Effects of dietary arginine supplementation on reproductive performance and immunity of sows

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ABSTRACT: Arginine (Arg) is considered to have beneficial effects on placental development and function, as well as reproductive performance. The well-developed placenta is highly required in late gestation for rapid fetal growth, however, it is unknown if there is a crucial role of Arg in late gestation. Likewise, the immunological response of sows to Arg needs to be determined. Therefore, this study is designed to investigate the effects of dietary Arg supplementation on reproductive performance and immunity of sows. At day 30 of gestation, sixty sows (Landrace × Large White) were allocated to 3 groups receiving corn and soybean-based control diet (control group, n = 20), control diet supplemented with 1% L-arginine HCl until day 90 of gestation (Arg90 group, n = 20), and control diet supplemented with 1% L-arginine HCl until day 114 of gestation (Arg114 group, n = 20), respectively. Litter performance was recorded at parturition. Blood samples (n = 6) collected at days 30, 90, and 110 of gestation were measured for metabolic and immunological parameters. At parturition, total litter size was not affected by dietary Arg supplementation. As a result of less pigs born dead, however, sows in Arg114 group had more pigs born alive than sows in control group (+1.6 pigs, $P < 0.05$), total and live litter weights were increased (+1.6~2.1 kg, $P < 0.05$) in Arg114 group relative to both control and Arg90 groups. Compared with control group, dietary Arg supplementation increased (+12~110%, $P < 0.05$) plasma levels of ornithine, proline, and arginine at either day 90 (Arg90 and Arg110 groups) or day 110 of gestation (Arg110 group). Moreover, immune response was enhanced in Arg-supplemented sows, as indicated by the increased levels of serum immunoglobulin and porcine reproductive and respiratory syndrome virus (PRRSV) antibody. These findings indicate dietary Arg supplementation can improve litter performance and immune response, and the beneficial effect of Arg on fetal growth is evident in late gestation.

Keywords: L-arginine; litter performance; placenta; humoral immune

In pig nutrition, L-arginine (Arg) is not only an essential amino acid for young pigs (Flynn et al., 2000), but also a substrate for the synthesis of nitric oxide (NO) and polyamines (i.e. putrescine, spermidine, and spermine), which are crucial for placental angiogenesis, trophoblast growth, and uteroplacental blood flow, thereby stimulating nutrients transfer and wastes exchange, consequently fetal growth and development (Wu et al., 2006). It has been reported that dietary Arg supplementation from early gestation until day 114 of gestation enhanced sow placental growth, litter size, and weight (Mateo et al., 2007; Gao et al., 2012). However, the sow placental growth has reached maximum in late gestation (McPherson et al., 2004; Freking et al., 2007), instead the efficient placenta in late gestation is physiologically required for rapid fetal growth in the last 20 days of gestation (Biensen et al., 1999; Macpherson et al., 2004). Therefore, it is likely the growth-enhancing effect of Arg on placenta may switch to improve placental efficiency such as stimulating blood flow and

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nutrients supply. The current study was designed to prove our hypothesis that litter performance in sows receiving Arg until day 114 of gestation would be better than in sows receiving Arg until day 90 of gestation.

In addition, dietary Arg supplementation has been widely reported to improve immune function in piglets, rats, and human beings (De Jonge et al., 2002; Li et al., 2007; Han et al., 2009; Tan et al., 2009). A recent study demonstrated that dietary Arg supplementation could reverse the reproductive failure in mice caused by Porcine circovirus type 2 (PCV2) infection (Ren et al., 2012). In sows, where the porcine reproduction and respiratory syndrome virus (PRRSV) induces reproductive failure including abortions, late-term dead fetuses, and weak pigs (Mengeling et al., 2000), PRRSV vaccine is generally injected before mating to prevent potential PRRSV-mediated reproductive failure. Considering the crucial role of Arg in developing immunity, we hypothesized dietary Arg supplementation is able to improve the immune response of sows.

MATERIAL AND METHODS

All procedures of the experiment were approved by the Animal Welfare Committee of the Sichuan Agricultural University, P.R. China.

