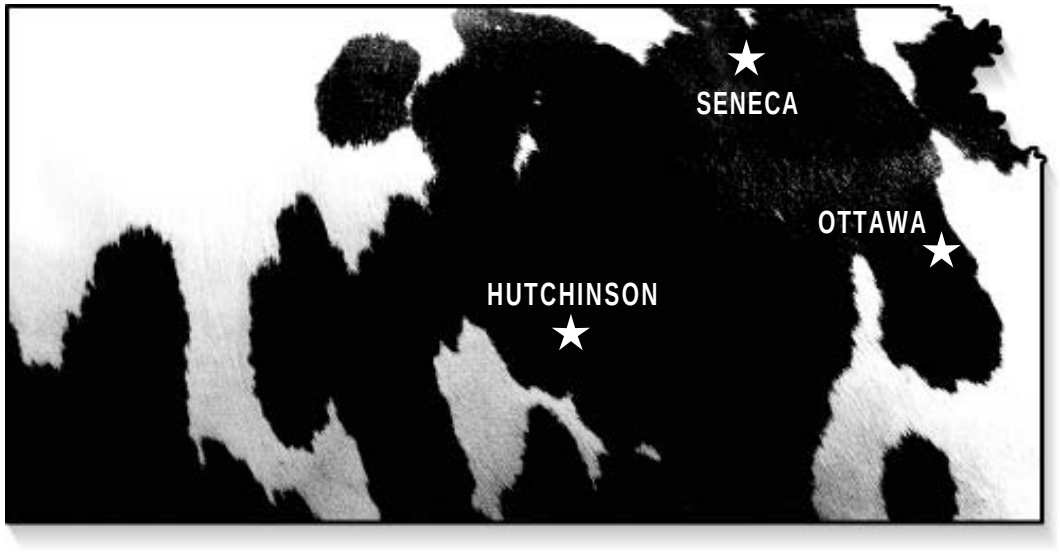
K-STATE Kansas State University AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE



DAIRY DAY 1998

Report of Progress 821

The 1998 Annual KSU DAIRY DAYS

1998 Dairy Day Program

10:00 A.M.	**Registration**
10:25	**Welcome**
10:30	**"How to Program AI Breeding of Your Dairy Cows"** Jeff Stevenson, Animal Sciences and Industry, KSU
11:15	**"Designing/Sizing of Cooling Systems for Dairy Cows"** Joe Harner, Biological and Agricultural Engineering, KSU
NOON	**Lunch - Sponsored by the Kansas Dairy Association (KDA)**
1:00 P.M.	**"What We Learned about Cooling Cows in Kansas"** John Smith, Animal Sciences and Industry, KSU
1:45	**"Milk Urea Nitrogen (MUN): A Management Tool"** John Shirley, Animal Sciences and Industry, KSU
2:30	**Adjourn**

Wednesday, November 18, 1998 - Franklin County Fairgrounds, Ottawa

Thursday, November 19,l 1998 - Whiteside, Hutchinson

Friday, November 20, 1998 - Valentino's Restaurant, Seneca

FOREWORD

Comparison of Heart of America Cows with Kansas Cows - 1997

Item	HOA	KS
No. of herds	1,415	400
No. of cows/herd	94	93
Milk, lb	18,293	19,332
Fat, lb	661	690
Protein, lb	584	599
IOFC, $	1,356	1,397
Milk price*, $	12.89	13.59

*After subtracting hauling cost.

Comparison of 1996 to 1997 with the Dairy Herd Analyzer

Losses	1996	1997	± from 1996
Nutrition, $	430	391	!39
Genetics, %	32	31	!1
Milk quality, %	47	47	+0
Reproduction, $	224	249	+25
Net change, $			**!15**

Members of the Dairy Commodity Group of the Department of Animal Sciences and Industry are pleased to present this Report of Progress, 1998. Dairying continues to be a viable business and contributes significantly to the total agricultural economy of Kansas. Wide variation exists in the productivity per cow, as indicated by the production testing program (Heart of America Dairy Herd Improvement Association [DHIA]). The Heart of America DHIA began business on January 1, 1995, by combining three labs into one. It is now testing about 133,000 cows per month from Kansas, Nebraska, Oklahoma, Arkansas, North Dakota, and South Dakota. A comparison of Kansas DHIA cows with all those in the Heart of America DHIA program for 1997 is illustrated above.

