# Milk iodine concentration in cows treated orally or intramuscularly with a single dose of iodinated fatty acid esters

I. Herzig[1], J. Poul[2], B. Písaříková[1], E. Göpfert[1]

[1]Veterinary Research Institute, Brno, Czech Republic
[2]Agricultural and Trading Cooperative, Žichlínek, Czech Republic

**ABSTRACT**: The effect of a single oral dose of iodinated fatty acid esters (IFAE) on iodine levels in colostrum and milk of goats was tested. In experimental goats that received a single oral dose of IFAE before delivery, significantly higher iodine levels in milk were recorded 60 days after the delivery. In the following period since day 75 after the delivery iodine levels decreased, however, remained higher compared to the control, e.g. on day 152 the levels were twice as high as in the controls. Based on these results, the effect of a single oral and parenteral application of IFAE was tested on dairy cows. The results of the experiment showed that a single oral application of IFAE increases milk iodine levels for a shorter period. Intramuscular application resulted in a significantly higher milk iodine levels during the whole experimental period compared to both untreated controls and cows with oral application of IFAE.

**Keywords**: goat; dairy cows; Lipiodol UF; lactation; iodine in milk; performance

Animals can utilise iodine present in feed or drinking water. The iodine content in plant and animal tissues is much more affected by geological composition of soil than by the distance from the sea coast (Anke *et al*., 1993). Results of investigations carried out by WHO at the end of the last century indicate that the territory of Central Europe must be regarded as an area affected by endemic goitre (Luckas, 1986).

The optimum biological indicator of insufficient iodine concentration in soil are ruminants (cattle, sheep, goats) which consume large quantities of roughages and water originating from the area where they are living. Low iodine intake and its limited utilisation due to the action of goitrogenic substances result in hypothyroidism associated with health disorders. Low iodine concentrations in foods are responsible for iodine deficiencies in the human population, particularly in babies and children, in whom milk and milk products are the major iodine sources (Hemken, 1980; Buliński *et al*., 1988; Pennington, 1990).

Urinary iodine concentrations are regarded as the decisive indicator of iodine status in man (Pohunková and Němec, 1988; Bourdoux, 1993). The suitability of this system (ICCIDD) for the assessment of iodine status in animals has been confirmed by Herzig *et al*. (1996), who found a moderate iodine deficiency in 50.6% of dairy cows. In addition to urinary iodine concentration, investigation of thyroid functions, and blood serum analysis, the iodine status can also be assessed by determination of milk iodine concentration, which varies significantly in dependence of iodine content in the diet (Ewy *et al*., 1962; Hemken *et al*., 1972; Groppel, 1993; Kaufmann *et al*., 1998), but can also be influenced by parenteral iodine intake. In this regard the effects of iodine-containing udder disinfectants were studied (Herzig *et al*., 1999).

In addition to the conventional methods of iodine supplementation (such as with potassium iodide), products containing iodine bound in the oil base – iodinated fatty acid esters (IFAE) are used in the prophylaxis of human iodine deficiency.

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IFAE are administered orally or parenterally to populations living in areas affected by endemic goitre (Delange, 1996a,b; Bourrinet *et al*., 1997; Zimmermann *et al*., 2000, and others). Treatment with a single dose of IFAE provided long-term protection against health disorders due to iodine deficiency. Oral administration of iodinated oil is simpler, but its effect is shorter that that of intramuscular treatment.

The efficacy of IFAE was sporadically tested in iodine-deficient laboratory and farm animals (Chambon and Chastin, 1993). Administration of IFAE to rabbits demonstrated transplacental passage of iodine and its excretion in milk in pregnant and lactating females, respectively (Bourrinet *et al*., 1997). Azuolas and Caple (1984) demonstrated significantly higher milk iodine concentrations in sheep 16 months after intramuscular administration of a single dose of iodinated oil.

Answer was sought to the question whether a single oral or intramuscular dose of iodinated oils can ensure sufficient iodine concentrations in milk throughout the lactation period in ruminants, which are characterized by several morphological and physiological particularities, a relatively high excretion of iodine into milk, possible long-term intake of goitrogens, and exposure to other factors that can influence iodine utilisation and its urinary excretion.

