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MACROSCOPIC AND MICROSCOPIC CHARACTERIZATION OF TERM PLACENTAS FROM NUTRITIONALLY RESTRICTED GOATS

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Abstract

The aim of this study was to describe the morphological, macroscopic, and microscopic characteristics in term placentas of goats, nutritionally restricted in the prepubertal period and during the second and third third of pregnancy gestation. Samples were collected from the placentas of goats separated into 3 treatments: control C, n= 9; prepubertal feed restriction PPFR, n = 5; pregnancy feed restriction (PFR) n=5. The placental cellular structure was studied using Masson's trichrome staining. The ultrastructural analysis was performed by high-resolution light microscopy and transmission electron microscopy. The present study revealed the effect of prepubertal and gestational feed restriction on macroscopic and microscopic characteristics in goat placentas with decreases in cotyledonary weight, height, and size in placentas from nutritionally restricted goats in both groups, PPFR and PFR. The smaller size and the change in the shape of the cotyledons could suggest compensatory mechanisms for prepubertal and gestational feed restriction to ensure placental and kid development.

Keywords:
fed restriction, placenta, pregnancy, goats.

1. Introduction

Goats (*Capra hircus*) are adapted to extensive production systems, particularly in regions characterized by the existence of dry seasons that affect growth, quality and availability of pastures, which directly impacts animal performance (Parreira *et al.,* 2020). It has been shown that maternal nutrient restriction during pregnancy impairs placental and fetal growth in humans and ruminant livestock species (Britt *et al*., 2021; Fiorimanti *et al*., 2021; Steinhauser *et al*., 2021; Edwards *et al.,* 2020; Ravikumar *et al.,* 2019). Placental growth and development occur primarily during the first half of gestation and are significantly affected by maternal nutrition (Edwards *et al.,* 2020). Indeed, the placenta plays a fundamental role in the exchange of nutrients, which requires adequate vascularization and remodeling of the maternal-fetal interface. In goats, with a synepitheliochorial and cotyledonary placenta (Whang *et al*., 2022), placentomes are the functional and nutrient exchange units in the fetoplacental unit, formed by the interdigitated fetal cotyledons in the maternal caruncles (Cristofolini *et al*., 2012; Díaz *et al*., 2015; Santos *et al*., 2017). In a previous work from our laboratory, we have evaluated the effect of feed restriction during the prepubertal period with or without monensin supplementation, followed by a re-feeding period, on placental cellular apoptosis and proliferation in goats (Turiello *et al*., 2019). Other authors have focused on determining the effects of feed restriction on fetal growth and neonatal survival in sheep (Steinhauser *et al*., 2021). Moreover, Hoffman *et al*., (2017) have determined the effects of subnutrition of sheep during the last trimester of gestation on the serum glucose/IGF1 levels and development of reproductive organs in their lambs. Also, it has been determined the impact of ergot alkaloid exposure during mid and late gestation on microscopic placental structure and vascular development in sheep (Britt *et al*., 2021). In addition, the effect of feed restriction was studied on the development of the placenta, uterine artery blood flow as well as macroscopic and microscopic placentome vascular density and the characteristics of the calves during the last third of gestation in cows (Lemley *et al*., 2018; Batista *et al*., 2020). Several authors suggest the existence of compensatory mechanisms to guarantee the normal development of the offspring (Edwards *et al*., 2020; Lekatz *et al*., 2022). However, to the best of our knowledge, the effect of feed-restriction on

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plancental development in prepubertal and gestational goats has not been studied. We hypothesize that when animals are subjected to a system of feed restriction, similar to natural breeding factors, the reduction in maternal basal metabolism affects placental development. The aim of this study was to describe the morphological, macroscopic and microscopic characteristics in term placentas of goats, nutritionally restricted in the prepubertal period and during gestation.

