

Iodine level of goats from Shiwalik and middle mountains of north-west Himalayas in relation to soil, fodder, and water status

R A WANI¹, R SINGH^{1✉}, HIMALINI¹, A M BHAT² and R K BHARDWAJ¹

Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, Jammu and Kashmir 181 102 India

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ABSTRACT

A baseline survey was carried out to determine the iodine status of goats and its relationship with the levels of soil, water, and fodder samples collected from different agro-climatic zones (sub-tropical, lower, and upper-intermediate) of the Jammu division. A total of 74 blood and 60 milk samples from goats, as well as soil (50), water (50), and fodder (56) samples, were collected. Plasma inorganic iodine (PII), milk inorganic iodine (MII), iodide ion (I⁻), and thyroid hormone (T₃ and T₄) levels were measured along with biochemical parameters. The average PII, I⁻, and MII concentrations of goats from unorganized farms were 55.99±4.56 ng/ml, 1.37±0.11 ppm, and 47.3±5.68 ng/ml compared 74.68±8.40 ng/ml, 1.43±0.11 ppm and 62.01±8.55 ng/ml, respectively from the organized farm. Based on PII level, 71.62% of goats had moderate deficiency (level 50-100 ng/ml) and 28.37% had severe deficiency (level <50 ng/ml). The average levels of iodine in soil and water were 0.24 ppm and 0.06 ppm, respectively. *Rabi* and *kharif* fodders showed average iodine levels of 1.25 ppm and 0.37 ppm, respectively. Significant changes were recorded in glucose, HDL and T₄ levels. Pearson correlation performed between PII (ng/ml) and biochemical parameters established correlation with T₄ ($r = -0.465$), glucose ($r = 0.510$), HDL ($r = -0.355$) and cholesterol ($r = 0.271$). The study concluded that iodine deficiency is prevalent in the goat population due to lower levels in the environment implying an urgent need for regular supplementation in the diet.

Keywords: Fodder, Glucose, Goats, Iodine, Milk, Soil, Thyroxine, Triiodothyronine, Water

Iodine is a component of thyroid hormones (triiodothyronine and thyroxine), which play an important role in thermoregulation, growth, development, reproduction, muscle function, the immune system, and blood circulation in the body (Herdt and Hoff 2011). Iodine deficiency symptoms are linked to specific geographical areas as soils and, as a result, plants are the primary sources of iodine for livestock (Bires *et al.* 1996). Around 30% of the global population lives in areas with iodine-deficient soil (Khazan *et al.* 2013). Milk iodine concentration has been linked to dietary iodine intake linearly (Suttle 2010) and has been proposed as an indicator of an animal's iodine and goitre status in a given area (Underwood 1981). The Jammu division, which is located on the western slope of the Himalayas, is the most endemic belt of iodine deficiency. Since generations, nomadic populations have relied on Kaghani (Bakerwali) goat husbandry for wool and meat production, whilst sedentary flocks in the lower parts of Jammu, Udhampur, and Kathua districts have goats with varied blood levels. The purpose of this study was to conduct a baseline survey to determine the status of

iodine in goat populations from various agroclimatic zones *vis-a-vis* soil, water, and fodder level.

MATERIALS AND METHODS

Study areas: Two different agro-climatic zones, located in the western Himalayas i.e., Sub-tropical zone (mean height 300-800 m from mean sea level, MSL) between longitudes 74.80°E and latitudes 32.6°N comprising Jammu district and Intermediate zone encompassing two belts viz. Lower intermediate belt (mean height 800-1000 m from MSL between longitudes 75.10°E and latitudes 32.5°N) comprising Samba and Kathua districts and Upper-intermediate belt (mean height 1000- 1500 m from MSL between longitudes 74.40°E and latitudes 33.0°N) comprising Rajouri district of Jammu division were selected.

