POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES

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Pol. J. Food Nutr. Sci.
2010, Vol. 60, No. 2, pp. 165-173

GOITROGENIC EFFECTS OF ALLYLISOTHIOCYANATE, NITRATE AND NITRITE IN RATS AND ALLEVIATING PROPERTIES OF IODINE AND SELENIUM SUPPLEMENTS

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Key words: goitrogens, iodine supplementation, selenium supplementation, iodine metabolism, thyroid gland

In Poland, a high level of nitrate and nitrite in food and iodine deficiency have been observed in the last years. The effects of potential goitrogens, namely allylisothiocyanate (SCN^-), nitrate (NO_3^-) and nitrite (NO_2^-) on growth performance, serum hormones (fT_4, TSH) and thyroid morphology were investigated in rats. Simultaneously, the potential antigoitrogenic effects of iodine and selenium supplements were studied.

In experiment 1, male Wistar rats of an initial body weight of 95 g were fed four experimental diets, based on AIN93G diet for rodents, with 0 or 2 µg iodine (KIO_3) supplement per rat per day. The diets were: AIN-93G- control (C), AIN-93G + I (C+I), AIN-93G +SCN^- (6 mg/100 g body weight) (SCN), AIN-93G + SCN^- (6 mg/100 g body weight) + I (SCN+I), AIN-93G + $NaNO_3$ (300 mg/100 g) (NO_3), AIN-93G + $NaNO_3$ (300 mg/100 g) + I (NO_3+I), AIN-93G + $NaNO_2$ (25 mg/100 g) (NO_2) and AIN-93G + $NaNO_2$ (25 mg/100 g) + I (NO_2+I). The diets were fed to eight groups of rats (n=6) for 18 days. Feed intake was restricted to 15 g/day/rat. Body mass of rats was monitored weekly. On day 18, the rats were anaesthetised and their blood was drawn by cardiac puncture. The immulite rat TSH application kit was used to determine TSH concentrations in blood serum. Serum fT_4 was determined according to the LIA method. The thyroid glands were excised and processed by the conventional paraffin technique. The growth of rats was not affected by the intake of goitrogens. Serum fT_4 concentration tended to decrease by the treatments (C – 24.6, SCN-19.8, NO_3 – 21.8 and NO_2 – 21.3 pmol/L). At the same time, serum TSH levels were significantly increased after administration of SCN ($p<0.02$) and NO_2 ($p<0.05$). The histological examination of thyroid glands showed a series of morphological alterations (high follicular epithelial cells and reduced amount of colloid). On the other hand, the rats fed the experimental diets supplemented with iodine (C+I, SCN+I and NO_3+I), showed no changes in the parameters studied, compared with the control animals. The only exception were the rats fed NO_2+I diet, showing still morphological alterations in their thyroid glands.

In experiment 2, male Wistar rats of an initial body weight of 120 g were fed five experimental diets, based on AIN93G rodent diet. The diets were: AIN93G (CON), AIN93G + Se, (Se), AIN-93G + $NaNO_2$ (25 mg/100 g) ($NaNO_2$), AIN-93G + $NaNO_2$ (25 mg/100 g) + Se ($NaNO_2$+Se), AIN-93G + $NaNO_2$ (25 mg/100 g) + Se + I ($NaNO_2$+Se+I). The diets were fed to five groups of rats (n=6) for 18 days. The feed intake was restricted to 15 g/day/rat. Body mass of rats was monitored weekly. On day 18, the rats were anaesthetised. The thyroid glands were excised and processed by the conventional paraffin technique. The growth of rats was not affected by the dietary treatments. The histological examination of thyroid glands showed a series of morphological alterations in rats fed nitrite diet ($NaNO_2$) and nitrite + selenium diet ($NaNO_2$+Se), whereas in rats fed nitrite + selenium + iodine diet ($NaNO_2$+Se+I), morphology of thyroid gland was similar to that of the control animals (CON).

In conclusion, dietary allylisothiocyanate, nitrate and nitrite impair thyroid metabolism in rats and lead to thyroid hypertrophy. At the same time, the goitrogenic effects of allylisothiocyanate and nitrate can be alleviated by dietary iodine whereas the goitrogenic effects of nitrite can be alleviated only by concomitant dietary supplements of selenium and iodine.

