Iodine content in consumer hen eggs

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ABSTRACT: This paper presents the latest information about the supply of iodine to meet its requirements in hens of laying type, on the basis of iodine content in egg yolk and about the importance of eggs as an iodine source in human nutrition. The Sandell-Kolthoff method was applied to determine iodine content in the yolk of eggs from 9 large flocks (54 eggs) and 16 small flocks (96 eggs) in 2004, and from 10 large flocks (135 eggs) and 15 small flocks (114 eggs) in 2005. Iodine content was also determined in the albumen of 70 eggs. In 2004, the iodine content in the yolk of eggs from large flocks was 1 014.1 ± 356.6 while in 2005 it amounted to 1 663.8 ± 1 179.7 μg/kg fresh matter ($P < 0.01$); the respective values for the yolk of eggs from small flocks in 2004 and 2005 were 307.1 ± 255.7 and 519.5 ± 508.2 μg/kg fresh matter ($P < 0.01$). Compared to 1996, in 2005, the iodine content in yolk increased by 123.7% in large flocks, and by 19.2% in small flocks. The iodine content in albumen was 16.2 ± 9.7 μg/kg fresh matter, and it accounted for 2.6–5.0% of the total iodine content in 1 egg. The correlation coefficient between iodine contents in yolk and albumen was $r = 0.67$. In the Czech Republic, 1 egg from large flocks contains on average 31.2 μg iodine while 1 egg from small flocks contains 10.0 μg. Eggs from large flocks cover 7–14% and from small flocks 2.2–4.4% of the daily iodine requirement in adults. Iodine concentrations exceeding 2 500 μg/kg yolk fresh matter in large flocks were measured between week 32 and 60 of the laying cycle and with daily intake of 0.116–0.132 mg iodine per hen.

Keywords: iodine supplementation; yolk; albumen; iodine need

The objective of an optimum supply of iodine to farm animals is motivated first of all by an effort to reduce losses caused by clinical forms of its deficiency, significantly influences iodine content in animal products – eggs, milk and meat. It explicitly delineates the share of foods of animal origin in the prevention of iodine deficiency in humans. With regard to their consumption and nutritional habits of the population, this group of foods is extremely important in the Czech Republic (CR) as a natural iodine source (Borkovcova and Rehurkova, 2001). E.g. in an experiment conducted by Krajcovicova-Kudlackova et al. (2001), nutrition based on foods of plant origin only evoked symptoms of iodine deficiency in 80% of experimental persons (urinary content of iodine below 100 μg/l) compared to 9% of persons on a conventional diet.

The iodine amount in eggs varies in relation to its intake through a feed ration while a larger portion of iodine is contained in yolk. In experiments conducted by Kroupova et al. (1999) when a diet supplemented with 0.3–0.7 mg I/kg was applied, the egg yolk of hens contained from 924.0 ± 121 μg/kg to 1 974 ± 243 μg/kg fresh matter. According to Kaufmann (1997) hen eggs contain on average 1 135 ± 205 μg iodine per kg of yolk fresh matter, and 49 ± 14 μg iodine per kg of albumen fresh matter.

E.g. Underwood (1977) or McDowell (1992) pointed to a preferential interception of iodine in the hen ovary, and to an easy passage of iodine to oocytes. Experimental knowledge of factors participating in the relatively easy iodine passage to yolk (Kroupova et al., 1999) makes it possible

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to control an increase in iodine content in eggs. Kaufmann et al. (1998) reported a significant linear correlation between iodine content in a feed mixture up to 5 mg/kg and iodine content in yolk (r = 0.93). The application of a feed mixture for laying hens supplemented with 3.5 mg iodine per kg in the form of potassium iodide resulted in an increase in iodine content in yolk to 18 597 µg/kg fresh matter after 47 days (Kroupova et al., 1999). In feed mixtures used in large flocks and only scarcely in small flocks, iodine content varies in relation to proteinaceous ingredients and to the type of mineral supplement. The standardised requirement of iodine in the Czech Republic is 0.3 mg for hens of light laying type and 0.5 mg iodine per kg of dietary dry matter for hens of heavier laying type (Zelenka et al., 1993).

