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ABSTRACT

Five experiments, involving the hand milking of 53 farrowing sows, examined aspects of colostrum yield during and soon after farrowing. The initial and abundant yield of colostrum from a teat (averaging 6 to 10 g/min) declined after several minutes of continuous milking. Thereafter, most colostrum was released in discrete ejections, possibly caused by discrete releases of oxytocin. Colostrum ejections varied greatly in their yield and duration, and were sometimes associated with the birth of a piglet, sounds of other sows nursing, or other factors.

Teats varied greatly in their yield. During the initial minutes of milking, the most anterior teats gave, on average, 3 to 5 times more colostrum than the most posterior teats, with a nearly monotonic decline from front to rear. However, the difference between anterior and posterior teats disappeared after several minutes of continuous milking. Stimulation of the anterior teats appeared to cause the release of more colostrum than did either the stimulation of the posterior teats or no stimulation of the udder at all. A strong sucking stimulus, applied to several teats by a milking machine, elicited a large, prolonged release of colostrum.

The results suggest that (1) much of the colostrum received by newborn piglets is obtained in discrete ejections rather than in a continuous manner; (2) appropriate stimulation of the udder by the piglets may be important to elicit maximum colostrum yield; and (3) a high initial yield from anterior teats, coupled with a higher yield when anterior teats are stimulated, may help to explain the piglets' preference for anterior positions on the udder.

INTRODUCTION

Colostrum fulfills at least two needs of the newborn pig. First, with their meagre store of glycogen (Elliot and Lodge, 1977), newborn piglets depend upon colostrum as a dietary energy source to prevent the onset of hypoglycaemia and rapid loss of condition to which they are prone. Second, colostrum protects piglets against disease by providing immunoglobulins in the blood and, perhaps, by blocking the uptake of bacterial toxins from the intestine. Not surprisingly, adequate intake of colostrum has been emphasized repeatedly as an important factor for piglet health and survival (e.g. Le Dividich and Noblet, 1981).

There has been considerable study of the sow's nursing behaviour and milk yield, but virtually all of this work has been concentrated in the established lactation. At that time, milk is given by the sow in brief, discrete ejections triggered by vigorous mechanical stimulation of the udder (Fraser, 1980; Ellendorff, Forsling and Poulain, 1982). Milk ejection is elicited much more readily by stimulation of the anterior, rather than the posterior, teats (Fraser, 1973), but the anterior and posterior glands do not appear to differ greatly in milk yield (Hartman, Ludwick and Wilson, 1962; Hemsworth, Winfield and Mullaney, 1976).

The delivery of colostrum to newborn piglets appears to follow rather different principles but is currently poorly understood. Typically, the sow lies with the udder exposed during much of the farrowing and post-farrowing period, and colostrum can be expressed easily by hand without coordinated stimulation of the udder by the piglets. This gives the impression that colostrum is supplied in an easy and uncomplicated manner, but in reality, as shown below, this is not the case.

In the following experiments sows were milked by hand, during and soon after farrowing, in order to explore various aspects of colostrum availability during this period.

MATERIAL AND METHODS

The five experiments involved a total of 53 Yorkshire sows of first to eighth parity from the Animal Research Centre's specific-pathogen-free herd at Ottawa. Most farrowings (37 of the 53) were induced by an injection of 125 to 175 µg of cloprostenol on day 112 or day 113 of pregnancy, with parturition usually occurring about 24 h after the injection. Farrowing sows were included in the experiments as they became available. All experiments included a mixture of induced and spontateous farrowings and involved a range of parity number.

Three to 5 days before farrowing was due, the sows were moved into farrow crates in pens measuring 2·1 by 1·7 m in rooms holding up to six sows and litters. All farrowings were attended, and newly born piglets were removed from the sow before they had suckled. Piglets were held in a warm, bedded box and were returned to the sow when the experimental hand milking had been completed.

Hand milking occurred while the sow was lying on one side with the udder exposed. Teats in the upper row were normally used, as they were more accessible. Bars of the farrowing crate were sometimes removed or repositioned to provide better access to the teats. During hand milking, the experimenter used a uniform stripping action with the thumb and one or two fingers to express as much colostrum as possible into a screw-top collection jar. Milking was done for the first 50 s of each minute, with the remaining 10 s used to change jars. The contents of each jar were subsequently weighed to the nearest 0·1 g; for simplicity, this was referred to as the yield per minute.

