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Analysis of the Reproductive Efficiency of the Dairy Herd at Western Kentucky University Farm

Gregorio Lagomba

Western Kentucky University

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Gregorio García
1985
ANALYSIS OF THE REPRODUCTIVE EFFICIENCY OF THE DAIRY HERD AT WESTERN KENTUCKY UNIVERSITY FARM

A Thesis
Presented to
the Faculty of the Department of Agriculture
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Gregorio Garcia Lagombra
December 1985
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ANALYSIS OF THE REPRODUCTIVE EFFICIENCY OF THE DAIRY HERD AT WESTERN KENTUCKY UNIVERSITY FARM

Recommended 11-27-85

John E. Shirley
Director of Thesis

Approved 1-3-86

Dean of the Graduate College
DEDICATED TO:

All the Dominican people who, either directly or indirectly, have given me their economic support. It is also dedicated to all of relatives and friends from the Dominican Republic that helped me with their moral encouragement. Special thanks to my American friends who shared with me the happy times spent here.
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A study of the reproductive performance of 179 dairy cows during the period from December 1978 through March 1984 was conducted at the Western Kentucky University Farm, Bowling Green, Kentucky. The climatic data showed seasonal variation in temperature as follows: winter 3.1°C, spring 15.7°C, summer 23.8°C, and fall 12.0°C. The seasonal humidity was similar for winter (81.2%), spring (83.4%), and fall (85.3%); but for summer it was considerably higher (89.4%).

The conception rate varied through all the months but was lowest during the summer months. Seasonal data for conception rate were obtained and the results were as follows: winter 54.1%, spring 46.4%, summer 15.6% and fall 39.0%. Low fertility during summer months was associated with high air temperatures and high relative humidities. The coefficient of correlation for temperature vs. conception was low (-0.15) because there was low fertility in some winter months and in some summer months. The coefficient of correlation for humidity vs. conception was high (-0.65), and the coefficient of determination was 42%. A completely randomized design and analysis were used, resulting in significant differences among seasonal fertility rates but no significant differences among months within seasons. Significant differences were found for the following comparisons: winter vs. spring, summer, and fall; spring vs. winter, summer, and fall; and summer vs. spring, fall, and winter. The total services involved were 546, and the total conceptions obtained were 155—resulting in a
service per conception ratio of 3.52. The average number of days open was 177 (79 cows). The average number of days in the calving interval was 457 (63 cows).
INTRODUCTION

Dairymen have accomplished many management objectives over the past fifty years. Nutrition, genetics, facilities, cow handling, and many other facets of the dairy business have been greatly improved during this time span. Concomitant with these improvements has been a decrease in reproductive efficiency. Poor reproductive performance has been attributed to increased stress due to confinement type facilities, high milk production, crowding, artificial insemination, and other factors too numerous to mention. In all probability, most of these factors have contributed to the problem at one time or the other.

Ideally, a cow should produce a calf every twelve months. This time frame would provide the most offspring for possible inclusion into the herd and provide the most milk over a cow's lifetime because most of her time would be spent in that part of the lactation period when production is at its highest level. To produce an offspring every twelve months, the cow must conceive within eighty-five days postpartum. Assuming a sixty-day dry period, she would be lactating approximately 305 days. Many factors are involved in the accomplishment of this goal.

Addressed in this study are environmental temperature and humidity effects on the reproductive efficiency of dairy cattle.
REVIEW OF LITERATURE

The reproductive performance of dairy cattle is a function of the integration of several factors. Therefore, this review is expanded beyond temperature and humidity influences to provide a broader framework for study and interpretation of final results. Specific attention is directed toward nutritional and neuro-endocrine relationships to reproductive efficiency, along with the primary subject of temperature and humidity.

Influence of Nutrition on Fertility of Dairy Cattle

Feedstuffs offered to dairy cattle are composed of various combinations of the six major classes of nutrients: proteins, carbohydrates, fats, minerals, vitamins, and water. The balance of nutrients and the specific amount of each nutrient in the diet may influence reproductive performance. Further, it is generally accepted that underfeeding or overfeeding specific nutrients within each major class can adversely affect reproductive performance. The importance of nutrition relative to reproductive performance must be assessed along with various other influencing factors (7). In this section the primary focus will be the specific influence of nutrition on reproductive performance, irrespective of other factors which will be addressed in later sections.

