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ENHANCEMENT OF SOW MOTHERING ABILITY TRAITS, SUCKLING PIG PERFORMANCE AND LIVABILITY USING EXOGENOUS INSULIN-LIKE GROWTH FACTOR-1 (IGF-1)

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ABSTRACT

Insulin-like Growth Factor-1 (IGF-1) is important in growth and development of animals. This study demonstrated the effects of dietary IGF-1 supplementation to sow udder morphometry, which impacts sow mothering ability. Twenty gilts bred in two batches were assigned to control or treatment diet (supplemented with exogenous IGF-1 at 50 g/50 kg of feeds) from day 1 of gestation to day 30 of lactation. Sow udder morphometric traits like teat diameter (DIA), teat length (LEN), same row adjacent teat distance (SAM), opposite row adjacent teat distance (OPR) and teat tip to floor distance (FLO) were measured from each sow during pre-breeding, post-breeding and post-farrowing stages. Strong relationship between LEN and DIA was observed during the post-breeding and post-farrowing. A higher ($P \leq 0.01$) IgG concentration was seen in sows given IGF-1 supplementation, indicating a positive effect of IGF-1 on colostrum quality. Moreover, data obtained on the average litter weaning weight, ADG, and diarrhea incidence in piglets were different ($P \leq 0.01$) between control and treatment groups, where piglets nursed by treated sows demonstrated better performance. Results of this study showed that dietary supplementation of IGF-1 improved sow mothering ability, which positively affected suckling pig performance.

Key words: IGF-1, mothering ability, sows, udder

INTRODUCTION

Swine production has always been an interest to many since most people are meat-eaters and this brought a significant increase in pig population worldwide (OECD, 2019). As pig farming continues to flourish, the commercial pig's prolificacy and quality have always been the focus of improvement. As a result, farms with faster growth rates at minimum production costs are established using a pig flow model applying batch breeding and weaning for better all-in/all-out production programs (Carr and Howells, 2016). Thus, growth in pigs will be more systematic and the potential of existing pig farms will be greatly realized (Chen *et al*., 2011).

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Among the topics experimentally explored is the role of growth factors in promoting animal bodily gains. An example of these is the Insulin-like Growth Factor-1 (IGF-1), which is found to be essential for embryogenesis, growth, reproduction and immune system development of animals (Yakar *et al*., 2005). IGF-1 is a peptide hormone composed of seventy (70) amino acid residue, which mediates the effects of the growth hormone (GH) in the body (Ketha and Ravinder, 2015). In pigs, IGF-1 plays a vital role in their growth and reproductive physiology since all the biological activity of this growth factor can translate to the improvement of their morphometric and economically important traits such as body height, loin muscle area (Li *et al*., 2013), scrotal length (Sangel and Roxas, 2011), ovulation rate (Dantzer *et al*., 1999), litter size (Rothschild and Bidanel, 1998), and uterine capacity (Riberio *et al*., 1997). Although there are a number of experiments on the effects of supplementation of exogenous IGF-1 in animals (Chu *et al*., 2008; Li *et al*., 2014; Jameson, 2016), these studies were mostly conducted using other animals such as rodents as the model and there are limited data available in swine. One fascinating research avenue is the sow udder morphology. Balzani *et al*. (2016) defined sow udder quality traits as the udder morphology and colostrum IgG content at farrowing, and improvement of these udder quality traits directly enhanced the sow maternal performance. The present study has demonstrated the effects of exogenous IGF-1 feed supplementation in sow mothering ability through analysis of sow udder morphometric traits and their relationship to the quality of colostrum produced and the suckling pig productive performance.

MATERIALS AND METHODS

Twenty crossbred primiparous gilts were used in this study. These gilts were randomly assigned into the control group or treatment groups where they were fed with basal gestation and lactation diets at respective production periods. The treatment group was supplemented with exogenous IGF-1 at the rate of 50 g per 50 kg of feed. Treatment was administered in the form of dietary free IGF-1 supplementation at the rate of 50 g per 50 kg of feeds, from day one of gestation until day 30 of lactation. The experiment was carried out using a Randomized Complete Block Design (RCBD) with the batch of the animal used as the blocking factor.