Most of this success occurs because of better management of what is measured in monthly DHI records. In addition, use of superior, proven sires in artificial insemination (AI) programs shows average predicted transmitting ability (PTA) for milk of all Holstein AI bulls in service (January, 1997) to be +1,351 lb compared to non-AI bulls whose average PTA was +357 lb of milk. More emphasis should be placed on furthering the DHIA program and encouraging use of its records in making management decisions.

Based on comparisons (next column) from 1996 to 1997 using the Dairy Herd Analyzer, better nutrition reduced loss in income over feed cost by $39 per cow, improved genetics reduced the loss by $1 per cow, but milk quality had no effect. Reproductive performance increased the loss by $25 per cow. In summary, a net reduction in losses of $15 per cow was achieved from 1996 to 1997.

We are proud of our new 72-cow tie stall barn that was constructed in 1991 through the generous support of Pharmacia & Upjohn, Clay Equipment Company, and Monsanto Company and under the direction of Dr. John Shirley. This new facility gives us the ability to expand our research efforts in various studies involving nutrition and feeding, reproduction, and herd management. The excellent functioning of the DTRC is due to the special dedication of our staff. Appreciation is expressed to Richard K. Scoby (Manager, DTRC); Donald L. Thiemann (Asst. Manager, DTRC); Michael V. Scheffel (Research Assistant); Daniel J. Umsheid; Charlotte Boger; Becky K. Pushee; Lesa Reves; and William P. Jackson. Special thanks are given to Betty Hensley and Cheryl K. Armendariz, and a host of graduate and undergraduate students for their technical assistance in our laboratories and at the DTRC.

Each dollar spent for research yields a 30 to 50% return in practical application. Research is not only tedious and painstakingly slow but expensive. Those interested in supporting dairy research are encouraged to consider participation in the Livestock and Meat Industry Council (LMIC), a philanthropic organization dedicated to furthering academic and research pursuits by the Department (more details about the LMIC are found at the end of this publication).

J. S. Stevenson, Editor
1998 Dairy Day Report of Progress

Dedication to Dr. J. R. (Dick) Dunham

James Richard (Dick) Dunham was born on November 25, 1937 at Walnut, Kansas. He grew up in the dairy business and entered Kansas State University as a freshman in Dairy Science in 1955. He returned to the family dairy farm in 1959 after completing requirements for a B.S. degree in Dairy Science. In 1964, Dick returned to Kansas State University. He received an M.S. degree in 1967 and a Ph.D. in Animal Nutrition in 1969.

He served one year as a Dairy Extension Specialist at Iowa State University before he was recruited by Dr. Charlie Norton to return to K-State in 1970 where he was a Dairy Extension Specialist for 28 years. Dick was very active in his service to the Kansas Dairy Industry and an integral part of the Dairy Herd Improvement Association team. He was a member of the Kansas Forage and Grassland Council and the Kansas and National Mastitis Councils. Dick was involved in several regional and national activities including the National DHIA Technical Committee (2 years), North Central Region Extension Dairy Specialists (3 years), National 4-H Dairy Cattle Judging Contest Committee (10 years), and numerous committee assignments with the Mid-States Dairy Record Processing Center (25 years).

Dick published numerous articles in refereed journal and Dairy Day reports, extension publications and popular press articles and developed 11 computer software programs. Five of his software programs are included in the CD-ROM National Dairy Database.

His active participation at the State Fair, dairy shows, breed association meetings, and other dairy events have endeared him to dairy producers throughout the state. His advice and counsel on nutrition and management problems were constantly in demand even at night or on weekends.

His service to the dairy industry was recognized by numerous honors and awards throughout his career. He was the recipient of the following honors: Kansas Junior Dairy Show Award of Appreciation, Epsilon Sigma Phi-Alpha Gamma Rho Meritorious Service Award, Friend of County Agents Award, Kansas Dairy Leader Award, Kansas 4-H Clover Award, Gamma Sigma Delta Excellence in Extension Award, Honorary Lifetime Member of the K-State Dairy Club, and Honorary Lifetime Member of the Kansas Holstein Association.

