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Effect of Iodine Supplementation on Physiological Responses and Metabolic Rate of Saidi Pregnant Ewes and the Performance of their Lambs

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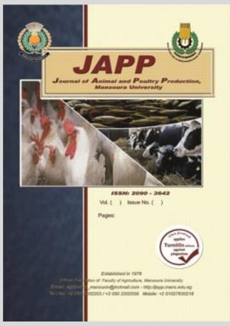

ABSTRACT

Forty Egyptian Saidi pregnant ewes were used to study the effect of iodine supplementation on physiological responses and the metabolic rate of Saidi pregnant ewes and their lambs' performance until weaning. Ewes were divided into two equal groups (20 ewes per each), control group and treatment group which was treated with 12 mg iodine solution every 2 days from the beginning of the last third of pregnancy and the lambing was during winter. Body weight of ewes at the end of pregnancy was higher in iodine supplemented group compared to control (43.9 vs. 41.1 kg, $P<0.05$). Gas volume per minute, tidal volume and metabolic rate values were significantly higher in the treated group compared to control group. Serum total protein and its fractions in addition to glucose concentrations tended to increase with iodine supplementation. Also, serum T3 and T4 concentrations were higher ($P<0.05$) in iodine supplemented group compared to control group (5.47 ng/dl &120.7 ug/dl *vs.* 4.0 ng/dl and 76.7 ug/dl, respectively). In conclusion, iodine supplementation beneficially influences the physiological responses, the metabolic rate and some blood constituents of Saidi pregnant ewes which subsequently improved the performance and the survivability of their lambs.

***Keywords*:** Iodine, physiological responses, metabolic rate, lambs survival, Saidi ewes.

INTRODUCTION

Adverse climatic conditions badly affected animal performance and increased the mortality rate, besides animal's thermoregulatory agents at birth, including brown adipose tissue, shivering, and physical activity (Vermorel *et al.*, 1983). Basal metabolic rate (BMR) is the total of the minimal activity of all tissue cells of the body under steady-state conditions. It is often expressed as the rate of heat production or oxygen consumption per unit of body size (Tata, 1964).

Iodine is an essential trace element for humans and animals, and more than 95 % of total iodine in the body is accumulated in the thyroid gland. The known role of iodine in metabolism is its incorporation into the thyroid hormones (Triiodothyronine "T3" and Thyroxine "T4") and into the precursor iodotyrosine (Flachowsky, 2007). Iodine deficiency should be included in the list of differential diagnoses for poor reproductive performance in ewes and the investigation of high perinatal lamb mortality rates (Sargison *et al.*, 1998). Iodine deficiency affects cellular energy, growth, and differentiation, and the deficiency "among ruminants" manifests primarily as diminished reproductive performance in dams and increased perinatal mortality of offspring (Campbell *et al.*, 2012; Knowles and Grace, 2015). The absolute iodine requirement is difficult to determine because of adaptive responses to varying iodine intake (Steve and Bill, 2012). In accordance with the national research council, the recommended iodine content in a feed ration for sheep and cows is only 0.5 mg/kg (NRC, 2001). It has been reported that sheep reared under an intensive system (do not exit to pasture) may suffer from iodine deficiency (Mulvaney, 1997).

Insufficient iodine intake by pregnant ewes and subsequent fetal hypothyroidism results in increased perinatal mortality and birth of weak lambs, and delayed skin and wool follicle development. In addition to many signs of iodine deficiency disorders such as neonatal goiter, alopecia and skeletal immaturity (Campbell *et al.*, 2012). It has been reported that the effective management of iodine deficiency will involve supplementation of the ewes during pregnancy (Boland *et al.*, 2008). The Egyptian Saidi sheep is the oldest breed located in Upper Egypt with coarse wool and the demand for this breed increases due to its high conception rate (82-92%) (EL-Hommosi and Abdel-Hafiz, 1982; Elshazly and Youngs, 2019), twining rate of 1.5% (Galal, 1987), mortality rate at birth ranges from 4.5 to 7.0%, and the mortality rate from birth to weaning is 10.0-18.2% (Elshazly and Youngs, 2019). So, the mortality rate of Saidi lambs was higher especially during unsuitable climate conditions (such as cold stress during winter) and consequently the survival rate is poor. This study's aim was to investigate the effect of iodine supplementation on physiological responses and metabolic rate of Saidi pregnant ewes and the performance of their lambs until weaning.

