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## ABSTRACT

The experimental animals were 18 Cinta Senese sows (7 primiparous and 11 multiparous) and relative purebred offspring. Individual weight of piglets was recorded at birth (or shortly afterwards) to the nearest 50 g and subsequently every 3-5 days up to weaning. At each recording, piglets were ranked in decreasing order according to weight within their respective litters. The behavior of a subsample of 8 sows and litters was observed during suckling, by recording the teat-piglet coupling. The sows had 12 functional teats, equally distributed in the two symmetric rows, that were numbered as pairs in the antero-posterior direction.

Starting from the third week, piglets of multiparous sows showed a faster growth rate than those of the primiparous ones. Repeatability of the piglets' weight during the suckling period was high ( $r = 0.56$ ) and repeatability of rank was even higher, but decreased up to weaning. Anterior teats were the most occupied and showed the highest suckling fidelity (consistency of suckling position). Various statistical analyses about the dependence of piglet weight (or weight rank within litter) on teat order indicated the highest milk productivity of the first teats and the lowest of the 5<sup>th</sup> & 6<sup>th</sup> teat pairs.

*Key words:* Cinta Senese, Piglet, Suckling behaviour, Teat preference, Weight gain

## RIASSUNTO

### EFFETTO DELLA POSIZIONE DEL CAPEZZOLO POPPATO SULL'ACCRESIMENTO DI SUINETTI CINTA SESESE

*Lo studio è stato condotto su 18 scrofe Cinta Senese, primipare e pluripare, e sulle rispettive nidiate allevate in stalletti. I 128 suinetti, sono stati pesati periodicamente ogni 3-5 giorni e ad ognuno è stato attribuito il valore della sua posizione (RANK) nella graduatoria ponderale entro la nidiata (1 al più pesante, ... n al più leggero). Su un sottocampione di 8 scrofe, primipare e pluripare e dotate di 12 capezzoli funzionanti simmetricamente disposti sulle due file, e sulle relative nidiate sono state effettuate osservazioni sul comportamento alla poppata. Le sedute di osservazioni, di circa 3 ore, sono avvenute mediamente ogni 2 giorni ed hanno previsto la registrazione dell'abbinamento suinetto-capezzolo. Per questo i capezzoli sono stati indicati come coppia e numerati da 1 a 6 in senso antero-posteriore e i suinetti identificati e marcati sul dorso. L'analisi statistica è stata effettuata con vari modelli a seconda dei parametri trattati, impiegando le Procedure GLM e MIXED di SAS.*

*Le pluripare hanno assicurato ai figli un maggior accrescimento, perlomeno dalla terza settimana di allattamento. Suinetti più pesanti in partenza hanno avuto buona probabilità di rimanere tali allo svezzamento come indica la ripetibilità del peso entro nidiata ( $r = 0,56$ ). Con i valori di RANK è stata ottenuta ripetibilità ancora più elevata, che è diminuita con il*

procedere del periodo di allattamento ( $r = 0,75$  e  $0,67$  rispettivamente fino a 7 giorni e fino allo svezzamento), a dimostrazione comunque di una buona costanza della graduatoria ponderale entro nidata.

Lo studio del legame tra mammelle e suinetti ha confermato la maggiore occupazione dei capezzoli anteriori (84,1; 86,9; 81,8; 61,9; 24,7; 3,4 % dalla 1° alla 6° fila) per i quali è risultata più elevata anche la frequenza di occupazione al capezzolo preferito, decrescente verso le coppie posteriori (92,5; 90,5; 83,3; 79,4; 66,9 % dalla 1° alla 5° fila). Subito dopo la nascita i suinetti più pesanti hanno occupato i capezzoli centrali della linea mammaria ma l'utilizzazione dei capezzoli anteriori è stata associata progressivamente ai suinetti di peso più elevato, con differenze particolarmente marcate fra quelli della prima e quelli delle ultime due coppie. Per questo, allo svezzamento la 1° coppia di capezzoli ha fatto migliorare il RANK entro nidata, la 2°, 3° e 4° l'hanno mantenuto quasi costante, le coppie 5&6 l'hanno peggiorato. L'accrescimento dei suinetti non è stato penalizzato dalla bassa "fedeltà al capezzolo" che dovrebbe essere indicativa della presenza di conflitti fra i neonati per l'occupazione delle mammelle preferite.