Dick and his wife, Evelyn, have been married since September 5, 1959. They have two children and six grandchildren. Dick enjoys pasture pool (golf) in his spare time. We wish both Dick and Evelyn many years of happiness in retirement.

CONTENTS

Page

Dairy Day 1998

THE WHY, HOW-TO, AND COST OF PROGRAMED AI BREEDING OF DAIRY COWS

J. S. Stevenson

Summary

Management of the estrous cycle is now more practical than it was a decade ago because of our understanding of follicular waves. With availability of three gonadotropin-releasing hormone (GnRH) products and two prostaglandin products, the cycle can be controlled for fixed-time inseminations with little loss in conception rate compared to inseminations after detected estrus. Various systems are effective for programming first inseminations with or without some heat detection. With the incorporation of transrectal ultrasonography for early pregnancy diagnosis 28 to 30 days after insemination, routine heat detection programs could be eliminated by reprogramming each cow after an open diagnosis. The most limiting factor in the control of the cycle is the proportion of missed heats in estrus-synchronization programs that rely partly or solely on heat detection. Pregnancy rate (the proportion of cows that become pregnant of all cows programmed for insemination) is the best measure of an estrus-synchronization program, because it measures total number of pregnancies achieved per unit of time rather than simple conception success at any given insemination.

(Key Words: AI Breeding, GnRH, Prostaglandin $F_{2"}$, Programmed Breeding, Economics.)

Introduction

Improving dairy herd reproductive management requires an understanding of the basic principles of getting cows pregnant. It is critical to understand each component of the estrous cycle as well as the annual reproductive cycle (calving interval) and determine where limited time and resources might be best concentrated to reach A.I.-breeding goals. A calving interval consists of four major components. The first component is the rest period or elective waiting period (EWP). The duration of this period is partly a management decision. This period varies from 40 to 70 days on most farms. Part of its duration is based on the physiological need of the cow, in which the reproductive tract must undergo an involution process (return to its nonpregnant size and function). Research indicates that when cows calve without complication, this healing process requires no more than 40 days. This process includes macro- and microscopic processes that prepare the uterus for another pregnancy.

The second component is the period of time between the end of the EWP and when the first estrus is detected for the first AI breeding. The duration of this period is a function of the heat detection rate as well as whether or not some hormonal regimen is used to bring cows into estrus after the end of the EWP (e.g., $PGF_{2"}$). Whether or not $PGF_{2"}$ is used to bring cows into estrus for first services, the percentage of cows detected in estrus depends on the rate of heat detection or the efficiency of detecting estrus in all cows.

The third component of a calving interval is the active AI breeding period for each cow and represents the number of days required for the cow to conceive after the first AI service. If a cow conceives at first service, then the third component is nonexistent. Otherwise, it is a function of the heat detection rate and the level of herd fertility. The level of herd fertility depends upon a number factors, including sire and cow fertility, correct thawing and handling of semen, AI breeding technique, and timing of insemination. Fertility and heat detection rates are very important to establishing pregnancy in a timely fashion.

The fourth component of a calving interval is gestation. The duration of gestation is fairly constant. It can't be shortened significantly without adversely affecting the health or viability of the newborn calf.

Based on these component parts of a calving interval, an EWP of 40 to 50 days is probably sufficient for essentially all cows. With a rate of heat detection of 65% and a conception rate of 65%, the average period from the end of the EWP until pregnancy is established in 95% of the cows should be 35 days. This means that some cows conceive immediately following the end of the EWP and others remain open for 100 or more days. With an EWP of 50 d, estrus and conception rates of 65%, and a gestation period of 280 d, an average calving interval of 365 days (50 + 35 + 280 = 365) is attainable, when it is desired that 95% of the cows conceive.

