Original Research Article

Physiological Responses of Adult Nubian Goats (*Capra hircus*) to Orchiectomy

ABSTRACT

Aim: This study was designed to investigate the effects of bilateral surgical castration on physiological responses in adult Nubian goats.

Methodology: Twenty male goats (bucks) were assigned to two equal groups, group A served as control and group B was subjected to bilateral castration; both groups were monitored for 4 weeks. The effects of castration on thermoregulation, hematologicalvariables, and serum biochemical constituents were investigated. An independent T-test was used to assess the effects of orchidectomy on the parameters monitored.

Results: Castration increased T_r, RR, HR, TLC and decreased bodyweight, PCV, RBCs, and Hb concentration. The ratios of lymphocytes, monocytes, and eosinophils decreased associated with an increase in the ratio of neutrophils. The castrated group had lower serum total protein and albumin concentrations and had higher urea, plasma glucose, GOT and GPT concentrations compared to the intact group.

Conclusions: The study concluded that castration altered thermoregulation, hematological and biochemical parameters in adult Nubian goats.

Keywords: Nubian goats ;bilateral orchidectomy; thermoregulation; hematological parameters; blood biochemical constituents.

1. INTRODUCTION

Castration (orchiectomy) is defined as any procedure that removes the testicles surgically, damaging them irreparably or causing them to atrophy by stricture of the blood supply

[1]. Castration is an important management practice for goats and sheep farmers to maintain control of their breeding program and successfully carry out breed improvement [2]. Also, the aim of castration is to prevent unwanted reproduction and to control the sexual behaviour of males. Castration causes sterilization; it also greatly reduces the production of testosterone. Surgical castration in animals is often called neutering [3]. Usually castrated animals, but not invariably, lack *libido*. Small amounts of testosterone from other sources, such as the adrenal gland, might be sufficient to provide *libido* in some animals [4]. Physical castration is used in livestock industries to prevent indiscriminate breeding, avoid undesirable odors, control aggression, and improve meat and carcass quality [5]. Intact males often become aggressive and dangerous to their handlers and other animals [6]. The castration abolishes aggressive behavior, prevents various diseases and the genetic transmission of abnormal conditions to the next generation [7].

In the clinical field, androgen deprivation therapy (ADT) has been used as the main treatment for advanced stage of prostate cancer in humans [8, 9]. Bilateral orchidectomy (surgical castration) is still considered the gold standard for ADT in prostate cancer [10, 11].

Previous studies have demonstrated that castration had effects on thermoregulation and heart rate. The heart rate, respiratory rate, and rectal temperature increased in bucks after one hour of Burdizzo castration [12]. Studies indicated that castration decreased red blood cells, PCV, Hb concentration, and lymphocytes accompanied with increased MCV, MCH, TLC and neutrophils in goats [12, 13, 14]. Also, studies have shown that castration influences metabolic responses. Castration decreases significantly serum total protein, albumin, and glucose level in Black Bengal goats [14]. Kayode and Obot [12] found that the concentrations of urea and creatinine increased and total protein, albumin and globulin decreased post-castration in goats.

Previous studies indicated that after one week of castration, serum testosterone levels were significantly lower in bucks [15]. Oyeyemi et al. [16] reported that bilateral orchiectomy results in the increased level of some diagnostically important enzymes, GOT and ALP in the serum of bucks.

This experiment was designed to provide information regarding the effects of castration on physiological responses in adult Nubian goats. The basic physiological information obtained can be utilized in assessing the impact of stress and monitoring alterations associated with pathological conditions in male goats .

2. MATERIAL AND METHODS

2.1 Experimental Animals, Housing and Management:

Twenty adult, apparently healthy male goats, obtained from the local market, were used in this experiment. The goats were kept in the small ruminant unit at the Department of Physiology, Faculty of Veterinary Medicine, University of Khartoum. They were kept in an animal house provided with adequate ventilation under natural light-dark photoperiod. The animals were examined clinically and were given prophylactic treatments of anthelmintic injection (Ivomec: 0.02 ml/kg BW: Alpha Laboratories Ltd, India) and antibacterial injection (Oxytetracycline: 7.5 mg/kg BW: Alpha Laboratories Ltd, India). The animals were maintained on a diet of dry lucerne hay (*Medicago sativa*) and tap water *ad libitum*. They were kept for an adaptation period of 2 weeks before experimentation so that they were accustomed to the experimental conditions and collection of blood samples. The experiment was conducted during September–October, 2018 (maximum temperature 41.6ºC, minimum 18.4ºC; mean relative humidity 36%).

2.2 Experimental Design

The animals were randomly assigned to 2 groups of 10 each. Group A served as control, group B was subjected to bilateral surgical castration. The rectal temperature (T_r), respiratory rate (RR), heart rate (HR), and blood profile were monitored pre-castration, and at days 1, 3, 7, 10, 15, 21 and 28 following castration.

2.3 Surgical Procedure:

Castration was performed under local anesthesia according to a standard method [17]. Animals were fasted overnight before surgery. The surgical region of each buck was prepared; the site was scrubbed with povidone-iodine 10% topical solution. Local anesthetic, 2% w/v lidocaine HCl injection (PSI, Jeddah, Saudi Arabia) 20 ml were injected in the scrotal skin and spermatic cord.

Vertical incisions were made on either side of the scrotum. The testis was identified and freed from its surrounding fascia with blunt dissection. The spermatic cord was isolated, ligated, and transected. Forceps were used for crushing the spermatic cord to induce hemostasis. The spermatic cord was ligated, the cremaster muscle was ligated with the vaginal tunic, and both were transected approximately 2 cm distal to the ligations. Transfixation sutures were done to prevent ligature slippage. The subcutaneous tissues were closed with chromic catgut size 1/0. Skin tissues were closed with chromic catgut size 2/0. Antimicrobial Almox L.A 15% injectable suspension (Star Laboratories, Pakistan) and anti-inflammatory Dexaphan (Pharma Swede, Egypt) medications were used for 5 days after surgery.

2.4 Physiological Investigations

During the experimental period, the rectal temperature (Tr) was measured by a digital clinical thermometer (Hartman-United Kingdom). The RR was measured by visually counting the flank movements for one minute using a stopwatch. The HR was obtained by monitoring the heart sounds for one minute using a stethoscope and a stopwatch. During the experiments, the animals were weighed using a traditional balance (Kinlee - Hanging scale, China). The parameters of erythrocytic indices and leukogram were

determined according to the standard methods [18]. Serum total protein concentration was determined by the Biuret method [19] using a kit (BioSystems, S.A., Spain). Serum albumin concentration was determined by the colorimetric method of Bromocresol green [20] using a kit (Bio Systems, S. A., Spain). Serum urea concentration was determined by the enzymatic-colorimetric test (Berthlot) [21] using a kit (BioSystems, S.A., Spain). The plasma glucose concentration was determined by the enzymatic colorimetric method [22] using a kit (Spinreact, S.A., Spain). Serum GOT and GPT activities were determined by the enzymatic method [23] using a kit (Spinreact, S.A., Spain).

2.5 Statistical Analysis

The data collected were subjected to standard methods of statistical analysis using Statistical Package for the Social Sciences [24]. In this experiment, an independent sample T-test was used to assess the effects of castration in adult male goats. The experimental data were expressed as mean values ± SD and were presented in figures (histograms) and the Tables of analysis were included in the text. P-value of <0.05 was considered statistically significant.

3. RESULTS

3.1 Thermoregulation (T_r), Respiratory Rate (RR) and Heart Rate (RR)

The effects of castration on Tr, RR and HR are presented in Table 1.

3.1.1 Rectal temperature (T_r)

The general pattern indicates that the castrated group had higher $T_r$values compared to the control group. The castrated group had significantly ($p \leq 0.05$) higher $T_r$values compared to the intact group at day 7 (Fig. 1).

3.1.2 Respiratory rate (RR)

Respiratory rate(RR) values of the castrated group were higher compared with the intact group until the end of the experimental period. The castrated group had significantly

higher RR, at days 1, 7 and, 21 ($p \leq 0.05$), and at day 15 ($p \leq 0.001$) compared to the intact group (Fig. 2).

3.1. 3 Heart rate (HR):

The general pattern indicates that the castrated group had higher HR values compared to the intact group until day 15and thereafter decreased . The castrated group had significantly higher HR values compared to the intact group at days 1 ($p \leq 0.001$) and 15 ($p \leq 0.05$) (Fig.3).

3. 2 Bodyweight (BW)

The initial mean values of BW ranged from 31.41 to 34.25 kg. The mean values of BW decreased in the castrated group compared to the intact group. On day 28, the castrated group had significantly ($p \leq 0.01$) lower BW compared to the intact group (Fig. 4).

3.3 The erythrocytic indices parameters

The effects of castration on erythrocytic indices parameters are presented in Table 2.

3.3.1 Packed cell volume (PCV)

Generally, the castrated group maintained lower PCV value compared to the intact group until the end of the experimental period. These lower values attained the level of significance at days10 ($p \leq 0.05$), 15 ($p \leq 0.01$), 21 and 28 ($p \leq 0.001$). However, on day1, the castrated group had a significantly ($p \leq 0.001$) higher PCV value compared to the intact group (Fig. 5).

3.3.2 Red blood cell count (RBCs)

The pattern indicates that the castrated group had a lower RBCs value compared to the intact group until day 21. The castrated group had a significantly lower RBC value compared to the intact group at days 7 ($p \leq 0.05$), 10, 15 and 21 ($p \leq 0.01$) (Fig.6).

3.3.3 Haemoglobin (Hb) concentration

The general pattern indicates that the castrated group had lower Hb concentration compared to intact group until day 28. The castrated group had significantly lower Hb concentration at day 15 ($p \leq 0.05$) and day 28 ($p \leq 0.01$) compared to the intact group (Fig.7).

3.4 Total Leukocyte Count (TLC) and Differential Leukocyte Count (DLC)

The effects of castration on TLC and DLC are shown in Table 3.

3.4.1 Total leukocyte count (TLC)

Generally, the castrated group had higher TLC values compared with the intact group until day 10. Thereafter, the TLC values decreased until day 28. The castrated group had a significantly higher TLC value compared to the intact group at days 1 ($p \leq 0.01$) and a lower value at day 15 ($p \leq 0.05$) (Fig.8).

3.4.2 Lymphocyte and neutrophil ratios

The general pattern indicates that the lymphocyte ratios of the castrated group were lower and neutrophil ratios higher compared to the intact group. On day 1, the lymphocyte ratio was significantly ($p \leq 0.05$) lower and the neutrophil ratio was significantly ($p \leq 0.01$) higher in the castrated group compared to the intact group (Figs. 9 and 10).