## MATERIAL AND METHODS

### Pilot study in goats

The pilot study was conducted in a goat herd in Ratibořice (district of Třebíč). Iodine concentrations in blood serum were determined in six randomly selected pregnant goats before the experiment. The experiment was carried out in four young pregnant goats, of which two received single doses of 1 200 mg of iodine orally in the form of IFAE (480 mg of iodine per 1 ml of iodinated oil) approximately 11 days before parturition and two served as untreated controls. All the goats delivered after 8 to 14 days. Colostrum and milk samples for the determination of iodine concentration were collected from day 7 after delivery and the sampling continued at intervals of 20 to 30 days until approximately day 150. The experimental goats were exposed to the same management and feeding conditions as the rest of the herd.

### Experiment in dairy cows

The experiment in dairy cows was conducted in three analogous groups of twenty dairy cows (Czech Red Pied × Ayrshire × Holstein) on the farm Luková of the Agricultural Cooperative Žichlínek from August (2000) to April (2001). The groups were formed considering the breed proportions, age, bodyweight, lactation number, milk yield for the last lactation period, reproductive status, and expected delivery date. Group A ($n$ = 20) was treated orally and Group B ($n$ = 20) intramuscularly with IFAE at 10 mg/kg body weight 14 days before the expected delivery date and untreated cows of Group C served as controls. The product Lipoidol (Byk Gulden, France), containing 480 mg of iodine per 1 ml of oil, was used.

The three groups were housed under identical conditions and were fed identical diets consisting of corn silage, clover haylage, meadow hay, wheat straw, and concentrates. The nutrient contents in forages corresponded to daily milk yield of 10 l. The amount of concentrates mixed with other components was calculated to meet the requirement of cows yielding 20 l of milk daily and dosage for cows yielding more than 20 l was individual. The ration was supplemented with an iodine-free mineral mix. The cows were monitored regularly for 157 day after delivery, which corresponded approximately to 170 days after the treatment. The last samples were collected at day 240 after delivery.

Milk iodine concentrations were determined spectrophotometrically after dry alkaline mineralisation at 600°C by the Sandell-Kolthoff method (Bednář *et al*., 1964). The principle of the method consists in reduction of $Ce^{4+}$ to $Ce^{3+}$ in the presence of $As^{3+}$ in a reaction catalysed by iodine. The method determines both total inorganic and protein-bound iodine. The obtained data were processed using the statistic and graphic software STAT-Plus (Matoušková *et al*., 1992).

## RESULTS

### Pilot study in goats

Initial mean concentration of iodine in blood serum was 89.5 ± 20.3 μg/l (range 59.9 to 115.6 μg/l). Bobek (1998) regards concentrations lower than 100 μg/l in cattle and small ruminants as a sign of insufficient iodine intake. Hence, the iodine status

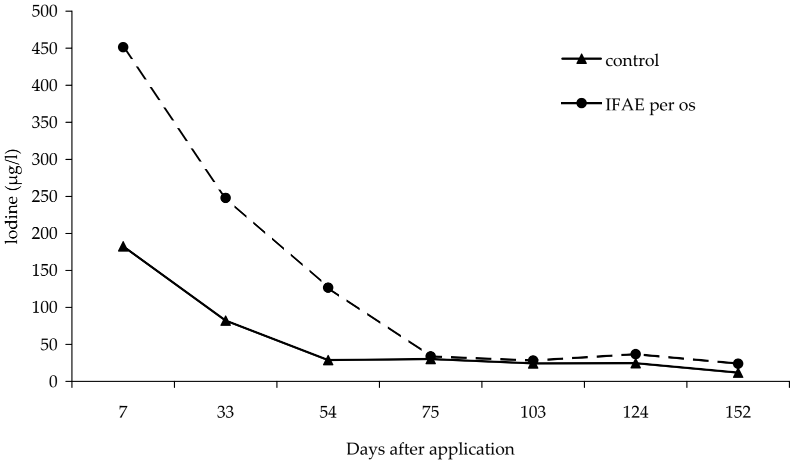


Figure 1. Dynamics of iodine concentration changes in colostrum and milk of goats after a single oral dose of IFAE

in the goat herd can be classified as moderate deficiency.

Dynamics of colostral and milk iodine concentrations during the observation period are shown in Figure 1. The results indicate that the concentrations in the first 54 days after oral administration of IFAE were markedly higher. Although they decreased in the period from day 75 to day 152, they always exceeded those found in the control group and were twice as high at day 152. The results clearly indicate that single oral administration of IFAE can meet the requirement for iodine for a limited period and increase its concentration in milk.

