DAIRY COW REPRODUCTIVE PERFORMANCE FROM PARTURITION TO CONCEPTION AS INFLUENCED BY CALCIUM TO PHOSPHORUS RATIO AND VITAMIN D IN HIGH ENERGY RATIONS

by

CARROL WRAY CAMPBELL

B. S., Kansas State University, 1966

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Dairy and Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1969

Approved by:

Major Professor

TABLE OF CONTENTS

INTRODUCTION

The economic importance of a 12-13 month calving interval in dairy cows has motivated physiologists to study specifically reproductive processes after parturition. Investigations concerning pathological conditions causing infertility in cows after parturition have been conducted extensively. Diseases such as Brucellosis, Vibrio fetus, Trichomoniasis, and Leptospirosis probably account for the greatest amount of infertility. Functional sterilities such as freemartinism, cystic ovarian disease, and anestrum are also responsible for many reproductive failures. Non-pathological factors of infertility have not been considered sufficiently and as a consequence many reproductive problems today are a result of poor feeding and management.

The relationship of nutrition and reproduction has long been known, especially the effect of protein and energy deficiency on the reproductive efficiency of the cow. More recently mineral nutrition has been considered and deficiencies have been found to be of importance. The significance of the proper ratio of calcium to phosphorus in the ration of dairy cattle has been emphasized in recent years. This has led some researchers to postulate that the ratio of calcium to phosphorus in the total ration may be of some importance in reproductive efficiency; however, the literature is inconclusive and lacks a specific study of the relationship between the Ca:P ratio and reproductive efficiency after calving in dairy cows. This study was designed to consider the postpartum reproductive problems of high milk production, anestrum, ovarian cysts, and other nonpathological conditions which result in lowered efficiency, in relation to the Ca:P ratio of the ration for milking dairy cows.

REVIEW OF LITERATURE

Rate of Uterine Involution

Casida and Venzke (1936) reported the average length of the interval from calving until the uterus was involuted to be 26.2 days. Buch et al. (1955) found the uterus to be completely involuted by 47 days. Average interval to complete uterine involution as determined by rectal palpation was 39 days as reported by Marion et al. (1968). Morrow et al. (1966) observed a rapid decrease in uterine size from 10 to 14 days postpartum until the main decrease in size was completed by 25 days postpartum in normal cows and 30 days in abnormal cows. They observed little palpable change in the uterus during the next 30 to 35 days. In a study of excised tracts, Gier and Marion (1968) found the post gravid horn reduced to half of its parturition size by 15 days and to a third by 30 days with involution essentially complete by 40 days.

Effect of Parity and Season. Casida and Wisnicky (1950) observed a tendency for longer intervals to complete involution in older cows. Buch et al. (1955) reported a significant difference in rate of involution between primiparous and pluriparous cows whose uteri were found to be regressed by 42 days and 50 days, respectively. Significant differences were also observed among seasons with the intervals being shortest in the summer and autumn. Foote et al. (1960), working with 13 pairs of twins (nine fraternal and four identical), found an average involution interval of 43.7 days. The interval was significantly affected by parity being 11 days shorter in the first service period (interval from calving to first service) than in the second. The variation in involution rate was significantly less between identical twins than between fraternal twins.

In more recent work Morrow et al. (1966) reported the rate of uterine involution decreased significantly as the number of lactations increased; however, season did not significantly affect the rate of regression. Marion et al. (1968) reported a significant effect of both parity and season on involution rate. Average intervals for primiparous and pluriparous cows were 34.0 and 40.6 days, respectively. They observed a shorter interval in both parity groups during the spring and summer and longer intervals during the winter. The authors stated that the increased variation in length of intervals observed during the summer seemed to be associated with ambient temperature. Regression was slower if parturition occurred during extremely hot periods of the summer.

Effect of Abnormal Parturition. Calving involving twins, retained placenta, dystocia, prolapse of the uterus, stillbirth or an abortion was considered as abnormal by Buch et al. (1955). The average interval to involution was five days longer following abnormal parturitions. The effect of parity could also be seen in this group of abnormal calvings as the primiparous cows tended to involute earlier than pluriparous cows. Morrow et al. (1966) also reported that uteri required 3 to 5 days longer to involute following abnormal calving. Marion et al. (1968) observed a highly significant lengthening of the interval from parturition to involution in cows having retained fetal membranes; however, primiparous cows seemed to be more affected than pluriparous.

Effect of Hormonal Treatment. Foote et al. (1960a) reported that injecting beef cows 14 days after calving with 1 mg of progesterone per pound of body weight had no effect on the interval required for involution of the uterus. Fosgate et al. (1962) found that injecting 100 mg of 17-alpha-hydroxy-progesterone-N-caproate (delalutin) on alternate days beginning with the day of calving and continuing for 42 days increased the involution interval in dairy cows. The treated cows had an average interval of 42 days while untreated cows required 27.5 days to regress. These results are in contrast to those of Foote and Hunter (1964) who observed a shortening of the involution interval in beef cows injected daily with 50 mg of progesterone from the twelfth through the twenty-third day after parturition. A shorter interval was also observed in cows administered 10 mg of 17 beta-estradiol on the twenty-fifth day following the daily progesterone treatment and in cows administered a single injection of estradiol after the same interval. Marion et al. (1968) found that daily treatment with 30 mg of progesterone beginning 3 days after parturition and continuing until uterine involution was complete significantly increased the regression interval. They also treated cows with 300 gm of medroxyprogesterone acetate which was found to have no influence on uterine involution; however, estrus was suppressed during treatment.

Stilbestrol has been used to correct some reproductive conditions such as anestrum in cows after parturition. Casida and Wisnicky (1950) reported that 20 mg of diethyl-stilbestrol dipropionate injected within nine hours after calving failed to produce an effect on uterine involution. The average interval for involution was 29.4 days. Marion et al. (1968) found that injections of 17 beta-estradiol at both the 0.05 mg and .10 mg levels did not influence significantly the rate of regression; however, involution intervals tended to be longer in treated cows.

Ovarian Activity and Estrus Behavior after Parturition

Chapman and Casida (1934) reported that the average interval from parturition to first estrus in clinically normal cows was 69 days. Clinically abnormal cows in which cystic follicles or retained corpra lutea had been detected in previous years had an average interval to first estrus of 71 days which was not significantly different from normal cows.

Casida and Venzke (1936) found the first ovulation an average of 40.7 days after parturition. The average interval from calving until a 12 mm follicle was palpated was 28.8 days. This indicated a 12 day interval between the 12 mm stage of growth and ovulation. They also noted that, when the follicular development during the postpartum period started in the opposite ovary from the one that contained the corpus luteum of the former pregnancy, the interval until a 12 mm follicle was detected was shorter. When the follicular development was in the same ovary as the corpus luteum of the former pregnancy the interval was 8.1 days longer.

Trimberger (1956) assigned 400 cows at random to an experimental group, which were examined by rectal palpation weekly, and to a control group which were not examined. The average intervals to first estrus for the control and experimental groups were 50.9 and 49.4 days, respectively. The interval for the experimental group as determined by rectal palpation was 43.7 days because 35 cows failed to exhibit estrus before ovulations in 49 estrous cycles. Before 90 days post-partum 93 percent of the cows in both groups had been in estrus.

Herman and Edmondson (1950) reported the average interval to first estrus was 57 days for 968 parturitions in 347 dairy cows. They found that 59 percent of the cows were first in heat by 60 days post-partum; 30 percent between 60 and 90 days; 7.6 percent between 90 and 120 days; and 3.4

percent after 120 days. Their work also indicated an influence of age on interval to first estrus. First calf heifers had an average interval of 75 days. The interval was shorter (50 to 60 days) for cows between 3 and 7 years of age and longer in older cows (60 to 90 days). Parity which is closely associated with age had a similar effect on the interval to first estrus. There seemed to be no relationship between season of the year and the occurrence of first estrus.

Buch et al. (1955) observed a highly significant differene among seasons regarding the interval from parturition to first estrus. The average interval to first heat was 33 days. The intervals during winter, spring, summer, and autumn were 38, 32, 28, and 32 days, respectively. They did not observe a parity effect, however, as the average interval was the same for both primiparous and pluriparous cows. The average interval to first heat following abnormal calvings was 36 days.

Clapp (1937) found no effect of age on the interval to first heat, but a significant difference due to season was observed. Cows calving in December, January, and February had the shortest intervals. Morrow et al. (1966) found no significant influence of season and parity on the interval from parturition to first estrus in clinically normal and abnormal cows. Foote et al. (1960c) also found that parity did not influence the interval from parturition to first estrus and ovulation in beef cattle.

Labhsetwar et al. (1963) found 23.7 percent of 3,076 ovulations were not accompanied by estrus. Trimberger (1956) reported 19.6 percent of the cycles longer than 25 days were associated with silent estrus. Morrow et al. (1966) noticed a decrease in the occurrence of ovulation without observed estrus in normal cows with each estrous cycle following parturition. The frequency of silent estrus associated with the first, second and third ovulations was 79.0 percent, 55.0 percent, and 35.0 percent, respectively. The decrease was also highly significant in clinically abnormal cows. The incidence of silent estrus was lower in older cows and higher in cows producing 16,000 pounds of milk per lactation period.