INTRODUCTION

Iodine is a specific substrate for thyroid hormone synthesis. The transport of inorganic iodine to follicular cells is maintained by the iodide pump located in the basal membrane; this is the rate-limiting step for thyroid hormone synthesis. A number of anions act as competitive inhibitors of iodine transport in the thyroid, including perchlorate (ClO_4^-), thiocyanate (SCN^-), and pertechnetate (TcO_4^-). Blockage of the iodine-trapping mechanism has a similar disruptive effect on the thyroid-pituitary axis as iodine deficiency. Nitrates can also interfere with normal iodine thyroid metabolism by inhibiting iodine uptake by the thyroid gland, thus leading to the development of goitre in laboratory animals, *e.g.* rats [Bloomfield, 1961; Horing *et al*., 1986; Jahreis *et al*., 1991] and also in humans [van Maanen *et al*., 1994; Gatseva *et al*., 1998; Gatseva & Argirova 2008; Vladeva *et al*., 2000; Tajtakova *et al*., 2006]. However, Below *et al.* [2008] demonstrated that a low alimentary intake of nitrate does not influence the thyroid volume in a population with currently sufficient alimentary intake of iodine [Below *et al.,* 2008]. Nitric oxide donors also inhibit iodide transport and organification in cultured bovine thyroid cells [Costamagna *et al*., 1998]. Nitrates, in contrast to nitrites, are relatively nontoxic, but an elevated nitrate load may produce potential harmful effects *via* an endogeneous conversion of nitrates to nitrites [Jensen, 1995; Panesar & Chan, 2000].

Selenium occurs in the form of the amino acid selenocysteine in selenoproteins which exert various effects, while maintaining the reduction-oxidation balance in a cell. The discovery that all three deiodinases that convert thyroxine (T_4) into triiodothyronine (T_3) contain selenocysteine shows how

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the production of the active thyroid hormone is dependent on Se status. The selenoenzyme families of glutathione peroxidases and thioredoxin reductases exhibit powerful antioxidant properties and form a complex defense system that protects thyrocytes against oxidative damage.

The above studies do not provide morphological evidence of goitrogenic effects of allylisothiocyanate (SCN^-), nitrate (NO_3^-) and nitrite (NO_2^-) on the thyroid tissue (*i.e.* thyroid follicles) nor information on the secretion of the thyroid stimulating hormone (TSH) involved in the thyroid metabolism. Additionally, they are lacking information on the potential alleviating effects of iodine or selenium on thyroid metabolism in rats fed the above goitrogens.

Because high levels of nitrate and nitrite in food and iodine deficiency have been observed in Poland, the goitrogens effect of these substances and alleviating properties of iodine or selenium should by studied.

In view of the above, the objective of the present study (Experiment 1) was to determine the effect of three goitrogen treatments (allylisothiocyanate, nitrate and nitrite) and two levels of iodine supplementation (0 – control treatment and 2 μg – supplementation per animal per day) on growth performance, thyroid morphology and serum level of hormones (fT_4, TSH) in rats. The objective of Experiment 2 was to determine the potential antigoitrogenic effects of selenium and selenium+iodine supplements in rats fed nitrite.

MATERIAL AND METHODS

Animals, housing and feeding

All experimental procedures complied with the Polish Ethical Standards. Male rats of Wistar strain, approximately five weeks old, were obtained from the Institute of Animal Production in Kraków. They were housed individually in screen-bottomed stainless steel cages, in an isolated room with controlled temperature (25°C) and ambient humidity, with 12-h light-dark cycle. The rats were fed semi-purified AIN-93G diets with complete mineral and vitamin mixture [Reeves, 1993] and had free access to distilled water. All chemicals used in the mineral and vitamin mix were of analytical grade.

In Experiment 1, male Wistar rats of an initial body weight of 95 g were fed four experimental diets, based on AIN93G diet, with 0 μg iodine (I) supplement or 2 μg iodine (I) supplement (as a potassium iodate) per rat per day. The diets were: AIN-93G- control (C), AIN-93G + I (C+I), AIN-93G +SCN^- (6 mg/100 g body weight) (SCN), AIN-93G + SCN^- (6 mg/100 g body weight) + I (SCN+I), AIN-93G + $NaNO_3$ (300 mg/100g) (NO_3), AIN-93G + $NaNO_3$ (300 mg/100 g) + I (NO_3+I), AIN-93G + $NaNO_2$ (25 mg/100 g) (NO_2) and AIN-93G + $NaNO_2$ (25 mg/100 g) + I (NO_2+I), (Table 1A). The levels of goitrogens were chosen on the basis of our previous experiments [Kostogrys *et al*., 2006a, b]. The diets were fed to eight groups of rats (n=6) for 18 days. Goitrogens and iodine were prepared daily per rat as a water solution and mixed with the diet. Feed intake was restricted to 15 g per rat per day. Body mass of the rats was monitored weekly.

In Experiment 2, male Wistar rats of an initial body weight of 120 g were fed five experimental diets, based on AIN93G rodent diet with 0 μg iodine supplement or 2 μg iodine (I) supplement (as a potassium iodate) per rat per day and with 0 μg selenium supplement or 3.59 μg selenium (Se) supplement (as a Na_2Se0_4) per rat per day. The diets were: AIN93G (CON), AIN93G + Se, (Se), AIN-93G + $NaNO_2$ (25 mg/100 g) ($NaNO_2$), AIN-93G + $NaNO_2$ (25 mg/100 g) + Se ($NaNO_2$+Se), AIN-93G + $NaNO_2$ (25 mg/100 g) + Se + I ($NaNO_2$+Se+I), (Table 1B). The diets were fed to five groups of rats (n=6) for 18 days. Goitrogens, selenate and iodine were prepared daily per rat as a water solution and mixed with the diet. Feed intake was restricted to 15 g per rat per day. Body mass of the rats was monitored weekly.

