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EFFECT OF HOUSING SYSTEM AND SEASON ON PHYSIOLOGICAL RESPONSE AND SEMEN QUALITY OF FRIESIAN BULLS.

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ABSTRACT

A total of 16 healthy Friesian young bulls aged 15 months and averaged 291±15.6 kg live body weight was divided into two equal groups according to their live body weight. Bulls were housed in two different housing systems (tie-stall and loose bran) under the same environmental conditions to evaluate semen quality and some physiological responses during three seasons (winter, spring and summer). Air temperatures (AT, ^{o}C), relative humidity (RH %), temperature humidity index (THI), and body temperatures (BT) were recorded twice a day at 08:00 hr and 14:00 hr. Blood samples were collected twice a month to evaluate the hemoglobin content (Hb, mg/dl), hematocrit values (Ht%) and testosterone hormone concentration (ng/dl). Semen was collected from all bulls under the two housing systems twice a week using an artificial vagina to evaluate the semen characteristics and morphology traits. Results showed highly significant effect ($P<0.05$) of the environmental conditions on bull physiological responses. The animal housing could affect the semen quality; however, it did not affect all the seminal traits which were investigated in this study. The seasonal variation was more effective factor that changing the semen quality than housing system types. Bulls showed better results under loose housing system in all seasons. Summer season where the THI reached 91 had negative effects on semen traits. It could be concluded that animal housing systems and seasonal variations can affect the seminal quality and some physiological parameters of Friesian bulls.
Keywords: Friesian bulls, tie-stall, loose housing, season, semen, testosterone.

INTRODUCTION

The heart of any dairy farm is where animals are housed, fed, and milked (Graves, 2000). The actual bull fertility levels are the result of a combination of genetic potential and environmental factors. Sayah *et al.* (2008) reported that housing system significantly changed physiological parameters of Friesian males such as growth rate, blood metabolites and body reaction significantly. While, Stevenson (2000) reported that the effect of housing is not restricted only on growth performance; but could affect the bull fertility as well. Housing and dietary factors may impair bull fertility (Ray and Nebel, 2002). Price and Wallach (1990) suggested that short-term individual housing can reduce sexual interest or libido of bulls. However, Suriyasomboon *et al.* (2005) indicated that the sperm morphology traits were mildly affected by the different housing systems.

Although, cattle are considered a continuous (nonseasonal) breeding species, some endocrine and reproductive variables fluctuate in an annual pattern (Randel, 1984). In Holstein bulls, the number of sperm cells per ejaculate is affected by season of year (Everett *et al.*, 1978). Also, semen quality and testis size decreased in the winter in Brahman bulls (Godfrey *et al*., 1990). The high environmental temperatures have been reported to cause an increase in the proportion of sperm abnormalities (Gwazdauskas *et al*., 1980). Furthermore, bull fertility and semen quality are known to seasonally variable (Parkinson, 1985). In addition, a defect in spermatozoa is higher during summer than during winter (Shepherdson *et al*., 1993). Sperm concentration and motile cells per ejaculate of bulls are lower in summer than in winter and spring (Mathevon *et al*., 1998). Testosterone is involved in sperm production through its action on the Sertoli cells (Ball and Peters, 2004). Severiano *et al*. (2003) found that testosterone concentrations of beef bulls at 4 years old in loose yards were affected by season. There is a great deal of agreement between authors according their results that cattle body reactions were related to temperature humidity index (THI) (West, 2003).

The main objective of the present study was to evaluate the effects of housing system and seasonal variations on semen quality and physiological response of Friesian bulls kept in two different housing systems; tie-stall system and loose system inside wide, good-ventilated and lighted barn.

MATERIALS AND METHODS

The study was carried out in Sakha Experimental Station, Animal Production Research Institute, Agricultural Research center, Egypt.