Nutritional effects on reproductive performance begin during prenatal development (2). Underfeeding during this period results in retardation of overall development along with underdevelopment of ovaries. Ovarian sacs fail to ripen, and the secretion of estrogen is depressed.
Consequently, the affected animal exhibits infertility or delayed sexual maturity.

**Relationship between dietary energy level and fertility**

Salisbury et al. (28) concluded that an insufficient supply of energy in the diet is the most common cause of reproductive disorders in dairy cattle. Insufficient energy levels generally occur when poor quality hay and pasture constitute the major portion of the diet. Lemenage et al. (22) found that differences in winter feeding levels, relative to energy, affected conception rates. In their (22) study, heifers fed low levels of ground ear corn exhibited a decreased conception rate and conceived later than those fed high levels of ground ear corn. Conversely, Grieve et al. (13) were able to obtain normal reproductive efficiency as measured by date of first calving, calving interval, and services per conception when Holstein heifers were fed (ad libidum) diets of corn silage alone or corn silage plus hay or haylage without supplemental grain. One of the primary physiological effects of low energy diets may be a decrease in ovarian function resulting in depressed estrogen production. Jurgens (21) observed that silent heat was often the cause of delayed breeding in energy deficient cows. That observation tends to support the contention that estrogen production is depressed because of its role in the expression of heat. The long-term effects of depressed energy intake on the reproductive performance of primiparous heifers may be overcome by adequate intake during their first lactation.

Overfeeding energy may be just as harmful relative to reproductive efficiency as is underfeeding. Experiments conducted with overweight cows in South Africa (5) resulted in an increase in sterility, decreased estrous, and long interovulatory periods. Subsequent examination of these
cows revealed heavy deposition of fat in the ovaries and around the oviducts. It has also been observed (10) that calving problems such as retained placenta, increased length of birthing time, and metritis are more common in overfat cows. Calving problems can lead to an increase in the length of time required for uterine involution, thereby delaying conception and increasing calving interval. Even though overfeeding tends to aggravate reproductive performance, it likely is not as deleterious as underfeeding. Salisbury et al. (28) concluded that underfeeding appeared to be more important at least in regards to sexual maturity in dairy heifers. Underfeeding energy has resulted in decreased ovulation, estrogen production, and fertilization rate as well as increased prenatal deaths (17).

Relationship between protein intake and fertility

The role of proteins and their components, amino acids, dictates that they be consumed daily if high performance is to be achieved. They form an integral part of enzymes, hormones, deoxyribonucleic acid (DNA), ribonucleic acid (RNA), body tissues, and immunoglobulins. These proteinaceous body substances are in a constant state of catabolic and anabolic activity, thus a constant supply of building components must be available to maintain homeostasis and provide for growth and milk production.

The importance of protein in the daily ration is emphasized by the fact that protein deficiency results in depressed appetite. More specifically, the metabolic rate slows down and fewer nutrients are moved from the blood stream into tissue cells—hence a constant stimulation of the satiety center depresses appetite. Inadequate protein intake has both a direct and an indirect effect on reproductive performance. It is required for appetite maintenance (indirect effect) and is used in the
production of hormones that affect ovarian and uterine functions (a direct effect). There is very little available data that directly relate protein deficiency to reproductive performance per se. Asdell (2) stated that "It's difficult to imagine a practical condition of management in which protein alone would be a limiting factor in feedstuffs." However, it has been observed that reproductive patterns change with seasons and that part of that change is associated with the seasonal change that occurs in the nutrient content of forages (2, 21).

Relationship between selected vitamins and fertility

Vitamin A

Circumstantial evidence that vitamin A plays an important role in overall reproductive performance has existed for a long time. Symptoms often associated with vitamin A deficiency include retained placentas, weak or still-born calves, and low conception rate. These deficiencies have been observed when cows were fed diets low in provitamin A or B-carotene (18).