3.4.3 Monocyte and eosinophil ratios

Generally, there was no significant effect of castration on monocytes and eosinophil ratios, and the values of both of them were lower in the castrated group compared to the intact group. There were considerable fluctuations during the experimental period (Figs. 11 and 12).

3.5 Blood Metabolites and Enzymes

The effects of castration on serum levels of metabolites and enzymes are shown in Table 4.

3.5.1 Serum total protein and albumin

The pattern indicates that the castrated group maintained lower total protein and albumin concentrations compared to the intact group during the experimental period. The castrated group had significantly ($p \leq 0.01$) lower albumin concentration, at day1, and lower ($p \leq 0.05$) total protein concentration at day 7 compared to the intact group (Figs. 13 and 14).

3.5.2 Serum urea

The general pattern indicates that the castrated group had higher urea values compared to the intact group until day 10. The castrated group had significantly higher urea concentration compared to the intact group at day1 ($p \leq 0.001$) and day 3 ($p \leq 0.05$). On days 15, 21, and 28, the castrated group had lower urea concentration compared with the intact group (Fig.15).

3.5.3 Plasma glucose

The pattern indicates that the castrated group had higher plasma glucose compared to the intact group until day 3. On day1, the castrated group had a significantly ($p \leq 0.05$) higher plasma glucose value compared to the intact group. On days 7, 10 and 15, the plasma concentration of the castrated group was lower compared with the intact group (Fig. 16).

3.5.4 Serum enzymes

The pattern indicates that the castrated group had higher GOT and GPT values compared to the control group, except at days 1 and 15, the castrated group had lower serum GPT values compared to the intact group. Generally, there was no significant effect of castration on serum GOT and GPT concentrations (Figs. 17 and 18).

4. DISCUSSION

The results indicate that the rectal temperature (Tr) was higher in goats subjected to castration compared to intact goats. This increase is mainly attributed to inflammation reaction and pain after surgery. The relative hyperthermia experienced by castrated animals was related to post-surgical pain and stress [25, 26]. The stress response leads to

the secretion of many hormones resulting in hyper-metabolism, with the acceleration of most of the biochemical reactions [27]. Stress hormones increase metabolic rate and heat production and cutaneous vasoconstriction, which decreases heat loss and leads to rising in body temperature [28]. Simsek et al. [29] indicated that the body responds to trauma with an increase in oxygen consumption and an increase in body temperature. The current result in Nubian goats agrees with the findings in bucks castrated by the Burdizzo method [38].

The respiratory rate (RR) of goats was markedly influenced by castration illustrated by a significant increase in RR of the castrated group compared to the control. This increase may be related to pain and inflammation reactions. Painful stimuli increase the activity of the sympathetic nervous system and lead to a significant increase in RR [30-33]. Superficial nerve endings damage as a result of tissue trauma leads to acute pain [28]. The body responds to trauma with an increase in respiratory rate [29]; Okafor et al. [34] observed rapid shallow breathing after orchidectomy in goats.

The current study indicates that the HR of castrated goats increased compared to the control group until day15. The initial significant increase at day 1 may be attributed to the effects of castration stress responses, leading to activation of the sympathetic nervous system, resulting in increased secretion of catecholamines [35]. An increase in sympathetic activity results in well recognized cardiovascular effects of tachycardia [36]. The pain sensation causing sympathetic stimulation leads to rising in HR and blood pressure [28]. Niveditha et al. [26] reported that the increase in the HR post-operation on day one could be attributed to the stimulated sinus node by the effect of norepinephrine . The painful stimulus during surgery may activate the central nervous system which would cause a rise in the systolic arterial blood pressure [37]. The result in the current study agrees with the findings in bucks castrated by the Burdizzo method [38].

Castration affected the BW of goats, there was a decline in the castrated group compared to the control group at week 4. Protein catabolism stimulated by increased cortisol

concentration results in marked weight loss and muscle wasting after major surgical and traumatic injury [27]. The reduction in BW of castrated bucks could also be associated with the observed decline in food intake. A similar reduction in time spent eating was previously reported in castrated calves compared with the control group [39]. Also, this weight loss response may be related to the depletion of testosterone hormone in castrated animals. Testosterone has anabolic effects involving growth of muscles [40]. The current result in Nubian goats is in agreement with the previous findings inAwassi lambs [41]and in rats [42].

The results indicate that the erythrocytic parameters of goats were influenced by castration. This effect was illustrated by an increase at day 1 and then a gradual decrease in the PCV, total count of RBCs, and Hb concentration in the castrated group compared to the control group. The increase in these parameters at day one may be attributed to surgery. This agrees with the findings [43] in goats subjected to the flank laparotomy, the PCV, RBCs and Hb concentration increased 18- 24 hrs after surgery, and in piglets [44] . The decrease in PCV, total count of RBCs, and Hb concentration could be attributed to the effect of testosterone on erythropoiesis. A previous study reported that androgens stimulate hematopoietic system by mechanisms which include stimulation of erythropoietin release from the kidneys, increasing bone marrow activity and iron incorporation into the red blood cells [45]. Testosterone has the ability to increase erythropoiesis and red blood cells production in the kidney [46]. Previous study indicated that androgens stimulate erythropoiesis and increase the levels of red blood cells, haemoglobin and PCV [47]. The current results are consistent with the findings in goats [13] and in rats[46, 48] .

The current results indicated that the peripheral total leukocyte count (TLC) increased significantly at 24 hrs following castration . This change is due to multiple factors including reactive leukocytosis, physiological stress, inflammatory reaction and pain [41, 49]. The TLC increased due to reactive leukocytosis and stress associated with the

castration procedure as well as activation of defense mechanisms and immune system [13]. The present findings for TLC are in accordance with the findings of Chase et al. [50] who reported that TLC was significantly higher in castrated than in intact control bulls. Similar findings were also observed in goats [13] and calves [51] .

The neutrophils ratio increased significantly, while lymphocytes ratio decreased significantly at 24 hrs following castration . Previous study indicated that the increase in neutrophils may be due to adrenocortical stimulation and subsequent effect of glucocorticoids on circulating neutrophils, as well as acute inflammation in scrotum [52]. The ratio of neutrophils to lymphocytes was greater in castrated calves compared with sham group [39]. The present observation in Nubian goats is in line with Earley and Crowe [53] who reported increase in neutrophil and decrease in lymphocyte after surgical castration in bull calves. Similar findings were reported in goats castrated by Burdizzo method[38], in Awassi lambs [41], and in rats [34] .

The ratios of monocytes and eosinophils did not change significantly during the experimental period . The slight increase in eosinophils count in the present study may be related to acute inflammation. Similarly , previous studies [52 , 54] reported that there were no significant changes in monocyte and eosinophil count after castration of bull calves. Similar findings were also reported in dogs [55] .

The results showed that both serum total protein and albumin levels decreased at 24 hrs following castration . This change is presumably related to hepatic dysfunction as a result of tissue damage and hepatic response to tissue reaction [16]. Studies by Huber et al.[56] found that there was a decrease in the concentration of albumin post-operation. The hepatic albumin synthesis is impaired during the early postoperative period in order to facilitate the production of acute phase proteins needed in the host defense process [57]. The decrease in total protein in the current study is in agreement with previous results in bucks subjected to bilateral orchiectomy [16], and bucks castrated by Burdizzo method [13].

The present study showed that castration caused significant increase in serum urea level . This change may be attributed to inflammation and breakdown of tissues [16]. The stress of surgery is known to cause an increase in plasma urea associated with increase in muscles protein and nucleic acids breakdown due to increase in catabolic hormones concentration [58]. A previous study [38] indicated that the increased level of urea observed post-castration in goats could apparently be induced by elevated cortisol concentration. The reported increase in urea level is consistent with previous results in ruminants [13, 41].

The significant increase in glucose concentration following castration is clearly attributed to secretion of stress hormones. The release of cortisol leads to a delay in the metabolism and utilization of glucose, while increased plasma epinephrine causes gluconeogenesis in the liver, lipolysis and insulin resistance, preventing the uptake of glucose [28, 59]. Previous studies suggested that normal circulating level of testosterone is essential for maintaining optimum insulin concentration [60, 61]. The observed increase in glucose level in response to castration in Nubian goats is in agreement with previous findings in ruminants [13, 41] and rats [42]. In contract, a previous study reported that plasma glucose and insulin fasting levels were not modified by the testosterone deficiency in mice [62].

The results indicate that there was no significant effect of castration on serum levels ofglutamic oxalacetic transaminase (GOT) andglutamic pyruvic transaminase (GPT) during the experimental period . However, castrated goats had elevated GOT activity compared to the control group. This change may be attributed to tissues damage associated with castration [41]. Post-operative stress also increases catabolic breakdown of tissue and dehydration [38]. Previous study indicated that the initial increase in GOT level just after castration may be due to damage of scrotal cells [16]. However, serum GOT is not specific to any particular organ in the body [63]. The current results in goats agree with the finding of in bucks exposed to bilateral orchidectomy [16] . Also, these

findings are in accordance studies [13] which found no significant change in GOT value in bucks after castration. Previous studies also reported similar findings in calves [52, 64]. Olaifa and Opara [13] showed that GPT activity remained within normal limits in bucks after castration. Previous studies reported non-significant difference in serum enzymes after orchidectomy in bucks [16] and lambs [65].

5. CONCLUSION

Bilateral castration induced alterations in thermoregulation and haematobiochemical parameters in adult goats. The acute responses of goats to surgical castration and depletion of androgens included significantly higher T_r, RR, HR and PCV, leukocytosis, neutrophilia, lymphopenia, uremia and hyperglycemia. The findings have implications in the fields of gynecology and surgery of small ruminants. The generated information could also be utilized in biomedical context and translational medicine. Further studies are required to monitor the effect of castration on immune and endocrine responses in the goat model.