## Experiment in dairy cows

Urinary iodine concentrations were determined in a preliminary experiment in ten randomly selected cows differing in reproductive cycle stages to assess the iodine status. Mean concentrations in dry ($n$ = 4), highly pregnant ($n$ = 3), and calved cows ($n$ = 3) were 12.0 ± 13.4, 129 ± 71.9, and 146 ± 61.7 μg/l, respectively. The concentrations were significantly influenced by feeding a concentrate supplement containing trace elements, among them 5 mg of iodine per 1 kg. The results, summarized in Table 1, indicate that iodine intake during the dry period,

Table 1. Iodine levels in urine of cows in different stages of the reproductive cycle

| | Milk yield (l) | Lactation number | Delivery date | Iodine levels in urine (μg/l) |
|---|---|---|---|---|
| Dairy cows at the beginning of dry period | | | | |
| 1 | – | 3 | – | 0* |
| 2 | – | 2 | – | 24.4 |
| 3 | – | 4 | – | 22.1 |
| 4 | – | 2 | – | 0* |
| Dairy cows before calving | | | | |
| 5 | – | 0 | – | 53.3 |
| 6 | – | 6 | – | 196.3 |
| 7 | – | 3 | – | 137.9 |
| Dairy cows after calving | | | | |
| 8 | 36 | 2 | 6. 12. | 76.2 |
| 9 | 30 | 6 | 23. 12. | 194.1 |
| 10 | 32 | 3 | 19. 1. | 166.6 |

0* = unmeasurable iodine levels

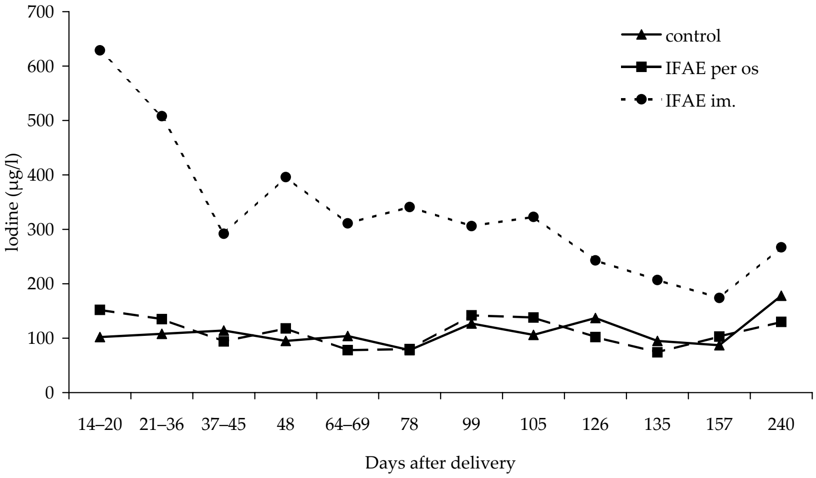


Figure 2. Dynamics of iodine concentration changes in milk of cows after a single oral and intramuscular dose of IFAE related to the delivery date

when the cows were fed roughages only, was insufficient. Feeding of the supplemented concentrate increased urinary iodine concentrations to a sufficient level, which persisted after calving, although it was markedly influenced by high performance (30 to 36 l per day).

IFAE were administered to cows of the experimental groups 14 days before the expected delivery date. Because of discrepancies between the expected and the actual delivery dates, the treatment-to-delivery period was not uniform. Therefore, the results were evaluated considering both the actual date of delivery and the treatment date.

Figure 2 shows dynamics of milk iodine concentrations in the control cows and those treated orally or intramuscularly with IFAE as related to the delivery date. Mean value for the control cows was 112 ± 54.0 μg/l. No marked fluctuations were observed during the experimental period. Single oral treatment with IFAE increased iodine excretion in milk only insignificantly and for a limited period for approximately 30 days. On the other hand, intramuscular treatment resulted in a marked increase of milk iodine concentration persisting throughout the observation period of 240 days. Compared with both the control and the orally treated cows, the differences were highly significant ($P < 0.01$). The decrease of milk iodine concentrations was slow with moderate fluctuations only.

