Effect of Hydroponic Green Forage Supplementation during Prepartum and Lactation on Sow and Litter Performances

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Abstract. *The incorporation of fibre in the diet of pregnant sows improves the performance during pregnancy and increases voluntary consumption during lactation. Hydroponic green forage (HGF) constitutes a method of cultivation without soil in controlled environmental conditions. The aim of this study was to evaluate the impact of the supplementation with HGF in lactating sows on productive performance and to investigate the metabolic state through the analysis of different biochemical parameters. Twelve sows of the Porcine Productive Unit of the Faculty of Veterinary Sciences were randomly assigned to 2 feeding groups: control (conventional diet) or HGF (hydroponic green forage diet, conventional diet supplemented with HGF) from 7 days prepartum until day 28 postpartum. Productive parameters in sows (weaning-to-oestrus interval and back fat thickness) and in the litter (number of piglets born and weaned, and piglet weight) were evaluated. The effect of the diet in the metabolism of the sows was evaluated by biochemical parameters (total plasma proteins, albumin, glucose, urea and creatinine). Supplementation with HGF did not significantly affect the litter size nor productive parameters but produced a higher weight of piglets at day 60. Although lactation affected some biochemical parameters, no substantial negative consequences of the HGF supplemented diet were observed. Our results suggest that the use of HGF could be an option to take into account in porcine production with economic and environmental benefits.*

Introduction

The transition from pregnancy to lactation is characterized by physiological changes in sows. It is accompanied by important changes in feeding. Nutritional restriction is a very common feed management performed in pregnant sows in order to avoid extra weight gain and problems with locomotion and farrowing. In contrast, ad libitum ingesting is encouraged during lactation to cover the nutritional requirements (Dourmad et al., 1996). Nevertheless, in prolific sows, the voluntary feed intake is generally insufficient to meet the demands (Boulot et al., 2008). The incorporation of fibre in the diet of pregnant sows, without altering the supplementation of daily energy, has shown a decrease in the stereotypic behaviour associated with the level of restricted feeding during pregnancy (Meunier-Salaün et al., 2001) and an increase in voluntary feeding during lactation (Courboulay & Gaudre, 2002). Worldwide, porcine diets are supplemented with a wide range of high fibre ingredients. These diets do not always maximize production parameters but they allow the use of locally grown food and thus contribute to a sustainable production (Jarrett & Anshworth, 2018). Although its use in non-ruminant animals has some limits, fibre can produce a large amount of benefits that requires further investigation, especially in peripartum sows (Oliviero et al., 2009).

Hydroponic green forage (HGF) constitutes a method of cultivation without soil in controlled environmental conditions, which allow obtaining a feed supplement in a few days with a higher crude protein content than conventional forage. The forage produced by this method is highly nutritious and with good palatability. Furthermore, it offers a sustainable production throughout the year, conserves water, requires minimal work for its production and is friendly to the environment because it does not use pesticides and does not present wasted nutrients (Pandey & Pathak, 1991). Animals fed with HGF have increased milk production with a higher content of fat and total solids (García-Carrillo et al., 2013). In this regard, HGF can be an easy and quick alternative to apply for the porcine producer. It is also a non-expensive option that would promote their animal feed production.

Many factors can affect the productive performance of pigs. Among them, nutrition plays an important role affecting both the metabolic state and productive parameters. However, little information is available about nutritional supplementation with HGF in pigs. The aim of this study was to evaluate the productive performance of sows and their litters after supplementing the sows with HGF during prepartum and lactation. In addition, the metabolic status was investigated by analyzing different biochemical sow parameters.

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Materials and methods

This study was conducted in accordance with the guidelines of the Institutional Committee for Care and Use of Experimental Animals, Faculty of Veterinary Sciences, Buenos Aires University.