Parole chiave: Cinta Senese, Suinetto, Comportamento alla poppata, Preferenza del capezzolo, Accrescimento.

## Introduction

Although littermate piglets are fairly uniform in birth weight, they differ greatly at weaning (Hemsworth *et al.*, 1976; Milligan *et al.*, 2002) and such lack of uniformity can complicate subsequent pig management. Since neonatal growth naturally depends on milk intake, there are a number of studies dealing with the behavior of suckling piglets and the mother-offspring relationship.

At birth, piglets tend to select the anterior teats (Hartsock *et al.*, 1977; Dyck *et al.*, 1987; Fraser *et al.*, 1992) and this preference may not be related to the hypothetical greater milk production, but rather to other survival factors (Orihuela and Solano, 1995). Moreover, for some Authors (Wyeth and McBride, 1964; McBride *et al.*, 1965) the anterior teats are occupied by the piglets with higher birth weight but Fraser and Morley Jones (1975) consider this association extremely weak. On the contrary, De Passillé and Rushen (1989) concluded that piglets do not compete for the most anterior teats.

Growth rate of piglets up to weaning is influenced by birth weight (Hemsworth *et al.*, 1976) and by the position of the suckled teat. Many studies have shown that piglets using the anterior teats tend to gain more than littermates using the posterior teats (Fraser *et al.*, 1979; Fraser and Thompson, 1986; Dyck *et al.*, 1987) but this finding is not confirmed in other works (Fraser and Morley Jones, 1975; Hemsworth *et al.*, 1976; Orihuela and Solano, 1995). Moreover, growth rate

can be influenced by teat fidelity which begins to develop in the first hours after birth and helps to reduce fighting (Hartsock and Graves, 1976) and to avoid missed nursings (Fraser and Thompson, 1986; De Passillé *et al.*, 1988).

All these results, although somewhat contradictory, have been obtained on improved pigs, but similar information is still lacking on autochthonous breeds, which are less productive and prolific. For example, as concerns reproductive traits, the Tuscan Cinta Senese has shown a moderate litter size (6.7 piglets on average), but a good number of teats (12) as determined in a recent work based on the population data (Bozzi *et al.*, 2002). The aim of this work was to furnish a contribution to the knowledge of how the growth of piglets is influenced by suckling behavior and teat position using the Cinta Senese breed as an example of an unimproved pig.

## Material and methods

The experimental animals were 18 Cinta Senese sows (7 primiparous and 11 multiparous) and relative purebred offspring. On day 105-110 of gestation sows were housed indoors, in individual cement-floored pens (about 4 x 4 m), provided by simple structures (vertical iron bars) to temporarily isolate the litter from the sow and to prevent crushing of the piglets. Straw was provided as bedding before farrowing, and a heat lamp was installed on one side of the pen. Piglets were individually ear tattooed and cared for according to

recommended management guidelines (iron injection and clipping of eye teeth). Males were castrated after weaning. After farrowing, the dietary intake (a 15% protein diet) of sows was gradually increased to 2.3 kg d<sup>-1</sup> plus 0.2 kg for each piglet nursed. Creep feed for the piglets was provided freely commencing at 14 d of age. The average litter size at farrowing was 6 (min. 4 - max. 8) and 7.82 (6 - 10) for primiparous and multiparous sows, respectively, and the relative age was 41 d (39 - 45) and 37.45 d (30 - 43). Individual weight of piglets, to the nearest 50 g, was recorded at birth (or shortly afterwards) and subsequently every 3-5 days up to weaning. Overall, the individual recording of weight, and the consequent growth study, concerned 128 weaned piglets (from 136 born alive). Within the litter at each recording, the rank of piglets' weight in decreasing order was performed, assigning 1, 2, 3... value at the first, second, third... heaviest animal. In the case of two or more identical weights, the average rank position was assigned to the involved pigs.

