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Goat placental efficiency determination by comparing litter weight to the surface area of the cotyledons

S. Ocak[1,5], S. Ogun[2], Z. Gunduz[3], H.Onder[4]

[1]Department of Animal Production and Technologies, Faculty of Agricultural Sciences and Technologies, University of Nigde, Nigde, Turkey.
[2]Red Rock Agricultural Pastoral, Istanbul, Turkey.
[3]Mustafa Kemal University, Faculty of Agriculture, Department of Animal Science, Antakya, Turkey.
[4]Ondokuz Mayis University Faculty of Agriculture, Department of Animal Science, Samsun, Turkey.

Abstract

The relationship between placental component weights and litter related factors was investigated in 81 Damascus goats. The aim was to extensively compare cotyledonary traits to ascertain the main influencial factors in placental efficiency (PE). Every cotyledon in the placenta was measured for surface area, weight and depth in order to link any possible correlations to birth weight (BW), birth type (BT) and sex. Twins, especially the mixed gender ones, were shown to have far more efficient placentas than singletons. A new efficiency parameter, cotyledon efficiency (CE) was used to measure the effectiveness of the cotyledons to further understand PE. A Newly adopted method was used to measure the individual and total surface area of all the cotyledons on the placenta of each animal, rather than just determining the total number and weight of the cotyledons. Where in earlier studies it was thought that cotyledon number was the main factor affecting litter weight (LW) and consequently kid survivability, this study showed that the size of the cotyledons and their surface area interrelationships were a feature with far more influence in the placental exchange, producing heavier and healthier offspring. Birth type significantly affected ($P < 0.001$) BW, LW, placental weight (PW), and total cotyledon surface area (TCSA). High positive correlation ($r = 0.75$) was observed between CE and PE. This association was affected by BT, where the correlation remained high for twins ($r = 0.829$) and poor ($r = 0.470$) for singles. A strong negative correlation ($r = -0.79$) was seen between CE and TCSA. Results indicated that the total weight of the cotyledons, whilst an integral component of the placental weight, was not the main indicator of its efficiency but its surface area was, suggesting that larger cotyledons were far more efficient than the equivalent sum of smaller cotyledons. Further investigation is needed to ascertain the main factors influencing the promotion of larger cotyledons in the placenta.

Keywords: cotyledon efficiency, goats, litter weight, placenta weight.

Introduction

Profitability in goat farming is largely dependent on the number of kids weaned per goat per year. Whilst it is often thought that post-natal decisions are important for kid survival, the resilient kids are the ones born to does that have been managed correctly from pre-mating to kidding. This could well influence the placental development and thus the fetal growth. Placental growth and the development of its functional ability are important because they are the means by which the fetus receives metabolic substances for growth (Ocak and Onder, 2011), therefore, the survival of a newborn is affected by sufficiency of the placenta (Mellor and Stafford, 2004). Placental exchange in the ovine is dependent upon the number and size of the placentomes, which may be influenced by both maternal and foetal factors (Alexander, 1964).

Placental traits are a valuable indicator of offspring mortality in ovines and caprines. In ruminants, as the embryo increases in size, the process of diffusion, which nourishes the zygote in its earlier stages, becomes inadequate to maintain life. The extra embryonic membranes and the placenta develop means to meet the ever increasing fetal nutritional requirement. This epitheliochorial attachment is cotyledonary in nature and is located in mushroom-like nodes known as placentomes, made up of maternal caruncles and fetal cotyledons (Frandson and Spurgeon, 1992). The chorioallantois and its attached foetal cotyledons were studied to ascertain whether specific efficiencies existed within the cotyledon components and, if so, how these were affected by litter type, weight and sex. In goat and sheep, a positive correlation was found between birth weight and the weight of cotyledons (Alexander, 1964; Alkass *et al*., 1999; Osgerby *et al*., 2003; Madibela, 2004; Oramari *et al*., 2011). Dwyer *et al*. (2005) ascertained that effect on lamb birth weight must be predominantly through the increase in the average weight of cotyledons as placental efficiency and the numbers of foetal cotyledons were unaffected. A new parameter for measuring cotyledon efficiency was envisaged for this study with the aim of more qualitatively testing the efficacy of the placentome,

