Theses of Doctoral (PhD) Dissertation

COMPARATIVE STUDY ON REPRODUCTIVE PERFORMANCE AND MANAGEMENT METHODS OF HUNGARIAN AND LAO INDIGENOUS PIG BREEDS

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1. INTRODUCTION

Hungary had a pig population of roughly 2.7 million in 2021. Nearly 5% dropped from 2020 when the pig population reached 2.8 million (HUNGARIAN CENTRAL STATISTICAL OFFICE, 2022), almost 1.56 times lower than the pig population in Laos, which reached 4.3 million in the same year. Nearly 4.33% increase from 2020 after recovering from the epidemic of ASF in the second half of 2019 (MATSUMOTO et al., 2021). In 2013, companies owned over 73% of pig farming in Hungary, with farmers owning around 27% (RAJCSANYI, 2017). In contrast, almost 92% of the pig population in Laos in 2019 were indigenous pig breeds owned by small-scale farmers, and only 8% were owned by companies (MAF, 2020). Although the pig population in Hungary gradually declined, pork production increased from 517 thousand tons in 2012 to 557 in 2014 and 599 in 2016 (BENE et al., 2016). Laos produced only 65 thousand tons of pork in 2015, while the country's requirement for more than 80 thousand tons annually. As a result, Laos needs to import finishing pigs from neighbouring countries to slaughter around 124,000 heads each year (KEONOUCHANH and DENGKHOUNXAY, 2017).

Improving reproductive management and new farm operation for Lao indigenous pigs, as Hungarian *Mangalica*'s successful experience, could improve reproduvtive performance of Lao indigenous pigs. Particularly modifying age and body weight for first mating, estrous synchronisation, and improving feeding and farrowing technology. Therefore, the present study:

(1) to evaluate and identify the reproductive management methods in *Mangalica* pig farms to be adopted to improve indigenous pig breeds in Laos.

(2) to evaluate the efficiency of utilizing estrous synchronization (ES) and artificial insemination (AI) with *Duroc* semen in improving the quality of the reproductive performance of *Moo Lath* gilts.

(3) to evaluate the effects of weaning age on the growth performance of piglets and body conditions of *Moo Lath* primiparous sows.

(4) to evaluate the effects of supplementing dried green banana to reduce diarrhoea in post-weaning piglets.

(5) to examine the bacteria-infected post-weaning diarrhoea in *Moo Lath* piglets.

(6) to study the effects of birth weight on age at puberty and first mating and reproductive performance of crossbred *Moo Lath* x *Duroc* gilts.

2. MATERIALS AND METHODS

2.1. Comparing the reproductive performance of *Mangalica* and *Moo Lath* pigs

In Hungary (survey)

A survey on reproductive management at Hungarian *Mangalica* farms was carried out with the support of NAMB. The semi-structured questionnaires were used as a main tool for collecting data, and 32 *Mangalica* pig farms participated in this study. The farm's size ranged from 10 to 835 breeding sows, with over 3,357 breeding sows involved in this study. The farms were grouped into three groups: A "farms with < 30 sows", B "farms ≥ 30 to 100 ≤ sows", and C "farms with > 100 sows".

In Laos (survey)

164 native pig-raising families from 5 representative provinces in northern Laos were involved in this study. The selected villages were grouped into three clusters based on kilometres (km) distance from the towns. It was slightly different from the PHENGSAVANH et al. (2011) study, which classified based on distance in hours. Similar to the methods used by VALLE ZÁRATE et al. (2010), carried out in Northwest Vietnam. The 1st village cluster was < 15 km, the 2nd was ≥ 15−30 km≤, and the 3rd was > 30 km from the towns.

2.2. Experiment on improving the reproductive performance of *Moo Lath* in Laos

36 *Moo Lath* gilts aged between 150−240 days, with a mean body weight of about 25−40 kg, were used in the study. Gilts were kept in individual pens (1.5 x 2 x 1 m, made with a concrete floor and under the tile roof) during the experimental period. The animals were divided into three groups, insemination with *Duroc* semen, G1 (18 gilts) was synchronisation using Altrenogest Regumate® (AR), while G2 (12 gilts) was not. G3 (6 gilts) was the control group mated naturally with a local boar.

Gilts, sows, and piglets were fed by the specific categories of complete mixed feed from the Lao-Hungarian feed factory (*Table 1*). All gilts and sows got the same feed and the same portion. Each gilt was fed 1.5 kg/day before and after estrous. After insemination, this amount was reduced to 1.2 kg/day between days 1 and 28. From days 28 to 100 of gestation, each pregnant gilt was fed 1.8 kg/day, and this amount was increased to 2 kg/day between days 101 of pregnancy until farrowing. During lactation, all sows got 2.3 kg/day. This feeding strategy is similar to MALLMANN et al. (2019); MIDDELKOOP et al. (2019); ŠKORJANC et al. (2008); NEWTON and MAHAN (1993), but that was a completely different breed and body weight of gilts and sows. In our case, the average body weight of gilts at insemination was 49.59±7.20 kg and 75.99±7.33 kg before farrowing.

Table 1

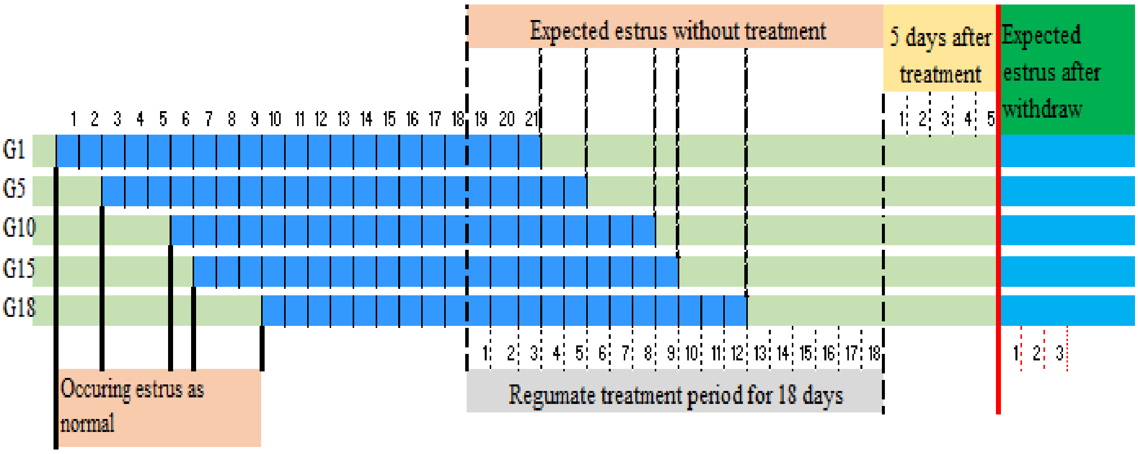
Nutrient content in the complete mixed feed used for the experiment

Nutrient Components	Gilt feed	Gestation feed	Lactation feed	Creep feed	Post-weaning feed
DM (%)	88.50	88.36	88.5	89.13	89.05
CP (%)	15.99	15.11	15.99	20.71	18.97
EE (%)	1.94	0.50	1.94	5.52	2.78
CF (%)	5.26	6.22	5.26	2.71	4.14
Ash (%)	8.48	8.18	8.48	4.65	5.26
AIA (%)	1.34	1.69	1.4	0.34	0.57

DM: dry matter; CF: crude fiber; CP: crude protein; EE: ether extract; ASH: ash; AIA: acid-insoluble ash.

The strategies of AR treatment were performed as described by (BRÜSSOW et al., 2008). All gilts in G1 were orally fed with 5 ml (20 mg of Altrenogest) of Regumate® at 7:00 am before the main feed for 18 consecutive days after estrous. Altrenogest was mixed into a small amount of feed and provided to each gilt in G1 to ensure that gilts got their portion before offering a regular feed. Five (5) days after AR withdrawal, the gilts were expected to come to oestrous within 3 days (*Figure 1*).

Figure 1: **Protocol for Altrenogest Regumate® treatment for *Moo Lath* gilts**



Source: Modified based on MSD Animal Health, Milton Keynes, UK

The body conditions of sows were recorded for the first time before the first insemination, at day 110 of gestation for the second, and weekly during their lactation period. Each sow was weighed using the 300 kg digital scale and measured backfat thickness using FarmScan® L70 Eye Muscles Veterinary Ultrasound.

