THE EFFECTS OF SEASON OF BIRTH AND PRE-WEANING DIET ON GROWTH RATE OF SPANISH-BOER DOELINGS

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
ADG	Average Daily Gain
BW	Body Weight
CAE	Caprine Arthritis Encephalitis
FSH	Follicle-Stimulating Hormone
GH	Growth Hormone
GnRH	Gonadotropin-releasing hormone
IGF	Insulin-like Growth Factor
LH	Luteinizing Hormone
NF	Nanny-fed
SM	Synthetic milk- fed

I. INTRODUCTION

Goats (*Capra aegagrus hircus*) are produced for meat, milk, and also in some breeds hair quality. According to the USDA, as of January 2020 all goats in the United States totaled 2.66 million. Texas was the leading state with 765,000 head of meat goats (USDA, 2020.) Some producers choose goats over cattle in production farming because they are smaller animals, require less land for foraging, and they have less input costs. The goat population worldwide has increased by 19.3% in the last 15 years; this is more than the increase in cattle and sheep populations combined (Mazhangara et al., 2019).

Meat goat production has been reported to have a smaller amount of carbon emissions than other ruminant species while providing adequate nutrients to humans. Carbon sequestration and greenhouse gas emissions in organic farms involving cattle, goats, sheep, and pigs were compared; goats had a lower emission value than cattle (Horrillo et al., 2020). People seeking a low-fat, red meat alternative source will most likely consume more goat meat (Dhanda et al., 2003). Many religious traditions involve meals that include goat meat because there are few religions that have objections to eating this type of meat, and there are increasing numbers of people, even in the U.S., that prefer goat meat for this reason (Ibrahim et al., 2008). Unfortunately, the need for goat meat has created unsustainable practices for goat meat producers so that they can make a profit in less time (Dhanda et al., 2003).

Replacement does are needed in any productive herd (Ghani et al., 2017). The following study can potentially increase knowledge surrounding replacement does based on the kid growth rate, season of birth and the serum metabolites circulating at the age of puberty. The hypothesis is that pre-weaning diet will affect the growth rate of female kids (doelings); and, season of birth will not affect the circulating blood metabolites around the age of puberty of doelings.

II. LITERATURE REVIEW

Growth Rate

Over 60 years ago the first study that linked nutrition and reproductive status was conducted on mature Hereford female cattle where the study of high-energy diet provided a reproductive advantage rather than a low-energy diet (Wiltbank et al., 1962). A model for hormones affecting beef cattle hypothalamic tissue pre and post-puberty involves leptin, insulin, and ghrelin are metabolic indicators that effect pubertal onset (Maciel, et al., 2004; D’Occhio et al., 2019). In beef cattle, hormones such as, progesterone, growth hormone (GH), IGF-1 (Insulin-like Growth Factor 1), insulin and metabolites such as glucose, were measured in the blood to indicate that the growth rate, body fat deposition, and age are all indicators and, therefore may affect, the age at puberty (Yelich et al., 1995).

After weaning, feed conversion is important in order to increase the growth of the muscle and fat depositions of the goat. Researchers have shown that nutrition effects growth by feeding a concentrated crude protein diet along with hay can improve feed conversion in goats (Rahman et al., 2018). According to Hernandez et al., it is possible that exposure to artificial long days could directly increase the growth of the kids by inducing a high secretion of growth-promoting hormones such as IGF-1, GH, insulin and thyroxin (2016).

Compensatory gain, the period after weaning from mother or bottle, may differ from Nanny-fed (NF) and Synthetic milk-fed (SM) kids. This is partly due to the stages of growth and development postnatal. This period can affect the goat’s body months later when pubertal onset occurs (Abeni, et al., 2019). Initially, compensatory growth is characterized by the deposition of very lean tissue, similar as during feed restriction. Then, protein synthesis decreases and high feed intake leads to increased fat deposition (Hornick et al., 2000). Body condition score has an effect on the compensatory gain of goats (Oliveira et. al., 2017*)*. In cattle, controlling the nutrient quality intake in the period postnatal to young juvenile can allow for optimal puberty timing in replacement heifers (Cardoso et al., 2014). Many use a step-down weaning nutritional program which can increase growth rate post-weaning (Mirzaei, et al., 2020).