[5]Corresponding author: sezenocak1@gmail.com
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which we termed cotyledon efficiency (CE). A far broader set of cotyledon components were measured in this trial to determine its effective function. The total number of cotyledons on each placenta was measured individually, as a whole, and in 5 different size categories for surface area, weight and depth. Following these measurements, correlations between these components were analysed. Previous studies in which relationships between cotyledon weight, number and size were investigated showed that litter size and BW affected placental weight and surface area of cotyledons (Kaulfuss *et al*., 2000; Dwyer *et al*., 2005; Ocak *et al*., 2009). However, the effect of surface area on BW or litter size was never too clear regarding the total or individual surface area of the cotyledons. Our goal was to not only distinguish the specific components that influence efficiency, but to show the correlation between these components. To test the reliability of the newly devised CE parameter we also compared the efficiency test using average cotyledon surface area (ie. ratio of litter weight to average cotyledon surface area) to decipher whether indivual cotyledon size (small, medium or large) rather than overall cotyledon surface area is a more determining component for efficacy. We hypothesized that if we could determine the components of the cotyledon which affected its efficiency and how these in turn influenced LW and BT of the offspring we could possibly influence a reduction in kid mortality.

Material and Methods

The study involved 81 Damascus goats and 115 kids during the 2013 kidding season. The distribution of animals by litter size and sex are shown in Table 1. All animals were housed and cared for under the same conditions in a controlled farm feedlot environment and were naturally mated using multiple sires. The does were all 3.5 years old, on their second parity and weighed between 45-55 kg. Does were given 600 g concentrate and dried grass hay 1 kg/doe/day. Water and mineral licks were available *ad libitum*. All experimental procedures were approved by the Zirve University Institutional Animal Care and Ethics Committee, Gaziantep, Turkey.

After birth, does and their kids were left undisturbed for a period of 5 h to allow sufficient time for a bond to be established between mother and offspring. Once suckling was witnessed the kids were identified, sexed, ear-tagged and weighed using suspended scales (range 0-20 kg) and the details recorded. Placentas were collected immediately after expulsion and weighed fresh on digital scales. Twin birth calculations were made from mean measurements of the total litter weight. In the study we did not differentiate between monocygote and dicygote twins. The total cotyledon number (CN), from each delivered placenta was measured and divided into five categories relevant to their size; (small <1 cm in diameter; medium between 1 and 3 cm; large; 3-5 cm, Xlarge; 5-10 cm and XXlarge >10 cm in diameter). Measurement of each cotyledon surface area was carried out on a 1 cm grid matrix whiteboard and was recorded, corresponding to the doe and kid ID ear-tag number. After measuring each cotyledon's surface area they were individually dissected from the chorioallantois and weighed in digital scales. Average cotyledon depth (ACDe) was measured with an electronic compass. Placental efficiency (PE) was calculated for each doe, as the ratio of total kid birth weight or BW (g) to placental weight or PW (g), according to Molteni *et al*. (1978). The proposed new parameter for measuring Cotyledon Efficiency (CE) was defined as the ratio of litter weight (LW) to the total cotyledon surface area (TCSA).

Data was analyzed by one-way ANOVA, and the model included litter weight, placental weight, average cotyledon depth, average cotyledon surface area, cotyledon efficiency and placental efficiency. To evaluate the conformity of the data for analysis of variance, the Kolmogorov-Smirnov one sample test and the Levene variance homogeneity test were applied. Means were compared by the Duncan multiple comparison test.

To analyze the other non-parametric traits the Kruskal Wallis and Mann Whitney U test were used. The Pearson correlation coefficient was used to test possible relationships between litter weight, placental weight, average cotyledon depth, average cotyledon surface area, cotyledon efficiency, cotyledon weights and placental efficiency. Kendall's Tau correlation coefficient was used for all other traits. All analyses were performed using the Univariate routine of the SPSS statistical package, 2011, via license to Ondokuz Mayis University.