ETHICS APPROVAL

This study was approved by the Research Board, Faculty of Veterinary Medicine, University of Khartoum and approved and monitored by the Ethical Committee of Veterinary Council, Sudan.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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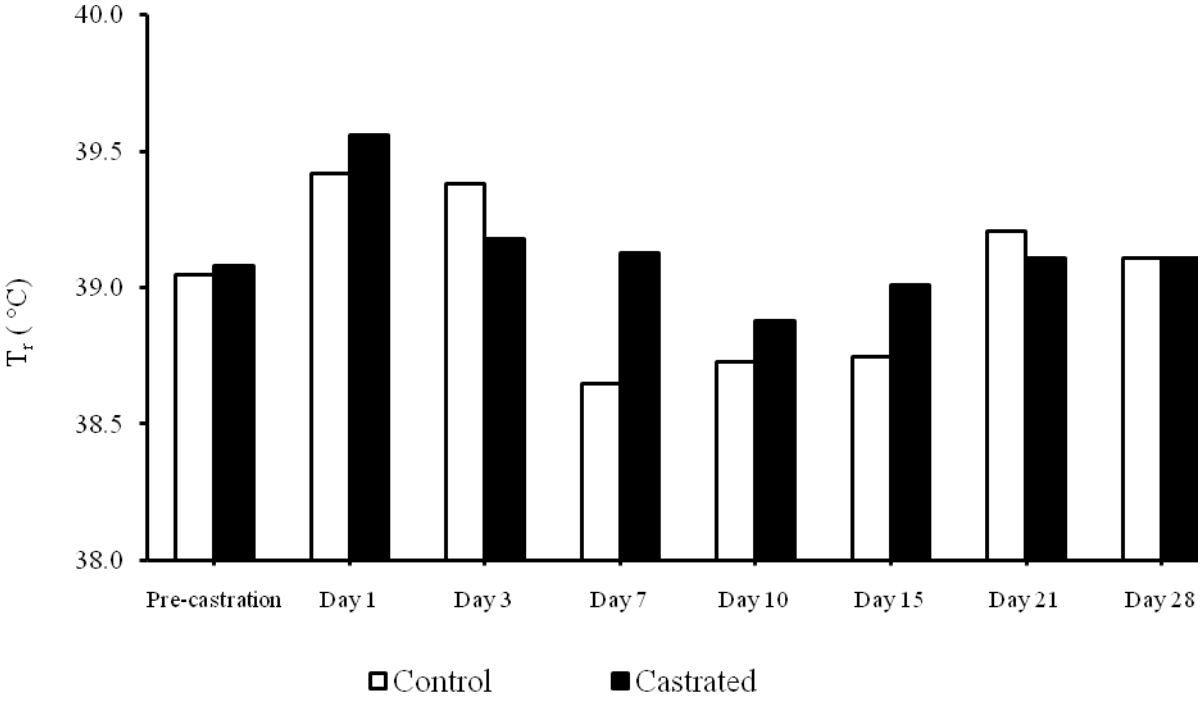

Fig.1. Effects of castration on rectal temperature, T_r in adult goats.

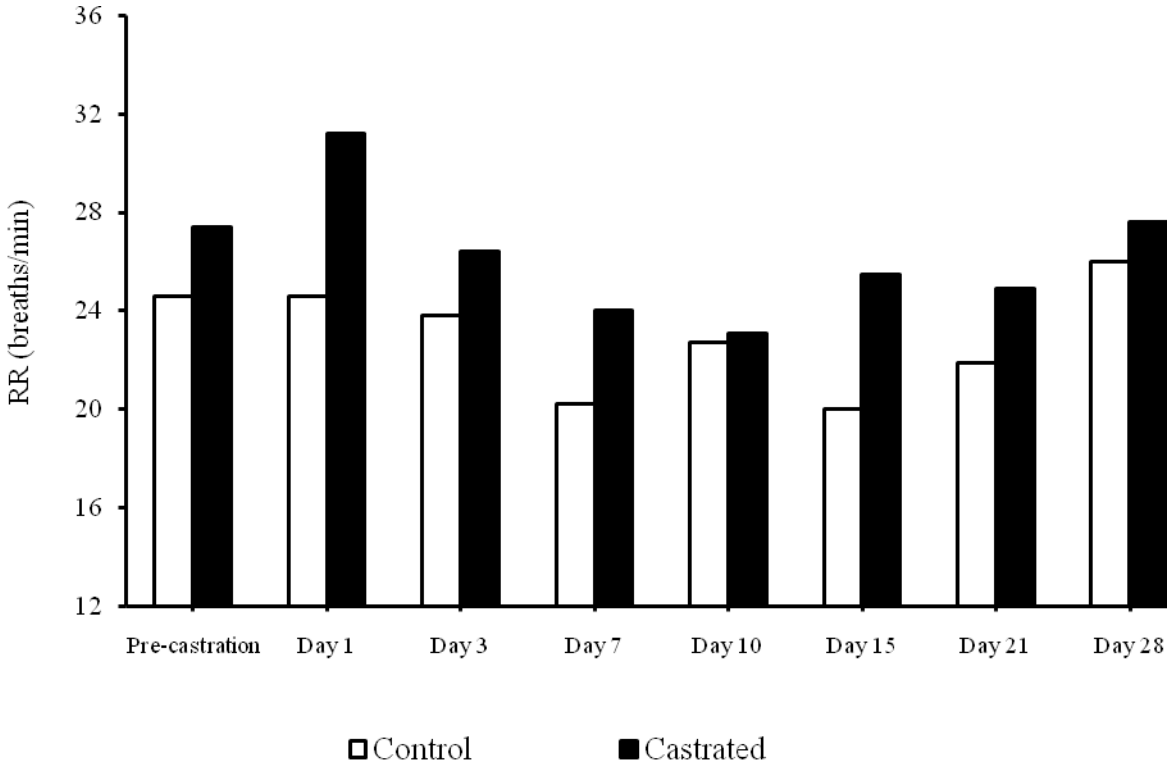

Fig.2. Effects of castration on respiratory rate, RR in adult goats.

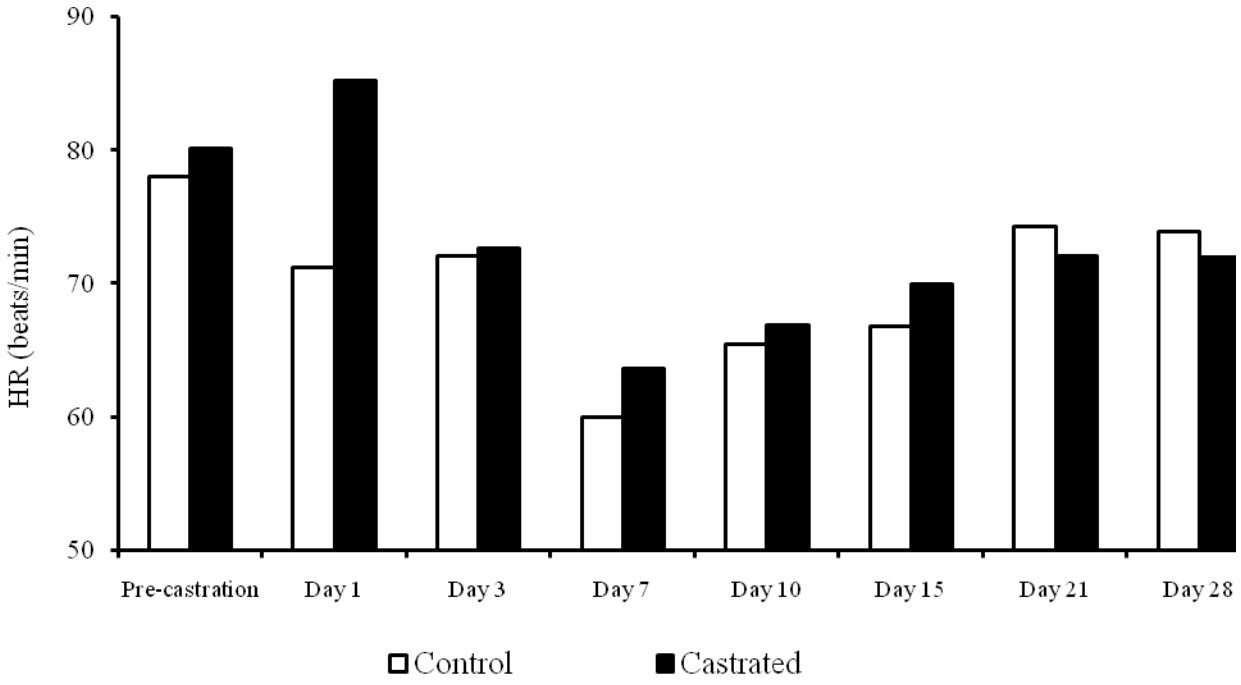

Fig.3. Effects of castration on heart rate, HR in adult goats.

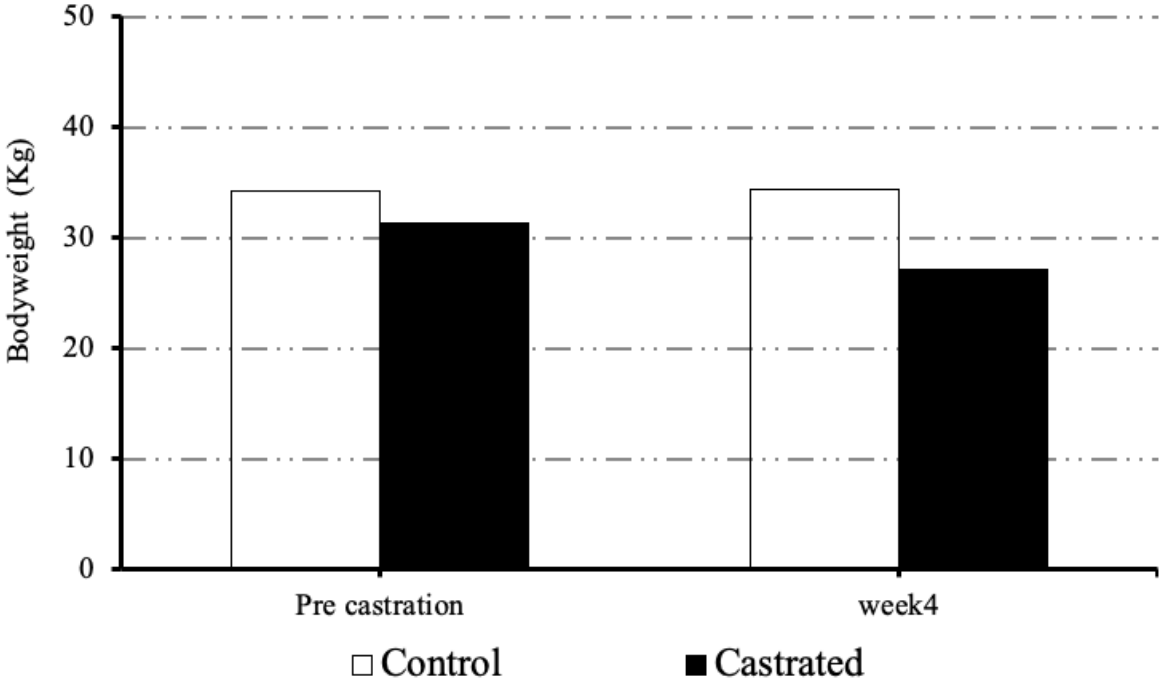

Fig .4. Effects of castration on mean body weight, BW in adult goats.