Blood sampling and thyroid gland histological examination

At the end of Experiments 1 and 2 (18 days) the rats were anaesthetised with thiopental (Biochemie GmbH, Austria; 25 mg/100 g body mass). Blood was rapidly collected by

TABLE 1A. Composition of experimental diets (%).

	C	C+I	SCN	SCN+I	NO_3	NO_3+I	NO_2	NO_2+I
Corn starch	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Caseine	10	10	10	10	10	10	10	10
Sucrose	10	10	10	10	10	10	10	10
Soybean oil	7	7	7	7	7	7	7	7
Celulose powder	5	5	5	5	5	5	5	5
Mineral mixture [a]	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Witamin mixture [b]	1	1	1	1	1	1	1	1
Choline	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Tert-butylhydrochinon	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
Iodine (μg/rat)	0	2	0	2	0	2	0	2
Alliloisothiocyanate			6	6				
Sodium nitrate (mg/100 g b.w.)					300	300		
Sodium nitrite (mg/100 g b.w.)							25	25

[a]AIN-93G mineral mixture, it contains 2 μg iodine/rat; [b]AIN-93G vitamin mixture.

TABLE 1B. Composition of experimental diets (%).

	CON	Se	$NaNO_2$	$NaNO_2$+Se	$NaNO_2$+Se+I
Corn starch	63.3	63.3	63.3	63.3	63.3
Caseine	10	10	10	10	10
Sucrose	10	10	10	10	10
Soybean oil	7	7	7	7	7
Celulose powder	5	5	5	5	5
Mineral mixture [a]	3.5	3.5	3.5	3.5	3.5
Witamin mixture [b]	1	1	1	1	1
Choline	0.25	0.25	0.25	0.25	0.25
Tert-butylhydrochinon	0.0014	0.0014	0.0014	0.0014	0.0014
Sodium nitrite (mg/100 g b.w.)			25	25	25
Iodine (μg/rat)					2
Selenium (μg/100 g b.w.)		3.59		3.59	3.59

[a]AIN-93G mineral mixture, it contains 2 μg iodine/rat; [b]AIN-93G vitamin mixture; [c] Na_2Se0_4.

cardiac puncture, transferred to centrifuge tubes with no anticoagulant, and serum was separated by low-speed centrifugation (1500 × *g*, 15 min). The serum samples were stored at -20°C until analysis. Thyroid glands were carefully excised and fixed in Bouin's fluid [Kiernan, 1990].

Analyses

Serum free thyroxine (fT_4) and serum thyroid stimulating hormone (TSH) concentrations were measured using the lumino-immunoassay LIA-mat F_4 kit (Byk-Sangtec Diagnostica GmbH&Co KG) and The IMMULITE Rat TSH Application kit (DPC Biermann GmbH), respectively.

Thyroid gland histological examination

A part of trachea with the thyroid gland on both sides were removed and fixed in Bouin's fluid for 3 days. Then the tissues were dehydrated in alcohol, embedded in paraffin and sectioned serially at 7 μm. For histological evaluation the sections were stained with: hematoxylin/eosin and trichrome and colloid were rendered visible by PAS reaction [Kiernan, 1990].

Statistical analysis

The effect of goitrogen treatments was analysed by two-way ANOVA generated by the STATISTICA version 6.1 package (StatSoft, Tulsa, OK.). Where appropriate, treatment means were compared using the Tukey's multiple range test and p values <0.05 and <0.02 were considered as showing a significant difference between treatment means.

RESULTS

Experiment 1

Body weight

The growth of rats (Figure 1A) was not affected by the potential goitrogens (allylisothiocyanate, nitrate and nitrite). In fact, the growth of rats receiving allylisothiocyanate, nitrate and nitrite, over the period of 18 days, was comparable with that of the control animals, irrespective of supplemental dietary iodine.

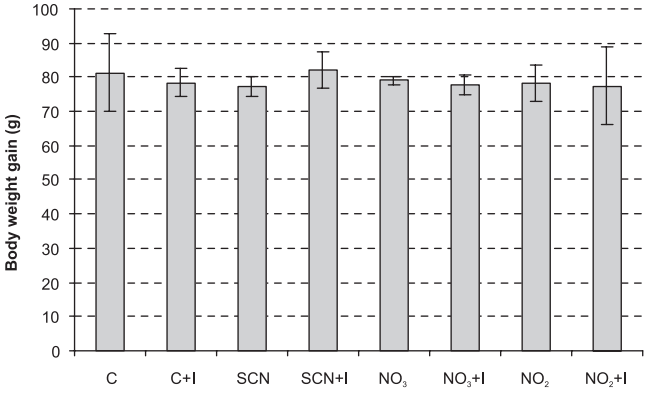

FIGURE 1A. The growth of rats from experiment I (g).