MATERIALS AND METHODS

This study was carried out in Mallawi Animal Production Research Station (Mallawi City, Minia Governorate, which lies between longitudes 27 º 43 ' N, latitudes 30 º 50 ' E and 52 meters above sea level), Agriculture Research Center, Cairo, Egypt. The experiment was done during the winter season.

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1- Animals

Forty Egyptian Saidi pregnant ewes aged 2.0-4.0 years, with body weights ranging between 33 and 36 kg, were used in this study. Ewes were subjected to routine vaccination programs for infectious diseases. From the beginning of the last third of pregnancy, ewes were fed rice straw and concentrate feed mixture (the chemical analysis of the used feedstuffs is presented in Table 1) according to NRC (2007). Animals had free access to fresh water throughout the day. Animal's body weights were recorded biweekly, and the amount of feed was adjusted throughout the experimental period according to the body weight change.

Table 1. Chemical composition of the used feedstuffs (on DM basis).

Item	DM	OM	CP	CF	EE	NFE	Ash
Concentrate feed mixture (CFM)	93.7	88.0	13.8	15.2	3.6	55.4	12
Rice straw	90.9	84.1	4.0	33.4	1.6	45.1	15.9

2- Experimental design

Ewes were divided into two equal groups (20 ewes per each) according to their age, parity, and body weight as control group and treatment group, which was treated with 12 mg iodine every two days (by oral adminstration of potassium iodide solution) from the beginning of the last third of pregnancy until weaning of their lambs.

Ambient temperature and relative humidity were recorded at all periods of the measurements through the experiment. A mercury centigrade thermometer was used to measure ambient temperature. A hygrometer hanging from the shed's roof at a level of about two meters from the ground was used to measure relative humidity.

3- Sampling and measuring procedure

Samples and measurements were taken from ewes biweekly from the beginning of treatment to the first three days post-lambing.

3-1- Blood biochemical parameters

Blood samples were collected from the jugular vein into 10 ml clean glass tubes. Blood samples were centrifuged at 1,800 × *g* for 20 min. at 4°C. Serum samples were stored at -20°C for subsequent analysis of blood metabolites and hormones. Total protein (TP) and albumin were determined according to Armstrong and Carr (1964) and Doumas *et al.* (1971), respectively; and globulin was calculated by subtracting the concentration of serum albumin from the corresponding concentration of total protein. Serum glucose was determined according to Trinder (1969). Direct radioimmunoassay (RIA) techniques were used to determine the serum Triiodothyronine (T3) and Thyroxine (T4) concentrations using ready-coated tub kits (Diagnostic Systems Laboratories, USA).

3-2-Thermal responses

Rectal temperature (RT, ºC) was measured using a clinical thermometer. Skin temperature (ST, ºC) and wool temperature (WT, ºC) were measured using a portable infrared thermometer (Radioshack) designed for temperature measurements. These parameters were taken in the morning (6-8 a.m) and afternoon (12-2 p.m).

3-3- Respiratory activities and gas exchange

Respiratory activities and gas exchange were determined. Respiration rate was expressed as the number of breaths per minute (breaths/minute) and measured by counting the flank movements. Complete inward and outward movement of the flank was counted as one breathed and recorded. The respiratory minute volume of exhaled air/minute was measured by Dry Gas Meters (liters), and gas volume was corrected to Standard Dry Temperature and Pressure (STPD), according to Yousef and Dill (1969). The volume of oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured with the open-circuit technique. Oxygen consumption was calculated from the oxygen deficit in expired air obtained from the oxygen analyzer (Servomex 570). The carbon dioxide production rate was calculated from the VCO_2 deficit in expired air obtained from an infrared Gas Analyzer (Model-AR-411). The expired air was passed through over dried calcium chloride to prevent water vapor from entering the gas analyzer cells.

