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Colostrum Intake by Newborn Piglets

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KEYWORDS

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ABSTRACT

Colostrum intake by newborn piglets was studied by weighing piglets every 10 min for their first 1-4 h with the sow, and their cumulative weight increases were used as estimates of colostrum intake. In seven litters, four piglets were monitored for 4 h beginning about 2 h after the birth of the first piglet in order to determine if colostrum is available continuously or released in discrete ejections. There was little synchrony between litter-mates in their intake in the first hour, but by the second hour of monitoring (starting about 3 h after farrowing began), much of the colostrum was released in discrete ejections and piglets achieved most of their intake during the few 10-min intervals when an ejection occurred. To examine the effect of birth sequence, four piglets were added to the udder each hour for 3 consecutive hours. Piglets added in the last hour showed a small but significant tendency ($P < 0.05$) to obtain less colostrum than those added in the middle of the sequence. In nine litters, three piglets were confined to posterior and three to anterior teats for 1.5 h to examine the effect of teat position. Those on posterior teats had slightly but significantly ($P = 0.02$) lower estimated intake than piglets on anterior teats. Although low-birth-weight piglets, late-born piglets, and piglets sucking only posterior teats tended to obtain less colostrum, the differences were small, and most piglets obtained an amount of colostrum consistent with normal serum immunoglobulin concentration.

The importance of an adequate intake of colostrum for neonatal health and survival has been well established. Piglets, in particular, require an early intake of colostrum both to develop immune protection and as a source of energy to prevent the often fatal hypoglycaemia to which they are prone (Aumaitre and Seve 1978; Le Dividich and Noblet 1981). Despite this importance, few studies have described the temporal pattern and factors influencing colostrum consumption by piglets.

During most of the lactation, nursing in pigs involves a complex series of behavioral and physiological events that have been well studied (Fraser 1980; Ellendorff et al. 1982; Algers and Jensen 1985; Illman and Herbst 1986; Rushen and Fraser 1989: Algers et al. 1990). Nursing occurs at regular intervals of 40-60 min with all or most of the litter suckling together. Milk is available to the piglets during only a brief milk ejection, which is triggered by the release of oxytocin. The periodic nature of milk ejection is partly due to a neural inhibition of oxytocin release (Ellendorff et al. 1982).

How soon after parturition this pattern of periodic nursing is established, however, is a matter of controversy. During parturition, colostrum can be easily expressed from the teats (Fraser 1984) and sows nurse continuously (Lewis and Hurnik 1985). Lewis and Hurnik (1985) concluded that there is a distinct phase of "neo-nursing" that begins at birth and continues until the piglets are approximately 11 h old on average; during this time colostrum is continuously available to the piglets, but thereafter it is consumed only during discrete ejections. In contrast, hand-milking of sows (Fraser 1984) and measurement of weight gains by piglets when suckling (Castrén et al. 1989) suggest that much of the sow's colostrum becomes available in discrete ejections (i.e., brief, pulsatile events separated by much longer periods with little or no release) soon after, or even before, the end of farrowing. Furthermore, because piglets within a litter only gradually become synchronized in their suckling, it is difficult to infer the nature of colostrum release from observations of suckling behavior (De Passillé and Rushen 1989).

Studies of immunoglobulin levels of piglets indirectly suggest several factors that may influence colostrum intake by piglets. Colostrum intake may be lower in piglets of low birth weight (Lecce 1971; Hendrix et al. 1978; Yaguchi et al. 1980; but see De Passillé et al. 1988), in those born late in the farrowing sequence (Coalson and Lecce 1973; Hendrix et al. 1978; Yaguchi et al. 1980; De Passillé et al. 1988), and in those that suckle infrequently or sample only a few teats (De Passillé et al. 1988). In addition, hand and machine milking of farrowing sows suggest that anterior teats may yield more colostrum (Fraser 1984; Fraser and Lin 1984; Fraser et al. 1985). However, the birth weight, birth order, and teat position of piglets are often inter-correlated (Scheel et al. 1911), and an experimental approach is needed to test their effects on colostrum intake with a minimum of confounding.

The following experiments used the simple technique of weighing piglets at frequent intervals (usually every 10 min) in order to monitor their weight changes while consuming colostrum. Four experiments were done (1) to explore the accuracy of such data as a means of estimating colostrum intake, (2) to monitor the development of episodic colostrum intake during the piglets' first 4 h of suckling, and to assess how (3) birth order and (4) placement on anterior or posterior teats influence colostrum intake. In these experiments we paid particular attention to piglets consuming < 40 g, as the data of Coalson and Lecce (1973) suggest that such low intakes may impair immune competence.

MATERIALS AND METHODS

Animals and Housing

A total of 33 farrowings were studied at the Centre for Food and Animal Research specific-pathogen-free Yorkshire and Yorkshire × Landrace herd. Sows were about equally divided among parities 1-3 (13 sows), 4-6 (11 sows), and 7-9 (9 sows), and were used in the experiments as they became available. Farrowings were attended, and piglets were removed from the sow to a warm, bedded box before they began to suckle. Experimental procedures began as soon as possible after the number of piglets needed for the experiment were born and dry. About half of the farrowings were spontaneous and half were induced by an injection of cloprostenol on the previous day. Cloprostenol (Estrurnate, ICI) is a prostaglandin $F_{2\alpha}$ analogue which was used to increase the likelihood of farrowing during daytime hours (Zerobin and Eggenberger 1983). Apart from influencing the timing of farrowing, it is considered to have no effect on sow health or the duration of farrowing (Fraser and Connor 1984).

Sows were housed in farrowing crates in pens measuring 2.1 × 1.6 m. The lowest rail of the crate was removed during the observations to allow the piglets unimpeded access to the udder (see Fraser and Thompson 1986). Ambient temperature was generally 21-25°C.

