II. Analysis of observational data within populations. Br Med J 1991; 302: 815–818.
5. WHO. International Society of Hypertension: Guidelines for the Management of Hypertension. Journal of Hypertension 1999; 17: 151–183.
6. WHO Report. Reducing salt intake in populations. Report of a WHO Forum and Technical meeting. 5–6 October 2006 .
7. Delange F, Burgi H. Iodine deficiency disorders in Europe. Bull. World Health Organ 1989; 67: 317–325.
8. Brzóska F, Bobek S, Kamiński J et al. Iodine content of milk in cows from southern Poland 30 years apart. Rocz Nauk Zoot 1998; 25: 63–71.
9. Brzóska F., Pyska H., Pietras M et al. Effect of iodine source on iodine content in milk and iodine status of dairy cows. Ann Anim Sci 1999; 26: 93–103.
10. Brzóska F, Pyska H, Brzóska B et al. Effect of iodine in daily ration on iodine content in milk and iodine status of dairy cows. Ann Anim Sci 2000; 27: 103–116.
11. Brzóska F, Pietras M. Effect of protein source and salt licks on cow's yield, milk nutrients and iodine content in milk. Ann Anim Sci 2002; 2: 97–107.
12. Brzóska F, Szybiński Z, Strzetelski P. Iodine content of feeds and possibilities for increasing iodine in milk. Med Wet 2005; 61: 145–149.
13. Ewy Z, Bobek S, Kamiński J. Study on the incidence of iodine deficiency in animals from the Kraków province. Rocz Nauk Rol 1962; 79: 311–334.
14. Ewy Z, Bobek S, Kamiński J. Iodine level in water and milk from the Katowice province. Rocz. Nauk Rol; 1966, ser. B, 88, 2: 131–136.
15. Pyska H, Ewy Z, Styczyński H. Milk and water iodine levels in the Rzeszów province. Rocz Nauk Rol 1970; 92: 495–503.
16. Bobek S, Kołczak T. Adaptation of the alkaline method of iodine determination in tissues, milk, urine and water and in green parts of plants. Endokrynol Pol 1960; 15: 181–186
17. Sandell EB, Kolthoff IM. Microdetermination of iodine by a catalytic method. Microchim Acta 1937; 1: 9–25.
18. Ruszczyc Z. Methodology of animal experiments. PWRiL, 2nd Edition, Warszawa 1970.
19. Haresign W, Cole JA. MAFF, DAFS, DANI, UKASTA, BVA Working Party Report. Mineral, trace element and vitamin allowances for ruminant livestock. Recent Advances in Animal Nutrition. Butterworths 1984; 113-142.
20. NRC. National Research Council. Nutrient requirements of dairy cattle. 6th revised edition. 1988. National Academy Press, Washington, D.C. 2000; 2: 103–116.
21. Mee JF, O'Farrell K, Rogers PAM. Incidence of iodine, selenium and copper deficiency in Irish dairy herds. Vet Surgeon 1993; 15: 27–30.
22. Rogers PA, Lynch PJ, Porter WL et al. A slow-release iodine, selenium and cobalt cattle bolus. Cattle Practice 1998; 6: 129–131.
23. Rogers PAM. Iodine supplementation of cattle. End of Project Report. Project No. 4381. December 1999. Ed. by Teagasc, Grange Research Centre, Dunsany, Co. Meath, Ireland.
24. Miller JK, Swanson EW, Spalding GE. Iodine absorption, excretion, recycling, and tissue distribution in the dairy cow. J Dairy Sci 1975; 58: 1578–1593.
25. Bobek S, Suchman A, Brzóska F et al. Use of EDDI and KI salt licks for dairy cows and their effect on milk iodine levels. Acta Agr Et Silv, ser. Zoot 1997; XXXV: 19–28.
26. Underwood EJ. Trace Elements in Human and Animal Nutrition (4th Ed.). Academic Press, New York, rok? 271–301.
27. Swansonn EW, Miller JK, Mueller FJ et al. Iodine in milk and meat of dairy cows fed different amounts of potassium iodide or ethylenediamine dihydroiodide. J Dairy Sci 1990; 73: 398–1593.
28. Pennington JAT. Iodine concentrations in US milk: variation due to time, season, and region. J Dairy Sci 1990;73: 3421–3427.
29. Hemken RW. Milk and meat iodine content: relation to human health. J Am Vet. Med 1980; 176: 1119–1121.
30. Dahl L, Opsahl JA, Mltzer HM, Julshamn K. Iodine concentration in Norwegian milk and dairy products. Br J Nutr 2003; 90: 679–685.
31. Lee SM, Lewis J, Buss DH et al. Iodine in British foods and diets. Br J Nutr, 1994; 72: 435–446.
32. Phillips DI. Iodine, milk, and the elimination of endemic goitre in Britain: the story of an accidental public health triumph. J Epidemic Community Health 1997; 51: 391–393.
33. Preiss U, Alfaro Santos C, Spitzer A et al. Iodine content of Bavarian consumer milk (in German). Bayerische Landesanstalt fûr Ernahrung, Munchen. 2. Ernahrungswiss. 1997; 36: 220–224.
34. Lamberg BA. Endemic goiter in Finland and changes during 30 years of iodine prophylaxis. Endocrinol Exp 1986; 20: 35–47.
35. Varo P, Saari E, Paaso A et al. Iodine in Finnish foods. Int J Nutr Sci 1982; 52: 80–89.