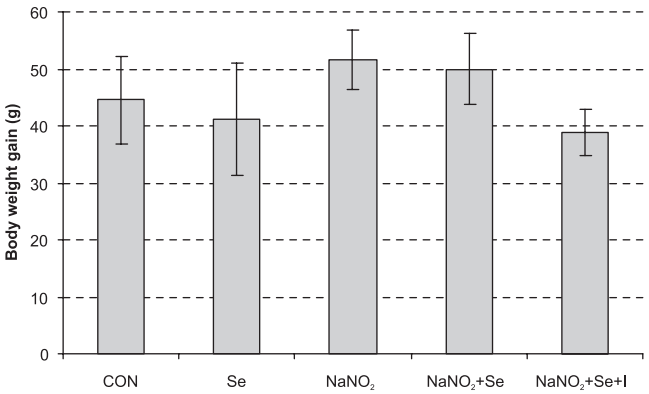

FIGURE 1B. The growth of rats from experiment II (g).

Serum free thyroxine (fT_4) and serum thyroid stimulating hormone (TSH) concentrations

Serum fT_4 concentrations tended to be reduced by allylisothiocyanate, nitrate and nitrite in rats (C – 24.6, SCN – 19.8, NO_3 – 21.8, NO_2 – 21.3 pmol/L, respectively), (Table 2). In contrast, serum TSH levels were significantly increased after administration of SCN ($p<0.02$) and NO_2 ($p<0.05$),

(Table 2). At the same time, the rats fed allylisothiocyanate, nitrate and nitrite and receiving iodine supplements (2 μg/day) (SCN+I, NO_3+I, NO_2+I) showed no changes in serum fT_4 and TSH concentrations (Table 2).

Thyroid follicle histology

The rats fed allylisothiocyanate (SCN), nitrate (NO_3) and nitrite (NO_2) showed a series of morphological alterations (Figure 2A and 3A) in their thyroid glands (high follicular epithelial cells and reduced amount of colloid). The height of the epithelial follicle cells was apparently increased in the thyroid gland of rats fed SCN, NO_3 and NO_2, compared with the control animals (C), thus indicating increased follicle activity (Figure 3A). In addition, mild to moderate irregularity of follicles and decreased amount of colloid were observed in the thyroid glands of rats fed SCN, NO_3 and NO_2. Moreover, the vascularity of the thyroid tissue from rats fed SCN, NO_3 and NO_2 was much more developed, compared with the control animals (C), (Figure 2A). Interestingly, the goitrogenic effects of SCN and NO_3 could be fully compensated by dietary iodine supplements. Namely, the rats fed SCN+I and NO_3+I those receiving iodine supplement (2 μg/d), showed no histological changes in their thyroid glands. In contrast, goitrogenic effects of dietary NO_2 in rats could not be alleviated by iodine supplement (2 μg/day). In more detail, in spite of iodine supplementation, the NO_2+I rats showed consistent histological changes in their thyroid glands, notably cell hyperplasia and hypertrophy.

Experiment 2

Body weight

The growth of rats was not affected by nitrite intake ($NaNO_2$) nor by Se ($NaNO_2$+Se) or Se+I supplements ($NaNO_2$+Se+I). In fact, the growth of rats receiving $NaNO_2$ over the period of 18 days was comparable with that of the control animals (CON), irrespective of dietary iodine or selenium (Figure 1B).

Thyroid follicle morphology

The histological examination of thyroid glands showed a series of morphological alterations after nitrite administration ($NaNO_2$) (high follicular epithelial cells and reduced amount of colloid). Equally, a series of morphological alterations was observed in thyroid glands of rats fed nitrite, receiving Se supplementation only ($NaNO_2$+Se). In contrast, the rats fed nitrite and receiving simultaneous selenium and iodine supplementation ($NaNO_2$+Se+I) showed similar thyroid morphology to those fed the control diet (CON) (Figure 2B).

TABLE 2. Serum fT_4 (pmol/L) and serum TSH (ng/dL) levels in rats after treatment with goitrogens in diets.

Group	Serum fT_4 (pmol/L)	Serum TSH (ng/dL)
C	24.58±1.98	1.91±0.22
C+I	28.08±3.19	2.25±0.27
SCN	19.77±1.08	2.98±0.29
SCN+I	19.36±1.60	2.23±0.10**
NO_3	21.85±1.48	1.66±0.11
NO_3+I	22.71±1.89	2.21±0.36
NO_2	21.31±1.99	3.09±0.58
NO_2+I	24.73±2.66	1.85±0.22*

Means followed by * are significantly different in column at * $p<0.05$; ** $p<0.02$.