Weighing Procedures

Except where specified, the piglets were weighed to the nearest 1 g in an open-topped box bedded with wood chips, on a Mettler PE24 top-loading balance with a Lab Pak attachment which provided a weight averaged over approximately 7 s. A weight was considered accurate if three or more identical weights had been obtained using the averaging option, or if the balance's stable-reading indicator was activated. Averaged readings were ignored if the piglet made major body movements during the averaging. Initial studies showed that averaged weighings were accurate to ± 1 g as long as the piglet made no major movements during the averaging. Up to 60 or 90 s were occasionally required to obtain an accurate weight for an active piglet. To encourage the piglets to urinate in the weighing box so that body weights could be corrected accordingly, cold shavings (from a freezer) or a damp cloth were sometimes added to the floor of the box.

Variation is expressed as standard deviations (SD) and/or range where the emphasis is on describing the sample, and as standard errors of the mean (SEM) where the significance of the difference is being reported. Median and quartile range (i.e., the range from the lower to the upper quartile) are used where an obvious skew in the data might make parametric statistics misleading.

Experiment 1: Methodological Study

The first experiment was a methodological study that documented the weight changes of piglets during their first 2 h of suckling (six litters) or when prevented from suckling (three litters), under close observation to detect all instances of urination and defecation. The test began 1.75-5.5 h (mean 2.8 h) after the birth of the first piglet, at which time 3 to 12 piglets had been born, with 0-4 additional piglets born during the 2-h test.

In the six litters that were allowed to suckle, piglets were confined beside the udder by a box (75 cm long by 40 cm wide) open at the top and on the long side adjacent to the udder so that the piglets had access to all of the sow's teats. The ends of the box were adjustable to fit against the udder and thus prevent piglets from escaping. The box floor was covered in light green blotting paper (which turned dark when wet) so that any urination would be seen immediately. A light-weight rubber grill was placed over the paper to give the piglet's better traction.

Four apparently normal piglets were chosen from each litter, marked for identification, and weighed individually in the same order every 10 min. Once a piglet had been weighed, it was placed in the box by the udder. The trial ended after 2 h and all piglets were then returned to the sow. Throughout the 2 h, a second observer watched the piglets continuously, noted any urination or defecation at the udder, and prevented piglets from escaping from the box.

In order to monitor weight changes in the absence of colostrum intake, 11 piglets in three additional litters were studied in a similar way, but with a box closed on all four sides so that the piglets could not consume colostrum.

Experiment 2: Development of Episodic Colostrum Release

The second experiment monitored piglets during a longer period (4 h) to determine to what extent colostrum was released continuously or in discrete ejections, and whether litter-mates tended to consume colostrum synchronously in the first hours after birth. Seven sows were used. Observations began 0.8-2.5 h (mean 1.9 h) after the birth of the first piglet, with 4-13 piglets born and 0-8 remaining to be born during the test.

At the beginning of observations, four piglets (usually the first born) were weighed individually and placed beside the udder of the recumbent sow. No assistance or interference was provided to encourage the piglets to suckle. Piglets were weighed every 10 min for 4 h. Written notes were made on any occasion when the sow sat, stood, or otherwise prevented suckling. Note was also taken of all occasions when a sow (1) had a clear ejection of colostrum as indicated by rapid grunting by the sow and synchronous rapid sucking by some of the piglets, which for older piglets is a reliable indicator of milk ejection (Rushen and Fraser 1989), or (2) was judged possibly to have had an ejection based on reasonably rapid grunting but no definitive sucking response by the piglets. The scheduled weighing of piglets every 10 min was maintained despite minor interruptions when the sows changed posture.

Experiment 3: Effect of Simulated Birth Order

The third experiment simulated the conditions met by piglets born early, middle or late in the birth order. On average, piglets are born 16 min apart (Randall 1972).To standardize collection and comparison of data, we simulated this timing by adding four pigs to the udder at the beginning of the hour for 3 consecutive hours and monitored the piglets' colostrum intake in their first hour of suckling.

The experiment involved eight farrowings. Observations began 1.2-4.6 h (mean 2.9 h) after the birth of the first piglet, with 7-14 piglets born and 1-4 remaining to be born during the test.

At the beginning of the observation period, four piglets, usually the first four born, were weighed individually and placed near the udder of the recumbent sow. After 1 h, four more pigs were added. After a further 1 h, a final group of four (usually the last born) were added. During each hour, only the four pigs most recently added were monitored. These animals were prevented by manual herding from leaving an area 60 cm wide beside the udder and bounded by the sow's front and rear legs. No other assistance in suckling was provided. Two observers noted the time elapsed until the pig first sucked a teat for a total of 10 s. The four piglets were individually removed and weighed, always in the same order, after every 10 min during the hour in which they were studied.

Small variations in the procedure were sometimes required. Two sows had only 11 piglets, so only 3 were studied in the final hour. In two other cases, a small litter size was anticipated from the outset, so each group of four pigs included three of the sow's own plus one foster piglet, which was also newly born and had been removed from its dam before sucking. On 11 occasions the sow interrupted suckling by standing or sitting. Five of these were < 3 min and were ignored. In three cases (duration of 5-14 min), the interval between successive weighings was prolonged correspondingly. In three other cases (duration of 14-71 min), the piglets were removed and the interval was restarted after the sow had settled.

The weight increases of each piglet in each of its six 10-min periods of observation were summed to give the estimated colostrum intake of each piglet in its first hour with the sow. These data, plus the time taken by the piglet to begin sucking, were analyzed by analysis of covariance using a model that included the eight litters, the three groups (first, second, or third group to be placed with the sow), the interaction of litters and groups, birth weight (included as a covariate), and an error term with 69 degrees of freedom.

Experiment 4: Anterior vs. Posterior Teats

Experiment 4 compared colostrum intakes of piglets suckling only the anterior or only the posterior teats. Nine sows and litters were used, beginning 2.0-3.5 h (mean 2.5) after the birth of the first piglet, with 6-15 piglets born and 0-6 additional piglets born during the test.