Follicular Growth during the Estrous Cycle

A follicle is similar to a fluid-filled water blister and contains the egg. The follicle is composed of an outer layer of cells (theca cells), which are exposed to blood capillaries. Blood delivers gonadotropic hormones (FSH and LH) from the anterior pituitary to the follicle, which stimulate its growth, production of gonadal steroid hormones, and growth and maturation of the egg. Inside the follicle, another group of cells (granulosa cells) surround a fluid-filled cavity that forms the antrum of the follicle. These cells take the androgen precursors (stimulated by LH) produced by the thecal cells and synthesize estrogen (stimulated by FSH). Deep in the antrum, surrounded by specialized granulosa cells, is found the microscopic egg cell. Hundreds of thousands of these follicles are found in the ovaries of the heifer at birth. Once she reaches puberty, these follicles grow in a cyclic fashion from diameters of <1 mm to ovulatory sizes of 16 to 18 mm in diameter .

For many years it has been known that as follicles grow, some eventually ovulate, whereas others become atretic (die). Earlier, it was thought that follicular growth was either bimodal or continuous. More recently, it was assumed that whatever follicle had reached ovulatory size at the right time during the cycle would be the one that would eventually ovulate. Although this concept is probably correct, it was based on the fact that at least one large follicle can be palpated in the ovaries on almost every day of the estrous cycle.

With the use of the real-time, B-mode ultrasonography, the same type of equipment used in hospitals by physicians to monitor development of human babies within the uterus of their mothers, we can examine the growth of follicles in cattle. This same technology is used to measure backfat and loin-eye areas in finishing cattle and pigs. The probe is inserted into the rectum with the gloved hand just above the reproductive tract as if the cow were palpated. Placement of the probe in this position allows visualization of the ovaries, uterine horns, and cervix. The probe emits ultrasound waves that are absorbed by fluid-filled cavities and appear on the viewing screen as images in various shades of grey or black. Follicles appear as round black circles, and the corpus luteum (CL) looks like a peppery elliptical structure.

Using this technology on a daily basis, several patterns of follicular growth have been described, along with new terminology to describe the dynamics of follicular growth. These terms were borrowed from similar studies performed in monkeys. Figure 1 shows the diameters of several follicles during the estrous cycle of a cow. Two groups or "waves" of follicles developed during the cycle. On days 1 and 2, four follicles were visualized, but only one continued to grow (dominant) from this group (cohort) and "dominated" the other (subordinate) smaller follicles. The subordinate follicles underwent atresia (death) and were no longer useful. The first dominant follicle underwent a growth phase (d 1 to 6), a static phase (d 7 to 9), and a regressing phase (d 11 to 12 or longer). The second wave of follicles visualized appeared around days 9 to 11, one of which dominated the other follicles and became the second dominant follicle that eventually ovulated after luteolysis (death of the CL).

Although any number of follicles can make up a wave of follicles, usually only one to six develop in a wave. The first wave and its

dominant follicle always appear at the same time during the cycle in all cows. A "two-wave" cow has an estrous cycle of 21 days. Two-, three-, and four-wave cycles have been observed in cattle, with the appearance during the cycle of the second, third, or fourth wave being more variable than the first. Estrous cycles become longer with increasing number of follicular waves. Two-wave cycles are 19 to 20 d, and four-wave cycles tend to be 23 to 25 d in duration.

The growth of a group of follicles that make up a wave is initiated by a transient increase in blood FSH, which is observed 1 or 2 days before the beginning of each follicular wave. Estrogen in the blood also rises and falls with the growth and regression of a dominant follicle. The dominant follicle apparently dominates its subordinate peers by producing substances that inhibit their further growth.

Variation in the Interval to Estrus after $PGF_{2\alpha}$

When $PGF_{2\alpha}$ was being tested as an estrus-synchronization hormone in cattle, a common endpoint to measure its success was the proportion of cows observed in heat during a 2- to 5-day period after injection. That period reflected the proportion of cows that had a functional CL secreting high blood concentrations of progesterone at injection time. Any cow coming into estrus much before 48 h most likely had natural or spontaneous luteal regression before the $PGF_{2\alpha}$ injection. These cows showing estrus before 48 hr were likely on days 19 to 21 of their cycles when $PGF_{2\alpha}$ was injected. Approximately 2 to 5 days after the injection, cows would come into estrus because blood progesterone would return to baseline concentrations within 12 to 24 hr, and the CL would no longer be functional. Interestingly, regardless of how soon a cow came into estrus, concentrations of progesterone would return to baseline at nearly the same time.

