The Effect of Iodine Drenching During Late Pregnancy on Thyroid Hormones and Biochemical Parameters of Black Goats and Their Kids Performance

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SUMMARY

The objective of the current experiment was to evaluate the influence of Iodine drenching during late pregnancy on thyroid hormones and biochemical parameters in Black goats and their kids performance. Pregnant black goats (n=24) were used in this study. Goats were drenched with potassium iodide (KI) based on 76% of Iodine with 0 mg KI/day (control; C), 0.50 mg KI/day (treatment one; T1) as low iodine group and 1.00 mg KI/day (treatment two; T2) as high iodine group. Blood was collected weekly from goats at week six before parturition and to parturition and 1st week of age from kids. Serum was separated from blood samples and analyzed for serum content of iodine, thyroid stimulating hormone (TSH), triiodothyronine (T3) and thyroxine (T4) and biochemical parameters of goats and their kids. The concentration of TSH was higher ($p<0.019$) in C group. Both T3 and T4 concentration were higher ($p<0.001$) in T1 and T2. There was no effect of KI drenching on TSH, T3 and T4 in kids. Total protein and glucose were significantly higher in T2 group compared with C group, while triglyceride was significantly more in C group compared with T1 and T2 groups. Higher level of glucose was recorded in T2 group, while higher level of cholesterol was recorded in C group of kids compared with other groups. Kids body weight were higher ($P<0.001$) in T2 groups compared with T1 and groups C. In conclusion, in response to KI drenching TSH level declined in T1 and T2, while remained higher in C group of late pregnant goats. Iodine drenching can improve total protein and glucose and also regulate T3 and T4 in the goat. Iodine drenching of pregnant goat can also increase new born kids body weight.

KEY WORDS

Iodine drenching; Late pregnancy; Black goats; Milk; Biochemical.

INTRODUCTION

Iodine is one of the essential components of thyroidal hormones for the synthesis of the thyroid hormones thyroxine (T4) and triiodothyronine (T3; Nudda et al., 2009) and through which it is involved in a number of biological functions of the animals (Dušová et al., 2014). There exists a great deal of evidence that it is the free or unbound portion of the circulating thyroid hormone that is accessible to the tissues of the animal body and its effect on their metabolism and functions (Todini, 2007). The T4 and T3 hormones contribute to the maintenance of protein and energetic metabolism homeostasis in the animal body; they influence body growth, thermoregulation and biochemical metabolites (Huszenicza et al., 2002). Low iodine concentrations in livestock feeds of high altitude area causes a long-term deficiency of iodine in traditional animal farms and their new born kids' performance (Dušová et al., 2014).

The deficiency of I is more prevalent primarily in high mountain regions and the area that were covered with Ice of the world such as the Himalayas mountain (Nyström et al., 2016; Pachuri, 1981), the European Alps, and the Andes, this may be due to the fact that the I has been washed away by glaciations, soil erosion and flooding as a result of high raining levels (Mercer, 2006). A deficiency of iodine also leads to hypothyroidism, which causes reduced immunity and inhibits physiological status of animal such as an effect on milk components, hormones and blood biochemical parameters (Sokkar et al., 2000; Nudda et al., 2009). Iodine deficiency has a significant impact on the unborn' mental and physical development; severe I deficits can lead to cretinism (Hetzel, 1983). As a result of insufficient food availability during late pregnancy and minerals such as I, does may lose weight, in active immunity (Osuagwuh, 1992), low growth rate and reproductive consumption such as an increase in the rat of abortion and neonatal mortality due to low birth weight of kid (Cappai et al., 2019).

The iodine requirement is usually higher in goats than in other ruminant animals: a dietary iodine concentration considered inadequate for goats (Meschy, 2000; Oramari et al., 2014). Due to its browsing behavior and lower soil consumption compared with other grazing animals, the goat is regarded

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as an indicator species of I deficiency (Smith and Sherman, 2009) because goats as browsers breeds are preferring to eat leaves, twigs, vines and shrubs (Lovreglio et al., 2014).
Even though the use of an iodine supplement in goats should be a common practice, a large database on iodine requirements in goats is not available. In accordance with NRC (2007) the recommended concentration of dietary iodine is 0.5 mg/kg of DM of the diet in growing and non-lactating goats and 0.8 mg/kg of DM for goats; however, these recommendations are based on a limited number of data base (Nudda et al., 2009). Black goats are mainly raised as a double purpose animal for meat and milk, in addition to secondary importance for hair production (Zebari et al., 2013; Juma and Al Kass, 2005). There are limited published study on the effect of Iodine drenching on black goats and their new born kids raised under traditional conditions. Therefore, the objective of the present study was to evaluate the effect of Iodine drenching during late pregnancy on thyroid hormones and serum biochemical parameters in black goats and their new born kids performance.

MATERIALS AND METHODS

The present study was conducted between 15th of November 2021 and 20th of January 2022 at one of the traditional goat farms, Zawita, Duhok, Kurdistan Region-Iraq. The Research Ethics Committee of Animal Production Department, College of Agricultural Engineering Sciences, University of Duhok approved the research protocol.

Experimental animal, housing and management

Pregnant black goats (N=24) with body weight (34.81±2.4kg) and ages (3.15±1.2 years) were used in the present study from six weeks before and one week after parturition at one of the traditional goat farm, Zawita, Duhok, Kurdistan Region-Iraq. At the start of the study, the goats were submitted for detection of any disease. The goats were kept with the main flock. The goats were put out to graze during the day from 06:00 am to 06:00 pm and housed in a free stall yard during the night. During housing, total mixed ration (TMR; hay, barley and wheat barn) was provided daily, sufficient for *ad libitum* availability. Nutrient content of the total mixed ration were Dry matter (DM) (88.79%), CP (11.16% DM), CF (23.4% DM), Fat (2.1% DM), NFE (46.34% DM), ash (5.79% DM), ME (2196.91 kcal/kg) and moisture (11.21%). Water was also provided *ad libitum* from water troughs at the free stall yard.

Pregnancy Diagnoses and Treatments

At the start of the study, pregnant goats were selected from the main herd using Veterinary Ultrasound Scanner (CD66V; Zhuhai Carellfe Medieal Technology Co., Ltd, China). The goats were randomly divided into three experimental homogeneous groups (n=8 per group) on the basis of live body weight (35.66±2.1 kg), (34.66±2.1 kg) and (34.11±2.1 kg).
Each goat was supplemented with potassium iodine (KI; Chem-Lab NV, Industriezone, B-8210 Zedelgem, Belgium) with 0 mg I/day (Control), 0.50 mg I/day (Treatment one; T1) as low iodine group and 1.00 mg I/day (Treatment two; T2) as high iodine group. The dose of KI was dissolved in water and then orally drenched daily each goat at 4:00 pm using a manual syringe gun six weeks before parturition (late pregnancy period) until parturition.

