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Udder characteristics of importance for teat use in purebred and crossbred pigs[1]

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ABSTRACT: Possible side effects of the current sow selection criteria on udder characteristics and their influence on teat use and functionality have not yet been investigated. The first aim of the present study was to investigate differences in udder morphology characteristics (distance between teats in a pair, teat length, and teat diameter) in 2 different pure breeds (Norsvin Duroc [ND; n = 12] and Norsvin Landrace [NL; n = 12]) and 1 crossbreed (Norsvin Landrace × Yorkshire [NL×Y; n = 14]) at 3 different time periods (Days 1, 21, and 35) during lactation. Second, we also investigated the association between udder morphology and teat use on d 1 and if some of these characteristics influence whether teats become nonfunctional (from d 1 to 35) during lactation. During lactation, udder morphology (teat pair distance, teat length, and diameter of functional teats) and teat use (from 6 consecutive nursings: functional teats being used/not being used and which teat row [left or right] was uppermost) were documented. The NL had shorter distance between teat pairs than ND (P = 0.030). Teat pair distance increased with sows' parity (P = 0.010) and was affected by teat position (P < 0.001). The ND had shorter teats than NL and NL×Y (P < 0.001). Teat length and diameter increased with parity (P = 0.027 and P = 0.043, respectively) and were affected by teat position (P < 0.001 and P < 0.001, respectively). Functional teats were less used on d 1 postpartum (21.4%) than at 2 later time periods (10.4% on Day 21 and 4.7% on Day 35; P < 0.001) during lactation. On d 1, the greater the distance between teat pairs in the middle and posterior position, the higher was the proportion of not-used functional teats (P = 0.003), with a larger decline in the lower teat row (P < 0.001), where approximately half of middle and posterior teats were not used. Proportion of not-used functional teats in the lower middle position increased when the teat pair distance exceeded 16 cm, whereas in the lower posterior position, this limit was 14 cm. Furthermore, the proportion of not-used teats on d 1 influenced teats becoming nonfunctional during lactation (P < 0.001). The greater the distance between pairs, the more teats became nonfunctional irrespective of teat position (P < 0.001). The present results suggest that teat pair distance is of importance for teat use in all breeds and should be included in the breeding program to ensure colostrum intake and maintain teat functionality during lactation.

Key words: breed, sow, teat functionality, teat use, udder characteristics

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INTRODUCTION

During the last decades, a substantial increase in number of live-born piglets has been achieved (Holm et al., 2004; Long et al., 2010). As a consequence of larger litter size, sibling competition increases (Pedersen et al., 2011b; Chalkias et al., 2014) and piglets have to compete more for access to the sow's teats and for their survival (Andersen et al., 2011; Bozděchová et al., 2014). Although the number of functional teats has increased due to this breeding goal, litter size commonly exceeds that number (reviewed by Drake et al., 2008). Previous results showed that only 46% of the functional teats in primiparous sows were used at first suckling and that the lower teat row was the least used, especially with increased parity (Vasdal and Andersen, 2012), and this may increase sibling competition and piglet mortality. At present, there are

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hardly any studies documenting the udder morphology traits in different breeds. Maternal sow lines (Landrace and Yorkshire) are, among others traits (production, carcass and meat quality, reproduction, and robustness), subjected to selection for litter size (total born and stillborn) and maternal ability (piglet survival, litter weight at 21 d, total number of teats, and reduction in inverted teats). In contrast, terminal sire lines (e.g., Duroc) are subjected only to traits such as growth, carcass quality, meat quality, and robustness (Norsvin, 2014; http://www.norsvin.lt/Genetic-Program/Breeding-Goals; Accessed January 3, 2015).

The aim of the present study was first to investigate differences in udder morphology characteristics (distance between teats in a pair, teat length, and teat diameter) in 2 different maternal pure breeds (Norsvin Duroc and Norsvin Landrace) and 1 crossbreed (Norsvin Landrace × Yorkshire) at 3 different time periods (Days 1, 21, and 35) during lactation. Second, we also investigated the association between udder morphology and teat use on d 1 and if some of these characteristics influence whether teats become nonfunctional (from d 1 to 35) during lactation.

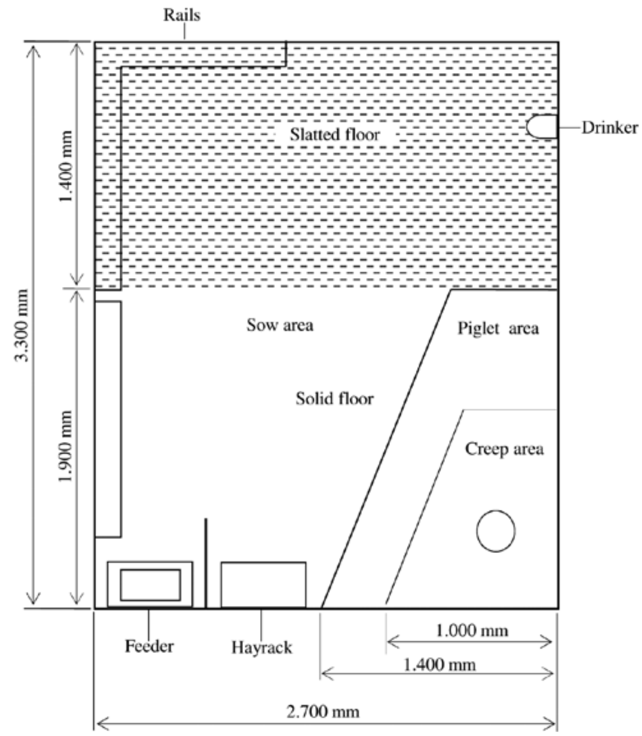

Figure 1. The farrowing pen.

