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Associations between Sow Body Condition with Subsequent Reproductive Performance

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Abstract

The objective was to quantify relationships between sow body condition and subsequent reproduction. Multiparous sows were measured at breeding (n = 1571) and farrowing (n = 887) on a commercial farm in eastern North Carolina. Sow body condition measures included: sow body condition caliper (CS), weight (BW), backfat, longissimus muscle area (LMA) and visual body condition score (BCS). Sow production traits were: number born alive (NBA), litter birth weight (LBW), number weaned (NW), piglet survival (PS), litter weaning weight (LWW), wean-to-conception interval (WCI), farrowing rate and lactation average daily feed intake. Data were analyzed in SAS using PROC GLM for continuous traits and PROC GLIMMIX for categorical traits. Breeding CS had a curvilinear relationship ($P < 0.05$) with NBA, LBW, NW, PS and WCI, with a CS of 15 being optimal for NBA, NW and PS and 14 ideal for LBW and WCI. Breeding LMA had a curvilinear relationship ($P < 0.05$) with PS, with 51.5 cm^2 maximizing survival. Breeding BCS had a curvilinear relationship ($P < 0.05$) with NBA, LBW, NW, PS and WCI, with 3.2 being optimal for NBA, NW and WCI and 3.0 ideal for LBW and PS. Farrowing CS had a curvilinear relationship ($P < 0.05$) with NW and PS, with 15 being optimal. Farrowing BCS had a curvilinear relationship ($P < 0.05$) with NW and PS, with 3.6 being ideal. Farrowing BW had a curvilinear relationship ($P < 0.05$) with LWW and PS, with a BW of 220 and 210 kg, respectively, being optimal. Farrowing LMA had a curvilinear relationship ($P < 0.05$) with WCI, with 51.6 cm^2 being ideal. Results provide sow body condition targets to maximize reproductive throughput. The present study suggests feeding sows to a target sow body condition caliper score of 14 to 15 (representing a back angle of 130˚ to 132.5˚) to maximize sow productivity.

Keywords

Backfat, Body Condition, Reproduction, Sow, Sow Caliper

1. Introduction

Sows are commonly fed during gestation based on a subjective body condition target [1]. Yet [2] reported participants consistently over or underestimated visual sow body condition, forming their own "ideal". Inconsistencies in visual body condition evaluation may lead to sows being improperly fed, resulting in impaired reproduction. Hence, objective methods of scoring sow body condition should be developed and evaluated in relation to reproductive performance.

Objective tools are available to measure sow body condition. Sow weight can be captured using a scale or estimated using heart girth circumference [3]. Backfat depth and longissimus muscle area can be estimated using ultrasound technology. The sow body condition caliper estimates a sow's body reserves by quantifying the angularity from the spinous process to the transverse process of a sow's back [4]. Yet the relationships between these objective body condition tools and subsequent reproduction are not well understood.

Ideal sow body condition in relation to reproductive performance is not well defined. When using a five-point scale to visually evaluate sow body condition, a three is ideal [5]. However, there is no evidence that a visual body condition score of three enhances reproduction. Hence, research is needed to identify optimal sow condition targets in relation to reproductive performance. Therefore, the objective was to quantify relationships between objective and visual sow body condition traits with subsequent reproduction.

2. Materials and Methods

2.1. Animals and Facilities

Multiparous crossbred sows were measured at breeding (n = 1571) and farrowing (n = 887) at a commercial sow farm in eastern North Carolina. Genetics of the sows consisted of Landrace boars mated to Large White × Chester White F1 females. Housing consisted of curtain-sided breeding and gestation barns fitted with cool cell pads, mechanical ventilation and flush gutters. Sows were housed in individual stalls until day 30 of gestation, then allocated to group pens (3.02 × 2.44 m) by size with four to five sows per pen. Pen flooring was 50% solid concrete and 50% slatted with one nipple drinker per pen. Sows lactated in individual farrowing stalls with woven wire flooring. During gestation and lactation, sows were fed diets that met or exceeded NRC requirements [6] and offered water ad libitum. In gestation, sows were hand-fed daily and feeding amounts were adjusted based on visual body condition score. During lactation, sows were hand fed twice a day for the first eight days of lactation on a step-up program starting with 1.81 kg of feed and increasing feed by 0.9 kg per day. After day eight of lactation, sows were fed three times per day to appetite.