A subsample of 8 sows, 4 primiparous and 4 multiparous, was considered with the aim to study the relationship between the weight of piglets and the suckled teat order. All the sows had 12 functional teats equally distributed in the two symmetric rows. The teat pairs were numbered in increasing order from the anterior to the posterior region, and the piglets within the litter were marked on the back with an ink number for permanent individual identification. Roughly every two days, series of behavioral observations lasting 3-6 hours were performed, often distributed in two daily sessions (the morning and afternoon) and the teat-piglet couplings were recorded. Considering that a sow's milk ejection is remarkably brief (Fraser, 1980), as suggested by Valros *et al.* (2002) a nursing was considered successful (with milk ejection) if a fast-sucking phase could be observed with piglets sucking intensively for about 15 s. Within litter and observation session, the rank of piglets' weight in decreasing order was performed as specified above, but, since the observation sessions were more frequent than the weight recording, piglets maintained the same weight and the same rank in all the sessions subsequent to the last weight recording.

Statistical analysis was carried out using the Procedures GLM and MIXED of SAS (1996). Models were different for the various parameters. The weight growth of piglets, as influenced by parity order (PO: primiparous vs. multiparous), has been analyzed using the following mixed model:

$$Y_{ijklm} = \mu + G_i + PO_j + S_{jk} + AGE^*PO_j + I_l + E_{ijklm}$$

Where:

Y = the dependent variable (weight);

$\mu$  = overall mean;

G = fixed effect of sex;

S = fixed effect of sow (litter) within parity order;

AGE\*PO = intraclass (parity order) regression on age tested up to the third degree;

I = random effect of the subject;

E = random effect of residual.

Repeatability of weight or weight rank has been calculated as the ratio between permanent variance (subject) and total variance (subject + residual) obtained from a similar mixed model which considered only litter and age\*litter as fixed effects. The relationship between weight (or weight rank) and suckled teat has been studied by the model:

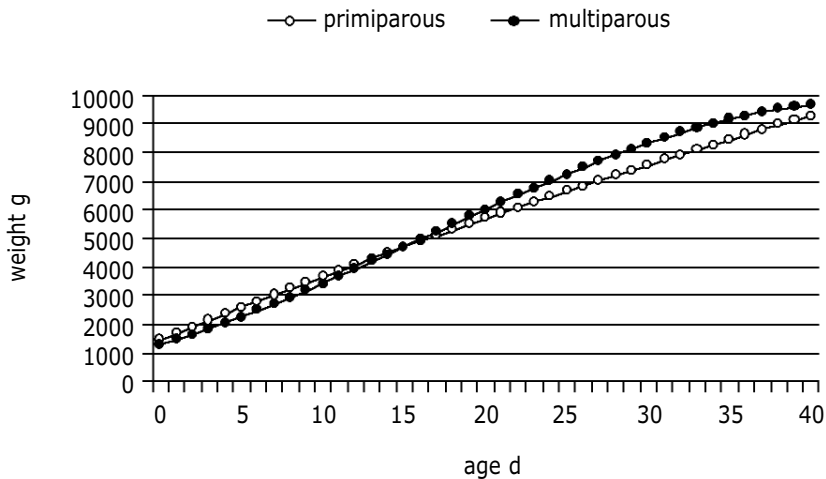
$$Y_{ijkl} = \mu + G_i + TP_j + S_k + AGE^*TP_j + AGE^*S_k + E_{ijkl}$$

Where TP is the fixed effect of teat pair and the other symbols have the aforementioned meaning; covariates have been tested up to the third degree and the intraclass regression AGE\*S was not inserted in the model for the weight rank.

## Results and discussion

The growth study of piglets up to weaning was carried out on the 128 animals of the most complete dataset and the trends of weight on age are shown in Figure 1. Offspring of primiparous and multiparous sows had similar behavior up to the second week but, afterwards, piglets of multiparous sows showed a faster growth rate and, even at 20 d of age, their weight was higher than the

Figure 1. Growth of the piglets according to the parity order of the dam



$$\text{primiparous: weight(g)} = 1460.8 + 230.7 * \text{age(d)} - 1.026 * \text{age}^2 + 0.0039 * \text{age}^3$$

$$\text{multiparous: weight(g)} = 1304.6 + 166.9 * \text{age(d)} + 5.809 * \text{age}^2 - 0.1188 * \text{age}^3$$

counterpart (319 g the difference between the estimated means;  $P < 0.01$ ). The results confirm the findings of Wülbers-Mindermann *et al.* (2002). The offspring of multiparous sows should have profited, particularly during the critical period of the third week, by a greater milk production. Even though creep feed was provided to piglets from the 14<sup>th</sup> d of age on, this fact would not influence the growth since, as reported by Sørensen *et al.* (1998), in the third and fourth week of lactation, creep feed consumed by the piglets corresponds to only 2-3% of the milk energy intake. No differences for

the growth rate of piglets were found between the sexes while the sow effect was significant within parity order.