Blood Collection and analytical techniques

Blood samples were collected from goats weekly from week six (6±0.7 SD) pre-partum. Blood collected from goats by jugular venipuncture using a 20 G needle syringe into 10ml vacuutainer tubes (Medicalet, Pingshan New District, Shenzhen City 518118, China). Blood samples were also taken from their new born kids (n=26) with a body weight of (4.25±0.6 kg). Blood samples were centrifuged at 6000g for 12 min using a SIGMA centrifuge (SIGMA Osterode am Harz, Germany). Serum was separated and stored at -20°C until analyzed for hormonal and biochemical parameters analysis. Serum T3, T4 and TSH and biochemical parameters (total protein, glucose, cholesterol, triglyceride, HDL and LDL) of goats and their newborn kids were analyzed by cobas 6000 (Hitachi High-Technology Corporation, Tokyo, Japan).

STATISTICAL ANALYSES OF DATA

The data were statistically analysed using Genstat statistical analysis software package (Genstat V 14th.19.1.14713 provided by VSN International Ltd, UK). Repeated measures ANOVA was used to analyze the data of serum TSH, T3, T4 and T3/T4 ratio and biochemical parameters of goats and to compare between treatments. Factorial one-way ANOVA analysis were used to compare between the datasets of serum TSH, T3, T4 and T3/T4 ratio, body weight and biochemical parameters of the newborn kids. The comparison between C, T1 and T2 was analyzed by Tukey test. Differences were reported as significant at $P<0.05$ and trends were reported when P-values were between <0.1 and >0.05.

RESULTS AND DISCUSSIONS

Effect of KI drenching on Thyroid stimulating hormone (TSH) in goats

There was a significant influence of time ($p<0.019$) on serum TSH concentration in goats during the study period (Figure 1). There was a significant increase in TSH from week three of treatment (W-4 before parturition) in groups C with progress in pregnancy period. These results are in constant with previous studies conducted by Bhardwaj (2018) and Singh *et al.* (2002). There was also a significant impact ($p<0.018$) of KI supplementation on serum TSH concentration. Significantly higher TSH (mean±SEM) concentration was recorded in C group (0.093±0.02 IU/mL) compared with T1 (0.062±0.01 IU/mL) and T2 (0.033±0.01 IU/mL) group of goats. The results of the present study agree with those reported by Davoodi *et al.* (2022) who found higher serum TSH levels in the iodine deficiency group of goats compared with the treated group of goats. Previously, it has been studied levels of TSH in the goats with hypothyroidism by Kadum and Luaibi (2017) and observed that levels of TSH were significantly lower in iodide treated group compared with control group. The level of TSH concentrations has been used as an indicator that reflects the deficiency of the dietary iodine intake by animals, with higher concentrations of TSH being revealing of lower iodine intake. While there was time and treatment interaction effect (p=431) on TSH levels.

The higher concentration of TSH in groups C may be due to that the iodine deficiency in the body leads to the overproduction of the TSH from the pituitary gland and the attempt of the thyroid to compensate for the deficiency in the thyroid hormones (Singh et al., 2002; Davoodi *et al.*, 2022). Inadequate amount of I in the thyroid gland lead to production of un-iodinated inactive prehormone compound instead to T4 which results the stimulation of pituitary gland to secret more TSH (Bhardwaj, 2018).

Effect of KI drenching on T3 and T4 hormone and T3/T4 ratio in goats

The data of serum T3 and T4 concentration and T3/T4 ratio are reported in Table 1. Regarding serum T3 concentration, there was a significant impact ($p<0.001$) of time on serum T3 hormone concentration during late pregnancy period of goats. There was an increase in serum T3 hormone level in both T1 and T2 groups during experiment progress. Similarly, an increase in T3 levels was found with progress in weeks of sampling in wool goats fed supplemented with Iodine (Pattanaik *et al.*, 2004). However, in contrast to the present results Todini (2007) and Nudda *et al.* (2013) found a slightly decrease in T3 concentration with advanced sampling weeks in lactating goats. These may be due to that Todini (2007) and Nudda *et al.* (2013) used goats during the lactating period rather than pregnant goats. While there was a fluctuation in the level of serum T3 hormone in C group. There was also a significant effect ($p=0.042$) of KI treatment on the level of T3 hormone, serum T3 level was higher in T1 and T2 groups compared with C group of goats. These results are agreed with those reported by Nudda *et al.* (2013) who found higher ($p<0.001$) T3 serum concentration in lactating goats fed diet with high iodine (0.90 mg of KI/day) compared with low iodine (0.0 mg of KI/day). Concerning the data related to serum T4 hormone, time had a significant effect ($p<0.001$) on the serum T4 hormone throughout the experiments period. There was also an effect ($p=0.035$) of KI drenching on the level of serum T4 hormone. Higher levels of serum T4 hormone were recorded in T2 group of goats that were supplemented with 1.0 mgKI/day compared with C group of goats. Similarly, Zarbalizadeh-Saed *et al.* (2020) found a higher ($p<0.05$) serum concentration of T4 in ewes supplemented with 0.4 mg of I per day compared with zero level of I supplementation. Nudda *et al.* (2013) also found a higher ($p=0.059$) serum concentration of T4 in lactating goats supplemented with KI compared with the control group. While, there was no significant different between T1 and T2 group of goats. Higher level of T4 concentration in T2 groups of goats received 1.0 mg/KI/day may be due to increased iodine titration for T4 synthesis in thyroid gland.

There was no significant effect of time ($p=0.398$) and KI treatment on the T3/T4 ration in serum of goats during late pregnancy. There was also no impact of time and treatment interaction on the serum T3 ($p=0.541$) and T4 ($p=0.803$) hormone and T3/T4 ration ($p=0.399$) of goats during late pregnancy. These results are in constant with those reported by Zarbalizadeh-Saed *et al.* (2020) who observed no significant difference ($p>0.05$) in T3/T4 ratio between (0.0 mg I/d) and (0.4 mg I/d) supplemented to ewes during pregnant period.