2. Methodology

2.1 Animals and treatments

All procedures were approved by the National University of Río Cuarto Ethical Committee of Research in animals (CoEdI), Res 186/2016. In experiment 1, a study of feed restriction in the prepubertal period for 8 months was performed at the facilities of National University of Río Cuarto, Córdoba, Argentina, 33°08' S, 64°20' O'. A total of 10 prepubertal crossbreed goats (Creole x Anglo Nubian) of similar age and weight from a local herd were treated (Age: 4 months; Body Weight (BW) = 11.9 kg ± 1.47; Body Condition BC = 3.5/5). The treatments were control group (C), goats fed *ad libitum* (C; n = 5) and prepubertal feed restricted goats fed at 70% of control, adjusted to a common basis, (PPFR; n = 5). The level of dry matter intake (DMI) for PPFR during the restricted period was adjusted using the formula adapted from Roberts *et al*. (2007), detailed in Turiello *et al.* (2019). Goats in PPFR were restricted for 250 days, and after this period, they were re-fed *ad libitum* for the rest of the trial. The energy density of the diet was 2.3 Mcal ME/kg DM and consisted of 70 % chopped alfalfa hay and 30% dry ground corn. All animals received a daily supplement of 7 g of a vitamin–mineral mixture. Goats were daily placed in individual cages for 8 h to allow individual feeding, and the rest of the day they were housed in groups in 8 × 4 m common pens, with free access to fresh water, allowing for social interaction. Refusals were collected daily before feed delivery. After 160 days of re-feeding, the goats were mated with a fertile and proven male and they all got pregnant. Another study, experiment 2, was performed to evaluate the effects of feed restriction during pregnancy with 10 primiparous crossbreed (Creole x Anglo Nubian) goats, of similar age and weight (Age: 1.5 years; BW = 30 kg ± 5; BC = 3.5/5). The animals were separated into a control group (C; n=5) and a feed restricted group (PFR; n=5). All the goats in the second study were synchronized with the application of intramuscular cloprostenol (a prostaglandin analogue (PGFα)), in two doses of 0.5 ml, separated by 15 days and became pregnant by natural mating. An experimental model of

Journal Pre-proof

"fetal programming" of energy restriction from the second third of gestation was used (Kwon *et al*., 2017). Goats were fed *ad libitum* diet from days 1 to 50 of gestation and then 70% of the control DMI diet until parturition. Subsequently and until the end of the trial, they were fed *ad libitum*. Goats were placed and managed under similar conditions as the previous study.

2.2 Placentas and tissue collection

After parturition 19 singleton placentas were collected, experiment 1: Control (C), n=5; Prepubertal feed restriction (PPFR), n=5; experiment 2: Control (C), n=4; Pregnancy feed restriction (PFR), n=5. One placenta from the control group was discarded due to twin pregnancy. The placentas were washed with Hank's saline solution (SSH) (Gibco, USA) containing 10,000 U/ml of penicillin G sodium, 10 mg/ml of sulphate of streptomycin and 2.5 µg/ml of fungizone (Gibco, USA) and then maintained at 4°C up to their processing in the laboratory. Samples from five cotyledons per placenta in the central zone randomly were taken and placed in buffered formaldehyde and samples from other five cotyledons per placenta in the central zone randomly were placed in glutaraldehyde for electron microscopy analysis and high-resolution light microscopy.

2.3 Morphometric analysis of the placenta and cotyledons

After collection of the placentas, the weights of the placentas and cotyledons were measured. The cotyledon larger (LD) and minor (MD) diameter, and height (H) were measured (Figure 1). The cotyledon density (CD) was calculated as the number of cotyledon (CN) in relation to the placental weight according to Turiello *et al*., 2019.

2.4 Conventional histological technique

Portions of approximately 6 mm^3 of placental tissue were fixed in 4% (v/v) buffered saline formaldehyde pH 7.2–7.4 at 4°C and dehydrated in a graded series of ethanol 65%, 75%, 80%, 90%, 95% and 100% and xylene. Paraffin-embedded placental tissue (Paraplast Plus®) was sectioned at ±4 µm and was stained with Masson’s trichromic. The differential staining was used to easily identify the presence of the different blood vessels. The placental sections were observed in a light microscope Axiophot (Carl Zeiss, Thornwood, NY, USA) fitted with a high-resolution digital camera PowerShot G6 7.1 megapixels (Canon INC,

Journal Pre-proof

Tokyo, Japan). Digital images were captured using AxioVision 4.6.3 software (Carl Zeiss, Göttingen, Germany).

2.5 High resolution light microscopy (HRLM)

Portions of approximately 1 mm^3 of placental tissue were processed by transmission electron microscopy conventional technique. Placental samples were fixed in 2.5 % glutaraldehyde in 0.2 M S-collidine pH 7.4, post-fixed in 1% osmium tetroxide in 0.2 M S-collidine pH 7.4, dehydrated in increasing concentration acetone, embedded in EMbed812 resin and sectioned with an ultramicrotome to obtain semi-thin sections (± 0.25 μm). These sections were counterstained with toluidine´s blue and were cover-slipped in DPX (Merk, Germany) embedding agent. Then, the sections stained were observed in a light microscope Axiophot (Carl Zeiss, Germany) fitted with a high-resolution digital camera Powershot G6 7.1 megapixels (Canon INC, Japan). Digital images were captured with Axiovision 4.6.3 software (Carl Zeiss, Germany).

2.6 Transmission electron microscopy (TEM)

Placental tissue embedded in EMbed 812 resin to HRLM was sectioned with an ultramicrotome Sorvall MT1A (Microtome Service Company, New York, USA). The obtained ultra-thin sections (± 60 nm) were cut and placed on copper grids, counterstained with saturated uranyl acetate and aqueous lead citrate. The ultrathin placental sections were examined in transmission electron microscope Elmiskop 101 (Siemens, Germany). Acquisition, digital analysis, and morphometric measurements were performed with transmission electron microscope JEM 1200 ExII (JEOL, Japan), using Digital Micrograph TM (Gatan, Inc., Japan) software (Critofolini *et al*., 2018).