These authors emphasized the importance of diseases of parturition on the occurrence of the first estrus following parturition and the significance of the shorter cycle following the first post-partum ovulation. The mean interval to first silent or standing estrus and ovulation was 15.0 days for normal cows compared to 34.4 days for clinically abnormal cows, indicating a delay in ovarian and estrual activity due to clinical conditions. The second estrus averaged 17.5 days after the first estrus which was significantly different from the interval between the second and third estrus. The authors stated that the shorter cycle following the first post-partum ovulation may have been a result of the failure to maintain the corpus luteum in a normal manner.

Marion and Gier (1968) confirmed these results. They found the average interval to first ovulation was 14.2 days with the second ovulation occurring an average of 15.2 days later which was significantly different from the 21.6 day interval observed between the second and third ovulations after parturition. They also noted that only 4.8 percent of the ovulations occurring before 20 days post-partum were accompanied by estrus. The number of ovulations occurring and the percentage associated with normal estrus increased significantly with each cycle.

Relationship Between Level of Milk Production and Estrus Behavior After Parturition

For many years investigators have postulated that difficulties in breeding after parturition are due in part to high levels of milk production constituting a stress upon the dairy cow. With this in mind Eckles (1929) compiled data including the reproductive performance of cows in the University of Minnesota dairy herd for the years 1900-1929. Although there was a drastic increase in level of production during the 29 years, there was no tendency toward an increase in breeding difficulties as determined by number of services required per conception, rate of abortion, and proportion of nonbreeders.

Gaines (1927), in an analysis of 4,671 records from the Guernsey Herd Registry, found the coefficient of correlation between the first full calendar month milk yield and the service period (calving to conception) to be 0.039. He stated that there was no evidence that a high rate of milk secretion interferes with the recurrence of conception.

In a later study Boyd et al. (1954) found that the average production for the first 120 days after calving for 519 cows was 4,520 pounds on a mature equivalent four percent fat corrected milk basis. No statistical significance was found between level of production and the number of services required for conception.

Clapp (1937) observed a difference in the interval from calving to first estrus in cows milked four times daily, nurse cows, and cows milked two times daily. However, no significant correlation was found between level of production and interval to first estrus in two-year-olds milked four times daily.

Olds and Seath (1953) reported that 32.1 days was the average interval to first estrus for 472 normal parturitions. A significant correlation between milk production for the first 120 days (mature equivalent, four percent fat corrected milk) and number of days from calving to first estrus was found. For each additional 1,000 pounds of four percent fat corrected milk produced in 120 days there was 1.5 more days between calving and first heat.

Carman (1955) considered the total lactation production corrected to a two milkings per day, 305 days, mature equivalent basis and found that the interval to first estrus was correlated with the level of production in the preceding lactation. However, days to first estrus showed little or no relation to production during the same post-partum period.

Herman and Edmondson (1950) also reported that the average daily milk production for the entire lactation did not seem to affect the interval to first estrus. When only the average daily milk production for the period up to the first estrus was considered, there was no effect on the interval to first estrus. Morrow et al. (1966) found a correlation of 0.62 between the production level and the interval to first estrus in clinically abnormal cows, but no significant correlation was found in clinically normal cows.

Cystic Ovarian Disease

Frequent heat periods have been generally recognized as a symptom of cystic ovaries. Garm (1949) classified symptoms into four groups: (1) nymphomania with permanent heat or periods of intense heat at frequent intervals, (2) nymphomania with normal heat at regular intervals, (3) nymphomania with mild symptoms of heat, (4) nymphomania with no heat. In some cases masculinization is a symptom of the condition. Casida et al. (1944) listed masculine behavior, pawing the ground, riding of other cows, relaxation of the pelvic ligaments, raised tailhead, and coarsening of the head and neck as symptoms.

Types of Cysts. There has been an attempt to classify the types of cysts which occur. Hansel (1964) stated that ovulation is generally considered as a prerequisite for cystic corpora lutea, distinguishing them from luteinized follicular cysts. McEntee (1958) considered cystic corpora lutea to be that structure which had a central cavity of greater than 7 mm in diameter and resulted from a follicle which had ovulated. Clinically, he found that follicular cysts had a smooth round surface and were characterized by lack of an ovulation scar which is evident in corpora lutea.

Morrow et al. (1966) found that luteinized follicles were difficult to detect by rectal palpation.

Estrus Behavior. Roberts (1955) reported that of 352 cows with cystic ovaries, 73 percent exhibited symptoms of nymphomania while 26 percent showed no signs of heat. Similar results were obtained by Johnson et al. (1966) who observed 34 of 49 cystic cows showing symptoms of nymphomania with the remaining showing no heat. Other investigators have found a much higher incidence of anestrum associated with cysts. Garm (1949) observed frequent heat in 16 percent of Swedish Red cattle with cysts and 48 percent with no estrous periods. The corresponding data for the Friesian breed were 33 and 32 percent, respectively. Bierschwal (1966) reported that anestrum occurred in 60 percent of Guernsey cows with cysts and 67 percent of cystic Holstein cows. Morrow et al. (1966) found an even greater incidence of anestrum with 81.8 percent of cows with cystic follicles showing no heat. Marion and Gier (1968) detected 4 of 29 cows with follicular cysts in estrus, thus concurring with earlier reports.

Dawson (1959) examined 286 cows clinically for 50 days followed by a post-mortem examination. He found 41 cases of cystic corpora lutea of which 14 were "borderline". Borderline cases were considered to be a normal stage of growth in healthy corpora lutea which have a central cavity in early stages of growth. Maximum tissue volume is usually attained by eight days post ovulation. McEntee (1955) found 69 cases of cystic corpora in 542 cows examined post-mortem. The cystic corpora were not associated with anestrum. Marion and Gier (1968) found that the cycle was not lengthened by the presence of a cystic corpus luteum with the exception of two cases where both a cystic corpus luteum and a follicular cyst were present. A total of 32 luteal cysts in 250 cows (16 percent) was detected. Morrow et al. (1966) detected cystic corpora in 25.2 percent of 357 post-partum cycles, including both normal and clinically abnormal cows. Persistence of corpora lutea was associated with pyometra.

Significance of Cystic Corpora Lutea. McEntee (1958) reported a low incidence of cystic corpora in pregnant cows examined post-mortem. This suggested an inadequate production of progesterone by cystic corpora during early pregnancy which could be an important cause of embryonic mortality. Hansel (1964) determined the progesterone contents and concentrations of 43 cystic and 142 non-cystic corpora lutea removed at 4, 7, 11, and 15 days post estrus. The progesterone concentrations in cystic corpora at day 7 and 11 of the cycle were lower than in normal corpora. Morrow et al. (1966)

reported similar results. The authors questioned the importance of the lowered levels of progesterone since in both studies the level was above the 100-150 mg of luteal progesterone which Hansel (1964) cited as being the amount necessary for normal embryo development.

Relationship Between Level of Milk Production and Incidence of Cysts. Morrow et al. (1966) reported the incidence of follicular cysts was not influenced by the level of milk production. The mean occurrence of follicular cysts was 12.3 percent for the first three post-partum cycles. Clinically abnormal cows had a significantly higher incidence of cystic follicles. The incidence of cysts was highest in the first estrous period and tended to decrease in the second and third cycle.

Casida and Chapman (1951) compared the frequency of cysts in cows not milked, cows milked twice daily, cows milked three or four times daily followed by twice-a-day milking, and cows milked three or four times daily. The frequency of ovarian cysts was 3.4, 6.8, 8.5, and 10.6 percent, respectively.

An increase in milk production associated with cystic ovaries was observed in Sweden by Henricson (1956). A study of 74 cows with follicular cysts by Johnson et al. (1966) also revealed that during their cystic lactation affected cows produced significantly more milk than their herdmates when compared to their production levels during their precystic lactation. The cystic cows averaged 379 kg more milk than their herdmates. Anestrous cystic animals had higher milk production than nymphomaniacs. Marion and Gier (1968) observed significantly longer intervals from parturition to first ovulation and estrus in cows producing over 30 kg per day for the first 120 days post-partum. They noted the frequency of luteinized follicular cysts increased with production which was the most important factor in lengthening the intervals from parturition to first ovulation, estrus, and conception. The authors suggested that the increased incidence of follicular cysts was a result of production stress causing imbalances in relationships between gonadotropic and steroid hormones. This hypothesis is similar to that of Jubb and McEntee (1955) who studied the involvement of the adenohypophysis in the cystic condition. They suggested a defect in adenohypophyseal function causing different amounts of L.H. to be released which results in different degrees of luteinization.

Marion and Gier (1968) found that of 157 cows calving between August and January, 21 had follicular cysts while 8 of 93 cows calving from January to August developed follicular cysts. They suggested the difference may be due to the effect of higher milk production in the fall and winter rather than a seasonal effect. Roberts (1955) and Morrow et al. (1966) both reported a higher incidence of cystic follicles in the winter.