Adequate feeding programs prove to improve growth performance for replacement breeder goats and begins with nutrient availability (Ghani et al., 2017).

Nutrient Availability

Post-natal nutrient sources include nanny's milk or synthetic milk replacers. Synthetic milk replacer was first produced in the 1970s as a prophylactic response to Caprine Arthritis Encephalitis (CAE). CAE is a virus of the retroviridae family that infects sheep and goats. The virus is transmitted from mother to kid through colostrum, milk, and can also be transmitted from adult to adult by blood or feces. This virus is still a factor that decreases yield in the underdeveloped countries and even in overexploited herds (Baraka et al., 2018).

Other reasons to feed synthetic milk to kids are that the nanny became incapacitated during parturition or by other means like injury. Most commonly, the producer decides to separate the mother and kid in order to decrease time between kidding which can increase production of the herd (Dhanda et al., 2003).

Glucose is the main energy source for physiological processes. Glucose is absorbed by cells of the intestine mainly after being broken down from carbohydrates. From there, glucose can be utilized by cells for energy; insulin is secreted in response to glucose. Glucose is commonly a metabolite analyzed in the blood to characterize insulin levels in pre-pubertal horses (Li et al., 2016).

Insulin is secreted by pancreatic cells when glucose is high in the blood. As part of glucose signaling, insulin acts on the hypothalamus and pituitary gland to transmit signals involved in energy metabolism. Insulin also acts on the follicles of the ovaries to promote ovulation (Castellano et al., 2009). Live weight at first estrus was related positively to insulin concentration and negatively to GH concentration (Rosales Nieto et al., 2019).

Cholesterol is a steroid hormone that is a precursor to reproductive hormones such as progesterone, estrogen, testosterone, and other hormones. It also aids in cell membrane function and synthesis. It is an indicator of adequate nutrition and may vary between breed of goats, sex, age, environment of the herd, and availability of feed and forage (Khan et al., 2013). Cholesterol is synthesized in the liver and transported to the gonads via lipoproteins. Once at the theca and granulosa cells inside the ovary, cholesterol can begin steroidogenesis (Norris and Carr, 2013). It has been found in previous studies that circulating cholesterol levels are an indicator of early puberty attainment in heifers (Abeni, et al., 2019).

Triglycerides are transporters of fatty acids to adipose tissue. These transporters are a blood indicator of the movement of fatty acids to adipose tissue (Khan et al., 2013). Once in the adipose tissue, these cells can be broken down and used to produce leptin. Leptin is a modulator of the reproductive system, and therefore puberty, by signaling to the hypothalamic neurons (Smith et al., 2002; Saleem et al., 2018).

A faster growth rate is implied to accelerate pubertal hormone release along the hypothalamic–pituitary–gonadal axis (Valasi et al., 2012). Alternatively, undernutrition can cause delayed puberty in sheep by decreasing the luteinizing hormone (LH) secretion. This causes underdeveloped follicle size and ovulation cannot occur. (Foster and Olster, 1984).

Pubertal Onset

Pubertal onset is a complex system that is influenced by environmental cues (Meza- Herrera et al., 2017). Goats are seasonally poly-estrus; generally, they breed in between the fall and spring equinox when the days are shorter. Puberty is defined as the first ovulation, and is accompanied by physical and endocrine changes that advance an animal's reproductive competency (Bon Durant et al., 1981).

The hormones regulating puberty are a part of the hypothalamic-pituitary-gonadal axis. Gonadotropin-releasing hormone (GnRH) is produced in neurons in the arcuate nucleus of the hypothalamus and travel through the portal system to the anterior pituitary gland (Thibault et al., 1993). GnRH stimulates gonadotrophic cells to produce both LH and follicle-stimulating hormone (FSH) that are transported in the blood to the ovaries of the female and affect the target cells (Hawken et al., 2012). LH and FSH both travel to follicles of the ovaries where, LH effects theca cells and its response aids in the conversion of cholesterol to androstenedione, and FSH effects granulosa cells of the follicle to take the androstenedione and convert to estradiol. Estradiol feeds back negatively to the hypothalamus where, during onset of puberty, it gradually increases the amount of GnRH, and therefore LH, being secreted (Day et al., 1984). That increase in frequency of pulses of LH triggers ovulation. After ovulation, progesterone is produced by the corpus luteum and gradually decreases as the estrous cycle continues.