Animals and management:

A total of 16 healthy Friesian young bulls aged 15 months and averaged 291±15.6 kg live body weight was divided into two equal groups according to their live body weight. The first group of bulls was housed in loose housing, while the second group was housed in tie stall system. Bulls in both groups were fed commercial diet (Table 1). Both groups were kept in a semi-open barn under the same environmental conditions during three seasons; winter (December-February), spring (March-May) and summer (June-September). Both groups were kept in a fully shaded barn (30 m length × 7.5 m width) (Diagrams 1 and 1), which was roofed with an asbestos sheet at 3.5 m height on a concrete floor and a proper drainage. In addition, the barn was divided into tow equal parts (15 m deep × 6.5 m width) and each part used for housing each animal group. The allocated space for each loose animal was 12 m^2. The barn was surrounded with brick walls having wide ventilation openings (about 60% of the barn). The animals were offered a daily allowance of concentrate ration in accordance with their body weight at the rate recommended by NRC (1981) once a day in the morning according to the farm routine. Beside that, the animals had fresh berseem in winter and spring seasons, and they had berseem hay in summer. Moreover, the calves had daily access to *ad libitum* rice straw.

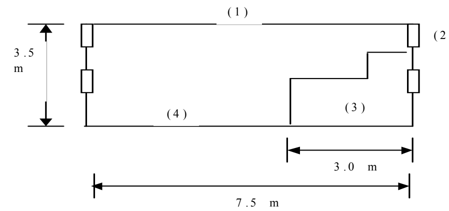

Diagram (1): Semi-open barn   Diagram (2): Front Layout of the semi-open barn
(1) Asbestos roof.   (2) Ventilation opening.   (3) A short wall.   (4) Concrete floor.

Table 1: Chemical composition (%) of the diet offered to bulls in both groups.

Item	DM%	Composition of DM (%)				
		CP	CF	EE	NFE	Ash
Concentrates	90.4	16.3	12.6	3.2	59.5	8.4
Berseem	16.9	15.2	23.9	2.6	47.1	11.2
Berseem hay	88.6	13.5	22.4	2.6	48.6	12.9
Rice straw	89.5	2.4	30.5	1.6	49.1	16.4

Experimental procedures:

Environmental conditions:

Air temperatures (AT, ^oC) and relative humidity (RH, %) were recorded twice a day at 08:00 hr and 14:00 hr using alcohol thermometer for AT and electronic thermo-hygrometer for RH. The following equation of the Agriculture Engineering Technology Guide (AETG, 1980) was used to determine the temperature-humidity index (THI) as an indicator of adverse climatic conditions.

$$THI = (1.8*T + 32) - (0.55 - 0.0055*RH)(1.8*T - 58)$$

Where: T is air temperature (ºC) and RH is relative humidity (%)

Physiological parameters and blood samples:

Rectal (RT) and skin temperatures (ST) were recorded twice a day at 08:00 hr and 14:00 hr. RT was measured by a digital thermometer and ST was measured by an infrared thermometer at the fore-flanks region. Observations were obtained from 24 readings for each housing system in every season. The following formula of Burton (1935) (BT = 0.64 *RT + 0.36 *ST) was used to calculate the core body temperature (BT) which includes both RT and ST as physiological parameters of the bulls against different environmental conditions.

Blood samples were taken twice a month from five animals in each group. Hematocrit values (Ht%) were determined using thin capillary tubes with a micro hematocrite centrifuge (10000 rpm) for 3 minutes. A small amount of blood (about 0.05 to 0.1ml) was placed in the thin capillary tube; the tube is sealed with wax, and then placed in a centrifuge to be spun. The height of the red cell column in the capillary tube equals the hematocrit (percentage of RBC's in the total blood volume).

Hemoglobin content (Hb, mg/dl) was estimated as hemoglobin concentration per 100 ml blood (g/dl) using special kits (Stanbio Hemoglobin delivered from Stanbio Laboratory, Texas, USA.). The test is based on quantitative colorimetric determination of hemoglobin in whole blood, according to the procedures outlined by the manufacturer.

Testosterone hormone concentration (ng/dl) was determined using special kits according to the procedures outlined by the manufacturers. The total serum testosterone assay was conducted by radio immune assay method (RIA). Determination- Pontex 335 kit (I^{125}) was used to measure the levels of testosterone. Types of testosterone assayed were (A) total testosterone (direct extraction-coated tubes) and (B) free testosterone. It is well known that total testosterone in serum include free testosterone and that bound to 1 pound to sex steroid hormone binding globulin (SHBG) albumin, corticosteroid binding globulin (CBG). According to the instructions of the producing company (Pantex Santa Monica), the solvents used in this assay break the protein binding during extraction process. The standard curve of testosterone ranged between 0.1 and 25.6 ng/ml.