Tidal volume was calculated by dividing the respiratory minute volume (GV) STPD by the respiration rate per minute. TV = GV 1/RR r.p.m. Metabolic Rate = [VO_2 × (3866 + (GV adjusted to STPD × VCo_2×1200)) × (1.163×60×24 / POWER (Body Weight, 0.75))]/1000

4- Statistical analysis

Statistical analysis was performed by SPSS v. 21.0 for Windows (SPSS Inc., Chicago, IL). Data were analyzed by an independent sample T-test. The following statistical model was used: $Y_{ij} = \mu + T_i + E_{ij}$ Where, Yij= The studied trait, μ = The overall mean, Ti= The effect of treatment, Eij= The experimental error.

RESULTS AND DISCUSSION

Body weight changes

Results in Table 2 showed that the average body weight at the end of pregnancy was higher in iodine-supplemented group compared to the control (43.9 vs. 41.1 kg, $P<0.05$). Also, average body weight post-lambing was higher in the treated group than control (38.9 *vs.* 36.2 kg, $P<0.05$). Body weight increase during pregnancy refers to increasing fetal weight which was also improved by treatment (as we will see in birth weight). Similar results were found in sheep by Parker and McCutcheon (1989), in goats by Pattanaik *et al.* (2001) and in Buffalo by Zeedan *et al.* (2014). Sargison *et al.* (1998) found that iodine supplementation improved reproductive performance in Manawatu Romney sheep, with 21% and 14% more lambs born to the supplemented group than the control. Perinatal lamb survival was improved by treatment, and these effects were greater during the winter lambing season. These results can be due to the improvement in thyroid function as iodine supplementation increases the function of the thyroid gland and increases body metabolic activity and body weight (Abd El-Salaam *et al*., 2018).

Average birth weight and weaning weight of newborn lambs were higher ($P<0.05$ & $P<0.01$, respectively) in the supplemented group than control. Besides, the lambs' survival rate was higher in the treated group than the control at one, two, and three months of age (Table 2). Similarly, Rose *et al.* (2007) and Boland *et al.* (2008) showed that lamb's birth weight was significantly improved with iodine supplementation. Similar results were also found in Buffalo by Zeedan *et al.* (2010 & 2014) and in camels by Abd El-Salaam *et al.* (2018). These results may be explained by that iodine supplementation improved the metabolism which consequently improved the general performance of ewes and weights of fetuses during pregnancy and the lactation performance after lambing, which also improved their lambs' survival. It is well known that iodine's major role in the body is in the synthesis of the thyroid hormones (T3 & T4). These hormones regulate most cells' metabolic patterns and play a vital role in cellular differentiation, growth, and development in the foetus and neonate, probably mediated by effects on gene expression (Sethi and Kapil, 2004; Boland *et al.,* 2008). Others reported that iodine deficiency in ewes can hinder lamb development during pregnancy and cause lamb deaths and poor lamb survival (Mulvaney, 1997; Sargison *et al.* 1998). In a previous study, Sinclair & Andrews (1961) observed that iodine deficient lambs would not follow the ewe and refused to drink even when assisted before dying within 24 hours of birth.

Table 2. Effect of iodine supplementation on weights of ewes and their newborn lambs and lambs survival.

Item		Groups: Control (n=20)	Groups: Treatment (n=20)	Sig.
Weight at the end of pregnancy (kg)		41.1 ± 1.04	43.9± 0.85	*
Weight post-lambing		36.2 ± 0.97	38.9± 0.81	*
No. of total lambs born		26	27	-
No. of alive lambs born		25	26	-
Average birth weight (kg)		2.56 ± 0.14	2.96± 0.06	*
Lambs survival	1 month	21	25	-
	2 months	20	25	-
	3 months	20	25	-
Weaning weight (kg)		12.26 ± 0.42	14.23±0.31	**

*** = significant (P< 0.05), ** = significant (P< 0.01)**

Thermal responses, respiratory activities, and heat production measurements

The thermal response parameters and respiratory activities of ewes almost did not significantly differ between groups in the morning (Table 3). While in the afternoon, rectal temperature of ewes in control group was significantly (P<0.01) higher than in treated group (39.30 *vs.* 39.09 ºC). Skin, wool temperature and respiration rate did not differ between groups. At the same time, gas volume per minute (GV), tidal volume (TV) and metabolic rate (MR) values were significantly higher in iodine supplemented group compared to control group.