DISCUSSION

In the present study, no negative effects of goitrogens (allylisothiocyanate, nitrate and nitrite) on body weight of rats were evidenced in Experiment 1. Also, iodine supplementation had no effect on body weight of these animals. The same was true for the effects of nitrite intoxication and the effects of iodine and selenium supplements in Experiment 2. These findings could result from too short experimental periods (18 days), during which the potential toxic effects of goitrogens were not manifested. In contrast to our findings, nitrate intoxication may severely suppress the growth of rats [Chow *et al*., 1980; Fritsch *et al*., 1980; Ogur *et al*., 2000; Zaki *et al*., 2004]. However, the above experiments were conducted for much longer periods of time (2–14 months). The same effect was reported in studies by Bilczuk [1976], Fritsch *et al*. [1980] and Chow *et al*. [1980], but again, these experiments were conducted for 6-14 months. The potential causes of above effects were either a reduction in food and water intake or an increase in protein catabolism or decreased plasma T_3 and T_4 concentrations revealed by the low plasmatic level of total proteins and the high level of the uraemia observed in this study, or by growth deceleration induced by the low plasma T_3 and T_4 levels [Zaki *et al*., 2004].

In the present study, the administration of goitrogens altered thyroid hormonogenesis by decreasing (insignificantly) serum fT_4 and increasing ($p<0.02$ for alliloisothiocyanate and $p<0.05$ for nitrite) serum TSH levels (Table 2). Similarly, Schone *et al.* [1991] showed that under iodine deficiency conditions, alliloisothiocyanate acts negatively on thyroid metabolism by decreasing T_4 concentration below detection level. This was also the case for T_3 concentration in pigs receiving potassium thiocyanate (a decrease from 1.18 to 0.25 nmol/L) [Schone *et al*., 1997]. The finding that dietary alliloisothiocyanate decreased T_3 concentrations can be explained by decreased iodine uptake by the thyroid gland. Langer & Štolc [1965] showed that adult rats (200 g) intoxicated with alliloisothiocyanate had a lower thyroid I^{131} iodine uptake, compared with the control animals. Similar findings were reported by Kahl & Bobek [1971]. In line with the above effects of alliloisothiocyanate, nitrate administration in drinking water significantly decreased plasma T_3 and T_4 levels in rats [Zaki *et al*., 2004]. In turn, serum fT_4 was decreased in rats intoxicated with nitrite [Kostogrys *et al*., 2006b]. The above effects of the studied goitrogens may be due to the inhibition of iodine transmembrane transport by a competitive iodine inhibitor (*e.g*. nitrate) to thyroid epithelial cells. The iodine binding may be blocked by nitrate either indirectly, *i.e.* by inhibition of Na+/K+ ATPase complex or directly, *i.e.* by inhibition of sodium-iodide symporter Na+/I– [Chung, 2002; Dohan & Carrasco, 2003],