Relationship of Calcium and Phosphorus Nutrition to Reproductive Efficiency

Calcium and Phosphorus Deficiency. The literature pertaining to the relationship of calcium and phosphorus nutrition to reproduction is somewhat limited. Most of the early studies were done with cattle grazing on phosphorus deficient pasture which was prevalent in some areas of this country and abroad. One of these areas was in Minnesota where workers at the University of Minnesota conducted experiments to determine the effect of mineral supplementation on reproductive efficiency.

Eckles et al. (1926) purchased cattle showing signs of phosphorus deficiency such as depraved appetite and gave them mineral supplementation. The experimental cows which did not receive mineral supplementation did not recover and show normal signs of estrus as did the cows which received the supplementation. The delayed estrus periods were presumed to be a result of the phosphorus deficiency, although the factors were not controlled in the experiment. This led Eckles et al. (1935) to design an experiment under properly controlled conditions with phosphorus being the only limiting factor. The inorganic phosphorus of the blood plasma was maintained at 2.5 mg percent by varying phosphorus intake. The phosphorus content of the blood over the chemical analysis of the bones indicated the animals were deficient in phosphorus; however, this deficiency had no effect on the estrous cycle of the cows. The authors stated, "The disturbances in estrous and the low calf crop among cattle in phosphorus deficient areas are probably due to complicated nutritive deficiencies prevalent under such conditions and are not attributed to phosphorus deficiency alone."

Palmer et al. (1941) observed delayed sexual maturity in dairy heifers fed rations deficient in both phosphorus and protein. In addition, after normal cycling began a high incidence of silent heats was observed.

Another area of phosphorus deficiency was in South Africa where Theiler et al. (1928) used bonemeal as a supplement for beef cattle. Of the cows supplemented with bonemeal while on phosphorus deficient pasture, 80 percent calved normally, while only 51 percent of the non-supplemented cows calved normally.

Black et al. (1943) worked with range cattle grazing on phosphorus deficient pasture on the King Ranch in Texas. These workers observed an increase in percentage of calf crop and greater weight gains by the offspring when bone meal, disodium phosphate, and trace minerals were fed to cows and heifers on phosphorus deficient range.

A series of experiments concerning phosphorus supplements for beef cows and heifers was conducted by Wheeler (1945). He pastured four groups of cows in the summer with no supplementation and fed them in the lot during the winter. During the wintering phase Group 1 received a ration with the ratio of calcium to phosphorus of 6.2:1; Group 2, 5.0:1; Group 3, 4.9:1; and Group 4, 4.5:1. A cow was considered to have 100% reproductive efficiency when she had nine months of normal pregnancy during a 12-month period. The reproductive efficiency for lots 1 through 4 was 85.1, 76.9, 81.8, and 76.0, respectively.

In working with beef heifers fed a ration low in phosphorus, Wheeler (1945) observed delayed or irregular estrous cycles. These heifers were also deficient in protein. Another group of heifers fed an intermediate level of phosphorus was similar in its reproductive performance to the low phosphorus group. The heifers fed a high level of phosphorus showed delayed and irregular estrus, but conceived earlier and raised a higher percentage of calves. It was concluded that phosphorus alone was not the limiting factor.

Drake et al. (1964) studied the effects of low to high levels of calcium and phosphorus supplements on heifers grazing bluestem pasture. They found that moderate amounts of dicalcium phosphate seemed to improve reproductive efficiency.

Fitch et al. (1932) reported the breeding efficiency of dairy cows subjected to a ration deficient in calcium was not significantly different from cows on rations with sufficient or excess calcium. Palmer et al. (1941), in an extension of the study, removed the vitamin supplements from the ration and observed no difference in breeding efficiency.

<u>Calcium to Phosphorus Ratio</u>. Webster (1932) reported that insufficient phosphorus or a wide calcium to phosphorus ratio had an unfavorable influence on breeding efficiency. This theory was studied by Hignett (1951) who surveyed 39 herds and made observations on 802 cows and heifers in England. They considered 23 gm for maintenance and 19 gm for each gallon of milk to be the requirement for phosphorus. When the phosphorus maintenance level was 60 gm, the conception rate based on first service was 76 percent, an increase of 26

percent over the conception rate at the 23 gm maintenance level. Conception rate was correlated with the calcium to phosphorus ratio of the ration of different levels of phosphorus intake. In the case of cows receiving less than 20 gm excess phosphorus (above the requirement), conception rate decreased as the ratio widened. Conception rate increased as the ratio narrowed in cows receiving 20 gm or more excess phosphorus.

In a later study Hignett and Hignett (1952) reported lowered fertility and a high incidence of silent heat in heifers with less than 40 gm phosphorus intake per day.

In order to study the relationship of Vitamin D to fertility, Hignett and Hignett (1953) analyzed their data from the original study of 802 cows and heifers. A comparison of month by month conception rates was made starting with October and continuing through March with the assumption that the cattle came under observation with good reserves of Vitamin D and as winter progressed these reserves were depleted. The analysis of data indicated no significant difference in conception rate throughout the winter.

Wilson (1952) found that supplementing rations with phosphorus and trace minerals such as manganese, copper, and potassium improved the conception rate. Even though an improvement in conception rate was observed, the analysis of the feedstuff indicated a wide calcium to phosphorus ratio.

Littlejohn and Lewis (1960) reported a gross imbalance of the Ca:P ratio had no effect on fertility of dairy cattle. Heifers were fed low levels of both calcium and phosphorus, a high level of calcium, a high level of phosphorus, and a high level of both calcium and phosphorus. No significant difference in conception rate was observed between the four groups.

EXPERIMENTAL PROCEDURE

Twenty-four Holstein cows ranging in age from two to five years were selected according to their expected producing ability and stage of gestation and randomly assigned to four treatment groups 45 days prior to expected parturition. The treatments were designated, on the basis of Ca:P ratio of the ration, as narrow (N), narrow with vitamin D (ND), wide (W) and wide with vitamin D (WD). During the first year of the study five of the cows were culled and replaced, with the replacements conditioned on their respective rations for six months prior to parturition. These cows were distributed among the treatments as follows: 7N, 5ND, 6W, 6WD.

The cows were confined in two lots with loose housing type barns and fed alfalfa hay and concentrate rations which were formulated to meet the calcium, phosphorus and protein requirements recommended for dairy cattle (NRC, 1966). The compositions of the concentrate rations are given in Table I.

Table I. Composition of narrow and wide Ca:P ratio concentrate rations.

Narrow Ca:P ratio		Wide Ca:P ratio	
Ingredient	%	Ingredient	%
Sorghum grain	83.3	Sorghum grain	80.7
Soybean oil meal	14.7	Soybean oil meal	14.3
Diammonium phosphate	1.5	Urea	0.7
Trace mineralized salt	0.5	Calcium carbonate	2.8
Vitamin A (4,000 I.U./kg)		Dicalcium phosphate	1.0
		Trace mineralized salt	0.5
		Vitamin A (4,000 I.U./kg)	

Ten months after initiating the experiment, the non-protein nitrogen was removed from the ration to eliminate variation due to nitrogen sources. Soybean oil meal was added to both rations and the phosphorus in diammonium phosphate was replaced by monosodium phosphate. The composition of these rations are presented in Table II.

The average Ca:P ratios, which were based on the average calcium and phosphorus content of the concentrate mixtures and alfalfa hay, were 1.4:1 for the N group and 2.9:1 for the W group during the first lactation of the study and 1.3:1 and 2.3:1 for the second lactation, respectively. The lower ratios during the second lactation were due to the lower calcium content of the hay.

Table II. Composition of narrow and wide Ca:P ratio concentrate rations.

Narrow Ca:P ratio Ingredient	%	Wide Ca:P ratio Ingredient	%
Sorghum grain	78.7	Sorghum grain	76.6
Soybean oil meal	19.4	Soybean oil meal	18.9
Monosodium phosphate	1.4	Calcium carbonate	3.1
Trace mineralized salt	0.5	Dicalcium phosphate	0.9
Vitamin A (4,000 I.U./kg)		Trace mineralized salt	0.5
		Vitamin A (4,000 I.U./kg)	

Cows in the ND and WD groups designated for vitamin D treatment were given 300,000 units of vitamin D_3 once each week by capsule. Alfalfa hay was limited to 6.8 kg/cow daily to insure a high level of concentrate consumption which averaged 15 to 16 kg/cow daily.

Rectal palpations of the uterus were performed by Dr. G. B. Marion of the KSU research staff beginning 5 to 10 days after calving and continued at weekly intervals until the cow was bred. The uterus was considered completely regressed when it had returned to the normal nongravid position and size. The first of three consecutive palpations during which no uterine changes were found was considered the end of the regression interval.

The size and position of ovarian structures were determined and recorded at each palpation. In cows showing heat the time of ovulation was recorded as the day after estrus. In anestrum cows the day of ovulation was determined by the size of a new corpus luteum that had not been present in the ovary at the previous weekly palpation. The size, location, and duration of cystic structures were determined.

