INDUCTION OF PREGNANCY DURING LACTATION IN THE SOW

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Summary. In a preliminary experiment carried out in Essex sows, three treatments were compared with a control group of lactating sows. The treatments were: (1) intermittent separation of the sow from the young, (2) injection of pregnant mare serum gonadotrophin (PMSG), and (3) a combination of treatments 1 and 2.

None of the control sows exhibited oestrus during lactation. Of the oestrus-induction methods used, only the combination of separation and PMSG injection induced oestrus consistently.

In an extension of the preliminary experiment, the combined treatment was tested in Essex, Large White and Large White × Landrace sows. Of forty sows treated overall, thirty-three exhibited oestrus during lactation and twenty-four carried pregnancies to term as a result of mating at the induced oestrus. The mean interval between parturitions was reduced by approximately 25 days in sows becoming pregnant during lactation. There appeared to be no detrimental effects of 2 or 3 weeks of concurrent lactation on pregnancies established during lactation.

The results are discussed in relation to the possible modes of action of separation and PMSG injection in the lactating sow.

INTRODUCTION

The regular oestrous cycles of the pig are normally interrupted only by pregnancy and lactation. There is agreement that *post-partum* oestrus occurs in the sow within 60 hr of parturition but the percentage of sows exhibiting this has varied widely in different studies (Warnick, Casida & Grummer, 1950; Burger, 1952; Heitman & Cole, 1956; Self & Grummer, 1958). *Post-partum* ovulation does not occur, regardless of whether or not there is *post-partum* oestrus. This has been established by examining the ovaries of sows slaughtered shortly after *post-partum* oestrus (Warnick *et al.*, 1950; Burger, 1952) and about 10 days after parturition when *post-partum* oestrus had not occurred (Warnick *et al.*, 1950).

Throughout the remainder of lactation, the sow does not normally exhibit oestrus or ovulation (Marshall & Hammond, 1937; Burger, 1952; Heitman &

Cole, 1956; Allen, Lasley & Uren, 1957; Self & Grummer, 1958; Palmer, Teague & Venzke, 1965). When lactation is terminated by removal of the young some 8 weeks after parturition, oestrus and ovulation occur generally within about 4 to 7 days (Marshall & Hammond, 1937; Burger, 1952; Self & Grummer, 1958; Smidt, Scheven & Steinbach, 1965). In practice, weaning is now commonly carried out as early as 6 weeks after parturition. Since the duration of pregnancy in the pig is about 115 days, lactation and the period after weaning before oestrus represent together some 25 to 35% of the interval between successive parturitions.

The work reported here was designed to assess methods of inducing oestrus and ovulation in the sow during lactation with a view to reducing the interval between successive parturitions by causing pregnancy concurrent with lactation. A preliminary report of certain of the results has been presented previously (Crighton, 1968).

MATERIALS AND METHODS

Animals

Sows from two herds were used. The first herd was a commercial one consisting of Essex sows mated with a Large White boar, and the second was the experimental herd of the School of Agriculture consisting of Large White and Large White $\times$ Landrace sows mated with one of several Landrace boars. All sows had had at least one previous litter when they entered the experiment.

Experimental treatments

For a preliminary experiment, twenty-four Essex sows were divided at random into four groups. The litter size of these sows was standardized at nine or ten young. Three treatments were assessed with regard to their efficacy in inducing oestrus and permitting the establishment of pregnancy during lactation. The treatment groups were compared with a control group of lactating sows. All sows were tested once daily for oestrus with a boar from the 10th day of lactation to the 10th day after weaning. Weaning was carried out in all groups on the 49th day of lactation. Sows which came into oestrus during the period of testing were mated on 2 successive days whenever possible and, if lactating, were returned to their litters. The treatments were as follows:

1. Separation of each sow and litter for 12 hr each day, beginning on the 21st day of lactation and continuing until oestrus was induced or 10 days had elapsed.
2. Injection of each sow with 1500 i.u. pregnant mare serum gonadotrophin (PMSG) on the 21st day of lactation.
3. Separation of each sow and litter for 12 hr each day on the 21st, 22nd and 23rd days of lactation, followed by injection of the sow with 1500 i.u. PMSG at the end of the period of separation on the 23rd day of lactation.