Results

Birth type affected ($P < 0.05$; $P < 0.001$) BW, LW, PW, MCw, LCw, XLCw, ACSA, CN, CE, PE and TCSA (Table 2). Twin births had an increasing effect on all the placental components that showed statistical significance. Birth weight declined by around 0.602 kg for each unit increase in litter size. As expected, litter size affected LW with an average increase of 3.298 kg for twins over singles (Table 2). Weights for the XLCw were approximately two times higher for twins than for single litters (Table2). Twins were also associated with bigger and heavier cotyledons than single kids. The newly proposed parameter (CE) for measuring efficiency of the placentome showed single pregnancies to be less efficient than the twins (Table 2). Sex did not affect cotyledon depth (ACDe) or CN (Table 3). Mixed sex litters had the highest LW and PW (Table 3). Male kids had twice the number of LCw, XLCw and XXLCw than females and were also on average 78.27 g heavier than female kids. Sex did not have any significant effect on CN, females however had a greater number of small cotyledons. CE and PE were found significant for sex and the most efficient cotyledons were found in mixed sexlitters. ACSA was also highly significant ($P < 0.001$) for litter gender and recorded highest for mixed sex litters (Table 3).

As expected, a strong positive correlation was observed between BT and LW ($r = 0.88$; Table 4), as well as between PW and LW ($r = 0.65$; Table 4). Positive relationships were also observed between the large sets of cotyledons and ACSA, while a strong negative correlation was noted between small cotyledons and ACSA, as well as CE and TCSA (Table 4). These associations were not observed with BT (Tables 5 and 6). A high positive correlation ($r = 0.75$) was observed between CE and PE (Table 4); this association was affected by BT, where the correlation remained high for twins ($r = 0$ .829, Table 6) and poor ($r = 0.470$, Table 5) for singles. Strong negative correlations ($r = -0.79$) were seen between CE and TCSA (Tables 4, 5 and 6).

Discussion

Results indicated that birth type, litter weight and sex had significant effect on certain cotyledon components and were similar to previous results. Reduction in the BW of twin kids was in accordance with Dwyer *et al*. (2005); Ocak *et al*. (2009, 2013, 2014), as was the increase in PE for twins (Dwyer *et al*., 2005; Ocak *et al*., 2009). However, the newly introduced parameter for assessing the efficiency of the placentome yielded an unexpected outcome. Where in earlier studies it was thought that cotyledon number was the main factor affecting LW and consequently kid survivability, this study showed that the size of the cotyledons and their surface area interrelationships were far more an influencing feature in the placental exchange, producing heavier and healthier offspring (Dwyer *et al*., 2005; Ocak *et al*., 2009). In numerous other studies much emphasis has been placed on the relationship between placental and birth weights (Echternkamp, 1993; Jenkinson *et al*., 1995; Osgerby *et al.,* 2003; Madibela, 2004). Many of the factors that influence lamb vigour, such as parity, litter size, and breed may exert their effects, at least partially, before birth, by influencing placental development. Additionally, the placenta plays a pivotal role, not only in ensuring good foetal growth in late gestation, but also in the development of the foetal brain, with likely consequences for neonatal behaviour and survival (Dwyer *et al*., 2005). Few additional studies have also confirmed that foetal growth and the placental capacity for glucose transport are greatly influenced by the number of caruncles and the number of placentomes (Alexander, 1964; Owens *et al*., 1987; Jenkinson *et al*., 1995). There have been previous studies suggesting that litter size and weight affect placental weight and cotyledonary surface area (Kaulfuss *et al*., 2000). The greater number of larger and heavier cotyledons in twins (Table 2) and the strong negative correlations between TCSA and CE, SCw and ACSA (Tables 4, 5 and 6) attest to this finding. It has been found that fetal weight was strongly associated with placental weight (Knight *et al*., 1988). The total weight of the cotyledons, whilst an integral component of the placental weight, was not the main indicator of its efficiency. On the other hand, surface area was a clear indicator of placental efficiency, suggesting that the surface area of larger cotyledons was far more efficient than the sum of the surface area of smaller cotyledons. The increase in cotyledon number with multiple births may arise because ewes with a low number of caruncles in the uterus are incapable of carrying more than single fetuses, or because of differences in cotyledon recruitment due to litter size (Dwyer *et al*., 2005). The study involved a single breed only, therefore, testing for genetic influences for cotyledon components was not possible. Past studies have suggested that a critical component of uterine capacity was placental efficiency, however, variation among conceptuses within a litter for this trait was seen to be substantial, leading to the conclusion that placental efficiency is an individual conceptus trait (Wilson and Ford, 2001). Our study did not support this finding, except in the case of mixed sex twins, where PW, PE, CE, ACSA and LW were all significantly affected. Other significant differences measured for kid gender were in relation to cotyledon size; the largest cotyledons were found in mixed sex kids, followed by males then females. Mixed gender birth type affected a whole array of traits, which certainly requires a study on its own to decipher the specific influencing factor which triggers the physiological component in the mother promoting the supplementary growth and development of the conceptus. If we are to assume that a healthier conceptus results in a higher birth weight and since BW in livestock greatly influences the performance of the individual later in life (Mellor, 1980), it can be stated that, in order to improve kid survivability it is necessary to look closer at the efficacy of the nutrient supply to the fetus and the main components that affect this exchange.