Each sow was provided approximately 5 kg of rice straw on day 110 to build a nest for her farrowing. Weaker piglets were supported in drinking the colostrum, whereas the vigorous piglets were assisted in tearing the placental membrane and drying shortly after birth. All male piglets were castrated on day 10 after farrowing with local anaesthesia, and antibiotics were used right after the surgery. After farrowing, piglets had their teeth clipped but not their tails docked. All piglets were administered 1 ml of iron injection between 3−7 days of age.

The piglets were weaned either at days 28, 35, 42, 49, or 56 after farrowing. Weaned piglets were transferred to nursing pens, with 8−20 piglets per pen "3 x 4 m, or 12 m^2", with approximately 5 cm of bed-deep saw dust (*Picture 2*). They were fed the same post-weaning feed at the nursery pen until 2nd week after weaning before they were sold out. The post-weaning feed was mixed with the creep feed five days before weaning to ensure the piglets were familiar with the feed during the weaning phase.

Picture 2: **Piglets in the nursery pen are grouped based on their body weight**

A total of 20 faecal samples (1−2 ml) of 20 diarrhoea piglets were collected from the anus of the piglet using a pipette to ensure no contamination by other objects. The samplings were done in two periods, pre-weaning and post-weaning, 10 for each. The sampling was performed at 7:00 am using a sterilised pipette and placed in a sterilised sample bottle soon after collection. Soon after the samples were collected, all sample bottles were sent to be stored until diagnosed at the National Animal Health Laboratory.

18 crossbred *Moo Lath* x *Duroc* (CMD) gilts from our first experiment were selected soon after weaning. Each gilt was separated and kept in an individual pen after the onset of puberty based on birth weight (< 0.7; ≥0.7−0.8≤; and > 0.9 kg) to evaluate their reproductive performance. 15 mature purebred *Moo Lath* (PML) gilts reared by local farmers were also involved in this study to compare the morphologies at first mating between CMD and PML gilts.

2.3. Statistical analysis

One-way ANOVA of SPSS statistical package version 26, was used to evaluate the body condition of sows, litter size, growth performance of piglets, piglets' mortality, and effects of weaning age on the performance of sows and piglets. The independent-sample T-Test was used to compare the effects of supplementing green dried banana on post-weaning piglets' diarrhoea and the morphology comparison between the CMD and PML gilts. The Bivariate Pearson Correlation Analysis using to assess the correlation coefficients between reproductive parameters. A significant level of 0.05 ($p < 0.05$) was used as the significant difference.

3. RESULTS AND DISCUSSIONS

3.1. Overall reproductive performance of Hungarian and Lao indigenous pigs

3.1.1. Reproductive performance of *Mangalica* sows

There was no significant difference in the lifespan of *Mangalica* sows, with an average of 5.42 years. However, the farms in clusters A and B had marginally longer use of sows than those in cluster C (5.76, 5.25, and 4.50 years, respectively). Overall, no difference in the reproductive performance parameters of *Mangalica* sows among clustered farms. However, it significantly differed in specific types of *Mangalica* (pure (PM) vs. CM). The longest period of gilt development was in farms that produced pure SM, with a mean age at first mating was 450 d, while BM, RM, and CM were 429, 400, and 418 d, respectively. CM had a larger ($p < 0.05$) litter size (6.43) and birth weight (1.19), compared to PM, especially BM (*Table 2*). In addition, CM also had a slightly larger ($p < 0.05$) litter (1.46) per year compared to 1.03 in Red, 1.13 in SM, and 1.20 in BM. However, CM seems to be culled earlier than PM, especially SM. The average suckling period differed significantly ($p < 0.049$) between clustered farms. Particularly the sows in clusters A and C farms (6.54 vs. 5.21 w), while the cluster B farms were 5.87 w. The mean weaning age of most HM farms applying now was 6.17 w.

Table 2

Reproductive performance of different types of *Mangalica* sows

Parameters	Types of *Mangalica*				p-value
	BM	**SM**	**RM**	**CM**	
Number of farms	7	4	3	18	
First mating/AI, days	429	450	400	418	0.647
Weight at first mating, kg	117.86^{a}	110.00^{ab}	103.33^{b}	108.61^{b}	0.008
Litter size	5.31^{a}	6.13^{ab}	6.07^{ab}	6.43^{b}	0.217
Birth weight, kg	0.88^{a}	0.96^{ab}	1.10^{ab}	1.19^{b}	0.135
Lactation period, weeks	8.86^{a}	6.50^{ab}	6.83^{ab}	5.72^{b}	0.157
Weaning weight, kg	8.07	7.50	8.00	7.73	0.959
Pre-weaning mortality	1.87	1.31	1.43	1.15	0.516
Litter per year	1.20^{ab}	1.13^{ab}	1.03^{a}	1.46^{b}	0.068
Lifespan, year	6.07^{a}	7.25^{a}	5.33^{ab}	4.79^{b}	0.006

$^{a,b:}$ Mean in the same row with the same superscripts do not differ ($p > 0.05$)

3.1.2. Reproductive performance of Lao indigenous pigs

Lao indigenous gilts reach puberty (about 211±41 d, ranging from 120 to 330 d). The first farrowing ranged from 240−450 d, or approximately 339±43 d. The farrowing interval between two parities was 204 to 313 d, depending on the sows' lactation and dried periods. Lao indigenous sows gave roughly 1.30±0.53 litter per year, ranging between 0.7 to 2 litter per year, with the average litter size of 7.60±1.77. The mean birth weight and weaning weights were around 0.72±0.23 kg and 7.30±2.12 kg, with a suckling period of about 11.21±3.38 w. The mean WEI of native pig breeds reared by small-scale farmers in Northern Laos was 48.34±27 d (*Table 3*).

Table 3

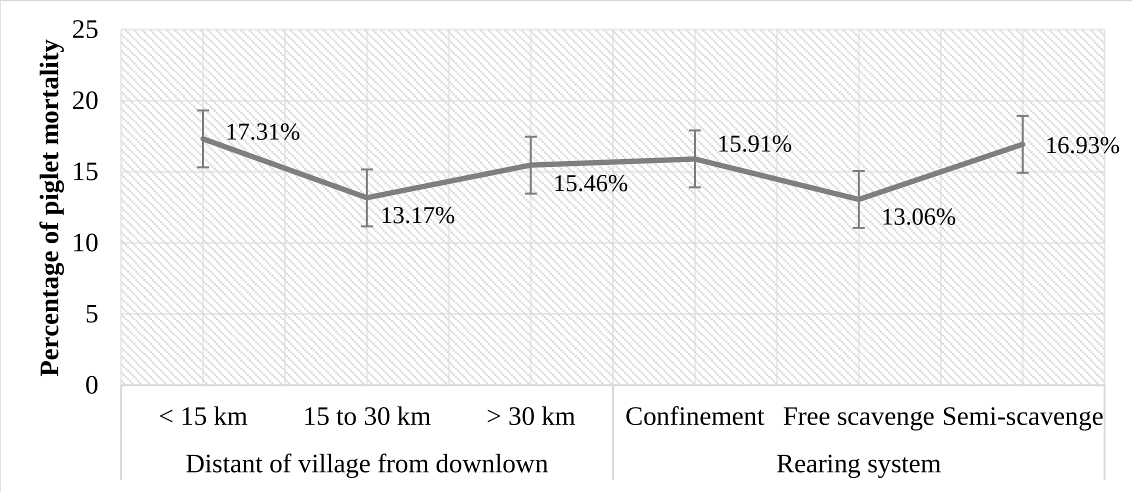
Reproductive performance of indigenous pigs based on rearing systems

Parameters	Pig rearing systems			Mean±SD	p-value
	CRS	FRS	SRS		
Families (n)	64	41	59		
Selection age, day	148^{a}	157^{a}	178^{b}	161±55	0.009
Puberty age, day	205	213	275	211±41	0.331
First mating age, day	225	224	226	225±43	0.961
First farrowing age, day	339	338	340	330±43	0.961
Litter size, head	7.36^{a}	8.50^{b}	7.22^{a}	7.60±1.77	0.001
Litter per year	1.45^{a}	0.87^{b}	1.41^{a}	1.29±0.53	0.000
Birth weight, kg	0.70^{a}	0.79^{a}	0.69^{b}	0.72±0.23	0.085
Suckling duration, week	10.19^{a}	11.64^{b}	11.98^{b}	11.21±3.38	0.006
Weaning weight, kg	6.74^{a}	7.76^{b}	7.57^{b}	7.30±2.12	0.023
Stillborn	0.20	0.06	0.12	0.14±0.41	0.206
Weaning-to-oestrus interval, day	46	48	50	48.34±27.04	0.664
Lifespan of sows, year	4.03^{a}	5.80^{b}	5.54^{c}	4.66±1.38	0.000
Lifespan of boars, year	3.81^{a}	3.50^{a}	2.76^{b}	3.36±1.33	0.000

$^{a,b,c:}$ Mean in the same row with the same superscripts do not differ ($p > 0.05$); CRS = Confinement rearing system; FRS = Free scavenging rearing system; SRS = Semi-scavenging rearing system.