MATERIAL AND METHODS

The present experiment was conducted in accordance with the current laws in Norway (www.lovdata.no).

Experimental Design

We studied udder morphology, teat use, and functionality in the following 3 different breeds: purebred Norsvin Duroc (**ND**) sows ($n = 12$; inseminated with ND boar semen), purebred Norsvin Landrace (**NL**) sows ($n = 12$; inseminated with NL boar semen), and crossbreed Norsvin Landrace × Yorkshire (**NL×Y**) sows ($n = 14$; inseminated with NL × Duroc boar semen) and at 3 different stages of lactation: Day 1 (first morning after farrowing), Day 21, and Day 35.

Housing and Management

The research was conducted on the Pig Research Unit at the Norwegian University of Life Sciences (Ås, Norway) between September 2013 and February 2014 in 3 subsequent batches. In the first and second batch, 7 NL sows and 7 NL×Y sows, and in the third batch, 12 ND sows and 2 NL×Y sows were moved from the gestation unit to the farrowing unit at 7 d before the expected farrowing date of the first sow in each batch. On entry to the farrowing unit, sows were randomly allocated to 1 out of 14 individual farrowing pens per batch.

Each farrowing pen measured 8.9 m^2 in total (Fig. 1), consisting of a piglet and a sow area. The piglet area (1.9 m^2), inaccessible to the sow, contained a feeder and a creep area heated with an infrared heating lamp. The sow area consisted of a solid concrete floor (3.3 m^2) beside the feeder and the hayrack and a plastic slatted floor (3.7 m^2) in the dunging area. Pens were equipped with 2 farrowing rails. Ambient temperature in the farrowing unit was kept between 17 and 20°C, and artificial lights were on between 0700 and 1500 h.

After parturition, sows were fed with a standard lactation concentrated diet (dry pellets, as detailed in Vasdal et al., 2011). Water was provided ad libitum from a nipple drinker.

From Day 112 after insemination until farrowing, straw as nest-building material was available ad libitum from a hayrack. During parturition, farrowing assistance was given when needed (sows were restless for more than 3–4 h and had contractions for more than 1–2 h without any newborn piglets). Oxytocin was injected only in the case when birth assistance was not enough. No other routines were performed. Immediately after parturition, additional water was available in the feeding trough. Cleaning of the pen was conducted twice a day, and new sawdust subsequently was added on the concrete solid floor and in the creep area. Cross-fostering was performed when litter size exceeded the number of functional teats. In such litters, the biggest piglets were cross-fostered after consumption of colostrum from their own mother, preferably within 24 h after parturition;

to optimize survival, staff also were allowed to cross-foster between 24 and 48 h to litters where the number of piglets was less than the number of functional teats. Litter size was then defined as the number of live-born piglets plus the number of piglets fostered on and minus the number of piglets fostered off. On d 1 postpartum, oral iron (Pluss Jernstarter, 1.5 mL; Felleskjøpet, Oslo, Norway) was individually given to each piglet, and subsequently, iron was given on a daily basis in peat (Pluss Smågristorv, 1 L per litter; Felleskjøpet, Oslo, Norway). Surgical castration was performed by a veterinarian and with the use of local anesthesia and systemic analgesics when piglets were between 10 and 14 d of age.

Assessment of Udder Morphology and Teat Use

Four sows were excluded due to health problems (stomach ulcer and birth difficulties). A total of 38 healthy sows with 469 piglets remained in the study. Sows in breed groups (ND, NL, and NL×Y) had their first (n = 6, n = 6, and n = 8, respectively), second (n = 5, n = 0, and n = 1, respectively), third (n = 0, n = 4, and n = 0, respectively), fourth (n = 1, n = 0, and n = 3, respectively), fifth (n = 0, n = 1, and n = 2, respectively), and sixth litters (n = 0, n = 1, and n = 0, respectively).

Morphological traits of the udder were monitored at 0800 h in the morning during the feeding time (while sows were standing up) on d 1 and later at 21 and 35 d of lactation. All teats were designated according to the side of the sow (left and right), numbered from 1 to 9 (where 1 was assigned to the most cranial teat pair), and the teat pair distance (**TPD**; the distance between the left and right teats in the same pair) for every pair was recorded. Sows in breed groups (ND, NL, and NL×Y) had 6 (6, 0, and 0, respectively), 7 (6, 3, and 5, respectively), 8 (0, 7, and 9, respectively), and 9 teat pairs (0, 2, and 0, respectively). Functional teats were defined as teats that produced milk (milk ejected at hand milking, with exclusion if the teat and mammary gland had undergone involution). Furthermore, only functional teats were measured for teat diameter (**TD**; at tip of a teat) and teat length (**TL**).

The results of udder characteristics are presented according to teat position (**TP**) as anterior (the first through third pairs for NL and NL×Y and the first and second pairs for ND), middle (the fourth through sixth pairs for NL and NL×Y and the third and fourth pairs for ND), and posterior (the seventh through ninth pairs for NL and NL×Y and the fifth through seventh pairs for ND) teats.

To determine teat use, sows with their litter were video recorded for 24 h on Days 1, 21, and 35 postpartum. Above each pen, a camera (Foscam FI9821W, 1280 × 720; ShenZhen Foscam Intelligent Technology Limited, Shenzhen, China) was mounted in the roof and positioned in such a way that teat use could be recorded.