Experiment 1

As an exploratory study, 10 farrowing sows were hand milked for 90 consecutive minutes from a single teat. Milking began at an average of 2 h (range from 0.5 to 3.5 h) after the birth of the first piglet, and after an average of six piglets (range from one to 11 piglets) had been born. The most anterior teat in the upper row was used for five sows, and the sixth or seventh teat (posterior) was used for the other five.

During the milking, notes were made on the time of birth of piglets or expulsion of large amounts of placenta and on any behaviour of the sow or other factors that appeared to coincide with changes in the yield of colostrum.

Experiment 2

Two teats were milked at the same time to determine whether ejection of colostrum generally occurs in synchrony for different teats. Eight sows were used. Starting at an average of 2.5 h after the birth of the first piglet (range of 0.5 to 5.5 h), two attendants hand milked one teat each for 30 consecutive minutes. The third and sixth teat, counting from the anterior, were used in most cases.

Experiment 3

In experiments 1 and 2, the amount of colostrum that could be expressed from a teat varied considerably among sows, and among teats on the same sow. Experiment 3 examined the variation more systematically. For seven sows, each of the seven teats of the upper row was milked by hand for 10 consecutive minutes. Teats were numbered from 1 (anterior) to 7 (posterior), and the order of milking was varied systematically according to a 7 × 7 Latin square. The remaining seven sows were treated in a similar way, but each teat was milked for 15 consecutive minutes instead of 10. In several cases, a teat from the lower row was used because the upper teat showed signs of previous injury. Hand milking began at an average of 1.5 h (range of 0 to 5 h) after the first piglet had been born for the 14 sows studied.

Experiment 4

In the established lactation, milk ejection and rhythmic nursing grunts are elicited much more readily by stimulation of the anterior, rather than the posterior teats (Fraser, 1973). Experiment 4 compared colostrum yield of a single gland during manual stimulation of anterior and posterior teats and when no extra stimulation was provided.

For six of the nine sows studied, hand milking began at 0 to 3 h after the first piglet had been born and before the placenta had been expelled. Hand milking of the remaining three sows began after the expulsion of all piglets and the placenta, between 5 and 7.5 h after the first piglet had been born.

For each sow, the fourth teat from the anterior was milked by hand for 40 consecutive minutes. The first 10 min allowed removal of the large amount of colostrum commonly available when milking begins. In the next three 10-min periods, a second attendant either (1) rubbed the three anterior teat pairs with the palms and fingers of both hands, (2) rubbed the three posterior teat pairs in a similar way, or (3) did not touch the udder. The order of the three 10-min treatments was varied for the nine sows according to three 3 × 3 Latin squares. The sow's grunts were recorded on a portable tape recorder, and were subsequently counted in each minute of milking.

Experiment 5

Experiment 4 showed that stimulation of the anterior teats can influence the yield of colostrum especially, perhaps, once farrowing is completed. Experiment 5 examined the effect of a strong sucking stimulus applied to the anterior teats near the beginning or the end of farrowing.

A sow milking machine was used to provide a strong, coordinated sucking stimulus. The machine design followed in most respects that described by Lodge (1957), but with several modifications (D. Fraser, C. Nicholls and W. Fagan, unpublished). In particular, the pulsation rate was approximately 3 per second and the teat cup liner had a vigorous action caused by alternating positive and negative pressure.

The experiment consisted of hand milking one posterior teat (5th to 7th position) for 15 consecutive minutes while the sow lay on one side with the udder exposed. No extra stimulation was provided during minutes 1 to 10; then, three or four teat cups were put on the most accessible of the anterior teats for minutes 11 to 15. The milking machine was left running during minutes 1 to 15 so that any effect of sound produced by the machine would apply equally throughout the experiment.