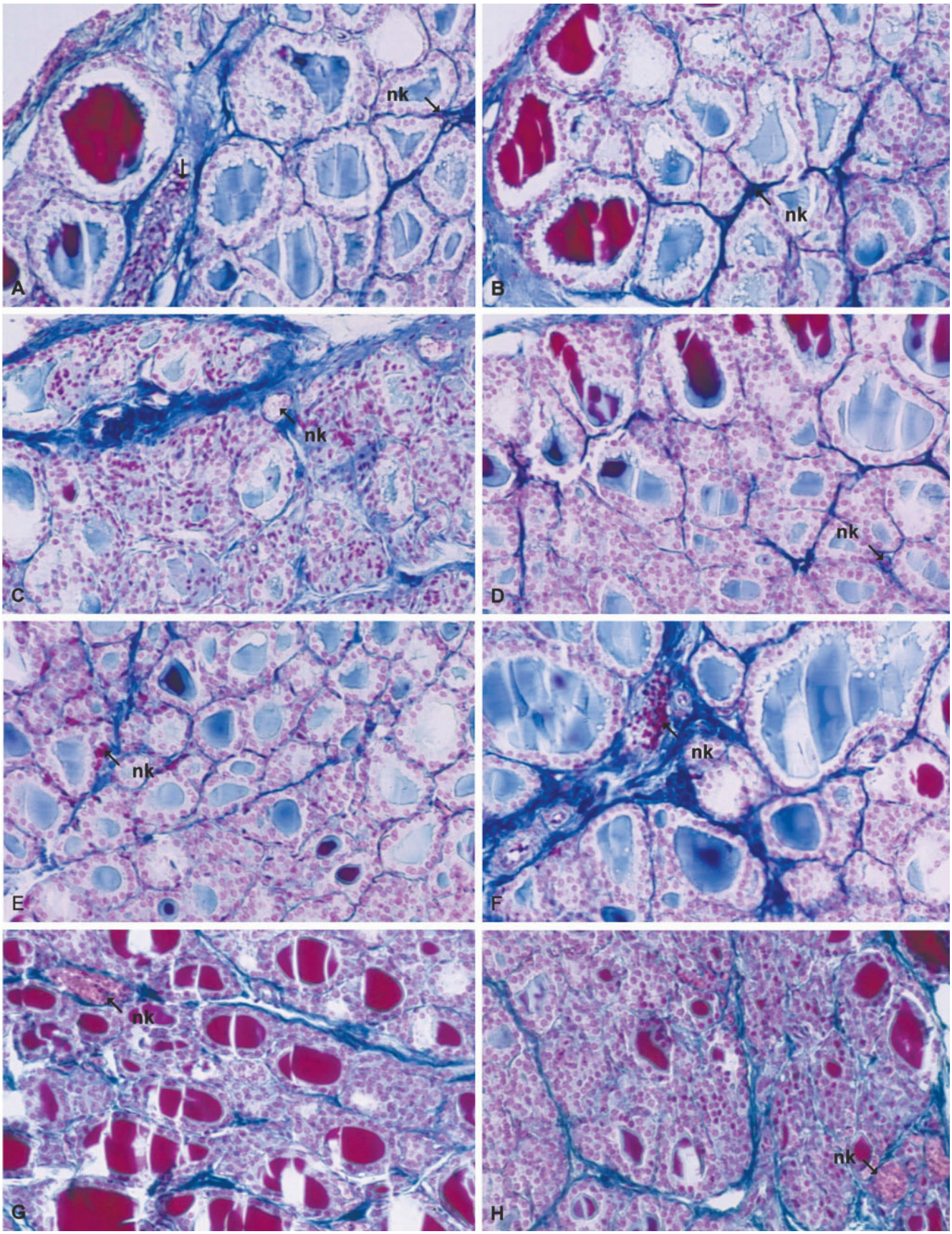

FIGURE 2A. Thyroid gland from experiment 1 stained with haematoxyclin/eosin (A – C group; B – C+I group; C – SCN group; D – SCN+I group; E – NO_3 group; F – NO_3+I group; G – NO_2 group; H – NO_2+I group; nk – blood vessels).