As an extension of the preliminary study, a further experiment was carried out in which the treatment combining separation and PMSG injection was evaluated in a total of twenty-nine Essex sows (eleven control, eighteen treated) including the thirteen sows (six control, seven treated) from the preliminary experiment and in thirty-two Large White and Large White $\times$ Landrace sows

(ten control, twenty-two treated). Litter size in the Essex sows was restricted within the range of eight to twelve young. No restriction was imposed in the Large White/Large White $\times$ Landrace herd. In the Essex herd, weaning was carried out on the 49th day of lactation and in the Large White/Large White $\times$ Landrace herd, on the 42nd day of lactation. In both herds, the procedure was as in the preliminary experiment except that, in the case of the Large White/Large White $\times$ Landrace herd, control sows were not tested daily for oestrus

TABLE 1

OESTROUS RESPONSE AND PREGNANCY DATA (PRELIMINARY EXPERIMENT, ESSEX SOWS)

Group	Sow no.	Litter size on the 21st day of lactation	Day of lactation on which oestrus exhibited	Day after weaning on which oestrus exhibited	No. of young born alive at subsequent parturition	Interval between successive parturitions (days)
Control	1	10	—	5	12	168
	2	9	—	4	10	167
	3	9	—	4	11	168
	4	10	—	5	12	169
	5	9	—	4	5	168
	6	10	—	1	10	165
Separation	7	10	—	5	11	169
	8	9	—	4	9	168
	9	9	—	1	9	167
	10	10	—	6	13	171
	11	9	25	—	11	140
PMSG injection	12	9	25	—	9	140
	13	10	26	—	9	144
	14	9	—	3	12	169
	15	10	—	4	13	168
	16	10	—	4	11	167
	17	9	—	3	11	169
Separation + PMSG injection	18	10	26 and 47	—	10	163
	19	9	30	—	12	145
	20	9	27	—	13	143
	21	9	28	5	5	171
	22	10	—	4	5	169
	23	10	—	5	11	168
	24	9	27	—	8	146

during lactation as it had been established previously that these sows do not normally exhibit oestrus during lactation (Crighton, unpublished data; Crighton & Lamming, 1969). Data were recorded from twenty-six lactations from the ten control sows in this herd.

Statistical analysis

The *t* test was used to assess the significance of differences between groups where appropriate.

RESULTS

The oestrous response and pregnancy data from the preliminary experiment are shown in Table 1. None of the control sows exhibited oestrus during lac-

TABLE 2
OESTROUS RESPONSE AND PREGNANCY DATA (EVALUATION OF COMBINED TREATMENT, ESSEX, LARGE WHITE AND LARGE WHITE X LANDRACE SOWS)

Breed	Treatment	No. of sows	Litter size on the 21st day of lactation (Mean $\pm$ S.E.)	No. of sows exhibiting oestrus during lactation	Interval between PMSG injection and oestrus in days (Mean $\pm$ S.E.)	No. of sows carrying pregnancy to term as result of lactational mating	No. of young born alive (Mean $\pm$ S.E.)	Interval between successive parturitions in days (Mean $\pm$ S.E.)
Essex	Control	11	9.8 $\pm$ 0.3	0	—	0	10.5 $\pm$ 1.1	169.6 $\pm$ 1.1
	Separation + PMSG injection	18	9.6 $\pm$ 0.3	16	4.2 $\pm$ 0.3	11	9.7 $\pm$ 0.6*	143.8 $\pm$ 1.8* (154.0 $\pm$ 3.5)†
Large White and Large White x Landrace	Control	10 (26 lactations)	8.2 $\pm$ 0.5	—	—	—	9.7 $\pm$ 0.5	168.1 $\pm$ 2.0
	Separation + PMSG injection	22	8.4 $\pm$ 0.4	17	4.5 $\pm$ 0.3	13	9.5 $\pm$ 0.8*	143.3 $\pm$ 2.7* (154.1 $\pm$ 3.1)†

* Mean of sows which carried pregnancy to term as a result of lactational mating.

† Mean of all sows treated.

tation but all returned to oestrus at a mean interval of 3.8 days after weaning. Of the treatments employed, the combination of separation and PMSG injection was clearly the most effective in inducing oestrus during lactation. Only one of the eight sows which exhibited lactational oestrus as a result of any of the treatments failed to carry pregnancy to term after mating during lactation. One sow which mated on the 26th day of lactation returned to oestrus 21 days later and conceived.

The oestrous response and pregnancy data from the evaluation of the combined treatment in the two herds are shown in Table 2. None of the control Essex sows which were tested daily exhibited oestrus during lactation but all returned to oestrus at a mean interval of 4.1 days after weaning. Of a total of forty sows treated overall, thirty-three (83%) exhibited oestrus during lactation. Of these, twenty-four farrowed as a result of mating at the induced oestrus (73% of lactationally oestrous sows; 60% of all sows treated).

The mean number of young born alive in either herd as a result of mating during lactation was not significantly different from the mean number born alive to control sows mated after weaning.