The cows were observed for estrus twice daily. A cow was considered to be in heat if she (a) stood to be mounted by other cows, (b) exhibited other external signs of estrus such as nervousness, swelling of the vulva, or presence of mucus, and (c) exhibited external signs in a lesser degree in combination with a regressing corpus luteum and a graffian follicle as determined by rectal palpation. Cows were artificially inseminated at the first estrus which occurred 40 days after parturition by the author using semen from a bull of known fertility. All semen used was from a single collection and frozen at Kansas Artificial Breeding Service Unit.

Ovaries were palpated at 12-18 days and 25-30 days post breeding to confirm the presence of the pregnancy corpus luteum. The horns of the uterus were palpated at 40-50 days post breeding to confirm the pregnancy.

The intervals from parturition to first, second, and third estrus; first, second and third ovulation; conception; and complete uterine involution were determined for all groups and analyzed for sources of variation among these groups. In addition a two-way analysis of variance was used to determine the effect of year, treatment, and interaction of these factors on the intervals.

Milk production for the first 120 days of each lactation was recorded and corrected to a four percent fat corrected milk basis to determine the effect of level of milk production on reproductive performance.

RESULTS AND DISCUSSION

Interval from Parturition to Uterine Involution

Buch et al. (1955) and Marion et al. (1968) both reported the interval from parturition to complete uterine regression was longer in the winter. Buch et al. (1955), Morrow et al. (1966) and Marion et al. (1968) also found the regression interval was longer in pluriparous cows. Since season and parity affect rate of uterine involution, these data were corrected to a pluriparous and winter basis using the correction factors shown in Table III as developed by Marion et al. (1968).

Table III. Parity and seasonal correction factors for converting uterine regression intervals to winter (pluriparous basis) in dairy cows.

Intervals	Additive correction factor (days)
Primiparous to pluriparous	6.83
Spring to winter	4.37
Summer to winter	4.57
Fall to winter	2.33

Average interval to complete uterine involution was 44 days in all cows which is longer than the unadjusted 25 day average interval reported by Morrow et al. (1966), but shorter than the 47 day average observed by Buch et al. (1955). The involution rate was slower in the narrow ratio (NR) group than those in the wide ratio (WR) group. Analysis of variance indicated a significant difference between treatment groups in the second year (P> .20) and when the two years were averaged (P> .05). The average intervals for the ND, N, WD, and W groups were 49, 42, 39, and 46 days, respectively. These data are presented in Table IV.

Intervals from Parturition to Ovulations

In the first lactation all cows ovulated within 20 days after parturition with a 13 day average interval which was statistically different (P> .01) from the 19 day average

Table IV. Average days to complete uterine involution for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.
	ND	N	WD	W	NR	WR	+D	-D	
Year I	46	41	40	46	44	43	43	44	43
Year II[1]	52^{a}	43^{bc}	39^{c}	47^{ab}	47	43	44	45	45
Ave.[2]	49^{a}	42^{ab}	39^{b}	46^{ab}	45	43	44	44	44

1 Treatments in this row having a common superscript are not statistically different ($P > .20$).

2 Treatments in this row having a common superscript are not statistically different ($P > .10$).

observed in the second year of the study. The longer intervals in the second year were found primarily in the NR group which averaged 10 days longer (P> .025) from parturition to first ovulation than the WR group. The averages for the NR and WR groups were 24 and 14 days, respectively. Significant differences are indicated in Table V.

Marion et al. (1968) and Sauiduddin et al. (1967) both reported a higher incidence of ovulations occurring from the ovary opposite the previously gravid horn during the first 20 days after parturition. Marion et al. (1968) suggested that the endometrium of the previously gravid horn had not returned to normal. It may be that the endometrial metabolism was below normal in the NR cows resulting in a slower rate of uterine regression and thereby an adverse effect on first ovulation after parturition. The average interval to first ovulation for the ND, N, WD, and W groups was 21, 17, 13, and 14 days, respectively. The two-way analysis of variance indicated a significant interaction between years and treatment groups (P>.005). Datá for days to first ovulation are presented in Appendix Table II.

The second ovulation occurred an average of 35 days after parturition (Appendix Table III) or an average of 19 days after the first ovulation. This interval is slightly

Table V. Average days to first ovulation for cows in all treatment groups.

	Treatment groups								
	Treatments				Ratio		Vitamin D		
	ND	N	WD	W	NR	WR	+D	-D	Ave.[3]
Year I	15	12	11	14	14	13	13	13	13^a
Year II[1]	28^a	20^{ab}	14^b	15^b	[2] 24^c	14^d	21	18	19^b
Ave.[4]	21^a	17^{ab}	13^b	14^b	19	14	17	16	16

[1] Treatments in this row having a common superscript are not statistically different ($P > .10$).

[2] Ratios in this row having a common superscript are not statistically different ($P > .025$).

[3] Values in this column having a common superscript are not statistically different ($P > .005$).

[4] Treatments in this row having a common superscript are not statistically different ($P > .01$).

longer than the 17.5 day interval between first and second ovulation reported by Morrow et al. (1966) and the 15.2 day interval observed by Marion et al. (1968). However, the intervals observed in the first lactation of this study are comparable to those reported by these workers. The average interval between first and second ovulation in the first year was 16 days which was statistically different ($P > .10$) from the 21 day average interval in the second year. The longer intervals in the second year were again found in the NR group which ovulated an average of 8 days later than the WR group.

Significant differences were also observed in the first lactation between treatment groups. These differences are indicated in Tables VI and VII.

Average intervals from parturition to third ovulation for all groups are presented in Table VIII. The average interval in the second year was 65 days as compared to the 57 day interval observed in the first year. This again reflects the slower cycling of the cows in the second year.

Intervals from Parturition to Estrus Periods

Marion and Gier (1968) reported the percentage of cows exhibiting normal estrus increased significantly with each

Table VI. Average days to second ovulation for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.[1]
	ND	N	WD	W	NR	WR	+D	-D	
Year I[2]	32[a]	27[b]	27[b]	33[a]	29	30	30	30	30[a]
Year II	47	42	32	40	[3] 44[a]	36[b]	39	41	40[b]
Ave.	39	33	29	36	38	33	34	36	35

1 Values in this column having a common superscript are not statistically different ($P > .01$).

2 Treatments in this row having a common superscript are not statistically different ($P > .10$).

3 Ratios in this row having a common superscript are not statistically different ($P > .25$).

Table VII. Average days between first and second ovulation for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.[1]
	ND	N	WD	W	NR	WR	+D	-D	
Year I[2]	17^a	14^b	15^b	19^a	15	17	16	16	16^a
Year II	19	21	17	26	20	21	18	23	21^b
Ave.	18	18	16	22	18	19	17	20	19

1 Values in this column having a common superscript are not statistically different ($P > .10$).

2 Treatments in this row having a common superscript are not statistically different ($P > .25$).

Table VIII. Average days to third ovulation for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.
	ND	N	WD	W	NR	WR	+D	-D	
Year I	49	54	52	76	51	64	150[a]	65[b]	57
Year II	79	61	61	63	63	62	69	62	65
Ave.	63	57	56	70	57	63	59	63	61

1 Treatments in this row having a common superscript are not statistically different ($P > .20$).

Table IX. Average days between second and third ovulation for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.
	ND	N	WD	W	NR	WR	+D	-D	
Year I	17	27	25	30	21	27	[1]21[a]	28[b]	25
Year II	32	29	29	23	30	26	30	26	28
Ave.	24	28	27	26	26	27	25	27	26

[1] Treatments in this row having a common superscript are not statistically different ($P > .20$).

succeeding cycle after parturition. Morrow et al. (1966) found the frequency of silent estrus during the first, second, and third estrus cycles was 79.0 percent, 55 percent and 35 percent, respectively. In our study an increase in the percentage of cows exhibiting estrus at each cycle was also observed. The percentage of cows exhibiting estrus preceding the first, second, and third ovulations was 25 percent, 60 percent, and 68 percent (Appendix Tables XI, XII, and XIII). During the second year when longer intervals from parturition to first, second, and third ovulations were observed, the percentage of cows exhibiting estrus was more, possibly a result of the later estrous cycles during the second year.

Herman and Edmondson (1950) found the average interval from parturition to first estrus to be 57 days, while Buch et al. (1955) observed an average of 33 days. In this study the average interval to first estrus was 41 days for all cows in both years as shown in Table X. A slight but consistent difference was found between vitamin D groups in the second year during which the cows receiving vitamin D supplement were in estrus an average of 11 days before cows without supplement. A higher incidence of anestrum was observed in the -D group.

The +D group in the second year also had slightly shorter intervals from parturition to second estrus ($P > .25$). The -D

Table X. Average days to first estrus for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.
	ND	N	WD	W	NR	WR	+D	-D	
Year I	46	52	31	54	49	43	39	53	46
Year II	33	39	26	42	37	34	[1] 30[a]	41[b]	35
Ave.	40	45	29	48	43	38	34	46	41

[1] Vitamin D treatments in this row having a common superscript are not statistically different ($P > .20$).