Specific effects of vitamin A on reproductive performance have been studied by several researchers (11,17,18). Generally, those studies suggest that B-carotene is more important than vitamin A per se. Hafez (17) summarized the early work and found that carotene deficient cows exhibited longer intervals between estrous periods, longer intervals between the beginning of estrous and the time of ovulation, reduction in strength of uterine contractions, firmer follicles on the first day of estrous, and smaller corpus luteum. Other workers have shown that a deficiency of vitamin A reduces ovum production and increases problems associated with uterine attachment. To date, the most definitive work (18) has shown that B-carotene stimulated reproductive performance even
when diets were supplemented with vitamin A. German studies reviewed by Hemken and Bremel (18) revealed that the concentrations of vitamin A in the ovaries appeared to be dependent on the B-carotene concentration in the corpus luteum and that cows consuming feedstuffs low in B-carotene exhibited low fertility.

**Vitamin D**

Hemken and Bremel (18) noted that as dietary vitamin D levels declined the incidence of silent heat and other reproductive problems increased. This phenomenon likely is due to the impact of vitamin D on calcium and phosphorus metabolism rather than being the direct effect of vitamin D on the reproductive system.

**Relationship between selected minerals and fertility**

**Phosphorus**

Phosphorus deficiency in dairy cattle has been reported to cause retarded sexual maturity, silent heat, nonfunctional ovaries, and a general decrease in fertility (8,18). Hurley et al. (19) investigated the relationship between estrous intensity and dietary phosphorus levels in Holstein and Jersey heifers. Three levels of phosphorus were used: 73% (low), 130% (medium) and 246% (high) of the amounts recommended by N.R.C. (National Research Council). Dietary phosphorus concentration affected serum inorganic phosphorus levels; but serum levels of progesterone, estrodial and other hormones associated with reproductive function were not significantly affected. They concluded that only a severe dietary phosphorus deficiency appeared to alter reproductive function.
**Calcium**

The specific function of calcium relative to reproductive function in dairy cattle is not clearly defined, however it is important due to its interrelationship with other minerals. Jurgens (21) reported that calcium reduces egg production, possibly a calcium-phosphorus imbalance rather than a direct calcium effect. Short-term calcium deficiencies are corrected by metabolic processes involving calcium absorption from the bone, thus long-term deficiencies are probably required for grass deficiency symptoms.

**Sodium**

Limited studies are available concerning the relationship between sodium and reproductive performance. It can be postulated that sodium is important to the maintenance of normal reproductive functions in that it constitutes the major ion in interstitial fluids. Suggestive evidence of a sodium effect was obtained by Salisbury et al. (28) who observed an improvement in breeding performance when sodium in the form of sodium carbonate was added to a diet consisting of corn meal, wheat bran, cottonseed meal, linseed meal, and sodium chloride.

**Summary and conclusions**

The nutrients mentioned are important in maintaining normal reproduction in dairy cows. Diets should be formulated to include at least the minimal essential level of each nutrient. Further, nutrient interrelationships must be considered in diet formulations. Reproductive performance studies require that adequate dietary formulas be used.
Neuro-endocrine Regulation of Reproduction

Reproductive functions in dairy cows are coordinated through the synergistic activities of the nervous system and endocrine system. The nervous system—composed of the brain, spinal cord, sensory nerves and motor nerves—constantly monitors the environment, both external and internal (23). The endocrine system consists of glands located at various points throughout the body; they manufacture chemical messengers (hormones) and release them into the bloodstream for action on various body cells. Generally, the body's activities are regulated by the combined efforts of the nervous system and endocrine system in that the nervous system has short-term regulatory responsibilities, whereas endocrine regulation involves long-term effects.

The hypothalamus serves as a major mediator between the two systems. Basically, its activity is triggered by impulses from the brain area; its reaction to these impulses involves the manufacture and release of chemical messengers called "releasing factors." These releasing factors travel to the pituitary where they effect the release of other chemical messengers referred to as "stimulating hormones." These stimulating hormones have stimulatory effects on specific endocrine glands causing them to manufacture and release hormones into the bloodstream where they have either a specific or general effect on a target organ. Hormones are well suited as regulators because they do not supply energy; they act in minute amounts; they can be rapidly removed from circulation (10-20 minutes); and they cause either an increase or decrease in target cell activity (17).