The pre-weaning mortality (PWM) was 15.45%, and no significance was observed between village locations or rearing systems. Interestingly, piglets from the FRS had the lowest PWM, about 13%, compared to 15.91% in the CRS and 16.93% in the SRS (*Figure 3*). Around 56% of mortality, this finding was estimated due to improper management during farrowing and lactation, which caused piglets to be crushed by sows and starvation. More than 54.26% of participating households did not keep their sows in a pen before farrowing. Additionally, more than 53.66% of farmers let their sows give birth to piglets in the nearby forest.

Figure 3: **The piglet mortality based on village clusters and rearing systems**



The chronic constraints on the reproductive performance of local pigs in Laos include (1) poor quality of piglets from farrowing to weaning, including weight gain and health conditions. (2) breeding cannot be controlled due to the rearing system *(Picture 2*); gilts and boars are not separated. (3) the farming system has not been developed yet, increasing more difficulty in reproductive management. And, (4) pigs grow with small body weights till their sexual maturity age, and it is rare to weigh > 100 kg. Therefore, improving the farming system and modifying the optimal body weight of gilts for their first mating should be the priority to enhance the development of native pig production in Laos.

Picture 2: **Uncontrolled breeding among native pigs in the traditional extensive system in rural areas of Laos (***gilts did not reach 30 kg, within 5 months of age***)**

3.1.3. Comparison of the reproductive performance of Hungarian and Lao indigenous pig breeds

Table 4 shows varied ages at first mating between *Mangalica* and *Moo Lath* sows (360−423 d vs. 225−245 d). *Moo Lath* sows produce a marginally larger litter size (7.60−7.75) than *Mangalica* sows, which range from 5.58−6.12. Considering the number of ovulations in Manglaica gilt was 10.60±3.10 (BRÜSSOW et al., 2004), while only 8.80±2.90 in *Moo Lath* gilts (RÁTKY et al., 2013). It was estimated that *Moo Lath* gilt might have a bit higher fertility than *Mangalica* gilt, so it had a slightly larger litter size. Based on the completed difference in breeds and raising environment, more scientific studies are required to compare reproductive physiology and their performance between Hungarian and Lao native pig breeds.

Table 4

The reproductive performance between *Mangalica* and *Moo Lath* Lao pig breeds

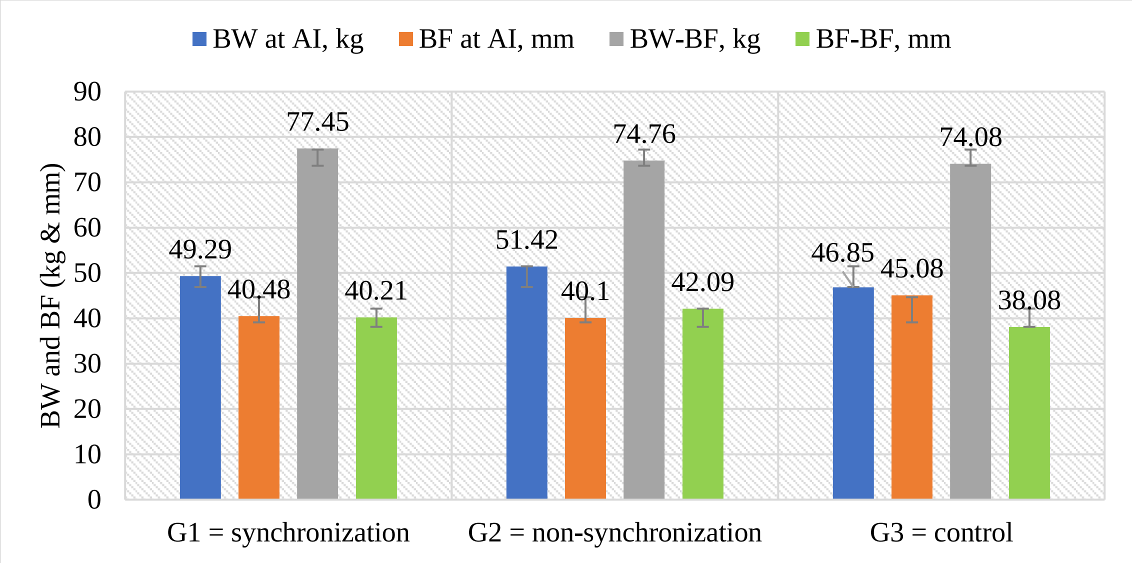
Parameters	*Mangalica*		*Moo Lath*	
	NAMB (2013)	Farmers (Survey 2020)	Extensive rearing	Farm experiment
Age at first mating, day	360	423	225	245
Weight at first mating, kg	100	110	37.50	49.59
Age at first farrowing, day	619	497	330	354
Weight at first farrowing, kg	-	-	50.56	75.99
Litter per year	1.41	1.32	1.31	-
Litter size	5.58	6.12	7.60	7.75
Birth weight, kg	-	1.09	0.73	0.64
Suckling period, week	3	6	11	(4−8)
Weaning weight, kg	4.70	7.80	7.30	3.48−5.92
Lifespan of sow, year	-	5.42	4.66	-

3.2. New strategies for improving the reproductive performance in *Moo Lath* pigs

3.2.1. The optimal body condition of *Moo Lath* gilts at first service and farrowing

The mean body weight of *Moo Lath* gilts before insemination were not significantly different (p = 0.446) in the studied groups. However, the body weight of the gilts in non-synchronisation (G2) was slightly heavier (51.42±8.81 kg) compared to 49.29±6.88 kg in synchronisation (G1) and 46.85±3.75 kg in the control group (G3). Gilts in G3 had the thickest backfat (BF) before insemination (45.08±3.81 mm), but it did not differ (p = 0.079) compared to those in G1 and G2 (40.48±5.60 and 40.10±4.79 mm). Conversely, gilts in G2 showed a thicker mean BF (42.09±5.23 mm) before farrowing, compared to 40.23±5.45 mm in G1 and 38.08±8.17 mm in G3 (*Figure* 4). The average body weight and backfat thickness at insemination and first farrowing were approximately 49.57±7.20 kg, 41.12±4.78 mm, and 75.99±7.33 kg, 40.48±5.87 mm, respectively.

Figure 4: **The body condition of the sows from the first insemination to farrowing**

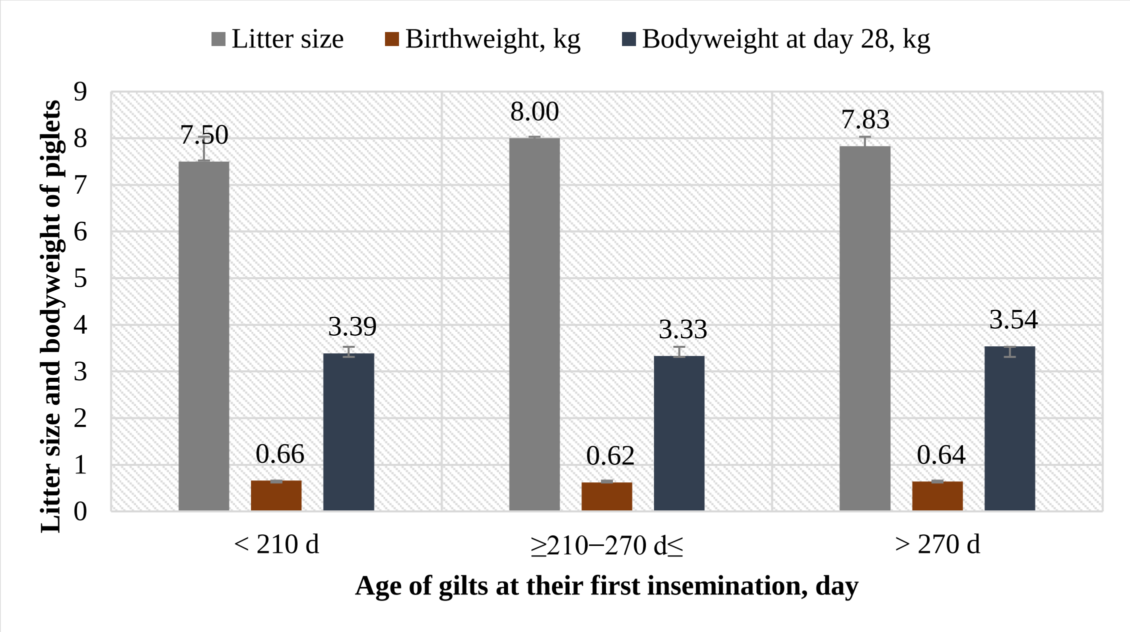


BW; BF at AI: body weight and backfat at insemination; BW-BF; BF-BF: body weight and backfat before farrowing.