Animals and experimental design

The animal experiment was conducted at Shangda pig farm, Guiling, Guangxi province of China. As in our previous study (Che et al., 2011), sows (Landrace × Yorkshire) were included into animal experiment when sow's backfat thickness was within two standard deviation units of the average backfat thickness. Therefore, at day 30 of gestation, sows between the 3rd and 4th parity with similar body condition (backfat 19.2 ± 1.5 mm) were randomly allocated to 3 groups receiving control diet (control group, n = 20), control diet supplemented with 1.0% arginine HCl until day 90 of gestation followed by control diet for the rest period of gestation (Arg90 group, n = 20), and control diet supplemented with 1.0% arginine HCl until day 114 of gestation (Arg114 group, n = 20), respectively. All diets were iso-nitrogenous with addition of 1.7% alanine in control diet (Table 1). The nutrient levels of ingredients were referred to the 18th edition of Feed Ingredients and Nutrient Values of China (2008). Diets were in meal form and met or exceeded the nutrient requirements of gestating sows as recommended by the National Research Council (1998) (Table 1).

Table 1. Composition and nutrient levels of diets (air dry basis)

Items	Control (%)	L-Arginine (%)
Ingredients		
Corn	63.30	63.30
Soybean meal	12.40	12.40
Wheat bran	18.00	18.00
L-Lysine HCl (98.5%)	0.19	0.19
DL-Methionine (98.5%)	0.05	0.05
L-Threonine (98.5%)	0.04	0.040
Limestone	1.45	1.45
$CaHPO_4$	1.30	1.30
Salt	0.38	0.38
$NaHCO_3$	0.15	0.15
Na_2SO_4	0.34	0.34
Premix[1]	0.70	0.70
Bentonite	–	0.70
L-Arginine HCl[2]	–	1.00
L-Alanine[2]	1.70	–
Total	100	100
Nutrient levels		
Crude protein (%)	13.50	13.50
Digestable energy (MJ/kg)	12.55	12.55
Calcium (%)	0.90	0.90
Available phosphorus (%)	0.40	0.40
L-Arginine (%)	0.73	1.54
D-Lysine (%)	0.62	0.62
D-Methionine + cysteine (%)	0.40	0.40
D-Tryptophan (%)	0.13	0.13
D-Threonine (%)	0.44	0.44
D-Valine (%)	0.50	0.50

[1]provided per kg of diet: vitamin A 1200 IU, vitamin D 3000 IU, vitamin E 90 mg, vitamin B_1 3 mg, vitamin B_2 10 mg, vitamin B_6 4 mg, vitamin B_{12} 40 μg, nicotinic acid 50 mg, pantothenic acid 30 mg, folic acid 4 mg, biotin 0.45 mg, choline chloride 750 mg, Cu 30 mg, Fe 100 mg, I 0.25 mg, Cr 0.3 mg, Zn 100 mg, Mn 40 mg, Se 0.25 mg

[2]L-arginine HCl and L-alanine products (≥ 98% contents) were supplied by Beijing Jiakang Techniology Inc.

Feeding and management

The pregnant sows were housed individually in stall (2.5 × 1.5 m) until day 7 before farrowing when sows were transferred to farrowing unit (2.1 × 1.8 m). All sows were injected intramuscularly with PRRSV vaccine (Intervet, Boxmeer, the Netherlands) 3 weeks before mating. Other vaccines targeted at swine atrophic rhinitis, pseudorabies virus, foot and mouth diseases were also inoculated as recommendations from the supplier (Intervet, Boxmeer, the Netherlands). In days 1–30, 31–60, 61–90 of gestation and from day 91 to 3 days before farrowing, sows were fed 2.0, 2.2, 2.6, and 3.2 kg diet per day, respectively. Three days before farrowing, feed allowance was reduced by 0.5 kg per day until farrowing day when no diet was provided. All diets were supplied twice (8:00 and 17:00) daily with free access to water. Room temperature of gestation unit was approximately 23°C.