Figure 3 shows dynamics of milk iodine concentrations in the control cows and those treated orally or intramuscularly with IFAE as related to the treatment date. The obtained values and dynamics of concentrations are more accurate as milk iodine concentrations were influenced by time lapse since the treatment. A group of cows treated orally with IFAE had significantly ($P < 0.01$) higher iodine levels during 41 days after the treatment compared with the control group. Milk iodine concentrations were significantly ($P < 0.01$) higher throughout the monitoring period (240 days) in cows treated intramuscularly with IFAE compared with both control and the orally treated cows.

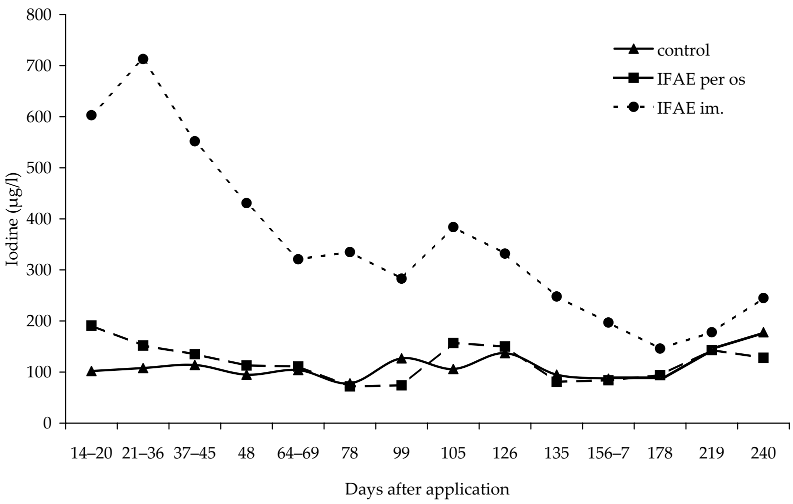


Figure 3. Dynamics of iodine concentration changes in milk of cows after a single oral and intramuscular dose of IFAE related to the treatment date

Table 2. Milk yield of lactating cows before the experiment, after 100 and 200 days following application of IFAE

| | Milk (kg) | | | Milk fat (kg) | | | Milk protein (kg) | | | Lactose (kg) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | per head/day | FCM/per head | FCM/total amount | % | per head | total amount | % | per head | total amount | % | per head | total amount |
| Milk yield during the last lactation | | | | | | | | | | | | |
| Control | 24.6 | 2 465 | 34 505 | 4.28 | 105 | 1 476 | 3.16 | 78 | 1 090 | 4.99 | 123 | 1 721 |
| IFAE im | 24.5 | 2 451 | 34 315 | 4.61 | 113 | 1 582 | 3.18 | 78 | 1 091 | 5.04 | 124 | 1 729 |
| IFAE po | 23.3 | 2 326 | 32 564 | 4.06 | 94 | 1 322 | 3.11 | 72 | 1 012 | 5.06 | 118 | 1 648 |
| Index im (%) | 99.5 | 99.4 | 99.4 | 107.7 | 107.2 | 107.2 | 100.6 | 100.0 | 100.1 | 101.3 | 100.5 | 100.5 |
| Index po (%) | 94.7 | 94.4 | 94.4 | 94.9 | 89.6 | 89.6 | 98.4 | 92.8 | 92.8 | 101.4 | 95.8 | 95.8 |
| Milk yield after 100 days of lactation | | | | | | | | | | | | |
| Control | 25.6 | 2 555 | 33 218 | 3.65 | 94 | 1 215 | 3.12 | 80 | 1 037 | 4.98 | 127 | 1 656 |
| IFAE im | 30.0 | 3 003 | 39 042 | 3.84 | 116 | 1 501 | 3.19 | 96 | 1 244 | 5.07 | 152 | 1 979 |
| IFAE po | 26.8 | 2 683 | 26 827 | 3.82 | 102 | 1 025 | 3.18 | 85 | 853 | 5.06 | 136 | 1 357 |
| Index im (%) | 117.2 | 117.5 | 117.5 | 105.2 | 123.5 | 123.5 | 105.6 | 119.9 | 120.0 | 101.8 | 119.5 | 119.5 |
| Index po (%) | 104.7 | 105.0 | 80.8 | 104.6 | 109.6 | 84.4 | 101.9 | 106.9 | 82.2 | 101.6 | 106.5 | 81.9 |
| Milk yield after 200 days of lactation | | | | | | | | | | | | |
| Control | 21.6 | 4 287 | 60 020 | 3.83 | 164 | 2 301 | 3.28 | 141 | 1 970 | 4.95 | 212 | 2 970 |
| IFAE im | 24.3 | 4 868 | 87 616 | 4.01 | 195 | 3 515 | 3.36 | 164 | 2 943 | 5.02 | 244 | 4 395 |
| IFAE po | 23.5 | 4 708 | 65 919 | 3.93 | 185 | 2 589 | 3.30 | 155 | 2 175 | 4.97 | 234 | 3 279 |
| Index im (%) | 112.5 | 113.5 | 146.0 | 104.7 | 118.8 | 152.8 | 102.4 | 116.2 | 149.4 | 101.4 | 115.1 | 148.0 |
| Index po (%) | 108.8 | 109.8 | 109.8 | 102.6 | 112.5 | 112.5 | 100.6 | 110.4 | 110.4 | 100.4 | 110.4 | 110.4 |