Video analyses of teat use started in the morning (after artificial lights came on at 0900 h), and during 6 consecutive nursings, the following parameters were recorded: identity of functional teats being used, identity of functional teats not being used, and which teat row (left or right) was uppermost.

Statistical Analysis

Descriptive statistics were presented as arithmetic mean and SE. The statistical analyses were performed in the SAS program (SAS Inst. Inc., Cary, NC). The differences in udder morphology (TPD, TL, and TD) were analyzed using a PROC GLM procedure including the fixed effects of breed (ND, NL, and NL×Y), parity (primiparous sows [parity = 1]) and multiparous sows [parity > 1]), TP (anterior teats, middle teats, and posterior teats), and day (Day 1, Day 21, and Day 35) and the interaction between breed and parity, the interaction between breed and TP, and the interaction between breed and day. Sow nested within breed and parity was specified as a random effect in the model. The data set of udder morphology (TPD, TL, and TD) consisted of 709, 1,465, and 1,464 observations, respectively.

The variables "proportion of not-used functional teats," "number of functional teats per piglet," and "proportion of nonfunctional teats" were analyzed using a GENMOD procedure (Poisson distribution) including the following fixed effects: breed (ND, NL, and NL×Y), parity (primiparous sows [parity = 1] and multiparous sows [parity > 1]), day (Day 1, Day 21, and Day 35), and sow nested within breed and parity as class variables, including the interaction between breed and parity in the model. The data set consisted of 112, 114, and 113 observations for proportion of not-used functional teats, functional teats per piglet, and proportion of nonfunctional teats, respectively.

Teat use on d 1 postpartum (calculated as a proportion of not-used functional teats) was analyzed using a PROC GLM procedure, including the following fixed effects: breed (ND, NL, and NL×Y) and parity (primiparous sows [parity = 1]) and multiparous sows [parity > 1]) as class variables. The relationships between teat use on d 1 postpartum and the proportion of sucklings in which a teat was in the upper teat row on d 1 and TP (anterior teats, middle teats, and posterior teats), TPD on d 1 and TP (anterior teats, middle teats, and posterior teats), TL on d 1 and TP (anterior teats, middle teats, and posterior teats), and TD on d 1 and TP (anterior teats, middle teats, and posterior teats) were included in the model. Sow nested within breed and parity was included as a random effect.

Teats becoming nonfunctional (from d 1 to 35 postpartum) were analyzed using a GLIMMIX procedure

Table 1. Udder morphology (mean [SE] cm) in relationship to breed, parity, and teat position (TP), irrespective of time of lactation

	Breed[2]			Parity		TP		
UM[1]	ND	NL	NL×Y	Primiparous	Multiparous	Anterior	Middle	Posterior
TPD	14.4 (0.1)	13.5 (0.1)	14.7 (0.1)	13.7 (0.0)	14.7 (0.1)	13.7 (0.0)	16.3 (0.0)	11.9 (0.0)
TL	2.7 (0.0)	3.4 (0.0)	3.6 (0.0)	3.1 (0.0)	3.5 (0.0)	3.4 (0.0)	3.5 (0.0)	2.8 (0.0)
TD	1.1 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.1 (0.0)	1.0 (0.2)	1.1 (0.2)	1.0 (0.0)

[1]UM = Udder morphology; TPD = teat pair distance; TL = teat length; TD = teat diameter.

[2]ND = Norsvin Duroc; NL = Norsvin Landrace; NL×Y = Norsvin Landrace × Yorkshire.

(binominal distribution) and included the following fixed effects: breed (ND, NL, and NL×Y) and parity (primiparous sows [parity = 1] and multiparous sows [parity > 1]) as class variables and the proportion of not-used functional teats (proportion of not-used teats calculated from nursing events [$n = 6$] on d 1) as a continuous variable. The relationships between teat becoming nonfunctional and the proportion of sucklings in which a teat was in the upper teat row on d 1 and TP (anterior teats, middle teats, and posterior teats), TPD on d 1 and TP (anterior teats, middle teats, and posterior teats), TL on d 1 and TP (anterior teats, middle teats, and posterior teats), and TD on d 1 and TP (anterior teats, middle teats, and posterior teats) were included in the model. Sow nested within breed and parity was specified as a random effect. Data sets for both analyses, teat use on d 1 and teats becoming nonfunctional (from d 1 to 35 postpartum), consisted of 521 observations. Statistical significance was accepted at $P \leq 0.05$.

RESULTS

Udder Morphology

Teat Pair Distance. There was a difference between breeds in TPD (Table 1 and 2). Norsvin Landrace sows had the shortest distance between pairs when compared with the other 2 breeds (Table 1). In all breeds, mean TPD was greater in multiparous than in primiparous sows (Tables 1 and 2). Teat pair distance was affected by TP (Table 2), with the greatest distance in the middle pairs and the shortest distance in posterior pairs (Table 1). There was no significant interaction effect between TP and breed (Table 2). Teat pair distance mean value was 14.4 ± 3.4 cm (range 6.2–25.0 cm) on Day 1, 14.2 ± 3.4 cm (range 3–22 cm) on Day 21, and 13.9 ± 3.8 cm (range 4–23 cm) on Day 35 (Fig. 2a), irrespective of breed. During lactation, TPD decreased, on average, 3%, but this change was not significant (Table 2). There was no interaction effect between breed and day of lactation (Table 2). There was a significant effect of sow in the model for TPD (Table 2).