2.2. Measurements

Body condition measures included the sow body condition caliper [4], weight, backfat, longissimus muscle area and visual body condition score. The sow body

condition caliper quantifies the angularity from the spinous process to the transverse process of a sow's back [4]. A sow caliper score of 12 to 15 is considered ideal, representing a back angle of 125˚ to 132.5˚, respectively. Hence, a one-unit increase in sow caliper score corresponds to a 2.5˚ degree increase in the angle of the sow's back. Weight at farrowing was captured approximately one week prior to parturition. Therefore, farrowing weight was adjusted to account for piglet and placental weight using the following equation weight (kg) = −19.75 + 0.973 × pre-farrow weight − 1.09 × number of pigs born [7]. A National Swine Improvement Federation certified real-time ultrasound technician measured backfat and longissimus muscle area from a cross-sectional 10th rib image using an Aloka 500 V SSD ultrasound machine (Corometrics Medical Systems, Inc., Wallingford, CT). Visual sow body condition was assessed by the first author using a five-point scale with 1 being too thin, 3 representing ideal and 5 being overly fat.

Reproductive traits included number born alive, litter birth weight, number weaned, litter weaning weight, piglet survival, wean-to-conception interval, lactation average daily feed intake and farrowing rate. Litter birth weight, measured at birth, included all liveborn piglets. Piglet survival was calculated as piglet survival = number weaned ÷ (total number born + number of piglets cross-fostered).

2.3. Statistical Analysis

Data were analyzed using general linear models (PROC GLM) for continuous traits and generalized linear mixed models (PROC GLIMMIX) for categorical traits in SAS 9.3 (SAS Inst. Inc., Cary, NC). The PROC GLM procedure is an analysis of variance that computes means using an F-test. The PROC GLIMMIX procedure was used to analyze a response variable from a non-normal distribution and obtain probabilities for a binary trait. Like linear mixed models, generalized mixed linear models assume normal (Gaussian) random effects and conditional on the normally distributed random effects, data can have any distribution in the exponential family. A value of $P < 0.05$ was considered statistically significant in all tests. Fixed effects in all models included: farrowing group, barn, parity and the interaction between farrowing group and barn. The following is an example of the statistical model that was used: reproductive trait = farrowing group + barn + farrowing group*barn + parity + body condition trait.

3. Results

Average total number born, number born alive, litter birth weight, number weaned, litter weaning weight, piglet survival, wean-to-conception interval, lactation average daily feed intake and farrowing rate were 12.2, 11.2, 16.9 kg, 10.2, 72.7 kg, 82%, 4.7 days, 6.9 kg and 86%, respectively. At breeding, average sow caliper score, body weight, 10th rib backfat, 10th rib longissimus muscle area and body condition were 15, 228 kg, 26 mm, 50.1 cm^2 and 3.2, respectively.

3.1. Sow Body Condition and Subsequent Reproduction

Regression estimates between sow body condition traits at breeding with subsequent reproductive performance are reported in Table 1. A greater sow caliper score at breeding was associated ($P < 0.05$) with increased farrowing rate (Figure 1). Relationships between sow caliper score at breeding with subsequent number born alive, litter birth weight, number weaned, piglet survival and wean-to- conception interval were curvilinear ($P < 0.05$). A sow caliper score at breeding of 15 maximized reproduction for subsequent number born alive, number weaned and piglet survival (Figure 2) and a sow caliper score at breeding of 14 maximized litter birth weight and minimized wean-to-conception interval.

Regression estimates between sow body condition at farrowing with reproductive performance are reported in Table 2. A one unit increase in sow caliper score at farrowing was associated ($P < 0.05$) with decreased number born alive, litter birth weight and lactation average daily feed intake. Associations between sow caliper score at farrowing with number weaned and piglet survival were curvilinear ($P < 0.05$). A sow caliper score at farrowing of 15 maximized number weaned and piglet survival (Figure 3).

Relationships between sow body weight at breeding with subsequent reproduction were linear. An increase in sow body weight at breeding was associated ($P < 0.05$) with decreased litter weaning weight and piglet survival and increased wean-to-conception interval.

