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Original article

Plasma lactose after weaning and its relationship with lactose content of milk, post-weaning plasma oestradiol-17ß and weaning to mating interval in sows

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Summary — Twenty first-litter sows were used to investigate the relationship between plasma lactose concentrations following weaning and milk production, total milk content of lactose, post-weaning plasma œstradiol-17ß (E_2) concentration and weaning to mating interval. Milk production was estimated from 6 out of 8 hourly successive "weighing-suckling-weighing" of piglets on day 21 of a 28-day lactation. Sows were cannulated in the jugular vein and sampled at 8-h intervals from 2 h to 66 h after weaning. Plasma lactose concentrations ($\bar{X} \pm$ SE) after weaning increased from 52 ± 4 µM at the beginning of sampling to a peak value of 183 ± 23 µM 40 h later and then decreased to 91 ± 11 µM 66 h after weaning ($P < 0.001$). Milk production on day 21 (7.5 ± 0.3 kg) and the corresponding mik content of lactose (400.5 ± 0.2 g) were not related ($P > 0.10$) to area under the curve, timing, amplitude and spreading of the lactose peak in plasma. Similarly, none of the characteristics of the lactose peak were related ($P > 0.10$) to weaning to mating interval. There was a linear increase ($P < 0.0001$) in mean plasma E_2 concentrations ($\bar{X} \pm$ SE) from 5.6 ± 0.3 pg/ml, 2 h after weaning, to 12.9 ± 1.2 pg/ml at the end of the sampling period. On a within-sow basis, there was a correlation ($r = 0.28$; $P < 0.01$) between post-weaning plasma lactose and E_2 concentrations. Results showed the existence of the post-weaning peak of plasma lactose in sows. None of the characteristics of this peak was related to milk lactose; studies are needed to evaluate the importance of the weak relationship with the post-weaning changes in E_2 concentrations.

sow — plasma lactose — milk lactose — œstradiol 17ß — weaning

Résumé — Les variations post-sevrage du lactose plasmatique et leur relation avec le lactose du lait, l'estradiol-17ß plasmatique après le sevrage et l'intervalle sevrage-saillie chez les truies. *Vingt truies de première portée ont été utilisées pour étudier la relation entre l'évolution du lactose plasmatique après le sevrage et la production laitière, le contenu en lactose du lait, les concentrations post-sevrage d'estradiol-17ß (E_2) et l'intervalle sevrage-saillie. La production laitière a été estimée à partir de 6 valeurs choisies parmi 8 mesures consécutives, à toutes les heures, de pesées de la portée avant et après la tétée. Cette mesure a été faite au jour 21 d'une lactation de 28 jours. Les truies ont été canulées à la veine jugulaire; un prélèvement sanguin a été effectué toutes les 8 h, de 2 à 66 h après la sevrage. Les concentrations de lactose plasmatique ($\bar{X} \pm SE$) se sont accrues de 52 ± 4 µM au début des prélèvements jusqu'à un pic de 183 ± 23 µM, 40 h plus tard pour ensuite décroître à 91 ± 11 µM, 66 h après le sevrage ($P < 0,001$). La production laitière au jour 21 (7,5 ± 0,3 kg) de même que la quantité totale de lactose correspondante (400,5 ± 0,2 g) n'étaient pas reliées ($P > 0,10$) à la surface sous la courbe, l'amplitude, l'étalement et le moment*

où le pic de lactose s'est produit. De même, aucune des caractéristiques de ce pic de lactose n'était reliée (P > 0,10) à l'intervalle sevrage-saillie. Les concentrations de E_2 ($\bar{X} \pm SE$) sont passées de 5,6 ± 0,3 pg/ml, 2 h après le sevrage à 12,9 ± 1,2 pg/ml à la fin de la période de prélèvement. Après correction pour les variations entre truies, il y avait une corrélation (r = 0,28, P < 0,01) entre les concentrations plasmatiques de lactose et de E_2. Les résultats démontrent l'existence d'un pic de lactose plasmatique après le sevrage chez la truie. Aucune des caractéristiques de ce pic n'était reliée au contenu en lactose du lait; d'autres études s'avèrent nécessaires pour évaluer l'importance de la faible corrélation observée avec les concentrations post-sevrage de E_2.