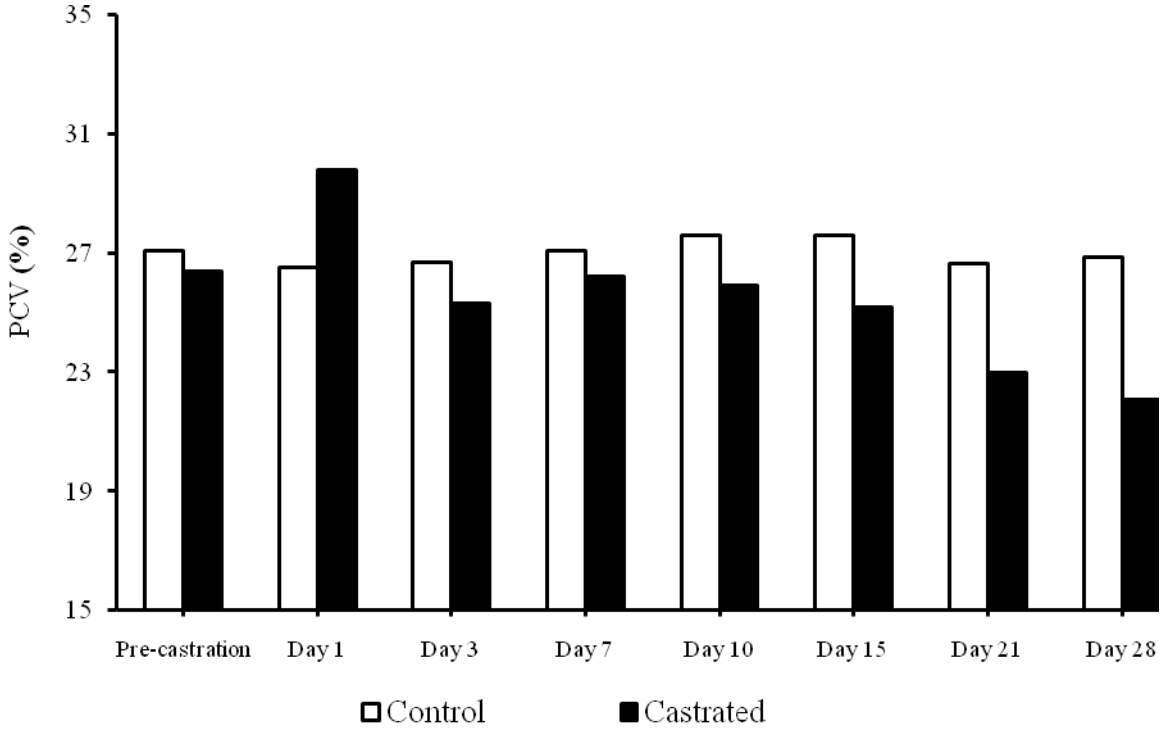

Fig. 5. Effects of castration on packed cell volume, PCV in adult goats.

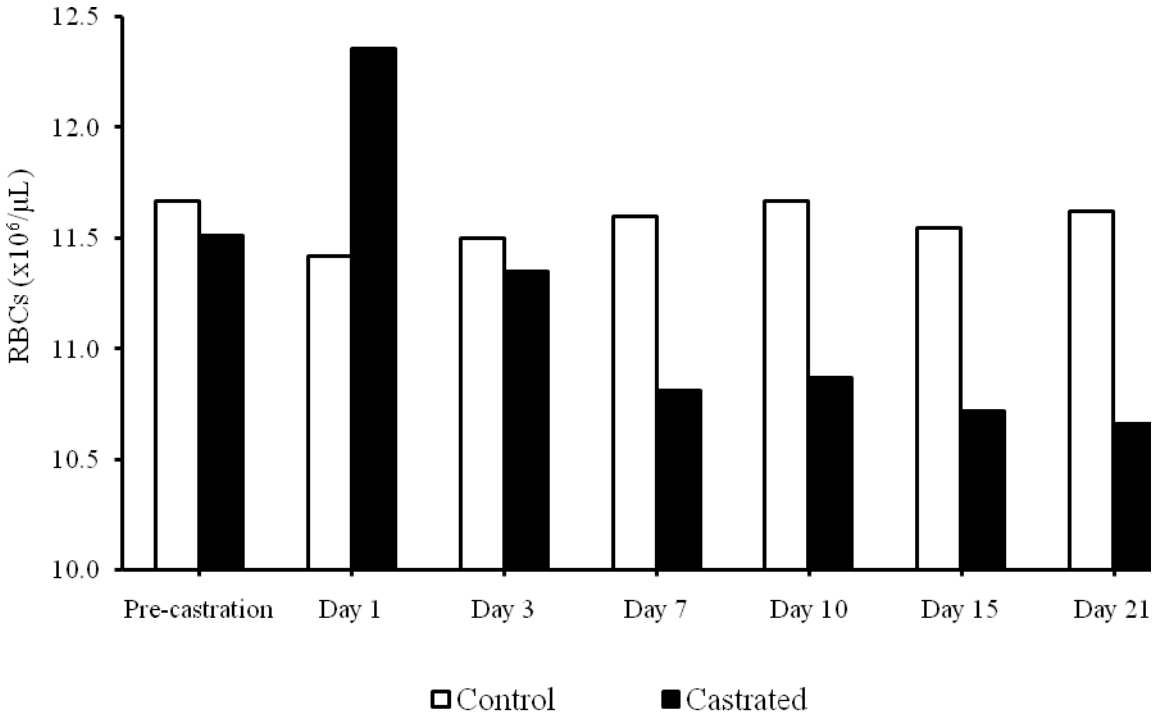

Fig. 6. Effects of castration on red blood cells count RBCs in adult goats.

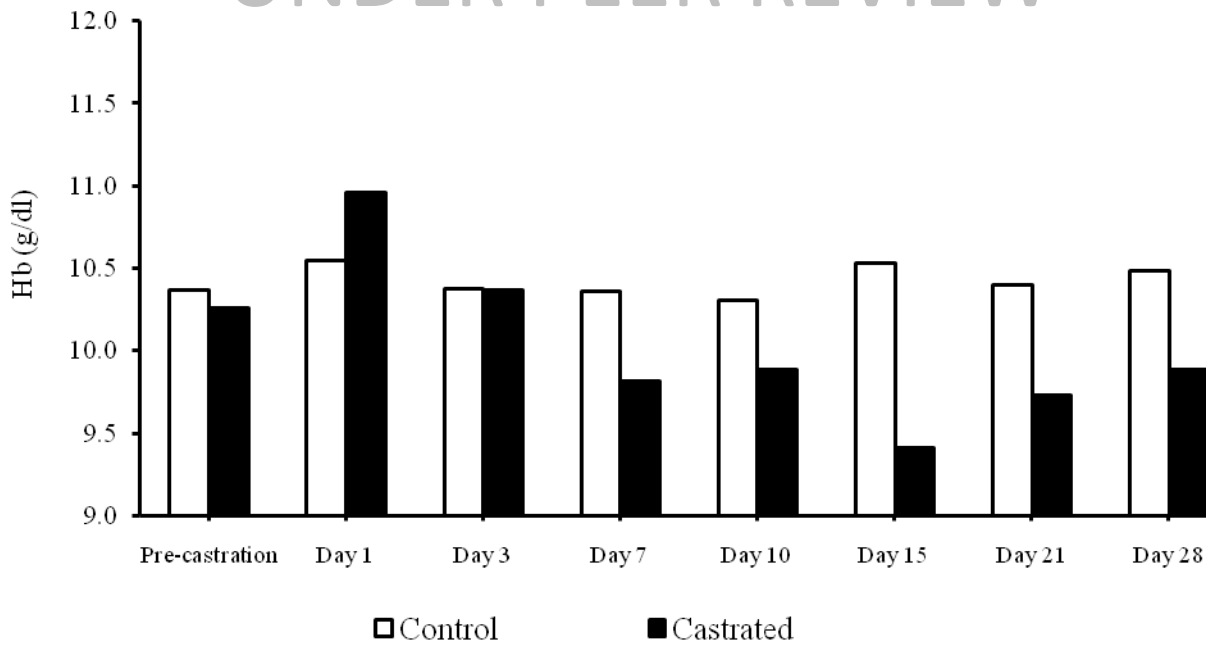

Fig. 7. Effects of castration on haemoglobin concentration, Hb in adult goats.

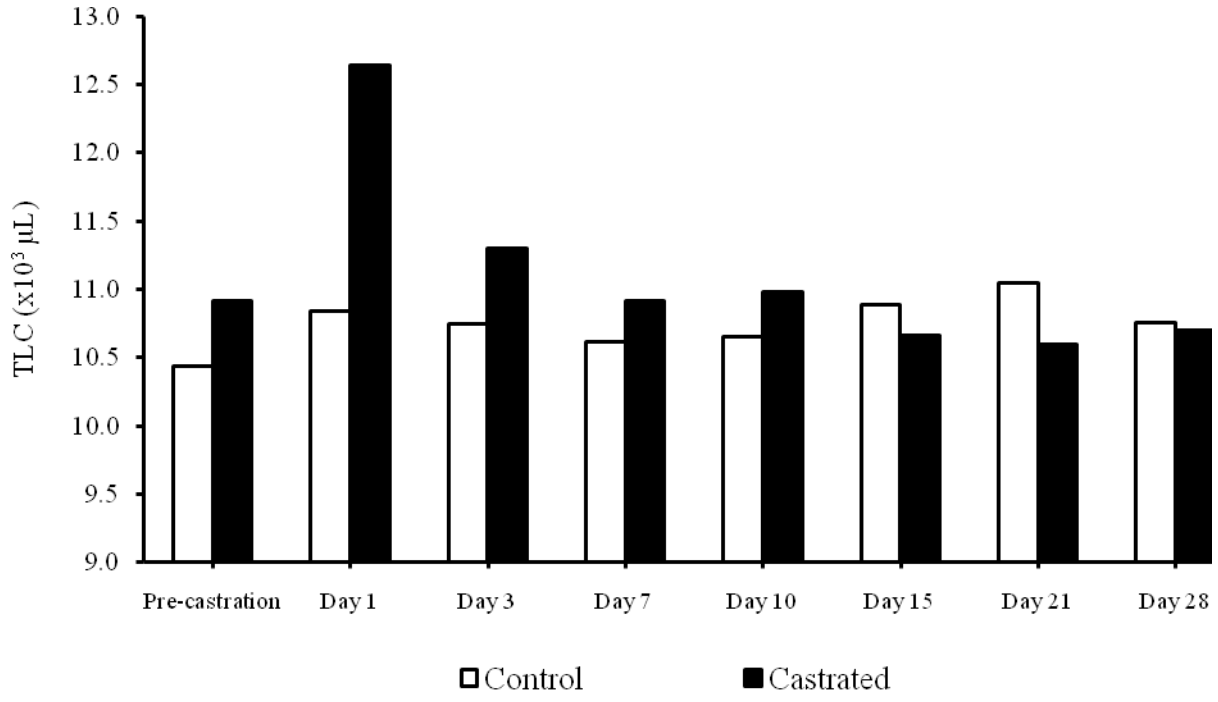

Fig. 8. Effects of castration on total leukocyte count, TLC in adult goats.