2.7 Statistical analysis

Data were analyzed with InfoStat Version 2019P software (Di Rienzo et al., 2019). An ANOVA test and a posteriori an LSD-Fisher test were performed to analyze the experiments separately. The variables evaluated were placental weight, number, weight, larger diameter, minor diameter, height and density of the cotyledons. When a parametric ANOVA test could not be accomplished, even with transformations of the variable, a nonparametric ANOVA by ranks (Kruskal-Wallis test) was used: larger diameter, minor diameter, height and density of

Journal Pre-proof

the cotyledons. A generalized linear mixed models was also carried out to include in the model the fixed effect of experiment, and goat nested in experiment as a random effect to analyze the two experiments together. Data are expressed as mean ± SEM, and means were statistically different at P <0.05.

3. Results

3.1 Morphological description

In the group control of experiment 1, we observed that the trophoblastic epithelium (TE) is highlighted with the presence of numerous binucleated cells (Bn). Fetal mesenchyme (FM) is characterized by the presence of connective tissue with a large number of collagen fibers. Blood vessels (BV) of different diameters were found in the fetal mesenchyme (Figure 2, A).

In prepubertal feed restricted (PPFR), the trophoblastic epithelium is composed of columnar palisade cells and numerous binucleate giant cells (Figure 2, C and E). In the fetal mesenchyme, we observed numerous cells with elongated nuclei, loose connective tissue, highly vascularized with blood vessels of different diameters. No considerable histological differences are observed between the control group and the PPFR (experiment 1).

In experiment 2, we have found normal placental tissue in the pregnancy feed restriction control group, with characteristics similar to those described in the prepubertal feed restriction control group (experiment 1). In the group of pregnancy feed restriction (PFR), as observed in Figure 2 D and F, fetal trophoblastic cells in the villi in a palisade arrangement and the presence of mononucleate and giant binucleate cells with numerous blood vessels in the fetal mesenchyme are observed.

3.2 Morphometric analysis

Results of the placental weight and morphometric measurements of the cotyledons are presented in table 1. In both experiments 1 and 2, there were no significant differences in placental weights when both experiments were analyzed separately (Table 1). (P>0.05). In experiment 1, cotyledons numbers were not statistically different among treatments (P>0.05) (Table 1). In experiment 2, there was a significant decrease in the number of cotyledons in the PFR group.

Journal Pre-proof

However, when the 2 experiments were analyzed together, we found that the control group placentas weighted in average 473.17 g, and there were no significant differences between PFR and PPFR (Table 2).

Comparing the two experiments, as shown in table 2, cotyledons were significantly smaller in the PPFR than controls and PFR (P<0.05). In the PPFR group, cotyledons were ovoid shaped, smaller, elongated and lower, compared to cotyledons of the control group. Indeed, cotyledons of both treatments were characterized by a smaller size but those in experiment 2 were significantly heavier (P<0.05). Moreover, cotyledons were smaller in PPFR than in PFR. The smaller size was accompanied by a significant decrease in both the largest and smallest diameter (P<0.05). Cotyledons height was significantly lower in PPFR compared to control and PFR (P<0.05). In addition, no significant differences were found in cotyledon density (CD) between the restricted groups and control (P>0.05).

3.3 High resolution light microscopy (HRLM)

We observed in greater structural detail the cells that constitute the goat placenta through HRLM. In the placental semi-thin sections corresponding to the control group (Figure 3 A and B), we found mononuclear trophoblastic cells and binuclear cells, metabolically active, cylindrical, with central and round nuclei and rich in euchromatin.

In addition, we detected abundant blood vessels in the fetal mesenchyme in both groups of PPFR (Figure 3 C and E) and PFR (Figure 3 D and F). In the pregnancy feed restriction group, we observed the presence of more collagen fibers in fetal mesenchymal compared to control and PPFR groups (Figure 3 F).

3.4 Transmission electron microscopy (TEM)

Through transmission electron microscopy we were able to identify the ultrastructural characteristics of goat placentas.

In the control group, the presence of small blood vessels, with well-defined walls, in close contact with mononucleated and binucleated cells were observed (Figure 4, A). These small vessels were observed in all treatments without major changes. Two or more endothelial cells formed the walls of these small caliber blood vessels, with few or several erythrocytes inside. In Figure 4 F, a pericyte on the wall of the blood vessel is shown.

Many binucleated cells and several nuclei with different degrees of cellular degeneration were observed in the PPFR (Figure 4 C and E). In Figure 4 D and F,

Journal Pre-proof

corresponding to the group of PFR, the fetal mesenchyme with apparently greater collagen fibers quantity in relation to the PPFR and the control is shown.