Hormones associated with reproduction are mainly derived from the hypothalamus, pituitary gland, gonads, and the placenta. The relationship between these glands dictate, in large part, the activities of the
reproductive system. The hypothalamus is the higher center, the pituitary gland the middle center, and the gonads and placenta the lower centers of this regulatory system. This review will be focused on the pituitary gland with specific emphasis on the adenohypophysis. The adenohypophysis consist of three basic cell types: the chromophores or precursor cells, the chromophils which secrete somatotrophic (STH) and lactotrophic (prolactin) hormones, and the basophils which secrete gonadotrophic, tyrotrophic, and corticatrophic hormones (23).

The pituitary gland is divided into three lobes: anterior, intermediate, and posterior. The anterior lobe is extremely important with regard to reproductive tract activities since it secretes follicle stimulating hormone (FSH), luteinizing hormone (LH), prolactin, growth hormone (GH or STH), adrenocorticotropic hormone (ACTH) and thyroid stimulating hormone (TSH) (17,23). The posterior lobe of the pituitary stores oxytocin, produced by the hypothalamus, (23). Oxytocin relationship to reproductive tract functions centers on its ability to excite muscular activity in the reproductive tract at parturition and the mammary gland myoepithelial muscle cells during the milking process.

The female gonadal hormones include progesterone and the estrogens. These two hormones are also produced at various times by the placenta during gestation. The placenta, depending on the species, produces such hormones as pregnant mare serum gonadotropin (PMSG), human chorionic gonadotropin (HCG) and placental lactogens (17). The placental lactogens are a diverse group of hormones found in humans, rats, goats, sheep, and cows. These hormones appear to function similarly to growth hormone and prolactin (17). Since blood levels of lactogens during gestation are twice as great in high producing dairy cows as compared to low producing
dairy cows and beef cows, they may possibly exert a regulatory effect on maternal metabolism.

Another group of compounds that influence reproductive activity is the prostaglandins. These compounds are derived from the essential fatty acid arachidonic and exert hormone-like effects. The two most important types relative to reproduction are prostaglandin $F_2\alpha$ (PGF$_2$) and prostaglandin $E_2\alpha$ (PGE$_2$). These compounds do not appear to be produced at specific locations within the body but act locally wherever they are produced. Prostaglandins exert specific and quantifiable affects on blood pressure, lipolysis, gastric secretion, blood clotting, stimulation of gonadotropin release, ovulation, corpus luteum regression, uterine motility, parturition, and sperm transport in the uterus (23).

Effects of Climate on Reproduction

Reproductive efficiency, as measured by either services per conception or conception rate, has a very low heritability (0.09) and a very low repeatability (0.11) (28). Nutritional and management effects on reproductive efficiency have not been carefully quantitated but are generally considered to have minimal effects relative to climatic factors (42). Badinga et al. (3) reported that approximately 4 percent of the total month to month variation in conception rate could be accounted for by genetic and management factors when nutritional factors were held constant. Many studies have revealed seasonal differences in breeding efficiency in dairy cattle (1,4,9,29,31). Many variables may affect conception rate and should be considered in recommendations. However, the environment of cows and their management relative to environmental conditions have a decided influence on the seasonal variation observed in reproductive efficiency (3,14,26).
Solar radiation, temperature, humidity, and wind have all been associated with reproductive performance in dairy cattle (34,42). However, this review will be confined to temperature and humidity effects.

Dairy cattle produce and reproduce at optimal levels in environments that do not adversely effect their normal body physiology. Webster (41) defines the "Zone of Thermal Neutrality" as that temperature range in which a warm-blooded animal does not expend additional energy to sustain normal body temperature to keep warm or to keep cool. This zone is bounded by high and low critical temperature. Thus, as the ambient temperature falls below the critical temperature, the dairy cow's metabolic rate increases to produce heat. Conversely, as the ambient temperature exceeds the upper limit (critical temperature) the cow's system must increase respiration rate and other body activities designed to lower body temperature. Both of these adjustments require energy. Thus, energy available for production and/or reproduction functions is diverted to maintain body temperature.

