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Maternal age modulates the effects of early-pregnancy L-proline supplementation on the birth-weight of piglets

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ABSTRACT

Previous results obtained in gilts maintained under experimental conditions suggest that amino acid supplementation during pregnancy may be a promising strategy for diminishing the incidence of embryo losses and low birth-weight newborn. The current study evaluated the effects of a short-term supplementation with L-proline, around implantational stages, on litter size and birth-weight of piglets in sows of different parities maintained under commercial farm conditions. There were no significant effects in mature sows with three or more parities, but the supplementation improved the reproductive efficiency of the high-prolific first-parity sows and of all the sows at second-parity. There were numerically higher litter size (of around two more live piglets; n.s.) and higher birth-weights ($P < 0.05$) in the supplemented animals. The results of this study indicate that the effects of L-proline supplementation on litter size and birth-weight are strongly modulated by the maternal characteristics; specifically by parity and prolificacy and that supplementation may be cost-efficient for the management of females with compromised energy balance; specifically, sows at second farrowing and highly-prolific primiparous gilts.

1. Introduction

The efficiency of swine production is determined by the number of piglets obtained per sow and year and by the growth patterns and the carcass and meat quality of these piglets. The number of offspring per sow is determined, in turn, by the age at first farrowing, the interval between farrowings and the number of piglets in each farrowing (prolificacy). Prolificacy in swine, as in other multiparous species, depends on the number of ovulations and/or the embryo losses during pregnancy. The selection of highly-prolific dam lines has been mainly focused on the selection of genotypes with high ovulatory quota. However, when ovulatory rate is high, the increases in the number of ovulations fail to correspond with proportional increases in the number of newborn (Freking et al., 2007; Rosendo et al., 2007). In this case, the determining factor for prolificacy is the rate of embryo losses, mainly at implantational and early post-implantational stages (Foxcroft et al., 2006; Freking et al., 2007).

Embryo losses are partly due to intrinsic deficiencies of the embryo, affecting its viability, and partly due to competition among embryos of highly-prolific dams for the uterine space necessary for implantation and adequate placental development (Town et al., 2004; Van der Waaij et al., 2010); inadequacy of placental growth causes inadequate supply of nutrients and oxygen to the conceptus and the death of some embryos resulting in lower piglet numbers and reduced reproductive efficiency.

Foetuses with deficient placental development may survive, but their life-conditions and growth are compromised by a process

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known as Intrauterine Growth Retardation (IUGR; Ashworth et al., 2001; Foxcroft et al., 2006; Wu et al., 2006). The newborn affected by IUGR are prone to increased morbidity and mortality rates by gastrointestinal, metabolic, respiratory and/or immune dysfunctions. The growth, health and welfare of the surviving piglets affected by IUGR will remain hampered by these conditions, which usually exacerbate with age (Quiniou et al., 2002; Bee 2004; Gondret et al., 2006; Wu et al., 2006). From a productive point of view, IUGR decreases postnatal performance (reduced daily gain and increased conversion ratio, and decreased carcass and meat quality compared with larger littermates; Gondret et al., 2006; Young et al., 2009; Nissen and Oksbjerg 2011).

The negative effects of intrauterine growth retardation on swine production can be large, due not only to high foetal losses (up to 50%), but also because of the IUGR incidence in swine (Royston et al., 1982; Wootton et al., 1983; Wu et al., 2010). Thus, there is intense research in strategies for alleviating their incidence; most of them focused on amelioration of placental efficiency.

Placental efficiency is determined by adequate development favouring blood flow and exchange of nutrients and oxygen to the conceptus (adequate interdigitation of placenta and endometrium to increase exchange surface, vascular dilation and angiogenesis; Wu et al., 2006). These processes are driven by nitric oxide (NO), which is a potent stimulator of vasodilatation and angiogenesis. Hence, there are several studies on the use of functional amino acids (AA) precursors of NO; mainly arginine.