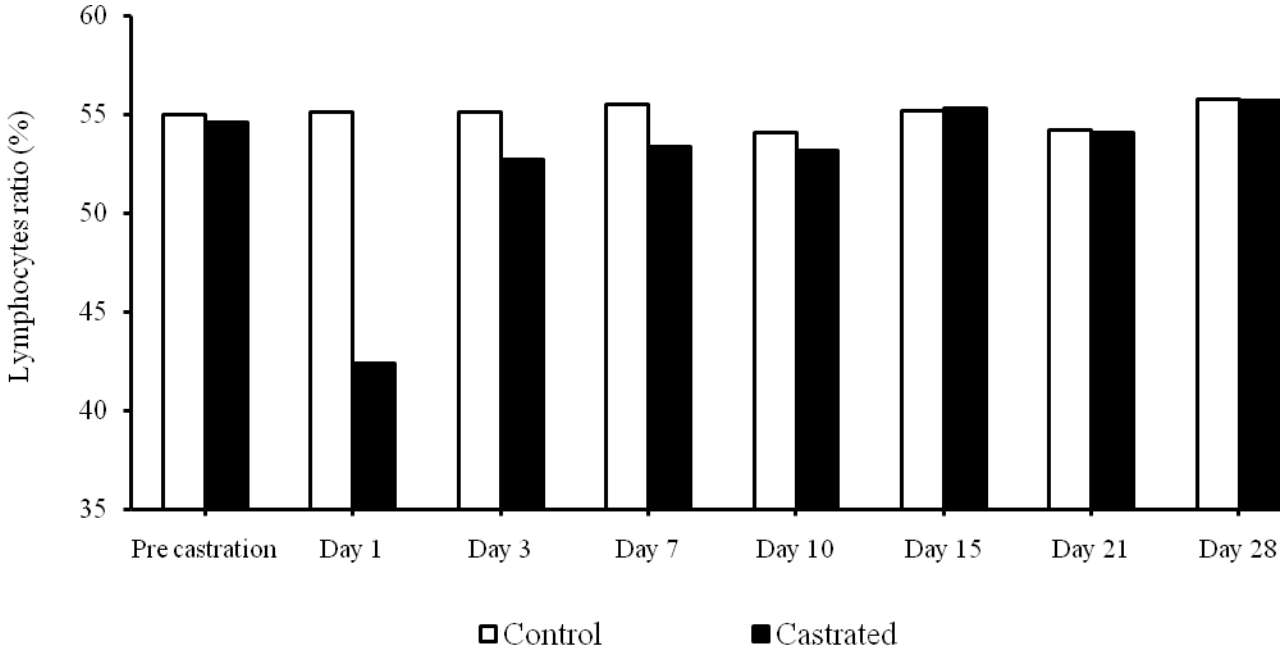

Fig. 9. Effects of castration on lymphocytes ratio in adult goats.

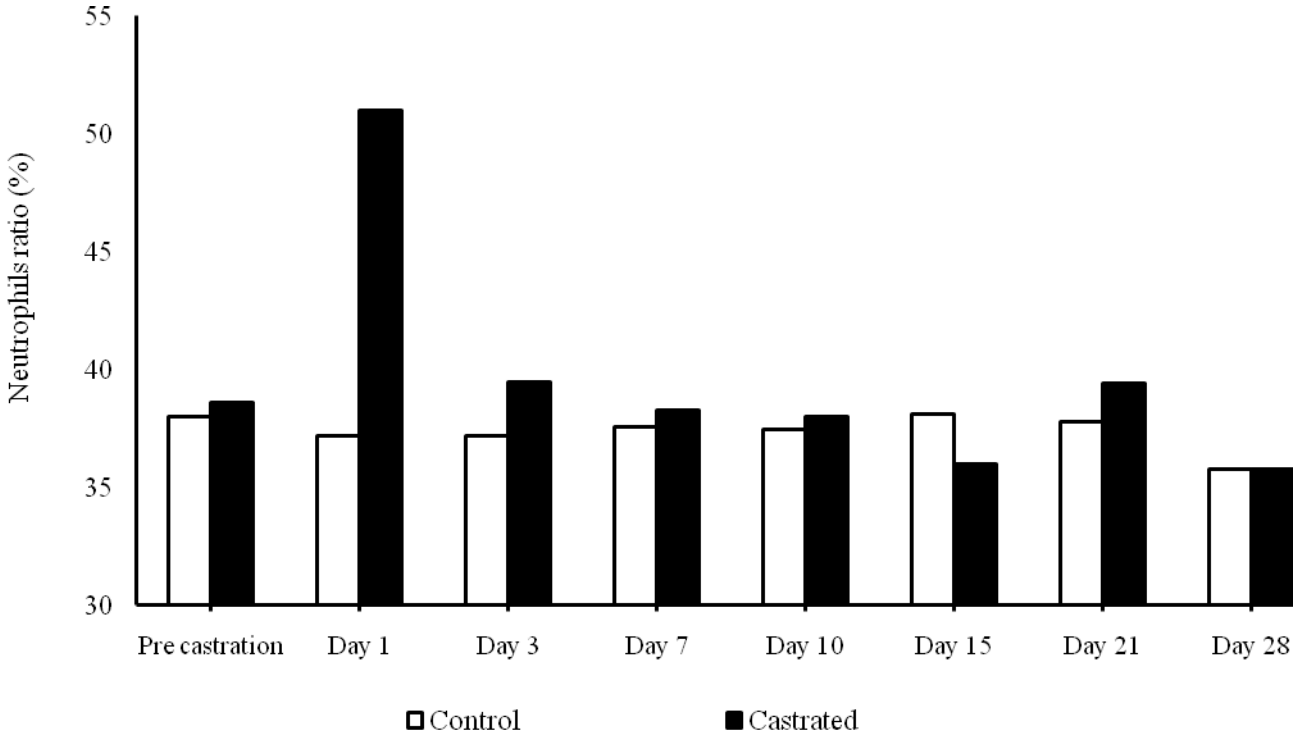

Fig. 10. Effects of castration on neutrophils ratio in adult goats.

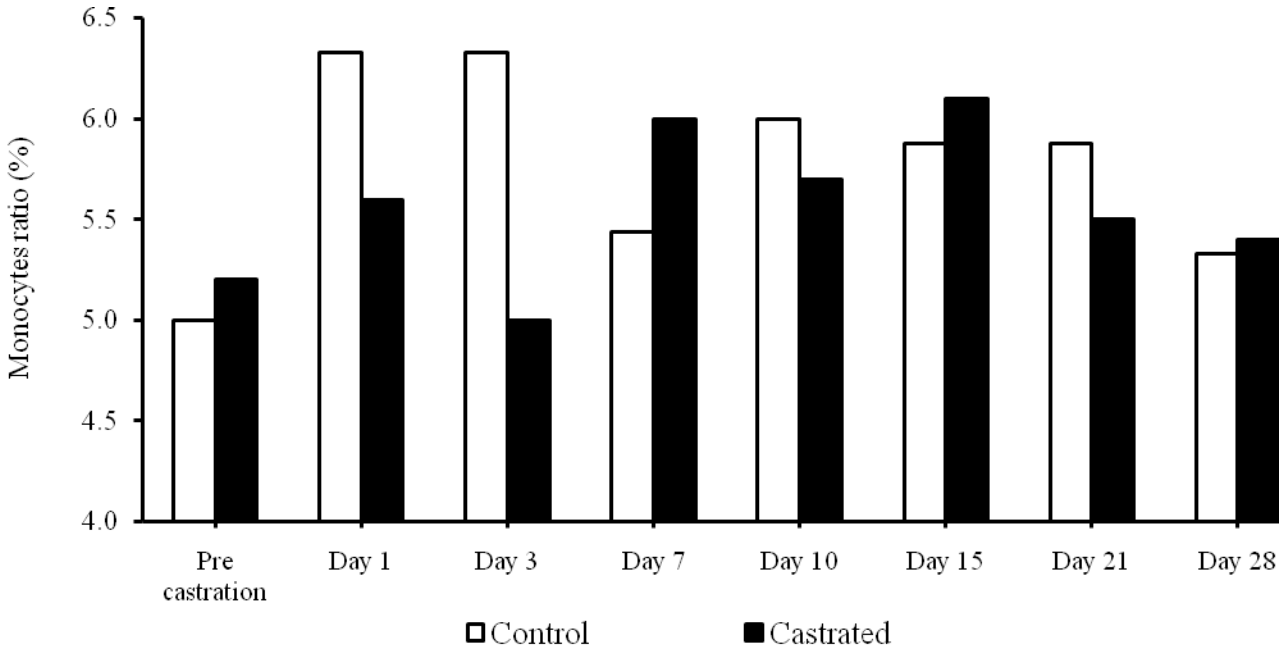

Fig. 11. Effects of castration on monocytes ratio in adult goats.