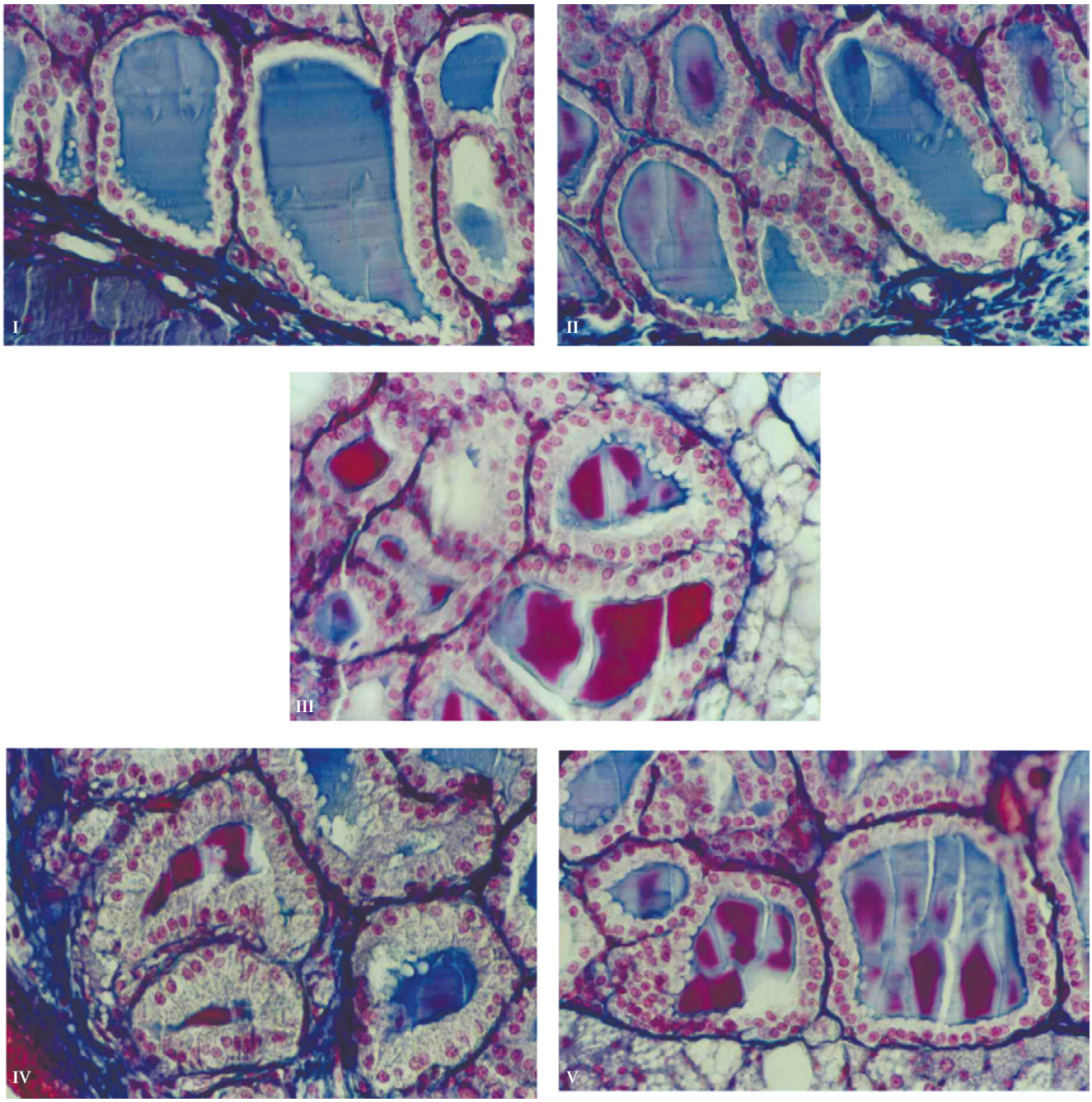

FIGURE 2B. Thyroid follicles stained with Pasini's trichrome (I – CON, II – Se, III – $NaNO_2$, IV – $NaNO_2$+ Se, V – $NaNO_2$ + Se+ I).

both involved in iodine trapping by these cells. The increased serum TSH concentrations, observed in our studies, could be expected. Namely, in a number of experiments, feeding animals with iodine-deficient diets decreased the concentrations of circulating fT_4 thyroid hormone and increased the release of TSH from the pituitary gland. Thus, the effects observed in our studies suggest the same negative feedback mechanism, involving the thyroid-pituitary hormonal axis, similar to that produced upon iodine deficiency [Kanno *et al*., 1992].

Administration of iodine supplement in Experiment 1, alleviated negative effects of allylisothiocyanate, nitrate and nitrite on thyroid hormonogenesis in rats. However, in spite of this, thyroid morphology was negatively affected by nitrite intoxication (see below).

Goitrogen treatments led to changes in thyroid gland morphology in rats, in Experiments 1 and 2 (Figures 2A, 3A, 2B). In fact, allylisothiocyanate, nitrate and nitrite intoxication resulted in both hyperplasia and hypertrophy of the thyroid gland. The height of the epithelial follicle cells was increased, mild to moderate irregularity of follicle was found, and a decrease in the amount of follicular colloid was observed, in the intoxicated animals. These changes were essentially the same as in iodine-deficient animal models. For example, long-term administration of a low iodine diet has been reported to cause follicular hyperplasia and hypertrophy in rats [Kanno *et al*., 1992], similar to that observed in our studies. Thus, the observed effects suggested the same negative changes in thyroid morphology as produced by io-