Measurements

Pigs born were recorded as pigs born alive, pigs born dead, or mummified. All pigs were weighed individually and litter performance including total pigs born, pigs born alive, total and live litter weight were recorded or calculated. The uniformity of newborns was determined by intralitter coefficient of variation (CV), as calculated via dividing standard deviation by average birth weight within litter. Intrauterine growth restricted (IUGR) pig was defined when birth weight was less than 1.0 kg. Blood samples (n = 6) were collected from the ear vein of sows 2 h postprandial at days 30, 90, and 110 of gestation. 5 ml of blood were collected into heparinized tubes and centrifuged at 3000 g at 4°C for 10 min (Bio-Rad Laboratories, Hercules, USA), the plasma was stored at –20°C for analysis of amino acids, urea, and total protein. Another 5 ml blood sample was obtained, allowed to clot, centrifuged at 3000 g at 4°C for 10 min to provide serum which was analyzed for IgG and IgM antibodies to PRRSV.

Plasma amino acids, urea, and total protein

The plasma (400 µl) was mixed with sulfosalicyclic acid (1200 µl) and centrifuged at 8000 g to attain supernatant (Beckman Coulter, Fullerton, USA). The supernatant was analyzed for amino acids using the Hitachi L-8800 Amino Acid Analyzer (Hitachi, Tokyo, Japan). The enzymatic method for the quantitative determination of plasma urea was used. According to the protocol from the kit manufacturer (Maike, Shenzheng, China), briefly: the blank, standard and sample wells in duplicates were arranged and 1000 µl of reagent A (Tris PH 7.8, 2-ketoglutarate, ADP, urease, glutamate-dehydrogenase, and sodium azide) were mixed with 10 µl standard urea (50 mg/dl) or samples diluted with distilled water (1 : 20) at 37°C for 5 min, then this mixture was incubated with reagent B (NADH, sodium azide) at 37°C for 30 s to immediately read absorbance 1 (A1) and after 60 s A2 at a wavelength of 340 nm (Multiskan MK3; Thermo Labsystems, Beverly, USA). We determined the ΔA by equation as [(A1 – A2) sample or standard] – [(A1 – A2) blank] and calculated the concentration of urea (mg/dl) by equation as [(ΔA sample/ΔA standard) × 50]. In addition, biuret method was used to measure plasma total protein. According to the protocol from the kit manufacturer (Maike, Shenzheng, China), as above, the blank, standard (bovine serum albumin), and sample wells were added with 200 µl reagent R (potassium sodium tartrate, sodium hydroxide, potassium iodide, copper sulfate) and 4 µl standards (76 g/l) with a series of dilution and plasma samples, gently mixed and incubated at 37°C for 10 min, then the absorbance of mixture was read at a wavelength of 546 nm (Multiskan MK3). The total protein concentration in the samples was then calculated by comparing the optical density (OD) value of the samples to the standard curve.

PRRSV antibody

Serum concentrations of PRRSV antibody were determined by Sandwich ELISA kit (Nanjing Jiancheng Biochemistry Inc., Nanjing, China). Briefly, PRRSV antibody standards diluted at a series of concentrations, blank control, and serum samples (1 : 5 dilution) in duplicates (50 µl each) were added into purified PRRSV antigen pre-coated wells. All wells were incubated at 37°C for 30 min before washing (PBS + 0.05% Tween 20) on a rotary shaker. Then all wells were incubated with horseradish peroxidase (HRP)-conjugate reagent (50 µl) at 37°C for another 30 min and washed again. Afterwards, the Chromogen Solutions A (50 µl) and B (50 µl)

were added into each well with light preservation at 37°C for 15 min. This reaction was terminated by adding sulphuric acid solution and the colour change was measured spectrophotometrically at a wavelength of 450 nm for OD value (Multiskan MK3). The concentration (U/l) of PRRSV antibody in the samples was then determined by comparing the OD value of the samples to the standard curve.

IgG and IgM

The immune transmission turbidity assay was performed to detect serum IgG and IgM following the recommended protocol by the manufacturer (ELIKAN Bio-Tech Inc., Zhejiang, China). This assay included three sets of U-bottom plate wells for blank, standard, and samples in duplicates. The blank, standard (IgG or IgM standard), and sample wells each were added 3 µl of de-ionized water, standards and serum samples, respectively, then 300 µl of complete reagent containing 100 mmol/l Tris buffer, 40 g/l polyoxyethylene, 0.95 g/l preservative and goat-anti-swine IgG or IgM antibody. Afterwards, the plates were incubated at 37°C for 10 min. The OD values of standards and serum samples at 600 nm (IgG) or 340 nm (IgM) were measured (Multiskan MK3). Serum IgG or IgM (mg/ml) was calculated by comparing the OD value of the samples to the standard curve.