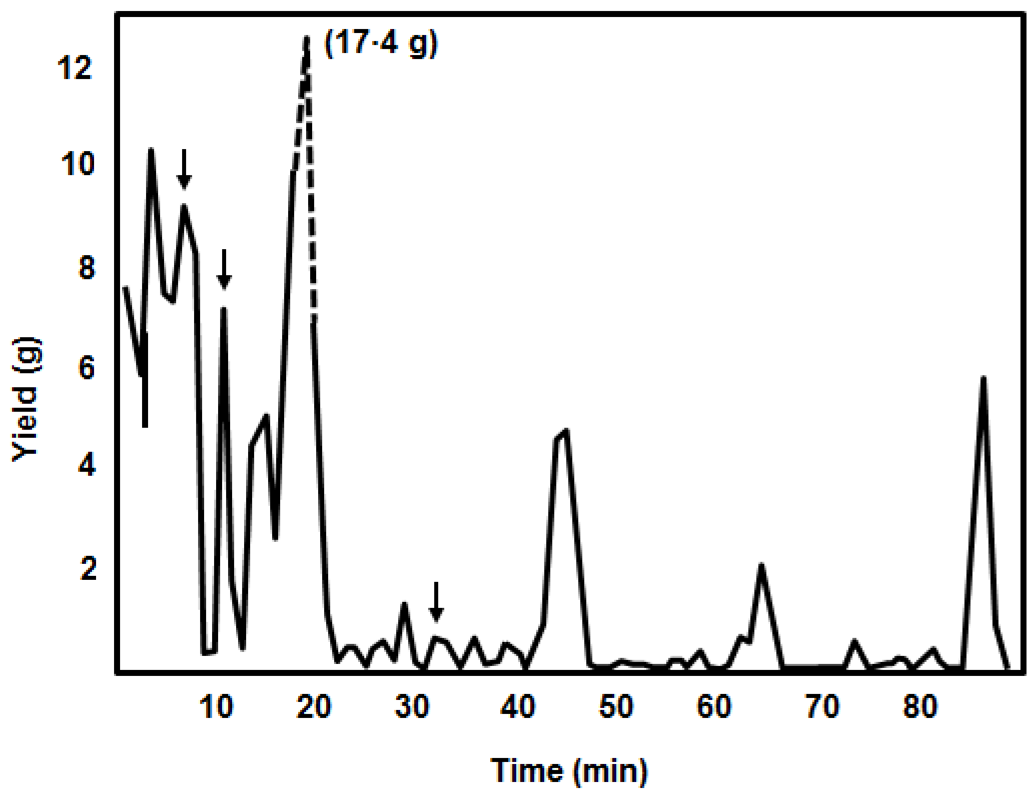
For six of the 12 sows used, the experimental period began early in the farrowing, within 1 h of the birth of the first piglet and after an average of three piglets (range 1 to 6) had been born. The other six sows were studied after farrowing was judged to be nearly complete, 4 to 6 h after the first piglet was born, and after 8 to 13 piglets and some or all of the placenta had been expelled. Two of these sows gave birth to a single late piglet after the milking was completed.

RESULTS

Experiment 1

For the 10 sows milked during 90 consecutive minutes, the yield of colostrum was high during the initial minutes of milking, averaging 10·4 g/min during the first 3 min when an anterior teat was milked, and 6·2 g/min for posterior teats. Average yield declined sharply to about 2 g/min by minute 15. In the last 60 of the 90 min, yield averaged 0·7 g/min for anterior teats and 0·5 g/min for posterior ones.

FIG. 1. Colostrum collected from one anterior teat of a second parity sow during 90 consecutive minutes. Yields remained high during the first 8 min which included the birth of a piglet (indicated by arrow) in minute 7. A birth in minute 11 was accompanied by a sudden increase in yield, but the birth in minute 32 was not. Sharp increases in yield in minutes 18 to 20 and 43 to 46 occurred when other sows and litters in the room began nursing. The increase in minutes 85 to 86 was not accompanied by any obvious external factor.



Once the initial high yield had declined, most of the colostrum was collected during discrete ejections (Figure 1). Colostrum ejections were highly variable, lasting 1 to 4 min, reaching yields of 2 to 20 g/min, and occurring at intervals of 5 to 30 min. Generally, little or no colostrum was obtained in the intervals between discrete ejections. Some ejections appeared to be associated with the birth of a piglet, with body movements by the sow, or with sounds from other animals, but none of these events appeared to trigger an ejection in a predictable way.

