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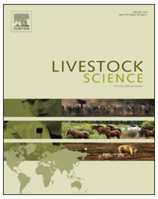

Effect of dietary amino acid supplementation during gestation on placental efficiency and litter birth weight in gestating gilts

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ABSTRACT

Arginine is an important amino acid for angiogenesis and vasodilation, and recent studies have established ideal amino acid ratios for maternal, placental, fetal, and mammary gland tissue growth during gestation. This study was carried out to evaluate the effects of supplementing gestation diets with arginine and/or amino acid blend (lysine, methionine, threonine, and tryptophan) on placental efficiency and piglet birth weight (BW) in hyper-prolific females. Pregnant gilts were divided into four treatment groups, namely, Control (corn-soybean meal based diet from D25 to D112), Arginine (supplemented with 1% Arg from D25 to D80); Blend (20 g of blend from D81 to D112) and Argiblend (supplemented with 1% Arg from D25 to D80 and 20 g of blend from D81 to D112 of gestation). The supplementation with Blend increased the weight of gilts at D112). The total number of piglets born, percentage of mummified fetuses, average BW, within-litter coefficient of variation in BW, percentage of low-birth-weight piglets (≤850 g or ≤1000 g), placental weight, placental efficiency and expression of vascular endothelial growth factor (VEGF) were not affected by the supplements. The supplementation with arginine decreased the number of born alive piglets and increased then percentage of stillborn piglets. The average placental weight was higher in Blend than in Control gilts. The effects of supplementation were also evaluated based on prolificacy of females categorized as either high (> 14 total piglets born) and low (≤14 total piglets born). Within LowProlif group, gilts fed on the blend treatment had increased LitBW and AvgPBW compared to control gilts. LowProlif gilts supplemented with arginine also had higher AvgPBW than Control gilts. The LowProlif gilts fed on the arginine or blend diets had lower percentage ($P < 0.05$) of low BW piglets (≤850 g and ≤1000 g) than those fed on the control and argiblend diet. Even though gestation diets supplemented with arginine and/or an amino acid blend did not influence average piglet BW and the within-litter variation in BW, when all the litters were taken into account, the supplementation with arginine or blend increased the average BW and reduced the percentage of low-weight piglets at birth when the litter size was less than 14.

1. Introduction

A negative correlation between litter size and piglet BW is well documented (Quiniou et al., 2002; Devillers et al., 2007; Wolf et al., 2008). Essentially, low BW in piglets is attributable to nutrient restriction during development which leads to intra-uterine growth retardation (IUGR) and weight changes in the liver, spleen, and the intestines (Town et al., 2004; Foxcroft, 2007).

Various methods to improve BW through sow feeding programs have been investigated to reduce the number of low-weight piglets born to hyper-prolific sows. Protein deposition is, respectively, 18.5-fold and 24.4-fold greater in the fetus (McPherson et al., 2004; Kim et al., 2009) and the mammary glands (Ji et al., 2006), after day (D) 70 of gestation compared to the period between D0 and D70. Thus, parity-segregated phase feeding (Wu et al., 2006; NRC, 2012) and phase feeding at different stages of gestation (Kim et al., 2009; NRC, 2012; Samuel et al., 2012) have been suggested as potential strategies to manipulate nutrient intake so as to achieve ideal maternal and fetal growth and mammary gland development (Wu et al., 2006).

Kim et al. (2009) have evaluated the dynamics of fetal, placental,

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and mammary growth in pregnant gilts by reviewing several studies and have proposed a change in the arginine (Arg), threonine (Thr), and leucine (Leu) to lysine (Lys) ratio required during late gestation in sows. Recently, the role of arginine and its end products in placental angiogenesis and umbilical vessel function have been studied as these processes increase fetal nutrient and oxygen supply, which would then enhance the capacity of the uterus for maintaining adequate growth of a greater number of fetuses (Wu and Morris, 1998; Wu et al., 2004; Liu et al., 2012). While supplementation with arginine has resulted in a greater number of live births in some studies (Ramaekers et al., 2006; Mateo et al., 2007; Gao et al., 2012; Che et al., 2013), only few studies have shown positive effects on average BW (Wu et al., 2012) or within-litter weight uniformity (Quesnel et al., 2014).

There are only a few reports on the effects of amino acid supplementation in gestating gilts (Mateo et al., 2007; Bass et al., 2011) and most of them (Gao et al., 2012; Liu et al., 2012; Wu et al., 2012; Che et al., 2013) have used low prolificacy sows (10.6–12.5 total piglets born). Thus, there is a need to understand the effects of AA supplementation in hyper-prolific gilts as they could have higher dietary requirements to fulfill the demand for their growth and the greater number of fetuses. Therefore, the aim of this study was to evaluate the effects of dietary supplementation with arginine or a blend of other AA during different phases of gestation on piglet BW characteristics and placenta in hyper-prolific gilts.

2. Materials and methods

2.1. Animals, diets, and experimental design

The study was carried out in a breeding herd with 2100 sows. In total, 204 gilts (Landrace × Large White) were inseminated at their third estrous and individually housed throughout gestation. All gilts were in the same facility and were introduced weekly in the experiment at randomly assigned, always respecting the treatments. Every week, during 10 consecutively weeks, 20 gilts were selected for the experiment.

Treatments were assigned based on body weight at D15 prior to breeding (IniW). The gilts were fed 1.7 kg of gestation diet from D25 to D80 of gestation and 3.3 kg of pre-farrowing diet from D80 to D112. Both diets were corn-soybean based (Table 1) and offered in meal form, once a day. The Lys levels used were determined after considering the current diet formulation guidelines of the Brazilian pig industry and results of previous studies (Yang et al., 2009; Magnabosco et al., 2013).