To estimate the degree of similarity of subsequent weights of the same subject, repeatability of weight up to weaning was calculated. The value was high and ranged from 0.47 with a preliminary analysis (only regression on age as fixed effect in the model) to 0.56 with a within-litter model (litter and regression on litter\*age as fixed effects). Results are in agreement with the literature: Dyck *et al.* (1987) and Fraser and Morley Jones (1975)

Table 1. Repeatability (r) of weight rank within litter in various suckling periods

	Observation n. <sup>1</sup>	Permanent Variance	Residual variance	r
Up to				
7 d	289	3,8386	1,2580	0.753
14 d	413	3,8156	1,3817	0.734
21 d	526	3,7781	1,3892	0.731
28 d	664	3,5893	1,5384	0.700
Weaning	861	3,3837	1,6806	0.668

On 127 piglets from 18 litters

<sup>1</sup> Weight recordings \* piglets

Table 2. Estimates of weight and weight rank (within litter) by teat pair

	Weight (g)	Weight rank
Effect (5947)		
- litter	**	**
- sex	**	**
- regression on age	3 <sup>rd</sup> degree	1 <sup>st</sup> degree
r.s.d.	638.4	1.844
R <sup>2</sup>	0.92	0.26
Estimates <sup>1</sup>		
- at 5 days		
- pair 1 (1460)	2312 ± 28 <sup>a</sup>	4.79 ± 0.075 <sup>c</sup>
- pair 2 (1507)	2445 ± 28 <sup>b</sup>	3.34 ± 0.073 <sup>a</sup>
- pair 3 (1419)	2470 ± 29 <sup>b</sup>	3.30 ± 0.077 <sup>a</sup>
- pair 4 (1073)	2464 ± 33 <sup>b</sup>	4.08 ± 0.089 <sup>b</sup>
- pair 5&6 (429 + 59)	2308 ± 45 <sup>a</sup>	5.29 ± 0.122 <sup>d</sup>
- at 30 days		
- pair 1	8637 ± 36 <sup>d</sup>	3.18 ± 0.093 <sup>a</sup>
- pair 2	8259 ± 37 <sup>c</sup>	4.16 ± 0.093 <sup>c</sup>
- pair 3	8254 ± 38 <sup>c</sup>	3.75 ± 0.097 <sup>b</sup>
- pair 4	7992 ± 42 <sup>b</sup>	3.94 ± 0.106 <sup>bc</sup>
- pair 5&6	7245 ± 69 <sup>a</sup>	6.25 ± 0.172 <sup>d</sup>

On 56 piglets from 8 litters

<sup>1</sup> Means estimated along the slope of intraclass (teat pair) regression line

In brackets the number of observations (suckling episodes \* piglets)

\*\* :  $P < 0.01$ ; <sup>a,b</sup>:  $P < 0.05$

found a high positive correlation between birth weight and 35-d weight ( $r=0.60$ ) or 3-week weight ( $r=0.47$ ), respectively; Fraser and Thompson (1986) indicated that 0-day weight accounted for 30-40% of the within litter variation in 14 day weight.

Repeatability has been calculated on the values of weight rank in various periods up to weaning, as well (Table 1). The use of the within-litter rank instead of the weight values solves the problem due to the variation of weight variability as the age of piglets increases (Fraser and Thompson, 1986; Valros *et al.*, 2002) and furnishes an indication of possible competition within litter linked to weight difference, since the larger piglets are generally more socially dominant (Scheel *et al.*, 1977). Conversely, some statistical bias can exist because of the relative dependence of data, as the rank of each piglet is determined by the weight of the littermates, and the non-normality of the residuals distribution. As shown in Table 1, the repeatabili-

ty coefficient for rank was high but decreased as lactation continued. It indicates that even if the weight rank of piglets within litter was maintained in the majority of cases, some exceptions seem to exist particularly during the third week, when piglets can consume creep feed.