Animals and diet

The study was conducted with the animals of the Porcine Productive Unit of the Faculty of Veterinary Sciences (University of Buenos Aires). Twelve parity sows (Landrace x Yorkshire) of the first or the second gestation were used, and all of them mated with Landrace x Yorkshire boars. These sows were randomly assigned to 2 feeding groups: control (conventional diet) and HGF (hydroponic green forage diet, conventional diet supplemented with HGF) from 7 days prepartum until day 28 postpartum. The composition of the 2 diets is shown in Table 1. Sows started feeding the maintenance recommendation (6.8 Mcal metabolizable energy (ME) / day) since the day of birth, and the amount of food was increased until day 8 (1.7 ME / piglet / day). Then, the feed intake was maintained until weaning. The animals were fed twice a day, once in the morning and once in the afternoon. Water was available ad libitum and no considerable feed refusal was observed during the whole study.

Productive parameters evaluation

Oestrus detection was evaluated after weaning. A weaning-to-oestrus interval was recorded after oestrus confirmation by a female standing reflex in the presence of a boar. Back fat thickness (BF) was measured at partum (day 0) and weaning (day 28). The measurements of BF were performed at the P2 point (between the last and penultimate rib, at a distance of 5 cm from the vertebral column) with a Sonoscape A5 with a linear transducer of 5 to 12 Mhz.

Litter size, number of piglets born, number of piglets weaned and total kg of piglets weaned per litter were determined. Piglet weight was evaluated over 60 days (day 0, 28 and 60).

Metabolic parameters evaluation

Blood samples were taken to evaluate metabolic parameters during the whole study. The samples were obtained from the jugular vein from day 7 prepartum until day 28 postpartum. Samples were centrifuged at 400 g for 10 min and the serum obtained was immediately frozen at –20°C until analysis. Plasma concentrations of total plasma proteins, albumin, glucose, urea and creatinine were measured in a Shimadzu UV-VIS spectrophotometer, model UV-1900i. Total plasma protein and albumin levels were determined by the biuret colorimetric method. Glucose concentration was measured using a spectrophotometric assay based on the oxidation of the sugar by glucose oxidase and the subsequent determination of the hydrogen peroxide formed. Urea was measured with the assay of urease that decomposes urea, producing carbon dioxide and ammonia. The latter reacts with phenol and hypochlorite in the alkaline medium, producing indophenol blue, which is colourimetrically measured. Creatinine reacts with the alkaline picrate (Jaffe reaction) yielding a red chromogen that can be quantified by a photometric reading. All determinations were carried out with Wiener lab kits according to the manufacturer's instructions (Wiener lab, Rosario, Argentina).

Statistical analyses

Results are given as mean and standard error of the mean (SEM). The quantitative data collected were analyzed for normality assumption by the Shapiro-Wilk test and variances homogeneity using the Levene test. Productive parameter values were analysed by the Student t test except for BF, which was evaluated by the paired Student t test. Piglet weight and metabolic parameters were analysed by two-way ANOVA (treatment, days and their interactions) according to a repeated measure model. The Bonferroni test or post hoc general contrast was used for comparison among means. A value of $P < 0.05$ was considered as statistically significant. All statistical tests were performed with InfoStat (Córdoba University, Córdoba, Argentina, see http://www.infostat.com.ar/).

Results

Supplementation with hydroponic green forage did not significantly affect litter size nor sow productive parameters. However, this supplementation produced a higher weight in piglets at 60 days of life.

No significant effect of HGF supplementation

Table 1. Ingredients and dietary composition

	Control				HGF		
Ingredients	%	g	Mcal ME		%	g	Mcal ME
Ground corn	68	680	2.40		54.1	605	2.13
Soybean pellet	28.9	289	1.07		23	257	0.94
Vitamin and mineral premix	3.1	31	–		2.8	31	
HGF	–	–	–		20.1	225	0.35
Total	100	1000	3.47		100	1118	3.42

HGF: hydroponic green forage; ME: Metabolizable energy. Control diet: maintenance recommendation 2000 g per day; lactation recommendation 500 g per piglet per day. HGF diet: maintenance recommendation 2240 g per day; lactation recommendation 560 g per piglet per day.

was observed in the weaning-to-oestrus interval. Regarding back fat thickness, a similar significant decrease was observed during lactation days (23% in control and 17% in HGF treatment) without differences between treatments (Table 2).

