Effects of arginine supplementation on reproductive performance in Rambouillet ewes

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The objective of the current study was to determine if supplementation with the amino acid arginine enhances ovarian function and reproductive performance in sheep. Since prenatal mortality represents a large portion of economic loss in the sheep enterprise appropriate strategies need to be developed for reducing lamb losses before birth. Arginine supplementation is proving to be an effective strategy to improve the number of lambs born per ewe.

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Introduction

Reproductive performance is the largest determinant of income in the livestock enterprise. In sheep embryonic and fetal deaths during pregnancy account for 25 to 50% of the total number of fertilized ova (Inskeep et al., 2003; Dixon et al., 2007), and can lead to complete pregnancy losses or decreases in dam productivity. Even if prenatal losses do not occur, improper growth and development before birth can decrease immediate survival after birth (Moulet et al., 1956), alter feed efficiency (Greenwood et al., 2003), decrease carcass yield (Greenwood et al., 2001), and impair reproductive performance during later life (Da Silva et al., 2001; Martin et al., 2007). Clearly, the development of strategies for enhancing prenatal growth and survival in sheep could have a major economic impact.

The amino acid L-arginine is important for the synthesis of polyamines and nitric oxide, both of which are essential for proper development of the embryo and placenta. It is reasonable to hypothesize that supplementation with arginine would have beneficial impacts on prenatal growth and survival ruminant livestock. Gestating sows supplemented with arginine achieved a 22% increase in live piglets born when compared to non-supplemented sows (11.4 vs. 9.4, $P < 0.03$, respectively) (Mateo et al., 2007). In addition to these beneficial effects on prenatal survival, arginine treatment during late pregnancy increases transport of nutrients to the unborn lamb (Thureen et al., 2002) and enhances lamb birth weight (De Boo et al., 2005).

The objective the current study was to determine the effects of arginine supplementation on ovarian function, early reproductive losses and lamb birth weight in Rambouillet ewes.

Procedures

In April of 2008, Rambouillet ewes of a similar BW (68 ± 1.8 kg) and age (4.7 ± 0.32 yr) received a CIDR device for 12 d followed by a single injection of 400 IU PMSG. Thereafter, ewes were exposed to fertile rams at a ratio of 1 ram: 2ewes. From d 0 (estrus) to d 15 post-estrus ewes received L-arginine HCl (equivalent to 27 mg of L-arginine/kg of BW, ARG, n = 20) or saline (CON, n = 20) i.v. once daily. Daily blood samples were obtained from 5 ewes / group immediately after treatment (0 h) to assess progesterone (P4) concentrations and at -0.5, 0, 0.5, 1, 2, 4, 8, and 24 h on d 12 to determine circulating concentrations of arginine in response to treatment. Ovarian hemodynamics (d 12) and reproductive losses (d 25 and 45) were determined with color-Doppler and B-mode ultrasonography techniques, respectively.

Results

On d 12 of pregnancy, serum concentrations of arginine (nmol/ml) were elevated in ARG vs. CON ewes at 0 ($P < 0.001$), 0.5 ($P < 0.001$), 1 ($P < 0.001$), 2 ($P < 0.005$), and 4 h ($P < 0.05$), but were similar ($P > 0.05$) at -0.5, 8 and 24 h (Figure 1).

Resistance index in the ovarian artery was reduced ($P < 0.05$) on d 12 at approximately 4 h after treatment in ARG vs. CON ewes (Figure 2). Despite similarities in the number of corpora lutea in those ewes that were blood sampled (ARG, 1.8 ± 0.20 and CON, 1.8 ± 0.20 CL/ewe; $P > 0.05$), ARG ewes had greater ($P < 0.004$) P4 concentrations throughout treatment compared to CON ewes (Figure 3).

Treatment with L-arginine did not influence pregnancy rate (ARG, 55% and CON, 60%; $P > 0.05$) or the number of corpora lutea among all ewes studied (ARG, 1.8 ± 0.12 and CON, 1.8 ± 0.199; P > 0.05). However, ARG ewes had more (P < 0.05) embryos per ewe (Figure 4) and less CL not represented by embryos (0.18 ± 0.122 vs. 0.58 ± 0.155, $P < 0.05$) compared to CON ewes at d 25 of pregnancy. As pregnancy progressed to d 45, ARG ewes continued to have more ($P < 0.03$) embryos present compared to CON ewes (Figure 4), and the difference in the number of CL not represented by embryos was even greater ($P < 0.03$) in CON (0.75 ± 0.227) vs. ARG ewes (0.18 ± 0.122). The overall proportion of ewes conceiving, but then exhibiting embryonic loss by d 45 of pregnancy was reduced in ARG vs. CON ewes (18 vs. 58%, respectively, P < 0.05).

Ewes treated with L-arginine gave birth to more lambs when compared to control ewes (ARG, 1.6 ± 0.16 vs. CON, 1.1 ± 0.16 lambs born per ewe), but average lamb birth weights were not affected (ARG, 10.9 ± 0.32 and CON, 10.7 ± 0.18 lbs.).

Discussion

This is the first study to demonstrate that reproductive losses can actually be prevented with supplementation of the amino acid arginine during early pregnancy. Ewes receiving arginine from the time of standing estrus to d 12 of pregnancy lost fewer embryos during early pregnancy and ultimately gave birth to more lambs per ewe. Mateo et al. (2007) observed similar results when gestating sows were supplemented with arginine. Sows supplemented with arginine achieved a 22% increase in live piglets born when compared to non-supplemented sows (11.4 vs. 9.4, $P < 0.03$, respectively). The latter results may be due to an increase in nutrient delivery to the developing embryo/fetus.