An increase in sow body weight at farrowing was related to a decrease in number born alive and number weaned. Associations between sow body weight at farrowing with litter weaning weight and piglet survival were curvilinear ($P < 0.05$). A sow body weight at farrowing of 220 and 210 kg maximized reproduction for litter weaning weight and piglet survival, respectively. A 10 kg increase in sow body weight at farrowing decreased ($P < 0.05$) lactation average daily feed intake by 0.029 kg.

Correlations between backfat at breeding and backfat at farrowing with subsequent reproduction were linear. Greater backfat at breeding was associated ($P < 0.05$) with improved farrowing rate (Figure 4). Increased backfat at breeding was related ($P < 0.05$) to lower subsequent number born alive, litter birth weight, litter weaning weight and lactation average daily feed intake. Increased backfat at breeding was also correlated ($P < 0.05$) with a greater wean-to-conception interval. Greater backfat at farrowing was associated ($P < 0.05$) with reduced number born alive and lactation average daily feed intake.

Relationships between sow body condition score at breeding with subsequent number born alive, litter birth weight, number weaned, piglet survival and wean-to-conception interval were curvilinear ($P < 0.05$). A sow body condition score at breeding of 3.0 maximized reproduction for litter birth weight and piglet survival and a sow body condition score of 3.2 maximized productivity for number born alive, number weaned and wean-to-conception interval (Figure 5). A greater sow body condition score at breeding was associated ($P < 0.05$) with

Table 1. Regression estimates between sow body condition at breeding with subsequent reproductive performance from 1571 multiparous crossbred sows.

	Body condition trait at breeding[†]							
Reproductive trait	CS	CS[‡]	BW, kg	BF, mm	LMA, mm^2	LMA[‡], mm^2	BCS	BCS[‡]
Farrowing rate, %	0.09*		0.0037	0.028*	0.027		0.23	
Number born alive	1.37*	−0.046*	−0.0045	−0.044*	0.032		20.93*	−0.46*
Litter birth weight, kg	1.46*	−0.052*	−0.0049	−0.061*	0.019		30.68*	−0.60*
Number weaned	1.25*	−0.042*	−0.0081	−0.025	0.022		30.53*	−0.56*
Litter weaning weight, kg	−0.42		−0.067*	−0.17*	−0.14		−10.98*	
Piglet survival, %	9.26*	−0.31*	−0.083*	−0.151	30.66*	−0.036*	230.7*	−30.9*
Wean-to-conception interval, d	−3.17*	0.11*	0.023*	0.074*	0.023		−60.04*	0.97*
Lactation ADFI, kg	0.011		−0.0008	−0.013*	0.007		−0.003	

Regression estimates from PROC GLM except farrowing rate estimates from PROC GLIMMIX. [†]CS = sow body condition caliper score; BW = sow body weight; BF = 10th rib backfat depth; LMA = 10th rib longissimus muscle area; BCS = visual sow body condition score (five-point scale with 1 being too thin, 3 representing ideal and 5 being overly fat); [‡]Quadratic estimate for respective trait; *P < 0.05.

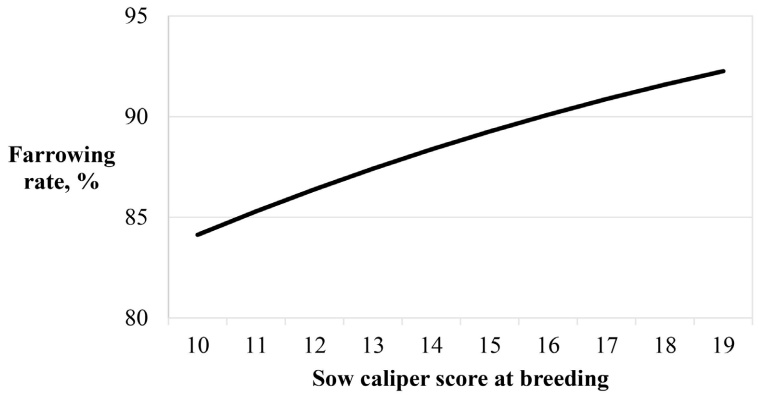

Figure 1. Association between sow caliper score at breeding with subsequent farrowing rate for 1571 multiparous crossbred sows.