Six apparently normal piglets were assigned at random, three to the anterior and three to the posterior teats. Piglets were confined to the teats by a box similar to that used in exp. 1 but with a central partition which kept the piglets at the designated end of the udder. The floor of the box was raised about 4 cm so that the lower row of teats was inaccessible, and partitions were adjusted so that six apparently normal teats in the upper row were exposed to the piglets. These were numbers 1-3 (anterior) and usually 4-6 (posterior).

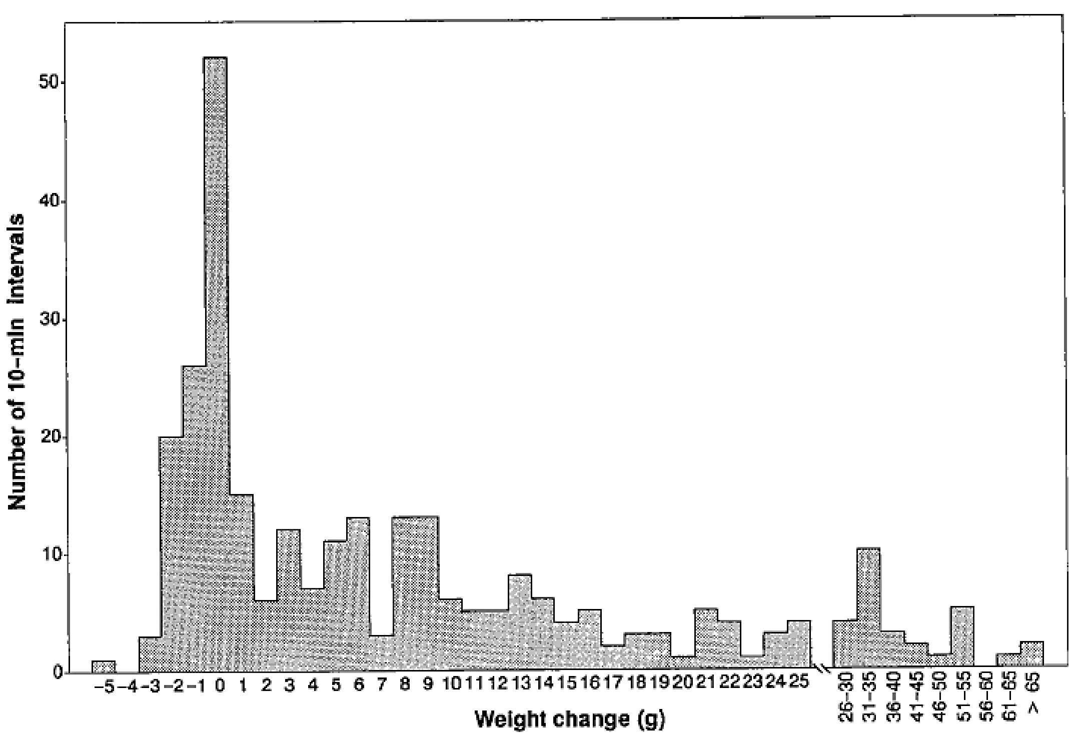
Piglets were monitored for 90 min and were reweighed at 15-min intervals in order to allow 10 min of uninterrupted behavioral observation between each set of weighings. At the start of the trial, the first piglet was weighed and placed at the anterior half of the udder, the second at the posterior, and so on in alternating fashion. All reweighing was done in the same order. Two assistants gently directed the piglets toward the teats to encourage sucking as early in the trial as possible.

In each interval an observer watched the piglets for 10 min, beginning when the last piglet had been weighed, and recorded whether or not each piglet had a teat in its mouth. This was recorded by instantaneous sampling at the end of every 30-s interval for 10 min.

This experiment was done using a balance which weighed piglets only to the nearest 5 g (Toledo Model 8134) as the more accurate balance was not available. While the reduced precision makes the quantitative estimates of intake less precise, the comparison of anterior- and posterior-sucking piglets should remain valid.

Five piglets were omitted from the analysis because they did not suck or had a weight loss of ≥ 10 g in one of the intervals, suggesting error or urinary loss. For the remaining 49 piglets, estimated colostrum intakes over the 1.5 h were analyzed by analysis of covariance. The model included the two positions (anterior or posterior), nine litters, the interaction of positions and litters, birth weight (included as a covariate), and an error term with 30 d.f.

Fig. 1. Frequency histogram showing the distribution of piglet weight changes in 10-min intervals in exp. 1. Results are based on 24 piglets, each allowed to suckle for twelve 10-min periods.



RESULTS

Preliminary analysis of all four experiments showed no evidence of differences in birth weights or weight increases between spontaneous and cloprostenol-induced farrowings, nor any relation of these measures to sow parity number. Therefore, these factors were ignored in subsequent analysis.

Experiment 1: Methodological Study

In the three farrowings in which piglets were prevented from consuming colostrum, all urination and defecation occurred in the weighing box where it could be quantified. Weight changes recorded at 10-min intervals (after subtracting any urination and defecation losses) were usually losses of 0, 1 or 2 g. For the 11 piglets, these values (summed over each hour) averaged 6.0 ± 1.1 g (mean ± SD) for the first hour and 4.6 ± 1.4 g for the second. Gains of 1 or 2 g were recorded on rare occasions, presumably because of measurement error.

For the 24 piglets that had access to colostrum, the most commonly observed weight change was 0, –1, or –2 g during the 10-min intervals (Fig. 1). The four cases of weight loss > 2 g likely involved some combination of measurement error and real respiratory and evaporative losses. Urination occurred 78 times, and all but one case occurred in the weighing box. The 24 piglets urinated a mean of 3.2 times (range of 0-6), losing a mean of 6.2 g (range of 1-21) each time, and 20 g (range of 0-53) over the 2-h test, with large differences between litters (Table 1). Six instances of defecation were noted, all in the weighing box, with most losses amounting to < 1 g. Total fecal loss per piglet averaged 0.3 g per piglet (range of 0-4 g) over the 2 h.