To verify the relationship between teat order and weight of piglets, the dataset of the behavioral observations on 8 litters and sows has been used and the weight of the relative 56 piglets has been regressed on age according to the teat pair (i.e. at each teat pair, the weight of the piglet which suckled at the moment of the observation has been attributed). Because of the low number (4) of primiparous or multiparous sows, the effect of parity order never attained significance and a pooled analysis was performed. On average, 106 suckling episodes per piglet were recorded and teat pairs 5 and 6 were considered together because of the low number of observation for the caudal teats. The

Figure 2. Trend of the piglets' weight during the suckling period according to teat pairs



trend of weight per teat pair is shown in Figure 2 and the estimated means at the 5<sup>th</sup> and 30<sup>th</sup> day are reported in Table 2. Similar analysis has been carried out on the weight rank (Figure 3 and the same Table 2).

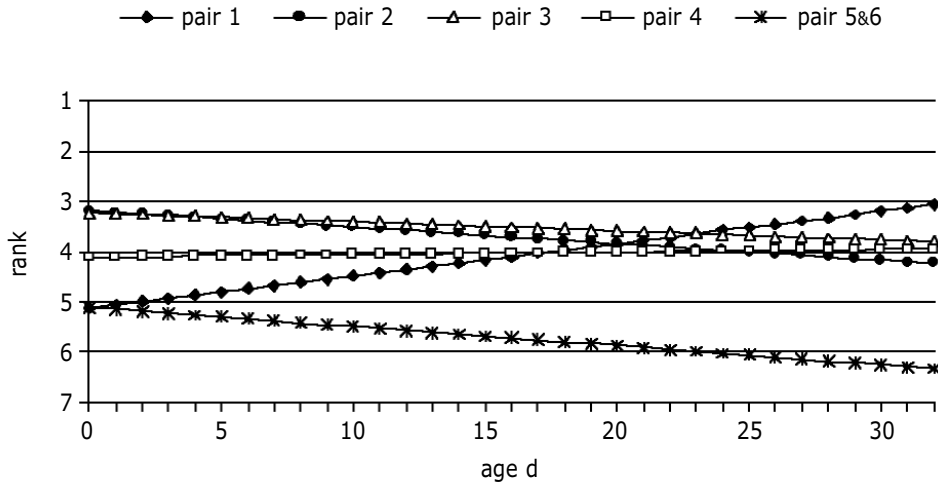
As shown in Table 2, at 5 d the heaviest piglets arranged themselves on the teat pairs in the middle of the udder while the lightest ones were found at both ends, but differences, though significant, appear slight (maximum 260 g). Analysis carried out on rank values highlights the link between the relative weight within litter and the suckled teat. Piglets of lower rank (at top of the weight list) suckled at teat pairs 2 and 3 while those of higher rank (at bottom of the classification) occupied the first and most caudal pairs. Several authors (Hartsock and Graves, 1976; Hartsock *et al.*, 1977; Scheel *et al.*, 1977) have depicted the nursing order of piglets as involving active competition, with the more vigorous piglets and those with higher birth weights assigning themselves to the more anterior teats. However, Fraser and Morley Jones (1975) and Fraser *et al.* (1992) found that the association between teat order and birth weight was weak, though significant. This was also confirmed by the present study which showed

the anomalous behavior of the first teat pair in a general cranio-caudal increasing gradient of weight rank as teat order increases.

The piglets' preference of the anterior teats is probably due to various factors: those teats are in a safer region because more far from the dam's hind legs (Scheel *et al.*, 1977); the piglets choose the teats closest to the sow's grunts (Jeppesen, 1982) or they prefer teats where suckling stimulate the sow to grunt (Fraser, 1973); piglets may tend to avoid smaller teats, which are more common at the posterior end (Orihuela and Solano, 1995). In this experiment, where piglets had wide possibility of choice since litter size (on average 7 piglets, min. 5 and max. 9) was always lower than the number of teats (12), the preference of the anterior teats is evident. In 868 observations concerning each teat pair, the occupation frequency was 84.1, 86.9, 81.8, 61.9, 24.7, 3.4 from the 1<sup>st</sup> towards the 6<sup>th</sup> row. A similar gradient is reported by Dyck *et al.* (1987) in litters of improved breeds.