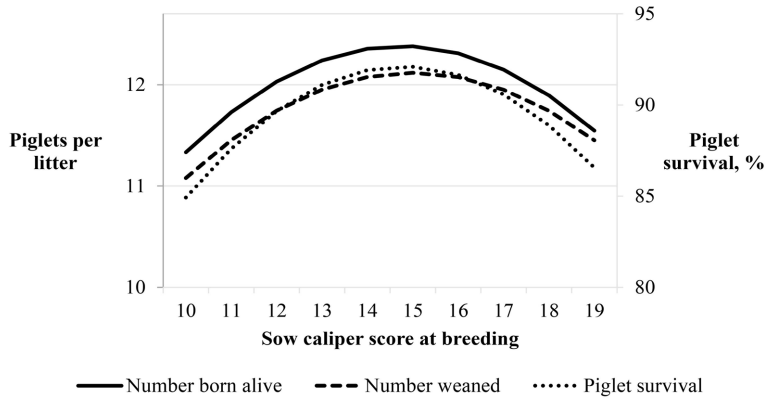

Figure 2. Relationship between sow caliper score at breeding with subsequent number born alive, number weaned and piglet survival for 1571 multiparous crossbred sows.

Table 2. Regression estimates between sow body condition at farrowing with subsequent reproductive performance from 887 multiparous crossbred sows.

	Body condition trait at farrowing[†]								
Reproductive trait	CS	CS[‡]	BW, kg	BW[‡], kg	BF, mm	LMA, mm^2	LMA[‡], mm^2	BCS	BCS[‡]
Number born alive	−0.154*		−0.0111*		−0.031*	−0.042*		−0.22	
Litter birth weight, kg	−0.306*		−0.0036		−0.059	−0.042		−0.96*	
Number weaned	10.06*	−0.036*	−0.0067*		−0.018	−0.015		30.05*	−0.44*
Litter weaning weight, kg	−0.019		0.920*	−0.0021*	−0.028	0.26		20.25	
Piglet survival, %	0.098*	−0.0032*	0.0084*	−2E−05*	−0.001	−0.0003		0.27*	−0.039*
Wean-to-conception interval, d	0.021		0.004		0.017	−0.405*	0.0039*	0.048	
Lactation ADFI, kg	−0.035*		−0.0029*		−0.011*	0.110*	−0.0012*	−0.12*	

Regression estimates from PROC GLM except farrowing rate estimates from PROC GLIMMIX. [†]CS = sow body condition caliper score; BW = sow body weight; BF = 10th rib backfat depth; LMA = 10th rib longissimus muscle area; BCS = visual sow body condition score (five-point scale with 1 being too thin, 3 representing ideal and 5 being overly fat); [‡]Quadratic estimate for respective trait; *P < 0.05.

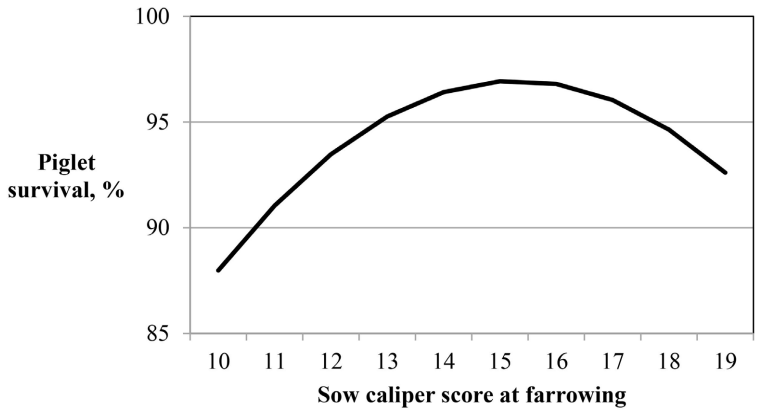

Figure 3. Correlation between sow caliper score at farrowing with piglet survival for 887 multiparous crossbred sows.

