

RELATIONSHIP BETWEEN GROWTH OF NURSING PIGS AND COMPOSITION OF SOW COLOSTRUM AND MILK FROM ANTERIOR AND POSTERIOR MAMMARY GLANDS

ŠAMANC H*, SLADOJEVIĆ Ž**, VUJANAC I*, PRODANOVIĆ R*, KIROVSKI M***, DODOVSKI P**** and KIROVSKI DANIJELA*

* University of Belgrade, Faculty of Veterinary Medicine, Belgrade, Serbia;

** Veterinary Station „Veterina system Sladojević“, Gradiška, Bosna and Herzegovina, Republic of Srpska;

*** „Veterinary Institute Subotica“, Subotica, Serbia

****University St Kliment Ohridski-Bitola, Faculty of Veterinary Medicine, Bitola, FYRM

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Piglets that nurse anterior mammary glands grow faster than those suckling posterior mammary glands. The underlying mechanisms are not known. The purpose of this study was to investigate if there is a difference in composition in colostrum and milk secreted by anterior and posterior mammary glands. Seven healthy sows were used. The first three pairs of mammary glands were defined as anterior mammary glands (AMG) and the rest as posterior mammary glands (PMG). Additionally, the total of 87 born piglets from 7 litters derived from the sows involved in the experiment was analyzed. Piglets from each litter that nursed AMG were defined as AMG group while the rest of piglets from the litter were defined as PMG group. Colostrum and milk were collected at days 1, 2, 3 and 7 after parturition. Samples taken from anterior and posterior mammary glands were pooled, respectively. Results showed that total protein, IGF-I and insulin concentrations were significantly higher in the colostrum of anterior than posterior glands and IGF-I concentration remained significantly higher in milk of anterior compared to posterior glands. There were no significant differences in fat, dry matter and lactose among anterior and posterior glands during all examined periods. Additionally, blood samples from nursing sows were obtained at days 1 and 7 after parturition. Results showed that concentrations of Ca, glucose, total protein, albumin, globulin, total bilirubin and insulin significantly increased from day 1 to day 7 of parturition while concentrations of P, BUN, CK and IGF-I did not significantly change during this period. Initial body weight of pigs nursing the anterior gland was higher but not significantly that those suckling posterior glands. Pigs that nursed anterior glands gained

weight faster than those which suckled posterior glands resulting with significantly higher body weight of piglets nursing anterior compared to posterior glands at day 8 of neonatal life ($p < 0.05$). Therefore, it may be concluded that the priority of anterior glands milk secretion in total protein and growth stimulating factors may have an impact on increased body weight gain of nursing pigs.

Key words: anterior and posterior mammary gland, lactating sows, nursing pigs

INTRODUCTION

The piglet is born with low energy reserves (Mellor and Cockburn, 1986) and without immune protection (Gaskins, 1998). Namely, the piglets are born with as little as 2% of body weight as fat (Seerley *et al.*, 1981), limited stores of glycogen (Boyd *et al.*, 1978) and an immature immune defence (Sangild, 2003). Since sow's colostrum is the only food for newborn piglets during first days of neonatal life, nutritional quality of the sow's colostrum and milk is one of the main factors that influence the performance of the piglets (Gálik *et al.*, 2011). Sows' colostrum and milk are the sources of very digestible nutrients (Lin *et al.*, 2009) and various forms of bioactive compounds, including immunological defense factors, enzymes, hormones, and growth factors (Michaeliclou and Steijns, 2006) for suckling piglets. Therefore, colostrum and milk provide the piglet with energy for heat production and metabolism and passive immunity to help prevent infections (Le Dividich *et al.*, 2005). Colostrum also plays an important role in the development of the gastrointestinal tract of the piglet (Xu *et al.*, 2002). As such, early and increased intake of colostrum is of vital importance for piglets. The production of colostrum, however, is very variable between sows and the factors affecting this variability are not well known (Farmer *et al.*, 2006). These factors are divided into genetic and non-genetic (Trakovická *et al.*, 2005; Trakovická *et al.*, 2006; Gábor *et al.*, 2008).

Within the first few hours after birth, competition for mammary glands occurs among newborn piglets, the anterior mammary glands are preferred, and the offspring that acquire milk from the anterior mammary glands grow faster than piglets suckling posterior mammary glands (Puppe and Tuchscherer, 1999; Kim *et al.*, 2000). The underlying mechanisms are not clear although several explanations have been proposed, which include differences in anatomical structures (Algers, 1993; Nielsen *et al.*, 2001) and amounts of milk production (Skok *et al.*, 2007) between the anterior and posterior mammary glands. However, other workers have reported no difference in milk production between the anterior and posterior mammary glands (Hartman *et al.*, 1962).