IFAE = iodinated fatty acid esters; FCM = fat constant milk
po = per os; im = intramuscular

Mean milk iodine concentrations throughout the experimental period (240 days) were 112 ± 54.0, 116 ± 50.8 and 350 ± 168.5 μg/l in the control cows, in orally treated cows and in intramuscularly treated cows, respectively.

Table 2 shows the assessment of milk yield in cows during the last lactation prior the experiment, after 100 and 200 days of lactation with IFAE treatment. Milk yield was enhanced by both oral and intramuscular treatment with IFAE. Performance (kg of milk/animal) calculated to constant milk fatness 4% was 2 432 kg in the control during the first days of lactation, and 2 941 kg in cows with intramuscular treatment, i.e. by 20.9% higher. At oral treatment the performance was 2 603 kg i.e. by 7% higher compared with the control. After 200 days of lactation the corresponding values were 4 175, 4 872 and 4 618 kg, it means by 16.7% and 11.6% higher compared with the control groups.

## DISCUSSION

Iodine deficiency in the Czech Republic results from the local geological composition and its geographic position. The three groups of geological formations, that can be distinguished in the Czech Republic, include: crystalline rocks with almost zero iodine content, volcanic rocks with a higher iodine content in West Bohemia, and Quarternary sediments, including Pannonian clay with the relatively highest iodine content in South Moravia. None of the three formations is enough rich in iodine to assure a satisfactory level in the food chain (Oliveriusová, 1997). Moreover, the Czech Republic is situated on a watershed from which the major part of precipitation water streams off after eluting iodine from rocks. This process is accelerated by intensive farming which results in a decrease of organic matter in soil and acceleration of iodine elution. The areas with the lowest iodine content in soil, water, and crops include South and Southeast Bohemia, Southwest Moravia, and the Jeseníky Mountains in North Moravia.

A sufficient iodine intake is of essential importance for normal function of the thyroid gland. Its hormones play an important role in metabolic processes and basal functions. Hypofunction of thyroid gland due to low iodine intake is usually accompanied with health disorders.

Data in the literature vary on the reference iodine levels in milk of ruminants. Changes in iodine levels in dairy cows are due to several causes and predisposition factors. Restrictive measures in feeding, especially the use of feedstuffs without mineral supplements containing iodine, unbalanced composition of nutrients in the ration and feed quality play an important role. Feeding of roughages and watering with high-nitrate-level water can affect iodine intake (Van der Heide and Schrõder-van der Elst, 1993; Písaříková *et al*., 1996) as well as diets containing glucosinolates that increase iodine accumulation in the thyroid gland. If iodine intake in the diet is low, goitrogenic and other factors can affect iodine utilization resulting in its insufficiency. Goitrogens can reduce iodine utilization by thyroid gland or influence its metabolism (Pennington, 1988; McDowell, 1992). Abandonment of udder disinfection with iodine containing preparations as well as large scale breeding of farm animals with increased loading of animals are other important factors (Hennig, 1992). All these factors can influence iodine levels in blood sera and milk and consequently affect iodine levels in humans.