3.2.2. Effects of first insemination age on reproductive performance of *Moo Lath* gilt

Figure 5 shows the average age of sows for this study was roughly 245±40 d (ranging from 195 to 315 d) at first insemination and 339 d at first farrowing. There was no significant difference (p = 0.656) in the mean litter size and birth weight related to the age of the gilts at insemination/mating. However, the sows with age < 210 d had the smallest litter size (7.50) compared to those sows with between 210 to 270 d (8.00) and with > 270 d (7.83) at first insemination. In contrast, the gilts with age < 210 d at first insemination had slightly heavier birth weight (0.66 kg) compared to those born from the sows with that age between 210 and 270 d (0.62 kg), and the sows with > 270 d (0.64 kg) at first service. The ages of gilts at first insemination also did not show significant differences in the mean growth performance of piglets on day 28 after farrowing.

Figure 5: **Litter size and growth performance of piglets based on the age of gilts at first insemination or mating**

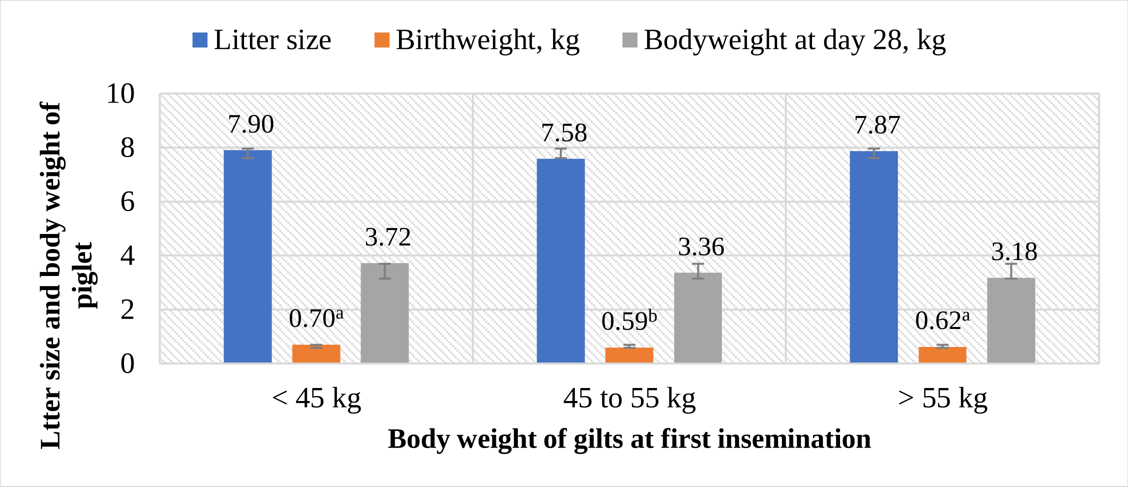


< 210; ≥210−270≤; >270 d: age of the gilts at first insemination.

3.2.3. Effects of body weight of *Moo Lath* gilts on their reproductive performance

Figure 6 shows that sows with a body weight of less than 45 kg at first insemination got the largest litter size (7.90) compared to those sows with a body weight of between 45 to 55 kg (7.58) and sows with a body weight of more than 55 kg (7.87). On the other hand, the birth weight of the piglets born from the sows with body weight <45 to 55 kg> was lower (0.59 kg) than those born from sows with body weight < 45 kg, and > 55 kg (0.70 and 0.62 kg, respectively). In contrast, the birth weight and growth performance on d 28 of the piglets born from sows with body weight < 45 kg were slightly significantly heavier than the other two groups.

Figure 6: **Litter size and piglet performance based on body weight of gilts at first insemination**

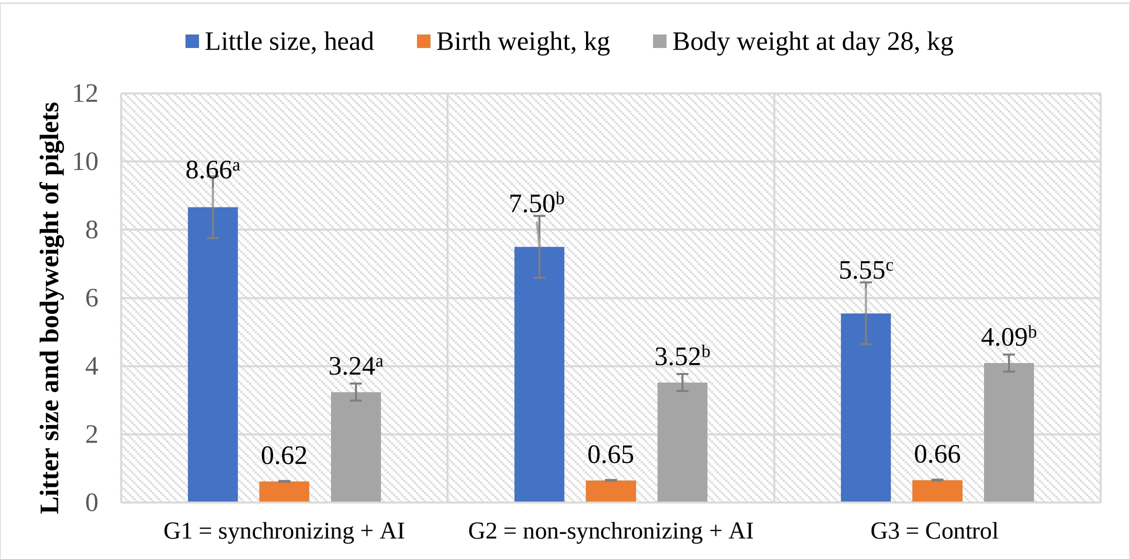


< 45 kg; 45 to 55 kg; > 55 kg: body weight of gilts at first insemination. [a,b]: mean with the same superscripts do not differ ($p > 0.05$).

3.2.4. Effects of ES and AI on the reproductive performance of *Moo Lath* gilts

Figure 7 shows the primiparous sows in G1 had a larger litter size (8.66, $p < 0.001$), more than 1.16 piglets compared to 7.50 in G2, and more than 3.11 piglets (5.55) in G3. Conversely, no significant difference in birth weight ($p = 0.804$). At the same time, the most minor ($p < 0.013$) mean body weight of piglets on d 28 of life was found in the piglets from G1 (3.24 kg), compared to 3.53 kg born from G2 and 4.09 kg in G3.

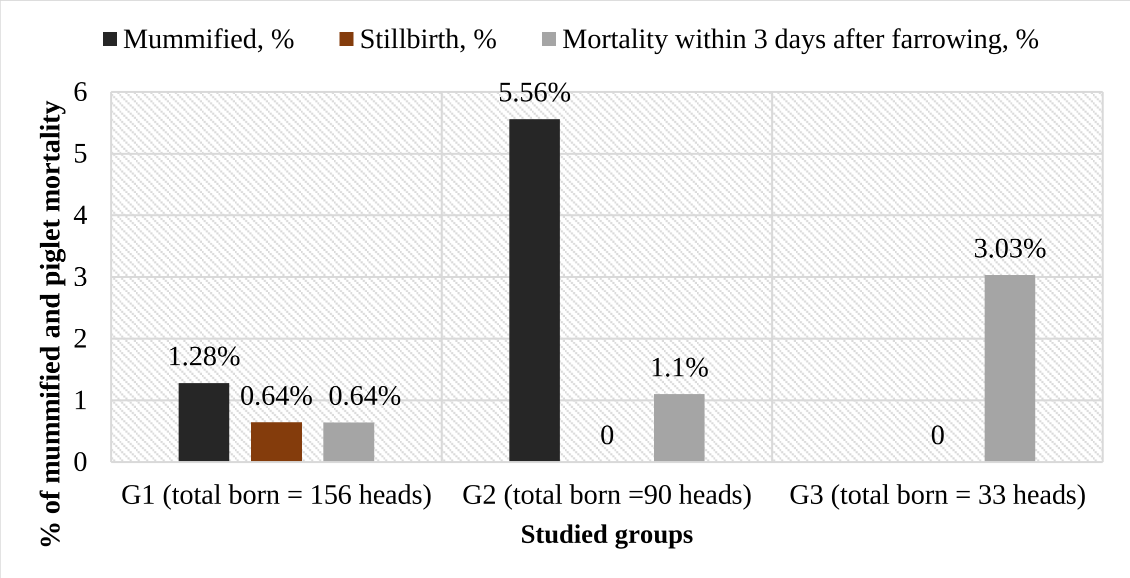
Figure 7: **Litter size and growth performance of piglets between groups**



[a,b]: Mean with the same superscripts do not differ ($p > 0.05$)

In the present study, piglet mortality was approximately 3.94% of the total born (279), of which 2.51% were mummified piglets, 0.36% were stillborn, and 1.076% died within 3 days post-farrowing. Interestingly, mummified piglets were delivered only in G1 and G2, but G3 did not. It was observed that it mostly occurred in the gilts with a litter size ≥ 8. As shown in *Figure 8*, sows in G2 had approximately 5.56% of mummified piglets and 1.28% in G1.