Litter productive sizes were not significantly affected by HGF supplementation. Piglet weight increased during lactation time. At day 60, a significant difference was observed in the HGF group (Table 3).

Some metabolic parameters in sows were affected in the lactation period. Total plasma proteins increased up to day 7 postpartum and then returned to prepartum levels, but only for the control treatment; in HGF supplementation, no differences were observed during lactation days (Fig. 1). Albumin was not affected by supplementation, as its value decreased

Table 2. Effect of hydroponic green forage supplementation on sows' productive parameters

	Treatment	
Productive parameter	Control	HGF
Weaning-to-oestrus interval	5.25 ± 0.22^{a}	4.93 ± 0.16^{a}
BF (mm) at day 0	22.89 ± 0,83^{a}	23.40 ± 0.73^{a}
BF (mm) at day 28	18.58 ± 1.05$^{a\#}$	19.94 ± 0.88$^{a\#}$

Values (mean ± SEM) of control and HGF (hydroponic green forage) treatments. BF: back fat thickness. Columns with different letters indicate significant ($P < 0.05$) differences between treatments. $^{\#}$ indicates significant differences between day 0 and 28.

Table 3. Effect of hydroponic green forage supplementation on litter productive parameters

	Treatment	
Productive parameter	Control	HGF
Number of piglets born	13.15 ± 0.61^{a}	13.43 ± 0.79^{a}
Number of piglets weaned	10.54 ± 0.57^{a}	10.57 ± 0.69^{a}
Total kg of piglets weaned per litter	81.60 ± 4.72^{a}	85.46 ± 3.02^{a}
Piglet weight (kg) at day 0	1.24 ± 0.04$^{a\#}$	1.48 ± 0.04$^{a\#}$
Piglet weight (kg) at day 28	7.57 ± 0.27$^{a\#\#}$	7.94 ± 0.14$^{a\#\#}$
Piglet weight (kg) at day 60	13.61 ± 0.51$^{a\#\#\#}$	16.13 ± 0.53$^{b\#\#\#}$

Values (mean ± SEM) of control and HGF (hydroponic green forage) treatments. Columns with different letters indicate significant (< 0.05) differences between treatments. $^{\#, \#\#, \#\#\#}$ indicate significant differences between days.