For the analysis of the sow udder morphometric profile (summarized in Table 1), the teat length, teat distance and teat diameter were recorded for both the control and treatment groups. The teat length and teat distance were measured using a tape measure, while the teat diameter was measured using a Vernier Caliper. The said traits were measured during the pre-breeding period, after a successful pregnancy diagnosis and after parturition. In order to obtain more accurate results, the traits were measured in cm and taken in standing position as suggested in the study of Balzani *et al*. (2015).

After a sow in both the control and treatment groups gave birth to their first piglet, the colostrum samples were collected until 12 hours after. These samples were collected from both the first and last two pairs of teats located on the anterior and posterior ends of the udder and were stored immediately upon collection at -20 ºC. Moreover, oxytocin was administered intramuscularly to the sow after the birth of the sixth piglet to facilitate ease in parturition and milk ejection. For immunoglobulin G (IgG) analysis, the method was adapted from Balzani *et al*. (2015), wherein a refractometer (Atago, Tokyo, Japan) was calibrated using a distilled water before the next drop of well-mixed colostrum was placed

Table 1. Definition of sow udder morphometric traits.

Traits	Description
LEN	length of the teats from the base to the tip
DIA	diameter of the teat
SAM	tip inter-teat distance between adjacent teat bases in the same row
OPR	row distance between the adjacent teat base in the opposite row
FLO	distance between the teat tip and the pen floor

on the refractometer prism. The refractometer gives a Brix percentage reading, which corresponds to the colostrum antibody level, was read and recorded.

After giving birth to the whole litter, each piglet was weighed using an analogue weighing scale and each birth weight was recorded. The piglets were weighed on day 0 and at weaning. The weight in day 0 was subtracted from the weaning weight and divided by the number of days from birth to weaning in order to compute for the average daily gain (ADG). This was done since the piglets were solely dependent on milk and there were no feeds offered during the entire nursing period. Moreover, the number of dead piglets was also recorded for the computation of pre-weaning mortality. Thus, a reasonable record on litter size at weaning was obtained. In addition, the incidence of diarrhea was also recorded using a Diarrhea Score Guide (Table 2) developed by Sulabo and Decena (2016).

All data on sow udder morphometric traits, colostrum quality, and suckling pig production performance were subjected to statistical analyses using multivariate analysis of variance (MANOVA) for both the control and treatment groups. Wilk's Lambda was used for mean comparison while Pearson's correlation coefficient was used in analyzing the linear relationship of data from the sow morphometric profile gathered from the three phases of production. Mann-Whitney U-test, on the other hand, was used to analyze significant differences among fecal scores obtained from the piglets.

RESULTS AND DISCUSSION

The udder is one of the most important parts in the body of a female pig. Specifically, immediately after birth, the teat is what the piglets search to suckle (Balzani *et al*., 2016). This present study dealt with the analysis of the udder morphometric profile in primiparous gilt or sow by direct measurement of some quantitative udder traits, i.e. teat length (LEN), teat diameter (DIA), and teat distances on same row (SAM), opposite rows (OPR) and to floor (FLO). All procedures were adapted from Balzani *et al*. (2015).

As shown in Table 3, correlation analyses resulted to variable degrees of association between the traits measured from the three specified stages of production (i.e. pre-breeding, post-breeding and post-farrowing). During the pre-breeding stage, only SAM showed a strong positive correlation with LEN and OPR. Also, FLO had a strong negative relationship to SAM and LEN, and a moderately inverse relationship with OPR. This variation and inverse relationship observed can be accounted to the uncontrolled movement of the sow. Thus, affecting measurements with reference to the floor. Our observation conforms to the previous report (Balzani *et al*., 2015) emphasizing higher accuracy in measurement of traits with reference to anatomical landmark rather than those traits with reference to the floor.