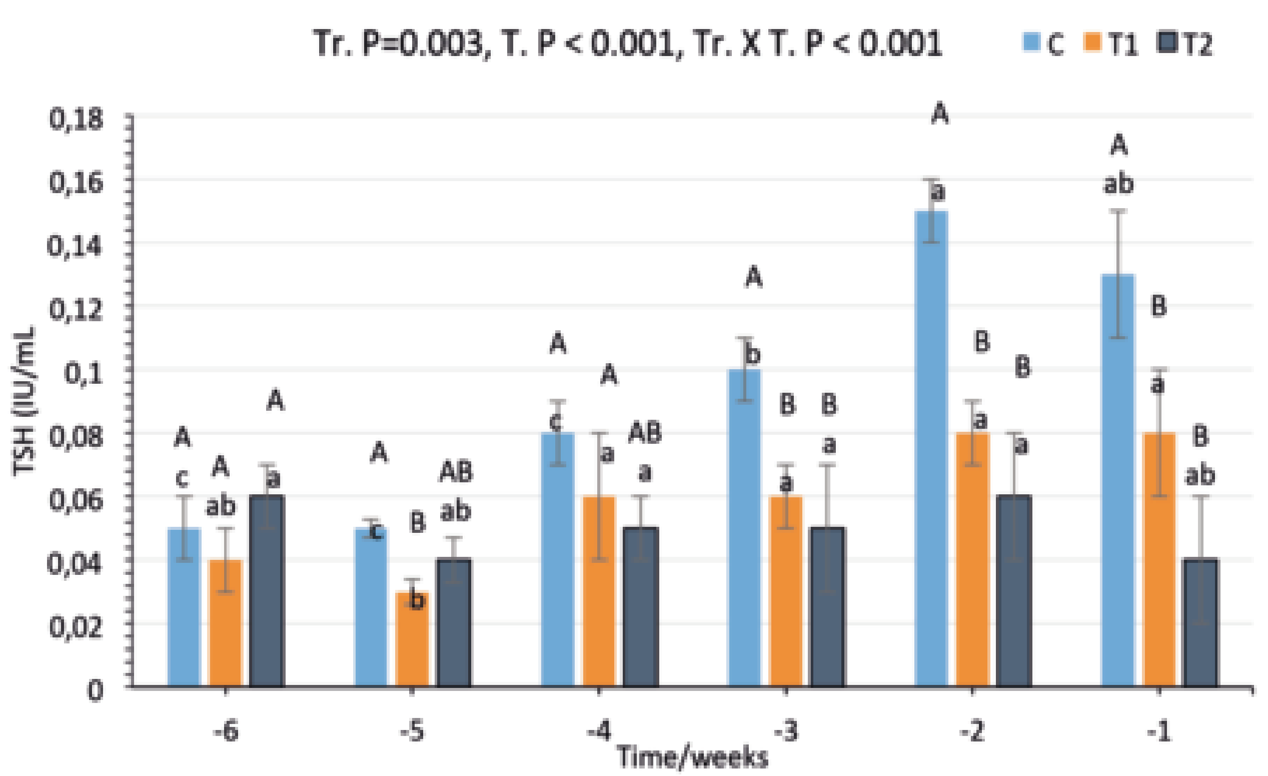

Figure 1 - The effect of I doses on serum thyroid stimulating hormone (TSH) of black native goats. Tr.=treatment, T.=time, Tr.xT.=treatment and time interaction, C=control (no I supplementation; 0 mg Zn/day), T1=Treatment one (0.50 mg I/day), T2=Treatment two (0.1 mg I/day), Error bars indicate SEM. AB– Letters with superscript is significantly regarding the effect of treatments. abc– Letters with superscript is significantly regarding the effect of time/week of treatments.

Table 1 - The effect of KI doses on serum T3 and T4 hormone and T3/T4 raio of black native goats.

Parameters	Tr.	Overall means	Time/weeks						P Value		
			-6	-5	-4	-3	-2	-1	Tr.	T.	Tr. x T.
T3 (nmol/L)	C	2.3±0.2[b]	2.4±0.3	2.7±0.2	2.2±0.4	2.3±0.5	2.4±0.4	2.0±0.4	0.042	<0.001	0.541
	T1	2.5±0.3[a]	2.1±0.2	2.5±0.4	2.5±0.3	2.6±0.5	2.7±0.2	2.8±0.3			
	T2	2.6±0.3[a]	2.3±0.2	2.4±0.4	2.5±0.3	2.6±0.2	2.8±0.7	2.9±0.3			
T4 (nmol/L)	C	101.2±11.3[b]	112.5±9.4	105.4±13.8	94.3±9.9	108.7±9.8	96.1±12.3	89.9±12.8	0.035	<0.001	0.803
	T1	106.1±11.8[ab]	97.6±14.6	98.1±5.5	99.7±8.3	110.4±33.8	114.3±22.6	116.3±10.0			
	T2	114.4±12.3[a]	100.2±12.8	103.1±14.7	114.1±12.9	112.6±13.2	127.7±21.2	128.7±9.4			
T3 and T4 (%)	C	0.023±0.002	0.021±0.003	0.023±0.003	0.021±0.001	0.022±0.003	0.024±0.002	0.026±0.004	0.398	0.331	0.399
	T1	0.023±0.002	0.021±0.004	0.023±0.002	0.023±0.003	0.023±0.003	0.025±0.002	0.025±0.001			
	T2	0.23±0.002	0.021±0.002	0.023±0.002	0.024±0.002	0.024±0.004	0.024±0.002	0.022±0.003			

Tr.=treatment, T.=time, Tr.xT.=treatment and time interaction, T3=Triiodothyronine, T4=Thyroxin, C=control (no I supplementation; 0 mg Zn/day), T1=Treatment one (0.50 mg I/day), T2=Treatment two (0.1 mg I/day). Overall means with different superscript letters differ (*p*<0.05).

However, Nudda *et al.* (2012) found a significantly higher (P<0.001) T3/T4 in lactating goats supplemented with KI compared with control group, this may be due to that Nudda *et al.* (2013) used goat during different physiological status.

