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Original article

Milk production in crossbred sows (Large White × Landrace). Evolution and analysis of variation factors

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Abstract — Fifty-six lactations, 23 from primiparous Large White × Landrace sows and 33 from 11 multiparous sows were controlled. Milk yield was estimated by weighing the piglets before and after sucklings throughout a 12-h period on days 7, 14, 21, 28, 35 and 42 of lactation. Total milk yield and milk production per weaned piglet during a 6-week lactation period were 170.0 ± 48.8 kg and 29.4 ± 7.3 kg respectively for primiparous sows and 210.9 ± 33.6 kg and 26.9 ± 5.1 kg respectively for multiparous sows. In both groups, the peak of lactation was reached in the 3rd week and the lowest amount of milk was yielded during the 6th week (33.5 ± 14.3 kg and 23.3 ± 9.9 kg in primiparous sows and 43.3 ± 11.1 kg and 28.0 ± 9.8 kg in multiparous sows). Milk production curve was fitted to a gamma function ($R^2 = 0.86$ in primiparous and $R^2 = 0.91$ in multiparous sows). The season of farrowing had no significant influence ($P > 0.05$) on total milk yield and milk production per weaned piglet in primiparous sows. However, total milk yield was increased ($P < 0.001$) as a result of increased litter size. For each additional weaned piglet, total milk production increased 25 kg, whereas milk production per weaned piglet non-significantly decreased by 1.01 kg ($P < 0.2$). For multiparous sows, total milk yield and milk production per weaned piglet were significantly affected ($P < 0.05$) by sow and by parity. In the lactation 4 the milk output was higher than in the lactation 2 and 3. Litter size at weaning did not affect the total milk yield; it affected the milk production per weaned piglet ($P < 0.001$). Sow weight after farrowing and the changes in weight during lactation did not affect total milk yield or milk production per weaned piglet in primiparous and multiparous sows. © Elsevier / Inra

sow / milk production / season of farrowing / weight change / parity

Résumé — **Production de lait chez des truies Large White × Landrace. Évolution et analyse des facteurs de variation.** Cinquante-six lactations : 23 de truies primipares et 33 de 11 truies multipares

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Large White × Landrace ont été contrôlées. La production de lait a été estimée par le procédé direct de double pesée de la portée avant et après tétée grâce à 12 contrôles réalisés chaque heure entre 9 h et 20 h aux jours 7, 14, 21, 28, 35 et 42 de lactation. La production totale de lait, et la production par porcelet sevré durant les 6 semaines de lactation ont été de 170 ± 48,8 kg et 29,5 ± 7,3 kg respectivement pour les primipares et de 210,9 ± 33,6 kg et 26,9 ± 5,1 kg respectivement pour les multipares. Dans les deux groupes de truies, la production maximale de lait a été obtenue pendant la troisième semaine de lactation et la production minimale dans la sixième : 33,5 ± 14,3 kg et 23,3 ± 9,9 kg pour les truies primipares et 43,3 ± 11,1 et 28,0 ± 9,8 pour les truies multipares. La courbe de lactation a été ajustée a une fonction « gamma » (R^2 = 0,86 pour primipares et R^2 = 0,91 pour multipares). Pour les truies primipares la date de mise bas n'a pas eu d'effet significatif ($P < 0,05$) sur la production totale de lait ni sur celle exprimée par porcelet sevré. Toutefois par porcelet sevré supplémentaire la production totale de lait a augmenté ($P < 0,001$) de 25 kg tandis que la production de lait par porcelet sevré a diminué de 1,01 kg, diminution non significative ($P < 0,02$). Pour les truies multipares la production totale de lait et par porcelet sevré est affectée significativement ($P < 0,05$) par la truie et le numéro de mise bas. Les productions obtenues durant la quatrième lactation ont été supérieures à celles obtenues durant la troisième et deuxième lactations. Le nombre de porcelets sevrés a affecté la production de lait par porcelet sevré ($P < 0,001$). Pour les deux groupes de truies, le poids après la mise bas et les variations de poids observées durant la lactation n'ont pas eu d'effet significatif sur la production totale de lait et la production par porcelet sevré. © Elsevier / Inra