We have learned that the variable part of this interval is the period of time during which the follicle matures and induces estrus by secreting high concentrations of estrogen. So it seems that interval to estrus after $PGF_{2\alpha}$ was not related to concentrations of progesterone during the estrous cycle but rather to the relative maturity of a developing follicle at the time of $PGF_{2\alpha}$ injection or luteal regression.

What would happen if $PGF_{2\alpha}$ were injected at various stages of the cycle? Intervals to estrus are dependent on the relative diameter (maturity) of the dominant follicle at the time of $PGF_{2\alpha}$ injection. Short, medium, and long intervals to estrus after $PGF_{2\alpha}$ are based on when $PGF_{2\alpha}$ is injected in the cycle. So if $PGF_{2\alpha}$ were given when either a first or second dominant follicle is quite mature (large in diameter), the interval to estrus would be much shorter than if $PGF_{2\alpha}$ were given at mid cycle between follicular waves or later in the cycle when the second dominant follicle is relatively larger in diameter.

Evidence exists for these different intervals based on studies conducted in dairy heifers when $PGF_{2\alpha}$ was given at various stages of the cycle. Assuming that most heifers have two follicular-wave cycles, then injections of $PGF_{2\alpha}$ at various phases of follicular maturity, whether given while the first or second dominant follicle was present, would produce the various intervals to follicular maturation, estrogen secretion, and the onset of estrus (Table 1).

Is conception rate affected when $PGF_{2\alpha}$ is given at different times? Apparently it is not, as long as inseminations were based on detected estrus. For example, if a $PGF_{2\alpha}$ injection is given on day 6 or 7, when the first dominant follicle is growing (Figure 1), the CL would regress and the first dominant follicle would ovulate and be normally fertile when AI breeding was performed after detected estrus. Similar results occur for any dominant follicle that is in its growing phase at the time of $PGF_{2\alpha}$ injection.

Pregnancy Rate

Several factors determine the number of pregnancies or the number of calves born (e.g., herd fertility, technician ability, sire fertility, and heat detection rate). One method to examine the success of the insemination program is to determine the number of cows that become pregnant during each 21-day period after the end of the EWP. This concept is suggested to

be the best measuring stick for success of AI breeding.

The pregnancy rate (PR) equation can be simplified to two factors: heat detection rate (HDR) and conception rate (CR) or PR = HDR × CR (Table 2). Conception rate is determined by herd and sire fertility plus inseminator proficiency. Using the simplified method of determining pregnancy rate, one can evaluate the success of the AI breeding program, including whatever programmed breeding system is used to synchronize estrus for first services after calving. Let's assume a 50-day EWP. Because no cows are AI bred until after 50 days, 100% of the fresh cows are open at that time. By graphing the percentage open, we can generate a curve that looks similar to those in Figure 2. At 50 days in milk, 100% of the fresh cows are open, and following heat synchronization and first services and as a result of inseminations at repeat estrus, the percentage of open cows decreases with each subsequent estrous cycle or 21-day period.

Heat Detection and Conception Rate

The downward slope of those generated curves (pregnancy rate) in Figure 2 are determined by the number of cows detected in estrus and their resulting conception rate after each AI breeding. In Table 3, a few examples of various heat detection and conception rates are shown to illustrate their effects on pregnancy rate during each 21-day period. In the first four examples, holding heat detection rate constant at 60%, conception rates were varied from 30 to 60% (low to high). The resulting pregnancy rates range from 18 to 36%, or in other words, 18 to 36% of the cows detected in estrus and inseminated became pregnant during each 21-day period. In the last four examples in Table 3, conception rate was held constant at 50%, and heat detection rate varied from 40 to 70% (low to high). Resulting pregnancy rates ranged from 20 to 35%. The number of pregnancies achieved during each 21-day period, or after each additional estrous cycle, can be affected by various rates of conception and heat detection. For example, one herd could achieve a 24% pregnancy rate with better than average heat detection (60%) and an average conception rate (40%), whereas another herd could achieve a similar pregnancy rate (25%) with average heat detection (50%) and better than average conception rate (50%).