Effect of KI drenching on serum biochemical parameters of black native goats

The effect of KI drenching on serum biochemical parameters are illustrated in Table 2. Potassium Iodine drenching had a significant effect (p=0.045) on serum total protein (g/dl). Significantly higher total protein was recorded in T2 group of goats compared with C group, while there were no differences between T2 and T1 groups. These results agree with those reported by Abozed et al. (2020) who found that the treated group of ewes had a significantly higher concentration of serum total protein (6.43 ± 0.13 g/dl) compared with control group (5.65 ± 0.20 g/dl). Likewise, previous studies also found higher serum total protein in I supplemented group of sheep compared with the control group (Zeedan et al., 2010; Dušová et al., 2014). The higher levels of total protein in KI drenching groups of goats during late pregnancy may be due to that I supplementation increased the level of thyroid hormones both T3 and T4 hormones which in turn the thyroid hormones participate in the maintenance of the level of total protein (Huszenica et al., 2002). However, Pattanaik et al. (2011) found no significant effect of iodine (0.1 mg I/day) supplementation on total protein concentration (8.98 g/dl) in serum compared with control group (8.65 g/dl) of indigenous adult goats. This may be due to fact that in the present study were used goats that were in the late

Table 2 - Serum biochemical parameters (Means ± SEM) in response to Potassium Iodine (KI) drenching from week -6 to parturition in black native goats.

Parameters	Tr.	Overall means	Time/weeks						P Value		
			W-6	W-5	W-4	W-3	W-2	W-1	Tr.	T.	Tr. x T.
Total protein (g/dl)	C	6.6±0.2b	6.4±0.4	6.9±2.0	6.7±0.4	6.7±0.4	6.6±0.5	6.4±0.2	0.048	0.363	0.547
	T1	7.0±0.2ab	7.4±0.3	7.1±0.3	6.8±0.2	6.9±0.4	6.8±0.3	6.8±0.2			
	T2	7.4±0.2a	7.7±0.4	7.4±0.5	7.5±0.2	7.4±0.1	7.3±0.2	7.2±0.3			
Glucose (mg/dl)	C	56.2±1.8b	58.2±1.9	56.3±3.3	56.5±4.1	54.5±2.9	57.8±5.7	53.7±2.8	0.037	0.137	0.446
	T1	59.9±2.3a	58.3±2.7	57.0±3.1	59.8±5.6	57.0±3.8	60.5±7.8	62±2.3			
	T2	60.6±1.7a	61.7±5.9	58.2±3.2	61±3.3	59.5±1.2	60±6.0	61.2±4.1			
Cholesterol (mg/dl)	C	85.5±9.3	70.5±10.9	83.8±20.2	81.2±9.7	86.8±6.9	91.2±14.8	99.2±8.1	0.894	<.001	0.349
	T1	84.6±10.5	66±9.8	83.3±13.0	90.8±14.1	84.2±10.6	85.7±10.8	97.5±11.3			
	T2	81.8±9.0	66.5±12.5	84±14.8	79±7.1	81.2±9.4	86.8±12.0	93.2±8.6			
Triglyceride (mg/dl)	C	24.0±6.3b	15.3±6.9	19.3±13.5	21.2±9.2	27.2±9.0	30±4.4	30.8±16.7	0.015	<.001	0.644
	T1	24.3±5.8b	20.5±1.9	17.5±10.4	21.7±12.7	23.83±9.9	29±6.6	33±8.0			
	T2	31.6±6.5a	26.8±12.6	25.3±5.8	29±5.4	29.7±13.7	36.7±15.9	42.3±9.6			
HDL (mg/dl)	C	52.5±4.6	45.17±5.4	52.8±9.8	49.8±5.0	52.8±6.5	56.5±5.6	57.7±4.1	0.172	<.001	0.623
	T1	52.0±4.6	45.33±6.0	50.2±5.5	57±7.8	49.2±5.6	53.7±4.3	56.8±5.0			
	T2	55.1±8.7	46.0±8.7	50.7±7.3	59.7±10.2	56.2±9.6	63.3±9.1	71.8±10.2			
LDL (mg/dl)	C	30.1±5.2	20.7±3.9	29.7±7.7	30.7±3.0	30.7±7.2	32±6.4	36.5± 7.7	0.721	<.001	0.352
	T1	33.9±6.1	24±12.1	31.2±4.2	33.7±5.8	34.5±5.8	37.8±11.9	42±5.7			
	T2	34.4±6.7	27±8.0	32.3±14.3	31.3±11.9	32±4.7	37.5±4.4	46.3±3.0			

SEM=standard error of means, C=control (0 mg I/day), T1=treatment one (0.5 mg I/day), T2=treatment two (1.0 mg I/day), W=week, Tr.= treatments and T=time. Means with different superscript letters in overall means columns differ (*p*<0.05).

pregnancy period, while Pattanaik et al. (2011) used adult non-pregnant goats.

Glucose was significantly (p=0.037) higher in group T2 (60.6±1.7 g/dl) compared with group C (56.2±1.8 g/dl), while there was no significance different between T2 and T1 (59.9±2.3 g/dl) groups. Similar to the finding of the present study, it has been reported that the concentration of serum glucose increased with iodine supplementation. Zeedan et al. (2014) found that glucose concentration was significantly (p<0.05) higher with iodide supplementation in Buffalo. Furthermore, El-Salaam et al. (2018) reported higher glucose levels in supplemented KI of pregnant camels during pre and post-partum periods compared with control groups. An increase of serum concentration of total protein glucose and their fractions may be attributed to increasing thyroid hormones, which leads to stimulate the basal metabolic rate through regulation of the carbohydrates and proteins metabolism in the animal body (Lawrence and Fowler, 1997). Dandan Wang et al., (2021) reported a relationship between iodine status and blood glucose. There was also no significant effect of KI drenching on cholesterol (mg/dl). In contrast to the results of the present study, Pattanaik et al. (2011) reported a significantly lower serum cholesterol concentration in I supplemented group (149.04 mg/dL) compared with control group (132.55 mg/dL). However, the period of treatment of KI drenching had a significant effect (p<0.001) on cholesterol; the higher concentration of cholesterol was recorded in week -1 before parturition in group C. Kaneko (1997) reported a negative relationship between iodine (thyroid) status and serum cholesterol concentration.