Animals and sample collection: The study included migratory Kaghani (Bakerwali) goats from the upper belt of intermediate zones and stationery Beetal cross goats from the lower intermediate and subtropical zones (Table 1). A total of 74 blood and 60 milk samples of goats from different agro-climatic regions were collected during the period from 2019 to 2020. Only open grazing was used to feed selected animals, with no supplemental diets. In addition, 18 healthy Beetal goats reared under a semi-intensive system were selected from an organized

Present address: ¹Faculty of Veterinary Sciences and Animal Husbandry, SKUAST-Jammu, R S Pura, Jammu, J&K. ²Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab. ✉Corresponding author email: rajivrajiv101@gmail.com

Table 1. Details of goats selected from different geographical regions

Geographical regions		No. of animals (Blood samples)				No. of animals (Milk samples)	Soil samples	Water samples
		Total	Age group					
			<1.5 yr	1.5-3 yr	>3 yr			
Subtropical zone (Jammu district)		18	6	6	6	20	10	10
Intermediate zone	Upper belt (Rajouri district)	20	6	8	6	--	10	10
	Lower belt (Samba and Kathua districts)	18	6	6	6	20	30	30
Organized farm (Kathua district)		18	6	6	6	20	-	-
Total		74	24	26	24	60	50	50

government goat breeding farm, Rajbagh, Kathua district. Animals were divided into three age groups: Group 1 (1.5 years), Group 2 (1.5-3 years), and Group 3 (>3 years).

Blood samples were collected for hematology in ethylene diamine-tetraacetic acid (EDTA) and in heparinized vials (10-12 ml) for biochemical and iodine estimation after harvesting plasma through centrifugation (3500 rpm for 15 min). Plasma samples were stored in mineral-free glass vials and milk samples in plastic vials and kept in a deep freeze at -10°C for subsequent analysis. Based on PII levels, goats were classified as moderately deficient (levels 50-100 ng/ml) or severely deficient (levels <50 ng/ml) in terms of iodine deficiency.

Blood and milk samples analysis: An analyzer was used to examine hematological parameters (Hb, PCV, TLC, and DLC) (Compact Diagnostics Pvt. Ltd. India). Plasma and milk inorganic iodine was determined by a chromatographic and colorimetric technique developed by Aumont and Tressol (1987). Iodide ion (I⁻) estimation was done by an ion-selective electrochemistry analyzer (ISA) (Thermo Scientific Orion). Biochemical parameters such as glucose, cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglyceride, and blood urea nitrogen (BUN) were measured in serum samples using standard kits (ERBA®) using Chem-7 Erba biochemistry analyzer. The plasma triiodothyronine (T₃) and thyroxine (T₄) levels were determined using a goat-specific ELISA kit (Cusabio Biotech Co. Ltd).

Soil, water and fodder samples, and analysis: For iodine analysis, 50 soil and water samples, as well as 56 fodder samples, were collected from various agro-climatic zones. One kilogram of soil was collected from five different spots

(4 corners and one center) at a specific location. At least 5-10 composite samples measuring 100 ml were collected from each location for analysis of water samples. These samples were kept at room temperature until they were analyzed as per the method described by Mahesh *et al.* (1992).

Statistical analysis: The data were statistically analyzed using standard methods and statistical software, and the significance was tested using the Tukeys Multiple Range test and statistical software SPSS 20.

RESULTS AND DISCUSSION

A significantly ($p<0.05$) lower level of PII was found in goats reared under field conditions at various private farms (average value 55.99 ± 4.56 ng/ml) compared to goats reared at organized farms (average value 74.68 ± 8.40 ng/ml) (Table 2). Geographical zone-wise analysis of goat samples revealed a significant ($p<0.05$) low level of PII in upper-intermediate (46.14 ± 4.89 ng/ml) compared to lower intermediate (54.97 ± 5.81 ng/ml) and subtropical zones (66.87 ± 2.99 ng/ml). Bobek (1998) identified PII (ng/ml) levels in ruminants less than 100 ng/ml as a sign of insufficient iodine intake. The mean PII (ng/ml) levels in goats reared in organized and unorganized farms in our survey were lower than the critical level (100 ng/ml). Rana *et al.* (2019) reported mean PII levels in sheep and goats from Punjab's central districts as 58.82 ± 6.61 and 53.19 ± 2.53 ng/ml, respectively, and from Punjab's southwestern district as 68.26 ± 5.88 and 62.23 ± 4.34 ng/ml, respectively. Several researchers have reported iodine levels in dairy cattle and buffaloes from Jammu and the adjoining state of Punjab. The baseline survey in

Table 2. Plasma inorganic iodine (PII), iodide ion and milk iodine status of goats from different agroclimatic zones of Jammu (Mean±SE)