truie / production de lait / saison de mise bas / changement de poids / parité

1. INTRODUCTION

Maternal and environmental factors such as breed, age of sow, litter size, feeding, health and management affect sow milk production. The estimation of sow total milk yield by weighing piglets before and after suckling is an accepted method to estimate the quantity of milk produced by sows [1]. The evolution of milk production and the effect of maternal and environmental factors affecting total milk yield have been studied in some previous experiments [2, 4, 6–8, 11, 12]. Studies concerning the relationship between total milk yield and feeding during pregnancy and lactation have been more numerous.

The estimation of sow total milk yield can be a useful guide to consider improvements in the feeding and management strategies of sow and offspring and subsequently to increase the weight of piglets at weaning. The aim of this experiment was to study the evolution of total milk yield for primiparous and multiparous sows and to analyze the effects of specific factors such as season of farrowing, weight of the sow after farrowing and the weight change of the sow during lactation for both groups of sows and including the parity number for multiparous sows.

2. MATERIAL AND METHODS

56 lactations, 23 from 23 primiparous LW × LR sows and 33 from 11 multiparous sows (2nd, 3rd, 4th lactation) were controlled under the same management conditions.

During pregnancy, sows were fed 2.5 kg/d concentrate containing 2900 kcal DE/kg; 14 % CP and 0.6 % lysine. During the lactation period the sows were fed ad libitum a concentrate containing 3100 kcal DE/kg, 16.5 % CP and 0.8 % lysine. Piglets were fed prestarter containing 3400 kcal DE/kg, 22 % CP and 1.4 % lysine from 5 weeks of age.

Every day temperatures were recorded in the farrowing pen.

Total milk production for each sow was measured once a week during a 6-week lactation period. Before and after suckling, piglets were individually weighed throughout a 12-h period on days 7, 14, 21, 28, 35 and 42 of lactation by an

electronic balance equipped with an integration system. The piglets were separated from the sow early in the morning of the weighing day (7.00 h), 1 h later the piglets were weighed and then allowed to suckle. After nursing, the animals were weighed and again separated from the sow for 1 h. After that they were weighed again, allowed to suckle and weighed again.

In order to avoid errors in milk yield estimation, piglets were encouraged to urinate and defecate just before weighings. The weight gain was assumed to be the amount of milk produced by the sow. Daily milk production was considered to be twice the amount of estimated milk in the 12-h periods and weekly milk production was estimated as 7 × daily milk production [1].

The milk intakes of some piglets estimated as weight gain during suckling (23.3 % of total weighings) were abnormally low or even negative because of defecating, urinating, strugglings etc. Then, the measured milk intake of these piglets was replaced by the average milk intake over the other measurements of the day. During the sucklings, the litter weight gain was also corrected by weight losses due to water evaporation and metabolism between weighings according to Klaver et al. [10]. The sows were weighed next day after farrowing and immediately after weaning.

2.1. Statistical analyses

Analysis of variance was used to study the evolution of weekly milk production, the week of lactation being one fixed effect. Moreover, a gamma function to the lactation data was fitted.

In primiparous sows total milk yield and milk production per weaned piglet in the 6-week lactation period were analyzed by an analysis of covariance. The model was:

$$Y_{ij} = \mu + S_i + \alpha\, DP + \beta\, W + \gamma\, WCL + \varepsilon_{ij}$$

where μ, general mean; S_i, farrowing season (winter: December-February; spring: March-May; summer: June-August; autumn: September-November); DP, litter size at weaning; W, post-partum weight of sows; and WCL, weight change of the sows during lactation period.

In multiparous sows, an analysis of covariance was used to study total milk yield and milk production per weaned piglet. The model was:

$$Y_{ij} = \mu + So_i + P + \alpha\, DP + \beta\, W + \gamma\, WCL + \varepsilon_{ij}$$

where μ, general mean; So, sow; P, number of parity; DP, litter size at weaning; W, post-partum weight of sows; and WCL, weight change of the sows during the lactation period. Results are presented as least squares means.