The zone of thermal neutrality is not a constant but is dependant on level of milk production and feed intake (6) and on breed of cattle (43). The zone shifts downward as milk production and feed intake increases. This shift occurs because of the heat produced during the digestive and metabolic processes required to support high milk production. Holsteins have a lower zone of thermal neutrality than do Jerseys, probably due to the fact that Holsteins are larger and, hence, have a greater maintenance requirement.

Reproductive efficiency is sensitive to external thermal stress (15,31,35,40) as demonstrated by the inverse association of reproduction with monthly climatic measurements. Ingraham et al. (20) reported that
conception rates declined \( r=.87 \) as the temperature and humidity increased. Low fertility during periods of elevated temperature have also been observed by Stott (32) and more recently by Thatcher (35) and Stevenson (31).

Thatcher et al. (35) concluded, after observing climate/reproduction relationships over a 10-year period, that when maximum environmental temperature and solar radiation effects were removed no variability in conception rates from month to month was detected. Ingraham et al. (20) were able to account for 19.5 percent of the variation in conception rate by temperature/humidity effects during a 5-day period surrounding the day of breeding. However, only the measurement taken 2 days prior to breeding was significantly related to conception rate. These data (20,43) suggest that climatological factors may have a direct effect on reproduction in addition to the indirect effect observed through energy partitioning.

Uterine (14) and rectal (39) temperatures on the day of or day after insemination are negatively associated with conception rate. Thatcher and Ponce (36) recently reported that a .5°C increase in uterine temperature above mean uterine temperature the day of or day after insemination resulted in decrease in conception rate of 12.8 and 6.9 percent, respectively. These data suggest that elevated temperatures affect either fertilization or the ability of the developing embryo to live in the uterine environment. The prevalent hypothesis (17,35) is that fertilization takes place but the embryo fails to survive past the two or four cell stage.

Thermal stress not only affects reproduction through energy partitioning and direct effects on uterine environment but also through the endocrine system. Thermoregulatory receptors in the skin continuously
monitor ambient temperature and forward messages to the central nervous system. The central nervous system continuously monitors and adjust conditions within the body to maintain homeostasis with respect to body temperature. Dairy cows exposed to elevated temperatures (above critical temperature) respond outwardly by increased respiratory rate and moisture evaporation via the skin. This movement of water out of the body carries heat with it and thus reduces body temperature. Simultaneously, the metabolic rate drops and the cow increases resting time relative to feeding time. Conversely, cows exposed to temperatures below the lower critical level respond by decreased respiration rate, heat loss through evaporation via the skin, and increased metabolic rate. These outward manifestations of climatic adjustments are preceded by nervous system effects either directly or indirectly through the endocrine system on blood flow rate, respiration rate, and metabolic rate.

Basal metabolic rate (BMR) refers to the speed with which oxygen \( (O_2) \) is used by the cells and with which carbon dioxide \( (CO_2) \) is produced. Thyroidectomized animals experience a decreased metabolic rate, decreased heart rate, and reduced feed intake (33, 34). Conversely, as thyroxine is added back to the thyroidectomized animal a concomitant increase in these parameters is observed. Thyroid gland activity, as measured by circulating levels of thyroxine, is sensitive to ambient temperature. Turner (38) reported that blood thyroxine levels during the winter months in Missouri (mean temperature = 39°F) averaged 5.4 mg per day per 1000 pounds of body weight and 2.0 mg per day per 1000 pounds of body weight in the summer months (mean temperature = 71°F). Low levels of thyroxine have an unfavorable effect upon the reproductive organs of both males and females. Ovarian cycles may decrease or stop entirely, and ovarian
hormone secretion rate may be reduced. Spielman et al. (30) observed silent heat in cows with depressed circulating levels of thyroxine. Similarly, Petersen et al. (25) noted that bulls with depressed thyroxine production continued to produce sperm but lacked libido and would not mate with the cow. Bulls with poor breeding records have shown marked improvement when a thyroxine-like substance, thyroprotein, was added to the diet (27).