On 23 occasions, piglets were born during the hand milking. Ten births coincided approximately with a distinct colostrum ejection which usually began 10 to 25 s after the piglet had been expelled. Eleven births were not accompanied by any noticeable change in colostrum yield, and two births occurred in the initial minutes of hand milking when yields were too high and irregular for any relationship to be noticed.

Yield of colostrum often increased, sometimes sharply, when piglets began squealing nearby, or when other sows in the room began the rhythmic grunting that usually accompanied nursing (Figure 1). In some cases, the sow being hand milked also gave the characteristic, rhythmic nursing grunts when colostrum yield increased.

Major body movements by the sow were often followed by increased yield. Sudden release of colostrum followed in all six cases in which the sow stood or sat up for a few minutes and then lay down again, or rolled onto its udder and then back onto its side. Smaller body movements, such as flexing the abdomen or kicking the legs were also accompanied by increased colostrum release in some cases.

Large, distinct colostrum ejections were most common during the milking of anterior teats. Of the 28 milk ejections judged to be the most pronounced (with yield increasing at least five fold to at least 2 g/min), 21 occurred during the milking of an anterior teat, and seven during the milking of a posterior teat.

Experiment 2

Colostrum yield from the two teats milked simultaneously was generally high during the first few minutes and then declined to a lower but fluctuating level, as seen in experiment 1. Most but not all fluctuations in yield occurred in synchrony for the two teats being milked. In a typical example (Figure 2), both teats showed a pronounced peak in yield in minute 15, 19 and 24. The peak in minute 19 coincided with the birth of a piglet, but the other two peaks did not. Piglets were also born at minute 11, coinciding with a less distinct increase in colostrum yield, and at minute 28, just before a large increase in the yield from one teat.

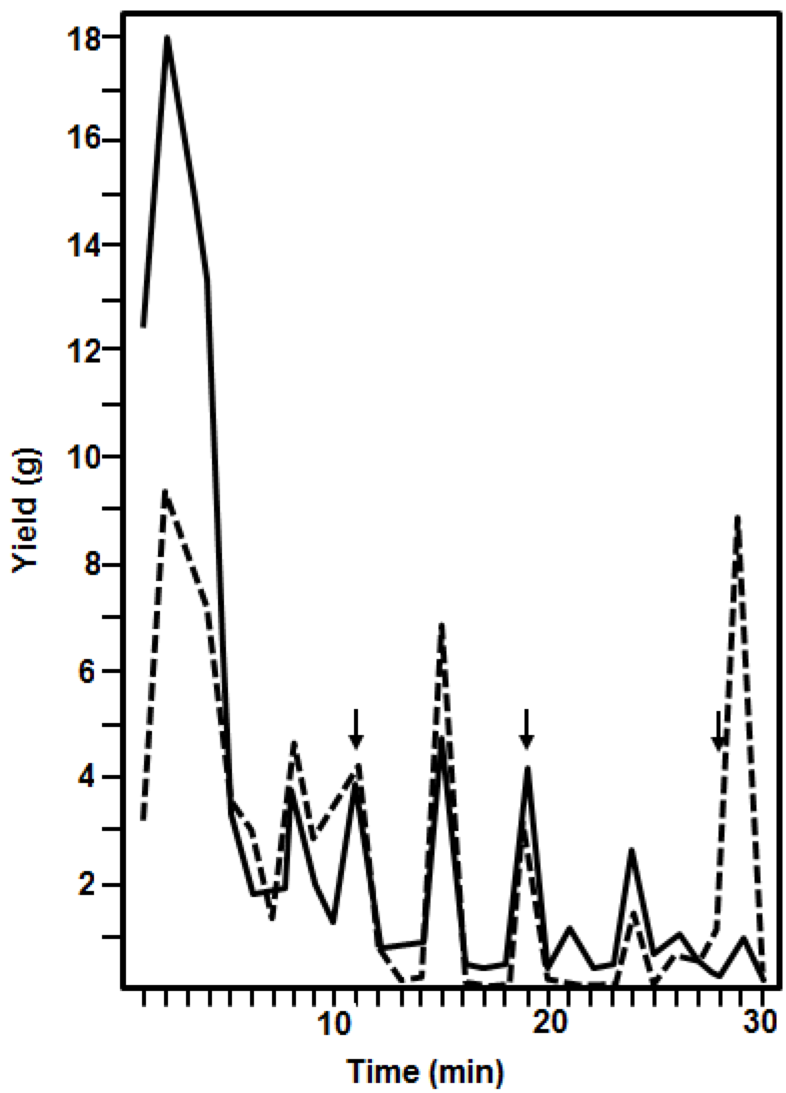
To express the synchrony in the pattern of colostrum yield, Spearman rank-order correlation coefficients, corrected for ties were calculated for the yield of the two teats during successive minutes (Siegel, 1956). The first 10 min were omitted because of the high initial yield. Correlations ranged from 0·51 ($P < 0{\cdot}05$) to 0·78 ($P < 0{\cdot}01$) for six of the eight sows, but were lower (0·25 and 0·15, $P > 0{\cdot}05$) for the other two.