Progesterone is produced by the corpus luteum and marks the onset of ovulatory activity when analyzed by radioimmunoassay (RIA) (Duricic et al., 2017). Before puberty, the progesterone levels in the body are low and produce small feedback to the hypothalamus. Approaching puberty this secretion becomes greater and greater as a result of receptors becoming desensitized to progesterone (Bon Durant et al., 1981). Following first ovulation, the luteal phase of the estrous cycle can be detected by the pulsations of luteinizing hormone, which is also analyzed by RIA (Tamboura et al., 1998).

Goats breeding season is based on seasonal photoperiod; generally, they breed in between the fall and spring equinox when the days are shorter. This occurs because females respond to photoperiod through melatonin receptors (BonDurant et al., 1981).

One natural way to alter the breeding season of goats is by introducing the male near the end of their breeding season. If copulation occurs towards the fall equinox, this results in the next kid crop being born in the summer months (Zarazaga et al., 2005). This could lead to the potential for the females of the newest crop to reach puberty at a younger age, and the females will then have the capacity to produce two kid crops per year (one during the standard mating period, and one in the non-standard mating period). This is also known as an accelerated breeding program where three kid crops are produced in two years or 5 crops in three years (Ahmad et al., 2014). This is a desirable protocol for goat production because it will increase yields, and if the goats are given enough nutrients, can bring higher revenue to producers (Dhanda et al., 2003).

Some breeders will intentionally speed up the onset of puberty using injections of hormones to synchronize herds (Alvarado-Espino et al., 2016). Exogenous hormones such as progesterone, prostaglandins, and melatonin have been injected into livestock to induce not only reproductively active females but also a precocious puberty for young does (Alvarado-Espino et al., 2016; Delgadillo et al., 2014; BonDurant et al., 1981). The use of injectables has become expensive and unpopular to the populations buying goat meat. When goats are housed inside, artificial light (long hours of dark vs light) can be a tool that producers use to promote a precocious puberty (Deveson et al., 1992; Hernandez et al., 2016). Allowing the young does to interact with the buck, (the male effect) has also been reported to reduce the age at puberty (Hawken et al., 2012; Chasles, et al., 2018). This can cause the secretion of GnRH and LH to increase at an earlier age and begin pubertal processes. All of these methods have pros and cons in the eyes of the producer and consumer (Dhanda et al., 2003).

Similarly, sheep have a reproductive cycle that is based on seasonality (Rivera et al., 2003). However, studies show that if born out of the normal breeding season, female lambs will postpone necessary processes that give rise to puberty (Valasi et al., 2012). Lambs born in the spring (natural season) will reach puberty between 30-35 weeks of age; this is the same for goats. Lambs born in the fall will delay puberty until almost a year of age (Deveson et al., 1992). Studies show that doelings pubertal onset will be precocious if born in the fall and can occur as early as 12 weeks of age (Duricic et al., 2012). Decisions made by the producer may be affected by the age the does go through puberty, and therefore, can become replacement does in the breeding herd.

Undernutrition can cause delayed puberty in sheep by decreasing the LH secretion. This causes underdeveloped follicle size and ovulation cannot occur. (Foster and Olster, 1984). Increasing producer’s knowledge surrounding growth rate, season of birth, and nutrient availability could help in choosing replacement does for the breeding herd.

Physical and behavioral signs of estrus have been studied and are valid detection signs in practical goat production systems (Vikash Chandra et al., 2010). These detectors include vulval discharge, vulval swelling, flagging or wagging tail, aggression towards other goats, and/or vocalization and were noted upon first observation in the doelings.

Objectives

The objectives of the present study can potentially increase knowledge surrounding the producer's breeding herd management of replacement does based on the kid growth rate, season of birth and the serum metabolites circulating at the age of puberty. These objectives include:

1. Determine the effect of pre-weaning diet on growth, and
2. Compare blood metabolites around the age of puberty

The hypothesis is that pre-weaning diet will affect the growth rate; and, season of birth will not affect the circulating blood metabolites around the age of puberty.