3. RESULTS

Litter size at weaning was 6.0 ± 2.2 for primiparous sows and 8.4 ± 1.6, 8.2 ± 1.8 and 8.0 ± 2.4 for multiparous sows during 2nd, 3rd and 4th farrowing, respectively. The weights after farrowing and the weight change during lactation were 197.6 ± 12.8 kg and 222.6 ± 15.5 kg and 12.0 ± 8.7 and 5.51 ± 11.0 for primiparous and multiparous sows, respectively.

3.1. Evolution of milk production

Average weekly milk production was 28.3 ± 11.2 and 35.1 ± 10.5 kg in primiparous and multiparous sows respectively. The weekly milk yield from primiparous and multiparous sows is shown in *table I.*

In primiparous sows, a non-significant increase in milk production was observed from the week 1 to the week 3; and later, from the week 3 to the week 5 a non-significant decrease was noted. The only significant statistical differences in milk production

Table I. Average weekly milk production (kg) in primiparous and multiparous sows.

Weeks of lactation	Primiparous[1]	Multiparous[2]
1	26.4 ± 9.8^{ab}	32.5 ± 8.8^{cd}
2	30.9 ± 12.3^{ab}	38.9 ± 9.7^{ab}
3	33.5 ± 14.3^{a}	43.3 ± 11.1^{a}
4	29.5 ± 12.3^{ab}	36.4 ± 10.9^{bc}
5	26.5 ± 11.1^{ab}	31.7 ± 12.1^{cd}
6	23.3 ± 9.9^{b}	28.0 ± 9.8^{d}

[1] 23 lactations. [2] 33 lactations. Means within columns with different superscript differ, $P < 0.05$.

were obtained between the 3rd and the 6th week of lactation ($P < 0.05$).

In multiparous sows, total milk production increased and was significantly different between the 1st and 2nd and 3rd weeks of lactation. A significant decrease took place in the weeks 4, 5 and 6 of lactation compared to milk produced by sows in the week 3.

In both groups of sows, the lowest and the highest milk production were obtained in weeks 3 and the 6 of lactation, respectively.

Gamma functions were calculated to fit the weekly data (*figure 1*). The equations were the following:

Primiparous sows:

$$Y = 34.02 * t^{0.67} * e^{-0.264} \ (R^2 = 0.86)$$

Multiparous sows:

$$Y = 44.0 * t^{0.79} * e^{-0.315} \ (R^2 = 0.91)$$

with t representing the week of lactation (1...6).

3.2. Factors affecting total milk production

3.2.1. Primiparous sows

The average total milk yield and the average milk production per weaned piglet from primiparous sows during a 42-day lactation period were 170.0 ± 48.8 and 29.5 ± 7.3 kg, respectively.

Season of farrowing, litter size at weaning, weight of sows after farrowing and weight change of the sows during lactation explained 64.5 % and 35.3 % of the variability observed in total milk yield and milk production per weaned piglet, respectively.

The season of farrowing had no significant influence on total milk yield and on milk production per weaned piglet (*table II*). Total milk yield was significantly increased ($P < 0.001$) by 25.0 kg for each additional piglet weaned, whereas milk production per weaned piglet decreased non-significantly ($P < 0.2$) by 1.01 kg. By increasing the weight of the sow after farrowing, total milk yield and milk production per weaned piglet