Experiment 3

For the seven sows milked for 15 min on each teat, colostrum yield varied among sows and among teats, with greater average yield from the more anterior teats. Average yield declined almost monotonically from 77·8 g/15 min from teat 1 (most anterior) to 29·0 g from teat 7 (most posterior). Latin square analysis of variance, after logarithmic transformation to reduce heterogeneity of variance, showed significant variation among sows ($P < 0{\cdot}001$) and among teat positions ($P < 0{\cdot}01$) with no significant effect of the order in which the teats were milked.

Most of the difference between anterior and posterior teats occurred during the first 3 min of milking when yields were particularly high. During minutes 4 to 15, by contrast, yields were similar for the different teat positions (Table 1). Latin-square analysis of variance showed significant variation among sows and among teats for the colostrum yield of minutes 1 to 3 combined ($P < 0{\cdot}001$), but only a sow effect for minutes 4 to 15 combined ($P < 0{\cdot}001$).

FIG. 2. Yield of colostrum (g/min) from a fifth parity sow hand milked for 30 consecutive minutes from the third teat (solid line) and the sixth teat (broken line) from the anterior right-hand side of the udder. Piglets were born in minutes 11, 19 and 28 as indicated by arrows.



The seven sows that were milked for 10 min on each teat showed similar trends but with somewhat greater variation. Colostrum yield varied among sows and among teats, with a general decline from anterior to posterior. Latin-square analysis of variance, after logarithmic transformation, showed significant differences among sows ($P < 0{\cdot}001$) and among teat positions ($P < 0{\cdot}05$), but no significant effect of the order of milking. As with the other sows, the first 3 min showed a steady decline from anterior to posterior teats, with more erratic differences in the remaining minutes of milking (Table 1).

Despite the decline in average yield from anterior to posterior teats, the teats on individual sows varied in idiosyncratic ways. Sow 1, for example, had the greatest yield from teat 2 (44 g), followed by teats 1 and 4 (35 and 31 g), with teats 6, 5, 3 and 7 giving the least colostrum (19, 13, 12, and 5 g respectively).

Table 1. Colostrum yield (g/min) from teats 1 to 7 in experiment 3.

	Sows milked for 15 min[†]				Sows milked for 10 min[†]			
	min 1 to 3		min 4 to 15		min 1 to 3		min 4 to 10	
Teat	Mean	s.e.	Mean	s.e.	Mean	s.e.	Mean	s.e.
1	15·0	4·1	2·7	0·6	10·5	2·7	2·7	0·8
2	11·9	2·6	3·1	0·5	7·8	1·3	4·8	2·0
3	9·9	1·9	2·4	0·7	8·0	1·8	2·1	0·6
4	9·9	2·6	2·5	0·7	6·8	2·1	4·4	2·0
5	4·5	1·1	2·0	0·5	5·5	1·3	2·3	0·3
6	5·6	1·8	2·7	0·7	5·4	1·3	2·6	0·6
7	3·3	1·3	1·6	0·4	3·4	0·9	1·3	0·4

[†] For the seven sows milked for 15 consecutive minutes, results are shown for minutes 1 to 3 combined and minutes 4 to 15 combined. For the seven sows milked for 10 consecutive minutes, results are shown for minutes 1 to 3 combined and minutes 4 to 10 combined.