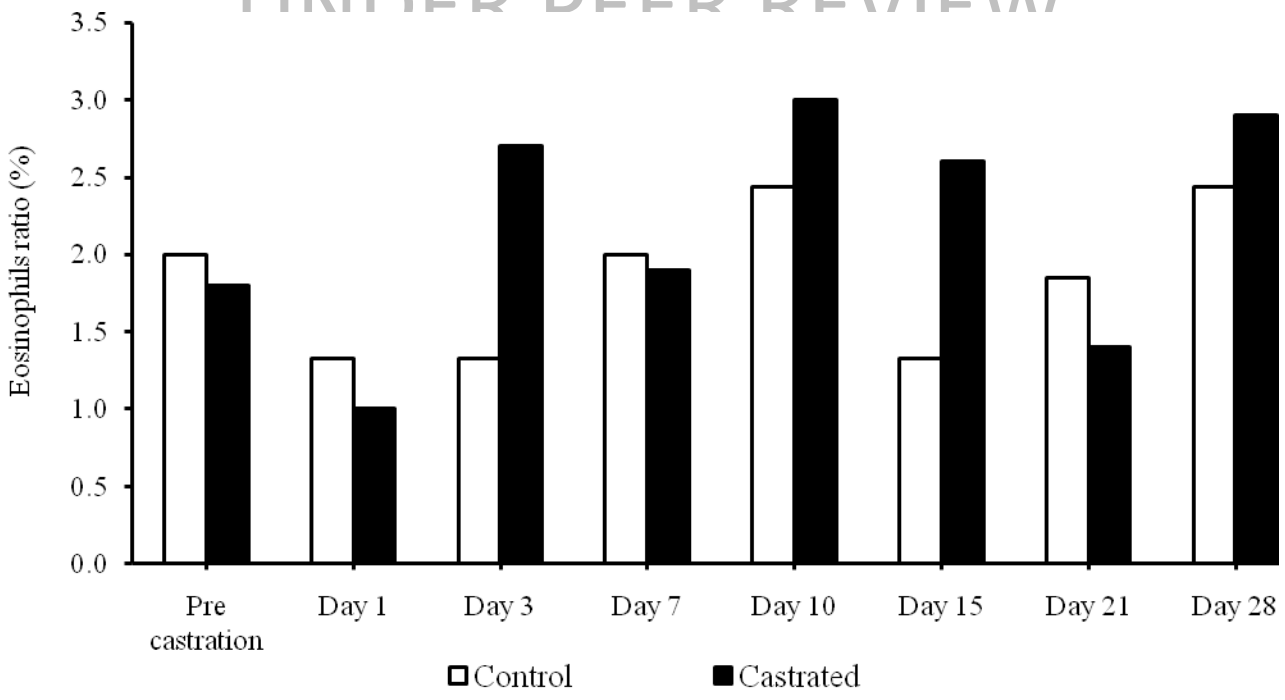

Fig. 12. Effects of castration on eosinophils ratio in adult goats.

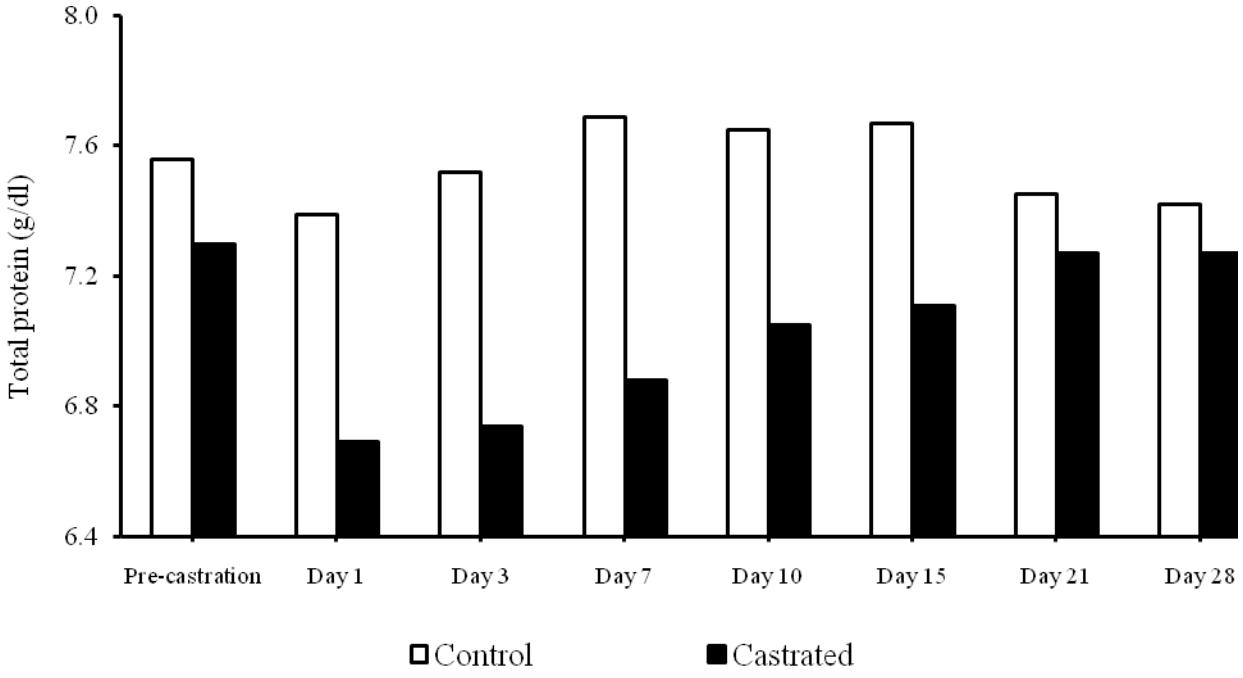

Fig. 13. Effects of castration on serum total protein concentration in adult goats.

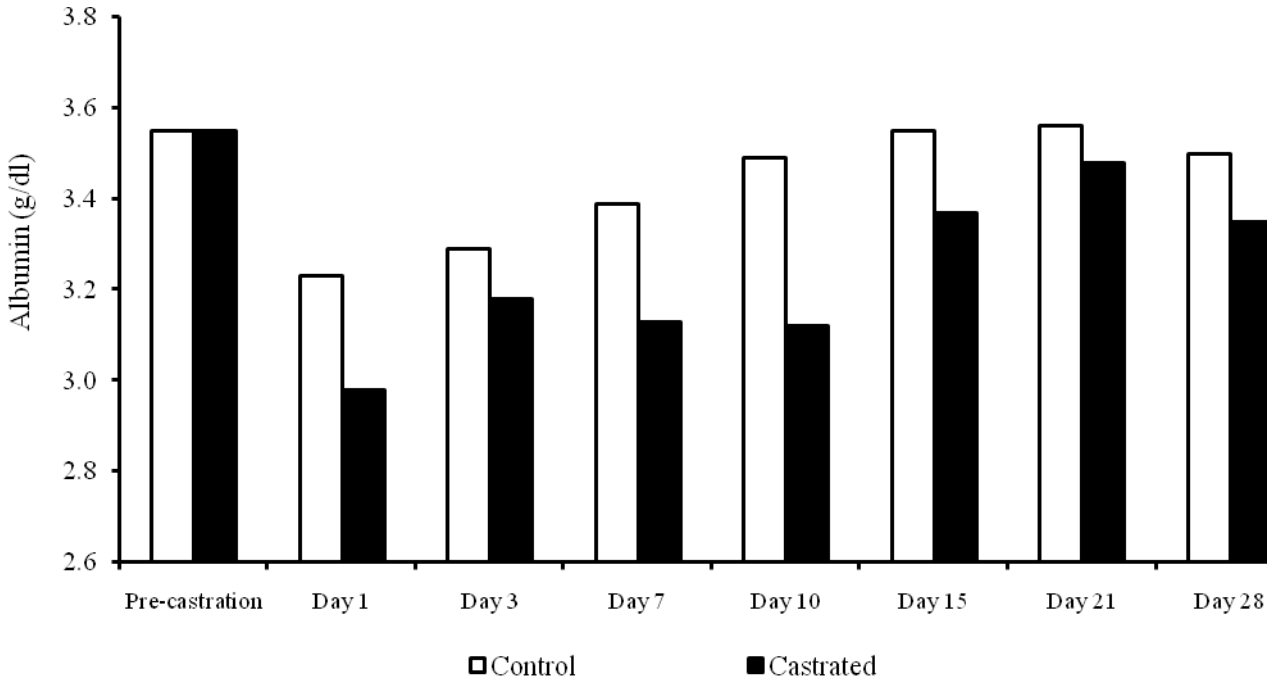

Fig. 14. Effects of castration on serum albumin concentration in adult goats.

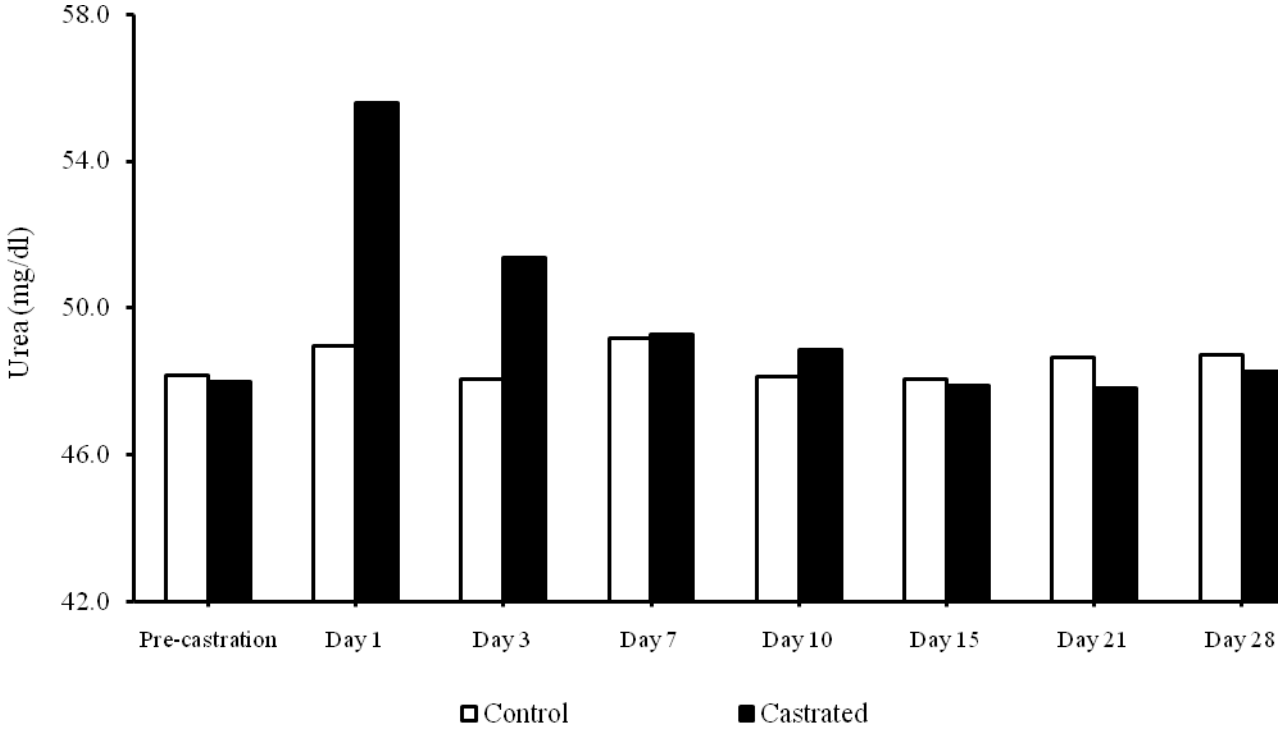

Fig. 15. Effects of castration on serum urea concentration in adult goats.