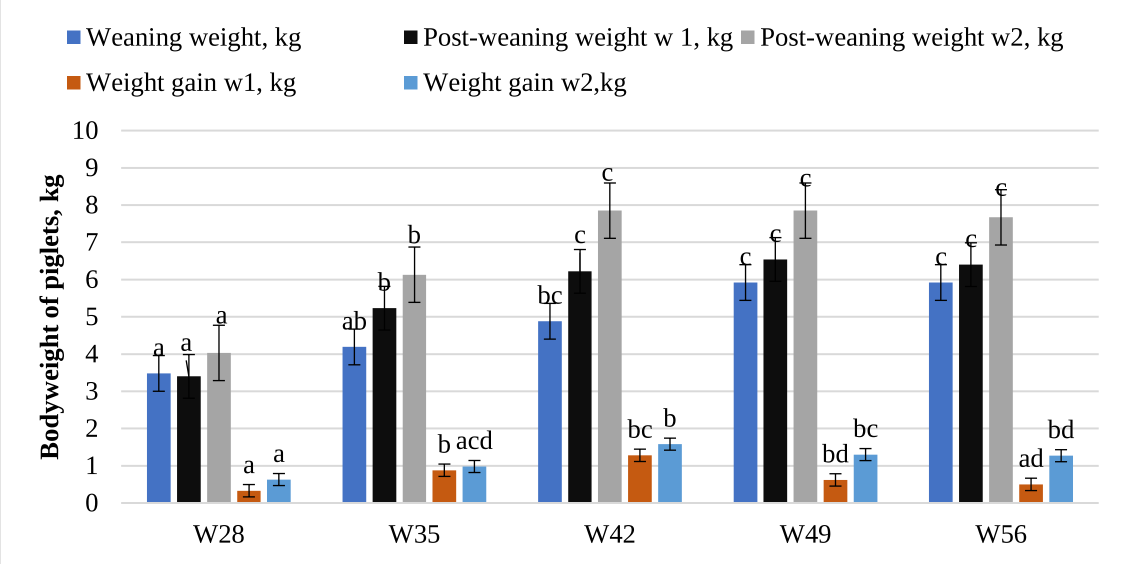
Figure 8: **Comparison of mummified and piglets' mortality between groups**



3.2.5. Effects of weaning age on post-weaning growth performance of piglets

Figure 9 shows no significant difference in the mean weaning weight (WW) of piglets in groups W28 and W35 (3.48 and 4.19 kg, respectively). Similarly, groups W35 and W42 found no difference in the WW of piglets. There was also no difference in the mean WW of the piglets in groups W42, W49, and W56 (4.88, 5.92, and 5.92 kg, respectively). The mean body weight of piglets during the 1st and 2nd post-weaning weeks did not differ in groups W42, W49, and W56, but it differed compared to W28 and W35. Piglets from group W42 gained the highest weight gain ($p < 0.040$) in 1st week after weaning (1.28 kg), whereas piglets from groups W28 and W56 gained substantially less (0.33 and 0.50 kg). In contrast, in the 2nd week, piglets in groups W42, W49, and W56 gained 1.58, 1.30, and 1.27 kg, respectively, almost double the weight gain in groups W28 and W35.

Figure 9: **Post-weaning growth performance of piglets as affected by weaning age**

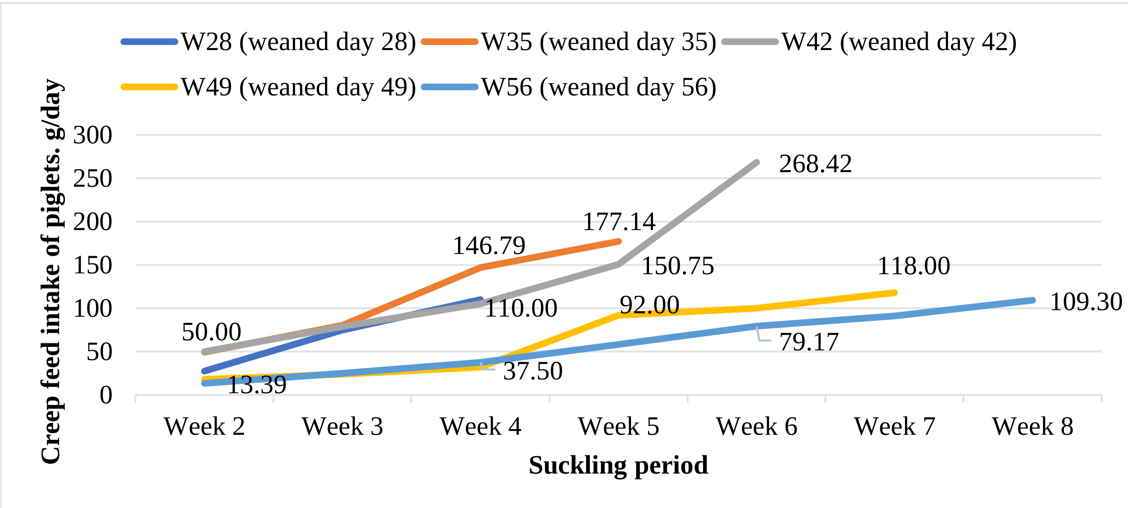


W28, W35, W42, W49, W56: the group of piglets were weaned at days 28, 35, 42, 49, and 56, respectively. [a,b,c:] mean with the same superscripts do not differ ($p > 0.05$).

3.2.6. Effects of weaning age on post-weaning feed intake of *Moo Lath* piglets

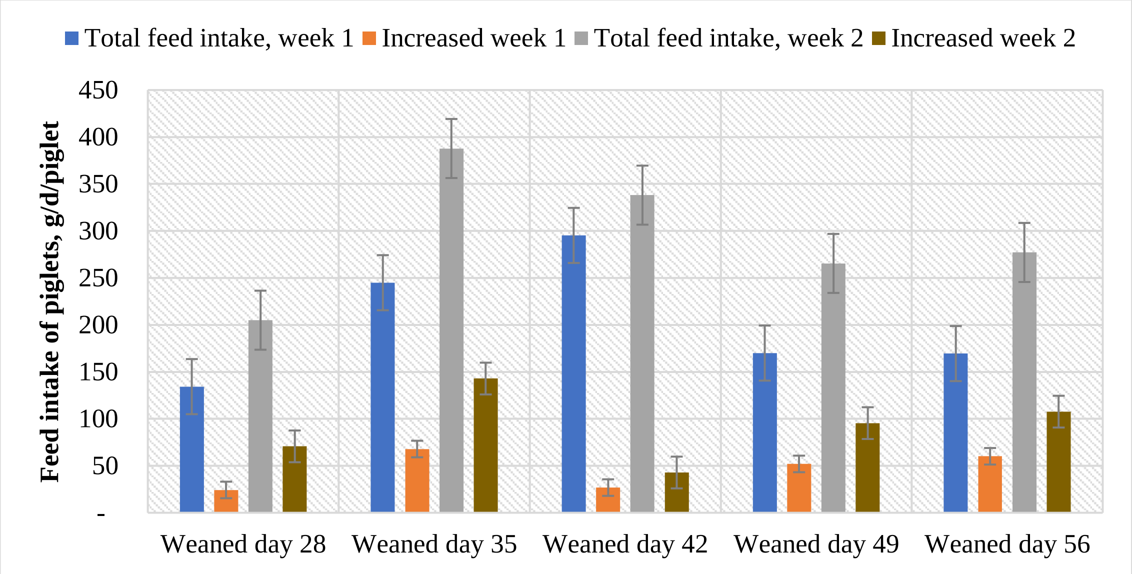
As mentioned above, growth performance and creep feed intake of piglets in this study were influenced by diarrhoea and the ability to recover after diarrhoea of the piglets. Between days 7 and 21 of suckling, most piglets were infected by bacteria and got diarrhoea, particularly after consuming solid creep feed on day 7 and chewing rice straw on the floor. *Figure 10* shows the overall piglets consumed the creep feed of about 32 g/day/piglet in the second week after farrowing. From weeks 5 to 6, the piglets consumed more creep feed, ranging from 92 to 268 g/day/piglet.