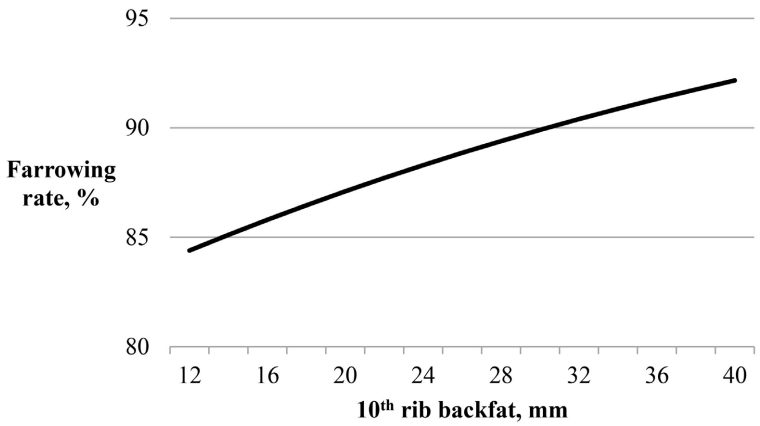

Figure 4. Association between sow 10th rib backfat at breeding with subsequent farrowing rate for 1571 multiparous crossbred sows.

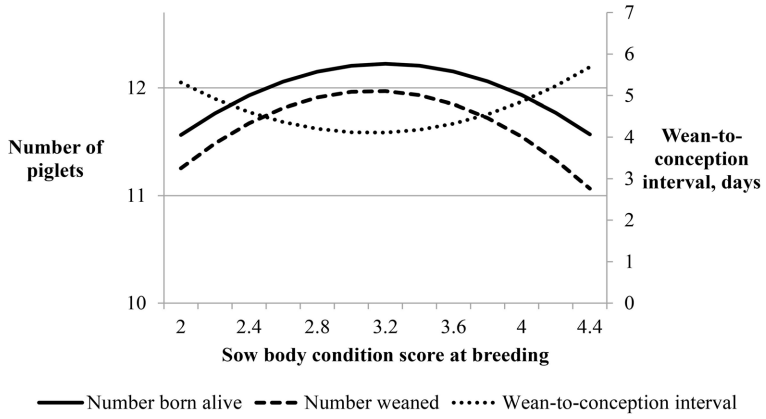

Figure 5. Relationship between sow body condition score at breeding with number born alive, number weaned and wean-to-conception interval for 1571 multiparous crossbred sows.

lower litter weaning weight.

A higher sow body condition score at farrowing was associated ($P < 0.05$) with decreased litter birth weight and lactation average daily feed intake. Yet associations between sow body condition score at farrowing with number weaned and piglet survival were curvilinear ($P < 0.05$). A sow body condition score of 3.6 maximized reproduction for number weaned and piglet survival (**Figure 6**).

3.2. Lactation Average Daily Feed Intake and Reproduction

Relationships between lactation average daily feed intake with reproductive performance are shown in **Table 3**. An increase in lactation average daily feed intake increased ($P < 0.05$) subsequent number born alive and litter birth weight.

In the concurrent lactation, associations between lactation average daily feed intake with number weaned, piglet survival and wean-to-conception interval were curvilinear ($P < 0.05$). A lactation average daily feed intake of 6.6 kg minimized wean-to-conception interval. Yet lactation average daily feed intake increased ($P < 0.05$) substantially as number weaned and piglet survival increased. An increase in lactation average daily feed intake was associated ($P < 0.05$) with improved litter weaning weight.

4. Discussion

To our knowledge, the present study is the first to identify "ideal" sow body condition in relation to reproduction across multiple sow condition measures. Hence, pig farmers can use this information to help define body condition targets for their respective sow herds.

4.1. Sow Body Condition Caliper

"Ideal" sow condition targets were established for the sow body condition caliper. The ideal sow caliper score at breeding in relation to number born alive, litter birth weight, number weaned, piglet survival and wean-to-conception interval

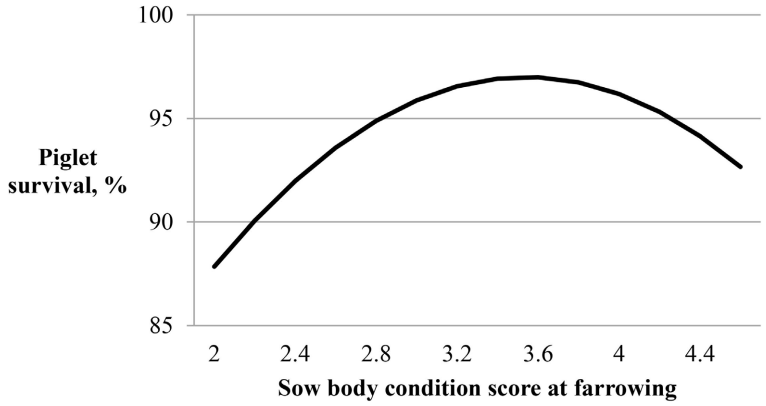

Figure 6. Association between sow body condition score at farrowing with piglet survival for 887 multiparous crossbred sows.