It is concluded that twin Damascus kids, in particular those of mixed gender, have far more efficient placentas than those of single births. The novel parameter for measuring placental efficiency indicates that cotyledon size, rather than amount, is the main determining factor for this efficacy. Larger cotyledons were, in fact, better nutrient suppliers for twin and single male births, as indicated by their higher live weight. Further investigation is needed to ascertain the main factors influencing the promotion of larger cotyledons in the placenta, whether environmental, nutrition based, genetic or other.

Table 1. Distribution of Damascus goats by birth type and gender.

Birth type	No. of does giving birth	No. of kids	Male	Female
Single	47	47	21	26
Twin	34	68	37	31
Total	81	115		

Table 2. Effect of birth type on placental component weights in Damascus goats.

	BT		
	Single (Mean ± SE)	Twin (Mean ± SE)	Sig
BW (g)	4533 ± 98.41[a]	3923.17 ± 102.6[b]	<0.001
LW (g)	4533.20 ± 98.41[b]	7831.33 ± 20.84[a]	<0.001
PW (g)	525.54 ± 19.65[b]	803.40 ± 59.19[a]	<0.001
SCw (g)	52.06 ± 4.52	39.63 ± 5.13	0.078
MCw (g)	93.00 ± 5.08[b]	146.17 ± 8.99[a]	<0.001
LCw (g)	35.10 ± 5.28[b]	62.93 ± 8.27[a]	<0.05
XLCw (g)	15.40 ± 2.79[b]	24.23 ± 4.47[a]	<0.05
XXLCw (g)	9.64 ± 2.00	10.00 ± 9.62	0.283
ACDe (mm)	4.27 ± 0.09	4.37 ± 0.11	0.47
ACSA (cm^2)	6.12 ± 0.31[b]	7.28 ± 0.39[a]	<0.05
CN	123.04 ± 4.61[b]	146.03 ± 8.00[a]	<0.05
CE	6.81 ± 0.22[b]	8.26 ± 0.55[a]	<0.05
PE	9.11 ± 0.25[b]	10.77 ± 0.75[a]	<0.05
TCSA (cm^2)	716.63 ± 31.63[b]	997.09 ± 62.44[b]	<0.001

BT= birth type; BW= birth weight (g); LW= litter weight (g); PW= placental weight (g); SCw= small cotyledon weight (g); MCw= medium cotyledon weight (g); LCw= large cotyledon weight (g); XLCw= extra large cotyledon weight (g); XXLCw= extra extra large cotyledon weight (g); ACDe= average cotyledon depth (mm); ACSA= average cotyledon surface area (cm^2); CN= cotyledon number; CE= cotyledon efficiency; PE= placental efficiency; TCSA= total cotyledon surface area (cm^2); Sig=Significance. Numbers are least square means (Mean ± SEM).

Table 3. Effect of fetal gender on placental component weights in Damascus goats.