Table 1. Mean (and range)[z] estimated intake of colostrum, net weight increase. urinary weight loss, and defecation weight loss during the 2 h trials in exp. 1

Litter	Estimated[y] intake (g)	Net weight[x] increase (g)	Urinary weight loss (g)	Defecation weight loss (g)
1	157 (144 – 169)	122 (80 – 150)	29 (13 – 53)	0 (0 – 0)
2	97 (57 – 144)	65 (25 – 121)	29 (21 – 42)	0 (0 – 0)
3	101 (65 – 135)	74 (49 – 105)	21 (10 – 38)	2 (0 – 4)
4	98 (39 – 136)	90 (36 – 130)	7 (0 – 18)	0 (0 – 0)
5	108 (90 – 134)	91 (84 – 115)	14 (7 – 18)	0 (0 – 0)
6	118 (111 – 137)	97 (80 – 116)	20 (11 – 29)	0 (0 – 0)
All	133 (39 – 169)	90 (25 – 150)	20 (0 – 53)	0.3 (0 – 4)

[z] Data are based on four piglets per litter.

[y] Sum of all weight increases over the twelve 10-min intervals.

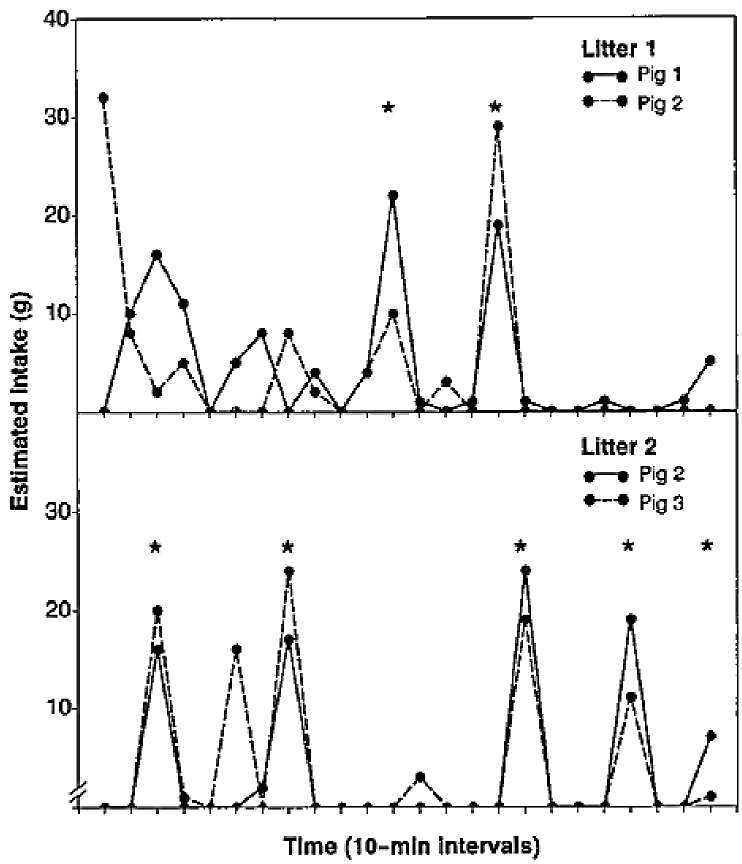
[x] Final weight (after 2 h) minus initial weight.

Based on these observations, the sum of all weight increases recorded for an animal was considered to provide a simple and reasonably accurate estimate which would underestimate colostrum intake by only 1-2 g per 10-min interval. Calculated in this way, colostrum intake averaged 113 ± 33 g (mean ± SD) over the 2 h, with a range of 39-169 g (Table 1). Omission of all weight increases of < 3 g, on the grounds that some of these were likely due to measurement error, had almost no effect on the estimates (r^2 = 0.99). The net weight change over the 2 h (final weight minus initial weight) averaged 90 ± 33 g, with a range of 25-150 g (Table 1). For individual piglets, the net weight change averaged 78 ± 13 percent (range of 44-96%) of the estimated colostrum intake.

Few pigs showed evidence of difficulty in obtaining colostrum. All but one of the 24 pigs had established successful sucking (as evidenced by a weight gain of 5 g or more) in the first or second 10-min interval.

Only three of the 24 pigs consumed < 40 g in the first 1 h; and only the lightest pig in the experiment (birth weight of 707 g) consumed < 40 g in 2 h.

Fig. 2. Estimated colostrum intake by two piglets in litters 1 (above) and 2 (below) selected to illustrate the trends seen in exp.2. In the first hour, most (litter 1) or some (litter 2) colostrum intake showed little synchrony between litter-mates. Thereafter, much of the colostrum intake occurred in peaks that were synchronized between litter-mates and were usually associated with behavioral evidence of colostrum ejection (indicated by asterisks).