Table XI. Average days to second estrus for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.
	ND	N	WD	W	NR	WR	+D	-D	
Year I	72	47	60	80	60	69	66	63	65
Year II	58	70	58	101	65	80	[1]58[a]	84[b]	72
Ave.	65	60	59	91	63	74	62	75	68

[1] Vitamin D treatments in this row having a common superscript are not statistically different ($P > .25$).

group was in estrus an average of 26 days later than the +D group. Two cases of follicular cysts which resulted in anestrum and lengthened the intervals contributed to the longer average in the -D group.

When the intervals from parturition to third estrus were analyzed a difference was found among treatments ($P > .005$), between ratio groups ($P > .10$), and between vitamin D groups in the first lactation ($P > .25$). The 211 day average interval to third estrus observed in the W group was due primarily to four of the six cows conceiving on the second estrus while the other two were anestrus after their second cycle. These averages are presented in Table XII.

Interval from Parturition to Conception

The average days to conception for the 48 cows was 125 days. The only significant differences were in the first lactation where cows receiving additional vitamin D conceived 53 days sooner than -D cows ($P > .05$). This difference was also indicated in the analysis among all groups within the first year ($P > .25$). A significant interaction was found between years and treatments ($P > .10$). These differences are indicated in Table XIII.

Table XII. Average days to third estrus for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.
	ND	N	WD	W	NR	WR	+D	-D	
Year I[1]	75[a]	69[a]	76[a]	211[b]	[2] 72[a]	121[b]	[3] 76[a]	110[b]	91
Year II	99	104	92	141	102	95	95	117	106
Ave.[4]	88[a]	89[a]	85[a]	164[b]	114	87	87	114	100

[1] Treatments in this row having the same superscript are not statistically different ($P > .005$).

[2] Ratios in this row having a common superscript are not statistically different ($P > .10$).

[3] Vitamin D treatments in this row having a common superscript are not statistically different ($P > .25$).

[4] Treatments in this row having a common superscript are not statistically different ($P > .005$).

Table XIII. Average days to conception for cows in all treatment groups.

	Treatments				Ratio		Vitamin D		Ave.
	ND	N	WD	W	NR	WR	+D	-D	
Year I[2]	90^{c}	134^{ab}	89^{bc}	152^{a}	114	120	[1]90^{a}	143^{b}	117
Year II	152	133	131	111	142	124	140	126	134
Ave.	121	133	110	138	128	122	115	136	125

1 Vitamin D treatments in this row having a common superscript are not statistically different ($P > .05$).

2 Treatments in this row having a common superscript are not statistically different ($P > .25$).

Incidence of Ovarian Cysts

Ten cases of follicular cysts were detected in the 48 post-partum periods. A lengthening of the cycle or anestrum was observed in nine of the cases while only one cow exhibited characteristic nymphomania symptoms. This high incidence of anestrum associated with follicular cysts is in agreement with Bierschwal (1966), Morrow et al. (1966), and Marion and Gier (1968).

Incidence of follicular cysts did not appear to be influenced by treatment; however, seven of the ten cysts were detected in the second year as presented in Table XIV. The incidence of cysts detected in the second year is considerably more than found by Marion and Gier (1968), Morrow et al. (1966), and Casida and Chapman (1951). The percentage of cows that formed follicular cysts in the first year was 12 percent which is similar to the incidence reported by these workers.

The frequency of luteal cysts was 17 percent or a total of eight detected in the 48 post-partum periods. These data are in agreement with Marion and Gier (1968) who detected luteal cysts in 16 percent of 250 post-partum cows.

The estrous cycle was not lengthened by the presence of cystic corpus luteum. McEntee (1955) reported cystic corpora

Table XIV. Incidence of follicular cysts in all treatment groups.

	Year I				Year II				
Group	No. cystic	No. lengthened cycle	No. shortened cycle	No. recovered	No. cystic	No. lengthened cycle	No. shortened cycle	No. recovered	Total cystic both years
ND	2	2	-	1	1	1	-	1	3
N	-	-	-	-	2	2	-	2	2
WD	-	-	-	-	2	1	1	2	2
W	1	1	-	1	2	2	-	-	3
Total for two years	3	3	-	2	7	6	1	5	10

were not associated with anestrum. Marion and Gier (1968) found that the cycle was not lengthened by the presence of a luteal cyst except when both a cystic corpus luteum and a follicular cyst were present.

Influence of Level of Milk Production on Reproductive Performance

Morrow et al. (1966) reported the incidence of follicular cysts was not influenced by the level of milk production. Henricson (1951), Johnson et al. (1966), and Marion and Gier (1968) found an association between level of milk production and incidence of cysts. Marion and Gier (1968) reported the frequency of cysts increased with level of production.

When the cows were divided into two production groups, under 22 kg per day and 22 kg and over per day, the mean frequency of cysts was 26 percent and 27 percent, respectively. The cystic cows averaged 23 kg of milk per day during the first 120 days of lactation as compared to the 22 kg per day average of the noncystic cows. These results which are presented in Table XV would indicate the frequency of cysts was not influenced by level of milk production; however, this study did not include cows with extremely high levels of production. Of the 48 cows only two exceeded 30 kg per day for the first 120 days of

Table XV. Relationship between incidence of follicular cysts and average daily production of 4% fat corrected milk during first 120 days after parturition.

	Under 22 kg/day		22 kg and over/day	
	No. cows	Daily production	No. cows	Daily production
Cystic	4	19.5	6	25.1
Noncystic	15	16.6	23	25.7
Frequency	26%		26%	

lactation. Marion and Gier (1968) found the incidence of cysts highest in cows producing over 30 kg per day. Average milk produced per day for all cows in both years is presented in Appendix Table XIV.

Olds and Seath (1953) found a significant correlation between milk production for the first 120 days of lactation and number of days from calving to first estrus. Marion and Gier (1968) reported significantly longer intervals to first ovulation and estrus in cows producing over 30 kg per day. In our study cows producing less than 22 kg per day were in estrus an average of 10 days before cows producing over 22 kg per day ($P > .25$). No difference was observed in days from parturition to first ovulation.

Morrow et al. (1966) reported a correlation of 0.25 between level of production and interval from parturition to conception. Marion and Gier (1968) observed a lengthening of the interval to conception in cows producing over 30 kg per day. A longer average interval to conception was also observed in this study, but the difference was not significant. It should be noted again that this study did not include cows producing above 30 kg per day; therefore, the extreme stress associated with high levels of milk production was not present. The effect of the level of milk production on the intervals to first estrus, first ovulation, and conception is shown in Table XVI.

Table XVI. Relationship between level of production and average days from parturition to first estrus, ovulation, and conception.

	Average level of production	
	Under 22 kg/day	22 kg/day and over
No. of cows	29	19
Av. days to first ovulation	16.2	16.1
Av. days to first estrus[1]	34.0[a]	44.7[b]
Av. days to conception	114.8	129.6

[1] Averages in the same row having a common superscript are not statistically different (P>.25).

SUMMARY AND CONCLUSIONS

Data were obtained from 48 post-partum dairy cows assigned among narrow (N), narrow with vitamin D (ND), wide (W), and wide with vitamin D (WD) Ca:P ratio rations. The average Ca:P ratio of the N and W rations were 1.4:1 and 2.9:1 during the first lactation, and 1.3:1 and 2.3:1 for the second lactation, respectively. The ND and WD groups were given 300,000 units of vitamin D once each week by capsule.

Average interval from parturition to complete involution was 44 days in all cows. The average intervals for the ND, N, WD, and W groups were 49, 42, 39, and 46 days, respectively.

Longer intervals to first, second and third ovulation were observed in the second year of the study. Average interval from parturition to first ovulation during the first year was 13 days which was statistically different from the 19 day average observed in the second year. The longer intervals in the second year were found primarily in the NR group which had an average interval of 24 days whereas the WR group averaged 14 days from parturition to first ovulation.

The second ovulation occurred an average of 19 days after the first ovulation. The average interval between first and second ovulation in the first year was 16 days which was statistically different from the 21 day average observed in the second year. Ovulations were detected in the NR group an average of 8 days later than the WR group.

The longer interval between estrous cycles in the NR group was not as evident when intervals from parturition to third ovulation were compared; however, the intervals in the second year were again longer than in the first year.

A decrease in the frequency of silent estrus of each ovulation following parturition was observed. The percentage of cows exhibiting estrus following the first, second, and third ovulations was 25, 60, and 68 percent. The frequency of silent estrus in the first year was higher, possibly a result of the earlier ovulations observed during the first year.

A slight but consistent difference was found between vitamin D groups in the second year. Cows receiving the additional vitamin D supplement tended to be in estrus earlier following parturition than the cows without the vitamin supplement. The average interval to first estrus was 30 days in the +D group whereas the -D group was in estrus 11 days later.