Table 2. Diarrhea scores used in the assessment of the fecal condition of nursing pigs.

Score	Description
1	Characterized as stool having dry, whole, firm, well-formed appearance; ideal stool appearance in general.
2	Characterized as stool having semi-normal, moist appearance; mostly solids; approximately 10%-25% liquid: 75-90% solid distribution.
3	Characterized as stool having soft, pasty appearance; approximately 50% liquid: 50% solid distribution.
4	Characterized as stool having wet, mushy appearance; mostly liquid, few solids; approximately 75-90% liquid: 10-25% solid distribution.
5	Characterized as stool having watery appearance; no solid pieces, entirely liquid; worst stool appearance in general.

On the other hand, data obtained during the post-breeding stage mostly demonstrated very weak relationships between traits (Table 3). It was also noticeable that the udder conformation before and after breeding had almost no relationship. Moreover, there was a decrease in negative association between FLO and the other traits. This suggests that the udder conformation during this period was not affected by the growth of the mammary glands due to lactogenesis. This observed trend is similar to the results reported by Kim *et al*. (1999).

Furthermore, there were stronger correlations established between the morphometric profile in post-breeding and post-farrowing (Table 3). Specifically, udder traits such as LEN, DIA and SAM had strong linear relationships. These findings, however, is contrary to the study of Balzani *et al*. (2015), where no significant relationship between udder traits was observed. The variation of the present results for DIA with the previous report of Balzani *et al*. (2015) could be accounted to the modification in the adapted procedure used. In the present study, DIA measurement via caliper was not pressed hardly on teats since this will pose bias on the person taking the measurement.

The current study clearly showed that sow udder morphometric profile can be used as selection criterion for replacement gilts. Moreover, these traits are highly (for LEN and DIA) and moderately (for SAM) heritable traits (Balzani *et al*., 2016). Thus, gilts exhibiting better udder conformation during selection will produce female pigs with good udder conformation as well which conforms to the study of Luxford *et al*. (1998). In the long run, these traits will improve the productive capacity and performance of the farm since these traits will provide sows with better capacity to meet the needs of their suckling piglets. In addition, this study proposes the widening of morphological strategic selection in gilts to include udder morphometric traits since the conventional evaluation has been limited to the number of functional teats.

Table 4 shows the measurements of the teats of the sows assigned in the control and treatment groups during pre-breeding and before the supplementation of exogenous IGF-1 was given. As expected, both groups were comparable with reference to the traits measured.

After breeding, administration of treatment was carried out (i.e. supplementation of exogenous IGF-1 at 0.1% inclusion rate in feeds). Quantitative characterization of sow udder in the treatment group differed from those in the control. Specifically, DIA and LEN

Table 3. Correlation analysis of the sow udder morphometric traits across different stages of production (n=20).

		Pre-Breeding					Post-Breeding					Post-Farrowing				
		LEN	DIA	OPR	SAM	FLO	LEN	DIA	OPR	SAM	FLO	LEN	DIA	OPR	SAM	FLO
Pre-breeding	LEN	1.00														
	DIA	-0.01	1.00													
	OPR	0.45*	-0.23	1.00												
	SAM	0.83**	-0.15	0.72**	1.00											
	FLO	-0.79**	0.26	-0.65**	-0.85**	1.00										
Post-Breeding	LEN	-0.04	0.04	0.23	-0.17	-0.04	1.00									
	DIA	0.14	0.23	0.14	-0.05	-0.19	0.84**	1.00								
	OPR	0.75**	-0.02	0.24	0.54*	-0.59**	-0.21	-0.13	1.00							
	SAM	0.22	0.16	0.30	0.12	-0.29	0.56**	0.68**	0.07	1.00						
	FLO	-0.03	0.02	-0.30	-0.26	0.43	0.06	-0.23	0.09	-0.35	1.00					
Post-Farrowing	LEN	0.17	-0.06	0.23	0.02	-0.26	0.80**	0.81**	0.02	0.60**	-0.14	1.00				
	DIA	0.04	-0.02	0.35	-0.03	-0.21	0.91**	0.83**	-0.1	0.72**	-0.18	0.83**	1.00			
	OPR	-0.32	0.11	-0.23	-0.37	0.14	0.11	0.20	-0.31	0.05	-0.30	0.09	0.15	1.00		
	SAM	0.01	-0.03	0.20	-0.12	-0.13	0.75**	0.74**	-0.13	0.75**	-0.09	0.71**	0.85**	-0.05	1.00	
	FLO	0.60**	-0.35	0.36	0.43	-0.48*	0.34	0.33	0.20	0.35	-0.01	0.54*	0.31	-0.04	0.27	1.00