4. Discussion

During mid-gestation, vascularization of the ruminant placenta increases markedly, especially within the cotyledonary portion of placentomes, to develop a sufficient absorptive area for nutrient exchange (Reynolds *et al.*, 2001; Edwards *et al*., 2020). The limitations of this type of study were due to the handling of the animals and the experiments that had to be done separately to optimize the facilities. However, all the conditions to which the animals were subjected were carefully controlled.

The present study demonstrated that feed restriction in goats, prepubertal or from mid-gestation to parturition, impaired the development of structural characteristics of the placenta in different degrees. Our results showed no effect of feed restriction on placental weight, number of cotyledons and cotyledon density in agreement with previous studies in our laboratory (Turiello *et al*., 2019). This result could be explained, because the number of cotyledons is defined during early gestation, similar to cows, where it is defined before end of the second half of gestation (Batista *et al*., 2020; Vonnhame *et al*., 2007; Assis Neto *et al*., 2010). Indeed, in yak (*Bos grunniens*), during gestation, there are no significant changes in the total number of placentomes (Liu *et al*., 2010).

In PPFR, the effects of the prepubertal restriction of the female would not be enough to affect the number of cotyledons. Previous studies we demonstrated that feed restriction during the peripubertal period followed by a refeeding period, did not affect cotyledon number and litter size (Turiello *et al.*, 2019). Furthermore, in that previous study, we showed no effect of feed restriction on placental efficiency, however there is a tendency to greater placental efficiency with smaller placentas and lower kid weights (Fiorimanti *et al*., 2021). This increase in placental efficiency would suggest changes in cellular and vascular histoarchitecture to compensate for nutrient transport across the placenta. In addition, in this work, no effect of feed restriction on the ultrastructural characteristics of the placenta was found in agreement with previous study by Turiello *et al*. (2019).

However, we found a greater quantity of binucleate cells and various nuclei of mononucleate cells with different degrees of cell degeneration compatible with some signs of epithelial and trophoblastic degeneration that could be related to what was reported by Santos *et al.* (2017), who found alterations of inflammation at the end of the pregnancy for a perfect

Journal Pre-proof

expulsion of placenta and avoid its retention. The BNC is a terminally differentiated cell, but it does undergo additional maturation, fusing with an uterine epithelial cell to create a fetomaternal trinucleate cell (TNC) (Wooding 1987). After the formation of TNC, BNC migration and fusion can continue, which leads to the establishment of syncytial plaques, although this differs between species (Geiser and Spencer, 2021). In this study we did not find syncytial plaques in the placentas analyzed, but this result could be explained because they are placentas delivered at term.

On the other hand, our data coincide in part with those reported in previous studies by Cristofolini *et al.* (2012) and Turiello *et al.* (2019) who detected apoptotic cells and performed the TUNEL assay to determine the apoptotic index, determining differences between restricted in prepubertal stage and restricted with monensin supplementation. Here, we also highlight a greater amount of collagen fibers in the PFR group vs C determined through HRLM and TEM.

Through the HRLM technique, we have observed a greater number of binucleated cells and abundant blood vessels, especially smaller caliber, in both groups PPFR and PFR vs C, results similar to those obtained by Turiello *et al*. (2019). This finding may be associated to compensate for adequate blood flow for fetal development due to nutrient shortage. In the placentome bovine, although nutrient restriction had little effect on placental vascularity by day 125, upon realimentation, alterations in vascularity became apparent by day 250 of gestation, suggesting a placental programming effect (Vonnahme *et al*., 2007).

Other authors have determined that the flow of the ipsilateral umbilical artery decreases in feed restriction between days 50 to 180 of gestation in cows, but the macroscopic cotyledonary vascular density increases (Lemley *et al.,* 2018). In sheep, placental and fetal weights would be increased to maintain normal fetal growth despite limited maternal nutrient availability (Edwards *et al*., 2020). Moreover, it has been shown that exposure to ergot alkaloids alters the shape of blood vessels and the luminal area, indicating changes to counteract the reduction in blood flow due to vasoconstriction (Britt *et al*., 2021).

However, our results revealed decreases in cotyledonary weight and size in placentas from feed restricted goats in both groups, PPFR and PFR. Cotyledonary height also decreased significantly in the PPFR group. Under physiological conditions, the capillary area density increases gradually as the pregnancy progresses and is positively correlated with the proportion of proliferating cells during the early stage of pregnancy in goats (Wang *et al*., 2022). In the caruncular region increases due to the growth of capillary size, while in the cotyledonary region the increase is due to the rise in the capillary number density (Díaz *et*

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al., 2015). Considering this, it is possible that the smaller size of the placentomes is compensated by an increase in vascularity.