Statistical analyses

Data were analyzed using the General Linear Models (GLM) Procedure of SAS (Statistical Analysis System, Version 9.1, 2009). Multi-comparison was conducted by Duncan's multiple-range test. Values are presented as mean ± SE. $P < 0.05$ was considered statistically significant, and a tendency was recognized when $P < 0.1$. The Chi-Square test was used to detect differences in the frequency of IUGR piglets in litters among the three treatment groups of sows.

RESULTS

Performance

The totals of pigs born were not significantly different among dietary treatments. However, sows in Arg114 group had fewer dead piglets (average of –0.6 piglets, $P < 0.05$) than control sows and there was a trend ($P = 0.08$) for sows in Arg90 group to have more live piglets (+1.2) than for control sows (Table 2). The mean birth weight of total or live pigs born did not markedly differ among the 3 groups. However, total litter weight was higher in sows receiving Arg114 treatment relative to control (+2.0 kg, $P < 0.01$) and Arg90 (+1.7 kg, $P < 0.05$) groups (Table 2). Likewise, live litter weight was increased in sows receiving Arg114

Table 2. Effects of dietary arginine supplementation on reproductive performance of sows[1] ($n = 20$)

	Control	Arg90	Arg114
Total pigs born	11.24 ± 0.54	11.37 ± 0.57	12.33 ± 0.55
Total pigs born alive	10.19 ± 0.48^{a}	10.58 ± 0.50^{ab}	11.81 ± 0.47^{b}
Total pigs born dead	0.95 ± 0.16^{a}	0.74 ± 0.15^{a}	0.35 ± 0.14^{b}
Birth weight of total pigs born (kg)	1.46 ± 0.04	1.48 ± 0.05	1.51 ± 0.05
Birth weight of live pigs born (kg)	1.48 ± 0.05	1.39 ± 0.06	1.50 ± 0.05
Total litter weight (kg)	16.03 ± 0.54^{a}	16.42 ± 0.57^{a}	18.10 ± 0.56^{b}
Live litter weight (kg)	14.81 ± 0.69^{a}	15.30 ± 0.53^{a}	16.91 ± 0.70^{b}
CV of birth weight of total born (%)	22.20 ± 0.01	21.60 ± 0.01	20.00 ± 0.01
Intrauterine growth restricted pigs (%)	8.90	8.50	4.40

Control = group receiving corn and soybean-based control diet, Arg90 = group receiving control diet plus 1% L-arginine HCl until day 90 of gestation, Arg114 = group receiving control diet plus 1% L-arginine HCl until day 114 of gestation, CV = coefficient of variation

[1]values not sharing the same superscript letters mean significant difference ($P < 0.05$), $n = 20$

Table 3. Effect of dietary arginine supplementation on plasma amino acid levels (μmol/l) of sows during gestation[1]

	Control	Arg90	Arg114
Alanine			
Day 30	956 ± 74	939 ± 44	936 ± 36
Day 90	1287 ± 269[a]	666 ± 48[b]	685 ± 91[b]
Day 110	1494 ± 162[a]	1460 ± 160[a]	761 ± 132[b]
Ornithine			
Day 30	138 ± 24	144 ± 15	139 ± 8
Day 90	125 ± 19[a]	183 ± 11[b]	182 ± 20[b]
Day 110	148 ± 13[a]	140 ± 39[a]	238 ± 12[b]
Arginine			
Day 30	238 ± 39	245 ± 11	242 ± 30
Day 90	220 ± 23[a]	455 ± 36[b]	459 ± 36[b]
Day 110	245 ± 17[a]	286 ± 34[a]	466 ± 30[b]
Proline			
Day 30	296 ± 15	308 ± 17	294 ± 28
Day 90	364 ± 29[a]	408 ± 27[b]	412 ± 19[b]
Day 110	344 ± 31[a]	350 ± 21[a]	410 ± 30[b]

Control = group receiving corn and soybean-based control diet, Arg90 = group receiving control diet plus 1% L-arginine HCl until day 90 of gestation, Arg114 = group receiving control diet plus 1% L-arginine HCl until day 114 of gestation
[1]values not sharing the same superscript letters mean significant difference ($P < 0.05$), $n = 6$

compared with control (+2.1 kg, $P < 0.001$) and Arg90 (+1.6 kg, $P < 0.01$) groups (Table 2). Furthermore, the percentage of IUGR pigs in Arg114 group was approximately by 4% lower than in control and Arg90 groups ($P = 0.08$~0.12).