*P<0.05
**P<0.01

Table 4. Measurements of udder traits during the pre-breeding period in sows assigned to control and treatment groups (n=20).

Pre-Breeding Teat Measurements	**Traits (cm)**	**Control**	**Treatment**	***P*-Value**
Left fore udder	DIA	10.79 ± 0.55	10.34 ± 0.64	0.6034
	LEN	1.81 ± 0.15	1.86 ± 0.16	0.8234
	OPR	9.40 ± 0.34	9.73 ± 0.45	0.5666
	SAM	11.60 ± 0.58	10.88 ± 0.71	0.6493
	FLO	26.50 ± 1.34	25.30 ± 1.08	0.4946
Right fore udder	DIA	10.55 ± 0.29	10.48 ± 0.40	0.8883
	LEN	1.68 ± 0.17	1.81 ± 0.14	0.5643
	OPR	9.90 ± 0.46	9.80 ± 0.47	0.8809
	SAM	11.30 ± 0.58	10.88 ± 0.71	0.6493
	FLO	27.35 ± 1.86	26.50 ± 1.67	0.7373
Left rear udder	DIA	10.65 ± 0.43	10.63 ± 0.31	0.9268
	LEN	1.74 ± 0.17	1.79 ± 0.17	0.8358
	OPR	10.30 ± 0.52	9.75 ± 0.53	0.4689
	SAM	13.92 ± 1.00	13.03 ± 1.26	0.5883
	FLO	29.55 ± 0.54	29.30 ± 0.61	0.7636
Right rear udder	DIA	10.90 ± 0.43	10.56 ± 0.21	0.4836
	LEN	1.75 ± 0.18	1.77 ± 0.16	0.9347
	OPR	9.33 ± 0.43	9.93 ± 0.58	0.4165
	SAM	13.92 ± 1.00	13.03 ± 1.26	0.5883
	FLO	31.55 ± 1.45	31.10 ± 1.38	0.8244

were found to be statistically different between groups (Table 5). The better growth and development of teats in treated sows is attributed to a higher level of free plasma IGF-1 since higher free IGF-1 blood plasma levels have been implicated to improve body development (Lupu *et al*., 2001). Furthermore, the study conducted by Chen *et al*. (2011) showed a positive correlation between IGF-1 expression level and body weight. This improvement in body development was clearly demonstrated through improved udder morphometric traits like DIA and LEN.

On the other hand, SAM, OPR and FLO were comparable between the two groups. These traits quantitatively indicate the udder development in preparation for lactation. The results of this study are similar to the findings of Davis (2017), where sow udder still continue to grow and develop until the first three weeks of lactation. In addition, litter size has been shown to play a role in the rate of growth and development of sow udder from pregnancy until lactation (Davis, 2017).

As shown in Table 6, immediately after farrowing, there was a notable increase in LEN and DIA for both the control and treatment groups. Significant differences between control and treatment groups were also demonstrated with reference to LEN and DIA.

Table 5. Measurements of sow udder traits during the post-breeding period in sows between the control and treatment groups (n=20).