Table 3. Regression estimates between sow lactation average daily feed intake (ADFI) and reproductive performance.

Reproductive trait	Lactation average daily feed intake, kg		
	Previous lactation	Concurrent lactation	
	ADFI	ADFI	ADFI[†]
Number born alive	0.691*		
Litter birth weight, kg	0.996*		
Number weaned	0.339	2.98*	−0.162*
Litter weaning weight, kg	0.611	8.64*	
Piglet survival, %	2.21	25.2*	−1.51*
Wean-to-conception interval, days	0.696	−7.63*	0.578*
Farrowing rate, %	0.009		

Regression estimates from PROC GLM except farrowing rate estimates from PROC GLIMMIX. [†]Quadratic estimate for respective trait; *P < 0.05.

was 14 or 15 (representing a sow back angle of 130˚ to 132.5˚). In agreement, [8] reported reproductive throughput was maximized at a sow caliper score of 13. However, that study included substantially fewer sows (n = 75). [9] recommended sows be maintained at a sow caliper score of 12.5 to 14. Taken together, these studies suggest sow reproductive throughput is maximized at a sow caliper score at breeding of 13 to 15 units. Hence maintaining sows at much higher sow caliper scores will lead to excessive feed costs and may impair reproduction. Further, feeding sows to a much lower sow caliper target may impair sow reproductive performance and sow well-being [10].

At farrowing, a greater sow caliper score was associated with lower number born alive, litter birth weight and lactation average daily feed intake. Yet relating sow body condition at the end of gestation to reproduction is likely confounded with litter size. Sow's carrying smaller litters (vs. larger litters) are more likely to gain body reserves in late gestation as fewer nutrients are needed to sustain their

progeny. Hence, relating sow condition in late gestation to litter size, and other reproductive traits, should be met with caution. Nonetheless, sow body condition in late gestation should be managed to keep sows near an "ideal" sow body condition target. Similar to the present study, [9] reported lactation average daily feed intake decreased as sow caliper score at farrowing increased.

[11] correlated gilt caliper score at farrowing with subsequent reproductive performance on over 4,000 females. Gilts with a caliper score of 12 to 15 at farrowing had greater retention rate, number of total pigs born and total pigs weaned through parity 3 when compared to thinner or fatter gilts. While gilts were not present in the current study, perhaps the study by [11] suggests the sow body condition caliper may also be used to manage gilt body condition and optimize reproductive throughput.

A greater sow caliper score at breeding was associated with increased farrowing rate. This indicates heavier conditioned sows at weaning were more likely to farrow a subsequent litter. The sow caliper score is a composite trait of weight, backfat and muscling [4] essentially estimating the fleshiness of a sow. Past research supports the concept that sows with sufficient muscle reserves at breeding should have enhanced subsequent reproduction [12].

4.2. Sow Body Weight

A greater sow body weight at breeding reduced subsequent litter weaning weight and piglet survival. In agreement, [13] [14] [15] reported heavier sows had greater piglet mortality. [16] proposed the association between sow body weight with piglet mortality is related to farrowing crate length suggesting that larger sows are less comfortable in shorter farrowing crates. This concept is supported by [17] who reported sows that were large, relative to farrowing crate dimensions, had greater piglet mortality than sows that were smaller. Taken together, these studies suggest heavier sows have impaired piglet survival and that optimal farrowing crate dimensions, especially farrowing crate length, should be evaluated in relation to piglet survival.

4.3. Sow Backfat

In the current study, relationships between sow backfat with reproductive traits were linear. In contrast, [18] and [19] suggested an "ideal" last rib backfat of 18 to 20 mm at farrowing. Suggesting an "ideal" sow backfat is challenging without establishing curvilinear relationships between sow backfat and reproduction. Yet [1] did report sows entering lactation with greater than 21 mm of backfat had smaller subsequent litter sizes than sows with 17 to 21 mm of backfat.