Region	PII			Iodide ion (I ⁻) level (ppm)	MII level (ng/ml)
	Level (ng/ml)	Per cent deficient			
		Moderately deficient (50-100 ng/ml)	Severely deficient (<50 ng/ml)		
Subtropical belt	66.87±2.99 ^a	100% (18)	0% (0)	1.37±0.05 ^a	51.01±6.9 ⁶ a
Lower Intermediate belt	54.97±5.81 ^b	61.1% (11)	38.8% (7)	1.39±0.11 ^b	43.59±4.41 ^b
Upper Intermediate belt	46.14±4.89 ^c	30% (6)	70% (14)	1.35±0.14 ^a	--
Total (unorganized farm)	55.99± 4.56	100% (18)	0% (0)	1.37±0.1	47.3± 5.68
Organized farm	74.68±8.40 ^d	71.62% (53)	28.37% (21)	1.43±0.11 ^b	62.01±8.55 ^c

Different superscripts in the column differ significantly at $p<0.05$

crossbred cattle and buffaloes of northwest Himalayas reported average values of PII as 61.21 ± 2.76 ng/ml and 62.98 ng/ml, respectively (Singh and Singh 2011). Randhawa *et al.* (2014) conducted a baseline survey involving 73 buffaloes from central districts of Punjab and found that 38.4% of the population was deficient in iodine. The observed difference in PII levels between agro-climatic zones could be attributed to differences in fodder composition, soil iodine level (Crush and Caradus 1995) and intestinal parasitism.

The iodide ion (I⁻) level in goats was 1.385 ± 0.10 ppm on an average. Similarly, goats from organized farms had significantly ($p < 0.05$) higher levels of I⁻ (1.43 ± 0.11 ppm) than goats from unorganized farms (1.37 ± 0.1 ppm). The I⁻ levels of goats from subtropical (1.37 ± 0.05 ppm) and upper-intermediate (1.35 ± 0.14 ppm) zones were significantly ($p < 0.05$) lower than the lower intermediate (1.39 ± 0.11 ppm) belt. There are no comparable data on I⁻ levels in the literature.

According to severity, 71.62% of goats had moderate deficiency (PII value 50-100 ng/ml) and 28.37% of goats had severe deficiency (PII < 50 ng/ml) (Table 2). Iodine deficiency had also been reported in Punjab goats. According to Rana *et al.* (2019), 98.2% of goats from central districts and 85.7% of goats from Punjab's south-western district had mean levels of PII below 100 ng/ml. Based on PII levels, Singh *et al.* (2006) found iodine deficiency in 35.21% of buffaloes and 48.7% of crossbred cattle from Punjab's sub-mountainous regions. Kaur (2002) surveyed the iodine status of dairy animals in 10 villages of the Ludhiana and 9 villages of the Sangrur districts and found that cows and buffaloes had a prevalence rate of 72.22 and 76.66%, respectively, of iodine deficiency. Our findings show significantly ($p < 0.05$) lower levels of PII (42.85 ± 2.33 ng/ml) in younger goats (1.5 years), followed by 66.06 ± 1.71 and 59.43 ± 2.78 ng/ml in 1.5-3 years and >3 years goats, respectively. Singh *et al.* (2011) discovered significantly higher levels of PII in middle-aged buffaloes (3-6 years) than in old-aged buffaloes (>6 years). Singh *et al.* (2006), in contrast to the current study, reported a non-significant ($p > 0.05$) variation in the PII among different age groups of crossbred cattle.

Inorganic iodine levels in milk samples were found to be significantly ($p < 0.05$) higher (62.01 ± 8.55 ng/ml) in goats from organized goat farms compared to unorganized goat farms from different agroclimatic zones (Table 2) as observed in plasma analysis. MII levels correlate with plasma levels, with animals from the Jammu division's intermediate lower belt having significantly lower levels of PII (average values 54.97 ng/ml), followed by the subtropical belt (average values 66.87 ng/ml). Goats with severe iodine deficiency (PII 50 ng/ml) had the lowest average milk iodine levels, 39.83 ± 2.68 ng/ml, compared to 66.93 ± 6.71 ng/ml in moderately (PII level 50-100 ng/ml) deficient animals. Gakhar (2004) determined the average MII levels in Punjab state cattle and buffalo populations as 68.51 ± 5.46 and 72 ± 14.95 ng/ml, respectively. Trávníček and

Kursa (2001) reported milk iodine levels among goats from the Czech Republic as 31.6 µg/l and 63.0 µg/l in the years 1998 and 1999, respectively, and concluded that levels were indicative of iodine deficiency. The corresponding average value of iodine in milk samples of goats provided iodized salt (35 mg iodine per 1 kg) was 142.1 ± 102.6 µg/l (range values 51.8 to 393.6), while the remaining unsupplemented goats had milk levels of 19.3 ± 13.2 µg/l. The study further reported that the mean iodine levels ranged from 8.5 to 23.3 µg/l from farms having a history of neonatal goitre.