Teat Length. Teat length was significantly affected by breed (Table 2). Norsvin Duroc sows had the shortest teats regardless of TP (Table 1). Primiparous sows had shorter TL in comparison with multiparous sows (Tables 1 and 2). There was no significant interaction effect between breed and parity (Table 2). Teat length was affected by TP (Table 2), with the longest being the middle teats and the shortest being the posterior teats (Table 1). A significant interaction effect between breed and TP showed that NL×Y had the longest teats in the middle part of the udder, whereas this was not the case for ND and NL breeds (Table 2; Fig. 3a). Mean TL value was 3.4 ± 1.0 cm (range 1.1–6.0 cm) on Day 1, 3.3 ± 0.9 cm (range 1.2–6.0 cm) on Day 21, and 3.2 ± 0.8 cm

Table 2. Influence of fixed effects on udder morphology

	TPD[1]		TL[1]		TD[1]	
Fixed effects	$F_{()}$	P	$F_{()}$	P	$F_{()}$	P
Breed	$3.9_{(2, 34)}$	0.030	$13.9_{(2, 32)}$	<0.001	$1.4_{(2, 32)}$	ns[2]
Parity	$7.5_{(1, 33)}$	0.010	$5.4_{(1, 32)}$	0.027	$4.5_{(1, 32)}$	0.043
Breed × parity	$0.1_{(2, 33)}$	ns	$1.2_{(2, 32)}$	ns	$1.7_{(2, 32)}$	ns
TP[3]	$155.1_{(2, 659)}$	<0.001	$74.1_{(2, 1.415)}$	<0.001	$71.3_{(2, 1.414)}$	<0.001
Breed × TP	$1.7_{(4, 659)}$	ns	$6.8_{(4, 1.415)}$	<0.001	$7.6_{(4, 1.414)}$	<0.001
Day	$0.3_{(2, 659)}$	ns	$15.0_{(2, 1.415)}$	<0.001	$12.4_{(2, 1.414)}$	<0.001
Breed × day	$1.1_{(4, 659)}$	ns	$1.7_{(4, 1.415)}$	ns	$24.4_{(4, 1.414)}$	<0.001
Sow (breed × parity)	$5.5_{(32, 659)}$	<0.001	$13.6_{(32, 1.415)}$	<0.001	$19.3_{(32, 1.414)}$	<0.001

[1]TPD = teat pair distance; TL = teat length; TD = teat diameter.

[2]ns = not significant.

[3]TP = teat position.

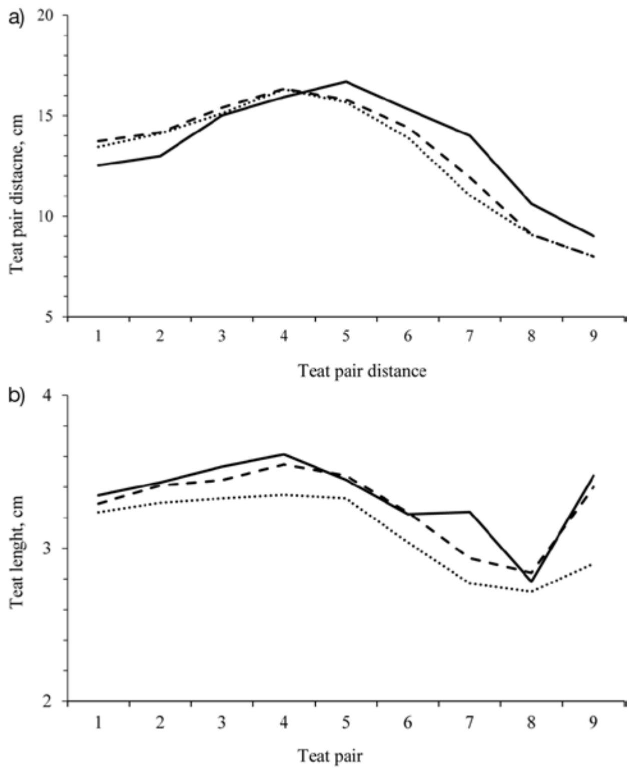

Figure 2. a) Mean teat pair distance in relation to teat pair and day of lactation (— = Day 1; - - - = Day 21; · · · = Day 35); sows had 6 (n = 6), 7 (n = 14), 8 (n = 16), or 9 teat pairs (n = 2), respectively. b) The mean teat length in relation to teat pair and day of lactation (— = d 1; - - - = d 21; · · · = d 35).