Some results in literature have shown that the within-litter variation in body weight can be explained, not only by variation in birth weight, but also by a tendency toward superior weight gains of piglets suckling the more anterior teats

Figure 3. Trend of the piglets' weight rank within litter during the suckling period according to teat pairs



(Fraser *et al.*, 1979; Fraser and Thompson, 1986; Dyck *et al.*, 1987) however, this finding is not confirmed by other Authors (Fraser and Morley Jones, 1975; Hemsworth *et al.*, 1976; Orihuela and Solano, 1995). In this work, as effect of the different trends shown both in Figure 2 (for weight) and in Figure 3 (for rank), at 30 d (Table 2) the heaviest and the lightest piglets occupied pair 1 and pairs 5 & 6 respectively, with a fairly uniform situation on the pairs 2, 3, and 4, particularly when

the rank values are considered. Figure 2 shows that the anterior nipples produced the highest weight gain whereas the caudal ones produced the lowest. Figure 3 defines that the first pair determined a marked improvement of weight rank of piglets within litter while pairs 2, 3, 5 & 6 worsened the rank position.

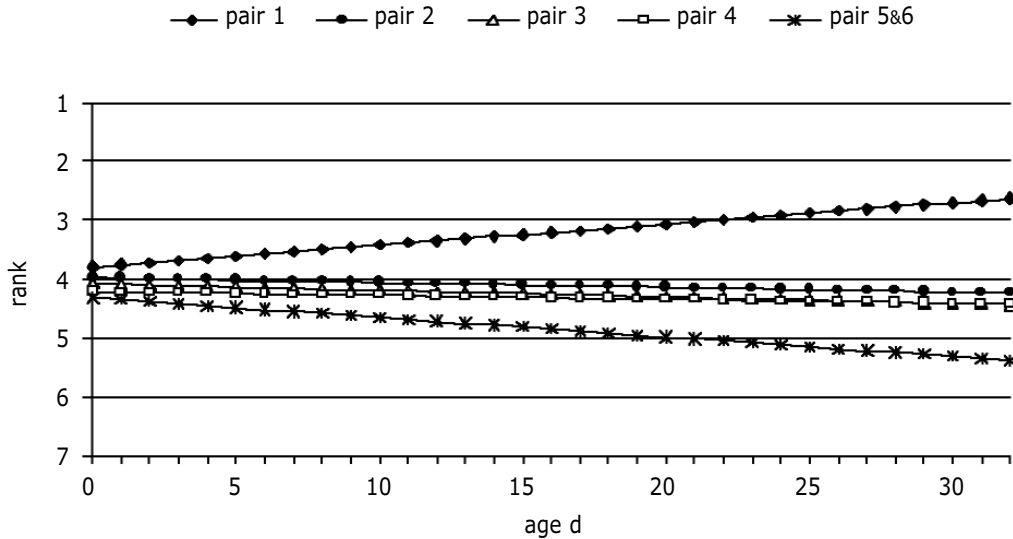
It is unclear whether this result is due to the greatest milk production of the anterior teats or to the systematic occupation of the anterior teats

Table 3. Teat fidelity as frequency of occupation of the teat pairs by piglets that suckled at the preferred teat

	Preferred teat				
	pair 1	pair 2	pair 3	pair 4	pair 5
n. piglets	14	14	13	11	4
pair 1	<b>92.50±11.31</b>	1.03±1.72	0.96±1.02	0.98±1.79	1.18±2.36
pair 2	3.25±2.9	<b>90.52±6.38</b>	4.58±5.87	1.12±1.93	0.47±0.54
pair 3	0.59±0.80	6.72±5.91	<b>83.31±10.28</b>	8.58±7.04	11.81±20.50
pair 4	1.04±2.62	1.41±1.93	9.98±7.76	<b>79.37±12.59</b>	8.33±8.13
pair 5	2.55±8.29	0.30±0.72	0.73±1.07	9.50±11.73	<b>66.91±16.47</b>
pair 6	0.05±0.2	0	0.43±1.06	0.46±0.81	11.32±12.71