Non-essential AA (arginine, proline and glutamine), together with some essential AA like leucine and tryptophan, constitute the group of functional AA; defined as those AA that regulate key metabolic pathways to improve health, survival, growth, development, lactation, and reproduction of organisms (Wu 2009). Deficiency of functional AA (either essential or non-essential) impairs not only protein synthesis but also whole-body homeostasis (Wu 2010). In pregnant animals, functional AA play a prominent role in the development of the placenta, conceptus and associated gestational structures (Wu et al., 2008, 2010), including the differentiation of embryonic stem cells (Pistollato et al., 2010). Functional AA regulate synthesis of proteins during pregnancy and also of polyamines and NO (Li et al., 2009; Wu et al., 2005, 2013). The synthesis rate of polyamines and NO in the porcine placenta is greatest during the early gestation (Gao et al., 2009), since they are crucial not only for embryogenesis but also for an adequate placental growth, angiogenesis and blood-flow and therefore for the transfer of nutrients and oxygen from the mother to the conceptus (Wu et al., 2006). A compromised placental development and/or its inability to supply adequate amount of nutrients and oxygen to the foetuses are, as previously mentioned, important factors in the occurrence of embryo death and IUGR.

Results obtained in gilts maintained in experimental conditions suggest that AA supplementation may be a promising strategy for diminishing incidence of embryo losses and IUGR (Mateo et al., 2007; Wu et al., 2006, 2010; Gao et al., 2012; Li et al., 2014), although translation from basic research to practice may be hampered by technical and economic factors. We hypothesized that management conditions (experimental vs commercial farms) and parity of the sow may affect the response to the AA supplementation. Thus, the objective of current study was to evaluate the effects of a short-term supplementation with L-proline, around implantational stages, on litter size and birth-weight of piglets in sows of different parities maintained under commercial farm conditions.

2. Material and methods

2.1. Animals and experimental procedures

The current study was carried out under a Project License from the INIA Scientific Ethic Committee. Animal manipulations were performed according to the Spanish Policy for Animal Protection RD1201/05, which meets the European Union Directive 86/609 about the protection of animals used in experimentation. A total of 115 Landrace × Yorkshire crossbreed inseminated sows were used. All the animals were housed indoors, in passively ventilated facilities with a controlled temperature of around 22 °C and maintained during the trial in individual pens over concrete slatted floors, at the facilities of the Dehesa-3 farm (Castillejar, Granada, Spain). Throughout the experiment, sows had *ad libitum* access to water and were fed with a standard grain-based diet with mean values of 88% of dry matter, 13,5% of crude protein, 2,3% of fat and 9.1 MJ/kg of net energy (sows), calculated for fulfilling their daily maintenance requirements for pregnancy (Table 1). At Day 11 after artificial insemination, the sows were pair-matched according to age, number of previous deliveries and body-weight. Half of them ($n = 57$; group PROL) received a supplementation of 14 g of L-proline [MiaProgest, Miavit GmbH, Essen (Oldb), Germany] per sow per day by individually top-dressing over their morning feed. The remaining sows acted as a control ($n = 58$, group CON).

Parity distribution had 15 PROL and 15 CON gilts at first parity, 13 PROL and 12 CON sows at second parity, and 29 PROL and 31 CON sows had three or more parities.

Proline supplementation was given from Day 11–30 of pregnancy, concomitantly to the period of embryo implantation and early placental development (Ashworth et al., 2006; Whittemore and Kyriazakis, 2006). At farrowing, number and body-weight of all the piglets (live and stillborn) were determined for each sow.

2.2. Statistical analyses

Effects of maternal proline supplementation on litter-size, birth-weight and birth-weight distribution of the piglets were assessed by analysis of variance (ANOVA) variables; a Duncan post-hoc test was performed to contrast the differences between groups. Statistical analysis of results expressed as percentages was performed after arc-sine transformation of the values for each individual percentage. The analysis included parity (first, second, and three or more) and prolificacy (over and under the mean). All the results were expressed as means ± SEM and statistical significance was accepted for $P < 0.05$.