Semen collection and evaluation:

Throughout the experimental period, semen was collected at 18 to 21 months of age from all bulls in each group twice a week using an artificial vagina. Immediately after collection, the percentage of mass motility, livability and abnormalities of spermatozoa, as well as, sperm cell concentration were evaluated according to Barth (2002).

Abnormal sperm were classified into four categories according to descriptions used for bovine evaluations (Barth, 2000) in terms of effects in head, mid-piece, and tail beside proximal droplets.

Statistical Analysis

Statistical analyses of data were carried out applying the package of SAS (1996) according to the following models: $Y_{ijk} = \mu + H_i + S_j + HS_{ij} + e_{ijk}$

Where: Y_{ijk} =the studied dependent variable, μ =the overall mean, H_i =the effect of housing system (i, 1 & 2), S_j= the effect of season (j, 1, 2, & 3), HS_{ij} = the effect of interaction between housing system and season and e_{ijk} = random residual effect.

The significant differences among means were tested using Duncan Multiple Ranges Test (Duncan, 1955). The percentage values of semen characteristics were subjected to arcsine transformation before performing the analysis of variance. Means were presented after being recalculated from the transformed values to percentages.

RESULTS AND DISCUSSION

Environmental conditions:

Air temperature (AT, ^oC), relative humidity (RH %) and the temperature humidity index (THI) inside the semi-open barn during three experimental seasons are shown in Table 1. The present results revealed great seasonal and diurnal differences in the climatic conditions. According to Johnson (1987), the upper critical THI for Holstein-Friesian cattle is 72. Therefore, Friesian bulls were suffered from heat stress at 08:00 hr. and 14:00 hr in summer (75.98 and 91.34, respectively) and at 14:00 hr in spring

(74.78). Thus, the summer hot condition is apt to impose extra stress on the animals, which reflected on the animal performance severely. The THI values in winter either in the morning or in the afternoon (54.70 and 66.93, respectively) showed the lowest values than summer and spring seasons at the same daytimes. Mader *et al.* (2006) stated that although knowledge of THI alone is beneficial in determining the potential for heat stress, wind speed and solar radiation adjustments to the THI would be more accurately assess animal discomfort.

Table 2: Means ± SE of air temperature (AT, °C), relative humidity (RH%) and THI as affected by season.

Season	AT (°C)		RH %		THI	
	08:00hr	14:00hr	08:00hr	14:00hr	08:00hr	14:00hr
Winter	12.3±0.07	21.7±0.18	75.3±0.50	55.0±0.99	49.29±0.11	66.37±0.17
Spring	18.7±050	26.0±0.45	69.3±0.14	34.8±0.57	61.55±0.62	74.78±0.47
Summer	25.3±0.25	32.8±0.07	77.3±0.28	47.3±0.14	75.98±0.41	91.34±0.08

(AT) Air Temperature. (RH) Relative Humidity. (THI) Temperature Humidity Index.

Body temperature:

Body temperatures (BT, °C) of Friesian bulls kept in different housing system during three different seasons are shown in Table 3. The present results showed that BT was effected significantly ($P<0.05$) by season, being the highest in summer (35.26 °C), moderate in spring (33.93 °C) and the lower in winter (33.44 °C). However, no significant effect was found for housing system (Table 3). Similar results were obtained by Shafie and El-Sheikh Aly (1970), who found seasonal variation of Friesian body temperature during different seasons. They reported that the increase in body reaction in Friesian cattle is a result of both gradual rise in atmospheric temperature and the variable increase in body activities of the animal.

Table 3: Means ±SE of body temperature (BT, °C) of Friesian bulls kept in different housing systems during three different seasons.