Post-Breeding Teat Measurements	**Traits (cm)**	**Control**	**Treatment**	***P*-Value**
Left fore udder	DIA	10.74 ± 0.14	13.13 ± 0.27	0.0000***
	LEN	1.41 ± 0.06	2.29 ± 0.05	0.0000***
	OPR	9.68 ± 0.54	9.80 ± 0.57	0.8804
	SAM	11.58 ± 0.51	12.80 ± 0.70	0.1729
	FLO	23.74 ± 1.53	21.90 ± 0.67	0.2870
Right fore udder	DIA	10.65 ± 0.08	12.07 ± 0.34	0.0007***
	LEN	1.60 ± 0.07	2.27 ± 0.09	0.0000***
	OPR	10.59 ± 0.71	10.50 ± 0.64	0.9257
	SAM	11.28 ± 0.39	13.46 ± 0.47	0.0023**
	FLO	25.75 ± 1.80	24.80 ± 1.69	0.7045
Left rear udder	DIA	10.48 ± 0.09	11.90 ± 0.28	0.0001***
	LEN	1.65 ± 0.05	2.16 ± 0.09	0.0001***
	OPR	10.95 ± 0.53	10.60 ± 0.65	0.6921
	SAM	14.40 ± 1.22	14.00± 0.80	0.7873
	FLO	26.60 ± 0.98	26.05 ± 1.20	0.7275
Right rear udder	DIA	10.50 ± 0.15	12.12 ± 1.23	0.0000***
	LEN	1.60 ± 0.05	2.21 ± 0.06	0.0000***
	OPR	10.82 ± 0.60	10.10 ± 0.31	0.3007
	SAM	14.40 ± 1.22	14.00 ± 0.80	0.7873
	FLO	29.14 ± 1.75	28.30 ± 1.12	0.6909

*P<0.05
**P<0.01
***P<0.001

Lactation period in the sows greatly affects the udder conformation because of the milk that they continuously produce to provide nourishment for the suckling piglets. Moreover, as previously discussed, there is a positive correlation between litter size and the udder conformation of lactating sows (Davis, 2017).

Collectively, measurements observed from pre-breeding (Table 4), post-breeding (Table 5) and post-farrowing (Table 6) showcased the gross morphological changes that occurred in the sow udder. These findings were similar to the study of Rempel *et al*. (2015), showing how sow udder conformation is greatly affected by the purpose wherein its body is being used for, in this case, for lactation. The data observed in the current study also validated the beneficial effects of exogenous IGF-1 supplementation in enhancing the sow udder morphometric profile. Specifically, by improving traits like LEN and DIA. These traits are important since these are indicative of good mothering ability in sows (Balzani *et al*., 2016). Moreover, they are highly heritable traits. On the other hand, this study suggests for traits like SAM, OPR and FLO to be measured both from the base and the tip of the teats.

Table 6. Measurements of the udder conformation during post-farrowing of both the control and treatment sows (n=20).

Post-Farrowing Teat Measurements	Traits (cm)	Control	Treatment	*P*-Value
Left fore udder	DIA	10.79 ± 0.08	12.51 ± 0.21	0.0000***
	LEN	2.23 ± 0.04	2.61 ± 0.02	0.0000***
	OPR	10.70 ± 0.40	10.50 ± 0.31	0.6945
	SAM	11.40 ± 0.19	12.95 ± 0.20	0.0000***
	FLO	23.55 ± 0.80	22.85 ± 0.30	0.4182
Right fore udder	DIA	10.62 ± 0.15	12.52 ± 0.11	0.0000***
	LEN	2.15 ± 0.03	2.51 ± 0.05	0.0000***
	OPR	10.90 ± 0.35	11.40 ± 0.37	0.3388
	SAM	11.25 ± 0.24	12.90 ± 0.22	0.0001***
	FLO	24.80 ± 0.75	25.25 ± 0.91	0.7067
Left rear udder	DIA	10.74 ± 0.11	11.79 ± 0.17	0.0001***
	LEN	2.21 ± 0.02	2.40 ± 0.03	0.0003***
	OPR	14.25 ± 0.64	14.63 ± 0.62	0.7230
	SAM	26.00 ± 1.14	26.40 ± 1.16	0.6774
	FLO	10.48 ± 0.13	12.28 ± 0.08	0.8082
Right rear udder	DIA	11.20 ± 0.29	10.80 ± 0.29	0.0000***
	LEN	2.14 ± 0.03	2.63 ± 0.03	0.0000***
	OPR	14.25 ± 0.64	14.63 ± 0.62	0.3433
	SAM	28.00 ± 0.33	28.90 ± 0.27	0.6774
	FLO	10.79 ± 0.08	12.51 ± 0.21	0.0493*