Heat stress has been associated with silent heat, shorter estrus cycles, reduced intensity of estrus, and increased bleeding after ovulation in dairy cattle (16). Since similar symptoms are observed in thyroid deficient animals (as noted above) and since thyroid activity is depressed during the summer months, it seems logical to assume that the outward signs of heat stress on reproduction may be mediated at least partially through its effect on thyroid gland activity.
MATERIALS AND METHODS

Reproductive performance data from 179 Holstein cows of various ages were obtained from records maintained on the Western Kentucky University dairy herd. Data used were extracted from recordings made between December 1978 and March 1984. Performance data on cows that were culled prior to calving and on cows with incomplete lactations were not used in this study. No allowances were made for age or number of lactations even though it is realized that primiparous animals may react differently from multiparous animals. Further, cows that exhibited gross health problems during the observation period were excluded from the study.

Information obtained from individual cow records included calving dates, breeding dates, days in milk, days dry, and age at each breeding. These data were used to calculate services per conception, days open, calving interval, and days to first service. Individual cow data were grouped for month and seasonal analyses.

Seasonal, monthly and daily temperature data were obtained from records secured and maintained by the Kentucky Climatic Center under the auspices of the Department of Geography and Geology, Western Kentucky University. The Climatic Center is physically located approximately six miles from the Dairy Center. Humidity values used were also obtained from the Kentucky Climatic Center records. However, humidity recordings were taken at the Bowling Green-Warren County airport, which is approximately four miles from the Dairy Center. Monthly and seasonal averages for temperature and humidity represented six and four years, respectively.
RESULTS AND DISCUSSION

The reproductive status of the Western Kentucky University Dairy herd was evaluated utilizing data accumulated from December 1978 through March 1984. The number of services performed was 546 resulting in 155 conceptions for a service per conception rate of 3.52 (Table 1). This value (3.52) compares unfavorably with the average found in excellent herds (1.5 services/conception) and good herds (1.8 services/conception) as reported in a summary article by Garcia (12). The poor conception rate observed resulted in long "days open" (176 days) and an extremely long calving interval (457 days). Ideally, the average number of days open should be eighty-two; the result would be a calving interval of 365 days and a lactation period of 305 days.

Salisbury et al. (38) concluded that environment plays a major role in the reproductive status of a dairy herd. They (28) found that services per conception and conception rate had a low heritability (0.09) and a low repeatability (0.11). Thompson (37) and Webster (41) reviewed the influence of the climatic environment on the physiological and metabolic processes of dairy cattle, respectively. They (37,41) concluded that the reproductive status of a dairy herd is significantly influenced by temperature and humidity when other factors such as nutrition and skill of the artificial insemination technician are held constant.

Once the reproductive status of Western Kentucky University's Dairy herd was established and the nutritional program was found to be sound (as evidenced by ration analysis and milk production level) the researcher then decided to study the relationship between conception rate and
Table 1. Reproductive data on Holstein cattle for a five-year period.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Services</td>
<td>546.0</td>
</tr>
<tr>
<td>Conceptions</td>
<td>155.0</td>
</tr>
<tr>
<td>Services/conception</td>
<td>3.5 (179)*</td>
</tr>
<tr>
<td>% of conception</td>
<td>34.8 (179)</td>
</tr>
<tr>
<td>Days open</td>
<td>176.8 (79)</td>
</tr>
<tr>
<td>Calving interval</td>
<td>457.4 (63)</td>
</tr>
</tbody>
</table>

*Numbers in parentheses indicate cows observed.
environmental temperature and humidity at breeding time. The average monthly temperature and humidity values for the five-year study period are shown in Table 2. The temperature ranged from a low of -1.0°C in January to a high of +26.2°C in July. The relative humidity followed the same general trend in that it was lowest during the months of January through April, highest during the period of June through September, and moderate during the months of May, October, November and December. These findings are consistent with values reported by others (35,36,37, 41,42).