Housing system	Season			Overall mean
	Winter	Spring	Summer	
Tie Stall	33.54±0.17	34.13±0.16	35.19±0.09	34.29±0.13
Loose barn	33.44±0.17	33.93±0.16	35.32±0.09	34.26±0.14
Overall mean	33.49±0.12^{c}	34.03±0.11^{b}	35.26±0.06^{a}	

a, b and c: Means denoted within the same row are significantly ($P<0.05$) different.

Hematological and testosterone responses:

The hematocrit (Ht, %), and hemoglobin (Hb, g/dl) and serum testosterone (ng/dl) concentration of Friesian bulls are shown in Table 4. Values of hematocrit, and hemoglobin and testosterone concentrations were not affected significantly by housing system. These results are in agreement with Grasso *et al*. (2004), who found that blood hematological levels were not affected by housing system. However, Sayah *et al*. (2005) found significant effect on housing system on Hb and Ht. Price and Wallach (1990) reported that short-term individual housing can reduce sexual interest or libido in bulls, although the present results indicated unaffected testosterone level, which may mean that bulls kept under both housing systems may have similar libido.

The results shown in Table 4 revealed significant effect of housing system only on Hb and testosterone concentrations. Bulls showed significantly ($P<0.05$) the highest testosterone and the lowest Hb concentration during summer, the highest Hb in spring and the lowest testosterone in winter, respectively. The present result are in agreement with Sayah (1997) and Ashour *et al*. (1998). Also, Shaffer *et al.* (1981) observed variations in Hb and oxyhemoglobin in different environmental conditions. It was the highest during intermediate seasons and lowest during hot months. This depression may be due to hemodilution effect where more water is transported in the circulatory system for evaporative cooling.

Table 4: Means ±SE of hematocrit (%) and concentration of hemoglobin (g/dl) and testosterone (ng/dl) as affected by housing system, season and its interaction.

Item	Ht (%)	Hb (g/dl)	Testosterone(ng/dl)
Housing system:			
Loose barn	28.58±0.94	13.71±0.48	01.89±0.31
Tie stall	28.79±0.97	14.94±0.51	01.82±0.30
Seasons:			
Winter	29.54±1.21	$14.73{\pm}0.30^{ab}$	$1.41{\pm}0.21^{b}$
Spring	28.16±1.04	$15.11{\pm}0.29^{a}$	$1.72{\pm}0.23^{ab}$
Summer	28.39±0.92	$14.17{\pm}0.25^{b}$	$2.45{\pm}0.28^{a}$
Housing system x season:			
Loose barn × Winter	30.08 ±1.12	14.21 ±0.61	1.28 ±0.32
Loose barn × Spring	27.92 ±1.06	14.88 ±0.59	1.76 ±0.30
Loose barn × Summer	27.75 ±0.84	14.00 ±0.45	2.64 ±0.31
Tie stall × Winter	29.00 ±1.12	15.25 ±0.61	1.53 ±0.33
Tie stall × Spring	28.33 ±1.06	15.23 ±0.51	1.67 ±0.30
Tie stall × Summer	29.03 ± 0.84	14.34 ± 0.45	2.25 ± 0.31

$^{a\ and\ b}$: Means denoted within the same column with different superscripts are significantly ($P<0.05$) different.

On the other hand, Moustafa *et al*. (1977) found that Hb values increased during summer months in Upper Egypt to over 29 ^{o}C air temperatures and 55.5 % relative humidity. In accordance with the present results, Concerning the observed significantly ($P<0.05$) higher testosterone concentration in summer than in winter (2.45 vs. 1.41 ng/dl, Minton *et al*. (1981) found that the average of serum testosterone concentration was similar in both heat-stressed and control bulls.

The effect of interaction between housing system and season on Ht, Hb and testosterone was not significant, reflecting the highest values of Hb and Ht in winter with loose barn and tie stall systems, respectively. However, the highest testosterone concentration was observed in summer with loose barn system (Table 4).