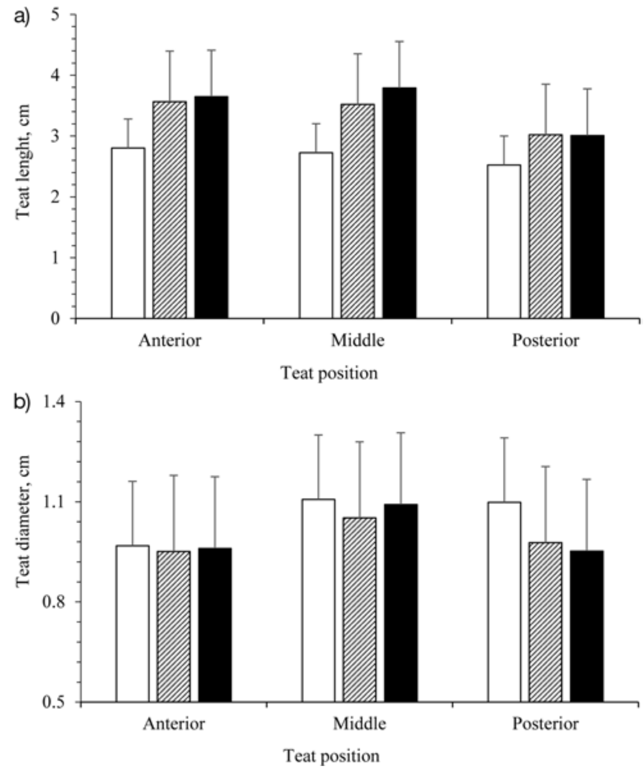

Figure 3. a) Mean teat length in relation to the interaction between teat position (anterior, middle, and posterior) and breed (= Norsvin Duroc [ND]; = Norsvin Landrace [NL]; = Norsvin Landrace × Yorkshire [NL×Y]; $F_{4, 1.415}$ = 6.8, P < 0.001). b) Mean teat diameter in relation to the relationship between teat position (anterior, middle, and posterior) and breed. ☐= ND; ▨ = NL; ■= NL×Y; $F_{4, 1.414}$ = 7.6, P < 0.001.

(range 1.7–5.2 cm) on Day 35 (Fig. 2b). Teat length significantly decreased by, on average, 5.5% from Day 1 to Day 35 (Table 2). There was a significant effect of sow in the model for TL (Table 2).

Teat Diameter. There was no significant effect of breed on TD (Table 2). In all breeds, primiparous sows had smaller TD in comparison with multiparous sows (Tables 1 and 2). Teat diameter was affected by TP, with the greatest TD in the middle teats and the least TD in the anterior teats (Tables 1 and 2). A significant interaction between breed and TP showed that ND and NL sows had the smallest diameter of anterior teats, whereas in NL×Y, this was not the case (Table 2; Fig. 3b). Teat diameter means were 1.06 ± 0.24 cm (range 0.3–1.6 cm) on Day 1, 1.00 ± 0.22 cm (range 0.4–1.6 cm) on Day 21, and 0.98 ± 0.20 cm (range 0.5–1.6 cm) on Day 35. Teat diameter significantly decreased by, on average, 7.5% from Day 1 to Day 35 (Table 2). A significant interaction effect between breed and day showed that during lactation, TP decreased in the NL and NL×Y breeds, whereas this was not the case for the ND breed. There was a significant effect of sow in the model for TD (Table 2).

Teat Use and Functionality

Teat Use. There was a difference between breeds in the proportion of not-used functional teats (Table 3 and 4). Norsvin Duroc sows had a higher proportion of not-used functional teats when compared with the other 2 breeds (Table 3). The proportion of not-used functional teats was not affected by parity or the interaction between breed and parity (Tables 3 and 4). During the lactation period, the proportion of not-used functional teats significantly decreased (Fig. 4). On average, 21.4 ± 2.3% of functional teats were not used on d 1 postpartum (Fig. 4). On Day 21, as few as 10.4 ± 2.3% of functional teats were not being used, whereas on Day 35 of lactation, only 4.7 ± 1.6% of functional teats were not used. There was a significant effect of sow on the proportion of not-used functional teats (Table 4). Because most of the teats were being used on Day 21 and 35, in contrast to d 1, we have focused on analyzing the influence of udder morphology on teat use on d 1 postpartum.

Teat Use on Day 1. There were no effects of breed ($F_{2, 36}$ = 0.1, P = 0.392) or parity ($F_{1, 40}$ = 3.2, P = 0.081) on the proportion of not-used functional teats on d 1. From anterior to posterior TP, the proportion of not-used functional teats increased (Fig. 5). A significant effect of interaction between the proportion of sucklings in which a teat was in the upper teat row and TP showed that in the middle and posterior part of the udder, the proportion of not-used teats decreased when the proportion of

Table 3. Proportion of not-used functional teats, number of functional teats per piglet, and proportion of nonfunctional teats (mean [SE] cm) in relation to breed and parity, irrespective of time of lactation

	Breed[1]			Parity	
Variable	ND	NL	NL×Y	Primiparous	Multiparous
Not-used functional teats, %	17.4 (3.4)	11.1 (1.6)	8.2 (1.6)	11.0 (1.6)	13.4 (2.2)
Functional teats per piglet, no.	1.5 (0.1)	1.1 (0.0)	1.2 (0.0)	1.2 (0.0)	1.3 (0.1)
Nonfunctional teats, %	20.7 (3.0)	10.4 (1.7)	9.4 (1.8)	12.0 (1.5)	14.8 (2.3)

[1]ND = Norsvin Duroc; NL = Norsvin Landrace; NL×Y = Norsvin Landrace × Yorkshire.

times a teat was in the upper row increased, but this was not the case for teats in the anterior part of the udder ($F_{3, 472}$ = 31.0, P < 0.001; Fig. 5). When considering TPD, an interaction between TPD and teat position occurred; a greater distance between pairs was associated with a higher proportion of not-used functional teats in the middle and posterior part of the udder, while this was not the case in the anterior part of the udder ($F_{3, 472}$ = 4.6; P = 0.003).When TPD exceeded 16 cm (as many as 60% of the sows), teats in the lower teat row in the middle part of the udder were not used and this threshold was 14 cm for the lower posterior teats (Fig. 6 shows the mean TPD for posterior and middle pairs with mean TPD thresholds when teats became not used in the lower middle and posterior part of udder). With further extension of TPD to 18 cm, the upper middle teats were not used. Concerning TL, the relationship between TL and TP showed that shorter teats were significantly unfavorable for teat use in the anterior part of the udder, whereas there were no effects of TL in the middle or posterior part of the udder ($F_{3, 471}$ = 2.6, P = 0.050). The relationship between TD and TP showed that greater diameter significantly decreased the proportion of used teats in the posterior part of the udder, whereas this was not the case in the anterior or middle part of the udder ($F_{3, 472}$ = 3.0, P = 0.031). There was a significant effect of sow on the proportion of not-used functional teats ($F_{3, 472}$ = 4.5, P < 0.001).