The conception rate (Table 3) and temperature had a correlation of -0.15 with a coefficient of determination of 2.25%. This correlation was not significant (P>.05). The relationship between temperature and conception rate is somewhat confounded because dairy cows are negatively affected by both low temperatures and high temperatures. Webster (41) explains this relationship in his definition of the "Zone of Thermal Neutrality" and "critical temperature." The "Zone of Thermal Neutrality" is defined as the zone in which metabolic heat production is independent of air temperature. This zone is bordered by high and low "critical temperatures." The critical temperature of the lower limit stimulates the animal's metabolic processes to increase heat production, whereas the critical temperature of the upper limit stimulates the animal's body to accelerate heat loss. The correlation between conception rate and temperature in this study was determined using data collected throughout the year (Table 4). Thus, both high and low critical temperatures were exceeded, thereby diminishing the degree of the relationship. In essence, the conception rate was highest when the temperature was in the range of 8°C to about 20°C and lowest when the temperature exceeded 20°C or fell below 8°C.
Table 2. Average monthly temperature (December 1978-March 1984), humidity (January 1979-March 1984), and conception rate.

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature °C</th>
<th>Humidity (%)</th>
<th>Conception (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. January</td>
<td>-1.0</td>
<td>80.2</td>
<td>34.0 (63)*</td>
</tr>
<tr>
<td>2. February</td>
<td>1.0</td>
<td>80.5</td>
<td>58.3 (57)</td>
</tr>
<tr>
<td>3. March</td>
<td>8.0</td>
<td>79.9</td>
<td>43.5 (66)</td>
</tr>
<tr>
<td>4. April</td>
<td>13.4</td>
<td>78.0</td>
<td>41.9 (44)</td>
</tr>
<tr>
<td>5. May</td>
<td>18.2</td>
<td>85.9</td>
<td>40.7 (38)</td>
</tr>
<tr>
<td>6. June</td>
<td>23.1</td>
<td>89.8</td>
<td>38.9 (25)</td>
</tr>
<tr>
<td>7. July</td>
<td>26.2</td>
<td>90.5</td>
<td>21.4 (34)</td>
</tr>
<tr>
<td>8. August</td>
<td>25.2</td>
<td>89.4</td>
<td>13.9 (44)</td>
</tr>
<tr>
<td>9. September</td>
<td>20.9</td>
<td>88.1</td>
<td>22.4 (93)</td>
</tr>
<tr>
<td>10. October</td>
<td>13.8</td>
<td>85.4</td>
<td>44.4 (81)</td>
</tr>
<tr>
<td>11. November</td>
<td>9.0</td>
<td>83.5</td>
<td>35.2 (73)</td>
</tr>
<tr>
<td>12. December</td>
<td>4.3</td>
<td>84.2</td>
<td>32.2 (78)</td>
</tr>
</tbody>
</table>

*Numbers in parentheses indicate cows observed.
Table 3. Five-year temperature averages (December 1978-March 1984) and conception rate in Holstein cows.

<table>
<thead>
<tr>
<th>Season</th>
<th>Conception rate</th>
<th>Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter (December 22-March 20)</td>
<td>54.1% (185)*</td>
<td>3.1</td>
</tr>
<tr>
<td>Spring (March 21-June 20)</td>
<td>46.4% (125)</td>
<td>15.7</td>
</tr>
<tr>
<td>Summer (June 21-September 20)</td>
<td>15.6% (150)</td>
<td>23.8</td>
</tr>
<tr>
<td>Fall (September 21-December 21)</td>
<td>39.0% (240)</td>
<td>12.0</td>
</tr>
</tbody>
</table>

*Numbers in parentheses indicate cows observed.)
Table 4. Five-year average monthly services per conception, conception rate, and temperature (December 1978-March 1984) for Holstein cows.

<table>
<thead>
<tr>
<th>Month</th>
<th>Services/Conception</th>
<th>Conception (%)</th>
<th>Temperature °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2.9 (63)*</td>
<td>34.0</td>
<td>30.2</td>
</tr>
<tr>
<td>February</td>
<td>1.7 (57)</td>
<td>58.3</td>
<td>33.8</td>
</tr>
<tr>
<td>March</td>
<td>2.3 (66)</td>
<td>43.5</td>
<td>46.3</td>
</tr>
<tr>
<td>April</td>
<td>2.4 (44)</td>
<td>41.9</td>
<td>56.0</td>
</tr>
<tr>
<td>May</td>
<td>2.5 (38)</td>
<td>40.7</td>
<td>64.8</td>
</tr>
<tr>
<td>June</td>
<td>2.6 (25)</td>
<td>38.9</td>
<td>73.6</td>
</tr>
<tr>
<td>July</td>
<td>4.7 (34)</td>
<td>21.4</td>
<td>79.1</td>
</tr>
<tr>
<td>August</td>
<td>6.3 (44)</td>
<td>15.8</td>
<td>77.3</td>
</tr>
<tr>
<td>September</td>
<td>4.5 (93)</td>
<td>22.4</td>
<td>69.6</td>
</tr>
<tr>
<td>October</td>
<td>2.2 (81)</td>
<td>44.4</td>
<td>56.8</td>
</tr>
<tr>
<td>November</td>
<td>2.8 (73)</td>
<td>35.2</td>
<td>48.1</td>
</tr>
<tr>
<td>December</td>
<td>3.1 (78)</td>
<td>32.2</td>
<td>39.7</td>
</tr>
<tr>
<td>Totals</td>
<td>3.2 (696)</td>
<td>35.7</td>
<td></td>
</tr>
</tbody>
</table>