In the current study, it would appear that treatment with arginine enhanced the early uterine environment making it more ideal for embryonic survival. Ewes treated with arginine had higher concentrations of progesterone, a hormone necessary for maintaining pregnancy. Several studies have shown that low levels of progesterone can lead to a greater incidence of embryonic loss in sheep and ultimately result in decreases in ewe productivity. Progesterone is necessary for the secretion of histotroph by uterine glands during early pregnancy (Spencer et al., 2001), which is important for early embryonic growth and development. Increases in progesterone production may have resulted from greater ovarian function in ewes supplemented with the amino acid arginine. Arginine is important for many biological functions, including the synthesis of nitric oxide, a chemical important for dilating blood vessels and increasing tissue blood flow. Increases in ovarian blood flow and/or vascular perfusion of the corpus luteum (structure responsible for

progesterone production during early pregnancy in sheep) probably resulted in higher concentrations of progesterone in ewes treated with arginine.
In summary, early reproductive losses can be prevented, at least in part, by treatment with arginine. Decreased ovarian vascular resistance and increased concentrations of progesterone may result in a more ideal environment for early embryonic survival.

Implications

Although a more suitable delivery method must be developed, the current results imply that embryonic survival in sheep can be enhanced when L-arginine is supplemented during early pregnancy. We are currently evaluating a rumen protected source of arginine for enhancing embryonic survival and ultimately ewe productivity. In the near future it may be possible to include a rumen protected source of arginine in your breeding ewe ration at a relatively low cost.

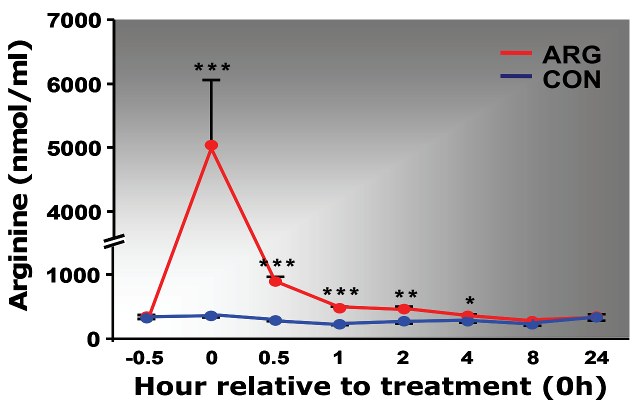

Figure 1. Serum arginine concentrations relative to injection (0 h) in ARG and CON ewes on d 12. Data are means ± S.E.

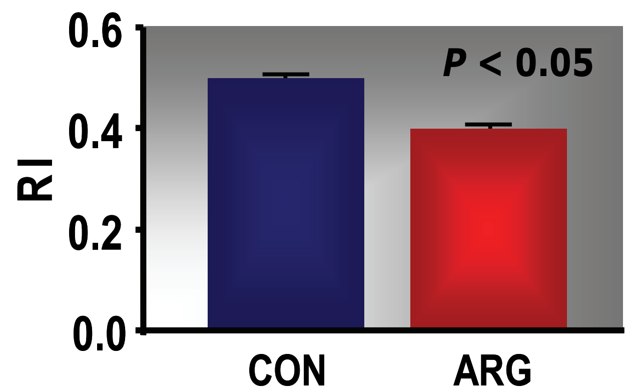

Figure 2. Resistance index (RI) in the ovarian artery 4 h after injection in ARG and CON ewes on d 12. Data are means ± S.E.

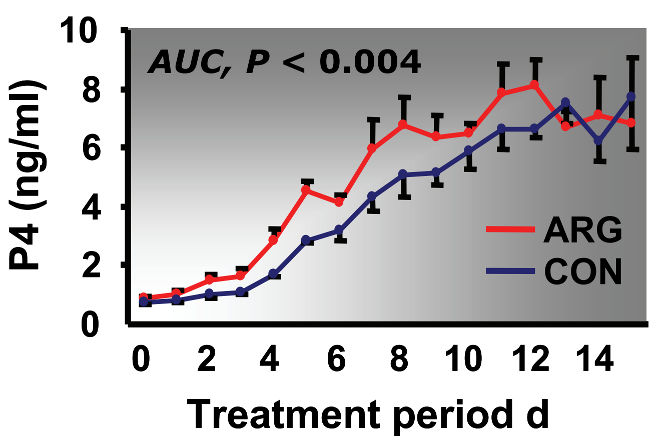

Figure 3. Serum progesterone (P4) concentrations throughout the treatment period in ARG and CON ewes. Data are means ± S.E.

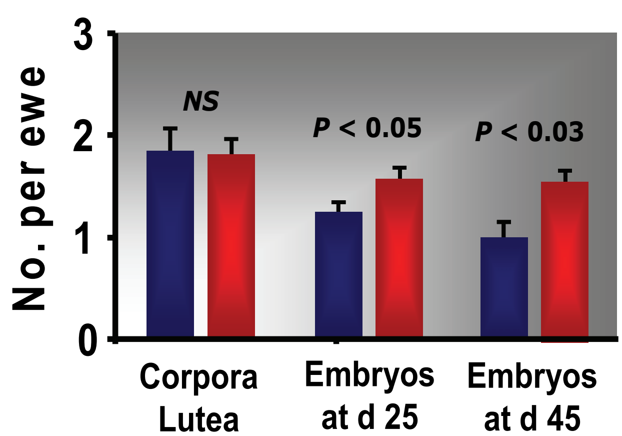

Figure 4. Number of corpora lutea and embryos (d25 and 45) present ARG and CON ewes. Data are means ± S.E.