Teat Functionality. The ND breed had, on average, 12.6 ± 1.0 functional teats (range 11 to 14), whereas for NL and NL×Y, the respective mean values were 15.9 ± 1.0 (range 14 to 18) and 15.1 ± 1.1 (range 13 to 16). For primiparous and multiparous sows, the mean number of functional teats was 14.5 ± 1.7 (range 11 to 18) and 14.4 ± 1.7 (range 11 to 17), respectively. There were no significant effects of breed, parity, interaction between breed and parity, day of lactation, or individual differences between sows in number of functional teats per piglet (Tables 3 and 4). When analyzing the proportion of nonfunctional teats, there were no significant effects of breed or parity (Tables 3 and 4). A significant interaction between breed and parity showed that in ND and NL×Y breeds, primiparous sows had a lower proportion of nonfunctional teats in comparison with multiparous sows, but this was not the case in the NL breed (Table 4). The proportion of nonfunctional teats significantly increased during the lactation period (Fig. 4). The proportion of nonfunctional teats at different stages of lactation was 3.4 ± 1.0% (2.0% nonfunctional on the left side vs. 1.4% nonfunctional on the right side) on Day 1, 15.2 ± 2.0% (8.6% nonfunctional on the left side vs. 6.6% nonfunctional on the right side) on Day 21, and 21.5% (12.0% nonfunctional on the left side vs. 9.5% nonfunctional on the right side) on Day 35. During lactation, the proportion of nonfunctional teats increased from the anterior to the posterior TP (Fig. 7). There was a large individual difference between sows in the proportion of nonfunctional teats (Table 4). Because the highest proportion of nonfunctional teats was on Day 35, in contrast to Day 1 and Day 21, we have focused on analyzing the effect of udder morphology and the proportion of teat use on d 1 postpartum on teats becoming nonfunctional from d 1 to 35.

Teats becoming Nonfunctional from Day 1 to 35. There were no effects of breed ($F_{2, 33}$ = 1.9, P = 0.174) or parity ($F_{1, 33}$ = 0.8, P = 0.366) on teats becoming nonfunctional from Day 1 to Day 35. A positive relationship was found between the proportion of teats not used on Day 1

Table 4. Influence of fixed effects on proportion of not-used functional teats, number of functional teats per piglet, and proportion of nonfunctional teats

	Not-used functional teats, %		Functional teats per piglet, no.		Nonfunctional teats, %	
Fixed effects	$\chi^2_{()}$	P	$\chi^2_{()}$	P	$\chi^2_{()}$	P
Breed	$8.8_{(2, 112)}$	0.012	$0.1_{(2, 114)}$	ns[1]	$1.7_{(2, 113)}$	ns
Parity	$0.1_{(1, 112)}$	ns	$0.0_{(1, 114)}$	ns	$2.3_{(1, 113)}$	ns
Breed × parity	$0.3_{(2, 112)}$	ns	$0.2_{(2, 114)}$	ns	$48.0_{(2, 113)}$	<0.001
Day	$529.0_{(2, 112)}$	<0.001	$0.6_{(2, 114)}$	ns	$562.2_{(2, 113)}$	<0.001
Sow (breed × parity)	$56.5_{(2, 112)}$	<0.001	$0.3_{(6, 114)}$	ns	$162.4_{(2, 113)}$	<0.001

[1]ns = not significant.

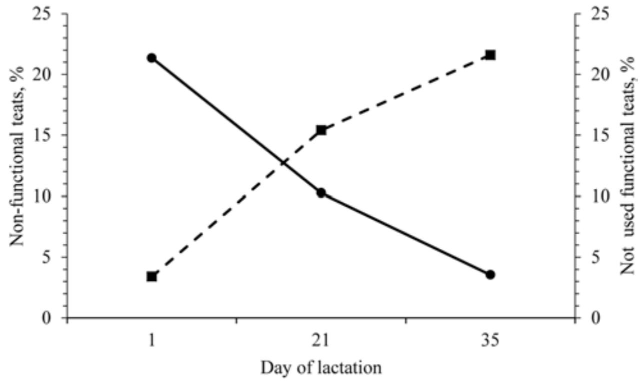

Figure 4. Proportion of nonfunctional teats (- ■ -) and not-used functional teats (–•–) at different stages of lactation (Day 1, 21, and 35).