In our study, average iodine levels in water from various agroclimatic regions ranged from 0.03-0.09 ppm (average value of 0.06 ppm) (Table 3). There is no comparable data in the literature because this was the first study of the region; however, certain workers have reported levels from other Himalayan states in India. Singh *et al.* (2002) found a significantly low level of iodine in water samples from the state of Uttarakhand. Kumar *et al.* (2011) found average values ranging from 0.006-0.026 ppm in the states of Uttar Pradesh and Uttarakhand.

Comparing iodine levels in various water sources revealed lower levels (average value 0.05 ± 0.02 ppm) in tap water from deep bore tube well sources compared to surface flowing water from springs with an average level of 0.14 ± 0.02 ppm. It could be because of water management protocols in tap water, such as precipitation, filtration, and disinfection, where some iodine is absorbed.

Iodine levels in soil samples from various agroclimatic regions ranged from 0.14-0.35 ppm (average value of 0.24 ppm) (Table 3). The relatively high level of iodine in subtropical zone soil samples (0.35 ppm) correlates with the PII level (66.87 ± 2.99 ng/ml) of goats from the region. Several workers reported higher iodine range values in soil samples from other parts of the country. Singh *et al.* (2002) recorded iodine concentrations in soil samples from various parts of Uttarakhand state from the Himalayan region ranging from 3.65 to 9.52 ppm. According to Shivakumar (2007), the iodine content of the soil from the Uttarakhand state ranged from 2.14 to 3.28 ppm. Kumar *et al.* (2011) conducted an epidemiological survey in Uttar Pradesh and Uttarakhand and found soil iodine levels ranging from 2.22 to 5.66 ppm. Agarwal *et al.* (1987) measured I levels in Gangetic belt soils at 1.46 ± 0.93 ppm. Saleh (2000) measured 0.001 ppm of iodine in the soil from an Egyptian oasis. Since this was the first study of the region, there is no comparable data in the literature.

Iodine levels in winter (*Rabi*) and summer (*Kharif*)

Table 3. Iodine level (ppm) of soil and water samples from different agro-climatic zones of Jammu division

Agro-climatic zone	District	Water level (ppm)	Soil level (ppm)
Subtropical	Jammu	0.06 ± 0.02	0.35 ± 0.26
Lower intermediate	Kathua	0.03 ± 0.015	0.21 ± 0.03
	Samba	0.08 ± 0.052	0.19 ± 0.04
Upper-intermediate	Udhampur	0.04 ± 0.01	0.18 ± 0.05
	Rajouri	0.09 ± 0.007	0.14 ± 0.08

Table 4. Iodine level (ppm) of fodders from different agroclimatic zones of Jammu division

Crop	Fodder	District	No. of samples	Iodine level (ppm)
Rabi	<i>Leucaena</i>	Kathua	5	1.96±0.95
	<i>leucocephala</i>	Samba	2	0.65±0.05
	<i>Trifolium</i>	Kathua	5	0.75±0.12
	<i>alexandrinum</i>	Samba	2	0.68±0.13
	Rice straw	Kathua	5	0.59±0.03
		Samba	2	0.38±0.09
	Local grass	Kathua	5	0.62±0.11
		Samba	2	0.57±0.15
		Rajouri	2	0.55±0.10
	Kharif	<i>Zea mays</i>	Kathua	5
		Samba	2	0.36±0.05
		Rajouri	3	0.32±0.04
<i>Sorghum</i>		Kathua	2	0.26±0.04
<i>bicolor</i>		Samba	5	0.31±0.05
Wheat straw		Kathua	2	0.41±0.07
		Samba	2	0.32±0.04
<i>Pennisetum</i>		Kathua	3	0.48±0.02
<i>glaucum</i>		Samba	2	0.39±0.04

fodders from various agroclimatic regions ranged from 0.55-1.96 ppm (average value 1.25 ppm) and 0.26-0.48 ppm (average value 0.37 ppm), respectively (Table 4). Kumar *et al.* (2011) reported similar results in fodders from Uttar Pradesh and Uttarakhand, with values ranging from 0.126-0.303 ppm. Several workers reported lower iodine concentrations in feed and fodders from various regions of India. Singh *et al.* (2002) found that the mean iodine concentration in fodder samples from Uttarakhand state ranged from 0.127 to 0.267 ppm. Shivakumar (2007)

reported similar results in fodder samples from Uttarakhand, ranging from 0.14±0.01 to 0.28±0.01 ppm. Subabul, a leguminous fast-growing perennial green bushy fodder used for animal feeding, contains adequate to high levels of iodine (0.3-0.5 µg/g DM), according to Bedi (1991).