Plasma amino acids, urea, and total protein

At day 30 of gestation, concentrations of amino acids in plasma were not different between treatment groups. However, at day 90 of gestation, plasma levels of ornithine, proline, and arginine were by 3~45% ($P < 0.01$), 24~46% ($P < 0.01$), and 12% ($P < 0.05$) higher in Arg-supplemented sows compared with sows in control group (Table 3). However, plasma levels of alanine were significantly lower (about 48% decrease, $P < 0.01$) in sows receiving Arg114 and Arg90 relative to control group. At day 110 of gestation, the higher plasma levels of ornithine, proline, and arginine but a lower level of alanine (all $P < 0.05$) were still observed in sows receiving Arg114 compared with other groups (Table 3). The plasma levels of other amino acids were similar through the gestation among the 3 dietary treatments (data not shown). At days 90 and 110 of gestation, Arg-supplemented sows had significantly lower plasma urea level (14~18% decrease, $P < 0.05$) than sows in control group (Table 4). During the gestation, however, no significant differences were observed for total protein concentration among groups.

Table 4. Effects of dietary arginine supplementation on plasma urea (mmol/l) and total protein concentrations (g/l) of sows[1]

	Control	Arg90	Arg114
Urea			
Day 30 of gestation	3.83 ± 0.11	3.88 ± 0.16	3.83 ± 0.10
Day 90 of gestation	4.90 ± 0.07[a]	4.00 ± 0.08[b]	4.15 ± 0.10[b]
Day 110 of gestation	4.98 ± 0.07[a]	4.65 ± 0.07[ab]	4.28 ± 0.10[b]
Total protein			
Day 30 of gestation	65.60 ± 1.03	65.94 ± 1.03	64.86 ± 1.03
Day 90 of gestation	73.98 ± 1.00	74.64 ± 1.08	76.06 ± 1.08
Day 110 of gestation	66.04 ± 1.15	62.18 ± 1.18	64.58 ± 1.16

Control = group receiving corn and soybean-based control diet, Arg90 = group receiving control diet plus 1% L-arginine HCl until day 90 of gestation, Arg114 = group receiving control diet plus 1% L-arginine HCl until day 114 of gestation
[1]values not sharing the same superscript letters mean significant difference ($P < 0.05$), $n = 6$

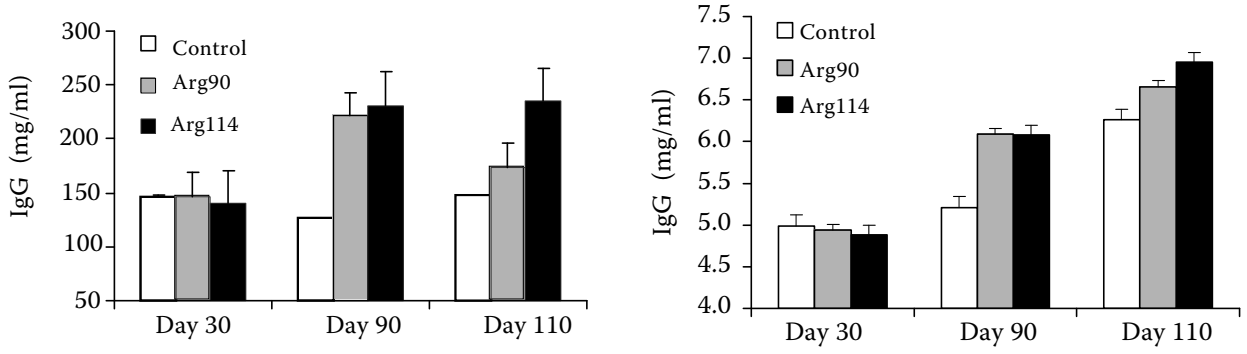

Figure 1. Effects of dietary arginine supplementation on the levels of serum IgM and IgG of sows during gestation
Bars not sharing the same superscript letters mean significant difference ($P < 0.05$), $n = 6$