III. MATERIALS AND METHODS

Farm Site

The population chosen for this study was the female offspring of nine Spanish does and one Boer buck. The Spanish breed was chosen for the ability to clear rough forage, meat, and they can live in harsh environments. The Boer breed was chosen for their meat production qualities and clearing unwanted brush (Lupton, et al., 2009).

All animal work was approved by Texas State University's Institutional Animal Care and Use Committee, Protocol #6503. This study used the goat herd at the Freeman Center (29.938053, -98.008424) in Hays County, San Marcos, Texas. The goats had access to 2.93-ha of native forage, *ad libitum* access to fresh water and alfalfa hay.

The animals used were the fifteen doelings, born during two separate kid crops July 2018 through February 2019. Each of the nine Spanish does were assigned random treatments of either the control, Nanny-fed (NF) milking, or Synthetic milk-fed bottle feeding (SM) prior to kidding. If a female kid was born, the kid would be fed the treatment assigned to their mother. Given more than one female, the first born would be fed the assigned feeding schedule and the other/s would be fed the opposite.

The control group, Summer-born (n=3) and Winter-born (n=5), had *ad libitum* access to doe's milk. The treatment subjects were fed a step-down weaning program (Mirzaei, et al., 2020). The treatment group, Summer-born (n=2) and Winter-born (n=5), were fed Doe's Match Milk Replacer by bottle until full three times daily until 30 days of age; after 30 days of age the synthetic milk-fed kids were fed twice daily until weaning at 45 days. Determination of "full" was made using a feel test of the abdomen after nursing the bottle. At 45 days of age all kids were weaned and had access to Nutrina medicated supplemental goat feed twice daily and *ad libitum* alfalfa hay.

Overall appearance, behavioral abnormalities, and physical and behavioral signs of estrus were noted to detect approximate age at puberty throughout the study. These physical and behavioral signs of estrus have been studied and are valid detection signs in practical goat production systems (Vikash Chandra, 2010). These detectors include vulval discharge, vulval swelling, flagging or wagging tail, aggression towards other goats, and/or vocalization and were noted upon first observation in the doelings.

Sampling and Testing

Weekly samples were collected from each goat to assess animal health. The weekly sample collection for this study consisted of body weight (BW) and calculations of average daily gain (ADG). Beginning at 3 mo, each goat had 10 mLs of blood taken via venipuncture weekly. The whole blood was chilled promptly until centrifugation at 2800 rpm for 15 minutes. Aliquots of serum were separated into 1.5 mLs microcentrifuge tubes and frozen at 4 degrees Celsius until further analysis occurred.

Upon the first estrus observation in that season of birth's group, the blood serum was then analyzed via colorimetric assays (WAKO Chemical) to determine levels of glucose by measuring wavelength. The calculation to obtain concentration of glucose (mg/dL) from the wavelength measurements is the same for cholesterol and triglycerides and is as follows:

$$\text{Glucose (mg/dL)} = (A_s/A_{std}) * C_{std}$$

Where: A_s = Absorbance of the sample, A_{std}= Absorbance of the Standard, and C_{std}= Concentration of the Standard

Statistical Analysis

Statistical analysis of the obtained BW, ADG, and serum metabolite data was performed by SPSS Statistics (SPSS, Inc., Chicago, USA). The mean ± the standard error from the mean (SEM) of body weights were analyzed using a two-sample t-test. This was repeated for weights taken weekly from birth until weaning. Similarly, the ADG was compared for the treatment and control groups for the same repeated measures. The factors were considered significant if the p-value was less than 0.05.

The Friedman test was the statistical analysis used to compare the blood metabolite values of both seasons of birth. The results were based on the notion that if P-value > α, where α= 0.05, then there was not enough evidence to reject the null hypothesis. If P ≤ α the null hypothesis was rejected, in other words, not all means were statistically significant as equal. The null hypothesis was that the means of blood metabolites were equal between Winter-born and Summer-born doelings.