T₄ levels in goats from different agroclimatic zones ranged from 30.62- 44.7 nmol/l (average value 33.2±0.26 nmol/l) (Table 5), which was lower than the normal range of 54-110.7 nmol/l (average value 82.4 nmol/l) quoted by Kaneko *et al.* (2008). The level of triiodothyronine (T₃) ranged from 2.37-2.52 nmol/l (average value 2.45±0.07 nmol/l), with no significant (p>0.05) variation among goats from different agro-climatic zones. The animals with severe iodine deficiency (PII <50 ng/ml) had a significantly (p<0.05) higher average values (37.52± 0.10mg/dl) than the animals with moderate (PII: 50-100 ng/ml) deficiency (30.62±0.08 mg/dl). The overall average plasma Ca, Mg, K, and Fe values in goats were within the normal ranges of 9.0-11.6 mg/dl, 2.10-2.90 mg/dl, and 3.80-5.70 mmol/l, quoted by Fielder (2015) as shown in Table 5. The overall mean plasma iron level of goats, however, was higher than the normal range of 17.9-35.8 mol/l (Radostits *et al.* 2007).

The mean glucose level (67.74 mg/dl) was within the normal range of 50-75 mg/dl (Fielder 2015). A non-significant (p>0.05) lower level of glucose was found in goats from the upper intermediate zone compared to those from the subtropical and lower intermediate zones. Goats from organized farms had a significantly (p<0.05) lower average values (64.09±2.70 mg/dl) than animals from unorganized farms from various agroclimatic zones. In contrast to our findings, other researchers had reported low glucose levels in hypothyroid goats. Hypoglycemia in hypothyroid goats was attributed to the inhibition

Table 5. Hemato-biochemical profile of goats from different agro-climatic regions of Jammu (Mean±SE)

Parameter	Agroclimatic zone			
	Unorganized			Organized
	Subtropical belt	Lower Intermediate Belt	Upper Intermediate belt	Organized farm
Hb (g/dl)	10.08±0.70	9.63±0.66	9.30±0.61	9.52±0.61
PCV (%)	31.69±1.93	32.82±2.14	29.35±1.78	27.7±1.92
TEC (×10 ⁶ /µl)	10.56±0.57	9.54±0.53	9.56±0.72	6.27±0.16
Glucose (mg/dl)	72.72±3.35 ^b	67.79±3.925 ^b	62.77±3.82 ^a	64.09±2.70 ^c
Triglycerides (mg/dl)	186.55±8.94	191.83±10.42	199.35±8.96	203.67±12.34
Cholesterol (mg/dl)	73.77±3.28	73.26±6.04	66.92±6.32	62.07±4.55
HDL (mg/dl)	129.60±4.90 ^a	130.7±4.40 ^a	159.93±12.33 ^b	124.28±9.69 ^b
LDL (mg/dl)	44.09±3.52	45.45±4.60	40.97±5.83	54.63±6.73
BUN (mg/dl)	14.78±1.24	15.55±0.97	14.36±1.30	16.7±0.95
T ₄ (nmol/l)	31.18± 0.08 ^a	30.62±0.07 ^a	37.8±0.11 ^b	44.7±0.05
T ₃ (nmol/l)	2.47± 0.06	2.52±0.08	2.37±0.07	2.42±0.04
T ₄ :T ₃	12.60	12.13	15.91	18.43
Ca (mg/dl)	9.30±0.65	9.37±0.48	9.75±0.60	9.77±0.45
Mg (mg/dl)	2.24±0.30	2.47±0.29	2.23±0.34	1.79±1.73
K (mEq/l)	4.78±0.33	4.80±0.61	5.95±0.37	3.6±0.27 ^b
Fe (µmol/l)	42.5±1.6	44.24±1.27	47.24±1.99	39.95±1.05 ^b

Different superscripts in the row differ significantly at p<0.05.