Percentage Open Curves

Using the first example (first four lines of data in Table 3), four curves are plotted in the Figure 2. The upper curve represents an 18% pregnancy rate for each 21 days. The remaining curves represent 24%, 30%, and 36% pregnancy rates. A horizontal line drawn across the graph at the 50 percentage open mark approximates average days open for each pregnancy rate curve. Using this method of evaluating the number of pregnancies established during each 21-day period after the end of the EWP, one can see how improvements in either heat detection rate, conception rate, or both can increase the number of pregnancies achieved in the AI breeding program. Because conception rate is determined easily, one also can estimate the herd heat detection rate by dividing the pregnancy rate for each 21-day period by the conception rate during that same period.

Programmed Breeding

Most dairy producers appreciate the benefits and advantages of using an estrus-synchronization program. Synchronizing estrus in cattle simply makes occurrence of estrus more predictable and AI breeding more convenient. Dairy producers have benefitted from the superior genetics of proven bulls, which have increased pride of ownership in better-bred cattle, as well as providing a pay off in greater milk production. Although most are sold on the idea of using heat synchronization, one question most frequently asked by dairy producers and dairy veterinarians is: What is the best way to synchronize estrus in dairy cows and heifers for AI breeding?

The program used successfully on dairy farms is probably the one that is the most simple to execute. Although heat synchronization of large numbers of cows and heifers is not typical on most dairy farms, except in large herds or where seasonal calving is practiced, one needs to develop a system for identifying cows (based on days after calving) and heifers (based on

age) that should go into each breeding group cluster.

The breeding cluster is one method that can be used. For example, if the EWP is 50 days before AI breeding, then a breeding cluster of cows can be organized that falls within a certain range of days in milk to fit the targeted first breeding date. These cows can be identified easily from a breeding wheel, computer records, or by simply keeping a chronological list of calving dates. In our herd of 200 cows, we cluster cows that calve during a 3-wk period so that the freshest cow in the cluster meets the minimum acceptable EWP. When the EWP is 50 days, then a cluster would consist of cows that are 50 to 71 days in milk during the targeted breeding week. Therefore, the average interval to first insemination is 60 days for the herd. Cows that fail to conceive should return to estrus during the breeding week of the next cluster of cows, which would be estrus-synchronized for AI breeding 3 wk after the first cluster of cows. This clustering method allows first services and repeat inseminations to occur during the same week, thus concentrating most inseminations during 1 wk out of every 3 wk. This same system can be employed for AI breeding of replacement heifers when they reach an acceptable age and weight to enter a breeding cluster.

In larger herds, grouping cows into a 1-wk cluster is necessary. This 1-wk cluster simplifies AI breeding of cows that meet the breeding criteria on a weekly basis. Therefore, during the period before the cows reach their targeted breeding date (based on days in milk and the EWP), estrus is synchronized to occur during each breeding week. Usually, the synchronization period is set so estrus or fixed-time insemination will occur in the Monday-to-Friday work week.

Choosing a Breeding System

Once a system is in place to identify cows and heifers that fit those criteria for inclusion in an AI breeding cluster, then the specific programmed breeding system is fit into a weekly management sequence. What successful programs are available? There are two general categories of programs from which to choose: 1) $PGF_{2\alpha}$; or 2) gonado-tropin-releasing hormone (GnRH) + $PGF_{2\alpha}$. The first involves using either of two prostaglandin products that are available in the U.S. market (Lutalyse® and Estrumate®). The second category uses either of three GnRH products (Cystorelin®, Fertagyl®, or Factrel®) plus a prostaglandin product in combination with heat detection or a fixed-time insemination.