The objective of this paper is to provide information on the present iodine content in consumer eggs and to evaluate eggs as a food source of iodine in human nutrition in the Czech Republic.

MATERIAL AND METHODS

In 2004, the iodine content was determined in the yolk of 54 eggs from 9 large flocks and of 96 eggs from 16 small flocks (150 eggs in total). Eggs from large flocks were bought in the outlet network. In 2005 we examined 135 eggs from 10 large flocks and 114 eggs from 15 small flocks (249 eggs in total). In 2005 eggs from large flocks were taken on the spot on production farms. The large flocks included in this survey came from five administrative regions in 2004 and from four administrative regions in 2005, while the small flocks came from eight and four administrative regions of the CR in 2004 and 2005, respectively. In 2005 iodine content in egg yolk from large flocks was evaluated in relation to daily iodine intake and to the actual week of laying cycle; it was calculated from dietary iodine content (from 0.220 to 1.180 mg iodine per kg of dietary dry matter) and from daily intake of feed mixture (from 112.2 to 140.0 g per hen). To assess the trend and dynamics of iodine content in egg yolk the data from 2004 and 2005 were compared with the results obtained at the authors' workplace in 1996 and 2003. To make an overview of total iodine content in eggs as a food, iodine was determined in the albumen of 70 randomly sampled eggs from large flocks (40 eggs) and small flocks (30 eggs).

Based on our own results of iodine content in yolk and albumen, and on data of the Ministry of Agriculture of the Czech Republic on egg consumption including self-suppliers, the importance of eggs as an iodine source in human nutrition in the CR was evaluated.

The iodine concentration in egg yolk and albumen was determined by a spectrophotometric method using alkaline ashing based on the Sandell-Kolthoff reaction (Bednar et al., 1964). The principle of the assessment is the reduction of Ce^{4+} to Ce^{3+} in the presence of As^{3+}, and the catalytic effect of iodine. Mineralization took place in an alkaline medium at

Table 1. Iodine content in the yolk of eggs from large hen flocks – 2004

Number of flock	Region	District	Eggs	Iodine content in the yolk (µg/kg fresh matter)					
			n	$\bar{x}$	SD	V%	min.	max.	median
1	Jihocesky	Ceske Budejovice	6	823.7	238.6	29.0	479.5	1 204.5	814.2
2	Jihocesky	Strakonice	6	774.1	256.1	33.1	466.1	1 088.0	751.3
3	Jihocesky	Pisek	6	1 189.2	537.0	45.1	575.5	2 022.0	1102.9
4	Jihocesky	Jindrichuv Hradec	6	699.5*	225.1	27.9	673.5	1410.4	996.1
5	Stredocesky	Benesov	6	1 126.2	162.3	14.4	880.9	1 346.3	1 143.2
6	Stredocesky	Kladno	6	1 149.2	256.7	22.3	750.4	1 459.5	1 151.7
7	Kralovehradecky	Hradec Kralove	6	1 118.8	198.4	17.7	884.1	1 417.4	1 117.5
8	Plzensky	Domazlice	6	1 397.2*	245.2	17.6	1 047.6	1 739.2	1 347.4
9	Jihomoravsky	Znojmo	6	849.2	409.2	48.3	506.3	1 417.4	660.8
			54	1014.1	356.6	35.2	340. 0	2 022.0	1 010.5

* t-test, $P < 0.01$

600°C. Total iodine, i.e. both inorganic and protein-bound iodine, was measured in this way.

Statistical processing of data included the calculation of mean values ($\bar{x}$), standard deviations (SD), variation coefficient (*V*%), minimum and maximum values, median and correlation coefficients (*r*); statistical significance was determined by *t*-test.