*$P<0.05$
**$P<0.01$
***$P<0.001$

Neonatal piglets are in dire need of colostrum in order for them to survive since this milk contains heavy concentration of immunoglobulins like IgG among others. These immunoglobulins are responsible for passive immunity in neonatal pigs (Rooke and Bland, 2002). In this study, the colostrum obtained from the sows in both the control and treatment groups were collected and analyzed for IgG content using Brix Refractometry (Balzani *et al*., 2015). Data revealed a higher IgG concentration of colostrum samples extracted from the sows receiving dietary IGF-1 supplementation (Table 7). This implies that exogenous IGF-1 supplementation can enhance the colostrum quality in lactating sows.

Likewise, this observation is similar to the findings of Savino *et al*. (2003) and Kelley (2004), where IGF-1 improved white blood cells (WBCs) activity thereby augmenting the immunity level of the animal. This better immunity in sows translated to better colostrum quality since B-lymphocyte, a type of WBC, produces immunoglobulin. In addition, Balzani *et al*. (2016) demonstrated that the colostrum IgG level is also a highly heritable trait.

In this study, the average litter weaning weight, average daily gain (ADG), pre-

Table 7. Immunoglobulin G (IgG) content of colostrum samples obtained from sows in control and treatment groups (n=20).

Site of Collection	**IgG Concentration (%)**		***P*-Value**
	Control	**Treatment**	
Left Posterior 1	12.03 ± 3.28	17.14 ± 4.60	0.0000
Right Posterior 1	12.38 ± 3.38	17.22 ± 4.70	0.0000
Left Posterior 2	11.77 ± 3.22	17.43 ± 4.76	0.0000
Right Posterior 2	12.04 ± 3.28	17.30 ± 4.73	0.0000
Left Anterior 1	12.42 ± 3.39	16.61 ± 4.54	0.0000
Right Anterior 1	12.12 ± 3.16	16.87 ± 4.63	0.0001
Left Anterior 2	11.97 ± 3.27	16.51 ± 4.55	0.0002
Right Anterior 2	12.37 ± 3.39	17.11 ± 4.67	0.0000

Traits were measured in Brix percentages (%).
All *P*-values significant at $P< 0.001$.

weaning mortality and diarrhea score were observed to be significantly different in piglets from the treatment group as compared to the control group at 10% and 5% level of significance, respectively (Tables 8 and 9). As previously discussed, the given exogenous IGF-1 could have enhanced the sow morphometric profile and colostrum quality leading to better mothering ability conforming to the study of Balzani *et al*. (2016) implicating enhanced sow mothering ability to the improvement of udder quality traits such as udder morphometry and colostrum quality. Also, it was noted by Jonas *et al*. (2008) that mothering ability of a sow is essentially dependent on the profile and functionality of the udder. Increase in LEN and DIA made suckling easier and more efficient for the piglets. This better suckling performance in piglets resulted in improved growth and higher chances of survival as demonstrated by higher ADG and average litter weaning weight in the treatment group. These findings conform to the results of Quensel *et al*. (2012), where induction of suckling on piglets through better teat conformation lead to better survival and weaning weight.