truie — lactose plasmatique — lactose du lait — estradiol-17ß — sevrage

Introduction

It is generally assumed that the hydrolysis by disaccharidases in the intestinal mucosa is so complete that practically none of the ingested disaccharides is absorbed by the intestine (Williams, 1986). However, in some circumstances, such as gastrointestinal and metabolic disorders, disaccharides may appear in the circulation (Weser and Sleisenger, 1967; Vitek *et al.*, 1975). Also, during lactation, basal concentrations (70—86 µM) of circulating lactose were measured in goats, cows (Kuhn and Linzell, 1970) and sows (Hartmann *et al.*, 1984); this phenomenon was associated with leakage of lactose from the mammary gland into the blood. The concentration of plasma lactose may be influenced by some husbandry practices. For example, in goats, extending the interval between milking caused a marked increase in plasma lactose concentration and lactosuria (Wheelock and Rook, 1966). In sows, with a limited number of animals (n = 6), Hartmann *et al.* (1984) observed a peak of plasma lactose 36 h after weaning. They associated this peak with the breakdown of alveolae followed by leakage of milk components into the extracellular fluid and finally into the circulation.

Changes in plasma lactose were also observed in sows during the peri-partum period; the concentrations started to increase some hours prior to parturition and reached a peak value 6 h after parturition (Whitely *et al.*, 1984). At the same time, a large proportion of sows showed behavioural signs of œstrus (Crighton, 1970; Edwards, 1982) that were attributed to the high levels of œstrogens seen at parturition (Holness and Hunter, 1975). However, recent evidence also suggested that carbohydrate metabolism may be involved in production and release of gonadotropin in gilts (Kirkpatrick *et al.*, 1967; Armstrong and Britt, 1987; Cox *et al.*, 1987).

This work was therefore undertaken to characterize the rise in plasma lactose concentration following weaning, and to evaluate its relationship with previous milk production, milk content of lactose, post-weaning plasma œstradiol-17ß (E_2) and return to œstrus in sows.

Materials and methods

Animals

Twenty Yorkshire sows involved in this trial were used immediately after their first lactation. During gestation and after weaning, sows were fed 2.5 kg of a commercial sow diet (Table I) once daily. One week before the expected time of parturition, sows were transferred to farrowing crates and fed progressively with a lactation diet (Table I). This diet was offered *ad libitum* throughout lactation. On day 113 of gestation, parturition was induced with an intramuscular

injection of 175 µg of PGF_{2a} analog (Planate^R, ICI Pharma, Ontario, Canada). Litter size was uniformized to 8 or 9 piglets within 3 days after parturition. The dams were weighed at parturition and weaning while weight of their piglets was taken every week during lactation. Creep feed was available to the piglets from day 21 to weaning on day 28. The sows were cannulated in the jugular vein 3 days after parturition.

Milk and blood collection

Milk production was evaluated on day 21 of lactation by the "weighing-suckling-weighing" technique, as described by Lewis *et al.* (1978). The procedure was repeated 8 times and the last 6 measurements were retained for evaluation of daily milk production. On day 22, after intravenous administration of oxytocin (10 IU), a complete milking was taken from 6 opposite glands (2 anterior, 2 medial and 2 posterior) for protein, fat and lactose measurements. Blood samples were collected every 8 h, between 2 and 66 h after cessation of lactation on day 28. Plasma samples were kept frozen at –20°C until assayed.

Assays

After deproteinization with barium hydroxide and zinc sulphate (Hartmann *et al.*, 1984), plasma galactose, plasma lactose and milk lactose were determined by a colorimetric assay using galactose dehydrogenase and ß-galactosidase enzymes (Boehringer-Mannheim, Lactose/Galactose Test Combination No. 176-303). Plasma E_2 concentrations were analysed by

Table I. Composition of the diets.