This difference between vitamin D groups was also indicated by the average intervals to second and third estrus. Average interval from parturition to first estrus in all cows in both years was 41 days. Vitamin D treatment also seemed to affect the interval from parturition to conception during the first year since the +D cows conceived 53 days sooner than the -D cows.

During the first year of the study, cows were assigned to the four treatment groups 30 days pre-partum. This period of subjection to treatment prior to collection of data was most probably insufficient time to allow the treatments to become effective. Any effect of treatment was expected in the second year which is consistent with these results.

Ten cases of follicular cysts (21%) were detected in this study. Anestrum was observed in 9 of these cases. A higher incidence of follicular cysts was observed in the second year. There were 8 cases of cystic corpora lutea (17 percent) none of which lengthened the estrous cycle.

The frequency of follicular cysts did not seem to be influenced by level of milk production. Slightly longer intervals to first estrus were observed in cows producing over 22 kg per day. The influence of high levels of milk production was not seen possibly because this study did not include cows producing above 30 kg per day.

ACKNOWLEDGMENTS

The author wishes to extend his sincere appreciation to Dr. G. B. Marion for the assistance given in planning and criticizing this research and thesis. Appreciation is also extended to Drs. G. M. Ward and C. L. Norton for their encouragement, assistance, and constructive criticism.

The author is indebted to Dr. Keith Huston and Lee Majeskie for their advice concerning statistical analysis. Appreciation is also extended to Miss Jeanie Kirk for her assistance in preparing the final copy of this thesis.

The author is particularly grateful to his parents, to whom this thesis is dedicated, for their inspiration, encouragement, and patience.

LITERATURE CITED

Bierschwal, C. J. 1966. A clinical study of cystic conditions of the bovine ovary. J. Am. Vet. Med. Assn. 149:1591.

Black, W. H., T. H. Lash, J. M. Jones and R. J. Kleburg, Jr. 1943. Effects of phosphorus supplements on cattle grazing on range deficient in the mineral. U. S. D. A. Tech. Bul. 856.

Boyd, L. J., D. M. Seath and D. Olds. 1954. Relationship between level of milk production and breeding efficiency in dairy cattle. J. Animal Sci. 13:89.

Buch, N. C., W. J. Tyler and L. E. Casida. 1955. Postpartum estrus and involution of the uterus in an experimental herd of Holstein Friesian cows. J. Dairy Sci. 38:73.

Carman, G. M. 1955. Interrelationships of milk production and breeding efficiency in dairy cows. J. Animal Sci. 14:753.

Casida, L. E. and A. B. Chapman. 1951. Factors affecting the incidence of cystic ovaries in a herd of Holstein cows. J. Dairy Sci. 34:1200.

Casida, L. E., W. H. McShan and R. K. Meyer. 1944. Effects of an unfractionated pituitary extract upon cystic ovaries and nymphomania in cows. J. Animal Sci. 3:273.

Casida, L. E. and W. G. Venzke. 1936. Observations on reproductive processes in dairy cattle and their relation to breeding efficiency. Proc. Am. Soc. An. Prod. p. 221.

Casida, L. E. and W. Wisnicky. 1950. Effects of diethylstilbestrol upon postpartum changes in the cow. J. Animal Sci. 9:238.

Chapman, A. B. and L. E. Casida. 1934. Factors associated with breeding efficiency in dairy cattle. Proc. Am. Soc. An. Prod. p. 57.

Clapp, H. 1937. A factor in breeding efficiency of dairy cattle. Proc. Am. Soc. An. Prod. 30:259.

Dawson, F. L. M. The significance of cystic enlargement in the bovine corpus luteum. British Vet. J. 115:46.

Drake, C. L., E. F. Smith, H. G. Spies, D. Richardson and D. L. Good. 1964. The effects of feeding different levels of dicalcium phosphate to heifers on bluestem pasture. Kan. Agr. Exp. Sta. Bul. 473.

Eckles, C. H. 1929. A study of breeding records of dairy herds. Minn. Agr. Exp. Sta. Bul. 258.

Eckles, C. H., R. B. Becker and L. S. Palmer. 1926. A mineral deficiency in the rations of cattle. Minn. Agr. Exp. Sta. Bul. 229.

Eckles, C. H., L. S. Palmer, T. W. Gullickson, C. P. Fitch, W. L. Boyd, L. Bishop and J. W. Nelson. 1935. Effects of uncomplicated phosphorus deficiency on estrous cycle, reproduction, and composition of mature dairy cows. Cornell Vet. 25:21.

Fitch, C. P., W. L. Boyd, C. H. Eckles, T. W. Gullickson, L. S. Palmer and C. Kennedy. 1932. Report on an experiment to determine the effect of a low calcium ration on reproduction in cattle. Cornell Vet. 22:196.

Foote, W. D., E. R. Hauser and L. E. Casida. 1960a. Some causes of variation in postpartum reproductive activity in Hereford cows. J. Animal Sci. 19:238.

Foote, W. D., E. R. Hauser and L. E. Casida. 1960b. Influence of progesterone treatment on postpartum reproductive activity in beef cattle. J. Animal Sci. 19:674.

Foote, W. D., H. J. Weeth and J. E. Hunter. 1960c. Effects of ovarian hormones on postpartum reproductive activity in beef cows. J. Animal Sci. 19:1321. (Abstr.).

Foote, W. D. and J. E. Hunter. 1964. Postpartum intervals of beef cows treated with progesterone and estrogen. J. Animal Sci. 23:517.

Fosgate, O. T., N. W. Cameron and R. J. McLeod. 1962. Influence of 17-alpha-hydroxyprogesterone-N-coproate upon postpartum reproductive activity in the bovine. J. Animal Sci. 21:791.

Gaines, W. L. 1927. Milk yield in relation to recurrence of conception. J. Dairy Sci. 10:117.

Garm, O. 1949. A study of bovine nymphomania. Acta Endo. Suppl. 3. p. 144.

Gier, H. T. and G. B. Marion. 1968. Uterus of the cow after parturition:involutional changes. Am. J. Vet. Res. 29:83.

Hansel, W. 1964. Some observations on bovine cystic corpora lutea. Proc. Fifth Internat. Cong. on Animal Reprod. and Art. Insem. Trento.

Henricson, B. 1956. Genetical and statistical investigations into so-called cystic ovaries in cattle. Acta Agr. Scand. 7:1.

Herman, H. A. and J. H. Edmondson. 1950. Factors affecting the interval between parturition and first estrus in dairy cattle. Mo. Agr. Exp. Sta. Res. Bul. 462.

Hignett, S. L. and P. G. Hignett. 1951. The influence of nutrition on reproductive efficiency in cattle. I. The effect of calcium and phosphorus on the fertility of cows and heifers. Vet. Rec. 63:603.

Hignett, S. L. and P. G. Hignett. 1952. The influence of nutrition on reproductive efficiency in cattle. II. The effect of phosphorus intake on ovarian activity and fertility in heifers. Vet. Rec. 64:203.

Hignett, S. L. and P. G. Hignett. 1953. The influence of nutrition on reproductive efficiency in cattle. III. The influence of vitamin D status on the effect of calcium and phosphorus intake on the fertility of cows and heifers. Vet. Rec. 65:21.

Johnson, A. D., J. E. Legates and L. C. Ulberg. 1966. Relationship between follicular cysts and milk production in dairy cattle. J. Dairy Sci. 49:865.

Jubb, K. V. and K. McEntee. 1955. Observations on the bovine pituitary gland. II. Architecture and cytology with special reference to basophil cell function. Cornell Vet. 45:593.

Labhsetwar, A. P., W. J. Tyler and L. E. Casida. 1963. Genetic and environmental factors affecting quiet ovulations in Holstein cattle. J. Dairy Sci. 46:843.

Littlejohn, A. I. and G. Lewis. 1960. Experimental studies of the relationship between the calcium-phosphorus ratio of the diet and fertility of heifers. Vet. Rec. 72:1137.

McEntee, L. 1958. Cystic corpora lutea in cattle. Internat. J. Fertil. 3:120.

Marion, G. B. and H. T. Gier. 1968. Bovine ovarian activity after parturition. J. Animal Sci. 27 (Nov. In Press).

Marion, G. B., J. S. Norwood and H. T. Gier. 1968. Uterus of the cow after parturition; factors affecting regression. Am. J. Vet. Res. 29:71.

Morrow, D. A., S. J. Roberts, K. McEntee and H. G. Gray. 1966. Postpartum ovarian activity and uterine involution in dairy cattle. J. Am. Vet. Med. Assn. 149:1596.

N. R. C. 1966. Nutrient Requirements of Farm Animals, No. 3. Nutrient Requirements of Dairy Cattle. National Research Council, Washington, D. C.

Olds, D. and D. M. Seath. 1953. Repeatability, heritability, and the effect of level of milk production on the occurrence of first estrus after calving in dairy cattle. J. Animal Sci. 12:10.

Palmer, L. S., T. W. Gullickson, W. L. Boyd, C. P. Fitch and J. W. Nelson. 1941. The effect of rations deficient in phosphorus and protein on ovulation, estrus, and reproduction of dairy heifers. J. Dairy Sci. 24:199.