IV. RESULTS

Weight Gain

The weights were recorded in order to calculate ADG and can be found in the Appendix. Table 1 depicts the BW of the control and treatment groups in both Summer and Winter-born kid crops from birth to weaning. The first note to make is that the mean BW at birth of the control groups in both seasons of birth were numerically higher than the treatment groups. This is graphically depicted in Figure 1 as well.

The ADG was calculated based on body weight (kg) and shown in Table 2 as mean ± SEM of the treatment and control groups or Summer-born and Winter-born kid crops. The t-test analysis shows the significant difference ($p < 0.05$) of control and treatment groups, however there was not a significant difference in season of birth.

Table 1. Comparison (mean ± SEM) of control (Nanny-fed) and treatment (Synthetic milk-fed) doeling body weight (kg) from birth to weaning.

	Summer Crop		Winter Crop	
	Treatment	Control	Treatment	Control
Age	Body Weight	Body Weight	Body Weight	Body Weight
Birth	$3.18^{a} \pm 0.69$	$3.82^{b} \pm 0.26$	$2.95^{a} \pm 0.38$	$3.63^{b} \pm 0.37$
7 d	$3.72^{a} \pm 0.23$	$6.27^{b} \pm 0.15$	$3.86^{a} \pm 0.36$	$5.30^{b} \pm 0.56$
14 d	$3.81^{a} \pm 0.00$	$8.54^{b} \pm 0.30$	$5.00^{a} \pm 0.39$	$7.42^{b} \pm 0.68$
21 d	$5.00^{a} \pm 0.00$	$10.18^{b} \pm 0.26$	$5.45^{a} \pm 0.47$	$9.09^{b} \pm 0.65$
28 d	$5.72^{a} \pm 0.23$	$12.00^{b} \pm 0.30$	$6.13^{a} \pm 0.61$	$10.61^{b} \pm 0.48$
35 d	$6.81^{a} \pm 0.45$	$12.63^{b} \pm 0.26$	$8.18^{a} \pm 0.60$	$12.72^{b} \pm 0.77$
42 d	$7.72^{a} \pm 2.04$	$13.09^{b} \pm 1.49$	$7.95^{a} \pm 0.65$	$13.03^{b} \pm 0.94$

^{a,b} Different alphabets within a row indicate significant difference between means using t-test at $p < 0.05$

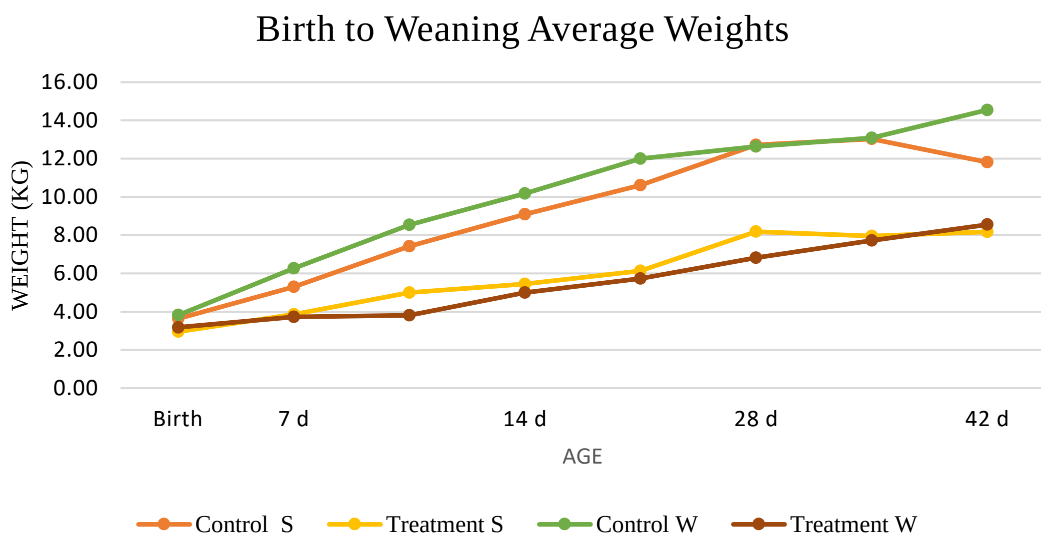

Figure 1. The average body weight of female kids from birth to weaning, where "S" = Summer-born and "W" = Winter-born. Control (Nanny-fed) and treatment (Synthetic milk-fed) groups of each season of birth are shown separately.