Ingredient, %	*Gestation*	*Lactation*
Oats	20.0	15.0
Wheat	15.0	20.0
Corn	20.0	20.0
Barley	27.8	15.4
Wheat bran	4.0	10.0
Wheat shorts	4.0	—
Soyabean meal	1.9	13.2
Meat meal	5.0	—
Animal fat	—	2.5
Limestone	0.6	1.3
Calcium diphosphate	0.9	1.7
Salt	0.3	0.4
Trace minerals and vitamin premix [1]	0.5	0.5
Calculated composition, %		
Digestible energy (Mcal/kg)	3.0	3.1
Crude protein	14.0	16.0
Crude fat	3.1	4.9
Crude fibre	5.9	5.6
Calcium	0.9	0.9
Phosphorus	0.8	0.8
Sodium	0.2	0.2

[1] Supplied per kg of diet : 40 mg Mn, 75 mg Fe, 25 mg Cu, 0.10 mg Co, 100 mg Zn, 0.6 mg I, 0.1 mg Se, 10,000 IU vitamin A, 1000 IU vitamin D, 15 IU vitamin E, 1 mg vitamin K, 0.02 mg vitamin B_{12}, 1 mg thiamin, 3 mg riboflavin, 8 mg pantothenic acid, 10 mg niacin, 0.1 mg biotin, 250 mg choline, 0.5 mg folic acid.

radioimmunoassay after extraction of 2 ml of plasma with a mixture of petroleum ether: ethyl acetate (5.5:1) as described by Guilbault *et al.* (1988) for cow plasma. Recovery of added (x) *vs* measured (Y) E_2 concentrations in sow plasma was described by linear regression (Y = 3.953 + 0.986x). Serial dilutions of sow plasma samples in late gestation displayed inhibition curves that apparently were parallel (homogeneity of regression; $P > 0.1$) to the standard curve. Sensitivity of the assay was 1 pg/tube. Inter- and intra-assay coefficients of variation for E_2 were 6.1% and 13.5%, respectively.

Statistical analysis

Each characteristic of the post-weaning profile of plasma lactose such as total area under the curve, timing, amplitude and spreading (area under the curve/amplitude) of the peak was used as an independent variable to establish its relationship with the following dependent variables : daily milk production, total content of lactose in milk and weaning to œstrus interval. Within-sow partial correlation analysis was performed between plasma lactose and plasma E_2 concentrations. These analyses were carried out using the General Linear Model (GLM) of the Statistical Analysis System (SAS, 1985).

Results

Data on lactation performances of sows are presented in Table II. Milk yield and composition were measured on day 21 and 22, respectively. Weaning to mating interval varied from 5 to 11 days. Plasma lactose concentrations (means ± SE) increased from 52 ± 4 μM 2 h following weaning, to a peak value of 183 ± 23 μM 40 h later and then decreased to 91 ± 11 μM at the end of the sampling period (Fig. 1; $P < 0.001$). In contrast, galactose concentrations (Fig. 1) did not show significant variations throughout the sampling period and remained low (4.7 ± 0.8 μM) as compared to lactose. Neither milk production on day 21 nor lactose content of milk was related ($P > 0.10$) to total area under the curve, timing, amplitude or spreading of the post-weaning peak of plasma lactose. Similarly, none of the characteristics of this peak had any relationship ($P > 0.10$) with the weaning to mating interval. In fact, none

Table II. Lactation performances of sows ($n = 20$).

Item	*Mean ± SE*
Milk	
Yield [1] (kg/day)	7.5 ± 0.3
Lactose [2] (%)	5.4 ± 0.8
Lactose content [2] (g/day)	400.5 ± 0.2
Fat [2] (%)	6.1 ± 0.3
Protein [2] (%)	4.9 ± 0.1
Piglets weight (kg)	
Birth	1.3 ± 0.2
Weaning	7.2 ± 0.6
Sows weight (kg)	
Parturition	179.5 ± 4.5
Weaning	144.8 ± 5.0
Weaning to mating interval (days)	6.6 ± 0.4

[1] Measured on day 21 of lactation (7 days before weaning).
[2] Measured on day 22 of lactation.