Miller and Swanson (1973) stated that in ruminants under normal conditions of iodine intake about 8% of iodine is excreted in milk. Iodine concentrations in milk increase if iodine-containing supplements are fed (Hemken, 1980; Šedin, 1987). Iodine levels in milk depend also on the stage of lactation, there is a direct correlation with milk production (Daburon *et al*., 1989). According to Ewy (1969), iodine at the amount from 30 to 100 μg/l is a constant milk component. Groppel *et al*. (1984) mentioned 20 to 70 μg/l of milk as normal values. Values lower than 20 μg/l suggest of iodine defficiency in the rations. Diet without iodine supplementation resulted in 44 μg/l in urine and 20 μg/l in milk (Herzig *et al*., 1999) which corresponds with the data of Vlčková (1986), who recorded milk iodine levels lower than 20 μg/l while feeding cereal meals.

Groppel *et al*. (1991) noted that colostrum and milk of sheep and goats contains more iodine than milk of cows under the same diet, and iodine levels lower than 79 μ/l (sheep) or 62 μg/l (goat) are considered defficient. Azuolas and Caple (1984) at extensive monitoring of 59 sheep herds found that average milk iodine concentrations varied from 79 μg/l to 1 831 μg/l. In two herds with goitre incidence in lambs milk iodine levels were in the range 45 μg/l to 98 μg/l. After supplementation with 30 μg of iodine per animal and day Mason (1976) recorded in milk of ewes 45 μg/l of iodine; at this level 80% of lambs suffered with neonatal goitre, while at daily doses from 80 to 100 μg of iodine the newborne lambs did not suffer with thyroid gland disorders and milk iodine content was 95 to 131 μg/l (Grace, 1995).

Percentage of supplemented iodine excreted in milk was 11.6%, 9.5% and 12.8% at 33%, 66% and 100% cover of iodine requirements, respectively (Herzig *et al*., 1999). These values represent 7 to 27% of those reported by Kirchgessner (1959) and correspond with the data of Binerts (1989) who gives 7 to 10%. Kaufmann *et al*. (1998) stated negative correlation between iodine intake and its excretion in milk at supplementation with 20, 60 and 150 mg of iodine per day except for the period with 60 mg iodine supplementation. Elimination of iodine sources from the ration of dairy cows is accompanied with a gradual decrease of iodine concentrations in urine, however, in milk the decrease was not similarly gradual.

Conventional iodine sources are potassium iodide (76.45% of iodine) and EDDI – ethylenediamine dihydroiodide (80.53% of iodine). A uniform increase of iodine levels in urine and milk was observed at their administration. At full cover of iodine requirements, the average level in urine was 336 μg, and in milk 147 μg of iodine per litre. A similar development of iodine level dynamics after oral application of KI and EDDI was found by Bobek *et al*. (1997).

In addition to iodine supplementation in the form of potassium iodide or EDDI, iodine bound in the oil base i.e. iodinated fatty acid esters (IFAE) have been more frequently used during the past decade in the prophylaxis of iodine deficiency in humans. IFAE are applied orally or intramuscularly to populations living in areas affected by endemic goitre (Delange, 1996; Bourrinet *et al*., 1997; Zimmermann *et al*., 2000). A single application of iodinated fatty acid esters provided in humans a long-term protection against health disorders caused by iodine deficiency. Oral application of iodinated oil is simpler compared with intramuscular treatment, but the effect is shorter (Bourrinet *et al*., 1997; Furnee *et al*., 1997). Data on iodine concentrations in milk of ruminants following application of iodinated fatty acid esters are only sporadic.

In school children the average efficiency time, based on iodine levels in urine higher than 0.40 µmol/l, was after a single application of iodinated fatty acid esters (490 mg/l) 13.7 weeks, in a splitted dose (2 × 245 mg/l) 9.9 weeks, and in a single dose of iodinated triacylglycerol fatty acid esters (675 mg/l) the effect persisted for 52.5 weeks (Furnee *et al*., 1995). Retention and elimination of iodinated oils is not influenced by a single or repeated oral application, splitting into two doses does not enhance efficiency.

In areas with selenium deficiency, which is the case of the Czech Republic (Kvíčala *et al*., 1995; Kučera *et al*., 1995), supplementation of selenium and iodine can result in increase of milk yield, and fat and protein content in milk of sheep (Angelow *et al*., 1993).

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*Corresponding Author*

Doc. MVDr. Ivan Herzig, CSc., Veterinary Research Institute, Hudcova 70, 621 32 Brno, Czech Republic
Tel. +420 541 321 241, fax +420 541 211 229, e-mail: herzig@vri.cz