Triglyceride (mg/dl) was higher (p=0.015) in T2 (31.6±6.5 mg/dl) in comparison to groups C and T1. Significantly higher concentrations of triglyceride were recorded in week -1 before parturition (42.3±9.6 mg/dl) in group T2 compared with other weeks of other groups. Previously, similar to the present results, Xia et al. (2013) observed a significant increase in the serum triglyceride level in I drenching mice group compared with control group. Xia et al. (2013) also found a positive association by the correlation of the dose dependent increase of serum triglyceride content (r00.498, p<0.01) and serum triglyceride concentration in iodine-loaded groups. An increase in serum triglyceride may be due to that the liver playing a pivotal role in systemic lipid homeostasis (Xia et al., 2013). The increased triglyceride concentrations observed in the serum of goats drenched with high iodine (1.00 mg KI/d) group could result from the significant up-regulation of the sterol regulatory element-binding protein 1c (SREBP-1c) and its target gene fatty acid synthase (FAS) which are involved in the synthesis of triglycerides. The SREBP- 1c is one of the three isoforms of the SREBP family. SREBP- 1c is involved in the regulation of triglyceride metabolism in the liver as a transcription factor. It stimulates transcription of the genes associated with fatty acid biosynthesis, such as acetyl CoA carboxylase and FAS and plays a crucial role in the development of fatty liver (Ahmed, 2007; Shimano et al., 2013)

Serum HDL (mg/dl) was not significantly affected by KI drenching comparing the overall means. While the period of KI drenching had a significant (p<0.001) effect on HDL concentration, the higher concentration of HDL in serum was recorded in week -1 before parturition in group T2 (71.8±10.2 mg/dl) in comparison to other weeks of different groups of the studied goats. There was also no significant effect of KI drenching on LDL concentration (mg/dl) comparing the overall means. The significantly higher serum LDL was recorded at week -1 (42±5.7 mg/dl) and (46.3±3.0 mg/dl) before parturition in T1 and T2 groups, respectively in comparison to other weeks of different groups of goats. These results agree with those reported previously by Barcelos et al. (2022) who found that HDL and LDL were increased with an advance in time of mineral and vitamin E supplementation in goats. An increase in LDL at the last week of treatment may be due to that triglyceride could be stored as lipid droplets in the liver of the pregnant goats and secreted a triglyceride-rich lipoprotein known as very low density lipoprotein (Davis, 1999). There looks to be a compensatory response in the liver. Due to the increased levels of triglyceride in the liver, the more triglyceride is converted into very LDL and secreted into the animal blood (Xia et al., 2013). There was no significant effect of treatment and time interaction on all serum biochemical parameters.

Effect of KI drenching in black goats during late pregnancy TSH, T3 and T4 hormone and T3/T4 ratio of newborn kids

The data related to newborn kid's hormone which include TSH, T3, T4 hormone and T3/T4 ratio are shown in Figure 2, 3, 4

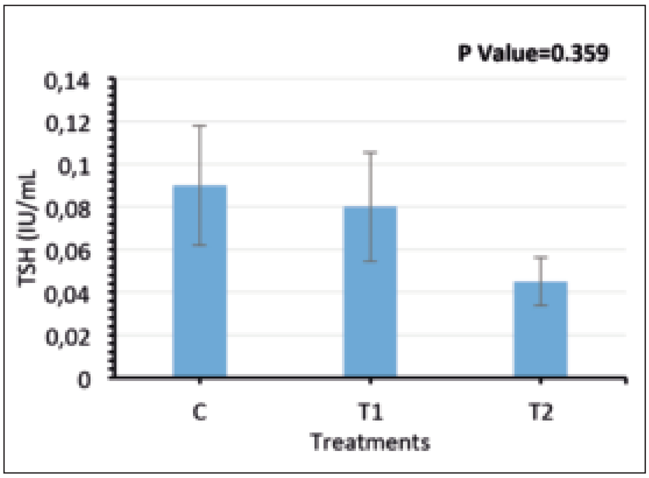

Figure 2 - The effect of I doses on serum thyroid stimulating hormone (TSH) of newborn kids. C=control (no I supplementation; 0 mg Zn/day), T1=Treatment one (0.50 mg I/day), T2=Treatment two (0.1 mg I/day), Error bars indicate SEM.

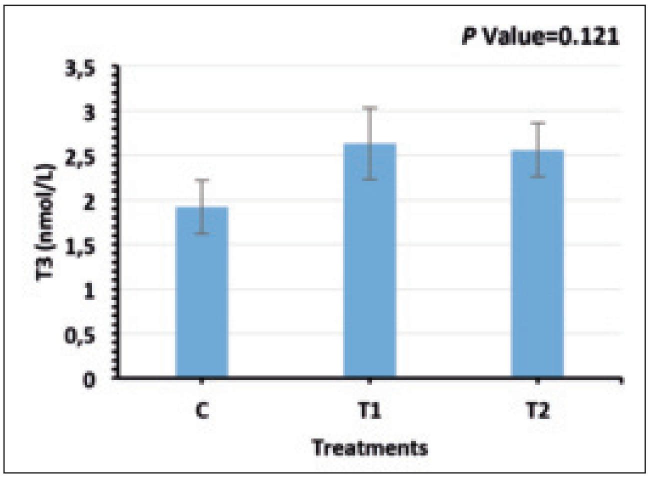

Figure 3 - The effect of I doses on serum triiodothyronine (T3) of newborn kids. C=control (no I supplementation; 0 mg Zn/day), T1=Treatment one (0.50 mg I/day), T2=Treatment two (0.1 mg I/day), Error bars indicate SEM.

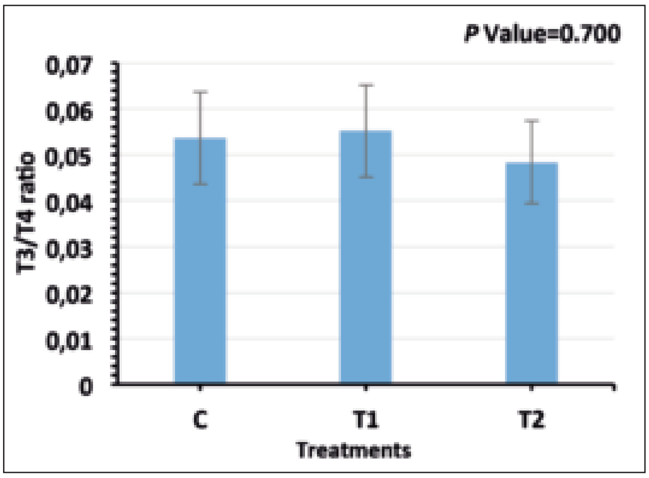

Figure 4 - The effect of I doses on serum thyroxine (T4) of newborn kids. C=control (no I supplementation; 0 mg Zn/day), T1=Treatment one (0.50 mg I/day), T2=Treatment two (0.1 mg I/day), Error bars indicate SEM.