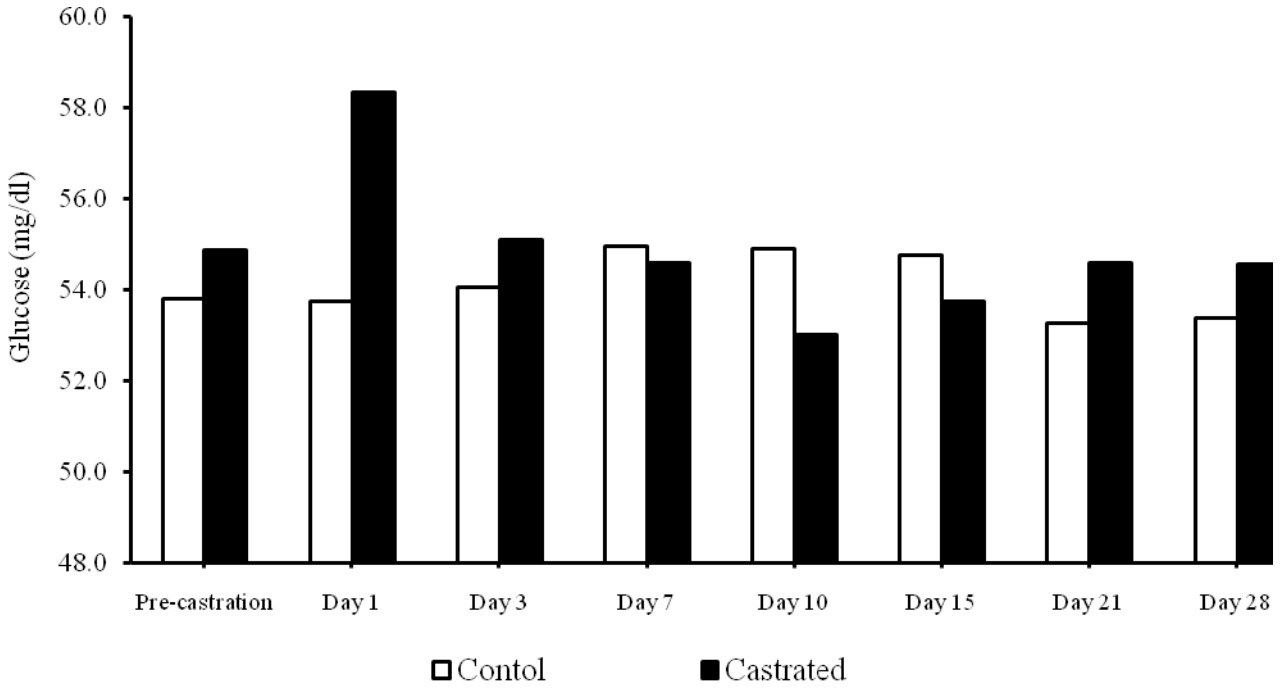

Fig. 16. Effects of castration on plasma glucose concentration in adult goats.

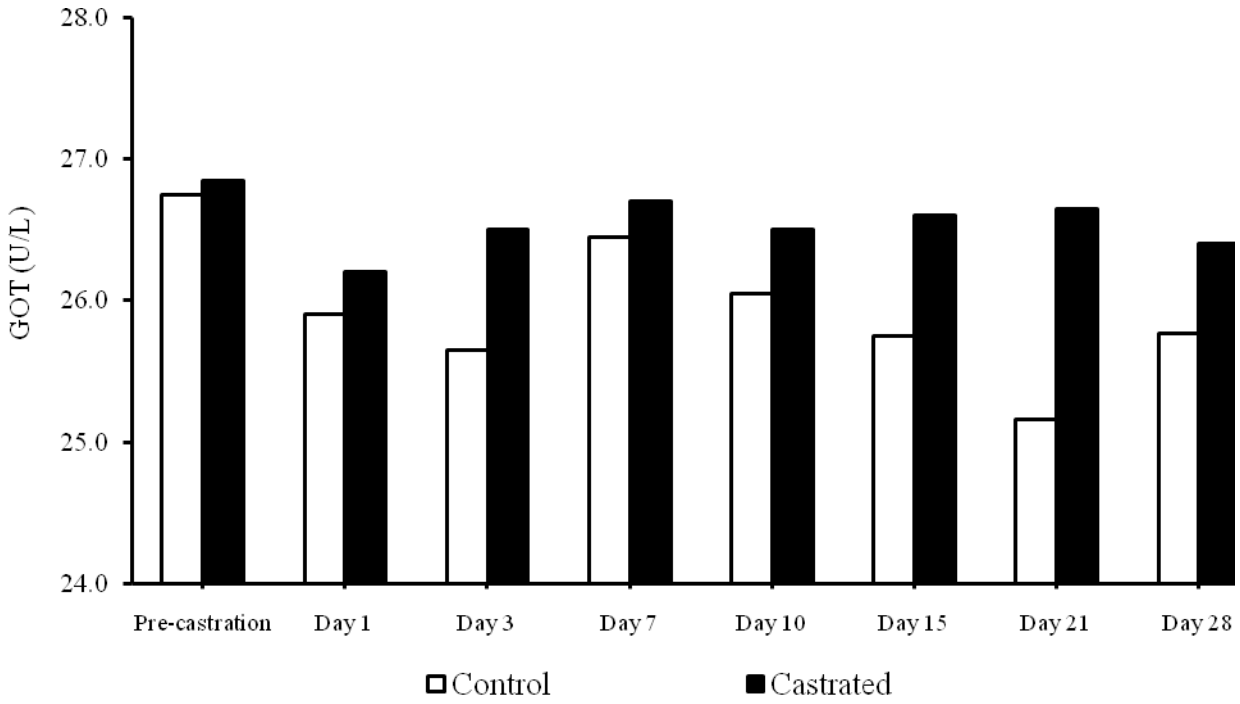

Fig. 17. Effects of castration on serum glutamic oxalacetic transaminase concentration, GOT in adult male goats.

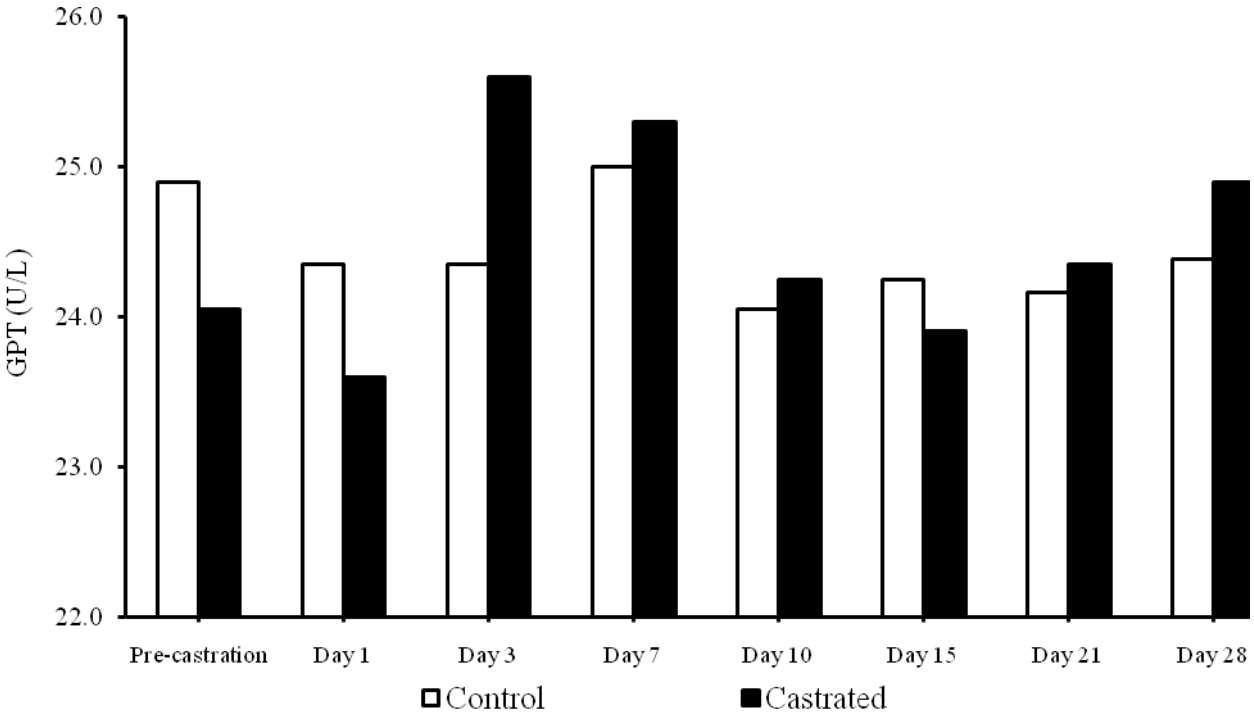

Fig. 18. Effects of castration on serum glutamic pyruvic transaminase concentration, GPT in adult goats.

Table1. Effects of castration on rectal temperature(T_r), respiratory rate (RR) and heart rate (HR) in adult goats.

Parameters	Groups	Baseline	Pre-castration	Day 1	Day 3	Day 7	Day 10	Day 15	Day 21	Day 28
T_r (°C)	Intact	39.17±0.4^{a}	39.05±0.2^{a}	39.42±0.2^{a}	39.38±0.2^{a}	38.65^{b}±0.5^{b*}	38.73±0.6^{a}	38.75±0.3^{a}	39.21±0.2^{a}	39.11±0.2^{a}
	Castrated	3926±0.3^{a}	39.08±0.2^{a}	39.56±0.4^{a}	39.18±0.5^{a}	39.13±0.4^{a}	38.88±0.2^{a}	39.01±0.4^{a}	39.11±0.2^{a}	39.11±0.2^{a}
RR (breaths/mint)	Intact	25.50±2.7^{a}	24.60±3.1^{a}	24.60±3.0^{b*}	23.80±2.6^{a}	20.20±3.1^{b*}	22.70±2.4^{a}	20.00±2.3^{b***}	21.88±1.7^{b*}	26.00±4.3^{a}
	Castrated	24.70±2.8^{a}	27.40±3.1^{a}	31.20±5.1^{a}	26.40±3.5^{a}	24.00±3.0^{a}	23.10^{a}±2.5	25.50±2.2^{a}	24.90±2.9^{a}	27.60±2.6^{a}
HR (beats/mint)	Intact	80.33±6.0^{a}	78.00±5.8^{a}	71.20±3.6^{b***}	72.11±3.1^{a}	60.00±3.7^{a}	65.44±2.1^{a}	66.77±1.7^{b*}	74.33±2.7^{a}	73.88±1.6^{a}
	Castrated	82.50±4.1^{a}	80.20±2.9^{a}	85.20±5.4^{a}	72.70±10.54^{a}	63.60^{a}±4.1^{a}	66.90±3.6^{a}	70.00±3.5^{a}	72.10±2.8^{a}	72.00±2.4^{a}

a, b: Mean values within the same column bearing different superscripts are significantly different.