of gluconeogenesis (Sengupta 1994). Kaneko (2008) reported that hypoglycemia in goitrous goats may have resulted from poor intestinal glucose absorption and that thyroxine improves intestinal glucose absorption as well as glucose turnover. One of the causes of hypoglycemia in hypothyroidism has been identified as increased insulin sensitivity (Nasseri and Prasad 1987). The animals with severe iodine deficiency based on PII levels ($\text{PII} < 50 \text{ ng/ml}$) had significantly ($p < 0.05$) lower glucose levels ($62.67 \pm 3.48 \text{ mg/dl}$) than the animals with moderate ($\text{PII} 50\text{--}100 \text{ ng/ml}$) deficiency ($70.53 \pm 3.86 \text{ mg/dl}$).

The average triglyceride (TG) value (195.11 mg/dl) was higher than the reference range of $21.4\text{--}42.8 \text{ mg/dl}$ (Kaneko *et al.* 2008). There were no statistically significant differences between animals from different zones or management systems. Several researchers had reported low triglyceride levels in hypothyroid goats (Tsuneyoshi *et al.* 1995, Angelov *et al.* 1996) whereas; Singh *et al.* (2003) reported higher TG level in hypothyroid goats. The average cholesterol value (67.92 mg/dl) recorded was below the normal reference range of $80\text{--}130 \text{ mg/dl}$ (Fielder 2015). The animals with severe iodine deficiency ($\text{PII levels} < 50 \text{ ng/ml}$) had significantly ($p < 0.05$) lower cholesterol levels ($67.58 \pm 6.19 \text{ mg/dl}$) than the animals with moderate ($\text{PII} 50\text{--}100 \text{ ng/ml}$) deficiency ($73.30 \pm 4.90 \text{ mg/dl}$). Cholesterol synthesis increases in the presence of excess thyroxine and decreases in the presence of thyroxine deficiency. It has been suggested that increased cholesterol is caused by decreased biliary excretion of cholesterol in hypothyroid animals, despite reduced synthesis (Dickson 1993). Furthermore, increased TSH in hypothyroidism may account for hypercholesteremia, and decreased lipoprotein lipolysis, decreased hepatic utilization, and increased hepatic production all contribute significantly to elevated blood cholesterol levels.

HDL levels in goats ranged from 124.28 to 159.93 mg/dl (with an average of 142.10 mg/dl). The study found that goats from the upper intermediate zone had significantly ($p < 0.05$) higher levels of HDL than animals from the subtropical and lower intermediate zones. When compared to animals from unorganized farms, goats from organized farms had lower average values ($124.28 \pm 9.69 \text{ mg/dl}$). The animals with severe iodine deficiency ($\text{PII} < 50 \text{ ng/ml}$) had a significantly ($p < 0.05$) higher average values of HDL ($152.17 \pm 9.87 \text{ mg/dl}$) than the animals with moderate ($\text{PII} 50\text{--}100 \text{ ng/ml}$) deficiency ($133.96 \pm 9.16 \text{ mg/dl}$). Angelov *et al.* (1996) reported that total lipid concentrations in goitre goats were significantly higher than in normal healthy goats. Randhawa and Randhawa (2001) discovered that iodine supplementation did not affect free fatty acid (FFA) levels in cows. There was no significant difference in LDL levels between goats from different zones or animals reared under different management systems. Angelov *et al.* (1996) reported that total lipid concentrations in goitre goats were significantly higher than in normal healthy goats. Pearson correlation performed between PII (ng/ml) and various biochemical and hormonal parameters

established correlation with T_4 ($r = -0.465$; $p < 0.001$), glucose ($r = 0.510$; $p < 0.001$), HDL ($r = -0.355$; $p < 0.001$) and cholesterol ($r = 0.271$; $p < 0.05$). The average mean values of Hb, PCV, and TLC were within the normal range (Fielder 2015) as shown in Table 5. Hypothyroidism has been linked to anaemia because the rate of erythropoiesis slows or stops (Cline and Berlin 1963).

Conclusively, widespread prevalence of iodine deficiency among goats was recorded as 71.62% of goats had moderate deficiency and 28.37% had severe deficiency. Iodine levels were low in the soil, water, and fodder samples from various agroclimatic zones. Elevated levels of iron were found in goat plasma samples, which could be contributing to the region's low I status. Goats need to be supplemented with iodine, as feedstuffs cannot provide adequate iodine.

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