The aim of this study was to investigate the composition of colostrum and

milk from porcine anterior and posterior mammary glands in order to give a contribution to the possible explanation why piglets suckling anterior mammary glands grow faster than their littermates suckling posterior mammary glands.

MATERIAL AND METHODS

Animals

Sows: Seven Landrace sows from a commercial farm were selected randomly at farrowing. During gestation, all the sows were housed in an open air space and fed with gestation feed. One week before farrowing, the sows were housed individually in farrowing crates within pens. In the week before farrowing, the sows were fed a commercial lactation feed. The sows and litters were provided with water *ad libitum*, but the litters had no access to sow feed. Shortly after birth, the piglets were administered 200 mg Fe-dextran complex (Intarfer-100 B12-Iron, Interchemie, Holland-Europe) via i.m. injection. Mean litter size was 10.9 piglets per sow with a range from 10 to 12 piglets. Sows with 12 mammary glands were selected for this study. Mammary glands were categorized as described by Kim *et al.* (2000). The first, second and third pair of mammary glands were defined as anterior mammary glands (AMG), the fourth, fifth and sixth pair of mammary glands were defined as posterior mammary glands (PMG).

Piglets: The total of 87 born piglets from 7 litters derived from sows involved in the experiment was analyzed. Piglets from each litter that nursed AMG were defined as AMG group while the rest of the piglets from the litter were defined as group PMG. Throughout the duration of the trial, mother colostrum and milk were the only feed of piglets, and they were not fed additionally with any concentrate. Average daily gain (ADG) of individual nursing pigs was obtained by measuring the weight at birth, and each following day until day 8 of their neonatal life.

Colostrum and milk sampling

Fresh colostrum and milk samples from each mammary gland were collected at 8.00 am on days 1, 2, 3 and 7 after parturition. After suckling, the piglets were separated from the dam. Two hours later, the sows were injected with 10 IU oxytocin and the colostrums i.e. milk was collected from all glands by hand milking. Fresh colostrum or milk samples from AMG and PMG were pooled, respectively. Colostrum and milk samples were immediately frozen at -20°C until analyzed.

Blood sampling

At day 1 and day 7 after farrowing, blood samples were obtained from the vena cava cranialis and the blood sera were stored at -20°C until use.

Laboratory methods

Colostrum and milk samples were analyzed for dry matter, total protein, fat and lactose (MilkoScan FT 120, Foss A/S). Commercial 125I-RIA kits validated for bovine colostrum and milk were used to determine IGF-I and insulin as described earlier (Nikolić *et al.*, 1998).

Blood samples were analyzed for Ca, P, glucose, blood urea nitrogen (BUN), total protein (TP), albumin (Alb), globulin (Glo), total bilirubin (TB) concentrations and creatin kinaze (CK) activity using a commercial test package (Bio-Medica). Insulin and IGF-I concentrations in the blood serum were measured by radioimmunoassay (RIA; INEP-Zemun, Serbia).

Statistical analysis

Test results were analyzed using standard statistical methods to calculate the mean and standard deviation. For evaluation of significant differences between mean values was used Student's t-test.

RESULTS AND DISCUSSION

Table 1 reports values for composition of colostrum and milk obtained from nursing sows at days 1, 2, 3 and 7 of lactation.

Dry matter was the highest at the beginning of farrowing and its concentration decreased significantly at day 7 of lactation. This decrease in the percentage of dry matter in the colostrum is attributed to a high decrease in the percentage of total protein. This pattern is similar to that found by Klobasa *et al.* (1987), Jackson *et al.* (1995) and Rolinec *et al.* (2009). The high colostrum levels of protein and dry matter reflect the high content of immunoglobulins. In fact, during the first 6h, IgG alone accounts for most of the total protein. Such a phenomenon is characteristic for all mammals in which the humoral immunological experience of the mother is transmitted to the blood of the neonate by a mechanism dependent on the transfer of IgG to the suckling neonate during the first few hours after birth (Butler, 1979). "Gut closure" i.e. the termination of the gut ability to absorb immunoglobulins, occurs primarily during the first day of life (Klobasa *et al.*, 1981; Werhahn *et al.*, 1981). Growth stimulating substances like insulin and IGF-I in the sow's mammary secretions are high in colostrum, but low in milk. Concentrations of growth promoting factors i.e. insulin and IGF-I significantly decreased from day 1 to day 7 of lactation. These results are in accordance with Jaeger *et al.* (1987) and Walton *et al.* (1989). Milk fat percentage values are in agreement with average milk fat values reported by Zou *et al.* (1992). Williams (1995) proposed that the composition of sows' milk evolved to enhance the survival of newborn pigs. Because pigs are born with very low amounts of body fat, the high fat content of sows' milk is necessary to promote the deposition of an energy store and an insulation layer. Our results for lactose concentration are in agreement with Jackson *et al.* (1995) and Rolinec *et al.* (2008). Devillers *et al.* (2007) published that the