Roberts, S. J. 1955. Clinical observations on cystic ovaries in dairy cattle. Cornell Vet. 45:497.

Saiduddin, S., J. W. Riesen, W. J. Tyler and L. E. Casida. 1967. Some carry-over effects of pregnancy on post-partum ovarian function in the cow. J. Dairy Sci. 50:1846.

Theiler, H., H. H. Green and P. J. Dutoit. 1928. Studies in mineral metabolism III. Breeding of cattle on phosphorus deficient pasture. J. Agr. Sci. 18:369.

Trimberger, G. W. 1956. Ovarian functions, intervals between estrus and conception rates in dairy cattle. J. Dairy Sci. 39:448.

Webster, B. M. 1932. Bovine sterility in New Zealand. Aust. Vet. J. 8:199.

Wheeler, S. S. 1945. Phosphorus supplements for beef cows and heifers. Wy. Agr. Exp. Sta. Bul. 269.

Wilson, J. G. 1952. Herd functional infertility with reference to nutrition and mineral intake. Vet. Rec. 64:621.

APPENDIX

APPENDIX TABLE I. Days to complete uterine involution for all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	48	A191	1	WD	31
A153	2	ND	61	A191	2	WD	48
157D	1	ND	53	143D	1	WD	47
A178	1	ND	39	143D	2	WD	50
A178	2	ND	44	166D	1	WD	32
B100	1	ND	49	180D	1	WD	35
B100	2	ND	60	180D	2	WD	33
155D	1	ND	37	A133	1	WD	44
155D	2	ND	39	A133	2	WD	35
A145	1	ND	36	139D	1	WD	33
A177	2	ND	42	139D	2	WD	31
33D	2	N	28	193D	2	WD	27
176D	2	N	38	159D	1	W	55
A167	1	N	48	159D	2	W	33
A167	2	N	40	A199	1	W	44
A190	1	N	40	A199	2	W	49
A190	2	N	44	165D	1	W	43
149D	1	N	30	165D	2	W	42
149D	2	N	47	A179	1	W	40
A126	1	N	46	A179	2	W	43
B103	1	N	36	A158	1	W	34
B103	2	N	41	A158	2	W	49
187D	1	N	30	177D	1	W	44
187D	2	N	56	144D	2	W	48

APPENDIX TABLE II. Days to first ovulation in all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	17	A191	1	WD	11
A153	2	ND	28	A191	2	WD	14
157D	1	ND	15	143D	1	WD	20
A178	1	ND	14	143D	2	WD	13
A178	2	ND	45	166D	1	WD	10
B100	1	ND	17	180D	1	WD	10
B100	2	ND	21	180D	2	WD	16
155D	1	ND	15	A133	1	WD	7
155D	2	ND	26	A133	2	WD	17
A145	1	ND	14	139D	1	WD	9
A177	2	ND	22	139D	2	WD	8
33D	2	N	14	193D	2	WD	17
176D	2	N	19	159D	1	W	18
A167	1	N	12	159D	2	W	14
A167	2	N	21	A199	1	W	13
A190	1	N	14	A199	2	W	14
A190	2	N	45	165D	1	W	20
149D	1	N	15	165D	2	W	12
149D	2	N	10	A179	1	W	12
B103	1	N	11	A179	2	W	17
B103	2	N	7	A158	1	W	11
187D	1	N	12	A158	2	W	11
187D	2	N	27	177D	1	W	11
A126	1	N	10	144D	2	W	20

APPENDIX TABLE III. Days to second ovulation in all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	33	A191	1	WD	23
A153	2	ND	53	A191	2	WD	45
157D	1	ND	29	143D	1	WD	26
A178	1	ND	36	143D	2	WD	24
A178	2	ND	58	166D	1	WD	34
B100	1	ND	35	180D	1	WD	32
B100	2	ND	44	180D	2	WD	32
155D	1	ND	29	A133	1	WD	23
155D	2	ND	48	A133	2	WD	29
A145	1	ND	32	139D	1	WD	21
A177	2	ND	34	139D	2	WD	22
33D	2	N	35	193D	2	WD	37
176D	2	N	31	159D	1	W	41
A167	1	N	32	159D	2	W	30
A167	2	N	42	A199	1	W	34
A190	1	N	23	A199	2	W	62
A190	2	N	100	165D	1	W	34
149D	1	N	20	165D	2	W	31
149D	2	N	22	A179	1	W	25
A126	1	N	20	A179	2	W	41
B103	1	N	29	A158	1	W	26
B103	2	N	17	A158	2	W	37
187D	1	N	35	177D	1	W	33
187D	2	N	46	144D	2	W	40

APPENDIX TABLE IV. Days between first and second ovulation for cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	16	A191	1	WD	12
A153	2	ND	25	A191	2	WD	31
157D	1	ND	14	143D	1	WD	6
A178	1	ND	22	143D	2	WD	11
A178	2	ND	13	166D	1	WD	24
B100	1	ND	18	180D	1	WD	22
B100	2	ND	23	180D	2	WD	16
155D	1	ND	14	A133	1	WD	16
155D	2	ND	22	A133	2	WD	12
A145	1	ND	18	139D	1	WD	12
A177	2	ND	12	139D	2	WD	14
33D	2	N	20	193D	2	WD	20
176D	2	N	12	159D	1	W	23
A167	1	N	20	159D	2	W	16
A167	2	N	21	A199	1	W	21
A190	1	N	9	A199	2	W	48
A190	2	N	55	165D	1	W	14
149D	1	N	5	165D	2	W	19
149D	2	N	12	A179	1	W	13
A126	1	N	10	A179	2	W	24
B103	1	N	18	A158	1	W	18
B103	2	N	10	A158	2	W	26
187D	1	N	21	177D	1	W	22
187D	2	N	19	144D	2	W	20

APPENDIX TABLE V. Days to third ovulation for all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	44	A191	1	WD	43
A153	2	ND	88	A191	2	WD	71
157D	1	ND	49	143D	1	WD	43
A178	1	ND	46	143D	2	WD	47
A178	2	ND	86	166D	1	WD	53
B100	1	ND	55	180D	1	WD	75
B100	2	ND	97	180D	2	WD	60
155D	1	ND	40	A133	1	WD	47
155D	2	ND	66	A133	2	WD	41
A145	1	ND	61	139D	1	WD	48
A177	2	ND	58	139D	2	WD	48
33D	2	N	51	193D	2	WD	97
176D	2	N	82	159D	1	W	71
A167	1	N	66	159D	2	W	61
A167	2	N	64	A199	1	W	47
A190	1	N	33	A199	2	W	89
A190	2	N		165D	1	W	60
149D	1	N	49	165D	2	W	46
149D	2	N	41	A179	1	W	41
A126	1	N	76	A179	2	W	61
B103	1	N	46	A158	1	W	48
B103	2	N	35	A158	2	W	57
187D	1	N	51	177D	1	W	97
187D	2	N	93	144D	2	W	66

APPENDIX TABLE VI. Days between second and third ovulation for all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	11	A191	1	WD	20
A153	2	ND	35	A191	2	WD	26
157D	1	ND	20	143D	1	WD	17
A178	1	ND	10	143D	2	WD	23
A178	2	ND	28	166D	1	WD	19
B100	1	ND	20	180D	1	WD	43
B100	2	ND	53	180D	2	WD	28
155D	1	ND	11	A133	1	WD	24
155D	2	ND	18	A133	2	WD	13
A145	1	ND	29	139D	1	WD	27
A177	2	ND	24	139D	2	WD	26
33D	2	N	17	193D	2	WD	60
176D	2	N	51	159D	1	W	47
A167	1	N	34	159D	2	W	28
A167	2	N	22	A199	1	W	11
A190	1	N	10	A199	2	W	27
A190	2	N		165D	1	W	43
149D	1	N	29	165D	2	W	15
149D	2	N	19	A179	1	W	18
A126	1	N	56	A179	2	W	20
B103	1	N	18	A158	1	W	37
B103	2	N	18	A158	2	W	20
187D	1	N	16	177D	1	W	22
187D	2	N	47	144D	2	W	26

APPENDIX VII. Days to first estrus in all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	44	A191	1	WD	23
A153	2	ND	28	A191	2	WD	45
157D	1	ND	53	143D	1	WD	36
A178	1	ND	43	143D	2	WD	13
A178	2	ND	58	166D	1	WD	53
B100	1	ND	14	180D	1	WD	32
B100	2	ND	21	180D	2	WD	32
155D	1	ND	13	A133	1	WD	23
155D	2	ND	26	A133	2	WD	29
A145	1	ND	107	139D	1	WD	21
A177	2	ND	34	139D	2	WD	22
A167	1	N	32	193D	2	WD	17
A167	2	N	21	159D	1	W	40
33D	2	N	14	159D	2	W	65
176D	2	N	19	A199	1	W	44
A190	1	N	22	A199	2	W	62
A190	2	N	16	165D	1	W	20
149D	1	N	20	165D	2	W	12
149D	2	N	74	A179	1	W	25
A126	1	N	190	A179	2	W	41
B103	1	N	11	A158	1	W	113
B103	2	N	35	A158	2	W	11
187D	1	N	35	177D	1	W	81
187D	2	N	93	144D	2	W	66