Targeted® Breeding Program

The Targeted Breeding program has been promoted by one of the $PGF_{2\alpha}$ manufacturers (Pharmacia & Upjohn) for synchronizing the AI breeding of lactating cows in a herd (Figure 3). Injections of $PGF_{2\alpha}$ are administered 14 days apart. This interval is simply based on the fact that sufficient time must pass after the first injection so those females responding to the first injection (their CL regresses and they come into estrus) have a new CL that is mature enough to respond to a second injection (at least on day 6 of the estrous cycle). In addition, those females that were not in a stage of the estrous cycle with a CL that could regress after the first $PGF_{2\alpha}$ injection should be responsive 14 days later. Targeted Breeding calls for the first injection (so-called set-up injection) to be given 14 days before the EWP ends. No cows are inseminated after the first injection, although about 50% show estrus in response to the first injection. The second injection (first breeding injection) then is given just prior to the end of the EWP, so first services can occur when cows are eligible for AI breeding. The Targeted Breeding program then suggests that if no estrus is detected after the second injection, a third injection (second breeding injection) is given in another 14 days. If no standing estrus is detected after this third injection, then one fixed-time insemination can be given at 80 hr after this third injection of $PGF_{2\alpha}$.

Ovsynch

The second method (named Ovsynch) is similar to the previous program, except it requires no heat detection (Figure 4). In fact, it is described more accurately as an ovulation synchronization program; hence the name, Ovsynch. An 100-µg injection of GnRH is given 7 days before a $PGF_{2\alpha}$ injection, and then

a second 100-µg injection of GnRH is administered 36 to 48 hr after $PGF_{2\alpha}$, with one fixed-time insemination given 8 to 20 hr later. (A recent study has found that 1 mL or 50 µg of Cystorelin is sufficient.) The first GnRH injection alters follicular growth by inducing ovulation of the largest follicle (dominant follicle) in the ovaries after the GnRH injection to form a new or additional CL. Thus, estrus usually does not occur until after a $PGF_{2\alpha}$ injection regresses the natural CL and the secondary CL (formed from the follicle induced to ovulate by GnRH). Therefore, a new group of follicles appears in the ovaries (based on transrectal ultrasonographic evidence) within 1 to 2 days after the first injection of GnRH. From that new group of follicles, a newly developed dominant follicle emerges, matures, and can ovulate after estrus is induced by $PGF_{2\alpha}$, or it can be induced to ovulate after a second injection of GnRH. The GnRH injections release pituitary luteinizing hormone (LH), the natural ovulation-inducing hormone of the estrous cycle. Few cows will show heat in this program. About 8 to 16% may show heat around the time of the $PGF_{2\alpha}$ injection. If so, those cows should be AI bred according to the AM-PM rule and the second GnRH injection eliminated.

This program works in replacement heifers, but because of lower pregnancy rates than can be achieved with other programs, it is not recommended. For some unexplained reason, the first GnRH injection fails to ovulate a follicle about 50% of the time in heifers compared to about 17% failure in lactating cows. We have found that the fixed-time insemination (Ovsynch) produces slightly lower conception rates than are achieved when AI breeding is done after detecting a cow in standing estrus (GnRH + $PGF_{2\alpha}$ + heat detection). However, looking at the number of pregnancies achieved per unit of time, we find that the second program is very competitive.

When fixed-time inseminations are performed in cows that you are attempting to A.I.-breed, then by definition conception rate is the same as pregnancy rate, because the heat detection rate (AI submission rate) is 100%. Therefore, PR = HDR × CR becomes PR = 1 × CR or PR = CR. For example, let's compare a traditional AI program that uses heat detection to Ovsynch in which no heat detection is necessary prior to first service (Table 4). If 70% of the cows in the traditional program are submitted for insemination (70% heat detection rate), with a 50% conception rate, 35% of the cows become pregnant in a 21-day period. With an Ovsynch program, 100% of the cows are inseminated, and with a similar conception rate, 50% of the cows become pregnant in a 10-day period. Therefore, 15 more pregnancies are achieved at a similar conception rate because all cows eligible for insemination are AI bred; or in other words, 30 eligible cows in the traditional program were not inseminated because they were not detected in heat. Therefore, more pregnancies can be established per unit of time.

Costs of Heat Detection

Programmed breeding systems not only provide an organized approach to administering first AI breedings to dairy cows or dairy heifers, but should be cost-effective in most herds. Can one determine whether or not the program-breeding system is cost-effective?