Figure 10: **Comparison of the creep feed intake of piglets between groups**



The average feed intake of piglets one week before weaning was approximately 165 g/day, ranging between 110 to 283 g/day. *Figure 11* exhibits the feed consumption of post-weaning piglets based on weaning age. The total feed intake in the 1st post-weaning week varied from 134−295 g daily. Interestingly, the total feed intake of piglets from groups W49 and W56 in the 1st post-weaning week was lower than those in groups W35 and W42. Although, in the second week of post-weaning, the piglets from each group consumed feed almost double compared to their first week. Still, the piglets from groups W49 and W56 consumed less feed than those from groups W35 and W42 (265 and 277 vs. 388 and 338 g, respectively). In contrast, the piglets from group W42 consumed feed increased by only 27 g in week 1 and 43 g in week 2 of post-weaning, different from other groups. Meanwhile, the piglets from group W35 consumed the highest feed intake, increasing the 1st and 2nd week after weaning.

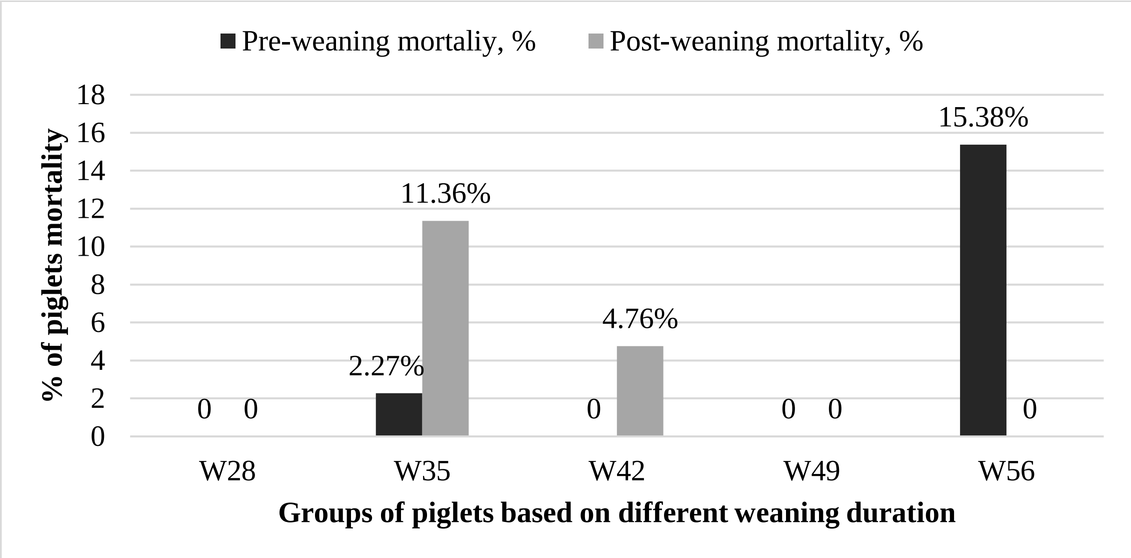
Figure 11: **The total feed intake of post-weaning piglets (g/day/piglets)**



3.2.7. Effects of weaning age on *Moo Lath* piglet mortality

As mentioned above, the present study found very low stillbirth and mortality of piglets within 3 days after farrowing. This study's average mortality of piglets was approximately 6.93% of live-born piglets, including 3.90% in pre-weaning mortality and 3.03% in post-weaning mortality. When observed explicitly, *Figure 12* shows the highest pre-weaning mortality was found in the piglets from group W56, with around 15.38% of the total born in the group died between weeks 7 and 8 of the suckling period, approximately 2.27% of total born in the group W35. In contrast, the highest post-weaning mortality was found in piglets from group W35, with about 11.36% of total born and 4.76% in piglets from group W42. This study was not found any piglets mortality in groups W28 and group W49.

Figure 12: **Comparison of piglet's mortality based on different weaning duration**

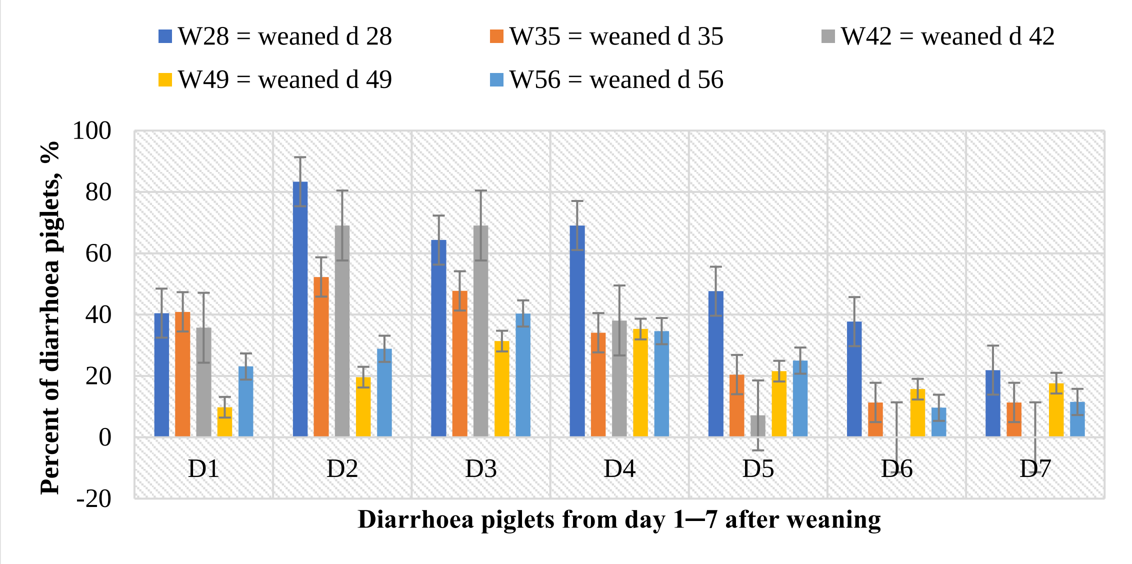


W28, W35, W42, W49, and W56: Weaned piglets at days 28, 35, 42, 49, and 56, respectively.

3.2.8. Effects of weaning age on diarrhoea infection of post-weaning *Moo Lath* piglets

Early post-weaning diarrhoea infection was a severe issue that blocked the growth performance of piglets in the present study, particularly on days 2 to 3 after weaning. However, there was no general difference ($p = 0.401$) in the percentage of diarrhoea piglets in the studied groups. But there was a significant difference ($p < 0.05$) when specific checks each day within the first post-weaning week, especially days 2 and 3. *Figure 13* shows approximately 83.33% on day 2 and 64.29% on day 3 of the total piglets in group W28 got diarrhoea. Meanwhile, groups W49 (19.6 and 31.37%) and W56 (28.85 and 40.39%) were less infected. Though, the percent of diarrhoea explored in the piglets between groups W28 and W42 did not differ and was very close to each other on days 2 and 3. But, the piglets in group W42 appeared to recover faster. Almost all piglets from each studied group had no new diarrhoea after day 10 of weaning. Bacteria-infected piglets in all studied groups were mainly caused by *Escherichia coli* (ssp.) infection covering 100%, *Enterobacter* (spp.) 80%, and *Klebsiella* (spp.) covering 40% of total diarrhoea piglets.

Figure 13: **Comparison of the diarrhoea piglets' percentage.**



D1, D2, D3, D4, D5, D6, D7: day 1, 2, 3, 4, 5, 6, and day 7 after weaning.

3.2.9. Effects of supplementing dried green banana in the diet on reducing *Moo Lath* piglets' post-weaning diarrhoea

To compare the effects of supplementing 10% of dried green banana in the piglets' diet 3 days pre-and post-weaning on reducing diarrhoea in piglets. Seventy-five (75) piglets were used in the study and divided into 2 groups (A "30 piglets" = supplement, and B "45 piglets" = not supplementing dried meal green banana in diet). Approximately 79.29% of total piglets in group B got diarrhoea infection after weaning, and 57.14% occurred within the 1st post-weaning week. Meanwhile, 40% of group A piglets got diarrhoea in the 1st-week and no new infection in the 2nd week.