5. Conclusions

The present study revealed the effect of prepubertal and gestational feed restriction on macroscopic and microscopic characteristics in goat placentas with decreases in cotyledonary weight, height, and size in placentas from feed restricted goats in both groups, PPFR and PFR. The smaller size and the change in the shape of the cotyledons could indicate compensatory mechanisms for prepubertal and gestational feed restriction to ensure placental and kid development. Further investigations are required to determine vascular changes and cell proliferation that would compensate for the lower supply of nutrients through the placenta.

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Conflict of interest statement

The authors have no conflict of interest to declare.

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Figure captions

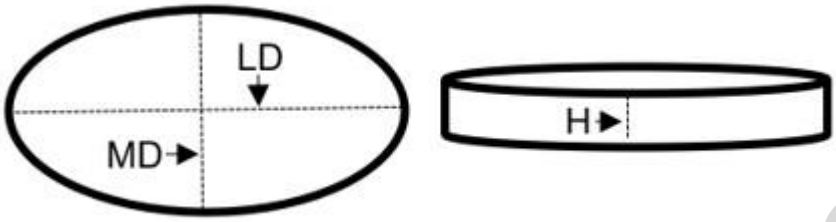

Figure 1. Diagram of the morphological characteristics used to morphometric measurements of the cotyledons. The illustration shows how cotyledon larger and minor diameter, and height were measured. LD: larger diameter, MD: minor diameter, H: height.

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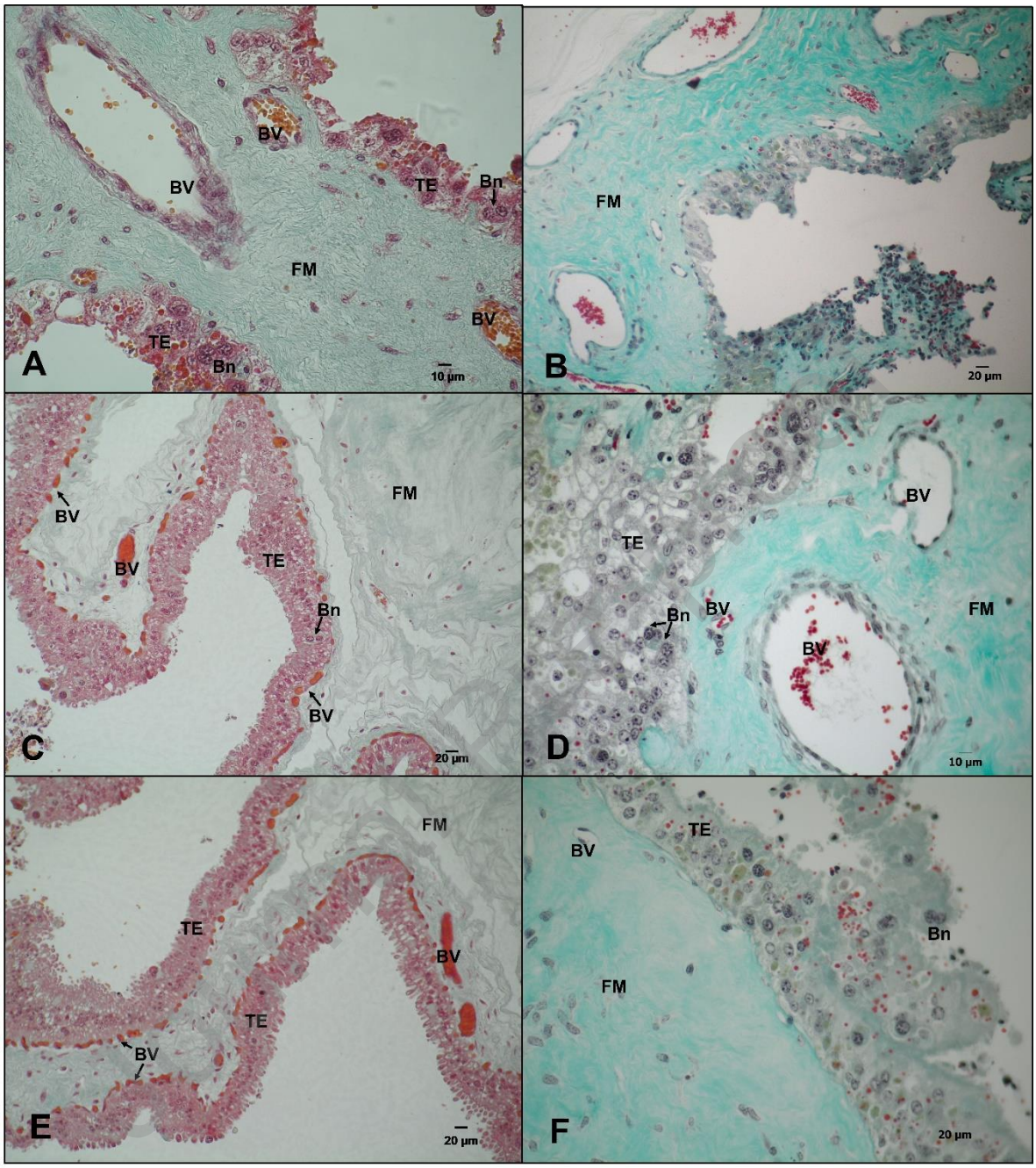

Figure 2. Photographs of at term goat placenta stained by Masson's trichrome dyes.