In the present study, greater sow backfat at breeding was associated with reduced subsequent piglet throughput (number born alive, litter birth weight and litter weaning weight). In agreement, [1] found sows with a backfat of greater than 21 mm had smaller subsequent litter sizes. Similarly, [15] showed sows with greater backfat tended to have smaller subsequent litters. In contrast, [20] reported subsequent litter size increased as backfat at breeding increased in young

sows. Yet [21] found no associations between backfat and number born alive. Taken together, the relationship between sow backfat at breeding with subsequent litter size is unclear. Yet the current authors recommend that scientists evaluating these types of relationships consider curvilinear associations during statistical analysis.

In the current study, greater sow backfat at breeding and at farrowing were associated with lower lactation average daily feed intake. In accordance, [1] [15] [22] reported increased sow backfat impaired lactation feed intake. These results suggest excessively high sow backfat should be avoided to enhance lactation average daily feed intake.

Similar to the association between the sow body condition caliper at breeding with subsequent farrowing rate, farrowing rate improved as sow backfat at breeding increased. In agreement, [23] reported low backfat levels at breeding, resulting from restricted lactation feed intake, was detrimental to subsequent pregnancy rate. Yet more studies evaluating the impact of body condition measures at breeding on subsequent farrowing rate are warranted.

4.4. Sow Body Condition Score

Visual sow body condition evaluation is subjective and may result in improper gestation feed allocation. [2] explored the repeatability of sow body condition scoring. The same authors reported reproducibility among participants was low indicating that participants formed their own "ideal" body condition. [2] further reported the repeatability of sow body condition scoring was greater for trained participants when compared to those without swine evaluation experience (0.75 vs. 0.64, respectively). In the present study an experienced evaluator scored sow body condition, which may not commonly be available on a modern commercial sow farm. Inconsistency in sow body condition scoring can lead to sows being under or overfed, especially if multiple staff members are responsible for scoring. Hence, the present authors recommend the use of objective sow body condition tools when determining feeding levels for gestating sows.

In the present study, associations between sow body condition score with reproductive performance were similar to those between sow body condition caliper score and reproduction. [4] reported the correlation between sow body condition score and sow caliper score was 0.77. The magnitude of the correlation between the two measures of sow condition likely explains similar associations with reproduction reported in the present study.

Based on the 5-point scale explained by [5], a sow body condition score of three is "ideal" in terms of appearance. Yet this "ideal" appearance correlated with improved reproduction in the current study.

In the present study, a sow body condition score at breeding of 3.0 optimized litter birth weight and piglet survival and a sow body condition score of 3.2 maximized number born alive and number weaned. In contrast, [20] reported subsequent litter size increased as sow body condition at breeding increased in young sows. Perhaps parity explains differences between the studies as the cur-

rent study utilized only multiparous sows and [20] used parity one sows.

At farrowing, a sow body condition score of 3.6 maximized reproduction for number weaned and piglet survival. In agreement, [24] recommended maintaining sows at a visual sow body condition score of 3.0 to 3.5.

4.5. Lactation Feed Intake

Increased lactation feed intake enhanced subsequent number born alive and litter birth weight. In agreement, [25] found a 1 kg increase in lactation average daily feed intake enhanced subsequent number born alive by 0.11 piglets per litter. [26] reported sows with higher lactation feed intakes and lower body reserve losses had greater subsequent litter sizes. Collectively, these studies suggest greater lactation feed intakes can enhance subsequent reproduction.

5. Implications

To our knowledge, the present study is the first to identify "ideal" sow body condition in relation to reproduction across multiple sow condition measures. Hence, pig farmers can use this information to help define body condition targets for their respective sow herds.

The present study associated both subjective and objective sow body condition methods with subsequent reproductive performance. While skilled evaluators can use visual sow body condition scoring to manage sow body reserves, an objective measure would be beneficial to farm staff with little to no training. Therefore, we recommend using objective sow body condition tools, such as the sow body condition caliper, sow body weight or sow backfat to achieve desired body condition targets, optimize feed cost and maximize reproductive performance. The ideal objective body condition tool may vary by farm or production system. Yet given data from the current analysis, we recommend the use of the sow body condition caliper as it showed consistent, curvilinear associations with a variety of reproductive measures. Based on study results, we recommend feeding sows to a target sow body condition caliper score of 14 to 15.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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