Effects of maternal nutrition and arginine supplementation on characteristics of wool quality in offspring

J. L. Peine*, P. B. Borowicz*, J. S. Caton*, and R. R. Redden*

*Department of Animal Sciences and Center for Nutrition and Pregnancy,
North Dakota State University, Fargo 58108

The objectives of this study were to evaluate effects of maternal nutritional plane and rumen-protected arginine supplementation on postnatal offspring wool quality and follicle development. We hypothesized that lambs from ewes receiving diets fed to nutrient requirements would have a greater density of wool follicles and more improved wool quality than lambs from nutrient restricted ewes; we also hypothesized that lambs from restricted ewes receiving a rumen-protected arginine supplement would present similar wool follicle numbers and quality to those lambs from adequately fed dams. We found that though maternal nutrient restriction did not appear to affect wool quality, maternal rumen-protected arginine supplementation may increase wool follicle density in offspring from nutrient-restricted dams and therefore potentially increase wool production.

INTRODUCTION

The United States' total wool supply has been declining over the last twenty years. In 1990, U.S. wool supply totaled 214.8 million clean pounds, with 131.9 million clean pounds in 2000 and dropping to 56.3 million clean pounds in 2010 (USDA, 2013). Similarly, total yield per head has been decreasing, albeit not as drastically (7.8 lb/head in 1990, 7.6 lb/head in 2000, and 7.3 lb/head in 2010; USDA 2013). These data support a need for improvement in U. S. wool production.

Development of wool follicles occurs during fetal life and plays an important role in postnatal wool output (Magolski et al., 2011). Skin has a defined number of dermal cells in the embryonic stage that will eventually permit postnatal follicle formation, meaning that postnatal wool follicle numbers are pre-determined by fetal development during gestation. Nutrition, especially amino acid availability, impacts wool growth and follicle development (Rogers, 2006). When maternal nutrition, particularly amino acid availability, during pregnancy is restricted, this can result in a decrease in wool follicle development (Schinckel and Short, 1960).

Knowing this, we hypothesize that lambs from ewes receiving diets fed to meet nutrient requirements during gestation will have a greater density of wool follicles and increased wool quality compared to lambs from ewes restricted in nutrients during gestation. We also hypothesize that lambs from ewes restricted in nutrients, but receiving a rumen-protected arginine supplement will present similar wool follicle numbers and quality to those lambs from dams receiving full nutrient requirements during gestation.

PROCEDURES

Ewes were confirmed pregnant and randomly assigned to one of three treatments at day 54 (standard deviation of start date was 3.89 days) of gestation: control (**CON**) receiving 100% NRC (1985, 2007) energy requirements, restricted (**RES**) receiving 60% of CON nutrients, and restricted plus arginine (**RES-ARG**) receiving the restricted diet in addition to a rumen-protected arginine supplement dosed at 81.7 mg/lb (180 mg/kg) body weight. All ewes were receiving a complete pelleted diet once daily containing 34% dehydrated alfalfa meal, 27% dehydrated beet pulp, 25% wheat middlings, 9% ground corn, 5% soybean meal, and a trace mineral premix exchanged for ground corn at the rate of 12 pounds per ton on an as fed basis. Rumen-protected arginine supplements were mixed into 0.11 pounds of corn and fed once a day at 8:00 am, just prior to offering pelleted diet. Ewes were weighed every 14 days, and diets were adjusted as necessary. Ewes were carried through gestational term on these treatments. Immediately post-lambing, lambs were separated from ewes and raised independent of their dam.

Lambs were maintained on a common diet of artificial colostrum for 20 hours after birth, dosed at 8.7 mL/lb body weight 0 and 2 hours post birth, and 11.6 mL/lb body weight 4, 8, 12, 16, and 20 hours post birth. These was followed by ad libitum milk replacer (Super Lamb Milk Replacer, Merrick's Inc., Middleton, WI) and water in addition to long stem mid-bloom alfalfa hay and creep feed for the remainder of the project. At 54 days of age (with a standard deviation of 3 days), lambs were weighed prior to stunning by captive bolt. Following wool collection, the corresponding 3 cm^2 sections of skin were obtained from the side (between 10^{th} and 12^{th} rib) and britch regions of the lamb for further histological analysis.

Skin sections were fixed and stained via a procedure using Mayer's Hematoxylin and Schiff Reagent. Sections were processed, embedded in paraffin blocks, and applied to glass slides for microscopic imaging. Photomicrograph images were analyzed in Image-Pro Plus software to measure two 1 mm^2 sections and count the total number of wool follicles visible in these areas. An average of the follicle counts for each of the two squares was taken for each lamb – one average value for the side and one average value for the britch.