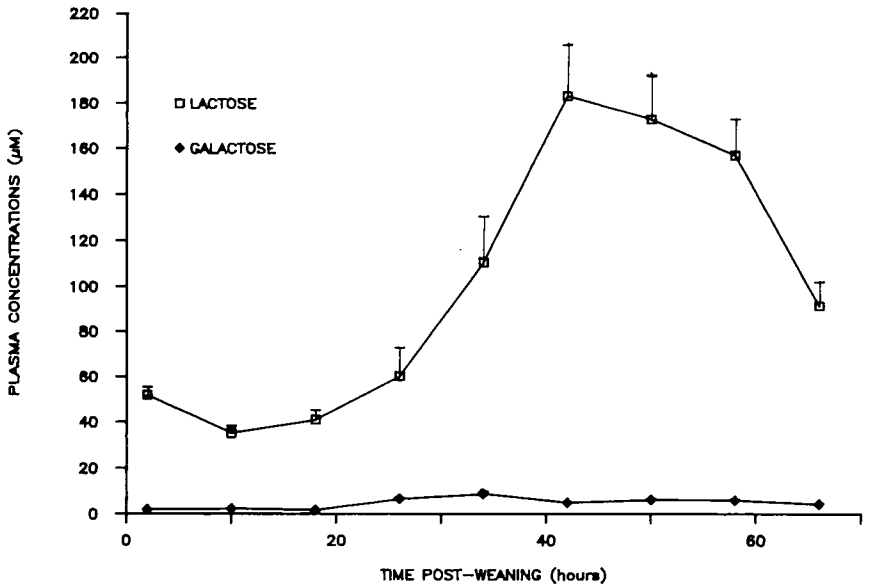

Fig. 1. Plasma lactose and galactose concentrations following weaning in sows.

of the independent variables taken together in the models contributed significantly to the variation of the dependent variables studied ($P > 0.10$).

There was a linear increase ($P < 0.01$) in the mean concentration of plasma E_2 (Fig. 2) from 5.6 ± 0.3 pg/ml 2 h following weaning, to 12.9 ± 1.2 pg/ml at the end of the sampling period. On a within-sow basis, there was a correlation ($r = 0.28$; $P < 0.01$) between post-weaning plasma lactose and E_2 concentrations.

Discussion

The post-weaning peak of plasma lactose observed in the present study was comparable to that reported by Hartmann *et al.* (1984). They observed a maximum level of 242 ± 54 µM of plasma lactose 48 h after weaning, while the corresponding values in our work were 183 ± 23 µM 42 h following weaning. The number of animals as well as the frequency of sampling may account for the variation between these 2 experiments; indeed, in the study of Hartmann *et al.* (1984), 6 sows were bled once daily, while 20 sows were sampled 3 times daily in the present work. The rise in the concentration of plasma lactose concentration after weaning could be associated with mammary gland involution (Hartmann *et al.*, 1984) and would occur either through an active mechanism, such as an increased permeability of the secretory cells, or passively, simply by a breakdown of the alveoli. In goats, variations in permeability of mammary cells would explain the rise in plasma lactose after cessation of regular milking (Kuhn and Linzell, 1970). Since milk lactose was not related to any characteristic of the post-weaning peak of plasma lactose, an active rather than a passive mechanism may account for the release of lactose from the alveoli.