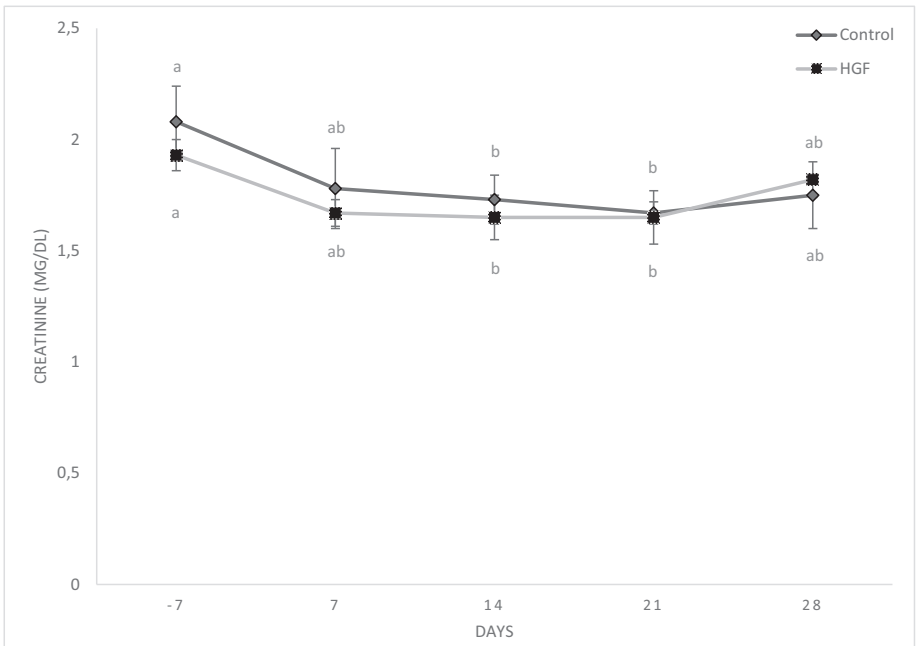

Fig. 1. Mean ± SEM of total plasma protein blood concentration in control and HGF supplemented diet. Values with different letters indicate significant ($P < 0.05$) differences between days.

at day 7 and then returned to prepartum levels in both treatments (Fig. 2). Glucose was not affected by supplementation treatment nor lactation (Fig. 3). Only in the control treatment, the urea increased up to day 21 and then returned to prepartum levels. In the case of HGF supplementation, a slight increase was observed with no significant differences with prepartum levels (Fig. 4). Creatinine was not affected by supplementation, decreased up to day 21, and then returned to prepartum levels (Fig. 5).

Discussion

The incorporation of HGF in diets of lactating sows did not affect productive parameters. Our results demonstrated no substantial negative consequences of the HGF supplemented diet on metabolic and productive parameters. In addition, a positive effect was observed on the weight of piglets, which was higher in HGF litters at 60 days.

Milk production in the sow has the highest priority during lactation and is positively affected by

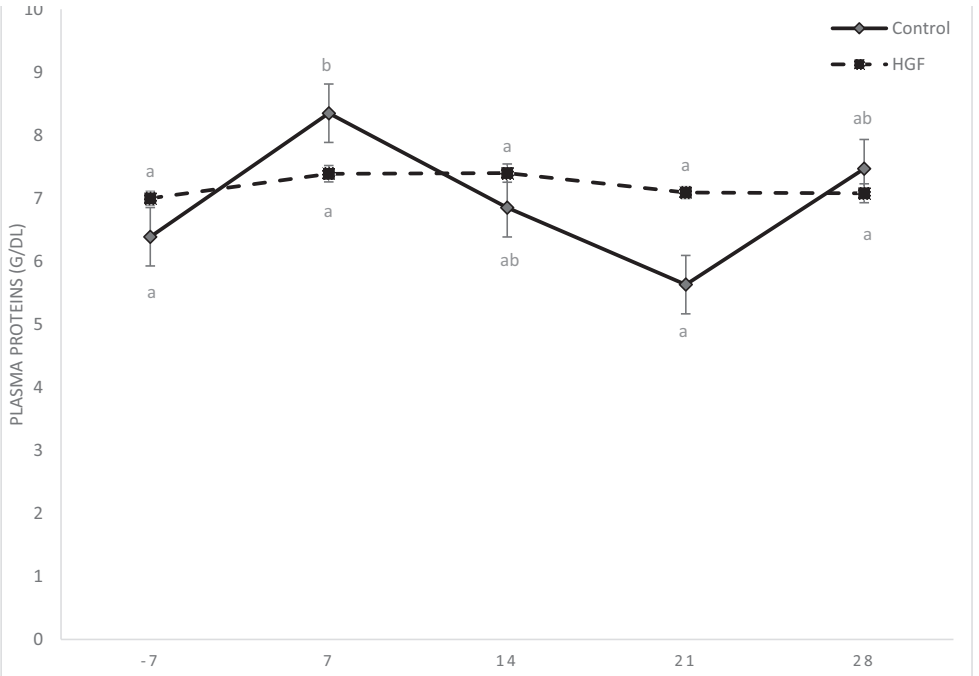

Fig. 2. Mean ± SEM of albumin blood concentration in control and HGF supplemented diet. Values with different letters indicate significant ($P < 0.05$) differences between days.