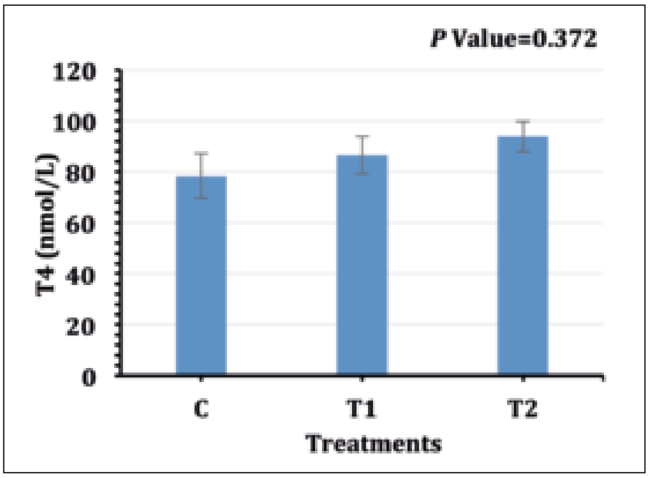

Figure 5 - The effect of I doses on serum T3/T4 ratio of newborn kids. C=control (no I supplementation; 0 mg Zn/day), T1=Treatment one (0.50 mg I/day), T2=Treatment two (0.1 mg I/day), Error bars indicate SEM.

and 5, respectively. Although, significantly higher serum concentrations of TSH were recorded in C group of goat and significantly higher concentration of T3 and T4 were recorded in supplemented groups of goat, while no significant effect of KI treatments on TSH (P=0.359), T3 (p=0.1221) and T4 (p=0.372) were recorded in newborn kids of different groups of studied pregnant goats. This may due to that there is no or lack transition of TSH, T3 and T4 hormones from mother through the placenta to the embryo (Zarbalizadeh-Saed *et al.*, 2020).

There was also no significant different (p=0.700) in T3/T4 ratio between newborn kids of different treated groups of goats. Previously, Zarbalizadeh-Saed *et al.* (2020) also found no significant (p<0.05) effect of 0.4 mg I/d on T3 and T3/T4 ratio compared with zero (0.0 mg I/d) level of iodine in newborn lams, while he found a significantly (p<0.05) higher concentration of T4 in newborn lambs received 0.4 mg I/d compared with zero level. This may be due to that Zarbalizadeh-Saed et al. (2020) used selenium with iodine rather than KI. Previously, it has been reported that selenium has the most important role in the metabolism of thyroid hormones after iodine, and there is a positive relationship between the amount of selenium in the animal body and activity of the thyroid hormones (Köhrle, 1999).

Effect of KI drenching in back goats during late pregnancy on newborn kids

Serum biochemical parameters

The effect of KI supplementation in black native goats during late pregnancy on their new born kids biochemical parameters are shown in Table 3. Serum total protein was not significantly affected by I drenching. The significantly higher (p=0.038) glucose (mg/dl) was found in group T2 compared with C and T1 groups of kids, while there was no significant different between C and T1 groups at the first week after parturition. Similarly, Kerslake et al. (2010) found that new born lambs from iodine-supplemented ewes had higher levels of plasma glucose concentration compared with new born lambs from non-supplemented ewes. This may due to that the glucose from the high iodine intake groups of goat defused to fetal by placenta, because significantly higher levels of serum glucose were recorded in iodine supplemented group of maternal goats during late pregnancy in the current study and maternal glucose is the primary source of energy for fetal and placental tissues (Bell and Bauman, 1997).

However, serum cholesterol (mg/dl) was significantly higher (P=0.053) in C group (54.6±11.7 mg/dl) compared with kids of treated groups of goats. While lower serum triglyceride was recorded in T2 (88.4±5.3 mg/dl) compared with other groups

Table 3 - Blood hematology parameters (Means ± SEM) in response to Potassium Iodine (KI) drenching at in first-week of age in black native goats kids.

Parameters	Treatments			P value
	C	T1	T2	
Total protein (g/dl)	6.21±0.4	5.87±0.2	6.41±0.2	0.423
Glucose (mg/dl)	102±3.7b	104.2±4.5b	119±5.0a	0.038
Cholesterol (mg/dl)	141±18.7a	106±15.4b	88.4±5.3c	0.053
Triglyceride (mg/dl	54.6±11.7	34.4±6.0	40.4±6.6	0.263
HDL (mg/dl)	70.2±9.4	57.8±5.8	53±2.5	0.203
LDL (mg/dl)	73±16.1	48.2±13.5	34.4±2.4	0.117

SEM=standard error of means, C=control (0 mg I/day), T1=treatment one (0.5 mg I/day), T2=treatment two (1.0 mg I/day).

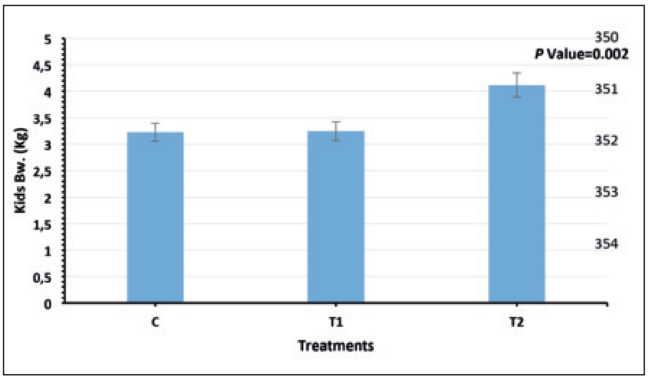

Figure 6 - The effect of I doses on birth weight (Kg) of newborn kids. C=control (no I supplementation; 0 mg Zn/day), T1=Treatment one (0.50 mg I/day), T2=Treatment two (0.1 mg I/day), Error bars indicate SEM.

of kids. The lower concentration of serum cholesterol of newborn kids of iodine drenched groups at late pregnancy is unclear.

There was no significant effect of KI drenching on triglyceride (mg/dl). The results of the present study also agree with the results of the present study, Xia et al. (2013) reported lower concentrations of serum triglyceride in I supplemented group of animals. There was also no significant effect of KI drenching HDL (mg/dl) and LDL (mg/dl) in new born kids of the supplemented goats during late pregnancy. Likewise to the current results, Vahedi et al. (2021) found no significant effect of macro algae (Azolla pinnata) on blood HDL and LDL level in lambs.