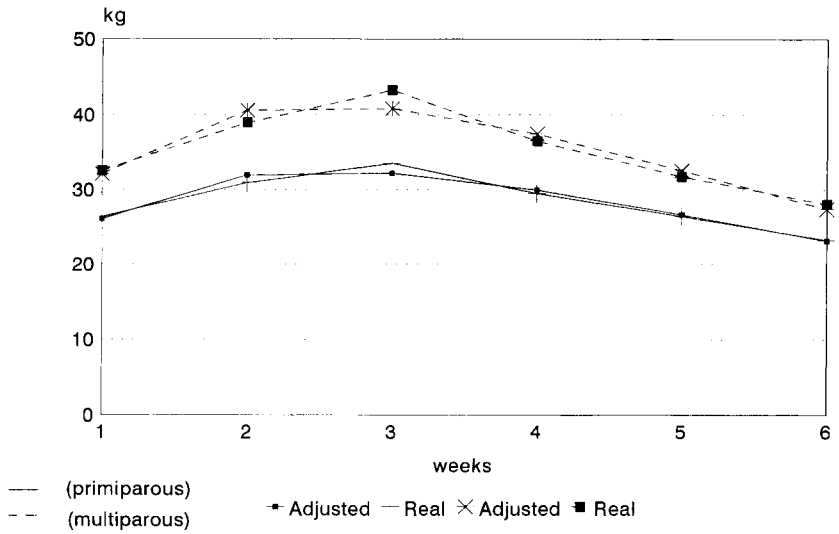

Figure 1. Gamma function for primiparous and multiparous sows for the estimation of weekly milk production.

Table II. Effect of farrowing season on total milk yield (TMY) and on milk production per weaned piglet (MPWP) in primiparous sows (LSM).

Farrowing season	Lactation number	Mean temperature (°C)	TMY (kg)	MPWP (kg)
Winter	8	11.8 ± 1.1	166.0 ± 21.0	28.1 ± 3.1
Spring	11	19.0 ± 1.0	168.7 ± 20.2	30.3 ± 3.1
Summer	7	26.5 ± 0.9	180.2 ± 24.5	30.4 ± 3.7
Autumn	7	16.3 ± 1.1	168.8 ± 20.9	29.3 ± 3.1

Table III. Influence of parity on total milk yield (TMY) and milk production per weaned piglet (MPWP) (least square means).

Lactation order	N	Mean temperatures	TMY (kg)	MPWP (kg)
2	11	22.0 ± 0.8	177.3 ± 16.9[a]	21.7 ± 2.5[a]
3	11	15.3 ± 0.9	207.3 ± 10.4[a]	26.1 ± 1.6[a]
4	11	22.1 ± 0.7	248.1 ± 15.7[b]	33.1 ± 2.4[b]

Means within columns with different superscript differs $P < 0.04$. N, number of observations.

also increased by 1.7 kg/kg and 0.3 kg/kg respectively, although not significantly ($P < 0.12$ and $P < 0.08$). The weight change of the sow during lactation did not significantly affect total milk yield ($P < 0.63$) and milk production per weaned piglet ($P < 0.6$) although both variables were increased by 0.74 and by 0.12 kg, respectively, per kg of change in weight during lactation.

3.2.2. Multiparous sows

In multiparous sows, the average milk yield and the average milk production per weaned piglet during the 42-day lactation period were 210.9 ± 33.6 and 26.9 ± 5.1 kg, respectively.

When using sow and parity number as fixed effects, and litter size at weaning, weight of sow after farrowing and weight change of the sow during lactation as covariables in the analysis this model explained 84 and 84.7 % of the variation in total milk yield and milk production per weaned piglet, respectively.

The fixed effect 'sow' had a significant effect ($P < 0.05$) on total milk yield, but it did not affect milk production per weaned piglet ($P < 0.23$). The number of parity significantly influenced total milk yield and milk production per weaned piglet, and an increase for both variables was observed in the 4th lactation (*table III*).

Total milk yield was not affected by litter size at weaning (+ 1.2 kg/additional piglet $P < 0.86$), but milk production per weaned piglet decreased by 4.17 kg ($P < 0.001$) for each additional weaned piglet.

As was observed in the primiparous sow group, the weight after farrowing and the weight change of the sows during lactation did not have a significant influence on total milk yield and milk production per weaned piglet in the multiparous sow group (*table IV*).

Table IV. Coefficients of partial regression between total milk yield (kg) and sows' weight (in kg) after farrowing (W) and weight changes of sows during lactation (WCL in kg).

Variable	W	P values <	WCL	P values <
Total milk yield	0.33	0.71[a]	–1.24	0.40[a]
Milk production per weaned piglet	–0.12	0.40[a]	–0.40	0.08[a]

[a] not significant.