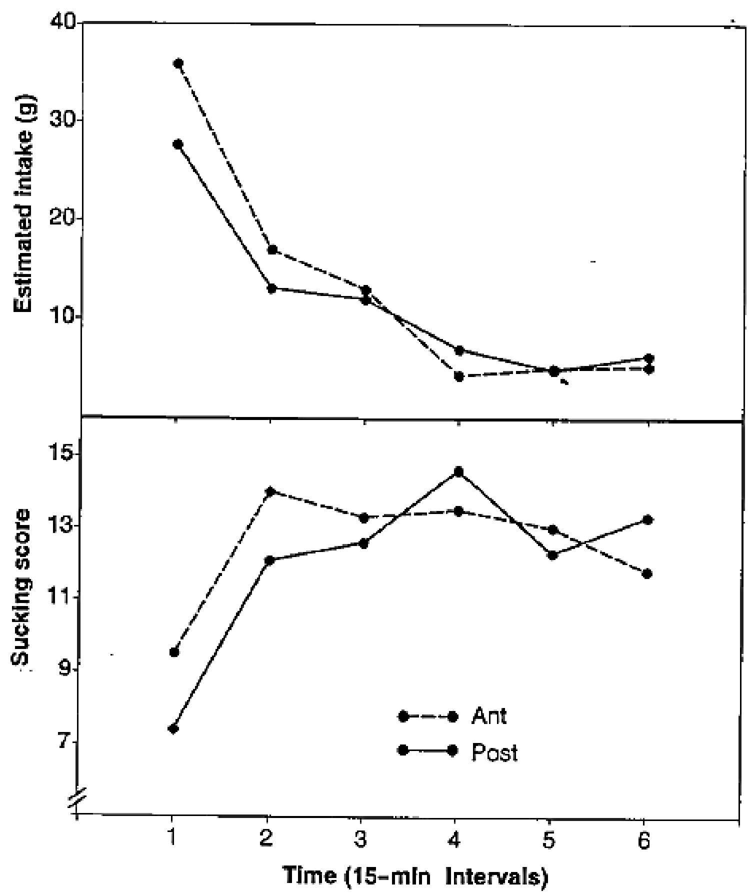


Experiment 2: Development of Episodic Colostrum Release

All 28 piglets established successful suckling as evidenced by cumulative weight increases averaging 105 ± 33 g (mean ± SD) with a range of 18-173 g over the 4 h. Colostrum intake averaged 42 ± 31 g in the first hour (mean ± SD) followed by 26 ± 19,21 ± 8, and 17 ± 11 in the remaining hours.

Out of the 168 10-mrn intervals studied (7 sows × 4 h × 6 intervals per hour), clear ejections of colostrum were seen in 28 cases (1-8 per sow), possible ejections in 12, and there was no behavioral evidence of ejection in 128. The first ejection occurred at a median of 49 min (range: 23-193 min) after the start of the 4-h observation period, and thus a median of 194 min (78-268 min; after the birth of the first piglet. Ejections tended to be less common in the first 1 h of observations (mean of 0.7 h^{-1} per sow) than in the third hour (1.1) or the fourth (1.4 per sow). In the first hour, colostrum intake was somewhat higher in intervals with ejections (median of 6 g; quartile range of 0-16 g) than in intervals without (median of 0 g, quartile range of 0-9 g). In the remaining hours, median intake was 9 g per piglet (quartile range of 3-14 g) in the 23 intervals with clear ejections and 0 (quartile range of 0-1) in the 91 intervals without. In the 12 intervals scored as possibly involving ejection, intake was intermediate with a median of 4 g and a quartile range of 1-10 g. Because there was some doubt over the occurrence of colostrum ejections in these 12 intervals, it was not possible to calculate a meaningful average time interval between successive ejections. However there were four cases in which a clear ejection occurred about 20 min after the previous one, this interval being appreciably shorter than is seen in the established lactation (Fraser 1977).

Fig. 3. Mean colostrum intake (g) and mean sucking score of piglets sucking anterior teats (broken line) or posterior teats (solid line) in exp. 4, over successive 15-min intervals. The sucking score represents the number of scans, done at 30-s intervals during a 10-min observation between each weighing, in which a piglet was holding a teat in its mouth (maximum score of 20).



To express synchrony between piglets in colostrum intake, we defined a "peak" of colostrum intake as a 10-min interval in which at least three of the four pigs achieved a weight increase of ≥ 5 g, and when the total weight increase was greater than seen in either the interval before or the interval after. In hour 1, only 25% of colostrum intake occurred in "peak" intervals. In hours 2-4, 51 % of the total estimated colostrum intake occurred in the 15% of intervals which met the criterion of a "peak". Figure 2 shows examples of litters where piglets had largely synchronous weight gains in the later hours, whereas some or most colostrum intake occurred asynchronously in the first hour.

Of the 28 piglets, 17 consumed ≥ 40 g in the first hour of the experiment, and only one (a pig of 927 g birth weight which discovered only the two most posterior teats) achieved < 40 g in the 4 h.

Experiment 3: Effect of Simulated Birth Order

The order in which the pigs were placed with the sow had only a small effect on their colostrum intake during the hour in which they were monitored. Intake was slightly higher for the second group of four pigs (mean of 65 g) than for the first (53 g) or the third (54 g). The difference was not statistically significant by analysis of variance of intake unadjusted for birth weight. However, inclusion of birth weight as a covariate reduced the error mean square and compensated for a tendency for the late-born pigs to be slightly heavier than their litter-mates. This analysis showed a significant difference in colostrum intake among the three groups ($P < 0.025$), highly significant differences among litters ($P < 0.001$), but no interaction of litters and groups. Mean intakes, after adjustment for birth weight, were 56, 67 and 49 g for the groups added first, second and third, respectively. The least significant difference at $P < 0.05$ was 18.0, showing that only the second and third groups differed significantly. The time taken to begin sucking averaged 12 ± 11 min (mean ± SD) and was very similar for the three groups of pigs.

Of the 94 piglets, 28 consumed < 40 g in the 1 h in which they were monitored. Most of these (19 of 28) involved the three litters with lowest average intakes, suggesting a low supply of colostrum by these sows. The remaining nine pigs tended to be of lower than average birth weight (mean ± SD of 1023 ± 245 g) and to take a longer time than average (20 ± 10 min) to establish themselves on a teat. The 28 low-intake piglets were about equally divided between the first group to be added (11 cases) and the last group to be added (12 cases), with only five cases among the middle group.