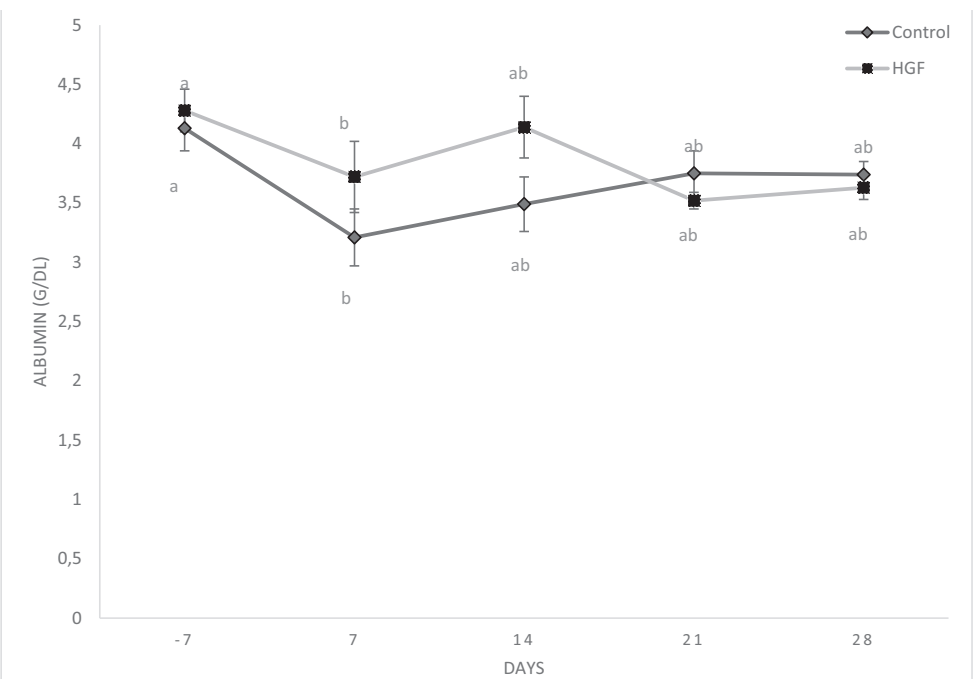

Fig. 3. Mean ± SEM of glucose blood concentration in control and HGF supplemented diet. Values with different letters indicate significant ($P < 0.05$) differences between days.

feed intake (Vadmand et al., 2015). All the nutrients are directed towards the mammary glands, which is reflected in a higher weight gain of the litter (Koketsu et al., 1997). Interestingly, this effect could not be due to the high feed intake, as the additional feed intake during lactation did not appear to be converted into milk production as no effect in the weight gain on the litter was observed (Mallmann et al., 2018). Although the feed supply was not ad libitum in our study, we observed that piglets from sows with HGF supplementation presented higher body weight at 60 days than those from sows of the control group.

Fibre contains substances such as cellulose that is not easily digested by non-ruminant animals. However, in pigs some of the fibre digestion takes place in the cecum and the colon due to the action of cellulolytic bacteria. The metabolism of these substances produces volatile fatty acids, which can provide up to 28% of the energy balance in piglets and even more in sows (Noblet & Le Goff, 2001). According