Table 2. Comparison (mean ± SEM) of control (Nanny-fed) and treatment (Synthetic milk-fed) doeling weight gain (kg/d) from birth to weaning. Two kid crops shown, where "W= Winter-born" and "S=Summer-born."

	Summer Crop			Winter Crop	
	Treatment W (n=2)	Control S (n=3)		Treatment W (n=5)	Control W (n=5)
Age	ADG	ADG	Age	ADG	ADG
Birth			Birth		
7 d	0.45 [a] ± 0.15	0.11 [b] ± 0.39	7 d	0.13 [a] ± 0.13	0.07 [b] ± 0.06
14 d	0.12 [a] ±0.06	0.34 [b] ± 0.02	14 d	-0.51 [a] ± 0.38	0.35 [b] ± 0.19
21 d	0.09 [a] ± 0.03	0.23 [b] ± 0.02	21 d	0.18 [a] ± 0.02	0.40 [b] ± 0.11
28 d	0.06 [a] ± 0.00	0.23 [b] ± 0.02	28 d	-0.20 [a] ± 0.09	0.20 [b] ± 0.05
35 d	0.19 [a] ± 0.06	0.21 [b] ± 0.02	35 d	0.39 [a] ± 0.04	0.77 [b] ± 0.03
42 d	0.32 [a] ± 0.00	0.30 [b] ± 0.18	42 d	0.19 [a] ± 0.06	0.43 [b] ± 0.04

[a,b] Different alphabets within a row indicate significant difference between means using t-test at $p < 0.05$

Blood Serum Metabolites

The subjects were observed for physical and behavioral signs of estrus and these observations noted if more than two doelings exhibited these signs in one week. The Summer-born doelings showed signs of head-butting, tail flagging and vulvar discharge at 3.5-4 months of age. The Winter-born doelings showed signs of estrus beginning at 7.5-8 months of age. These dates were recorded and chosen as the first week of samples to be analyzed for serum metabolites. Eight total weeks of samples were analyzed to capture any differences in season of birth in these metabolite concentrations over time around onset of puberty. The results of these triglycerides, glucose, and cholesterol concentrations are shown as mean ± SEM in Tables 3, 4, and 5, respectively.

Serum triglyceride values were within normal ranges (Karaşahin et al., 2019). The results were that there was no statistically significant difference between season of birth and blood serum triglyceride levels around the age of puberty. P-value= 0.15 > α, where α= 0.05. There was no need to run a post hoc test based on these results.

Table 3. Comparison of both kid crops control and treatment groups serum triglyceride concentrations mean ± SEM (mg/dL) around age at puberty.

	Summer Crop		Winter Crop	
	Treatment	Control	Treatment	Control
Wk 1	18.84 ± 6.74	19.80 ± 3.52	17.27 ± 3.63	22.18 ± 4.34
Wk 2	22.4 7 ± 3.11	23.75 ± 6.93	17.95 ± 3.91	13.14 ± 3.43
Wk 3	18.93 ± 2.00	16.57 ± 5.95	16.62 ± 1.02	14.2 ± 2.23
Wk 4	15.95 ± 2.00	21.45 ± 7.28	18.7 ± 3.85	23.28 ± 4.01
Wk 5	15.40 ± 0.88	21.37 ± 4.16	22.95 ± 4.84	18.56 ± 6.26
Wk 6	20.28 ± 6.33	15.63 ± 2.53	23.57 ± 2.11	19.59 ± 5.05
Wk 7	14.28 ± 2.65	22.09 ± 5.56	16.34 ± 4.65	18.12 ± 4.26
Wk 8	22.52 ± 0.74	12.56 ± 6.58	21.4 ± 4.55	19.38 ± 3.31

Serum glucose concentrations were calculated for each control and treatment group of the respective season of birth. Serum glucose values were within normal ranges (Karaşahin et al., 2019). The results were that there was no statistically significant difference between season of birth and blood serum triglyceride levels around the age of puberty. P-value= 0.20 > α, where α= 0.05. There was no need to run a post hoc test based on these results. This is a similar outcome as a study that evaluated glucose values of differing seasons of birth in doelings (Yede et al., 2020).