*In bold the frequency at the preferred teat*

Figure 4. Trend of piglets' weight rank within litter during the suckling period in the first five teat pairs. Data corrected for subject



by different heaviest piglets, because of the aforementioned reasons. The parameter "teat fidelity" (consistency of suckling position of piglet) can help to understand the phenomenon. For each piglet, the frequency of occupation of various teat pairs was calculated and the preferred teat has been identified as that with the maximum frequency (Table 3). The number of piglets that preferred a particular teat decreased from the first two pairs towards the subsequent ones but no piglets preferred the 6th pair. Along the same antero-posterior direction, the occupation frequency at the preferred teat decreased and the frequencies on the other teat pairs (mainly on the adjacent posterior pair) increased. The high fidelity regarding the anterior teats, excluding the hypothesis of the progressive occupation of different heavier piglets, seems to point to their higher milk production, but the lower growth rate observed in piglets which suckled at the posterior teats could be produced by a greater fighting of piglets, as the low teat fidelity should indicate. According to Fraser (1980) and De Passillé *et al.* (1988) teat fidelity is an advantage to piglets

because competition at suckling is reduced. Consequently, the piglets do not waste time finding teats and can avoid injuries whereas, if they are fighting, they can miss nursing and grow more slowly (Fraser and Thompson, 1986). To test if teat fidelity (or the opposite hypothetical fighting) affected the weight gain of these piglets, a statistical analysis was carried out using a model with litter, sex, and preferred pair as discrete factors and frequency of occupation at preferred teat as the continuous variable. The latter effect was not significant (regression coefficient  $-0.25 \pm 0.45$ ;  $P = 0.59$ ) indicating no disadvantage in growth rate for the piglets with low teat fidelity.

Moreover, analysis of the rank values with a model as in Figure 3 was conducted, adding the effect of subject within litter. This model furnishes results corrected for subject and can explain the capacity of teats to enable weight gain without the possible confusion due to particular piglets. The results are shown in Figure 4. At birth the rank values of different teat pairs are analogous, as expected, but while in pairs 2, 3 and 4, the trend slightly increased, there was a marked increase in



rank value (i.e. through the bottom of the weight classification within litter) for pairs 5 & 6 and a strong decrease for pair 1. If the weight gain of piglets can indicate the milk production ability of the nipples, we conclude that in these Cinta Senese sows there was an evident differentiation of milk productivity along the udder according to a cranio-caudal gradient, with particular evidence for the first and the last teat pairs, confirming the results of some Authors (Fraser *et al.*, 1979; Fraser and Thompson, 1986; Dyck *et al.*, 1987)

### Conclusions

This work aimed to study the performance and behavior of sow and litter during the suckling period using the Cinta Senese breed as a model for the autochthonous pig. Behaviour of Cinta Senese mother-offspring was in general agreement with the results obtained in improved swine.

The weight rank within litter had high repeatability during the suckling period and teat fidelity of piglets was particularly high on the most cranial nipples, with a decreasing trend though the posterior teats. Because of the large availability of nipples for piglets within litter, rather common in Cinta Senese swine considering their moderate prolificacy, low fidelity on the more caudal teats did not determine a lower weight gain in piglets. The study of the relationship between piglet weight and teat order revealed that in these sows the first teat pair was the most productive and the last pairs the least productive although the largest piglets of litter assigned themselves to the middle of the udder in the first days of suckling. To increase the knowledge of the Cinta Senese, analogous studies should be conducted in a free range system which is, at moment, frequently used for this unimproved pig.