This lack of relationship between milk lactose and post-weaning plasma lactose

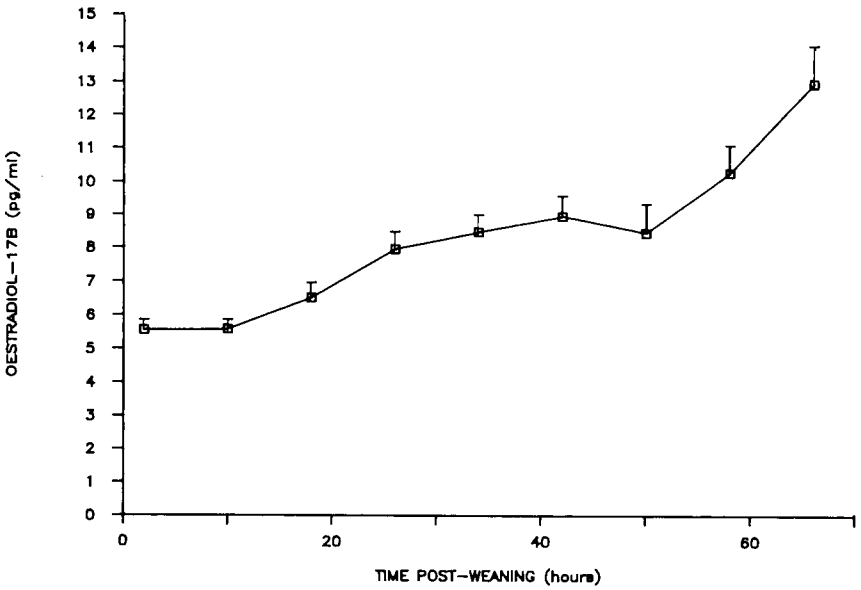

Fig. 2. Plasma E_2 concentration following weaning in sows

may also be due to the limited precision level of the measurement of sows' milk production (Pettigrew *et al.*, 1985, 1987). Moreover, there was a delay between milk measurements at 21 and 22 days of lactation and serum determinations after weaning. This factor is probably not important, because based on results reported by Elsley (1971), milk production and lactose concentration in milk reach a plateau between 21 and 28 days of lactation and reflect the sow's maximum daily milk and lactose production (Noblet and Etienne, 1986). It is therefore likely that milk yield and milk lactose on day 21 of lactation are good estimations of the daily production at the time of weaning, 7 days later. The lack of relationship observed in the present study between plasma and milk lactose at the end of lactation contrasts with the positive correlation observed previously between plasma lactose and amount of lactose in the mammary secretion, both collected from parturition to 3 days post-partum (Whitely *et al.*, 1984).

In contrast to lactose, the limited increase in plasma galactose concentration after weaning is in agreement with the assumption that breakdown of lactose to glucose and galactose is negligible since lactase is only present in the small bowel (Weser and Sleisenger, 1967). Approximately 40—60% of the lactose injected intravenously or of the lactose in plasma following cessation of regular milking in goat and cow (Wheelock and Roock, 1966; Kuhn and Linzell, 1970) is excreted in urine. However, little information is available on the lactose metabolism remaining in circulation. In rat, it is known that a small proportion (6%) of injected ^{14}C-labeled lactose is oxidized to $^{14}CO_2$ within 24 h (Weser and Sleisenger, 1967). In sow, if a similar proportion of this disaccharide stays in circulation, lactose release after cessation of lactation might be implicated in the post-weaning carbohydrate metabolism.

The positive correlation between post-weaning plasma lactose and plasma E_2 concentrations probably reflects the simultaneous rise of the two metabolites after weaning. However, plasma lactose concentrations peaked at 42 h post-weaning while those of E_2 were still rising at the end of the sampling period (66 h). Such association may reflect the synchronisation of 2 independent processes. Nevertheless, the possibility of a partial involvement of lactose metabolism in the postweaning mechanism of the return to œstrus might be considered, since carbohydrate metabolism is involved in the production and release of gonadotropins in gilts (Kirkpatrick *et al.*, 1967; Armstrong and Britt, 1987; Cox *et al.*, 1987) and beef cows (Rutter and Manns, 1987).

Conclusion

This study clearly showed the existence and determined the characteristics of the post-weaning peak of plasma lactose in sows. This peak was not associated with the previous milk production, lactose content in milk or weaning to mating interval. However, there was a positive correlation between post-weaning plasma lactose and plasma E_2 concentrations. More studies are needed to evaluate the importance of the post-weaning lactose status in the process leading to onset of œstrus in sows.

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