4. DISCUSSION

4.1. Evolution of total milk yield

The shape of the lactation curve of sows seems to be determined by breed [1], thermal environment and dietary energy source [18] and level of milk production [3], for which individual variations are quite important [16]. Our results showed a more regular lactation curve for primiparous sows than for multiparous sows and these findings do not agree with those reported by Concellón [3].

For primiparous sows as well as for multiparous sows, the highest weekly milk production was observed in the weeks 2 and 3 of lactation. Similar results were also found by Allen and Lasley [1] for Landrace × Poland sows, although they recorded a lower weekly milk yield (26.0 and 26.2 kg in the 2nd and 3rd weeks of lactation, respectively).

The results of Pond et al. [14], King et al. [11], Allen and Lasley [1] in Duroc and Landrace × Poland China sows (on the days 21, 17 and 21 of lactation, respectively) and our findings showed that the peak of milk production was reached in the week 3 of the lactation. However, Allen and Lasley [1] with Poland China sows, Ferreira et al. [6] and Grün et al. [7] with Landrace sows reported that the highest amount of milk production was obtained in the week 4. The maximal milk production was reached on day 14 of lactation in Pietrain sows and on 28th day of lactation for German Landrace sows [8] or during the week 5 in Landrace sows [1]. The later the peak of milk production is reached, the less milk is produced [3], although these phenomena could be observed neither in our experiment nor in those reported by Allen and Lasley [1] and Grün et al. [7].

Pomar et al. [13] computerized simulation models based on literature. The results showed initial daily milk yield was 70 % of the maximal yield and the peak milk yield was reached at the end of the week 4 of lactation. However, in our studies, the production in the 1st week was 78.8 % of the maximum weekly production for primiparous sows and 75 % for multiparous sows and the peak of production was reached in week 3.

4.2. Factors affecting milk yield

The season of farrowing in primiparous sows had no influence on milk yield; however, Haydon et al. [9] and Black et al. [2] reported a decline of feed intake in summer and a subsequent decline of milk production. In our experiment, the milk yield during summer did not decline and this could probably be attributed to the effect of ad libitum feeding and small litter sizes (5–8 piglets).

When the number of suckled piglets increased, total milk yield also increased [1, 5, 11, 15, 20] and milk production per weaned piglet decreased [17]. Our results showed that total milk yield increased significantly with litter size in primiparous sows, but not in multiparous sows. As a con-

sequence, milk production per weaned piglet only decreased significantly with each additional piglet in multiparous sows.

As expected, the average total milk yield was higher in multiparous than in primiparous sows [5]. Within the group of multiparous sows, after adjusting the litter size, total milk yield and milk production per weaned piglet were significantly higher in lactation 4 than in the parities 2 and 3. However, Salmon-Legagneur [17] found no differences in milk production among the 2nd and the following lactations. Likewise, Allen and Lasley [1] indicated a low and non-significant coefficient of correlation ($r = 0.16$) between the age of sow and total milk yield. Lima et al. [12] observed no statistically significant influence of parity on total milk yield, with average daily milk output of 6.48, 6.79 and 5.40 for the lactations 1, 2 and 3, respectively, but there was no record for the one 4. However, Ferreira et al. [6] observed a gradual increase in milk yield from the 1st to the 3rd farrowing, which was also found by Yatusevich and Roshchin [19] through the litter growth rate during lactation. Their results showed higher daily weight gains of the litter in the lactations 2 and 3. Thus, it seems to be reasonable to expect an increase in milk yield when sows become physiologically mature.

The effect of the sow weight at farrowing and weight changes during lactation on total milk yield have not been often studied. Allen and Lasley [1] found a low and non-significant coefficient of correlation ($r = 0.10$) between the sow weight at the farrowing and milk yield, and they observed in 60 controlled lactations that the sows which lost weight during lactation yielded the highest quantities of milk.

In our experiment, results on primiparous sows as well as multiparous sows showed that neither weight of sows nor changes in weight during lactation had a significant influence on milk yield. Limited mobilization of body tissue can probably be attributed to the high levels of feeding (ad libitum) [10]. In the group of multiparous sows rather important individual variations in milk yield and in milk production per weaned piglet were observed [16].

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