*Numbers in parentheses indicate cows observed.
The most notable exception was the month of February, when the highest conception rate (58%) was observed at a temperature of 1.0°C. A possible explanation is that the cows adjusted to the cold temperatures by February, coupled with the fact that daily temperatures often are variable during this month. Thatcher and Ponce (36) observed that temperature 0.5°C above or below the mean temperature of the uterine level on the day of or on the day after insemination reduced conception rate. Thus, insemination on the warmer days in February would possibly have a positive influence on conception rate.

A significant (P<.05) negative correlation (-0.65) was observed between humidity and conception rate (Table 2). Conception rate was significantly (P<.01) lower during the summer relative to fall, winter, and spring. In general, conception rate was affected (P<.05) by season but unaffected (P>.05) by months within a season.

Results of this study identify temperature and humidity effects on reproductive performance in lactating dairy cows but offer no clarification of 1) specific physiological effects and 2) techniques to improve reproductive performance during environmental stress periods. Future research in these two areas is implicated.
SUMMARY

A study of the reproductive performance of 179 dairy cows during the period from December 1978 through March 1984 was conducted at the Western Kentucky University Farm, Bowling Green, Kentucky. The climatic data showed seasonal variation in temperature as follows: winter 3.1°C, spring 15.7°C, summer 23.8°C, and fall 12.0°C. The seasonal humidity was similar for winter (81.2%), spring (83.4%), and fall (85.3%), but for summer it was considerably higher (89.4%).

The conception rate varied through all the months, but was lowest during the summer months. Seasonal data for conception rate were obtained and the results were as follows: winter 54.1%, spring 46.4%, summer 15.6% and fall 39.0%. Low fertility during summer months was associated with high air temperatures and high relative humidities. The coefficient of correlation for temperature vs. conception was low (-0.15) because fertility was low in some winter months and in some summer months. The coefficient of correlation for humidity vs. conception was high (-0.65) and the coefficient of determination was 42%. A completely randomized design and analysis were used to study differences among seasonal fertility rates. There were highly significant differences among seasons (P<.01) but no significant differences among months within seasons. Significant differences were found for the following comparisons: winter vs. spring, summer, and fall; spring vs. winter, summer and fall; and summer vs. spring, fall, and winter. The total services involved were 546, and the total conceptions obtained were 155 resulting in a service per conception.
ratio of 3.52. The average number of days open was 177 (79 cows). The average number of days in the calving interval was 457 (63 cows).
BIBLIOGRAPHY


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VITA

Gregorio Garcia Lagombra was born January 1, 1953, in Puerto Plata, Dominican Republic. He attended Antera Mota Elementary School and Jose Dubeau and San Felipe High Schools in Puerto Plata. He received the bachelor degree in animal production from Universidad Nacional Pedro Henriquez in 1978, Santo Domingo, Dominican Republic. The title of his thesis for this degree was "Analysis of the Reproductive Efficiency of the Dairy Herd at Western Kentucky University Farm." He spent about one year working in two private companies and since then has worked in the Livestock Research Department of the Agriculture ministry. Upon completing the requirements for the master of science degree in Agriculture at Western Kentucky University, he will return to the Dominican Republic to work as a researcher for the Livestock Research Department of the Agriculture ministry.
Laird,

Roger A.

1977
CORRECTION

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