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### REFERENCES

- BOZZI, R., BUTTAZZONI, L., PUGLIESE, C., FRANCI, O., 2002. Genetic parameters for teat number and litter size in Cinta Senese pig. Proc. 7th World Congr. Genet. Appl. Livest. Prod. 30:91-94.
- DE PASSILLÉ, A.M.B., RUSHEN, J., 1989. Suckling and teat disputes by neonatal piglets. Appl. Anim. Behav. Sci. 22:23-28.
- DE PASSILLÉ, A.M.B., RUSHEN, J., HARTSOCK, T.G., 1988. Ontogeny of teat fidelity in pigs and its relation to competition at suckling. Can. J. Anim. Sci. 68:325-338.
- DYCK, G.W., SWIERSTRA, E.E., MCKAY, R.M., MOUNT, K., 1987. Effect of location of the teat suckled, breed and parity on piglet growth. Can. J. Anim. Sci. 67:929-939.
- FRASER, D., 1973. The nursing and suckling behaviour of pigs. I. The importance of stimulation of the anterior teats. Br. Vet. J. 129:324-336.
- FRASER, D., 1980. A review of the behavioural mechanism of milk ejection of the domestic pig. Appl. Anim. Ethol. 6:247-255.
- FRASER, D., MORLEY JONES, R., 1975. The 'teat order' of suckling pigs I. Relation to birth weight and subsequent growth. J. Agric. Sci., Camb. 84:387-391
- FRASER, D., THOMPSON B.K., 1986. Variation in piglet weights: relationship to suckling behaviour, parity number and farrowing crate design. Can. J. Anim. Sci. 66:31-46
- FRASER, D., THOMPSON B.K., FERGUSON, D.K., DARROCH, R.L., 1979. The "teat order" of suckling pigs. III. Relation to competition within litters. J. Agric. Sci., Camb. 92:257-261.
- FRASER, D., THOMPSON B.K., RUSHEN, J., 1992. Teat production in second lactation sows: influence of use or non-use of teats during the first lactation. Anim. Prod. 55:419-424.
- HARTSOCK, T.G., GRAVES, H.B., 1976. Neonatal behavior and nutritional-related mortality in domestic swine. J. Anim. Sci. 42:235-241.
- HARTSOCK, T.G., GRAVES, H.B., BAUMGARDT, B.R., 1977. Agonistic behavior and the nursing order in suckling piglets: relationships with survival growth and body composition. J. Anim. Sci. 44: 320-330.
- HEMSWORTH, P.H., WINFIELD, C.G., MULLANEY, P.D., 1976. Within litter variation in the performance of piglets to three weeks of age. Anim. Prod. 22:351-357.
- JEPPesen, L.E., 1982. Eat order in group of piglets reared on an artificial sow. I. Formation of teat order and influence of milk yield on teat preference. Appl. Anim. Ethol. 8:335-345.
- MCBRIDE, G., JAMES, J.W., WYETH, G.S.F., 1965. Social behaviour of domestic animals. VII. Variation in weaning weight in pigs. Anim. Prod. 7:67-74.

- MILLIGAN, B.N., FRASER, D., KRAMER, D.L., 2002. Within-litter birth weight variation in the domestic pig and its relation to pre-weaning survival, weight gain, and variation in weaning weights. *Liv. Prod. Sci.* 76:181-191.
- ORIHUELA, A., SOLANO, J.J., 1995. Managing "teat order" in suckling pigs (*Sus scrofa domestica*). *Appl. Anim. Behav. Sci.* 46:125-130.
- SAS, 1996. SAS/STAT software, release 6.12. SAS Institute Inc., Cary, NC.
- SCHEEL, D.E., GRAVES, H.B., SHERRITT, G.W., 1977. Nursing order, social dominance and growth in swine. *J. Anim. Sci.* 45:219-229.
- SØRENSEN, M.T., DANIELSEN, V., BUSK, H., 1998. Different rearing intensities of gilts: 1. Effects on subsequent milk yield and reproduction. *Liv. Prod. Sci.* 54:159-165.
- VALROS, A.E., RUNDGREN, M., SPINKA, M., SALONIEMI, H., RYDHMER, L., ALGERS, B., 2002. Nursing behaviour of sows during 5 weeks lactation and effects on piglet growth. *Appl. Anim. Behav. Sci.* 76:93-104.
- WÜLBERS-MINDERMAN, M., ALGERS, B., BERG, C., LUNDEHEIM, N., SIGVARDSSON, J., 2002. Primiparous and multiparous maternal ability in sows in relation to indoor and outdoor farrowing systems. *Liv. Prod. Sci.* 73:285-297.
- WYETH, G.S.F., MCBRIDE, G., 1964. Social behaviour of domestic animals. V. A note on suckling behaviour in young pigs. *Anim. Prod.* 6:245-247.