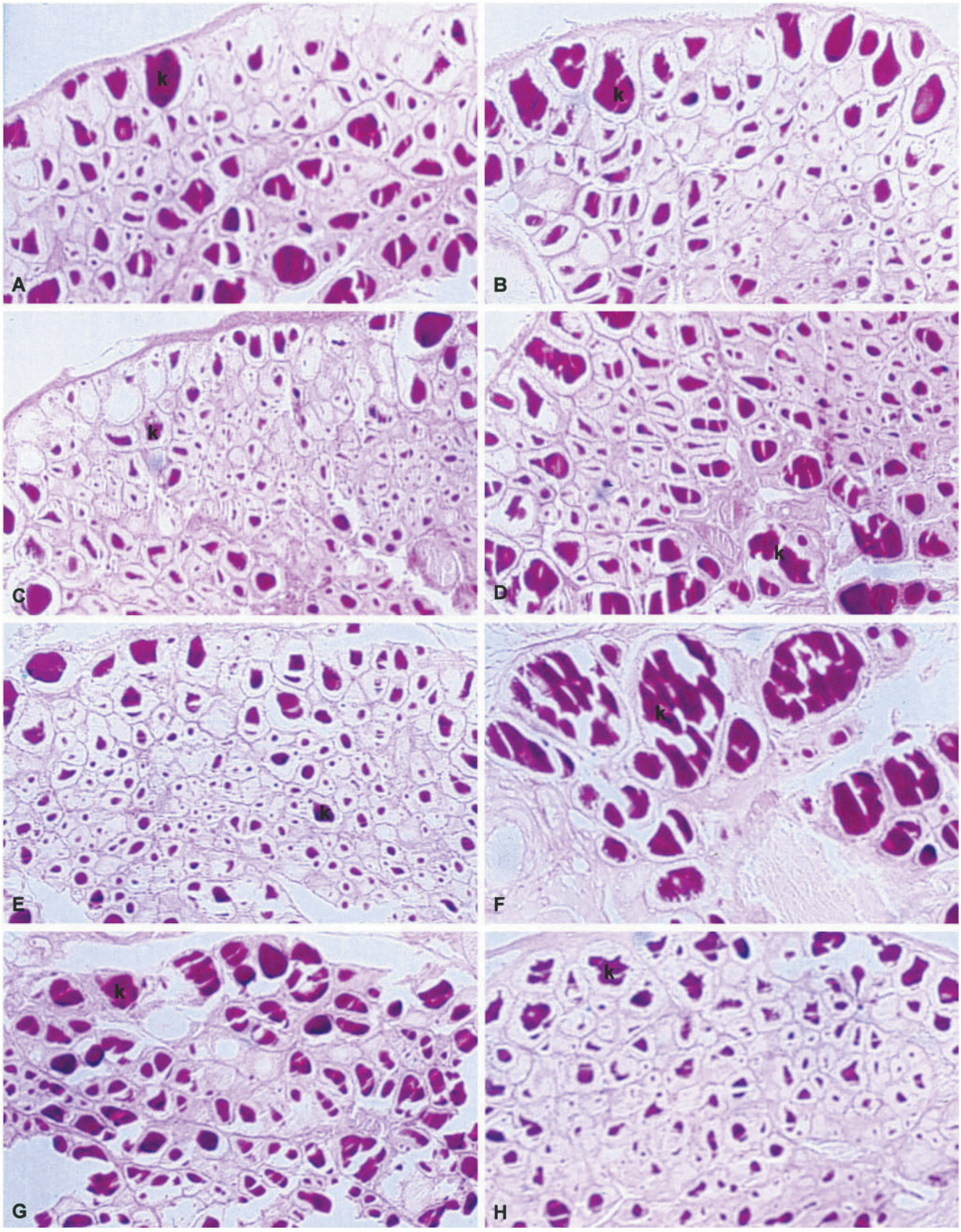

FIGURE 3A. Thyroid gland from experiment 2 stained with PAS (A – C group; B – C+I group; C – SCN group; D – SCN+I group; E – NO_3 group; F – NO_3+I group; G – NO_2 group; H – NO_2+I group; k – colloid).

dine deficiency [Kanno *et al*., 1992]. Moreover, in fish intoxicated with glucosinolates [Burel *et al*., 2000], the height of the epithelial follicle cells was increased (by 200%) and the amount of follicular colloid was decreased, compared with the control animals. Also, Langer & Štolc [1965] found that in iodine-deficient rats, allylisothiocyanate intoxication (2.5 and 5 mg per animal) significantly increased thyroid weight-defined as a goitrogenic effect. This effect of alliloisothiocyanate can be explained by increased TSH secretion, leading to the proliferation of thyroid cells, as observed under iodine deficiency conditions [Hurrell, 1997; Lee *et al*., 1999]. In nitrate intoxicated rats [Mukhopadhyay *et al*., 2005; Eskiocak *et al*., 2005], the weight of thyroid glands was increased significantly, compared with control animals. In addition, morphological changes were observed in thyroid glands [Eskiocak *et al*., 2005]. Surprisingly and in contrast to our observations, nitrate intoxication in rats [Zaki *et al*., 2004] flattened follicular epithelium (by 50%) and increased the amount of follicular colloid, compared with the control animals. The potential causes of these opposite observations could involve the duration of nitrate intoxication in our experiments, *i.e.* 18 days, and 5 months in that of Zaki *et al*. [2004] as well as the level of nitrate intoxication. In view of the above, allylisothiocyanate, nitrate and nitrite may be considered as competitive inhibitors of iodine binding by thyroid gland, thus affecting the thyroid-pituitary hormonal axis and changing thyroid morphology, in a way similar to that of iodine deficiency.

Administration of iodine supplement in Experiment 1, alleviated goitrogenic effects of allylisothiocyanate and nitrate in rats and was ineffective in animals intoxicated with nitrite. Interestingly, the goitrogenic effects of nitrite could be alleviated only by administration of iodine and selenium, as observed in Experiment 2. To offer an explanation, nitrates and nitrites are both oxidation products and ready sources of nitric oxide (NO). NO reacts rapidly with superoxide to form highly reactive peroxynitrite (ONOO-). High nitrite and nitrate intake is linked with an increased oxidative stress [Ogur *et al*., 2005]. Iodine and selenium are essential components of normal thyroid hormone metabolism and are involved in the modulation of the antioxidant defense system. It is known that the generation of H_2O_2 is inhibited by iodine *in vitro* and *in vivo* [Preedy *et al.,* 2009]. Because nitrite is more toxic than nitrate, iodine is not sufficient to alleviate the goitrogenic effects. Combined iodine and selenium supplementation is implicated to have alleviating properties in nitrite intoxicated animals.

CONCLUSIONS

Allylisothiocyanate, nitrate and nitrite have no effect on the growth of rats in 18-day experiments. On the other hand, intoxication of rats with allylisothiocyanate and nitrate impairs thyroid hormonogenesis and leads to thyroid hypertrophy. In addition, the goitrogenic effects of these ions can be alleviated by iodine supplementation. In contrast, the goitrogenic effects of nitrite intoxication in rats can be alleviated only by concomitant supplementation of iodine and selenium.

ACKNOWLEDGEMENTS

There is no conflict of interest. RBK – research and writing. PMP – comments. AP – research. The study was supported by the State Committee for Scientific Research, grant No. 6 P06T 040 21, Young Investigator Awards, TEMA 2002.

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Received April 2009. Revision received November 2009 and accepted March 2010.