Experiment 4: Anterior vs. Posterior Teats

Pigs on the anterior teats had a tendency to consume more colostrum (mean 82 g, common SEM of 4.3) than those on the posterior tears (72 g). The difference was due at least in part to several posterior-sucking piglets with very low intakes: of the six piglets consuming < 40 g, all but one were on the posterior teats and three were from one sow whose piglets on average obtained the least colostrum of the nine litters. Piglets with high intakes (≥ 100 g) were more evenly divided between anterior (seven piglets) and posterior (six piglets). With birth weight included as a covariate, analysis showed a significant difference between anterior and posterior piglets ($P = 0.02$), highly significant differences between litters ($P < 0.001$), no significant interaction, and a significant relation between colostrum intake and the covariate ($P < 0.05$). Mean intakes, after adjustment for birth weight, were 85 and 72 g (common SEM = 3.5) for anterior and posterior piglets, respectively.

All but 2 of the 49 piglets began sucking in the first 15-min interval, and the majority achieved their greatest colostrum intake during the interval. Average intake declined fairly steadily during the rest of the trial, but sucking behavior remained high and fairly constant (Fig. 3), although some piglets began sleeping toward the end of the trial, often while still holding a teat. Sustained sucking did not necessarily indicate that appreciable amounts of colostrum were being consumed (Fig. 3). Furthermore, the low colostrum intake achieved by some piglets did not correspond to less time spent sucking. In fact, the six piglets with intakes of < 40 g tended to spend more time sucking (mean ± SEM sucking score of 13.6 ± 0.9 per 10-min observation) than the 13 piglets with intakes of ≥ 100 g (11.5 ± 0.8), largely because most of the piglets with low intake continued sucking to the end of the trial while the well-fed were more likely to sleep.

Relation of Colostrum Intake to Birth Weight in all Experiments

In all experiments heavier piglets tended to consume more colostrum than their lighter litter-mates. The pooled within-litter correlations (where each piglet's value was expressed as a deviation from its litter's mean) ranged from $r = 0.28$ ($P < 0.05$) to 0.65 ($P < 0.01$), with a 100-g difference in birth weight being associated with a difference of 3.9-9.5 g in estimated colostrum intake, depending on the experiment (Table 2).

Table 2. Birth weight (mean ± SD), estimated colostrum intake in the entire test and in the first 1 h. and the relationship (correlation and regression slope) of intake over the entire test to birth weight in the four experiments

Exp. no.	Birth weight (g)	Test duration (h)	Estimated intake (g)		Within litters			Between litters		
			Entire test	First 1 h	n^z	r	Slope	n^z	r	Slope
1	1265 ± 277	2	113 ± 33	86 ± 32	24	0.59**	0.095 ± 0.028	6	0.76	0.071 ± 0.030
2	1224 ± 246	4	105 ± 33	42 ± 31	28	0.65**	0.085 ± 0.020	7	–0.24	–0.032 ± 0.058
3	1177 ± 252	1	57 ± 32	57 ± 32	94	0.48**	0.057 ± 0.011	8	0.73*	0.117 ± 0.045
4	1298 ± 200	1.5	77 ± 30	66 ± 27	49	.028*	0.039 ± 0.021	9	–0.27	–0.046 ± 0.062

n^z = number of piglets in the within litter analysis or the number of litter means in the between-litter analysis.

*, ** $P < 0.05$ and $P < 0.01$, respectively.

Litter means showed a less consistent trend (Table 2). In exps 1 and 3, litters of higher mean birth weight tended to consume more colostrum than litters of low mean birth weight (r = 0.76 and 0.73), but no such trend was seen in the other experiments.

Table 3. Estimated colostrum intake (mean ± SD) by the 24 piglets in exp. 1 and the 28 piglets in exp. 2 in the six 10-min intervals beginning with the piglet's first interval of successful sucking[z]

Interval	Exp. 1	Exp. 2
1st	33 ± 22	24 ± 16
2nd	23 ± 17	14 ± 14
3rd	14 ± 10	9 ± 10
4th	9 ± 10	4 ± 6
5th	4 ± 8	4 ± 5
6th	4 ± 6	4 ± 6
All	88 ± 29	59 ± 21
Percent of birthweight	7.0 ± 1.9	5.0 ± 1.8

[z] The first interval of successful sucking was defined as the first 10-min interval in which the piglet achieved a weight increase of ≥ 5 g.

Rate of Colostrum Intake

Because the piglets in exps. 1 and 2 were monitored continuously for 2-4 h of suckling with fairly unimpeded access to the udder (only four piglets present, and all teats available), the data indicate the amount of colostrum piglets can be expected to consume under close to ideal circumstances once they have begun successful sucking. For most piglets, intake was high in the first interval of successful sucking (defined as the first 10-min interval in which a piglet had a weight gain of ≥ 5 g) and then declined gradually over 30-60 min (Table 3). On average, in the first hour after establishing successful sucking the piglets had consumed 88 ± 29 g in exp. 1 and 59 ± 21 g in exp. 2. As a percentage of birth weight, these values corresponded to 7.0 ± 1.9% (range of 3.8-9.9) and 5.0 ± 1.8% (range of 1.8-7.6) in exps. 1 and 2, respectively.

DISCUSSION

Accuracy of the Method

In these experiments, we tried to estimate the amount of colostrum consumed by piglets by summing the increases in weight detected by re-weighing piglets at 10-min intervals. Weight loss through urination was the largest source of potential error, averaging almost 20% of total weight gain in exp. 1, whereas weight loss through defecation was slight. Fortunately, the piglets almost always urinated in the weighing box and so the urine could be weighed. Presumably, urination was stimulated by some combination of handling, removal from the udder, and the colder floor surface of the box. This occurred at an earlier age than noticed previously (Buchenauer et al. 1982; Petherick 1983). Owing to the largely urinary weight loss, net weight change over a 2-h period (final weight minus initial weight) was a much less accurate method of estimating colostrum intake.

Gradual weight losses, presumably due to evaporation and respiration, were another source of potential error. Experiment 1 showed that in the absence of any urination or colostrum intake, piglets lost about 5 g h^{-1}, corresponding to about 10% of average colostrum intake. Intake may also have been reduced slightly by frequent removal of the piglets for weighing and perhaps by any influence of disturbance on colostrum release by the sow. Since we could not adequately control or compensate for these effects, our method presumably underestimates colostrum intake to some extent, although within-litter comparisons should remain valid.