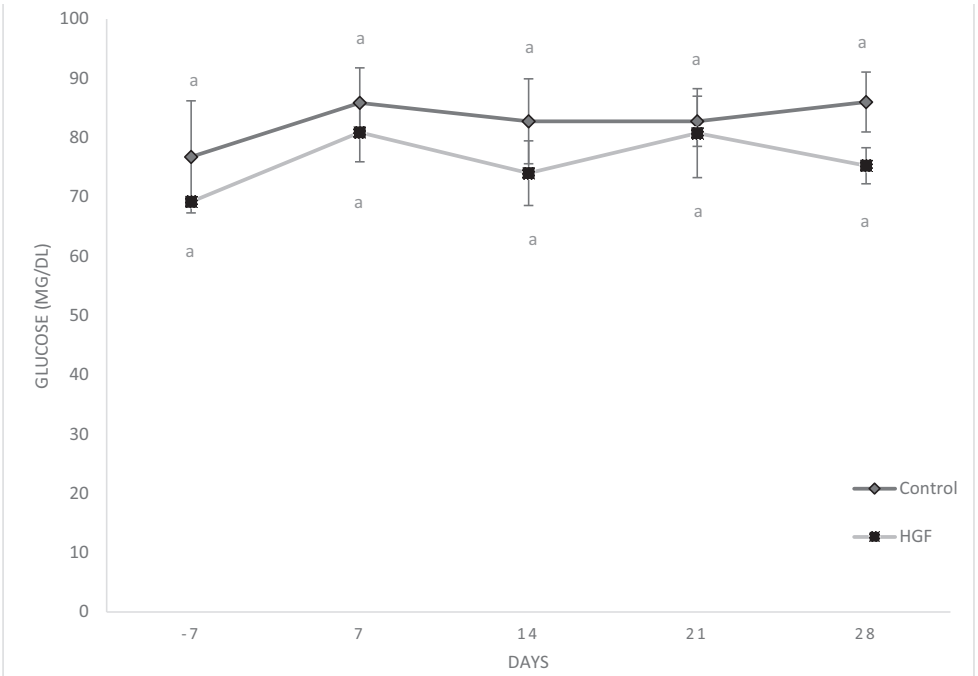

Fig. 4. Mean ± SEM of urea blood concentration in control and HGF supplemented diet. Values with different letters indicate significant ($P < 0.05$) differences between days.

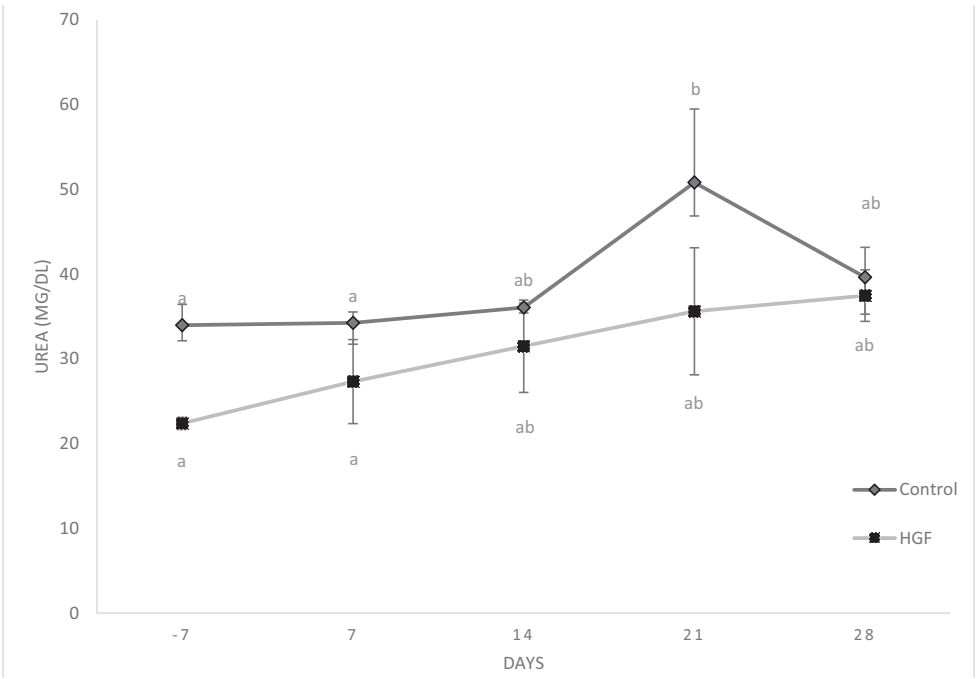

Fig. 5. Mean ± SEM of total creatinine blood concentration in control and HGF supplemented diet. Values with different letters indicate significant ($P < 0.05$) differences between days.