Table 4. Comparison of both kid crops control and treatment groups serum glucose concentrations mean ± SEM (mg/dL) around age at puberty.

	Summer Crop		Winter Crop	
	Treatment	Control	Treatment	Control
Wk 1	86.32 ± 7.13	82.37 ± 35.28	68.53 ± 4.39	64.44 ± 2.02
Wk 2	86.46 ± 12.12	71.65 ± 27.56	59.53 ± 5.15	70.59 ± 4.59
Wk 3	79.62 ± 1.30	77.59 ± 31.95	74.51 ± 5.37	60.84 ± 6.91
Wk 4	89.04 ± 0.99	83.33 ± 40.41	56.59 ± 6.01	63.85 ± 4.63
Wk 5	93.70 ± 8.29	93.34 ± 46.91	57.76 ± 7.25	78.11 ± 3.07
Wk 6	77.38 ± 21.19	85.39 ± 85.39	58.53 ± 6.55	73.31 ± 8.77
Wk 7	77.52 ± 14.24	87.07 ± 38.87	60.46 ± 9.89	60.01 ± 5.13
Wk 8	82.94 ± 5.5	82.47 ± 38.29	58.68 ± 5.63	58.31 ± 4.94

Serum cholesterol values were within normal ranges (Karaşahin et al., 2019). No serum cholesterol values were analyzed for the Winter-born kid crop, so a t-test was run for this data. The results were that there was no statistically significant difference between control and treatment group's cholesterol levels. This is a similar outcome as a study that evaluated cholesterol values of differing seasons of birth in doelings (Yede et al., 2020).

Table 5. Comparison of Summer-born control and treatment group serum cholesterol concentrations mean ± SEM (mg/dL) around age at puberty.

	Summer Crop	
	Treatment	Control
Wk 1	62.77 ± 6.97	82.69 ± 10.24
Wk 2	90.46 ± 7.66	92.64 ± 8.83
Wk 3	85.06 ± 3.42	72.46 ± 22.08
Wk 4	89.69 ± 9.73	66.57 ± 20.31
Wk 5	74.63 ± 18.28	77.04 ± 4.66
Wk 6	86.81 ± 6.96	85.16 ± 20.34
Wk 7	89.29 ± 2.72	84.33 ± 9.99
Wk 8	103.50 ± 8.8	87.44 ± 10.78

V. DISCUSSION

The objectives of the present study are to potentially increase knowledge surrounding replacement does based on the kid growth rate, season of birth and the serum metabolites circulating at the age of puberty.

1. Determine the effect of pre-weaning diet on growth, and

2. Compare blood metabolites around the age of puberty

Based on the results of the current study, pre-weaning diet does have an effect on the growth rate; and season of birth does not have a significant impact on the metabolites levels in blood serum around the age of puberty.

Birth weight was significantly different between NF and SM female kids. This significance was true for Summer and Winter-born female kids. Considering the treatments of NF and SM were pre-birth, the possible reasons for difference in birth weights was not analyzed in this study. The body weights stayed higher throughout the birth to weaning period for the control groups in both seasons of birth.

Pre-Weaning Diet

Capturing growth rate at this stage of life, birth to weaning, can be impactful in many metabolic processes throughout the goat's life **(**Yelich et al., 1995). Given that the birth weight happened to be larger in numerical value in the control group than the treatment group in both kid crops, this may have caused the consistent rate of growth throughout the study.

The ADG followed the same trend in that the control group had a significantly higher rate of gain than the treatment groups in both kid crops. This may have given the NF kids an advantage in the growth rate at an early phase. Statistical analysis shows that there is a significant advantage in NF growth rate rather than SM kids in a bottle feeding, step-down weaning procedure.

Season of Birth

Serum triglyceride concentrations showed no significant difference between means of control and treatment groups, between season of birth, and repeated for each week sampled. This is consistent with the mean triglyceride values of a similar study (Yede et al., 2020).