Table 1. The effect of days of lactation on the composition of sow's colostrum and milk sampled from anterior and posterior mammary glands throughout a 7-day nursing period

Days of lactation	Dry matter (%)		Total protein (%)		Fat (%)		Lactose (%)		IGF (nmol/L)		Insulin (μ U/L)	
	AMG	PMG	AMG	PMG	AMG	PMG	AMG	PMG	AMG	PMG	AMG	PMG
Day 1	27.25 \pm 2.38 ^A	24.40 \pm 2.68 ^A	10.16 \pm 2.59 ^A	7.69 \pm 0.55 ^{*A}	8.25 \pm 2.04 ^A	7.70 \pm 0.77 ^{AB}	2.55 \pm 0.32 ^A	2.47 \pm 0.26 ^A	25.6 \pm 6.3 ^A	19.90 \pm 2.7 ^{*A}	482.00 \pm 104.10 ^A	383.00 \pm 49.95 ^{*A}
Day 2	25.34 \pm 3.37 ^A	24.16 \pm 2.69 ^A	8.41 \pm 0.88 ^B	6.85 \pm 0.39 ^{*A}	9.47 \pm 2.23 ^B	9.82 \pm 1.84 ^{AB}	3.33 \pm 0.31 ^B	3.11 \pm 0.29 ^B	21.01 \pm 2.53 ^A	16.31 \pm 2.8 ^{**B}	460.43 \pm 84.65 ^A	368.43 \pm 84.38 ^A
Day 3	26.63 \pm 5.01 ^A	25.78 \pm 3.09 ^A	6.90 \pm 0.5 ^C	6.23 \pm 0.13 ^{**B}	10.24 \pm 1.61 ^{ABC}	8.82 \pm 1.54 ^A	4.03 \pm 0.14 ^C	3.91 \pm 0.16 ^C	15.31 \pm 2.9 ^B	11.97 \pm 2.2 ^{*C}	118.81 \pm 20.34 ^B	96.86 \pm 21.31 ^B
Day 7	23.06 \pm 3.96 ^B	19.96 \pm 0.54 ^B	6.09 \pm 0.46 ^D	5.82 \pm 0.48 ^C	8.07 \pm 1.48 ^{AC}	7.55 \pm 1.24 ^B	5.58 \pm 0.38 ^D	5.30 \pm 0.25 ^D	7.41 \pm 1.5 ^C	5.28 \pm 1.6 ^{*D}	33.14 \pm 6.47 ^C	28.57 \pm 1.51 ^C

A-D Means within a column with different superscripts differ (P < 0.05)

* - difference between concentrations in AMG and PMG at the same time period (p < 0.05)

** - difference between concentrations in AMG and PMG at the same time period (p < 0.01)

*** - difference between concentrations in AMG and PMG at the same time period (p < 0.001)

least represented nutrient in sow's colostrum is lactose. We found the impact of sampling day on protein, dry matter, lactose, IGF-I and insulin concentration. For the fat concentration the effect was not significant.

Among mammary glands secretions obtained from sows within 3 days postpartum, the anterior glands colostrum had significantly greater concentrations of protein and IGF-I compared with posterior glands, and IGF-I concentration remained significantly higher in the milk of anterior compared to posterior glands. Insulin concentration was significantly higher in anterior than posterior glands only on day 1 postpartum. There was no significant difference in the remaining measured parameters in the colostrum obtained from the anterior compared to posterior glands. Superiority of anterior mammary glands to posterior glands secretion immediately after farrowing may indicate that the growth rate of nursing pigs may be influenced by the anatomical locations of the mammary glands of sows (Kim *et al.*, 1999).

Additionally, some blood biochemical parameters in nursing sows are presented in Table 2.