RESULTS

In 2004, the mean concentration of iodine in yolk fresh matter of analysed eggs from large-scale production systems in the CR was 1 014.1 ± 356.6 μg/kg, and the median value was 1 010.5 μg/kg (Table 1). In 2005, the mean iodine content in yolk increased by 64% to 1 663.8 ± 1 179.7 μg/kg ($P < 0.01$), and the median value increased to 1 352.7 μg I/kg of fresh matter (Table 2). The increase in mean iodine content in yolk in 2005 was accompanied by a higher variability of the set (*V*% 70.9% against 35.5% in 2004), higher maximum value (8 128.8 μg I/kg against 2 022.0 μg I/kg in 2004) and by an increase in the number of flocks with maximum values higher than 2 000 μg I/kg (six flocks, also repeated, in 2005, only one flock in 2004) (Tables 1 and 2). The increase in iodine content in egg yolk from large flocks was also documented by the proportion of eggs with an iodine content above 2 000 μg/kg: 28.2% in 2005 and only 1.9% in 2004 (Table 5).

In comparison with large flocks, the eggs from small flocks contained approximately 3.2 times less iodine in yolk in 2005 and the variability of its content in yolk was higher, which was also reflected in higher values of the variation coefficient (Tables 3 and 4). E.g. in 2005, the highest mean value in small flocks was 16.4 times higher than the lowest value (flocks No. 6 and 8b, Table 4), while in large flocks it was only 7.2 times higher (flocks No. 3 and 8, Table 2). In 2004, the mean iodine content in the yolk of eggs from small flocks was 307.1 ± 255.7 μg/kg and the median value was 230.9 μg/kg, whereas in 2005 the mean value was 519.5 ± 508.2 ($P < 0.01$) and the median was 301.6 μg I/kg of yolk fresh matter. The increase in iodine content in the egg yolk from small flocks was documented in 2005 by the proportion of eggs with an iodine content in yolk above 1 000 μg/kg (Tables 5 and 6), amounting to 20.2% in 2005, and only 4.2% in 2004.

Table 2. Iodine content in the yolk of eggs from large hen flocks – 2005

Number of flock	Region	District	Eggs	Iodine content in the yolk (μg/kg fresh matter)					
			n	$\bar{x}$	SD	*V*%	min.	max.	median
1a	Jihocesky	Ceske Budejovice	10	1 738.3	1 220.5	70.2	489.2	4 917.7	1 531.4
1b	Jihocesky	Ceske Budejovice	5	2 775.6	863.8	31.1	1 901.9	4 043.6	2 785.4
1c	Jihocesky	Ceske Budejovice	10	2 998.2	695.5	23.2	1 651.8	3 858.4	3 209.2
1d	Jihocesky	Ceske Budejovice	10	977.9	628.1	64.2	201.4	2 480.3	801.4
2a	Jihocesky	Strakonice	10	2 545.6	2 319.8	91.1	911.6	8 128.8	1 586.3
2b	Jihocesky	Strakonice	10	1 590.0	416.4	26.2	1 053.6	2 283.0	1 514.2
3	Jihocesky	Jindrichuv Hradec	10	3 098.1*	526.7	37.2	1 979.7	3 762.4	3 141.8
4	Stredocesky	Benesov	10	1 181.8	632.5	56.8	681.1	2 971.6	1 061.5
5	Stredocesky	Rakovnik	10	1 822.0	700.7	40.5	1 083.3	3 662.7	1 627.6
6	Stredocesky	Praha Zapad	10	712.6	247.8	34.7	436.8	1 154.4	669.9
7	Plzensky	Plzen-Zapad	10	1 963.6	693.4	35.3	1 102.3	3 365.3	1 730.6
8	Plzensky	Plzen-Jih	10	429.4*	146.7	32.4	316.3	779.9	374.0
9	Ustecky	Litomerice	10	1 049.4	292.7	27.9	673.5	1 410.4	996.1
10	Ustecky	Litomerice	10	967.2	289.2	29.9	634.1	1 430.8	981.3
			135	1 663.8	1 179.7	70.9	201.4	8 128.8	1 352.7