PPFN group: A, C and E (A: control, C and E: fed restriction). Observe the folds of the allantoic chorion membranes that form the villi are observed (C and E). PFN group: B, D and F (B: control, D and F: fed restriction). Observe the fetal mesenchyme (FM), with loose connective tissue and collagen fibers, the trophoblastic epithelium (TE) and larger diameter

blood vessels (BV) (B). Bn: binucleate cells. A, D and F: 400x. B, C and E: 200x. Scale bar: A and D: 10 µm; B, C, E and F: 20 µm.

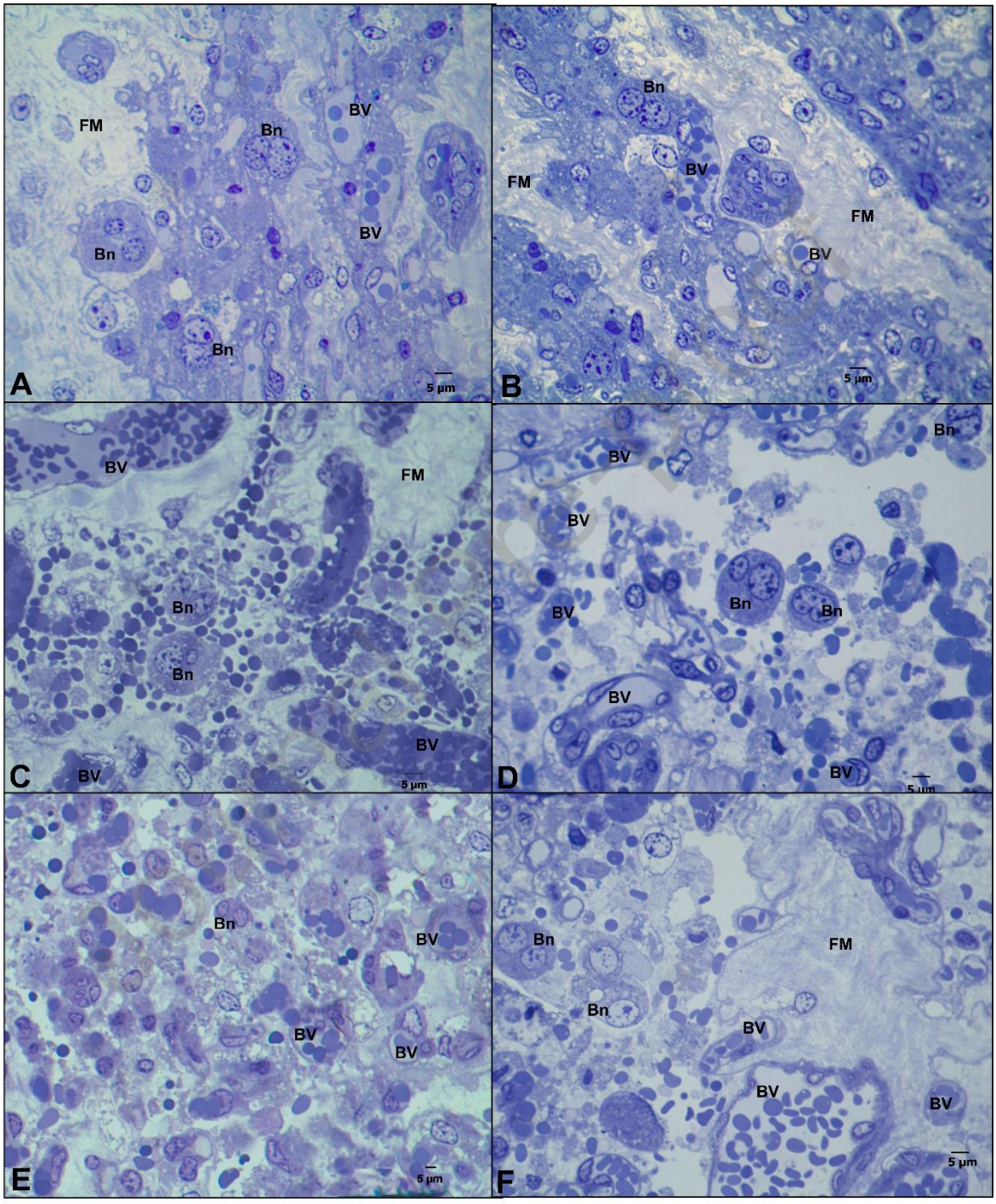

Figure 3. HRLM photographs of goat placenta from the PPFN group: A, C and E (A: control, C and E: fed restriction), PFN group: B, D and F (B: control, D and F: fed restriction). Bn: binucleate cells, BV: blood vessels FM: fetal mesenchyme. A-F: 1000x and scale bar: 5 µm.