Effect of KI drenching in back goats during late pregnancy on body weight (Kg) of newborn kids

The data regarding newborn kids body weight are shown in Figure 6. Newborn kids body weight (Kg; mean±SEM) were significantly higher (p<0.001) in groups T2 (4.12±0.22 Kg) of goats in comparison to T1 (3.25±0.17 Kg) and C (3.23±0.17 Kg) groups of studied goats. These results agree with results reported by Zarbalizadeh-Saed *et al.* (2020) who showed a significantly higher lambs performance of ewes supplemented during late pregnancy with iodine (0.4 mg/d) compared with control (0.0 mg/d) group. In agreement with the findings of the present study, Aghwan *et al.* (2013) found significantly higher daily body weight of iodine-fed diets growing male kids. The significant higher total body weight of Kids of the high I group (1.00 mg KI/d) of goat in the present study may be due to higher concentrations of T3 and T4 hormones in their blood, and improved their metabolic process (Aghwan et. At., 2013), which in turn increased the kid's body weight. In contrast to the results of the present study, Aumont *et al.* (1989) found no significant effect of I intake on the lamb's birth weight between three different groups of ewes fed diet with 0.13 mg/kg DM, 0.22 mg/kg DM and 10.77 mg/kg DM of iodine content, this may be due to that Aumont *et al.* (1989) used ewes in his study rather than pregnant goats during late pregnancy.

CONCLUSIONS

The concentration of TSH remained higher in C group, while TSH levels declined in T1 and T2 in response to KI drenching of late pregnant goats. Iodine drenching can improve total protein and glucose and also regulate the levels of both T3 and T4 in the goat during late pregnancy. The concentration of triglyceride was higher in C group without adverse effects on LDL and HDL. Regarding new born kids, the levels of serum glucose were increased in T2 group, while the levels of cholesterol were increased in C group in response to KI drenching in late pregnant goats. Iodine drenching of pregnant goat can also increase new born kids body weight.

Conflicts of interest

The authors declare that they have no conflict of interest.

Authors Contributions

All Authors who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the conception and design of this work or the analysis and interpretation of the data, as well as the writing of the manuscript, to take public responsibility for it. Authors believe the manuscript represents valid work. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication.

References

Abozed, G., Saleh, A.A.K., El-Sayed, E.H., Abdel Khalek, T.M.M. and Hamdon, H., 2020. Effect of Iodine Supplementation on Physiological Responses and Metabolic Rate of Saidi Pregnant Ewes and the Performance of their Lambs. Journal of Animal and Poultry Production, 11(8), pp.303-307.

Aghwan, Z.A., Sazili, A.Q., Alimon, A.R., Goh, Y.M. and Hilmi, M., 2013. Blood haematology, serum thyroid hormones and glutathione peroxidase status in Kacang goats fed inorganic iodine and selenium supplemented diets. Asian-Australasian Journal of Animal Sciences, 26(11), p.1577.

Ahmed, M.H. and Byrne, C.D., 2007. Modulation of sterol regulatory element binding proteins (SREBPs) as potential treatments for non-alcoholic fatty liver disease (NAFLD). Drug discovery today, 12(17-18), pp.740-747.

Aumont, G., Levieux, D., Lamand, M. and Tressol, J.C., 1989. Iodine nutrition in ewes. 2. Effects of low to high iodine intake by ewes on the I content of biological fluids and plasma immunoglobulins G in newborn lambs. Reproduction Nutrition Development, 29(2), pp.203-217.

Barcelos, B., Gomes, V., Vidal, A.M.C., de Freitas Júnior, J.E., de Araújo, M.L.G.M.L., Alba, H.D.R. and Netto, A.S., 2022. Effect of selenium and vitamin E supplementation on the metabolic status of dairy goats and respective goat kids in the peripartum period. Tropical Animal Health and Production, 54(1), pp.1-13.

Bell, A.W. and Bauman, D.E., 1997. Adaptations of glucose metabolism during pregnancy and lactation. Journal of mammary gland biology and neoplasia, 2(3), pp.265-278.

Bhardwaj, R.K. 2018. Iodine deficiency in goats. In Goat science. Rijeka: IntechOpen.

Cappai, M.G., Liesegang, A., Dimauro, C., Mossa, F. and Pinna, W., 2019. Circulating electrolytes in the bloodstream of transition Sarda goats make the difference in body fluid distribution between single vs. twin gestation. Research in veterinary science, 123, pp.84-90.

Davis, R.A., 1999. Cell and molecular biology of the assembly and secretion of apolipoprotein B-containing lipoproteins by the liver. Biochimica et Biophysica Acta (BBA)-Molecular and Cell Biology of Lipids, 1440(1), pp.1-31.

Davoodi, F., Zakian, A., Rocky, A. and Raisi, A., 2022. Incidence of iodine deficiency and congenital goitre in goats and kids of Darreh Garm region, Khorramabad, Iran. Veterinary Medicine and Science, 8(1), pp.336-342.

Dušová, H., Trávní ek, J., Peksa, Z., Šimák-Líbalová, K., Šimková, A., Falta, D. and Švejdová, K., 2014. The influence of high iodine intake on chosen blood parameters of sheep. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 62, p.8.

El-Salaam, A., El-Tahan, A.A.H. and Bakr, A.A., 2018. Impact of dietary iodine supplementation on productive and reproductive performance of Maghrebian She-camels.

Hetzel, B., 1983. Iodine deficiency disorders (IDD) and their eradication. The Lancet, 322(8359), pp.1126-1129.

Huszenica, G. Y., Kulcsar, M. and Rudas, P. 2002: Clinical endocrinology of thyroid gland in ruminants. Vet. Med.- Czech, 47, 7: 199–200.

Huszenicza, G.Y., Kulcsar, M. and Rudas, P., 2002. Clinical endocrinology of thyroid gland function in ruminants. VETERINARNI MEDICINA-PRAHA-, 47(7), pp.199-210.

Juma, K.H. and I.E. Alkass. 2005. Native goats of Iraq: A review. Dirasat, Agric. Sci. 32: 180-188.

Kadum, N.B. and Luaibi, O.K., 2017. Clinical study hypothyroidism in goats and treatment by iodine compounds. Journal of entomology and Zoology Studies, 5, pp.1956-1961.

Kaneko, J.J., Harvey, J.W. and Bruss, M.L. eds., 2008. Clinical biochemistry of domestic animals. Academic press. pp. 571–588.

Kerslake, J.I., Kenyon, P.R., Stafford, K.J., Morris, S.T. and Morel, P.C.H., 2010. Can maternal iodine supplementation improve twin-and triplet-born lamb plasma thyroid hormone concentrations and thermoregulation capabilities in the first 24–36 h of life?. The Journal of Agricultural Science, 148(4), pp.453-463.

Köhrle, J., 1999. The trace element selenium and the thyroid gland. Biochimie, 81(5), pp.527-533.

Lawrence, T.L.J. and V.R. Fowler. 1997. Growth of farm animals. CAB International. Wallingford, Oxon OX10 8DE, UK. 114.