* *t*-test, $P < 0.01$; 1a,b,c,d – repeated samplings in monthly intervals in flock No. 1; 2a,b – repeated samplings in monthly intervals in flock No. 2

Table 3. Iodine content in the yolk of eggs from small hen flocks – 2004

Number of flock	Region	District	Eggs n	Iodine content in the yolk (µg/kg fresh matter) $\bar{x}$	SD	V%	min.	max.	median
1	Jihocesky	Ceske Budejovice	6	386.0	389.9	101.0	169.3	1 174.5	231.5
2	Jihocesky	Ceske Budejovice	6	320.3	105.3	32.9	181.4	501.6	316.2
3	Jihocesky	Ceske Budejovice	6	221.1	83.8	37.9	116.3	322.1	226.8
4	Jihocesky	Ceske Budejovice	6	249.4	109.1	43.8	162.7	450.0	211.9
5	Jihocesky	Ceske Budejovice	6	323.9	122.3	37.8	169.1	529.0	327.6
6	Jihocesky	Strakonice	6	93.3*	20.1	21.6	73.1	126.7	87.9
7	Jihocesky	Pisek	6	105.9	17.3	16.3	85.0	125.6	107.5
8	Jihocesky	Cesky Krumlov	6	374.9	160.0	42.7	211.9	593.7	358.3
9	Stredocesky	Pribram	6	276.4	277.6	100.3	89.1	827.5	161.6
10	Vysocina	Pelhrimov	6	442.2*	149.2	33.8	236.5	634.0	448.2
11	Plzensky	Susice	6	181.6	52.8	29.1	142.2	275.3	154.2
12	Plzensky	Susice	6	291.9	135.1	46.3	159.2	476.5	245.8
13	Liberecky	Liberec	6	394.6	400.0	101.3	170.0	1 204.5	246.4
14	Pardubicky	Pardubice	6	172.9	31.7	18.3	148.6	233.6	162.7
15	Ústecky	Chomutov	6	229.9	85.0	37.0	140.6	378.9	224.8
16	Jihomoravsky	Znojmo	6	849.2	409.7	48.3	506.3	1 417.2	660.8
			96	307.1	255.7	83.3	73.1	1 417.4	230.9

*t-test, $P < 0.01$

Figure 1 illustrates a long-term trend in iodine content development in egg yolk when the mean values of yolk iodine from 2004 and 2005 are compared with the results obtained at the authors' workplace in 1996 and 2003. The mean content of iodine in the egg yolk from large flocks increased by 123.7% in 2005 (from 743.6 ± 251.3 in 1996 to 1 663.8 ± 1 179 µg/kg in 2005), while in small flocks it increased by only 19.2% (from 436.0 ± 134.4 to 519.5 ± 508.2 µg/kg).

Figure 2 shows the iodine content in yolk in relation to its intake through a commercial feed mixture in large flocks in 2005. With daily intake from 0.023 mg to 0.114 mg, the iodine content in the yolk of analysed eggs ranged from 967.2 to 1 822.0 µg/kg; with a higher daily intake (from