3.2.10 Effects of lactation length on *Moo Lath* primiparous sow's body conditions and post-weaning performance

Table 4 shows the mean body weight of gilts before farrowing was 76.22±9.09 kg, and the heaviest (89.08 kg) was found in sows in group W56. Meanwhile, the thinnest backfat thickness (BF) of gilts before farrowing was observed (41.52 mm) in group W42. There was no significant difference in the loss of body weight ($p = 0.894$) and BF ($p = 0.511$) of the sows after farrowing between the studied groups. Similarly, there was no difference ($p = 0.179$) in weight loss at weaning time, while BF ($p < 0.003$) was.

The largest body weight loss (24.58 kg) at weaning was found in group W56 sows; the smallest (17.51 kg) was observed in group W28 sows. Similarly, the largest BF loss (p <

0.034) was observed in the group W56 sows (15.14 mm). This differs significantly ($p < 0.05$) with group W28 sows (5.96 mm). Conversely, it was not the case ($p > 0.05$) if compared to sows from groups W35, W42, and W49 (8.66, 8.01, and 12.38 mm, respectively). Group W35 sows had the most significant weight loss of around 32%, while 25% in W28, 24% in W42, 29% in W49, and 28% in sows from group W56. In contrast, BF loss was observed in over 29% of sows from group W56, 27% in W49, 19% in W35 and W42, and over 12% in sows from group W28. Group W56 sows lost over 7 kg of their body weight compared to those sows in group W28. Over 9 mm of BF was lost at a weaning time in the group W56 sows compared to those in group W28.

Table 4

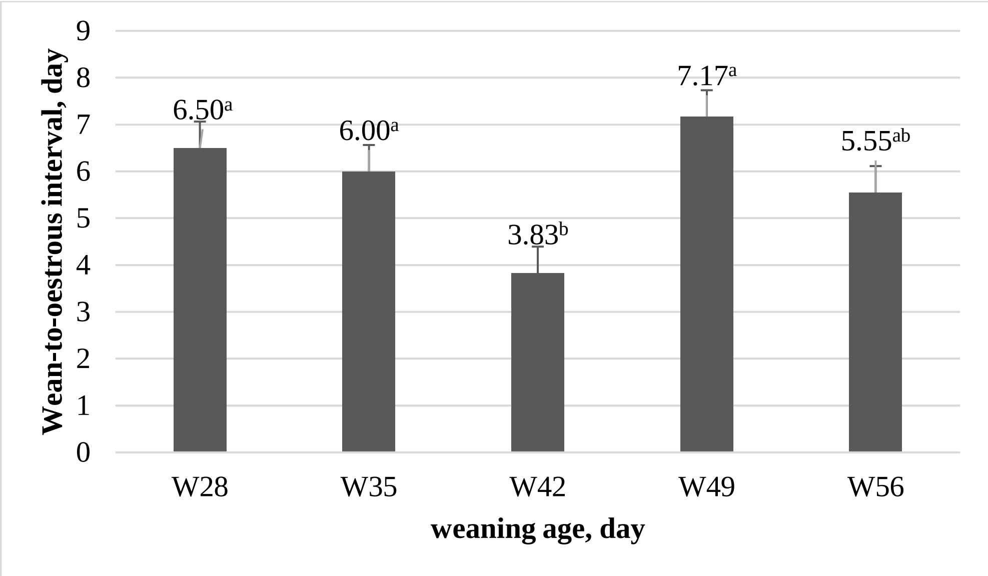
The BW and BF thickness of the sows changes from farrowing to weaning.

Parameters	**Weaning age (day)**					**Mean±SD**	**P-value**
	W28	**W35**	**W42**	**W49**	**W56**		
No. of sows	6	6	6	6	6		
BWF, kg	70.46^{a}	74.08^{a}	75.38^{a}	72.12^{a}	89.08^{b}	76.22±9.09	0.000
BFF, mm	48.62	45.95	41.52	46.87	52.05	47.00±6.69	0.082
WLF, kg	11.99	13.38	13.08	12.36	11.17	12.39±3.93	0.894
BFLF, mm	5.22	8.62	9.82	4.58	6.64	5.63±3.34	0.511
BWW, kg	58.46^{a}	60.70^{a}	62.30^{a}	59.75^{a}	77.90^{b}	63.82 ±10.31	0.001
BFW, mm	43.40^{ace}	37.33^{e}	31.70^{b}	42.28^{ace}	45.61^{dc}	40.06±7.63	0.005
BWLW, kg	17.51	23.98	17.73	20.99	24.58	20.95±6.54	0.179
BFLW, mm	5.96^{a}	8.66^{ab}	8.01^{ab}	12.38^{bc}	15.14^{c}	8.10±7.01	0.034

W28, W35, W42, W49, W56: sows weaned on days 28, 35, 42, 49, and 56, respectively. BWF, BFF: body weight and backfat of sow before farrowing; WLF, BFLF: weight and backfat lost 1 week after farrowing; BWW, BFW: body weight and backfat at weaning; BWLW, BFLW: body weight and backfat lost at weaning. $^{a,b,c,d:}$ Means with the same superscripts do not differ ($p > 0.05$).

The body weight of *Moo Lath* primiparous sows gradually decreased from week 4 (12%) and became more severe after week 7 (26%) of lactation. But, this loss did not find an adverse result on the first service conception of sows after weaning in the present study. The weaning-to-oestrous interval (WEI) of *Moo Lath* primiparous sows varied between 3 and 9 d after weaning, averaging about 5.80±1.76 d (*Figure 14*). There was a significant difference ($p < 0.007$) in the WEI of sows between the studied groups. Sows in group W49 had the longest mean WEI, while the shortest was observed in group W42 (7.17 vs. 3.83 d). In contrast, it differed in the WEI of the sows from group W42 compared to those in groups W28, W35, and W49. Sows in group W42 had the shortest mean WEI (3.83 d), while sows in group W49 had the longest (7.17 d).

Figure 14: **The WEI of *Moo Lath* primiparous sows due to the weaning age**



W28, W35, W42, W49, W56: sows weaned on days 28, 35, 42, 49, and 56, respectively. [a,b:] Means with the same superscripts do not differ (p > 0.05).

3.3. Effects of birth weight on age at puberty and first mating and reproductive performance of crossbred CMD gilts

Table 5 shows the birth weight of CMD gilts did not influence ($p = 0.126$) their age at puberty, with an average of about 137.47±10.07 d. The gilts in group A showed puberty slightly earlier than those in groups B and C (131.86±8.32, 142.75±13.57, and 142.00±3.56 d, respectively). Similarly, there was no difference in the mean body weight ($p = 0.826$) at puberty (31.35±5.44 kg). The gilts in group A had 30.62±5.09 kg of mean body weight at puberty, while those in group B had 32.85±8.63 kg, and gilts in group C had 31.13±2.73 kg.

In contrast, the birth weight of CMD gilts might influence the BF at puberty and first mating. The larger birth weight gilts showed a thicker backfat at puberty than those with smaller birth weights. As shown in *Table 5*, gilts in group C had a significantly thicker BF than those in group A at puberty and first mating (44.69 vs. 35.14 mm and 42.93 vs. 36.60 mm, respectively). The mean age at first mating was 193.27±16.71 d (168−229 d), with a body weight of about 39.69 kg and 38.18 mm of backfat thickness.