The mean interval between successive parturitions in sows carrying pregnancies established during lactation to term was reduced in both herds by approximately 25 days when compared with controls. When all treated sows were considered, the mean reduction was approximately 15 days. Sixteen sows failed to farrow as a result of treatment (seven Essex, nine Large White/Large White $\times$ Landrace). Of these, two were Essex sows which exhibited oestrus during lactation, failed to return to oestrus within 10 days after weaning and were therefore assumed to be pregnant but died subsequently from undetermined causes. No data on the pregnancies of these sows are available. A further seven sows exhibited oestrus during lactation (three Essex, four Large White/Large White $\times$ Landrace) and were mated but returned to oestrus at intervals ranging from 5 to 10 days after weaning (mean 6.6 days). Only one of these sows failed to conceive at this oestrus. This Large White animal exhibited oestrus on the 6th day after weaning, was mated but returned on the 31st day after weaning and conceived at this second oestrus. The remaining seven treated sows (two Essex, five Large White/Large White $\times$ Landrace) failed to exhibit oestrus during lactation but did so at intervals ranging from 4 to 32 days after weaning (mean 9.3 days).

Continuation of lactation in treated sows

On those days on which separation was imposed, suckling behaviour was resumed immediately on re-uniting sow and litter. Normal suckling behaviour continued throughout the period of lactational oestrus where this occurred and in early pregnancy. It was obvious from the frequency of suckling, the condition of the mammae and the growth of the young that lactation was not seriously disturbed by the treatment or by concurrent early pregnancy.

DISCUSSION

The finding that the Essex sows tested daily with a boar from the 10th day of

lactation onwards failed to exhibit oestrus until about 4 days after weaning confirms numerous previous observations in many breeds (Marshall & Hammond, 1937; Burger, 1952; Heitman & Cole, 1956; Allen *et al.*, 1957; Self & Grummer, 1958; Palmer *et al.*, 1965; Smidt *et al.*, 1965), including observations made previously on Large White sows in the second herd used in the present study (Crighton & Lamming, 1969). While it is known that ovulation without oestrus does not occur during lactation in this strain of Large White sows (Crighton & Lamming, 1969), it was not possible to verify this for the herd of Essex sows.

It has been suggested by Crighton & Lamming (1969) that lactational anoestrus and anovulation in the sow are due to gonadotrophic insufficiency: specifically, failure of release of follicle-stimulating hormone (FSH) and of synthesis of luteinizing hormone (LH). This suggestion was based on information obtained from pituitary FSH and LH bioassays and examinations of the reproductive tract. The latter showed a marked depression of ovarian follicular growth together with uterine atrophy during lactation which were rapidly relieved by weaning when this was effected on the 56th day of lactation, culminating in oestrus and ovulation some 4 to 6 days later.

Weaning at all stages of lactation in the pig results in a return to oestrus and ovulation and this has been the basis of attempts to develop 'early weaning' systems, although there is evidence that the earlier in lactation that weaning is effected, the longer and more variable is the interval between weaning and oestrus (Self & Grummer, 1958). This, and disease problems encountered when young pigs are reared away from the sow, have severely limited the application of 'early weaning' techniques.

'Partial early weaning,' that is the separation of sow and litter for a period each day, was recommended by Marshall & Hammond (1937) as a method of inducing oestrus in the lactating sow. No experimental evidence was offered as a basis for this and Burger (1952) was unable to confirm the efficacy of such a treatment, even when applied for extensive periods as a 12-hr separation overnight. Smith (1961), however, was able to induce oestrus consistently by 12-hr periods of separation during the day beginning on the 21st or 31st to 35th day of lactation, although he observed that sows nursing a first litter required a mean of 14.0 days of separation to elicit oestrus, whereas sows nursing a second litter required a mean of 5.6 days of separation when treatment was begun on the 21st day of lactation. The imposition of 8 hr of separation per day from the 21st day of lactation failed to result in oestrus in any sow until the 8th week of lactation.

In the present preliminary experiment, it was considered that failure to exhibit oestrus within 10 days of the start of separation would render the treatment of little value in practice and so separation was stopped after this period in all sows which had not exhibited oestrus. The results are in agreement with those of Burger (1952), since only one sow exhibited oestrus within the period specified. The variation in the effectiveness of this treatment may be related to the different breeds and strains employed by the investigators and to environmental factors, particularly the effect of proximity of a boar during separation which was excluded in the present study.