: Significant at P≤ 0.05*: Significant at P≤ 0.001*

Table 2. Effects of castration on packed cell volume (PCV),red blood cell count (RBCs) and haemoglobin concentration(Hb) in adult goats.

Parameters	Groups	Baseline	Pre-castration	Day 1	Day 3	Day 7	Day 10	Day 15	Day 21	Day 28
PCV (%)	Intact	25.6±1.4^{a}	27.10±1.5^{a}	26.50±1.4^{b***}	26.70±1.3^{a}	27.10±1.3^{a}	27.60±1.7^{a}	27.60±1.6^{a}	26.66±1.4^{a}	26.88±2.3^{a}
	Castrated	25.2±1.9^{a}	26.40±1.7^{a}	29.80±1.3^{a}	25.30±2.2^{a}	26.20±1.6^{a}	25.90±1.4^{b*}	25.20±1.9^{b**}	23.0±1.2^{b***}	22.10±1.1^{b***}
RBCs (x10^{6}/µL)	Intact	11.54±0.7^{a}	11.67±0.5^{a}	11.42±0.8^{a}	11.50±0.8^{a}	11.60±0.7^{a}	11.67±0.6^{a}	11.55±0.7^{a}	11.62±0.7^{a}	
	Castrated	11.65±0.6^{a}	11.51±0.6^{a}	12.36±0.8^{a}	11.35±0.7^{a}	10.81±0.5^{b*}	10.87±0.4^{b**}	10.72±0.5^{b**}	10.66±0.4^{b**}	
Hb (g/dl)	Intact	10.20±0.3^{a}	10.28±0.5^{a}	10.55±0.4^{a}	10.38±0.4^{a}	10.36±0.5^{a}	10.31±0.4^{a}	10.53±0.5^{a}	10.40±0.6^{a}	10.49±0.5^{a}
	Castrated	10.17±0.6^{a}	10.16±0.4^{a}	10.96±0.4^{a}	10.37±0.7^{a}	9.82±0.7^{a}	9.89±0.7^{a}	9.41±1.1^{b*}	9.73±0.7^{a}	9.89±0.3^{b**}

a, b: Mean values within the same column bearing different superscripts are significantly different.

: Significant at P≤ 0.05: Significant at P≤ 0.01***: Significant at P≤ 0.001*

Table 3. Effects of castration on total leukocyte count (TLC) and differential leukocyte count (DLC) in adult goats.

Parameters	Groups	Pre-castration	Day 1	Day 3	Day 7	Day 10	Day 15	Day 21	Day 28
TLC ($x10^3/\mu L$)	Intact	10.44 ± 0.6^{a}	$10.42\pm0.5^{b**}$	10.84 ± 0.6^{a}	10.62 ± 0.6^{a}	10.61 ± 0.7^{a}	10.89 ± 0.6^{a}	11.05 ± 0.6^{a}	10.76 ± 0.5^{a}
	Castrated	10.92 ± 0.6^{a}	12.64 ± 1.1^{a}	11.73 ± 1.3^{a}	10.92 ± 1.4^{a}	10.98 ± 1.0^{a}	$10.66\pm0.1^{b*}$	10.60 ± 0.6^{a}	10.70 ± 0.7^{a}
Lymphocyte ratio %)	Intact	55.0 ± 5.6^{a}	55.12 ± 8.5^{a}	55.12 ± 8.5^{a}	55.55 ± 6.2^{a}	54.11 ± 7.3^{a}	55.22 ± 7.7^{a}	54.22 ± 5.0^{a}	55.77 ± 6.0^{a}
	Castrated	54.6 ± 6.0^{a}	$42.40\pm9.7^{b*}$	52.70 ± 9.5^{a}	53.40 ± 8.2^{a}	53.20 ± 6.5^{a}	55.30 ± 4.3^{a}	54.10 ± 5.3^{a}	55.70 ± 6.3^{a}
Neutrophils ratio (%)	Intact	38.00 ± 3.6^{a}	$37.22\pm5.3^{b**}$	37.22 ± 5.3^{a}	37.55 ± 4.8^{a}	37.44 ± 5.8^{a}	38.11 ± 5.0^{a}	37.77 ± 4.1^{a}	35.77 ± 4.6^{a}
	Castrated	38.60 ± 5.1^{a}	51.00 ± 9.0^{a}	39.50 ± 7.2^{a}	38.30 ± 7.3^{a}	38.00 ± 5.4^{a}	36.00 ± 4.8^{a}	39.40 ± 5.1^{a}	35.80 ± 5.5^{a}
Monocytes ratio (%)	Intact	5.00 ± 2.0^{a}	6.33 ± 1.0^{a}	6.33 ± 1.0^{a}	5.44 ± 1.5^{a}	6.00 ± 1.4^{a}	5.88 ± 2.3^{a}	5.88 ± 2.0^{a}	5.33 ± 1.7^{a}
	Castrated	5.20 ± 2.0^{a}	5.60 ± 0.8^{a}	5.00 ± 1.6^{a}	6.00 ± 1.4^{a}	5.70 ± 1.8^{a}	6.10 ± 2.0^{a}	5.50 ± 2.0^{a}	5.40 ± 1.7^{a}
Eosinophils ratio (%)	Intact	2.00 ± 2.0^{a}	1.33 ± 1.2^{a}	1.33 ± 1.2^{a}	2.00 ± 2.4^{a}	2.44 ± 2.5^{a}	1.33 ± 2.1^{a}	1.85 ± 2.1^{a}	2.44 ± 1.8^{a}
	Castrated	1.80 ± 1.1^{a}	1.00 ± 0.7^{a}	2.70 ± 2.0^{a}	1.90 ± 1.4^{a}	3.00 ± 1.6^{a}	2.60 ± 2.2^{a}	1.40 ± 1.0^{a}	2.90 ± 1.5^{a}

a, b: Mean values within the same column bearing different superscripts are significantly different.

: Significant at P≤ 0.05: Significant at P≤ 0.01*

Table 4. Effects of castration on serum total protein, albumin, urea, plasma glucose concentration and serum enzymes activities in adult goats.

Parameters	Groups	Pre-castration	Day 1	Day 3	Day 7	Day 10	Day 15	Day 21	Day 28
Total protein level (g/dl)	Intact	7.56 ± 0.6^{a}	7.39 ± 0.7^{a}	7.52 ± 0.5^{a}	7.69 ± 0.4^{a}	7.65 ± 0.5^{a}	7.67 ± 0.5^{a}	7.45 ± 0.3^{a}	7.42 ± 0.2^{a}
	Castrated	7.30 ± 0.8^{a}	6.69 ± 1.0^{a}	6.74 ± 1.1^{a}	$6.88\pm0.8^{b*}$	7.05 ± 0.7^{a}	7.11 ± 0.7^{a}	7.27 ± 0.7^{a}	7.27 ± 0.5^{a}
Albumin level (g/dl)	Intact	3.55 ± 0.4^{a}	3.23 ± 0.1^{a}	3.29 ± 0.2^{a}	3.39 ± 0.4^{a}	3.49 ± 0.4^{a}	3.55 ± 0.3^{a}	3.56 ± 0.2^{a}	3.50 ± 0.2^{a}
	Castrated	3.48 ± 0.1^{a}	$2.98\pm0.1^{b**}$	3.18 ± 0.3^{a}	3.13 ± 0.4^{a}	3.12 ± 0.5^{a}	3.37 ± 0.3^{a}	3.48 ± 0.3^{a}	3.35 ± 0.3^{a}
Urea level (mg/dl)	Intact	48.14 ± 1.5^{a}	$48.97\pm1.1^{b***}$	$48.06\pm1.7^{b*}$	49.15 ± 1.6^{a}	48.11 ± 1.7^{a}	48.05 ± 1.5^{a}	48.63 ± 1.0^{a}	48.72 ± 1.0^{a}
	Castrated	47.99 ± 1.1^{a}	55.57 ± 2.6^{a}	51.35 ± 3.6^{a}	49.26 ± 0.7^{a}	48.86 ± 1.4^{a}	47.88 ± 1.7^{a}	47.81 ± 1.2^{a}	48.26 ± 1.6^{a}
Glucose level (mg/dl)	Intact	54.82 ± 2.5^{a}	$53.77\pm0.7^{b*}$	54.07 ± 1.3^{a}	54.97 ± 2.5^{a}	54.90 ± 3.4^{a}	54.76 ± 3.0^{a}	53.29 ± 1.6^{a}	53.39 ± 1.7^{a}
	Castrated	54.88 ± 1.9^{a}	58.35 ± 3.1^{a}	55.12 ± 3.0^{a}	54.59 ± 2.3^{a}	53.03 ± 1.5^{a}	53.76 ± 2.3^{a}	54.60 ± 2.1^{a}	54.56 ± 1.9^{a}
GOT (U/L)	Intact	26.75 ± 1.2^{a}	25.90 ± 1.5^{a}	25.65 ± 1.6^{a}	26.45 ± 2.0^{a}	26.05 ± 1.8^{a}	25.75 ± 1.1^{a}	25.16 ± 1.7^{a}	25.77 ± 1.7^{a}
	Castrated	26.85 ± 1.5^{a}	26.20 ± 0.8^{a}	26.50 ± 1.1^{a}	26.70 ± 1.2^{a}	26.50 ± 1.8^{a}	26.60 ± 1.5^{a}	26.65 ± 2.6^{a}	26.40 ± 1.6^{a}
GPT (U/L)	Intact	24.90 ± 2.7^{a}	24.35 ± 2.7^{a}	24.35 ± 2.7^{a}	25.00 ± 3.8^{a}	24.05 ± 2.26^{a}	24.25 ± 2.8^{a}	24.16 ± 1.9^{a}	24.38 ± 1.9^{a}
	Castrated	24.05 ± 3.7^{a}	23.60 ± 1.9^{a}	25.60 ± 3.5^{a}	25.30 ± 3.5^{a}	24.25 ± 2.7^{a}	23.90 ± 2.0^{a}	24.35 ± 2.4^{a}	24.90 ± 2.4^{a}

a, b: Mean values within the same column bearing different superscripts are significantly different.

: Significant at P≤ 0.05: Significant at P≤ 0.01**: Significant at*