to this, the supplementation with HGF did not affect the body condition of the lactating sows, as the same behaviour was observed in the back fat thickness with a decrease during lactation without differences between treatments. Nevertheless, a low feed intake during lactation and a great body mobilization can have a negative effect on the following reproductive cycle by increasing the weaning-to-oestrus interval (Baidoo et al., 1992). In our study, no increase of this interval was observed reinforcing the idea that HGF supplementation does not affect body condition.

The biochemical values found in the animals included in the study were in accordance with the reference values (Friendship et al., 1984). These parameters are of a great value for the clinical and productive interpretation and necessary to resolve any changes that may be observed. The effect of fibre supplementation on metabolic parameters is not fully elucidated. Some studies showed that the high fibre supplemented diets present lower levels of insulin-like growth factor-1 (IGF-1), leptin and lower plasma concentrations of ß-hydroxybutyrate, glucose, insulin and urea (Jégou et al., 2016; Weaver et al., 2013). In contrast, other studies have found no clear effect of dietary fibre or glucose and insulin responses overall. Moreover, the high fibre diet resulted in increased plasma short-chain fatty acids and non-esterified fatty acids (Yde et al., 2011). In this study, the total plasma protein concentration increased in the postpartum but only in the control treatment, whereas the HGF group presented no differences during the lactation period. It is known that the higher fibre content of feed promoted a higher water intake, which could stimulate the sows to drink more (Oliviero et al., 2009). The increase of total plasma proteins observed could be due to this slight dehydration observed in the control group. Plasma concentration of albumin throughout the study was similar in both groups, suggesting that the availability of proteins in the HGF group is suitable. Albumin production occurs in the liver and decreased concentrations are indicative of protein deficiency (Jahhor et al., 1996). Protein availability measured by albumin has been positively correlated with the ovulation rate and negatively correlated with the weaning-to-oestrus interval (Rempel et al., 2018), which proposes a favourable effect of protein availability on reproductive performance. Lactation diminishes glucose due to a greater absorption of it by the mammary gland for lactose synthesis (Dourmad et al., 2000). The lack of response of glucose concentration could be due to analytical techniques or diet composition as insulin concentration was higher in sugar beet pulp fed pigs compared with potato pulp and pectin (Yde et al., 2011). The greater circulation of urea during lactation is related to the increased protein intake or the increased catabolism of endogenous protein (Quesnel et al., 2009) as milk production has a great impact on protein metabolism (Strathe et al., 2017). Regarding plasma urea, our results showed that in both groups its concentration increased during lactation, largely due to the increased consumption of nutrients in general and protein in particular. The increase in the HGF group was slightly superior with respect to the control group, possibly, owing to less endogenous protein catabolism as suggested in the results of the determination of plasma creatinine. During lactation, the increase in feed consumption in the sow can be hampered and, as milk production increases, many sows could become catabolic in this period (Hansen et al., 2012). Plasma creatinine is the most efficient indicator of muscle catabolism since it is a direct product of creatinine metabolism (Mitchell & Scholz, 2001). Slightly different results observed in the HGF group could indicate a better energy balance related to biochemical parameters and could suggest an indirect effect of the diet on muscle catabolism.

Conclusions

Our findings indicate that supplementation of the diet with HGF did not affect productive performance in the sow or in the litter. Adding to these results, no negative effects on energy balanced related biochemical parameters were found. The higher weight of piglets observed at 60 days suggests that the use of HGF could be an option to take into account in porcine production with economic and environmental benefits.

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