The results obtained from the injection of PMSG alone confirmed the results of Cole & Hughes (1946), Heitman & Cole (1956) and Allen *et al.* (1957) in that oestrus was not induced consistently as a result of injections of PMSG on the 21st day of lactation. The finding of Cole & Hughes (1946) and Heitman & Cole (1956) that the response to PMSG improved substantially when injection was carried out after about 40 days of lactation was not examined in the present work.

The finding that the combination of PMSG injection with separation resulted in lactational oestrus in 83% of treated sows when the treatment was begun on the 21st day of lactation demonstrates that this treatment is appreciably more effective than PMSG injection alone. (The reasons for the augmentation of response obtained on combining the treatments may be rather complex.) The ability of PMSG to provoke ovulation in the immature rat has been shown to be due, not to its inherent LH activity, but to the LH-releasing action effected by way of the hypothalamus on the pituitary LH of the rat (McCormack & Meyer, 1962; Zarrow & Quinn, 1963; Szontágh & Uhlarik, 1964; Quinn & Zarrow, 1965). There is evidence suggesting that endogenous FSH is also released by PMSG (Rennels & O'Steen, 1967).

PMSG produces follicle growth and ovulation in the immature pig (Cole & Hughes, 1946). If the mode of action of PMSG is similar in this species, it would presumably be unable to exert its effect under circumstances where insufficient endogenous LH was available. Such circumstances appear to be present during lactation in the sow (Crighton & Lamming, 1969). On this basis, however, it is difficult to explain why, in the work of Cole & Hughes (1946) and Heitman & Cole (1956), the response to PMSG injection was appreciably greater in late lactation than in early lactation, since the results of Crighton & Lamming (1969) suggest that LH synthesis is suppressed up to the 8th week of lactation.

It is clear that, under certain circumstances, separation of sow and litter for a period each day can result in follicle growth, oestrogen secretion and ovulation (Smith, 1961). The combination of circumstances required for this to be achieved is uncertain but one of the main effects is presumably the reduction in suckling intensity which results, negating the inhibition of follicle growth mediated during lactation by the suckling stimulus. The slight evidence available suggests that ovarian insensitivity to circulating gonadotrophin is not a factor in follicular quiescence during lactation in the pig (Kirkpatrick, Lauderdale, First, Hauser & Casida, 1965). Thus, it seems likely that the effect of separation may be to increase synthesis and/or release of endogenous FSH and LH by changes in hypothalamic neuronal activity and the synthesis and release of hypothalamic neurohumoral agents controlling pituitary gonadotrophin secretion. In the present work, while the effects of separation were insufficient to result in oestrus in all but one sow, the initiation of these processes during the period of separation before PMSG injection may have created circumstances in which the gonadotrophin-releasing action of PMSG could be expressed, thus accounting for the greater degree of success achieved compared with PMSG injection alone.

Marshall & Hammond (1937) stated that should a sow be mated during lactation and lactation be continued normally, loss of the pregnancy would

take place due to the competing demands of concurrent lactation on the nutrition available. This did not occur in the present work, confirming the findings of Smith (1961) with a small number of animals in separation experiments. The length of exposure of pregnancy to concurrent lactation in the present study was 2 to 3 weeks and this failed to have any effect on numbers of young born alive. Seven out of thirty-three sows (21.2%) which came into oestrus and were mated during lactation returned to oestrus at intervals ranging from 5 to 10 days after weaning. This might be attributed to loss of pregnancy at about the time of implantation, failure of fertilization or failure to ovulate. Such a percentage failure of conception to mating at the first oestrus after weaning would certainly be considered rather abnormal. It is clear, however, that each of the processes leading to the maintenance of pregnancy was accomplished in the majority of treated sows under circumstances of continued lactation.

It was shown previously that ovariectomy of the sow at 20 to 21 days of lactation had no effect on the subsequent growth of young dependent solely on milk for nutrition (Crighton & Lamming, 1969). The independence of lactation from ovarian and uterine activity is confirmed by the present finding that lactation was not seriously disturbed by the series of ovarian and uterine changes starting from a state of atrophy and leading up to the establishment and maintenance concurrently of the first 2 to 3 weeks of pregnancy.

The results of these investigations suggest that the treatment combining separation and PMSG injection may provide an alternative to 'early weaning' as a means of reducing the interval between successive parturitions in the sow. Further experiments will be required to determine whether the treatment, in its present form, or with modifications, may be employed earlier in lactation than in the present study. While there seems to be no reason why oestrus and ovulation should not be induced earlier, the effects of longer periods than 2 to 3 weeks of concurrent pregnancy and lactation on the maintenance of either are as yet unknown. The value of the treatment in practice will depend on how early in lactation it can be applied without adverse effects on these processes.

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