Table 2. Colostrum yield and grunts emitted in 10-min milking periods by the nine sows experiment 4

	Colostrum (g/10 min)		Grunts (no. per 10 min)	
Period	Mean	s.e.	Mean	s.e.
First 10-min milking period	48·2	11·6	31	11
Subsequent 10-min milking periods:				
2nd	20·3	6·0	133	60
3rd	10·8	4·1	98	71
4th	5·6	2·6	122	80
Treatment:				
Anterior	26·0	5·5	299	90
Posterior	4·5	1·4	46	27
Neither	6·2	2·4	8	4

Experiment 4

In the fourth experiment, colostrum yields were generally high during the initial 10-min period, and declined throughout the three remaining 10-min periods in which the experimental treatments were applied. However, much more colostrum was obtained during anterior teat stimulation compared with posterior teat stimulation or no stimulation of the udder at all (Table 2). Latin-square analysis of variance, applied to the three treatment periods, but omitting the initial 10 min period, showed significant effects of treatment ($P < 0{\cdot}01$) and order ($P < 0{\cdot}01$) on colostrum yield.

Sows grunted repeatedly when the anterior teats were stimulated, but not during other treatments or during the initial 10-min period (Table 2). Latin-square analysis of variance showed only a treatment effect ($P < 0{\cdot}01$) on the number of grunts given.

When anterior stimulation began, the sows immediately began grunting rhythmically. However, colostrum yield remained low in the first minute (mean of 0·9 g), then rose sharply (mean of 7·1, 7·4 and 4·1 g in minutes 2, 3 and 4 respectively) and then declined to a mean of 1·1 g/min in the remaining minutes.

Although anterior stimulation gave significantly more colostrum when either posterior stimulation or no stimulation, it generally gave much less than in the initial 10-min period before the experimental treatments began (Table 2). In three cases, however, more colostrum was collected during anterior stimulation than was collected initially. Two of these three cases involved the sows that had finished farrowing when the milking began.

Experiment 5

In the first minute of milking, the six sows studied early in farrowing produced substantially more colostrum than those studied after farrowing was complete, with little overlap between the two sets of results. Thereafter, yields generally declined over the 10 min to similar levels for the two groups of sows (Table 3).

Table 5. Colostrum yield (g/min) from posterior teats in to 15 consecutive minutes of milking in experiment 5.

		Early farrowing		Farrowing nearly complete	
Treatment	**Minute**	**Mean**	**s.e.**	**Mean**	**s.e.**
Before anterior stimulation	1	13·3	2·3	5·5	1·8
	2	7·2	1·2	5·0	1·6
	3	3·3	1·1	3·6	1·0
	4	5·3	2·4	4·1	1·6
	5	6·1	2·7	4·1	1·6
	6	2·8	1·2	4·5	2·2
	7	3·7	1·2	2·0	1·0
	8	2·0	0·8	2·7	1·1
	9	1·3	0·4	1·6	0·8
	10	1·8	0·6	1·4	0·8
During anterior stimulation	11	8·7	2·0	4·8	1·9
	12	12·5	3·3	13·3	4·5
	13	14·9	2·8	9·0	2·9
	14	10·1	2·6	2·3	0·6
	15	4·0	1·0	1·6	0·3

During machine stimulation of the anterior teats, colostrum yield increased sharply. Contrary to experiment 4, the greatest yield per minute during anterior stimulation exceeded the greatest yield during the initial 10 min in most (10 out of 12) of the sows. Presumably the machine stimulation, with its rapid, rhythmic pulsation, was more effective in eliciting release of colostrum than hand stimulation had been in the previous experiment.

As in experiment 4, the increased yield during anterior stimulation occurred as a distinct ejection of colostrum beginning about 1 min after stimulation began. The ejection generally lasted 3 to 4 min for sows studied early in farrowing and 1 to 3 min for sows studied after farrowing was complete. Because of their generally longer ejections, the sows studied early in farrowing had greater average yields in the last 3 min of milking (Table 3).