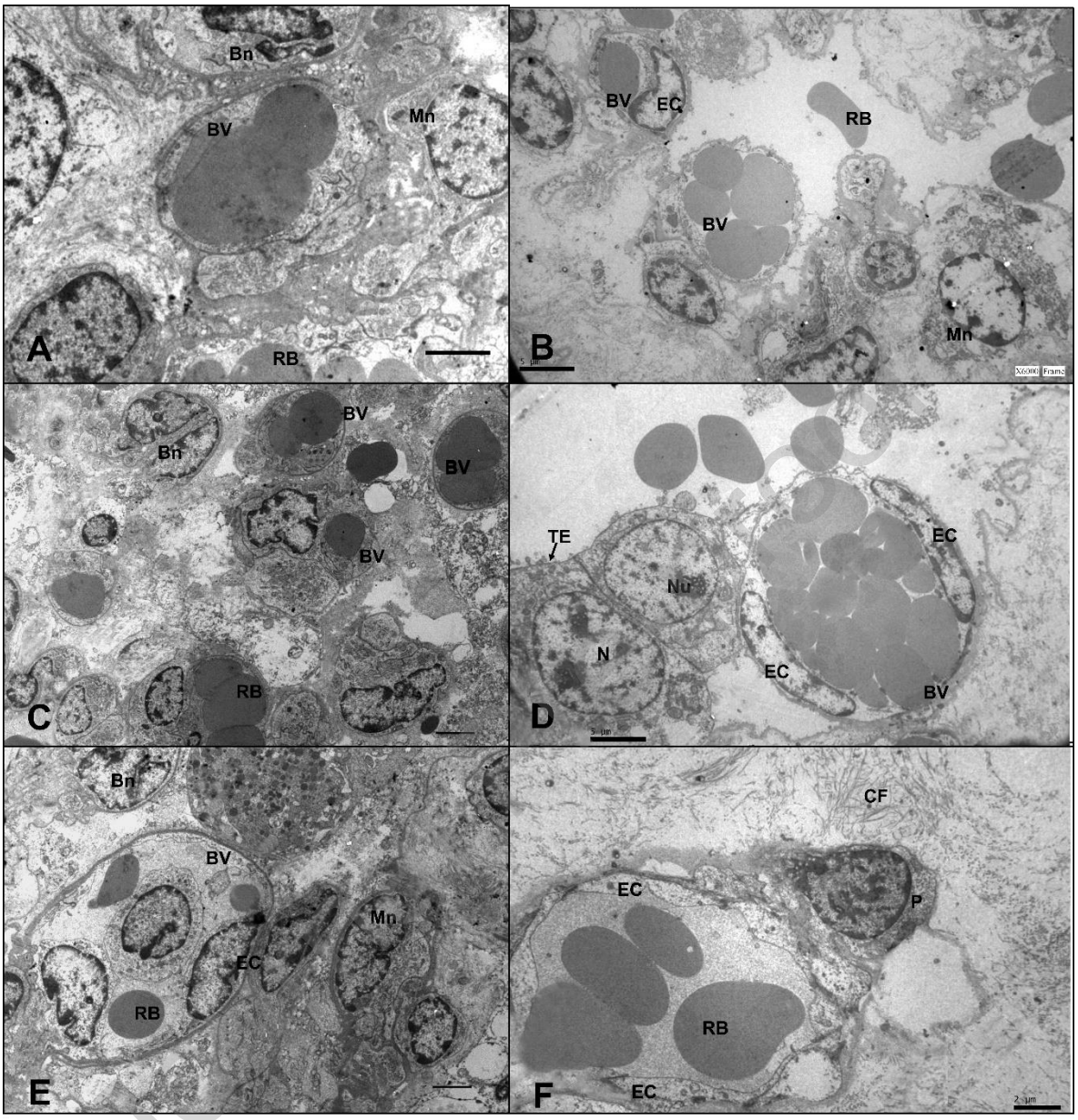

Figure 4. Photomicrography of goat placenta from PPFN group: A, C and E (A: control, C and E: fed restriction), PFN group: B, D and F (B: control, D and F: fed restriction). The mononucleated cells (Mn) showed big nuclei with a spherical tendency shape, with clear chromatin, evident nucleolus and clear cytoplasm (A and B). The nuclei of binucleate cells (Bn) had an irregular appearance and were partially more electron dense than the previous ones (A and C). BV: blood vessels, CF: collagen fibers, EC: endothelial cell, N: nuclei, Nu: nucleolus P: perycite, RB: red blood cell. Scale bar: A, B and D: 5 µm; C and E: 10 µm; F: 2 µm.