Table 5

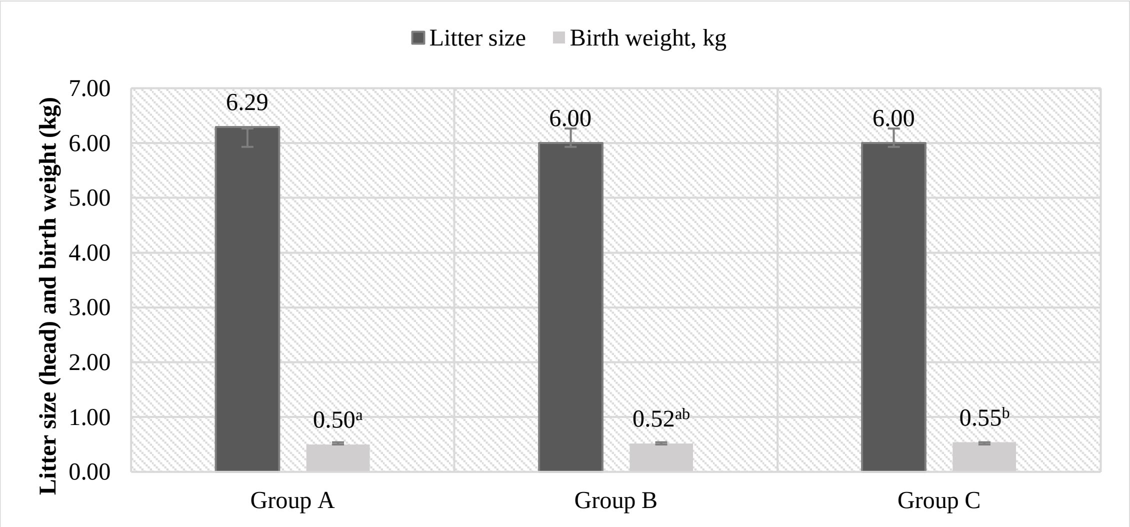
Ages at puberty and first mating and body condition of CMD gilts

Parameters	Gilts based on birth weight			Mean±SD	p-value
	A	B	C		
Number of gilts	7	6	5		
Age at puberty, day	131.86	142.75	142.00	137.47±10.07	0.126
Body weight at puberty, kg	30.62	32.85	31.13	31.35±5.44	0.826
Backfat at puberty, mm	35.14[a]	43.28[b]	44.69[b]	39.86±7.12	0.039
Age at first mating, day	195.57	198.00	184.50	193.27±16.71	0.493
Body weight at first mating, kg	36.60	41.85	42.93	39.69±5.91	0.162
Backfat at first mating, mm	32.66[a]	41.35[ab]	44.66[b]	38.18±8.29	0.031

A, B, C: groups of gilts based on their birth weight with < 0.7, ≥ 0.7−0. ≤, and > 0.9 kg, respectively. [a,b,:] Means in the same row with the same letters do not differ ($p > 0.05$).

The birth weight of CMD gilts did not influence their litter size ($P = 0.826$). However, *Figure 15* shows the mean litter size of gilts in group A was 6.29±0.76, marginally larger than those in groups B and C (6.00±0.82 and 6.00±1.16, respectively). On the other hand, the birth weight of CMD gilts influenced the birth weight of their offspring ($P < 0.042$). The mean birth weight of piglets born from the gilts in group C produced was 0.55±0.33 kg, which was slightly heavier than those from the gilts in groups A and B (0.50±0.03 kg and 0.52±0.3 kg, respectively).

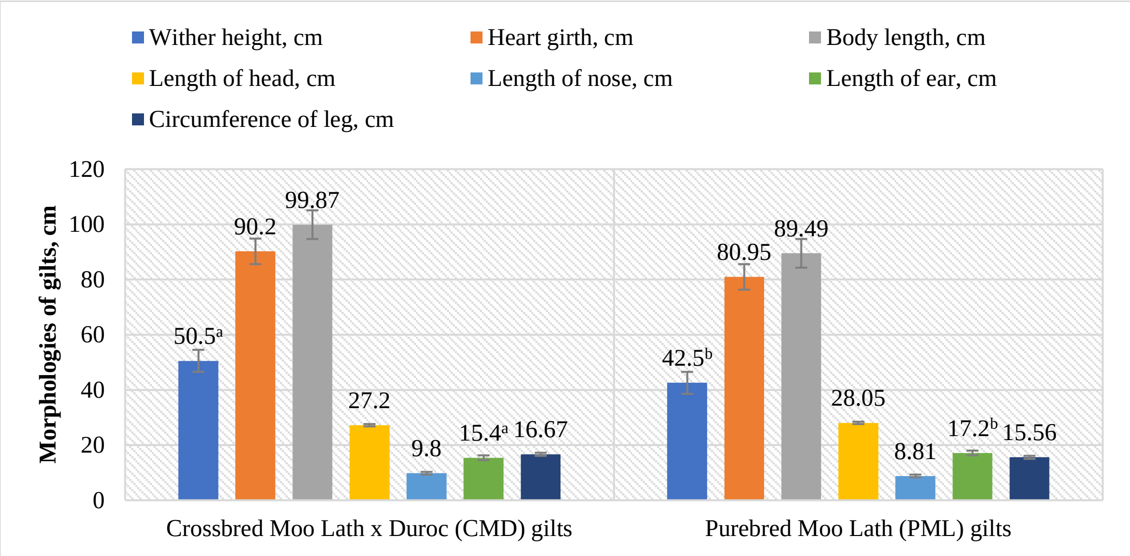
Figure 15: **Comparison of the litter size and birth weight based on the gilts' birth weight**



Group A, B, C: groups gilts based on their birth weight with < 0.7, ≥ 0.7−0.8 ≤, and > 0.9 kg, respectively. a,b,: Means with the same superscripts do not differ ($p > 0.05$).

Figure 16 indicates the CMD gilt has a significantly taller ($p < 0.026$) wither height than PML gilts (50.53±4.80 vs. 42.55±11.16 cm). The average body length and heart girth of CMP gilts at first mating are longer ($p > 0.05$) than the PML gilts (99.87±8.65 and 90.20±8.36 cm vs. 89.49±9.74 and 80.95±9.24 cm, respectively). The average body length and heart girth of CMD gilts at first mating are longer, almost 10 cm, than the mature PML gilts.

Figure 16: **Comparison of the morphology of the CMD and PML gilt at their first mating**



CMD: crossbred *Moo Lath* x *Duroc*; PML: purebred *Moo Lath*. [a,b]: Mean with the same superscripts do not differ ($p > 0.05$).

4. NEW SCIENTIFIC RESULTS

1) The litter size of Moo Lath primiparous sows can be increased by two or three piglets if assisted reproductive techniques are used.
2) The capacity of Moo Lath primiparous sows' uterus is not more than 8 fetuses.
3) The optimal body weight of Moo Lath gilts at first mating is between 40-45 kg when the age of the gilts is 210-240 days, and the backfat thickness is between 30-40 mm.
4) Supplementing 10% dried green banana (Musa Acuminata) can be beneficial to reduce diarrhoea incidence post-weaning piglets.
5) For Moo Lath sows, the body weight loss duration of lactation is between 17.50 and 24.58 kg, and loss of backfat thickness of about 5.97−15.14 mm did not have a severe negative impact on the weaning-to-oestrous interval and first conception after weaning.

5. RESULTS APPLICABLE IN PRACTICE

1. Combining the traditional pig-raising system in rural areas of Laos with modern extensive as the current Hungarian *Mangalica* pig-raising system in Hungary should be a high chance to improve the reproductive performance and pig quality production in Laos. This is because Laos, particularly in the rural areas, has more potential to apply the modern extensive pig-raising system. Therefore, traditional extensive pig-raising still domains in rural Laos, but it needs the proper management methods to operate sustainably for rural development based on Lao economic strategy.
2. Lactating pen, with areas of about 2 x 1.5 m, or 3 $m^{2,}$ can be used for only 5 to 6 weeks of lactation for a *Moo Lath* sow with about 7−8 piglets. This means that farmers need to consider increasing the proper size of the lactating pen for *Moo Lath* when the suckling period needs to be extended beyond 6 weeks. Otherwise, it will harm the welfare and health of both sows and piglets.
3. The optimal age of *Moo Lath* at first mating is between 210 and 240 days when they come to the 3rd and 4th oestrous cycle and attain a body weight of about 40 kg. With these figures, the gilts have the optimum body condition for lactating her 7−8 piglets until 5 or 6 weeks after farrowing.
4. Utilizing artificial insemination techniques could be a high chance of improving the reproductive performance of Lao indigenous pig breeds as well as meat quality.
5. Applying dried green bananas to treat diarrhoea in piglets for both pre-and post-weaning is an excellent option for native pig farmers, which not need higher skill to operate it. Moreover, there is plenty of banana (*Musa Acuminata*) in Laos, especially in rural areas. In this regard, the farmers do not need more expenditure on purchasing bananas for their piglets.

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7. PUBLICATIONS ON THE TOPIC OF THE DISSERTATION

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Doctoral School: Doctoral School of Animal Husbandry
MTMT ID: 10070656

List of publications related to the dissertation

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1. **Xayalath, S.**, Rátky, J., Komlósi, I.: Reproductive performance of indigenous pig breeds in Southeast Asia.
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3. **Xayalath, S.**, Mujitaba, M. A., Ortega, A. D. S. V., Khangembam, R., Novotniné Dankó, G., Rátky, J.: Effects of birth weight on puberty and the reproductive performance of crossbred Moo Lath x Duroc gilts = A születési súly hatása az ivarérésre és a szaporodásbiológiai teljesítményre keresztezett Moo Lath x Duroc kocasüldőknél.
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Total IF of journals (all publications): 5,184
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The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

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