Semen characteristics:

The effect of housing system on physical semen characteristics of Friesian bulls are shown in Table 5. Semen characteristics were affected significantly (P<0.05) by housing system, except ejaculate volume. It was observed that sperm concentration, and percentages of mass motility and live sperm significantly (P<0.05) increased and sperm abnormality percentage significantly (P<0.05) decreased for Loose barn as compared to tie stall housing system, being 1.246 x10^6, 76.11%, 78.89% and 10.69% vs. 1.069 x10^6, 61.95%, 66.61 and 16.95%). This means that bulls kept under loose housing system produce better semen quality than those kept under tie stall. In this respect, Zimmerman *et al.* (1981) reported that confinement and social restriction are factors that increase reproductive problems for young boars, often causing problems with reproductive behavior rather than semen quality.

Table 5: Means ±SE of semen characteristics of Friesian bulls kept under different housing systems.

Semen characteristics	Loose barn	Tie stall
Ejaculate volume (ml)	2.73±0.34	2.29±0.32
Sperm cell concentration (x 10^6/ml)	1.246±0.10^a	1.069±0.11^b
Mass motility (%)	76.11±3.6^a	61.95±3.5^b
Live sperm (%)	78.89±4.0^a	66.61±3.8^b
Sperm abnormality (%)	10.69±1.8^b	16.95±1.7^a

$^{a\ and\ b}$: Means denoted within the same row with different superscripts are significantly (P<0.05) different.

As affected by season (Table 6), bulls showed significantly (P<0.05) the highest motility and livability with the lowest sperm abnormality percentage in winter. While, the highest sperm cell concentration was observed in spring. However, ejaculate volume was not affected significantly by season. These results are in agreement with Safaa *et al.* (2008), who reported that overall semen characteristics were better in winter than in the summer season under the Egyptian environmental conditions. Generally, the effect of season is frequently attributed to a combination of two factors: photoperiod and temperature (Ciereszko *et al.,* 2000).

Table 6: Means ±SE of semen characteristics of Friesian bulls during three different seasons.

Semen characteristics	Winter	Spring	Summer
Ejaculate volume (ml)	2.73±0.3	2.43±0.31	2.39±0.29
Sperm concentration (x 10^6/ml)	1.192±0.06^{ab}	1.236±0.05^a	1.046±0.06^b
Mass motility (%)	63.75±1.9^a	57.92±2.5^{ab}	55.42±2.1^b
Live sperm (%)	77.20±1.7^a	70.84±1.2^b	70.34±1.8^b
Sperm abnormality (%)	12.30±1.1^b	12.29±1.2^b	16.27±1.2^a

$^{a\ and\ b:}$ Means denoted within the same row with different superscripts are significantly (P<0.05) different.

The results of housing systems effect on semen characteristics were clearer with the additional effect of the different seasons (effect of interaction was not significant) as illustrated in Figs. (1-4). It was observed that bulls kept under loose bran system showed high quality semen as compared to those kept under tie stall system in therms of sperm cell concentration, and percentages of motility, livability and abnormality in each season (Fig. 1).

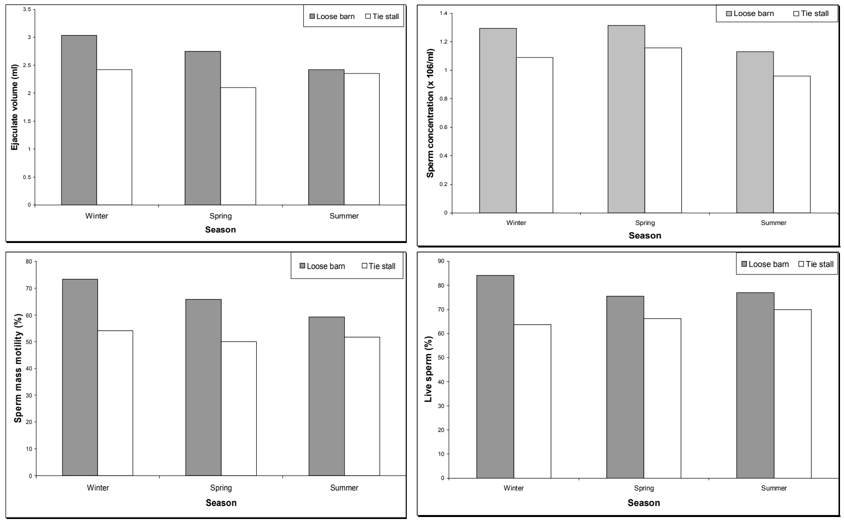

Fig. (1): Bull semen characteristics at different housing systems in different seasons.