	Sex			
	Male (Mean ± SE)	Female (Mean ± SE)	Mixed sex (Mean ± SE)	Probability (P<)
BW (g)	4460.61 ± 132.54[a]	4382.34 ± 110.09[a]	3779.67 ± 141.61[b]	<0.05
LW (g)	5734.55 ± 320.44[b]	4845.63 ± 214.24[c]	7820.00 ± 304.32[a]	<0.001
PW (g)	651.00 ± 42.29[b]	518.34 ± 25.32[b]	820.60 ± 96.58[a]	<0.001
SCw (g)	40.24 ± 5.57 [b]	58.25 ± 5.16 [a]	40.00 ± 7.05 [b]	<0.05
MCw (g)	109.15 ± 8.83	104.94 ± 7.22	138.33 ± 13.87	0.101
LCw (g)	54.85 ± 8.25 [a]	25.78 ± 4.07 [b]	67.20 ± 12.26 [a]	<0.05
XLCw (g)	21.64 ± 4.01[ab]	10.72 ± 1.95 [b]	29.33 ± 7.97 [a]	<0.05
XXLCw (g)	12.12 ± 2.63 [b]	5.59 ± 1.65 [b]	32.73 ± 19.49 [a]	<0.05
ACDe (mm)	4.25 ± 0.09	4.31 ± 0.13	4.42 ± 0.15	0.67
ACSA (cm^2)	7.08 ± 0.39[a]	5.48 ± 0.25[b]	7.68 ± 0.67[a]	<0.001
CN	127.67 ± 7.32	133.16 ± 6.04	137.27 ± 10.63	0.445
CE	7.23 ± 0.41[b]	6.73 ± 0.30[b]	8.95 ± 0.73[a]	<0.05
PE	9.59 ± 0.42[b]	8.88 ± 0.39[b]	11.86 ± 1.13[a]	<0.05
TCSA (cm^2)	829.55 ± 57.02	778.13 ± 54.64	897.94 ± 60.63	0.451

BT= birth type; BW= birth weight (g); LW= litter weight (g); PW= placental weight (g); SCw= small cotyledon weight (g); MCw= medium cotyledon weight (g); LCw= large cotyledon weight (g); XLCw= extra large cotyledon weight (g); XXLCw= extra extra large cotyledon weight (g); ACDe= average cotyledon depth (mm); ACSA= average cotyledon surface area (cm^2); CN= cotyledon number; CE= cotyledon efficiency; PE= placental efficiency; TCSA= total cotyledon surface area (cm^2); Sig=Significance. Numbers are least square means (Mean ± SEM).

Table 4. Correlation coefficients between placental traits and litter related factors in Damascus goats.

	Sex	LW	PW	SCw	MCw	LCw	XLCw	XXLCw	ACDe	ACSA	CN	CE	PE	BW	TCSA
BT	0.34	0.88*	0.51	-0.16	0.43	0.26	0.22	0.11	0.05	0.31	0.23	0.23	0.2	-0.42	0.45
Sex		0.25	0.13	0.10	0.09	-0.01	0.02	0.00	0.11	-0.03	0.11	0.19	0.11	-0.31	0.05
LW			0.65*	-0.26	0.39	0.36	0.28	0.23	0.08	0.49	0.08	0.28	0.24	-0.15	0.47
PW				-0.22	0.45	0.54	0.37	0.25	0.07	0.58	0.08	0.02	-0.04	-0.03	0.44
SCw					-0.1	-0.50	-0.50	-0.49	0.01	-0.73*	0.19	-0.02	-0.03	-0.03	-0.16
MCw						0.31	-0.12	0.07	0.1	0.22	0.14	0.07	0.05	-0.12	0.33
LCw							0.53	0.51	0.08	0.65*	-0.03	-0.13	-0.06	0.18	0.52
XLCw								0.5	0.10	0.61*	0.00	-0.16	-0.11	-0.06	0.40
XXLCw									0.03	0.62*	-0.07	-0.06	0.03	0.18	0.14
ACDe										0.05	-0.11	0.22	0.10	0.13	-0.05
ACSA											-0.15	-0.07	-0.00	-0.24	0.32
CN												-0.36	-0.06	0.28	0.42
CE													0.75*	-0.12	-0.79*
PE														-0.14	-0.34
BW															0.15

BT= birth type; LW= litter weight (g); PW= placental weight (g); SCw= small cotyledon weight (g); MCw= medium cotyledon weight (g); LCw= large cotyledon weight (g); XLCw= extra large cotyledon weight (g); XXLCw= extra extra large cotyledon weight (g); ACDe= average cotyledon depth (mm); ACSA= average cotyledon surface area (cm^2); CN= cotyledon number; CE= cotyledon efficiency; PE= placental efficiency; BW= birth weight (g); TCSA= total cotyledon surface area (cm^2). *= significant correlation (>0.6).