Rate of Colostrum Intake

Colostrum intake varied considerably from litter to litter. In some experiments, litters of high birth weight tended to consume more than lighter litters, but there must have been other important sources of variation, such as differences among sows in the amount of colostrum made available to the young. Evidently, the experimental procedures had some influence on colostrum intake. Estimates of colostrum intake in the first 1 h in exp. 1, where the piglets were confined close to the udder, were double the estimates of exp. 2 where the piglets were less constrained. This influence should be constant within each experiment, but care would be needed in extrapolating our estimates of actual intake to pigs in other situations.

Nonetheless, the results indicate the appreciable rate of intake that piglets can achieve. In the 1 h beginning with each piglet's first successful suckling, intake averaged 7 and 5% of body weight in exps. 1 and 2, respectively, and exceptional piglets consumed colostrum equivalent to almost 10% of their birth weight in 1 h. Having achieved a large initial intake, usually in about 30 min, the piglets then consumed at a more modest rate. In exp. 2, intake in the third and fourth hours was roughly 20 g h^{-1} per piglet, a value still somewhat higher than that reported by Le Dividich and Noblet (1981) during the first day after birth.

Episodic or Continuous Release of Colostrum?

We observed discrete ejections of colostrum, characterized by increased rate of grunting by sows and increased rate of sucking by piglets (Rushen and Fraser 1989), in the 4-h periods monitored during and soon after parturition in exp. 2. After the first hour of observations (which ended 1.8-3.5 h after the birth of the first piglet) little colostrum was ingested by the piglets except in periods marked by discrete ejections; consequently, there was considerable synchrony in weight gains among piglets and numerous intervals during which piglets sucked at a teat but gained little or no weight. This supports the findings of Fraser (1984) and Castrén et al. (1989) who reported discrete ejections of colostrum soon after and even during parturition. Before this time, however, piglets did ingest considerable amounts of colostrum in the absence of signs of an ejection, and there was a lack of synchrony between piglets in weight gains. During this early period, it appears that colostrum is indeed available ad libitum as noted by Lewis and Hurnik (1985), although occasional discrete ejections did occur during these early hours.

To explain these results, we postulate the following. The ease of withdrawing colostrum immediately after parturition likely results from the sustained high level of oxytocin in the blood associated with farrowing

(Forsling et al. 1979) which presumably causes a high intramammary pressure (Ellendorff et al. 1982). Initial removal of colostrum from a teat reduces intramammary pressure to the point that continued sucking on the teat results in little additional intake. However, during this period, piglets suckle from many teats (Hartsock and Graves 1916), and by sampling a number of different teats, a piglet may discover ones which still have sufficiently high intramammary pressure to allow ingestion of colostrum without an ejection. In general, however, most additional ingestion of colostrum will require a discrete ejection. These ejections appear to be easily triggered: they occur with little or no tactile stimulation of the udder (Fraser 1984) and before the time when piglets develop the massaging action (Castrén et al. 1989) which helps to stimulate milk ejection later in lactation. Therefore, the threshold for either the release or action of oxytocin must be lower immediately after parturition than several days later. The development of episodic release of colostrum occurs several hours before the piglets develop synchrony in their suckling behavior (De Passillé and Rushen 1989); this emphasizes the difficulty of drawing inferences about colostrum ejection from observations of suckling behavior alone.

Factors Influencing Colostrum Intake Within Litters

Within litters, the larger piglets tended to consume more colostrum than their smaller littermates. This is consistent with the highly significant correlation between birth weight and serum gamma globulin concentration at 12 h of age found by Hendrix et al. (1978). However, other studies have found little (Yaguchi et al. 1980) or no (De Passillé et al. 1988) relationship between birth weight and measures of serum immunoglobulins in the piglets, possibly because differences in blood volume between large and small piglets complicated any effect of colostrum intake on serum immunoglobulin concentration.

Experiment 3 showed that piglets added to the litter later in the farrowing sequence consumed slightly but significantly less colostrum in their first hour as compared to piglets added earlier. This suggests that in litters of 11 or 12 piglets, as used here, late-born animals need not be severely penalized. The finding is consistent with the small but significant tendency for late-born piglets to show reduced immunoglobulin concentrations (Ai 1973; Hendrix et al. 1978; De Passillé et al. 1988). The more severe effect on serum immunoglobulin noted by Coalson and Lecce (1973) might result from the longer (4 h) delay in suckling imposed on their piglets, or from the possibility that the piglets added last had been exposed to cool temperatures (see Blecha and Kelley 1981; Le Dividich and Noblet 1981).

The tendency in exp. 4 of piglets confined to posterior teats to gain slightly less than litter-mates on anterior teats appeared to be due at least in part to a few piglets that gained poorly on the posterior positions. This suggests that a few posterior teats yielded little, even though most were as productive as the anterior ones. The small magnitude of the difference is consistent with the finding that serum immunoglobulin levels at 12 h of age were not correlated with greater use of the anterior teats (De Passillé et al. 1988). The greater yield of anterior teats during hand milking (Fraser 1984) may have been caused by hand milking of the more sensitive anterior teats stimulating colostrum ejection more effectively.

CONCLUSIONS

Taken together, these experiments suggest that although the period of ad libitum availability of colostrum is relatively brief, and although piglets depend on discrete ejection of colostrum for much of their intake, most piglets still achieve a sizeable intake. Even those piglets added late to the udder, or confined to the posterior teats, or of low birth weight, usually consumed within 1-2 h the 40-60 g of colostrum considered by Coalson and Lecce (1973) to be required for normal serum immunoglobulin concentration. Where piglets fail to consume adequate colostrum in the first hours after birth, the fault may lie more with inadequate environment (e.g., exposure to cold) or with such causes as very low birth weight, impaired sucking ability, or poor colostrum production by the sow.