Sperm abnormalities:

Effect of housing system on sperm abnormalities of Friesian bulls are shown in Table 7. Results revealed that housing system affected significantly (P<0.0) on percentage of spermatozoa with defects in head and mid-piece, being lower for bulls kept at loose bran than tie stall system. Meanwhile, percentage of spermatozoa with defects in tail and proximal droplets was not affected by housing system. It is of interest to note that percentage of each type of abnormality relative to total abnormalities percentage was not affected by housing system. In this respect, Suriyasomboon *et al.* (2005) indicated that the sperm morphology traits were mildly affected by the housing system.

As affected by season, results presented in Table 8 revealed that bull semen showed significantly (P<0.05) higher percentage of spermatozoa with defects in head, mid-piece and proximal droplets in summer than in winter and spring. However, percentage of spermatozoa with defects in tail was not affected by season. It is worthy noting that only percentage of spermatozoa with defects in tail relative to total abnormalities occurred significantly (P<0.05) in winter than in summer and spring.

Table 7: Means ±SE of sperm abnormality percentage of Friesian bulls kept under different housing system

Sperm abnormality type	Loose barn		Tie stall	
	Absolute %	Relative to total %	Absolute %	Relative to total %
Head defects	5.59±1.1^{b}	51.30±4.2	9.81±0.9^{a}	57.73±3.6
Mid-piece defects	2.99±0.31^{b}	27.67±2.8	4.41±0.31^{a}	26.40±2.1
Tail defects	1.47±0.42	14.03±0.9	2.10±0.43	13.03±0.8
Proximal droplets	0.72±0.08	6.67±1.00	0.84±0.08	4.83±0.90

Means denoted within the same row with different superscripts are significantly (P<0.05) different.

Therefore, the discussion will focus mainly on the seasonal variations as interacted with housing system. Results illustrated in Fig. (2) revealed that percentages of all types of abnormalities were almost lower in semen of bulls kept in loose bran than in tie stall system in each season, being higher in summer than in other seasons. In agreement with the present results, many authors (Suriyasomboon and *et al.,* 2005; Safaa *et al.*, 2008; Oberst *et al.,* 2011; Aller *et al.*, 2012; Petrocelli *et al.,* 2015), who studied the effect of seasonal variations on semen production and sperm morphology. Moreover, the fluctuations in semen quality are associated with factors such as breed (Rijsselaere *et al.,* 2007), age (Stone *et al.,* 2013), seasonality (Chemineau *et al.,* 2008; Zhang *et al.,* 2013), temperature (Thonneau *et al.,* 1998), photoperiod (Kozdrowski and Dubiel, 2004), and other factors of different etiology. All of these factors require careful control to get the best semen quality for artificial insemination. According to Hoffman and Landeck (1999), temperature and photoperiod affect the hypothalamic-hypophysis-gonadal axis regulating spermatozoa production and maturation in the epididymis.

Table 8: Means±SE of sperm abnormality of Friesian bulls during three different seasons.

Abnormal sperm type	Winter		Spring		Summer	
	%	Relative	%	Relative	%	Relative
Head defects	6.86±1.1^{b}	54.4±3.4	6.59±1.2^{b}	52.6±3.5	9.67±0.9^{a}	56.55±3.2
Mid-piece defects	3.31±0.31^{b}	26.9±2.3	3.41±0.29^{b}	27.4±1.7	4.37±0.33^{a}	26.9±2.3
Tail defects	2.17±0.50	17.3±1.5^{A}	1.47±0.45	12.9±1.3^{B}	1.71±0.35	10.5±1.2^{B}
Proximal droplets	0.59±0.10^{b}	5.0±0.9	0.68±0.09^{b}	5.7±1.1	1.08±0.11^{a}	6.6±1.1

Means denoted within the same row with different superscripts are significantly (P<0.05) different.