Table 5. Correlation coefficients between placental traits and litter related factors for single births in Damascus goats.

	LW	PW	SCw	MCw	LCw	XLCw	XXLCw	ACDe	ACSA	CN	CE	PE	BW	TCSA
Sex	-0.18	-0.24	0.29	0.01	-0.17	-0.10	-0.24	-0.12	-0.25	0.20	0.03	-0.00	-0.16	-0.09
LW		0.48	-0.36	0.31	0.45	0.39	0.38	0.05	0.54	-0.20	0.05	-0.03	0.58	0.17
PW			-0.16	0.56	0.72*	0.50	0.36	0.14	0.50	-0.01	-0.28	-0.33	0.44	0.45
SCw				-0.19	-0.56	-0.59	-0.65*	0.13	-0.83*	0.32	0.23	0.19	-0.18	-0.19
MCw					0.28	-0.02	-0.07	-0.03	0.22	0.14	-0.17	-0.13	0.20	0.09
LCw						0.73*	0.73*	0.01	0.80*	-0.09	-0.44	-0.36	0.45	0.64*
XLCw							0.72*	0.10	0.81*	-0.23	-0.23	-0.23	0.39	0.43
XXLCw								0.07	0.82*	-0.25	-0.34	-0.12	0.30	0.44
ACDe									-0.01	-0.15	0.30	0.11	0.34	-0.07
ACSA										-0.37	-0.29	-0.24	0.41	0.40
CN												-0.05	-0.12	0.12
CE												0.47	0.03	-0.77*
PE													0.01	-0.46
BW														0.42

LW= litter weight (g); PW= placental weight (g); SCw= small cotyledon weight (g); MCw= medium cotyledon weight (g); LCw= large cotyledon weight (g); XLCw= extra large cotyledon weight (g); XXLCw= extra extra large cotyledon weight (g); ACDe= average cotyledon depth (mm); ACSA= average cotyledon surface area (cm^2); CN= cotyledon number; CE= cotyledon efficiency; PE= placental efficiency; BW= birth weight (g); TCSA= total cotyledon surface area (cm^2). *= significant correlation (>0.6).

Table 6. Correlation coefficients between placental traits and litter related factors for twin births in Damascus goats.

	LW	PW	SCw	MCw	LCw	XLCw	XXLCw	ACDe	ACSA	CN	CE	PE	BW	TCSA
Sex	-0.09	-0.01	0.13	-0.11	-0.01	0.00	0.18	0.22	0.02	-0.16	0.25	0.12	-0.19	-0.28
LW		0.49	-0.47	0.20	0.46	0.47	0.37	0.08	0.56	-0.17	0.01	0.01	0.45	0.19
PW			-0.38	0.11	0.48	-0.46	0.62*	-0.03	0.65*	-0.10	-0.12	-0.19	0.11	0.20
SCw				-0.11	-0.63*	-0.48	-0.23	-0.25	-0.77*	0.30	-0.15	-0.10	0.01	0.03
MCw					0.29	-0.26	-0.20	0.37	-0.05	-0.05	-0.07	-0.12	0.04	0.16
LCw						0.58	0.08	0.01	0.63*	-0.14	-0.12	-0.07	0.22	0.28
XLCw							0.54	0.03	0.77*	-0.04	-0.24	-0.15	0.16	0.28
XXLCw								-0.00	0.71*	-0.07	-0.06	0.01	-0.16	-0.01
ACDe									0.14	-0.19	0.14	0.07	-0.00	-0.13
ACSA										-0.19	-0.04	0.03	-0.04	0.08
CN											-0.40	-0.17	0.01	0.33
CE												0.83*	-0.01	-0.78*
PE													-0.06	-0.60*
BW														0.45

LW= litter weight (g); PW= placental weight (g); SCw= small cotyledon weight (g); MCw= medium cotyledon weight (g); LCw= large cotyledon weight (g); XLCw= extra large cotyledon weight (g); XXLCw= extra extra large cotyledon weight (g); ACDe= average cotyledon depth (mm); ACSA= average cotyledon surface area (cm^2); CN= cotyledon number; CE= cotyledon efficiency; PE= placental efficiency; BW= birth weight (g); TCSA= total cotyledon surface area (cm^2). *= significant correlation (>0.6).

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