Data available about the effect of iodine supplementation on gas exchange and metabolic rate of farm animals are scarce. It has been reported hat there was a linear relationship between peripheral blood flow and basal metabolic rate, i.e. the fall in basal metabolic rate was associated with a decrease in peripheral blood flow (Harold *et al.,* 1940). Kerslake *et al.* (2010) found that iodine supplementation in ewes had a positive effect on the base heat production. Also, they found that newborn lambs born to iodine-supplemented ewes had a greater base heat production per kg of live weight basis (W/kg) than lambs born to non-supplemented ewes. The increase in the MR of iodine supplemented ewes may be due to the increase in thyroid hormones. Barrett (2017) reported that thyroid hormones increase the basal metabolic rate by stimulating both catabolic and anabolic reactions in pathways affecting fats, carbohydrates and proteins.

Table 3. Effect of iodine supplementation on physiological parameters and respiratory activities of ewes.

Variable	Am: Control	Am: Treatment	Am: Sig.	Pm: Control	Pm: Treatment	Pm: Sig.
Rectal temp. (RT) Cº	38.77 ± 0.07	38.61± 0.06	NS	39.30 ± 0.05	39.09 ± 0.05	**
Skin temp. (ST) Cº	25.36 ± 0.15	25.27 ± 0.19	NS	30.72± 0.17	30.62 ± 0.22	NS
Wool temp. (WT) Cº	14.35 ± 0.22	13.94 ± 0.23	NS	24.71± 0.27	24.46 ± 0.03	NS
Respiration rate (RR) (breathe/minute)	25.8 ± 0.69	23.9 ± 0.55	*	35.1 ± 0.70	33.8 ± 0.79	NS
Gas volume (L/minute)	3.43 ± 0.21	3.84 ± 0.24	NS	2.91 ± 0.18	3.86 ± 0.20	**
Tidal volume (ml/breathe)	135.92 ± 8.65	147.75 ± 7.43	NS	88.99 ± 5.85	112.6 ± 5.66	**
Metabolic rate (Kcal/day)	61.6 ± 6.46	71.2 ± 6.15	NS	40.9 ± 3.27	71.6 ± 10.1	**

NS = not significant (P≥ 0.05), ** = significant (P< 0.01)

Blood metabolites and hormones

During both periods (a.m. and p.m.), total protein (TP) and globulin (GL) tended to increase significantly (P<0.01) in the treated group compared to the control group (Table 4). Also, TP concentrations were significantly (P<0.05) higher at lambing, 1st, 2nd and 3rd day post-lambing in the treated group (Table 5). These results are in agreement with several authors (Zeedan *et al*., 2010, 2012 and 2014). Also, Hana *et al.* (2014) found that total protein concentration was significantly higher in iodine-supplemented sheep. Besides, Abd El-Salaam *et al.* (2018) found that total protein, albumin, and globulin pre- and post-partum period were higher in potassium iodide supplemented pregnant camels (with 0.5, 0.8 & 1.0 mg /kg DM intake /h/d) compared to un-supplemented ones.

Table 4. Effect of iodine supplementation on some blood constituents of pregnant ewes.