The following treatments were imposed: Control (51 gilts) – corn-soybean meal based diet from D25 to D112 of gestation, with no supplementation; Arginine (51 gilts) – supplemented with 1% of arginine from D25 to D80 of gestation; Blend (51 gilts) – 20 g of blend from D81 to D112 of gestation, and Argiblend (51 gilts) – supplemented with 1% of arginine from D25 to D80 and 20 g of blend from D81 to D112 of gestation. The supplementation with arginine was started only at D25 of gestation as arginine negatively affects embryo survival when used during early gestation (Li et al., 2010).

The blend comprised L-tryptophan (Trp), L-threonine (Thr), L-Lys (Animal nutrition division - Ajinomoto do Brasil Indústria e Comércio de Alimentos Ltda, Limeira, São Paulo, Brazil), and DL-methionine (Met; Adisseo Brasil Nutrição Animal Ltda, São Paulo, Brasil), and 20 g of blend contained 1.2 g Trp, 4.1 g Thr, 5.1 g Lys, 3.7 g Met, and 5.9 g of pre-gelatinized corn. As suggested by Kim et al. (2009), both control and blend diets provided 72% (SID) Met+Cysteine (Cys): Lys, 82% SID Thr: Lys, and 24% SID Trp: Lys from D80 to D112 of gestation. The calculated daily intake of SID Lys was 25 g and 30 g for the control and blend diets, respectively. Arg supplementation at 1% (Aminoscience Division - Ajinomoto do Brasil Indústria e Comércio de Alimentos Ltda, Limeira, São Paulo, Brazil) was based on a study by Mateo et al. (2007). The Arginine, Blend and Argiblend treatments were provided to each gilt by top dressing the corn-soybean meal diets.

Table 1
Calculated chemical composition of experimental diets of the control group.

	Gestation[a]	Pre-farrowing[b]
Metabolizable energy, kcal/kg	3224	3315
Crude protein, %	17.10	16.87
Ether extract, %	2.97	4.26
Crude fiber, %	2.83	2.77
Ash, %	5.55	5.30
Calcium, %	1.00	1.00
Available phosphorus, %	0.57	0.50
Sodium, %	0.22	0.18
Chloride, %	0.35	0.28
Potassium, %	0.64	0.56
Magnesium, %	0.16	0.16
Sulfur, %	0.19	0.18
Standardized ileal digestible (SID) amino acids, %		
Arginine	1.05	1.04
Valine	0.73	0.72
Lysine	0.76	0.76
Methionine + Cysteine	0.52	0.54
Threonine	0.57	0.62
Tryptophan	0.18	0.18
Leucine	1.47	1.44
Isoleucine	0.65	0.64

[a] Gestation diet vitamin composition – vitamin A: 13.8 UI/g; vitamin D3: 2.76 UI/g; vitamin E: 92 UI/kg; vitamin K3: 3.082 ppm; vitamin B1: 2.300 ppm; riboflavin (B2): 5.060 ppm; pyridoxine (B6): 2.760 ppm; vitamin B12: 30.82 ppb; niacin: 30.82 ppm; pantothenic acid: 13.800 ppm; folic acid: 1.932 ppm; biotin: 0.97 mg/kg; choline: 1.800 ppm. Gestation diet mineral composition – selenium: 0.480 ppm; iron: 135.945 ppm; copper: 75.0 ppm; manganese: 49.765 ppm; zinc: 158.073 ppm; iodine: 1.520 ppm; fluorine: 34.855 ppm; cobalt: 0.600 ppm.

[b] Pre-farrowing diet vitamin composition – vitamin A: 12 UI/g; vitamin D3: 2.40 UI/g; vitamin E: 80 UI/kg; vitamin K3: 2.680 ppm; vitamin B1: 2.00 ppm; riboflavin (B2): 4.4 ppm; pyridoxine (B6): 2.4 ppm; vitamin B12: 26.80 ppb; niacin: 26.80 ppm; pantothenic acid: 12.0 ppm; folic acid: 1.680 ppm; biotin: 0.970 mg/kg; choline: 1.800 ppm. Pre-farrowing diet mineral composition – selenium: 0.400 ppm; iron: 113.416 ppm; copper: 50.0 ppm; manganese: 42.371 ppm; zinc: 131.672 ppm; iodine: 1.260 ppm; fluorine: 28.125 ppm; cobalt: 0.500 ppm.

2.2. Measurements in sows and their litters

The gilts were weighed on D80 (D80W) and D112 (D112W) of gestation when they were moved to the farrowing house and this was used to calculate weight gain during the first (WG1= D80W-IniW) and second (WG2= D112W-D80W) phases of gestation. All gilts were monitored during spontaneous farrowing, and indices such as total number of piglets born and number of piglets born alive, mummified fetuses, and stillborn piglets, were also recorded. Each piglet (alive or stillborn) was individually weighed to calculate the following: birth weight of the litter (LitBW), average piglet birth weight (AvgPBW), and the coefficient of variation in birth weight within the litter (CVBW). The total weight of placentas (PlacWt) was also recorded after farrowing. The average placental weight was calculated as PlacWt/number of piglets born alive + stillborn piglets by dividing PlacWt by the number of piglets delivered born alive + stillborn. Placental efficiency was calculated as LitBW/PlacWt.

2.3. Vascular endothelial growth factor (VEGF) expression in the placenta

The expression of VEGF was evaluated in a subset of placentas from each treatment (31–36 placentas) where the umbilical cord had remained connected to the placenta at birth; such placentas were identified by attaching a numbered cotton-twine to the placental stump. The intact placenta was gently stretched on a flat surface and samples (9 cm^2) were collected from above and below the point of umbilical cord insertion such that they were equidistant to the greater curvature of the placenta. Two samples were collected from each placenta and fixed in 10% buffered formalin, and VEGF expression