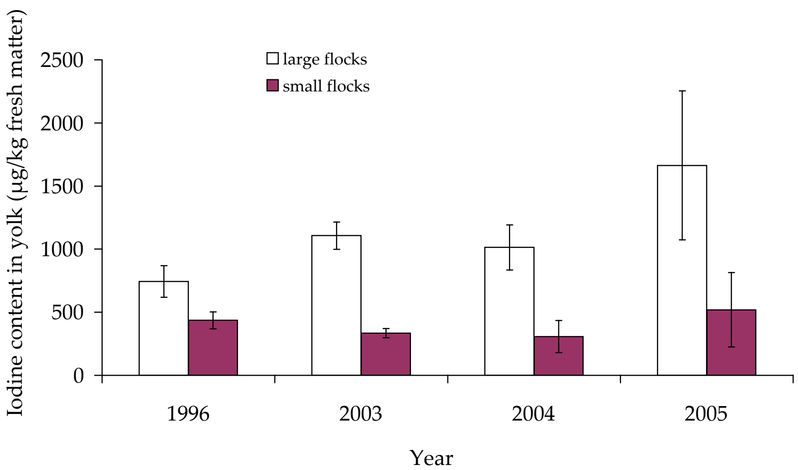

Figure 1. Iodine content in the egg yolk in years 1996–2000

Table 4. Iodine content in the yolk of eggs from small hen flocks – 2005

Number of flock	Region	District	Eggs	Iodine content in the yolk (µg/kg fresh matter)					
			n	$\bar{x}$	SD	*V*%	min.	max.	median
1a	Jihocesky	Ceske Budejovice	6	684.1	316.1	46.2	376.2	1 158.4	636.6
1b	Jihocesky	Ceske Budejovice	6	1 328.6	244.5	18.4	1 017.6	1 581.2	1 360.9
1c	Jihocesky	Ceske Budejovice	6	227.9	75.3	33.0	144.3	354.6	213.5
2a	Jihocesky	Ceske Budejovice	6	312.4	176.1	56.4	163.6	58.0	259.9
2b	Jihocesky	Ceske Budejovice	6	124.5	25.0	20.1	99.4	155.8	121.8
3	Jihocesky	Ceske Budejovice	6	153.6	18.7	12.2	135.5	189.4	147.8
4	Jihocesky	Strakonice	6	1 143.8	99.5	8.7	1 006.3	1 310.2	1 139.4
5	Jihocesky	Strakonice	6	623.9	303.4	48.6	291.2	1 177.7	553.1
6	Jihocesky	Strakonice	6	1 524.9*	763.1	50.0	712.2	2 463.3	1 370.6
7	Jihocesky	Strakonice	6	458.0	373.6	81.6	169.1	1 090.0	259.3
8a	Jihocesky	Pisek	6	150.1	63.1	42.0	102.4	269.3	126.7
8b	Jihocesky	Pisek	6	92.9*	17.6	19.0	73.9	117.4	89.4
9	Jihocesky	Prachatice	6	262.6	151.0	57.5	166.1	557.3	199.4
10	Jihocesky	Prachatice	6	172.0	96.8	56.3	103.2	356.6	126.6
11	Stredocesky	Kolin	6	297.1	84.3	28.4	169.5	382.8	317.3
12	Stredocesky	Kolin	6	517.2	183.9	35.6	298.8	834.8	472.6
13	Stredocesky	Kolin	6	1 212.6	495.3	40.8	452.3	1 690.7	1 275.5
14	Plzensky	Rokycany	6	108.6	34.7	31.9	70.7	154.8	100.9
15	Ustecky	Litomerice	6	476.7	164.2	34.5	310.0	747.0	447.8
			114	519.5	508.2	97.8	70.7	2 463.3	301.6

**t*-test, $P < 0.01$; 1a,b,c – repeated samplings in flock No. 1; 2a,b – repeated samplings in flock No. 2; 8a,b – repeated samplings in flock No. 8

0.116 to 0.132 µg/kg) the mean content of iodine in yolk exceeded 2 500 µg/kg.

The relationship between the actual week of hen laying in large flocks and iodine content in yolk (2005) is represented in Figure 3. The mean concentrations of iodine above 2 500 µg/kg were determined between weeks 32 and 60 of egg laying.