Lovreglio, R., Meddour-Sahar, O. and Leone, V., 2014. Goat grazing as a wildfire prevention tool: a basic review. Iforest-Biogeosciences and Forestry, 7(4), p.260.

Mercer, L.P. 2006, September. International iodine deficiency. In Forum on Public Policy: A Journal of the Oxford Round Table. Forum on Public Policy.

Meschy, F., 2000. Recent progress in the assessment of mineral requirements of goats. Livestock Production Science, 64(1), pp.9-14.

National Research Council (US). Committee on Nutrient Requirements of Small Ruminants, National Research Council, Committee on the Nutrient Requirements of Small Ruminants, Board on Agriculture, Division on Earth and Life Studies, 2007. Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids.

Nudda, A., Battacone, G., Bomboi, G., Floris, B., Decandia, M. and Pulina, G., 2013. Effect of dietary iodine on thyroid hormones and energy blood metabolites in lactating goats. Animal, 7(1), pp.60-65.

Nudda, A., Battacone, G., Decandia, M., Acciaro, M., Aghini-Lombardi, F., Frigeri, M. and Pulina, G., 2009. The effect of dietary iodine supplementation in dairy goats on milk production traits and milk iodine content. Journal of Dairy Science, 92(10), pp.5133-5138.

Nyström, H.F., Brantsæter, A.L., Erlund, I., Gunnarsdottir, I., Hulthén, L., Laurberg, P., Mattisson, I., Rasmussen, L.B., Virtanen, S. and Meltzer, H.M., 2016. Iodine status in the Nordic countries–past and present. Food & nutrition research, 60(1), p.31969.

Oramari, R.A., Bamerny, A.O. and Zebari, H.M., 2014. Factors affecting some hematology and serum biochemical parameters in three indigenous sheep breeds. Advances in Life Science and Technology, 21, pp.56-63.

Osuagwuh, A.I.A., 1992. Effects of strategic feed supplementation during pregnancy on birthweight and perinatal survival of West African Dwarf kids. The Journal of Agricultural Science, 119(1), pp.123-126.

Pachuri, S.P. 1981. Clinical Studies on Endemic Goiter in Goats in Tarai Status Report.Pantnagar, India: Department of Medicine, COVSc, G.B. Pant University of Agricultureand Technology.

Pattanaik, A.K., Khan, S.A. and Goswami, T.K., 2011. Iodine supplementation to a diet containing Leucaena leucocephala leaf meal: consequences on nutrient metabolism, clinical chemistry and immunity of goats. Animal Production Science, 51(6), pp.541-548.

Pattanaik, A.K., Khan, S.A., Mohanty, D.N. and Varshney, V.P., 2004. Nutritional performance, clinical chemistry and semen characteristics of goats fed a mustard (Brassica juncea) cake based supplement with or without iodine. Small Ruminant Research, 54(3), pp.173-182.

Shimano, H., Yahagi, N., Amemiya-Kudo, M., Hasty, A.H., Osuga, J.I., Tamura, Y., Shionoiri, F., Iizuka, Y., Ohashi, K., Harada, K. and Gotoda, T., 1999. Sterol regulatory element-binding protein-1 as a key transcription factor for nutritional induction of lipogenic enzyme genes. Journal of Biological Chemistry, 274(50), pp.35832-35839.

Singh, J.L., Sharma, M.C., Kumar, M., Rastogi, S.K., Gupta, G.C., Singh, S.P., Sharma, L.D. and Gandhi, V.K., 2002. Assessment of therapy in goitrous goats through some cardiac function tests. Small ruminant research, 44(2), pp.119-124.

Smith, M.C. and D.M. Sherman. 2009. Goat medicine. John Wiley and Sons.

Sokkar, S.M., Soror, A.H., Ahmed, Y.F., Ezzo, O.H. and Hamouda, M.A., 2000. Pathological and biochemical studies on experimental hypothyroidism in growing lambs. Journal of Veterinary Medicine, Series B, 47(9), pp.641-652.

Todini, L., 2007. Thyroid hormones in small ruminants: effects of endogenous, environmental and nutritional factors. Animal, 1(7), pp.997-1008.

Vahedi, V., Hedayat-Evrigh, N., Holman, B.W. and Ponnampalam, E.N., 2021. Supplementation of macro algae (Azolla pinnata) in a finishing ration alters feed efficiency, blood parameters, carcass traits and meat sensory properties in lambs. Small Ruminant Research, 203, p.106498.

Wang, D., Wan, S., Liu, P. Meng, F., Zhang, X., Ren, B., Qu, M., Wu, H., Shen, H. and Liu, L., 2021. Relationship between excess iodine, thyroid function, blood pressure, and blood glucose level in adults, pregnant women, and lactating women: A cross-sectional study. Ecotoxicology and Environmental Safety, 208, p.111706.

Xia, Y., Qu, W., Zhao, L.N., Han, H., Yang, X.F., Sun, X.F., Hao, L.P. and Xu, J., 2013. Iodine excess induces hepatic steatosis through disturbance of thyroid hormone metabolism involving oxidative stress in BALB/c mice. Biological trace element research, 154(1), pp.103-110.

Zarbalizadeh-Saed, A., Seifdavati, J., Abdi-Benemar, H., Salem, A.Z., Barbabosa-Pliego, A., Camacho-Diaz, L.M., Fadayifar, A. and Seyed-Sharifi, R., 2020. Effect of slow-release pellets of selenium and iodine on performance and some blood metabolites of pregnant Moghani ewes and their lambs. Biological trace element research, 195(2), pp.461-471.

Zebari, M.H., Buti, E.T.S. and Hamo, R.A.H., 2013. Some blood biochemical parameters of meriz does during different physiological status. Sovetskii Vrachebnyi Sbornik, 18, pp.190-194.

Zeedan, K.I., El-Malky, O.M., Mousa, K.M., El-Giziry, A.A. and Etman, K.E.I., 2010. Nutritional studies on some different sources of iodine on productive performance, ruminal fermentation and blood constituents of Buffalo. 1-Effect of two different iodine levels on productive and reproductive performance of buffalo cows. J. Am. sci, 6, pp.1090-1106.

Zeedan, Kh II, Weld Abd-Elkader, S.I., Kh Mousa, M.M. and Etman, K.E.I. 2014. Nutritional studies on some different sources and levels of iodine on productive performance, ruminal fermentation and blood constituents of buffalo. 3-Effect of different levels of iodine on productive performance of buffalo calves. Journal of Animal and Poultry Production 5, pp.143-156.