As the piglets were able to suckle colostrum instantly and with ease during the nursing period due to the improved udder morphometry, piglets showed higher chances of survival reducing cases of pre-weaning mortality. Moreover, the improved IgG content of the colostrum from the treatment group possibly gave the piglets a better level of passive immunity. Furthermore, piglets under the treatment group had near to perfectly normal stool. The decreased diarrhea occurrence in the piglets can be highly attributed to the increased IgG level ingested by the piglets at birth since these immunoglobulins specifically protect the body from viral and bacterial infections which conforms to the claims of Kelley (2004). This also contributed to the economic profitability of the farm as the amount of farm input was decreased in terms of anti-scouring medication. It would contribute to the revenue of the farmer as the production cost can be reduced and much wider profit can be gained since the cases of diarrhea and pre-weaning mortality were reduced.

The good mothering ability of treated sows brought about by the improved udder morphometry and colostrum quality, indeed, translated to better ADG and weaning weight among piglets. This can then provide an increase in the number of growing animals. Thus,

Table 8. Average measurements of the suckling pig production traits between the control and treatment groups.

Traits	Control	Treatment	*P*-Value
Litter size born alive	10.50 ± 0.687	9.60 ± 1.077	0.4902
Ave. weight at birth (kg)	1.67 ± 0.707	1.53 ± 0.309	0.0735
Ave. weight at weaning (kg)	6.63 ± 1.981	9.12 ± 1.642	0.0000***
ADG (kg/day)	0.16 ± 0.055	0.25 ± 0.048	0.0000***
Pre-weaning mortality (%)	0.12 ± 0.055	0.02 ± 0.010	0.0855

*P<0.05
**P<0.01
***P<0.001

Table 9. Mann Whitney U test results for the diarrhea score evaluated from suckling piglets under control (n=105) and treatment groups (n=96) in a span of 30 days.

Factors	Control	Treatment
Median	1	1
Rank Sum	6,222,150	6,938,865
Mann Whitney U	3,045,420	3,483,180
P-value	0.0000***	0.0000***

***P<0.001

improving farm production performance in the long run.

In conclusion, the study showed how IGF-1 enhanced sow mothering ability traits and suckling pig performance and livability. The improved sow mothering ability was a result of improved udder quality traits (i.e, teat length and diameter) and better colostrum quality, where dietary supplementation of IGF-1 helped in the better expression of these highly heritable traits in sow. The enhanced sow udder quality traits then resulted to enhanced mothering ability as it gave the suckling piglets better chance to suckle from the teat with enhanced morphometry and with better colostrum quality which is essential for their survival. These aforementioned enhanced traits also resulted in better suckling pig performance and livability in terms of ADG, average weaning weight and diarrhea score. Furthermore, the use of IGF-1 supplementation in the sows translated to better weaning weights in the piglets making it an advantageous innovation that the farmers can adopt.

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REFERENCES

Balzani A, Cordell HJ and Edwards SA. 2015. Development of a methodology to describe udder conformation in sows. *The Animal Consortium* 10(3):432-439.

Balzani A, Cordell HJ and Edwards SA. 2016. Relationship of sow udder morphology with piglet suckling behavior and teat access. *Theriogenology* 86:1913-1920.

Carr J and Howells M. 2016. Modeling Pig Flow. *Livestock* 21(3):180-186.

Chen R, Yin Y, Paan J, Gao Y and Li T. 2011. Expression profiling of IGFs and IGF receptors in piglets with intrauterine growth restriction. *Livest Sci* 136(2-3):72-75.

Chu YW, Schmitz S, Choudhury B, Telford W, Kapoor V, Garfield S, Howe D and Gress RE. 2008. Exogenous insulin-like growth factor 1 enhances thymopoiesis predominantly through thymic epithelial cell expansion. *Blood* 112(7):2836-46.

Dantzer R, Robert G, Johnson RW, Kelley KW and Rodney W. 1999. Central administration of insulin-like growth factor-1 inhibits lipopolysaccharide-induced sickness behavior in mice. *Neuro Report* 10:289–292.

Davis SR. 2017. Triennial Lactation Symposium/BOLFA: Mammary Growth During Pregnancy and Lactation and Its Relationship with Milk Yield. *J Anim Sci* 12:5675.