The iodine content in egg albumen of 70 examined eggs was 16.2 ± 9.7 µg/kg fresh matter (Table 6). The relationship between then iodine contents in

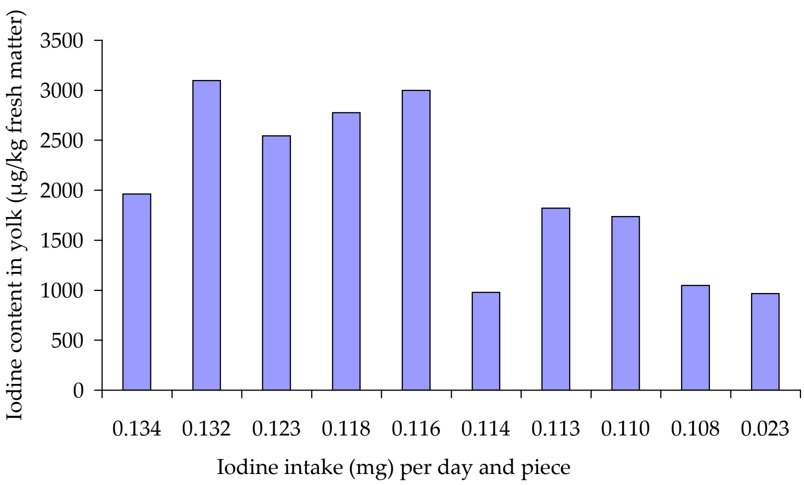

Figure 2. Relation between iodine intake and iodine content in yolk

Table 5. Relative proportions of iodine concentrations in egg yolk

Iodine in yolk (µg/kg fresh matter)	< 500	501–1000	1001–1500	1501–2000	2001–2500	> 2500
Type of flock	Relative proportions (%)					
Large flocks 2004	14.8	37.0	40.7	5.6	1.9	0
Large flocks 2005	8.9	22.2	25.9	14.8	8.2	20.0
Small flocks 2004	84.4	11.4	4.2	0	0	0
Small flocks 2005	67.5	12.3	14.9	3.5	1.8	0

Table 6. Iodine content in the albumen and yolk of eggs from small and large flocks

N		$\bar{x}$	SD	Max.	Min.	Median	r_{xy}
70	Yolk (µg I/ kg fresh matter)	855.6	762.9	2 468.4	96.8	486.7	0.67
	Albumen (µg I/ kg fresh matter)	16.2	9.7	56.9	4.6	13.0	
Regression function: $y = 9.0004 + 0.0085x$				y = iodine content in albumen		x = iodine content in yolk	

Table 7. Iodine content in one egg, in yolk and albumen

Type of flock	Iodine (µg) in yolk weighing 18 g	Iodine (µg) in albumen weighing 34 g	Iodine content (µg) in one egg
Large flocks	30.4	0.8	31.2
Small flocks	9.5	0.5	10.0

albumen and yolk was expressed by the statistically significant ($P < 0.01$) correlation coefficient $r = 0.67$ and by the regression function $y = 9.0004 + 0.0085x$ (y = iodine content in albumen, x = iodine content in yolk). Based on this regression function we calculated the expected iodine content in the fresh matter of albumen of eggs from large flocks (23.1 µg I/kg) and from small flocks (13.4 µg I/kg) in 2005. Assuming that the egg yolk weighs 18 g and the albumen weighs 34 g, one egg produced in large flocks contained 31.2 µg and in small flocks 10.0 µg of iodine (Table 7).

DISCUSSION

The authors examining iodine content in the egg yolk of gallinaceous fowl (Garwin et al., 1992; Richter, 1995; Kaufmann, 1997; Kroupova et al., 1999; Ungelenk, 2000) agreed on its significant