Side and britch wool samples were sent to Montana Wool Laboratory (Bozeman, MT) for analyses of mean fiber diameter, fiber diameter SD, and comfort factor with the Optical Fiber Diameter Analyzer 100.

RESULTS

Birth weight and growth performance of the lambs have been reported previously (Peine et al., 2013). At d 54 of age, there was no difference ($P \geq 0.16$) in lamb body weight due to maternal nutrition treatment, twin status, or fetal sex.

No differences ($P = 0.41$) were observed in follicle numbers between maternal nutrition treatments for skin samples taken from the side of the lamb, however singleton lambs had greater wool ($P = 0.04$) follicle density than twin lambs (87 ± 4.2 vs. 66 ± 9.1 follicles per 1 mm^2, respectively) (Table 1). In samples taken from the britch, lambs from RES-ARG ewes had greater ($P = 0.02$) wool follicle density than lambs from CON ewes, and tended to have greater ($P = 0.13$) wool follicle density than lambs from RES ewes. Singleton lambs also tended to have greater ($P = 0.13$) wool follicle density than twin lambs in samples taken from the britch.

The wool quality data reflected that mean fiber diameter, fiber diameter, and comfort factor all showed no differences between treatment, twin status, or fetal sex ($P \geq 0.15$).

DISCUSSION

Lambs from RES-ARG ewes had greater wool follicle density than lambs from CON ewes, and tended to have more wool follicle density than lambs from RES ewes in skin samples taken from the britch. Arginine is a precursor to synthesis of polyamines, which regulate DNA and protein synthesis, cell proliferation and differentiation, and regulation of gene expression (Kwon et al., 2003). Arginine-induced polyamine synthesis may have permitted differentiation and proliferation of wool follicle cells during fetal development. In addition, arginine is also a precursor to nitric oxide (**NO**) which regulates blood flow (Martin et al., 2001). Increased blood flow due to arginine supplementation and NO regulation may provide more nutrient availability for wool growth.

Twin status may have induced differences in wool follicle numbers in both the side and britch skin. Singleton lambs had greater wool follicle density in skin samples from the side than twin lambs. Similarly, singleton lambs tended to have greater wool follicle density in skin samples from the britch than twin lambs. This is probably due to singleton lambs having less competition for nutrients during fetal development than twin lambs (Freer et al., 1997).

There were no differences in mean fiber diameter, fiber diameter SD, or comfort factor based on maternal treatment, fetal number, or sex of the offspring. These results demonstrate a lack of improvement in wool quality in terms of fiber diameter based on either maternal nutrition or rumen-protected arginine supplementation.

IMPLICATIONS

These data imply that arginine supplementation has the potential to increase wool follicle density in offspring from ewes restricted in nutrients during gestation. However, arginine supplementation did not increase wool quality in those offspring.

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Table 1. Effect of maternal nutrition and arginine supplementation on wool follicle numbers and various wool quality measurements[1]

	Maternal Treatment[2]				*P* - values		
Item	CON	RES	RES-ARG	SEM	Treatment	Fetal no.	Sex
54 day body weight (lb)	52.6	48.3	52.2	2.27	0.25	0.81	0.16
Follicle No.							
Side	85	74	71	9.5	0.29	0.04	0.29
Britch	86[a]	93[ab]	106[b]	6.3	0.05	0.13	0.97
Mean fiber diameter (µm)							
Side	18.8	18.4	18.3	0.31	0.32	0.33	0.15
Britch	20.9	21.5	20.8	0.43	0.40	0.30	0.45
Fiber diameter SD (µm)							
Side	4.8	4.9	4.9	0.16	0.75	0.37	0.56
Britch	5.6	6.0	5.6	0.29	0.46	0.27	0.65
Comfort factor							
Side	98.5	98.5	98.6	0.37	0.98	0.57	0.13
Britch	94.6	93.1	95.0	1.35	0.47	0.16	0.16

[1]Wool follicle numbers and quality were assessed in offspring from ewes fed complete pelleted diets at varying levels of nutrient requirements with or without rumen-protected arginine (RP-ARG) supplementation.

[2]Treatments were administered to ewes as a complete pelleted diet daily. Rumen-protected arginine supplement was mixed in a 50 g fine ground corn carrier. Treatments were control (CON, 100% NRC requirements, n = 11), restricted (RES, 60% CON nutrients, n = 11), and restricted + arginine (RES-ARG, RES + rumen-protected arginine supplement, n = 10). Rumen-protected arginine was dosed at 81.7 mg/lb (180 mg/kg) BW.

[a,b,c] Means within a row without a common letter superscript differ ($P \leq 0.05$).