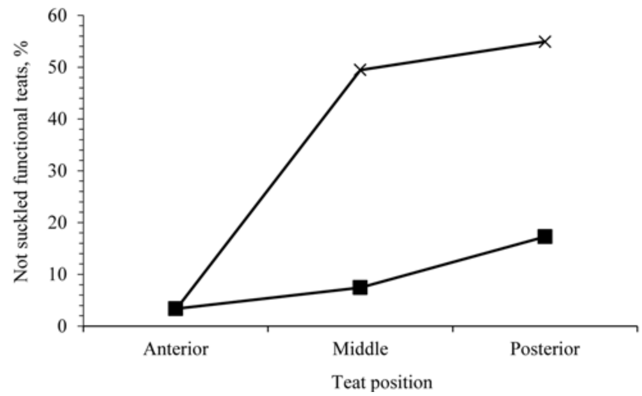

Figure 5. Proportion of not-used functional teats in relation to teat position and teat row (lower row: –×–; upper row: –■–).

and teats becoming nonfunctional on Day 35 postpartum ($F_{1, 471}$ = 12.3, P < 0.001). Teats becoming nonfunctional was not affected by the relationship between the proportion of times a teat was in the upper row and TP. When considering TPD, an interaction between TPD and teat position occurred; greater distance between pairs significantly influenced teats becoming non-functional in all sections of the udder, but the effect was less pronounced in the mid-section ($F_{3, 471}$ = 7.0, P < 0.001; Fig. 8). There were no interaction effects between TL and TP ($F_{3, 471}$ = 0.6, P < 0.097) or between TD and TP ($F_{3, 471}$ = 0.6, P < 0.618) on teats becoming nonfunctional.

DISCUSSION

Selection in the maternal sow line NL includes several traits such as production (growth and feed efficiency), carcass quality, meat quality, reproduction, robustness, and the main emphasis on litter size (total born and stillborn) and maternal ability (piglet survival, litter weight at 21 d, total number of teats, and reduction in inverted teats). The ongoing selection has resulted in larger litters, greater piglet weight gain, and an increased number of functional teats (Norsvin, 2014). Due to selection, modern maternal lines have become heavier and longer, but sows' body size (Moustsen et al., 2011) and mammary gland size (Nielsen et al., 2001) do not achieve their adult size until reaching the fifth (Moustsen et al., 2011) or sixth parity (McGlone et al., 2004). However, possible side effects of the current selection on udder characteristics, such as reduced teat accessibility (Vasdal and Andersen, 2012) and increased TPD, have not, to our knowledge, been investigated. This study was conducted to investigate the association between udder morphology and teat use on d 1 and if some of these characteristics influence whether teats become nonfunctional (from d 1 to d 35 postpartum) during lactation.

The current results provide the first demonstration that the maternal breeding line (NL) had shorter distance between teat pairs than the paternal breeding line (ND), irrespective of the position on the udder. These results show that current selection of maternal line NL has not increased TPD per se compared with other breeds. However, this trait was greatly affected by parity of the sow and TP on the udder.

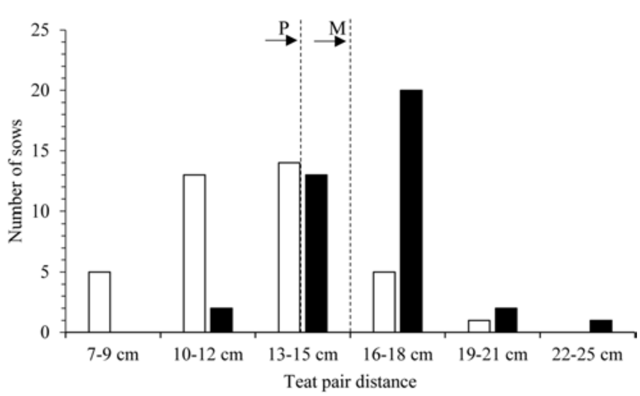

Figure 6. Number of sows distributed with respect to size of teat pair distance (TPD; □, distance between posterior pairs; ■, distance between middle pairs) with calculated thresholds for teats not being used (M, dashed line for mean TPD when teats became not used in the lower middle part of the udder; P, dashed line for mean TPD when teats became not used in the lower posterior part of the udder).

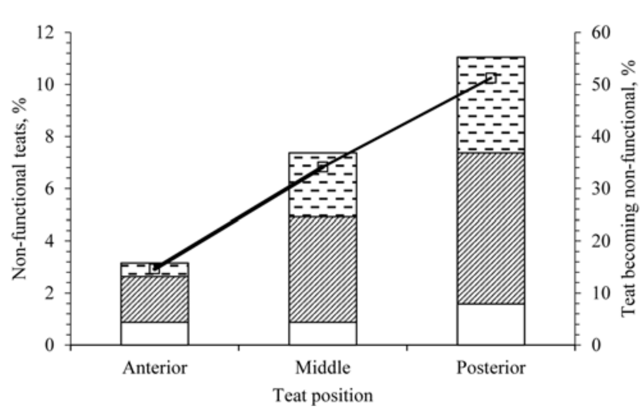

Figure 7. Proportion of nonfunctional teats in relation to teat position at different stages of lactation (□ = Day 1; ▨ = Day 21; ⊡ = Day 35), with line presenting proportion of teats becoming nonfunctional from d 1 to d 35 in relation to teat position.

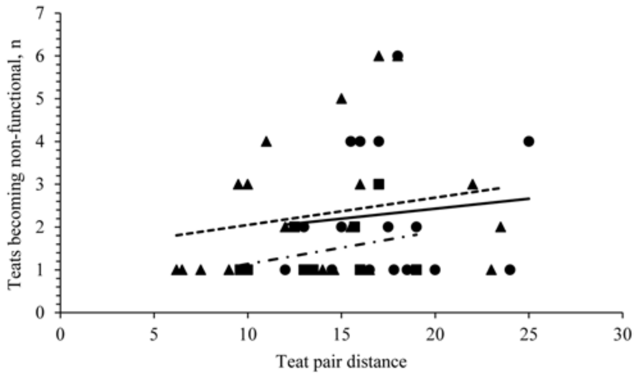

Figure 8. Teats becoming nonfunctional from d 1 until 35 in relation to the interaction between teat position (–•– = anterior, ––– = middle, and ---- = posterior) and teat pair distance (■ = distance between anterior pairs, ● = distance between middle pairs, and ▲= distance between posterior pairs; $F_{3,\,471} = 7.0$, $P < 0.001$).