IgM, IgG, and PRRSV antibody

At day 30 of gestation, serum levels of IgM and IgG were similar among groups. However, sows receiving Arg until day 90 of gestation had increased serum IgM and IgG levels (+56~83%, $P < 0.05$) compared with sows with no Arg supplementation. At day 110 of gestation, the sows receiving Arg114 treatment still had increased serum IgM and IgG levels (+50~60%, $P < 0.05$) compared with control group (Figure 1). For PRRSV antibody, only sows receiving Arg114 treatment had significantly higher (75% increase, $P < 0.05$) serum antibody level than sows in control group at day 110 of gestation (Figure 2).

DISCUSSION

The responses of embryo survival or litter performance to Arg were variable when Arg was supplemented in early gestation (Wu et al., 2006; Zeng et al., 2008; Novak et al., 2009; Li et al., 2010), the underlying mechanisms may relate to the alterations in the development of *corpora lutea*, production of progesterone, NO signalling and cellular redox state in early gestation (Wu et al., 2010). By excluding the early gestation period, dietary Arg supplementation starting from day 22 or 30 of gestation and continuing until farrowing markedly improved placental growth and litter performance (Mateo et al., 2007; Gao et al., 2012). In this study, Arg supplemented to sows from day 30 to day 90 (Arg90 group) or 114 of gestation (Arg114 group) did not markedly increase total pigs born, however, the less dead pigs in sows receiving Arg between days 30–114 of gestation resulted in more live-born pigs, compared with sows with no Arg supplementation. This finding is consistent with the results of Mateo et al. (2007) and Gao et al. (2012), who reported that dietary Arg supplementation from day 30 to 114 of gestation increased live-born pigs up to 2 per litter. The reduction in dead pigs in Arg-supplemented sows may be ascribed to the improved uterine capacity (Wu et al., 2006; Mateo et al., 2007). Arg is required for placental synthesis of both NO and polyamines, which do not only stimulate placental angiogenesis and vascular growth, but also utero-placental blood flow and maternal nutrients transfer (Wu et al., 2005), thereby developing an efficient uterine capacity for fetal growth and development (Reynolds et al., 2001; Kwon et al., 2004; Wu et al., 2006). Both NO and polyamines have been considered as one of the major factors contributing to intrauterine growth restriction (Wu et al., 2004, 2006). The amino acids measurements showed that dietary Arg supplementation increased the plasma levels of arginine, ornithine,

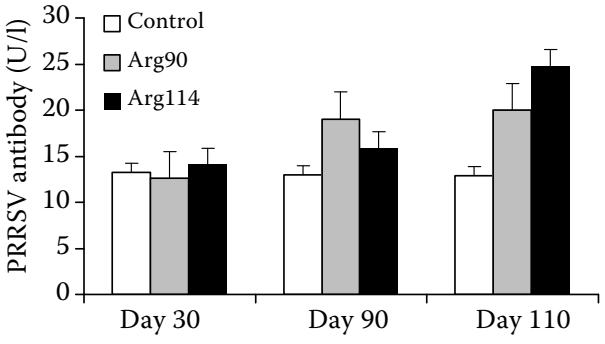

Figure 2. Effects of dietary arginine supplementation on the level of serum PRRSV antibody of sows during gestation

Bars not sharing the same superscript letters mean significant difference ($P < 0.05$), $n = 6$

and proline, which are necessary substrates for synthesis of NO and polyamines (Wu et al., 2006).