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REFERENCES

Ai, C. L. 1973. Relationship of birth and nursing order of pigs to preweaning growth and other parameters. Michigan State University, Agric. Exp. Sta. Res. Rept. 232.

Algers, B, and Jensen, P. 1985. Communication during suckling in the domestic pig. Effects of continuous noise. Appl. Anim. Behav. Sci. 14: 49-61.

Algers, B., Rojanasthien, S, and Uvnas-Moberg, K. 1990. The relationship between teat stimulation, oxytoxin release and grunting rate in the sow during nursing. Appl. Anim. Behav. Sci. 26: 267-276.

Aumaitre, A. and Seve, B. 1978. Nutritional importance of colostrum in the piglet. Ann. Rech. Vet. 9: 181-192.

Blecha, F. and Kelley, K. W. 1981. Cold stress reduces the acquisition of colostral immunoglobin in piglets. J. Anim. Sci. 52: 594-600.

Buchenauer, D., Luft, C. and Grauvogl, A. 1982. Investigations on the eliminative behaviour of piglets. Appl. Anim. Ethol. 9: 153-164.

Castrén, H., Algers, B,, Jensen, P. and Saloniemi, H. 1989. Suckling behaviour and milk consumption in newborn piglets as a response to sow grunting. Appl. Anim. Behav. Sci. 24: 227-238.

Coalson, J. A. and Lecce, J. G.1973.Influence of nursing intervals on changes in serum protein (immunoglobulin) in neonatal pigs. J. Anim. Sci. 36: 381-385.

De Passillé, A. M. B. and Rushen, J. 1989. Suckling and teat disputes by neonatal piglets. Appl. Anim. Behav. Sci. 22: 23-38.

De Passillé, A. M. B., Rushen, J. and Pelletier, G. 1988. Suckling behaviour and serum immunoglobulin levels in neonatal piglets. Anim. Prod. 47: 447-456.

Ellendorff, F., Forsling, M, L, and Poulain, D. A. 1982. The milk ejection reflex in the pig. J. Physiol. (Lond.) 333: 577-594.

Forsling, M. L., Taverne, M. A. M., Parvizi, N., Elsaesser, F., Smidt, D. and Ellendorff, F. 1979. Plasma oxytocin and steroid concentrations during late pregnancy, parturition and lactation in the miniature pig. J. Endocrinol. 82: 61-69.

Fraser, D. 1977. Some behavioural aspects of milk ejection failure by sows. Br. Vet. J. 133: 126-133.

Fraser, D. 1980. A review of the behavioural mechanism of milk ejection of the domestic pig. Appl. Anim. Ethol. 6: 247-255.

Fraser, D. 1984. Some factors influencing the availability of colostrum to piglets. Anim. Prod. 39: 115-123.

Fraser. D. and Connor. M. L. 1984. Effect of dosage of Cloprostenol on induction of farrowing and body temperature of sows. Can. Vet. J. 25: 421-423.

Fraser, D. and Lin, C. S. 1984. An attempt to estimate teat quality of sows by hand milking during farrowing. Can. J. Anim. Sci. 64: 165-170.

Fraser, D., Nicholls, C. and Fagan, W. 1985. A sow milking machine designed to compare the yield of different teats. J. Agric. Eng. Res. 31: 371 376.

Fraser, D. and Thompson, B. K. 1986. Variation in piglet weights: Relationship to suckling behavior, parity number and farrowing crate design. Can. J. Anim. Sci. 66: 31-46.

Hartsock, T. G. and Graves, H. B. 1976. Neonatal behavior and nutrition-related mortality in domestic swine. J. Anim. Sci. 42: 235-241.

Hendrix, W. F., Kelley, K.W., Gaskins, C, G. and Hinrichs, D, J. 1978. Porcine neonatal survival and serum gammaglobulins. J. Anim. Sci. 47: 1281-1286.

Illmann, G. and Herbst, H. G. 1986. Zur synchronisation von Saug- und Säugeverhalten bei Berliner miniaturschweinen der Rasse MINILEWE Mh. Vet.-Med. 41: 636-639.

Lecce, J. G. 1971. Rearing neonatal piglets of low birth weight with an automatic feeding device. J. Anim. Sci. 33: 47-51.

Le Dividich, J. and Noblet, J. 1981. Colostrum intake and thermoregulation in the neonatal pig in relation to environmental temperature. Bioi. Neonate 40: 167-114.

Lewis, N. J. and Hurnik, J. F. 1985. The development of nursing behaviour in swine. Appl. Anim. Behav. Sci. 14: 225-232.

Petherick, J. C. 1983. A note on the space use for excretory behaviour of suckling piglets. Appl. Anim. Ethol. 9: 367-371.

Randall, G. C. B. L972. Observations on parturition in the sow. I. Factors associated with the delivery of the piglets and their subsequent behaviour. Vet. Rec. 90: 178-182.

Rushen, J. and Fraser, D. 1989. Nutritive and nonnutritive sucking and the temporal organization of the suckling behavior of domestic piglets. Devel. Psychobiol. 22: 789-801.

Scheel, D. E., Graves, H. B. and Sheritt, G. W. 1977. Nursing order, social dominance and growth in swine. J. Anim. Sci. 45: 219-229.

Yaguchi, H., Murata, H., Kagaota, K. and Namioka, S. 1980. Studies on the relationship between the serum gamma globulin levels of neonatal piglets and their mortality during the first two months of life: an evaluation for the ammonium sulphate reaction. Br. Vet. J. 136: 63-70.

Zerobin, K. and Eggenberger, E. 1983. Die Verwendung eines Prostaglandinsanalogs (Estrumate ICI) zur Geburtsuberwachung bei Schweinen. Schweiz. Arch. Tierheilk. 125: 413-421.