APPENDIX TABLE VIII. Days to second estrus for all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	55	A191	1	WD	43
A153	2	ND	53	A191	2	WD	71
157D	1	ND	66	143D	1	WD	40
A178	1	ND	108	143D	2	WD	24
A178	2	ND	86	166D	1	WD	63
B100	1	ND	34	180D	1	WD	74
B100	2	ND	44	180D	2	WD	89
155D	1	ND	39	A133	1	WD	88
155D	2	ND	48	A133	2	WD	41
A145	1	ND	128	139D	1	WD	50
A177	2	ND	58	139D	2	WD	84
33D	2	N	34	193D	2	WD	37
176D	2	N	31	159D	1	W	87
A167	1	N	65	159D	2	W	242
A167	2	N	42	A199	1	W	70
A190	1	N	33	A199	2	W	89
A190	2	N	46	165D	1	W	77
149D	1	N	59	165D	2	W	46
149D	2	N	134	A179	1	W	43
A126	1	N		A179	2	W	61
B103	1	N	28	A158	1	W	
B103	2	N	82	A158	2	W	87
187D	1	N	50	177D	1	W	121
187D	2	N	117	144D	2	W	80

APPENDIX TABLE IX. Days to third estrus for all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	76	A191	1	WD	65
A153	2	ND	88	A191	2	WD	92
157D	1	ND	87	143D	1	WD	65
A178	1	ND		143D	2	WD	67
A178	2	ND	118	166D	1	WD	
B100	1	ND	54	180D	1	WD	96
B100	2	ND	142	180D	2	WD	97
155D	1	ND	83	A133	1	WD	
155D	2	ND	66	A133	2	WD	88
A145	1	ND		139D	1	WD	78
A177	2	ND	79	139D	2	WD	109
33D	2	N	51	193D	2	WD	97
176D	2	N	82	159D	1	W	169
A167	1	N	88	159D	2	W	262
A167	2	N	64	A199	1	W	
A190	1	N	51	A199	2	W	
A190	2	N	100	165D	1	W	
149D	1	N	79	165D	2	W	72
149D	2	N	195	A179	1	W	
A126	1	N		A179	2	W	81
B103	1	N	46	A158	1	W	
B103	2	N	98	A158	2	W	
187D	1	N	83	177D	1	W	253
187D	2	N	135	144D	2	W	145

APPENDIX TABLE X. Days to conception for all cows in both years.

Narrow				Wide			
Cow	Year	Group	Days	Cow	Year	Group	Days
A153	1	ND	74	A191	1	WD	124
A153	2	ND	88	A191	2	WD	92
157D	1	ND	87	143D	1	WD	86
A178	1	ND	108	143D	2	WD	122
A178	2	ND	118	166D	1	WD	63
B100	1	ND	98	180D	1	WD	96
B100	2	ND	104	180D	2	WD	194
155D	1	ND	83	A133	1	WD	88
155D	2	ND	179	A133	2	WD	104
A145	1	ND		139D	1	WD	78
A177	2	ND	271	139D	2	WD	138
33D	2	N	97	193D	2	WD	134
176D	2	N	109	159D	1	W	168
A167	1	N	87	159D	2	W	
A167	2	N	111	A199	1	W	299
A190	1	N	81	A199	2	W	91
A190	2	N	100	165D	1	W	77
149D	1	N	120	165D	2	W	72
149D	2	N	118	A179	1	W	43
A126	1	N	190	A179	2	W	
B103	1	N	180	A158	1	W	70
B103	2	N	264	A158	2	W	169
187D	1	N	148	177D	1	W	293
187D	2	N		144D	2	W	

APPENDIX TABLE XI. Frequency of silent estrus at first ovulation for all cows in all treatment groups.

	Group				
	ND	N	WD	W	Ave.
Year I	66%	83%	100%	83%	83%
Year II	40%	57%	66%	66%	60%
Ave.	55%	70%	83%	75%	75%

APPENDIX TABLE XII. Frequency of silent estrus at second ovulation for all cows in treatment groups.

	Group				
	ND	N	WD	W	Ave.
Year I	84%	17%	33%	66%	57%
Year II	0	40%	0	66%	30%
Ave.	45%	30%	17%	66%	40%

APPENDIX TABLE XIII. Frequency of silent estrus at third ovulation for all cows in treatment groups.

	Group				
	ND	N	WD	W	Ave.
Year I	33%	33%	33%	33%	33%
Year II	20%	30%	50%	17%	30%
Ave.	27%	31%	42%	25%	32%

APPENDIX TABLE XIV. Average daily production of 4% fat corrected milk during first 120 days after parturition.

Narrow				Wide			
Cow	Year	Group	Kg/day	Cow	Year	Group	Kg/day
A153	1	ND	25	A191	1	WD	24
A153	2	ND	19	A191	2	WD	24
157D	1	ND	18	143D	1	WD	24
A178	1	ND	19	143D	2	WD	20
A178	2	ND	29	166D	1	WD	27
B100	1	ND	24	180D	1	WD	16
B100	2	ND	23	180D	2	WD	20
155D	1	ND	20	A133	1	WD	28
155D	2	ND	18	A133	2	WD	28
A145	1	ND	24	139D	1	WD	28
A177	2	ND	17	139D	2	WD	18
33D	2	N	24	193D	2	WD	22
176D	2	N	14	159D	1	W	23
A167	1	N	17	159D	2	W	25
A167	2	N	13	A199	1	W	19
A190	1	N	21	A199	2	W	25
A190	2	N	28	165D	1	W	23
149D	1	N	24	165D	2	W	24
149D	2	N	22	A179	1	W	10
A126	1	N	28	A179	2	W	13
B103	1	N	25	A158	1	W	33
B103	2	N	25	A158	2	W	32
187D	1	N	24	177D	1	W	16
187D	2	N	29	144D	2	W	20

DAIRY COW REPRODUCTIVE PERFORMANCE FROM PARTURITION TO CONCEPTION AS INFLUENCED BY CALCIUM TO PHOSPHORUS RATIO AND VITAMIN D IN HIGH ENERGY RATIONS

by

CARROL WRAY CAMPBELL

B. S., Kansas State University, 1966

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Dairy and Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1969

Forty-eight Holstein cows were assigned over a two-year period to high energy rations with narrow (N), narrow with vitamin D (ND), wide (W), or wide with vitamin D (WD) calcium to phosphorus (Ca:P) ratios to investigate the relationship of reproductive performance after parturition to the rations. Cows assigned during the first year were preconditioned with their respective rations for 30 days. Cows assigned for the second year included some from the first year and others pre-conditioned at least six months on their respective rations. The average Ca:P ratio of the narrow and wide rations were 1.4:1 and 2.9:1 during the first lactation, and 1.3:1 and 2.3:1 for the second lactation, respectively. The ND and WD groups received 300,000 units of vitamin D_3 weekly by capsule.

Rectal palpations were performed weekly after parturition until after conception. Size, location and tone of each uterine horn as well as size and location of ovarian structures were recorded. The intervals from parturition to first, second, and third estrus; first, second, and third ovulation; conception; and complete uterine involution were determined. Milk production for the first 120 days of lactation was recorded and corrected to four percent fat corrected milk basis to relate reproductive performance to level of milk production. Cows were observed for estrus twice daily and first inseminated at the estrus which occurred 40 or more days after parturition.

The average interval from parturition to complete uterine involution was 44 days for all cows. The average interval of 49 days in the ND group was longer than the 39 day average of the WD group ($P > .1$).

The average interval from parturition to first ovulation during the first year was 13 days which was less than the 19 day average observed in the second year ($P > .005$). The longer intervals during the second year were primarily in the combined N and ND groups which averaged 24 days whereas the combined W and WD groups averaged 14 days from parturition to first ovulation ($P > .025$). Intervals from parturition to second ovulation averaged 30 days during the first year which was different from the 40 days observed in the second year ($P > .01$). The narrow ratio animals also experienced the second ovulation later after parturition than did those fed the wide ratio ($P > .25$).

Silent heat associated with first, second, and third ovulations occurred in 75, 40, and 32 percent of the cases, respectively. Cows receiving vitamin D supplement (+D) during the second year averaged 30 days from parturition to first estrus whereas cows without the supplement (-D) averaged 11 days later ($P > .2$). Earlier expression of second estrus was also observed in the +D cows which expressed estrus 26 days before -D cows ($P > .25$). During the first year conception in +D cows averaged 53 days sooner than -D cows ($P > .05$).

Follicular cysts were detected in ten of 48 cases. Anestrum was associated with nine cases and nymphomania with the other. Eight cystic corpora lutea were detected, none of which lengthened the cycle. The frequency of follicular cysts did not seem to be influenced by level of milk production. Slightly longer intervals from parturition to first estrus were observed in cows averaging more than 22 kg of milk per day during the first 120 days ($P > .25$).