There is, to our knowledge, no other study documenting udder morphology and its importance for teat use. The present results showed that many teats that produced milk are already not being used on d 1 after birth. To ensure sufficient colostrum consumption, access to a teat shortly after birth is crucial for piglets to obtain important maternal immunity and antibodies vital for disease prevention and growth and survival of the piglets (Bandrick et al., 2014). Altogether, starved, malnourished, and crushed piglets represent more than 60% of all deaths in loose-housed sows (e.g., Andersen et al., 2006; Vasdal et al., 2011) and the majority of these piglets die within the first 2 d after birth (Andersen et al., 2005; Pedersen et al., 2011a).

The longer the distance between teat pairs in the middle and posterior position, the less available the teats become for the piglets. Vasdal and Andersen (2012) found that the use of functional teats in the lower teat row was less for multiparous than primiparous sows, whereas the present study revealed more precisely that multiparous sows had a greater overall TPD than primiparous sows. Recording of TPD should, therefore, be focused on the posterior and middle teats in order to implement TPD in the breeding goal. On d 1, teat use declined from anterior to posterior position and has a larger decline in the lower teat row. Similar to the results documented by Vasdal and Andersen (2012), approximately half of the middle and posterior teats in the lower teat row were not used on d 1. More precisely, lower middle teats were not being used when TPD exceeded 16 cm, and this threshold was 14 cm for the lower teat row in the posterior part of the udder. Regarding the middle teats, in fact, as many as 60% of the sows in the present study exceeded this limit, which pinpoints the importance of this trait. In this study, increased TPD caused limitation in teat use in the middle and posterior position because of excessive height above ground for the upper row and poor exposure of the lower row. Fewer available functional teats during the colostrum period will increase aggressive competition among piglets, especially in large litters, and increase the risk that piglets will starve to death or become weak or crushed. Moreover, in the case that teats were not used shortly after birth, this increased the probability that they became nonfunctional during lactation. There are several studies demonstrating that teat use is a key factor in preserving milk production in the teats (Hurley, 2001; Theil et al., 2006; Farmer et al., 2012), but because a piglet has the ability to monopolize up to 7 teats (De Passillé et al., 1988; De Passillé and Rushen, 1989), there is no explanation why some teats eventually become nonfunctional during lactation. The present study revealed that teats becoming nonfunctional during lactation were the ones having greater distance between pairs at d 1 after birth. This prevailed in all parts of the udder. More importantly, more than 80% of teats becoming nonfunctional during lactation were situated in the middle and posterior position, pointing out the core of the problem. The present data show that TPD is the most important udder characteristic for teat use and, hence preserving teat functionality in all breeds, suggesting that this udder characteristic is a problem among breeds and probably overlooked for a long period of time. Therefore, this study showed that TPD in the middle and posterior udder should be included as a trait in the breeding goal. The significant variance between sows for this trait also indicates the possibility to select for TPD.

The paternal line (ND) had shorter teats than maternal lines (NL and NL×Y). In accordance with recent preliminary results (Balzani et al., 2015) that reported that crossbreed (Large White × Landrace) primiparous sows had smaller teats than multiparous sows, the present study revealed that with increasing parity, teats became longer in all 3 Norwegian breeds. However, TL was related to TP at the udder, the longest being middle teats and the shortest being posterior ones. One would assume that due to excessive height or poor exposure of teat rows, TL would play an important role in terms of the piglets' ability to easily grasp and suckle the teats. Although the longer anterior teats were more available for the piglets, there was no such effect in the middle or posterior position, where use of the teats was most problematic. Because as few as 3% of anterior teats were not being used at the beginning of the lactation, TL has minor effects in terms of teat use.

Furthermore, we have analyzed the differences in TD. The main findings were that with increasing parity, the TD became greater, and when comparing diameter between different TP, middle teats had the greatest and anterior teats had the smallest diameter. To some extent, teat use was affected by TD. The greater the diameter of posterior teats, the less available the teats became for the piglets. Because larger piglets at birth claim ownership over anterior teats (Drake et al., 2008), smaller piglets might gain access only to posterior ones. Therefore, it is not surprising that smaller diameter was beneficial in terms of the grasp and use of posterior teats.

Although the present results showed that many teats that produced milk were not being used shortly after birth, teat use on d 1 did not differ between breeds, possibly because of related differences in litter size and because some piglets have the capacity to monopolize more than 1 teat (Illmann et al., 2007).

The number of functional teats per piglet did not differ between breeds in the present study, even though the maternal line and crossbreed sows had, on average, at least 2 functional teats more than sows of the paternal line. In view of the fact that the present selection for maternal sow lines (Topigs Norsvin; Norsvin, 2014) includes traits of both litter size and number of teats, these results are not unexpected.

Conclusions

The main new message from the present study is that TPD, especially in the middle and posterior position of the udder, is the most important udder characteristic affecting teat use in all breeds. The results of this study showed that, on average, almost 22% of the functional teats are not being used on d 1 after birth. Use declined from anterior to posterior teats, especially in the lower teat row. To maintain teat functionality, it is essential that teats are used on d 1. Overall, these results underline the importance of emphasizing udder morphological traits, such as TPD, in the breeding program rather than just the number of functional teats.

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