Item	Am: Control	Am: Treatment	Am: Sig.	Pm: Control	Pm: Treatment	Pm: Sig.
Total protein (g/dl)	5.65 ± 0.20	6.43 ± 0.13	**	5.92 ± 0.11	6.61 ± 0.08	**
Albumin (g/dl)	3.94 ± 0.12	3.85 ± 0.12	NS	3.97 ± 0.08	3.71 ± 0.10	NS
Glubulin (g/dl)	1.71 ± 0.12	2.58 ± 0.16	**	1.95 ± 0.08	2.90 ± 0.14	**
Glucose (mg/dl)	46.4 ± 3.10	58.6 ± 2.66	**	52.9 ± 1.99	56.4 ± 1.45	NS

NS = not significant (P≥ 0.05), ** = significant (P< 0.01)

Serum glucose levels increased significantly (P<0.01) with iodine supplementation in pregnant ewes during the morning. However, it did not differ significantly afternoon. Also, post-lambing, serum glucose concentrations of supplemented ewes were significantly higher at the onset of lambing, 1st, 2nd, 3rd day post-lambing compared to control group (Table 5). Many investigators reported that blood glucose concentration increased with iodine supplementation. Kerslake *et al.* (2010) reported that lambs born to iodine-supplemented ewes had greater plasma glucose concentration than lambs born to non-supplemented ewes. Also, Zeedan *et al.* (2010, 2012 & 2014) illustrated that glucose concentration was significantly (P<0.05) higher with iodide supplementation. In addition, Abd El-Salaam *et al.* (2018) found that glucose levels during pre and post-partum periods were higher in supplemented potassium iodide of pregnant camels than in control. The recorded trend of increase in TP and their fractions as well as in glucose concentration may be attributed to increasing thyroid hormones, which stimulates the basal metabolic rate through regulation of the metabolism of carbohydrates and proteins (Lawrence and Fowler, 1997).

Table 5. Effect of iodine supplementation on some blood constituents of ewes after lambing.

Status	Groups	Total protein (g/dl)	Albumin (g/dl)	Glubulin (g/dl)	Glucose (mg/dl)
At lambing	Control	5.40 ± 0.18	2.98 ± 0.16	2.43 ± 0.27	49.9 ± 1.8
	Treatment	5.94 ± 0.16	3.33 ± 0.12	2.61 ± 0.19	59.4 ± 3.55
	Sig.	*	NS	NS	*
1st day after lambing	Control	5.50 ± 0.10	2.88 ± 0.21	2.62 ± 0.26	48.8 ± 1.7
	Treatment	5.96 ± 0.12	3.37 ± 0.08	2.60 ± 0.15	55.4 ± 2.05
	Sig.	**	*	NS	*
2nd day after lambing	Control	5.49 ± 0.17	3.10 ± 0.21	2.40 ± 0.22	44.1 ± 2.98
	Treatment	6.02 ± 0.11	3.54 ± 0.09	2.48 ± 0.09	54.8 ± 3.92
	Sig.	*	NS	NS	*
3rd day after lambing	Control	5.53 ± 0.12	3.16 ± 0.22	2.37 ± 0.23	46. 8 ± 3.04
	Treatment	5.92 ± 0.11	3.37 ± 0.14	2.55 ± 0.10	56.1 ± 2.41
	Sig.	*	NS	NS	*

NS = not significant (P≥ 0.05), * = significant (P< 0.05) ; ** = significant (P< 0.01)

Serum T3 and T4 concentrations (Table 6) were higher (P<0.05) in the iodine-supplemented group compared to the control (5.47 ng/dl &120.7 ug/dl *vs.* 4.0 ng/dl and 76.7 ug/dl, respectively). Also, serum T3 and T4 concentrations post-lambing were significantly (P<0.05) higher at the onset of lambing and the first day post-lambing in the supplemented group. Similar results were found in sheep by Ferri *et al.* (2003) and in goats by Pattanaik *et al.* (2001 & 2011), they found that iodine supplementation increased thyroid hormones significantly. Also, similar findings were observed in Buffalo by Zeedan (2010, 2012 & 2014). This significant increase in thyroid hormones in the iodine supplemented group was expected due to iodine supplementation, which increased the circulated iodine used by the thyroid gland to produce T3 and T4. Rose *et al.* (2007) showed that plasma concentration of T3 and T4 at birth and 24 hours after birth were significantly higher in the lambs born from ewes given iodine treatment (5.0, 9.9, 14.8 or 19.7 mg /kg DM). Besides, Aghwan *et al.* (2013) illustrated that combined dietary supplementation of selenium and iodine increased serum free T3 significantly. Furthermore, Abd El-Salaam *et al.* (2018) found that T3 concentration during pre- and post-partum was higher (P<0.05) in iodine treated groups than in control.