The novel finding in this study is that dietary Arg supplementation throughout gestation (Arg114 group) tended to increase the number of pigs born alive ($P = 0.06$) and live litter weight ($P < 0.05$) compared with sows receiving Arg until day 90 of gestation (Arg90 group), indicating the fetal growth-enhancing effect of Arg is profound in late gestation. The sufficient Arg supply in late gestation may be beneficial for optimal fetal growth, because the uterine uptake of Arg only marginally met the requirement for fetal growth in late gestation (Wu et al., 1999). A recent study in prolific ewes also demonstrated the parenteral administration of Arg in late gestation significantly enhanced fetal growth and survival (Lassala et al., 2011). In fact, supplying sufficient Arg to sows during late gestation may be physiologically required, considering the critical role of Arg in increasing placental angiogenesis. Because of the extreme nature of vascular growth and proliferation in placenta, the increasing placental angiogenesis in late gestation allows sufficient placental (or umbilical) blood flow and nutrients for the rapid growing fetus (Wilson et al., 2002; Vallet et al., 2009). Available evidence indicates that dietary Arg supplementation increases expression of placental angiogenin and circulating concentrations of vascular endothelial growth factor (VEGF) (Fiorito et al., 2008; Novak et al., 2009), both are potent growth factors for placental angiogenesis. Furthermore, the recent study demonstrated that dietary Arg supplementation in late gestation could regulate microRNAs (miR-15b, miR-222) targeting vascular endothelial growth factor A (VEGFA) and endothelial nitric oxide synthase (eNOS) expression in umbilical vein (Liu et al., 2012), thus stimulating vasodilation, blood flow, and subsequent improvement in nutrients and oxygen transfer from the mother to fetus.

In this study, the reduced plasma urea in Arg114 group suggests there was less degradation of whole-body amino acids, which means the pig fetus may efficiently utilize dietary amino acids. This metabolic advantage is of vital importance for sows in late gestation, considering 50% of fetal weight is gained during the last 20 days of gestation (McPherson et al., 2004). Moreover, the metabolic wastes such as ammonia and β-hydroxybutyrate were also reduced when Arg was supplemented in late gestation (Lassala et al., 2011), and amino acids metabolism was normalized when weaning pigs received Arg supplementation (He et al., 2011). In this study, alanine was added in control diet to equalize nitrogen content across groups. Accordingly, plasma level of alanine was by approximately 90% higher than that in Arg90 or Arg114 groups, however, the increasing alanine did not cause any negative effects on reproductive performance, as in previous report (Mateo et al., 2007).

The inflammatory stimuli activate iNOS or arginase that uses Arg as the sole amino acid substrate, thus alleviating Arg-dependent immune function (Peranzoni et al., 2007; Popovic et al., 2007). In a variety of animal models, dietary Arg supplementation improves immune response. Dietary supplementation with 0.4~0.8% Arg for 2 weeks enhanced cellular and humoral immunity of early-weaned pigs by modulating serum immunoglobulin level and cytokines profile (Tan et al., 2009). A recent study from our group indicated dietary Arg supplementation could attenuate the increase of serum C-reactive protein and excessive activation of Toll-like receptor 4-Myd88 signalling pathway in different tissues of weaned pigs challenged by *Salmonella enterica* serovar Choleraesuis C500 (S.C. 500), thereby preventing the negative effects induced by the immune challenge of S.C. 500 (Chen et al., 2012). Moreover, pregnant sows receiving supplemental dietary Arg had stronger immunity based on results indicating that they survived pathogenic insult, whereas all control sows died (Kim et al., 2007). In this study, there was increasing serum level of PRRSV antibody in sows receiving Arg until day 114 of gestation, suggesting the beneficial effect of Arg on specific immune response. It has been reported dietary Arg supplementation is able to enhance specific antibody production and innate immune response after vaccination against *Streptococcus pneumonia* in older people (Moriguti et al., 2005). The positive immune responses suggest a critical role for Arg in maturation of B cells and lymphoid organ development. The B cells, in particular, play a principal role in production of antibodies (Ochoa et al., 2001; De Jonge et al., 2002). The humoral immune response in Arg-supplemented weaning piglets increased (Tan et al., 2009), as was the case for Arg-supplemented sows in the present study based on increases in serum IgG and IgM. The better immunity in sows receiving Arg114 treatment may prevent the potential transplacental infection of conceptus by PRRSV (Mengeling et al., 2000)

and alleviate the lethal insult to fetus, which may partially explain why there are less dead pigs in Arg-supplemented sows.

CONCLUSION

Dietary Arg supplementation at days 30–114 of gestation (Arg114 group) increased the number of live-born pigs, total and live litter weights compared with sows in control group. Relative to Arg90 group, sows in Arg114 group had significantly higher total and live litter weights. There were metabolic and immunological advantages by sows in Arg114 group, as indicated by the reduced urea, elevated immunoglobulin, and PRRSV-specific antibody levels.

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