Results presented in Table 2 show that some biochemistry data of nursing sows were influenced by lactation day while the others were not. The Ca, glucose, total protein, albumin, globulin and total bilirubin increased ($p < 0.1$, $p < 0.01$, $p < 0.1$, $p < 0.1$, $p < 0.01$ and $p < 0.1$, respectively) during the first seven days of lactation, and P, glucose, BUN and CK were not significantly changed during the same period. Additionally, insulin concentration significantly decreased ($p < 0.001$) during the first week of lactation and IGF-I was not changed during the same time. Low levels of glucose and insulin immediately after farrowing are associated with negative energy balance at the beginning of lactation (Boyd *et al.*, 1987; Šamanc *et al.*, 1992). This negative energy balance may be also partly responsible for the reduction of the albumin levels coupled with an increase in the synthesis activity of the liver. The higher CK levels immediately after farrowing is probably related to parturition since it is reduced by day 7 after parturition.

The mean average body gain (ABG) and body weight of piglets nursing anterior i.e. posterior mammary glands from the birth to day 8 of neonatal life are given in Table 3.

The average BW at birth did not differ between groups of piglets. Pigs that nursed anterior glands gained weight faster than those which suckled the posterior glands resulting with a significantly higher body weight of piglets nursing anterior compared to posterior glands at day 8 of neonatal life ($p < 0.05$). Therefore, it may be concluded that the priority of anterior glands milk secretion in total protein and growth stimulating factors may have impact on increased body weight gain of nursing pigs.

Our results showed that there was no significant relationship between the birth weight of pigs and the preference for mammary glands, although pigs that preferred anterior mammary glands had almost 100 grams greater birth weight than those who nursed posterior mammary glands. This finding agrees with

Table 2. Sow` blood composition

Days in lactation	Ca (mmol/L)	P (mmol/L)	Glucose (mmol/L)	BUN (mmol/L)	TP (g/L)	Alb (g/L)	Glo (g/L)	TB	CK (U/L)	Ins (mU/L)	IGF-I (nmol/L)
1	2.25 ± 0.18	2.15 ± 0.17	4.93 ± 0.78	4.88 ± 1.44	59.85 ± 5.84	33.43 ± 9.28	26.43 ± 8.24	3.64 ± 1.09	894.86 ± 176.25	5.14 ± 0.95	7.38 ± 1.44
7	2.49 ± 0.14*	2.02 ± 0.26	5.93 ± 0.85*	5.11 ± 1.16	84.14 ± 15.00**	47.71 ± 12.84*	36.43 ± 3.87*	6.41 ± 1.38**	793.28 ± 200.50	18.01 ± 3.30***	7.67 ± 1.43

* - p<0.05; ** - p<0.01; *** - p<0.001.

Table 3. Body weight and average daily gain of nursing pigs by the location of the nursed mammary glands

Days of lactation	Body weight (g)		Average daily gain (g)	
	AMG group	PMG group	AMG group	PMG group
Day 1	1530.37 ± 242.90	1444.09 ± 193.71	-	-
Day 2	1593.96 ± 259.53	1506.82 ± 210.61	63.58 ± 42.63	62.72 ± 50.64
Day 3	1666.67 ± 276.94	1586.82 ± 219.52	72.71 ± 56.75	80.00 ± 72.56
Day 4	1837.50 ± 319.55**	1747.27 ± 282.65**	170.83 ± 82.35***	160.45 ± 106.03***
Day 5	2018.33 ± 328.34**	1917.73 ± 263.11**	180.83 ± 58.48	170.45 ± 73.55
Day 6	2180.00 ± 334.15*	2094.54 ± 251.06**	192.08 ± 33.89	176.82 ± 49.21
Day 7	2409.17 ± 363.39**	2274.09 ± 268.43**A	229.17 ± 84.85***	179.54 ± 63.32 ^A
Day 8	2611.67 ± 380.85**	2467.95 ± 265.61**A	202.50 ± 65.99	193.86 ± 72.82

A-D Means within a row with different superscripts differ ($P < 0.05$) for body weight and average daily gain, respectively

* - difference compared to values for previous day within same column ($p < 0.05$)