Table 6. Effect of iodine supplementation on serum Triiodothyronine (T3) and Thyroxin (T4) of ewes during different periods.

Item		Groups: Control	Treatment	Sig.
During pregnancy	T3 (ng/dl)	4.00 ± 0.44	5.47 ± 0.50	*
	T4 (ug/dl)	76.7 ± 7.29	120.7 ± 8.70	**
At lambing	T3 (ng/dl)	3.46 ± 0.61	5.20 ± 0.44	*
	T4 (ug/dl)	71.0 ± 9.60	100.2 ± 6.70	*
1st day after lambing	T3 (ng/dl)	4.22 ± 0.42	5.66 ± 0.44	*
	T4 (ug/dl)	64.7 ± 8.92	94.9 ± 7.15	*

*** = significant (P< 0.05) , ** = significant (P< 0.01)**

CONCLUSION

Iodine supplementation beneficially influences the physiological responses, the metabolic rate, and some blood constituents of Saidi pregnant ewes, which subsequently improved their performance and their lambs' survivability.

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تأثير المعاملة باليود على الاستجابات الفسيولوجية ومعدل التمثيل الغذائي للنعاج الصعيدي العشار وأداء حملانها

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تهدف هذه الدراسة لتقييم تأثير المعاملة بعنصر اليود على الآداء الفسيولوجي ومعدل التمثيل الغذائي للنعاج الصعيدي العشار وكذلك على أداء حملانها بعد الولادة (حيث أن هناك مشكلة واضحة تعانى منها نعاج الأغنام الصعيدى بموسم ولادة فصل الشتاء حيث يقل بشكل واضح وزن ميلاد حملانها وكذلك يزداد معدل نفوق هذه الحملان المولودة ويقل أيضا معدل بقائها حية حتى الفطام). أستُخدم فى هذه الدراسة عدد 40 نعجة صعيدي تم تقسيمهم إلى مجموعتين (20 نعجة لكل مجموعة); المجموعة الأولى هي المجموعة الضابطة أو الكنترول (لم تتلقى أي معاملة) والمجموعة الثانية هي مجموعة المعاملة (والتي تم إعطائها محلول يحتوى على 12 ملجم من اليود كل يومين عن طريق التجريع من بداية الثلث الأخير من الحمل وكان هذا خلال فصل الشتاء) وغذيت المجموعتين طبقا لمقررات NRC. أوضحت النتائج أنه عند نهاية الحمل كان متوسط وزن النعاج بالمجموعة المعاملة أعلى معنويا (P<0.01) مقارنة بالمجموعة الكنترول (43.9 كجم مقابل 41.1 كجم). كان متوسط حجم الغاز المتنفس بالدقيقة وحجم التنفسة الواحدة ومعدل التمثيل الغذائي أعلى بشكل معنوي (P<0.01) فى المجموعة المعاملة باليود مقارنة بالكنترول. بالنسبة لمكونات الدم, فقد ارتفع متوسط تركيز البروتين الكلى وكذلك مشتقاته بالدم وكذلك مستوى الجلوكوز بشكل معنوي نتيجة المعاملة باليود. أيضا, ارتفع تركيز كلا من هرموني الترايأيودوثيرونين والثيروكسين بشكل معنوي (P<0.05) نتيجة المعاملة باليود. ونستخلص من خلال النتائج السابقة أن معاملة النعاج العشار باليود فى الثلث الأخير من الحمل خلال الشتاء قد أدى إلى تحسين الاستجابات الفسيولوجية لها وكذلك معدل التمثيل الغذائي وبعض مكونات الدم والذي إنعكس على تحسن الأداء العام لها وكذلك تحسن أداء حملانها وبقائها حية حتى الفطام.