Serum glucose concentrations showed no significant difference between means of control and treatment groups, between season of birth, and repeated for each week sampled.

Due to limitations in the study, the cholesterol was only evaluated for the Summer-born doelings, however the control and treatment groups did not show a significant difference in concentration values in any given week's sample. This alludes to the fact that, similar to triglycerides and glucose, the season of birth should not affect the concentration values in the blood serum leading up to or at the age of puberty. There was a similar result in a study on the blood glucose values in pre-pubertal doelings (Li et al., 2016).

The conclusion drawn is that the season of birth does not affect the circulating blood metabolites around the age of puberty. Despite the pre-weaning diet, the blood metabolites around the age at puberty were statistically similar in both kid crops. This knowledge is beneficial to producers that may need to choose a replacement doe from a kid crop born in either the Summer or Winter. Although further investigation is needed to identify the exact week of the first estrus, (Santo, et al., 2018).

Suggested Breeding Management

Replacement does are a pivotal part of the breeding herd management practices of meat goat producers. With the findings of this study, the recommendation is that in identifying replacement does for the breeding herd, season of birth and pre-weaning diet of a doeling do not have an effect on the expected onset of puberty of the replacement doe. These findings did not encompass the male breeding herd and recommend further investigation occur of effects of pre-weaning diet of the male's onset of puberty.

Further investigation is needed for analysis of the reproductive endocrine hormones of female doelings in order to assess specific age at puberty, effect of pre-weaning diet on onset of puberty, metabolic differences in onset of puberty and the delay of puberty certain seasons of birth (Guzman, et al., 2005).

Limitations

There were the following limitations of this study of the Spanish-Boer doelings at the Freeman Center in the duration of this study:

1. Limited access to the behavioral and physical observations of these goats to 2-3 times per day.
2. The goats were observed by undergraduate and graduate students where the level of observation may have varied.
3. The level of “fullness” of the SM kids was subject to which undergraduate and/or graduate student was feeding that kid.
4. Laboratory analysis was confined to available resources and global pandemic. The cholesterol values of the Winter-born crop were not able to be analyzed.
5. This study provides producers with a general sense of timing of puberty, however does not indicate the specific week of pubertal onset.

APPENDIX SECTION

Body Weight

	Winter-born Doeling (kg)		Summer-born Doeling (kg)	
Age	Control Average	Treatment Average	Control Average	Treatment Average
Wk 0	3.64	2.96	3.64	2.96
Wk 1	5.30	3.86	5.30	3.86
Wk 2	7.43	5.00	7.43	5.00
Wk 3	9.09	5.45	9.09	5.45
Wk 4	10.61	6.14	10.61	6.14
Wk 5	12.73	8.18	12.73	8.18
Wk 6	13.03	7.95	13.03	7.95
Wk 7	11.82	8.18	11.82	8.18
Wk 8	13.94	9.55	13.94	9.55
Wk 9	15.15	10.23	15.15	10.23
Wk 10	15.61	10.91	15.61	10.91
Wk 11	16.21	11.36	16.21	11.36
Wk 12	16.52	12.50	16.52	12.50
Wk 13	18.03	13.64	18.03	13.64
Wk 14	19.70	15.00	19.70	15.00
Wk 15	19.70	15.45	19.70	15.45
Wk 16	21.06	15.91	21.06	15.91
Wk 17	21.67	16.36	21.67	16.36
Wk 18	21.97	16.36	21.97	16.36
Wk 19	21.97	17.50	21.97	17.50
Wk 20	23.79	18.86	23.79	18.86
Wk 21	24.39	19.55	24.39	19.55
Wk 22	24.70	19.32	24.70	19.32
Wk 23	25.45	20.00	25.45	20.00
Wk 24	26.36	20.91	26.36	20.91
Wk 25	28.03	21.82	28.03	21.82
Wk 26	28.48	22.50	28.48	22.50
Wk 27	29.55	22.50	29.55	22.50
Wk 28	29.70	23.41	29.70	23.41
Wk 29	30.00	23.86	30.00	23.86
Wk 30	28.18	23.18	28.18	23.18

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