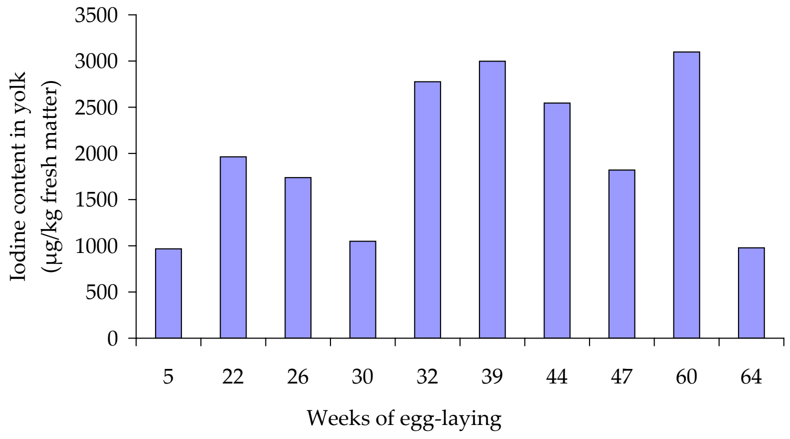

Figure 3. Iodine content in yolk during egg laying

relationship with the intake of dietary iodine in various forms. The standardised iodine content in 1 kg of dietary dry matter is on average at the level of 0.3–0.5 mg (McDowell, 1992; Zelenka et al., 1993). E.g. in 2005, the iodine content in feed mixtures applied to the examined large flocks ranged from 0.22 to 1.18 mg/kg dietary dry matter, and except in one case (0.22 mg I/kg dry matter) it exceed almost twice the above standard. A statistically significantly higher content of iodine in the yolk of eggs from large producers (Tables 1 and 2) compared to small flocks (Tables 3 and 4) corresponds to the saturation of laying hens with iodine in large flocks through iodine-supplemented feed mixtures, both in 2004 and 2005, as well as in preceding years (Figure 1). This difference in favour of large producers has increased significantly in the last ten years. In large flocks the mean content of iodine in fresh egg yolk increased by 123.7% from 1996 to 2005 while in small flocks it increased by 19.2% only (Figure 1). In 2005 mean iodine content in the yolk of eggs from large flocks in the CR exceeded the values measured in the Federal Republic of Germany ten years ago (Kaufmann, 1997).

The high variability of the iodine content in yolk reflects not only the real intake of iodine (Figure 2), but also the actual week of the laying cycle and related laying intensity and the length of the oocyte persistence in the ovary (Figure 3). In the interpretation of the influence of various factors on the iodine level in yolk, the regularities of homeostasis and homeorhesis cannot be neglected (Bobek, 1998; Kroupova et al., 1999) that are manifested by an increased deposition of superfluous trace elements in muscle or by their increased excretion and limited resorption.

Differences in iodine content in the yolk of consumer eggs originating from large flocks and from smaller ones are very important for the balance of iodine intake in consumers. Of the total amount of iodine contained in the egg (Table 7), iodine in the yolk of eggs from large flocks accounts for 97.4% and iodine in small flocks for 95%. Assuming the average annual consumption of 242 eggs per capita in the CR in 2005 (Roubalova, 2005), the eggs produced in large flocks may cover approximately 7–14% out of the 150–300 μg daily requirement of iodine in adults (Stransky and Rysava, 1997); it appears sufficient if the present supply of iodine from milk in the CR is considered (Kursa et al., 2005). Besides milk, eggs produced on large farms are an important natural source of iodine in human nutrition. Further increase in the intake of iodine from feed mixtures for poultry kept on large farms is not justified from the aspect of the health and performance of laying hens, or nutrition of the existing human population in the CR as it was e.g. in milk some time ago.

Greater attention should be paid to the lower iodine content in eggs from small flocks that are frequently sought for their taste qualities, and in connection with the growing interest in bio-foods. Their consumption covers only 2.2–4.4% of the daily requirement of iodine. In 2005, the production of self-suppliers is assumed to account for 38.7% of the total egg consumption in the CR (Roubalova, 2005). An adequate solution to the low iodine level in small flocks will be a higher supply of mineral supplements also certified for bio-production and their promotion (Jeroch and Strobel, 1999).

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