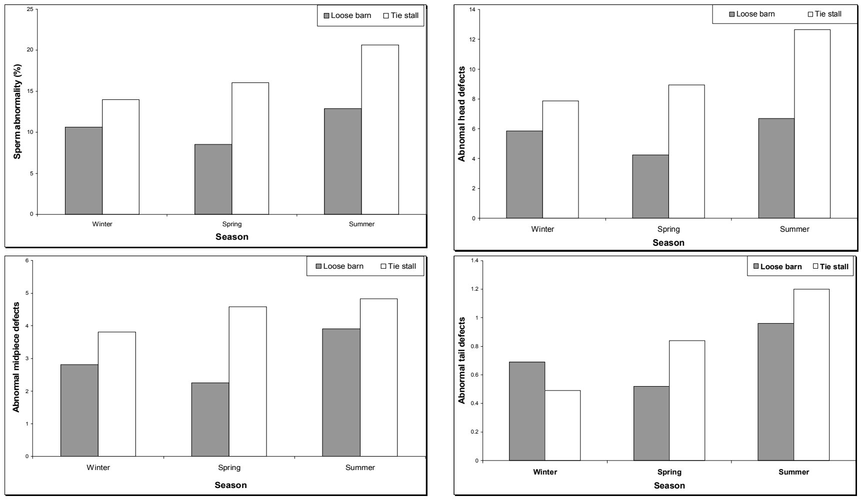

Fig. (2): Percentage of sperm abnormalities in semen of bulls kept at different housing system in different seasons.

CONCLUSION

Animal housing system could affect semen quality and some physiological parameters such as testosterone hormone and body temperature of Friesian bulls. Bulls showed better results under loose bran than tie stall housing system in all seasons.

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تأثير نظم الإيواء والموسم على الخصائص الفسيولوجية وجودة السائل المنوي لطلائق الفريزيان

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أستخدم فى هذه التجربة ١٦ من طلائق الفريزيان حديثة السن عمرها ١٥±١٢.٠ شهر ومتوسط وزن ٢٩١±١٥.٦ كجم. قسمت هذه الطلائق لمجموعتين متساويتين حسب العمر والوزن. وسكنت الطلائق فى نظامين مختلفين من الإيواء الحيواني (نظام الربط و نظام الحر) تحت نفس الظروف البيئية وذلك لدراسة تأثير اختلاف نظام الإيواء والتباين الموسمى فى درجات الحرارة والرطوبة على خصائص السائل المنوى والاستجابة الفسيولوجية لهذه الطلائق خلال مواسم الشتاء والربيع والصيف. قدرت درجات حرارة الجو ونسبة الرطوبة لتقدير مؤشر الحرارة والرطوبة وكذلك قدرت حرارة المستقيم والجلد لتقدير حرارة الجسم الفعلية وذلك خلال الساعة الثامنة صباحاً والثانية مساءً. أخذت كذلك عينات الدم مرتين شهرياً من خمسة حيوانات فى كل مجموعة لتقدير الهيموجلوبين والهيماتوكريت وهرمون التستيستيرون .بجانب ذلك جمعت عينات السائل المنوي من جميع الحيوانات باستخدام المهبل الصناعي مرتين فى الأسبوع لتقدير خصائص السائل المنوى المختلفة. أظهرت النتائج علاقة قوية بين استجابة الحيوانات والظروف البيئية. أثر الإيواء الحيوانى على بعض خصائص السائل المنوي ولم يؤثر على البعض الأخر. بالإضافة إلى أن التباين الموسمي فى درجات الحرارة والرطوبة كان أكثر تأثيراً من الإيواء الحيوانى فى تغيير خصائص السائل المنوى. وقد أظهرت الطلائق استجابة فسيولوجية وسائل منوى أعلى جودة تحت نظام الإيواء الحر خلال موسمى الشتاء والربيع حيث كان لموسم الصيف تاثير سلبى على جودة السائل المنوى مع وصول مؤشر الحرارة والرطوبة إلى ٩١ درجة.

وفى النهاية يمكن القول أن نظم الإيواء المختلفة والتباين الموسمى فى درجات الحرارة والرطوبة يمكن أن تؤثر على جودة السائل المنوى والخصائص الفسيولوجية لطلائق الفريزيان.