** - difference compared to values for previous day within same column ($p < 0.01$)

*** - difference compared to values for previous day within same column ($p < 0.001$)

previous work by Kim *et al.* (2000) and Hemsworth *et al.* (1976), but is inconsistent with a study by Scheel *et al.* (1977), which showed that pigs with greater birth weight had a specific preference for anterior glands. As explained by Kim *et al.* (2000), these differences may be a consequence of a greater number of well-developed mammary glands in the anterior locations in modern sows, compared with sows from past times, which may have had fewer well-developed anterior mammary glands (Donald, 1937; Fraser, 1973). During the 8-d lactation, pigs that were nursing the anterior mammary glands had a greater ADG compared with pigs nursing the remaining glands, but the difference was significant only at day 7 of lactation ($p < 0.05$). This resulted with significant greater body weight of pigs that nursed anterior compared to posterior mammary glands at day 7 and 8 after birth. It has been reported that the anterior glands may have advantages for higher sensitivity to stimulation for milk letdown (Fraser, 1973) and a greater flow of colostrum (Fraser, 1984). Milk production differences among mammary glands is believed to be a major source of this weight variation (Fraser and Jones, 1975; Fraser *et al.*, 1979). Nevertheless, Kim *et al.* (2000) showed that the first pair of the glands had lower weights and amounts of major tissue components compared with the middle glands at farrowing. Additionally, Wu *et al.* (2010) confirmed that there was a significant difference of proteomes in sow colostrums and milk from anterior and posterior mammary glands. Therefore, there are some implications in the literature data that composition of colostrum and milk differs between anterior and posterior mammary gland of the same sow. Our results showed that concentrations of growth promoting factors are significantly higher in colostrums of AMG compared to PMG indicating that this may be the main reason for faster growth of piglets nursing AMG.

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Address for correspondence:
Kirovski Danijela, DVM, PhD
Department of Physiology and Biochemistry
Faculty of Veterinary Medicine
University of Belgrade
Bulevar oslobođenja 18
11000 Belgrade, Serbia
E mail: dani@vet.bg.ac.rs

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ZAVISNOST RASTA NOVOROĐENE PRASADI OD SASTAVA KOLOSTRUMA I MLEKA PREDNJIH ODNOSNO ZADNJIH MAMARNIH KOMPLEKSA KRMAČA

ŠAMANC H, SLADOJEVIĆ Ž, VUJANAC I, PRODANOVIĆ R, KIROVSKI M, DODOVSKI P i KIROVSKI DANIJELA

SADRŽAJ

Prasad koja sisaju prednje mamarne komplekse rastu brže nego ona koja sisaju zadnje. Mehanizmi koji objašnjavaju ovu pojavu nisu sasvim poznati. Cilj ovog rada bio je da se ispita da li postoji razlika u sastavu kolostruma i mleka stvorenim u prednjim odnosno zadnjim mamarnim kompleksima. Sedam zdravih krmača je bilo uključeno u ogled. Prva tri para mamarnih kompleksa su definisana

kao prednji (PMK), a ostali kao zadnji mamarni kompleksi (ZMK). Dodatno, ispitano je 87 prasadi iz 7 legala poreklom od krmača uključenih u ogled. Prasad iz legla koja su sisala PMK su pripala PMK grupi dok su prasadi koje su sisale preostale mamarne komplekse grupisane u ZMK grupu. Kolostrum i mleko su uzorkovani 1., 2., 3. i 7. dana nakon prašenja. Uzorci uzeti iz prednjih odnosno zadnjih mamarnih kompleksa su zatim spojeni. Rezultati su ukazali da su koncentracije ukupnih proteina, IGF-I i insulina bile značajno više u kolostrumu PMK u odnosu na ZMK a koncentracija IGF-I je ostala značajno viša u mleku PMK u odnosu na ZMK. Nije bilo značajne razlike u koncentraciji masti, suvoj materiji i laktozi između sekreta PMK i ZMK tokom celog ispitivanog perioda. Dodatno, uzimani su uzorci krvi od krmača 1. i 7. dana posle prašenja. Rezultati su ukazali da su koncentracije Ca, glukoze, ukupnih proteina, albumina, globulina, ukupnog bilirubina i insulina značajno porasle od 1. do 7. dana nakon prašenja dok se koncentracija P, uree, kreatin kinaze i IGF-I nije značajno menjala tokom ovog perioda. Početna telesna masa prasadi koja su sisala PMK je bila viša, ali ne značajno, u odnosu na onu koju je sisalo ZMK. Posle toga, prasadi koje su sisale PMK su imale veći dnevni telesni prirast nego ona koja su sisale ZMK što je rezultiralo da su 8. dana neonatalnog života prasadi koje su sisale PMK imale značajno veću telesnu masu u odnosu na onu koja su sisale ZMK. Na osnovu svega navedenog se može zaključiti da kvalitetniji sastav sekreta PMK u pogledu sadržaja proteina i faktora rasta može da ima uticaj na veći telesni prirast prasadi koja sisaju ove komplekse u odnosu na prasadi koje sisaju ZMK.