DISCUSSION

It is commonly observed that colostrum can be expressed easily from the sow's teats at almost any time during and soon after farrowing. Hence, it might be assumed that piglets obtain colostrum in a simple and automatic manner, without having to provide coordinated stimulation of the udder of the type needed to elicit milk ejection later in the lactation. This is true up to a point. However, prolonged hand milking showed that the easy, abundant supply of colostrum declines after a few minutes of continuous extraction. Thereafter, much of the colostrum appears to be released in discrete ejections, the occurrence and magnitude of which may be influenced considerably by the behaviour of the piglets.

During most of lactation, milk ejections last about 20 s, occur at intervals of about 40 min, and are elicited only by vigorous mechanical stimulation of the udder (Fraser, 1980; Ellendorff *et al.,* 1982). With farrowing sows, colostrum ejections are often of much longer duration, occur at shorter intervals, and are elicited by much less stimulation of the sow. Colostrum ejection often occurred when the sole stimulation of the sow was the hand milking of a single teat, especially an anterior teat. The sound of the piglets squealing or other sows nursing appeared to trigger colostrum ejection when only a single anterior or posterior teat was being stimulated. Moreover, farrowing sows occasionally appear to have 'spontaneous' ejections, complete with rapid grunting and leaking of colostrum from the teats, in the absence of any apparently relevant stimulation (D. Fraser, unpublished results). These effects might be due to a very low threshold for the release of oxytocin at the time of farrowing. The long colostrum ejections seen at this time may represent large or multiple releases of oxyotcin that rarely or never occur later in lactation.

During the established lactation, milk ejection appears to occur largely as an 'all-or-none phenomenon' (Fraser, 1975). During farrowing, however, individual colostrum ejections vary considerably in their duration and yield, and this appears to depend partly on the stimulation received by the sow. With hand milking of a single teat (experiment 1) and with manual rubbing of the anterior teats (experiment 4), most later colostrum ejections gave a small yield compared with the quantity that could be removed from the teats during the initial minutes of milking. With a strong stimulus provided by the milking machine, colostrum ejections commonly lasted for several minutes and yielded large quantities. This suggests that a strong, coordinated sucking stimulus by the piglets may be important for maximum release of colostrum.

In some cases, release of colostrum appears to be independent of external stimulation of the sow. The birth of a new piglet was 'often, but not always, accompanied by an ejection of colostrum (cf. Bourne, 1969). Presumably, distension of the cervix by the emerging piglet sometimes caused a release of oxytocin, resulting in a colostrum ejection 10 to 25 s later. In some cases, ejection of colostrum accompanied or even preceded the birth. This could still be due to distension or stimulation of the cervix if the final expulsion of the piglet is delayed. Large body movements by the sow, which were followed by colostrum ejection in many cases, may also have been associated with movement of the unborn piglets near the cervix.

Piglets have an obvious tendency to use anterior, more than posterior teats. This could be due in part to the fact that piglets are attracted to the sow's vocalizations (Jeppesen, 1982; Lewis, 1982) and other cues from the udder might be involved (McBride, 1963). In early work, it was often assumed that the anterior teats were preferred because they produced on average more milk (e.g. Barber, Braude and Mitchell, 1955). However, most studies have found that differences in milk yield between anterior and posterior teats are small (Hartman *et al.,* 1962; Hemsworth *et al.,* 1976), and probably too small to explain any strong preference for the anterior positions. Research using an artificial udder indicates that the piglets' selection of teats can be influenced by milk yield as long as the differences among teats are relatively large (Jeppesen, 1982). In the present work, anterior teats yielded considerably more colostrum than posterior teats in the initial minutes of milking, and stimulation of the anterior teats elicited large releases of colostrum. These effects could well encourage piglets to use the anterior positions early in life, when long-lasting attachments to specific teats are being formed.

This study points to several features of colostrum availability that may be related to problems of piglet production. In designing farrowing accommodations, it is often thought desirable to encourage the piglets to lie well away from the sow in the first hours or days after birth when the young are vulnerable to being crushed. However, the continuous presence of the piglets at the udder may be important soon after farrowing if they are to take advantage of synchronized, episodic release of colostrum at irregular intervals. Ambient temperature or other factors that influence the vigour of the piglets or the comfort of the sow may affect the piglets' ability to stimulate the dam to release colostrum. Finally, large differences in colostrum supply from teat to teat, as seen in this study, may help to explain why some litters subsequently show such variable health and performance.

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