Tables

Table 1: *Mean values of placental weight and morphometric characteristics of the cotyledons in the different treatments. Experiment 1: Feed restriction in the prepubertal period (PPFR)(n=5), Control (C)(n=5); Experiment 2: Feed restriction during pregnancy (PFR)(n=5), Control(n=4) * (P ≤ 0.05)*.

Placenta		**Experiment 1**			**Experiment 2**		
		Mean	**±SEM**	***P-value***	**Mean**	**±SEM**	***P-value***
Weight (g)	***Control (C)***	539.40	61.24	0.54	402.50	30.40	0.24
	Pregnancy fed restriction (PFR)				350.72	27.19	
	Prepubertal fed restriction (PPFR)	535.17	55.90				
Cotyledon							
Number	***Control (C)***	90.40	9.49	0.60	97.75	3.04	0.03
	Pregnancy fed restriction (PFR)				87.20*	2.72	
	Prepubertal fed restriction (PPFR)	116.50	8.67				
Weight (g)	***Control (C)***	2.75*	0.09	0.03	1.47*	0.07	0.001
	Pregnancy fed restriction (PFR)				1.67	0.06	
	Prepubertal fed restriction (PPFR)	1.28	0.08				
Larger diameter (mm)	***Control (C)***	2.87*	0.06	0.39	2.44*	0.08	0.001
	Pregnancy fed restriction (PFR)				2.35	0.06	
	Prepubertal fed restriction (PPFR)	2.19	0.07				
Minor diameter (mm)	***Control (C)***	2.13*	0.05	0.07	1.56*	0.05	0.001
	Pregnancy fed restriction (PFR)				1.68	0.04	
	Prepubertal fed restriction (PPFR)	1.44	0.05				
Height (mm)	***Control (C)***	6.48	0.13	0.11	6.04*	0.11	0.001
	Pregnancy fed restriction (PFR)				6.26	0.09	
	Prepubertal fed restriction (PPFR)	5.46*	0.14				
Cotyledon density (CD)	***Control (C)***	0.18	0.03	0.22	0.24	0.03	0.65
	Pregnancy fed restriction (PFR)				0.26	0.02	

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	Prepubertal fed restriction (PPFR)	0.23	0.03

Tables

Table 2: *Mean values of placental weight and morphometric characteristics of the cotyledons in analysis of experiments 1 and 2 together. Control (C), Feed restriction during pregnancy (PFR), Feed restriction in the prepubertal period (PPFR). * (P ≤ 0.05).*

Placenta		**Experiment 1 and 2**		***P-value***
		Mean	**±SEM**	
Weight (g)	***Control (C)***	473.17	68.41	0,56
	Pregnancy fed restriction (PFR)	399.18	81.97	
	Prepubertal fed restriction (PPFR)	486.71	79.46	
Cotyledon				
Number	***Control (C)***	93.67	5.38	0.01
	Pregnancy fed restriction (PFR)	87.20	7.22	
	Prepubertal fed restriction (PPFR)	116.50*	6.59	
Weight (g)	***Control (C)***	2.13	0.65	0.001
	Pregnancy fed restriction (PFR)	2.32	0.65	
	Prepubertal fed restriction (PPFR)	0.63*	0.66	
Larger diameter (mm)	***Control (C)***	2.66	0.22	0.001
	Pregnancy fed restriction (PFR)	2.56	0.23	
	Prepubertal fed restriction (PPFR)	1.98*	0.23	
Minor diameter (mm)	***Control (C)***	1.85	0.29	0.001
	Pregnancy fed restriction (PFR)	1.96	0.29	
	Prepubertal fed restriction (PPFR)	1.15*	0.29	
Height (mm)	***Control (C)***	6.27	0.22	0.001
	Pregnancy fed restriction (PFR)	6.45	0.24	
	Prepubertal fed restriction (PPFR)	5.27*	0.25	
Cotyledon density (CD)	***Control (C)***	0.21	0.04	0.42
	Pregnancy fed restriction (PFR)	0.24	0.04	

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	Prepubertal fed restriction (PPFR)	0.25	0.04

Declaration of Competing Interest

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Mariana Fiorimanti reports a relationship with National University of Rio Cuarto that includes: employment. Mariana Fiorimanti reports a relationship with National University of Rio Cuarto that includes: employment.

Highlights

- Feed restriction affects placental development in goats.
- The weight, height, and size of the cotyledons decreases.
- Compensatory mechanisms would occur to ensure placental and kid development.

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