Jameson JL. Ed. 2016. Endocrinology: Adult & Pediatric. Philadelphia, PA: Elsevier Saunders

Jonas E, Schreinemachers HJ, Kleinwachter T, Un C, Oltmanns II, Tetzlaff S, Jennen D, Tesfaye D, Ponsuksili S, Murani E, Juengst H, Tholen E, Schellander K and Wimmers K. 2008. QTL for the heritable inverted teat defect in pigs. *Mamm Genome* 19(2):127-138.

Kelley KW. 2004. From hormones to immunity: the physiology of immunology. *Brain Behav Immun* 18(2):95-113.

Ketha H and Singh RJ. 2015. Clinical assays for quantitation of insulin-like-growth-factor-1 (IGF-1). *Methods* 81:93–98.

Kim SW, Osaka I, Hurley WL and Easter RA. 1999. Mammary gland growth as influenced by litter size in lactating sows: impact on lysine requirement. *J Anim Sci* 77:3316–3321.

Li J, Yang Z, Li Z, Gu L, Wang Y and Sung C. 2014. Exogenous IGF-1 promotes hair growth by stimulating cell proliferation and down regulating TGF-β1 in C57BL/6 mice in vivo. *Growth Horm IGF Res* 24(2-3):89-94.

Li Z, Wu Z, Ren G, Zhao Y and Liu D. 2013. Expression patterns of insulin-like growth factor system members and their correlations with growth and carcass traits in Landrace and Lantang pigs during postnatal development. *Mol Biol Rep* 5:3569-76.

Lupu F, Terwilliger JD, Lee K, Segre GV and Efstratiadis A. 2001. Roles of Growth Hormone and Insulin-like Growth Factor 1 in Mouse Postnatal Growth. *Dev Biol* 229(1):141-62.

Luxford BG, Campbell RG, Bunter KL and Owens PC. 1998. Use of IGF-1 as a selection criteria in pig breeding. AGBU Pig Genetics Workshop:17-21.

OECD. 2019. Meat consumption (indicator). doi: 10.1787/fa290fd0-en.

Quensel H, Farmer C and Devillers N. 2012. Colostrum intake: influence on piglet performance and factors of variation. *Livest Sci* 146:105-114.

Rempel L, Vallet J, Lents C and Nonneman D. 2015. Measurements of body composition during late gestation and lactation in first and second parity sows and its relationship to piglet production and post-weaning reproductive performance. *Livest Sci* 178: 289-295.

Riberio EL, Nielsen MK, Leymaster KA and Bennet GL. 1997. A stimulation model including ovulation rate, potential embryonic viability and uterine capacity to explain litter size in mice: II. Responses to alternative criteria of selection. *J Anim Sci* 75:652-656.

Rooke JA and Bland IM. 2002. The acquisition of passive immunity in the newborn piglet. *Livest Prod Sci* 78:13–23.

Rothschild MF and Bidanel JP. 1998. Biology and genetics of reproduction. in: M.F. Rothschild, A. Ravinsky (Eds.) The Genetics of the Pig. CAB International, Wallingford.

Sangel PP and Roxas NP. 2011. Relationship of porcine plasma free insulin-like growth factor-1 (IGF-1) with the growth performance and scrotal length of landrace boars. *Int J Agric Biol* 13:51-56.

Savino W, Smaniotto S, Binart N, Postel-Vinay MC and Dardenne M. 2003. *In vitro* effects of growth hormone on thymic cells. *NY Acad Sci* 992:179-285.

Sulabo R and Decena KS. 2016. Effect of standardized ileal digestible amino acid in diets containing increasing levels of copra expellers on growth performance, diarrhea occurrence, and efficiency of nitrogen utilization in nursery pigs. Poster presented at: 2016 Evonik Nutrition and Care, Animal Nutrition University Program.

Yakar S, Kim H, Zhao H, Toyoshima Y, Pennisi P, Gavrilova O and Leroith D. 2005. The growth hormone-insulin like growth factor axis revisited: lessons from IGF-1 and IGF-1 receptor gene targeting. *Pediatr Nephrol* 20:251-254.