The biggest problem in estimating the cost of a programmed-breeding system is estimating the real dollar value of heat detection and the convenience factor of using a programmed-breeding system. If all cows were AI bred during one season of the year (seasonal calving and breeding), the value of heat detection could be determined more easily as a component of the total number of pregnant cows at the end of the breeding season. Perhaps a similar value could be determined by calculating the number of pregnant cows at 100 or 150 days in milk, or the number pregnant after one round of a programmed breeding system. In this way, the value of heat detection, as a component of the pregnancy rate equation, might be estimated.

Because programmed breeding systems basically are designed to synchronize estrus before the first A.I.-breeding, cows must be watched to observe the repeat estrus that occurs when they fail to conceive to first service. One way to eliminate heat detection almost completely would be to determine an early pregnancy status (for example, by day 15, which is not possible now) before an open cow repeats to estrus and then synchronize the

repeat estrus so no heat detection is necessary. Another way would be to use ultrasound and diagnose pregnancy at 28 to 30 days and then reprogram the next estrus in the nonpregnant cows. Even with that approach, some cows will be repeating to estrus at 21 to 23 days after their first AI breeding that should have been detected in estrus and reinseminated before the pregnancy test. Therefore, our current programmed breeding systems require daily heat detection to pick up the repeat estrus. That being the case, the cost of heat detection should be viewed as a fixed cost just as milking labor.

Costs of Programmed AI Breeding

Assessing the costs of using programmed AI breeding is not easy. Further, most producers assume that it is more costly because of the extra labor, semen, and hormones. Table 5 summarizes how programmed breeding pays for itself. Let's assume that you are using Ovsynch and want to compare that to AI breeding cows based on heat detection, perhaps coupled with tail chalk, tail paint, or even Kamar®or Bovine Beacon® heat-mount patches. The total cost of Ovsynch is about $38 ($13 for the three injections, $5 for labor to administer injections, $15 for semen, and $5 for AI breeding). That compares to $20 (semen + AI breeding) for the traditional approach. If we assume that conception rate is 40% in both cases, then at a 70% heat detection rate, the traditional program would produce 28 pregnancies (70 × 40) and Ovsynch would produce 12 more pregnancies or 40 in total.

What is the additional value of those 12 pregnancies? To determine this, we need to estimate the value of one pregnancy after the cow has already failed to conceive once. It takes about 63 days to get a cow pregnant after the first unsuccessful service, so at only $1 per day, the pregnant cow has a $63 greater value compared to the nonpregnant cow. On average, 2.5 more doses of semen + AI labor will be needed or $50 more per pregnancy. If we assume that 20% of the cows will fail to conceive, the cost of a replacement heifer is $1200, and the value of a cull cow is $500, then we must add $140 ($700 × 20% culls). So one additional pregnancy is worth $253 ($63 + $50 + $140). Because those 12 additional pregnancies cost us $200 each, we have a positive return on our investment of $53.

Now if heat detection is closer to 50% as in most herds, then only 20 pregnancies are achieved in 21 days and that is 20 less that what is achieved with Ovsynch. Each of those pregnancies would cost only $140 ($3800 Ovsynch costs - $1000 traditional costs/20). Because of poorer heat detection, it will take one more estrous cycle or 84 days to get 80% of the remaining cows pregnant, so the value of a pregnant cow is $84 more than that of the open cow. The costs of semen, AI breeding, and culling are the same, so the value of one additional pregnancy at a 50%-heat detection rate is $274 ($84 + $50 + $140). That means the cost of

$140 per each additional pregnancy gained by Ovsynch gives a positive return of $134. Clearly, Ovsynch or other programmed AI breeding systems can pay for themselves because more cows become pregnant per unit of time, so even though more costs are associated with their use, the return on investment is greater. Based on these cost estimates, as either heat detection, conception rates, or both decline, the programmed AI breeding, in this case, Ovsynch, pays for itself.

These differences between the two programs might be even greater, if the costs of heat detection and tail chalk, tail paint, or heat-mount detectors in the traditional program were included. We know that heat detection cannot be eliminated completely, so it leaves us wondering how to estimate the real costs of administering a programmed-breeding system. Of course, many variables determine the cost-benefit ratio of a given system on each farm, for example, the number of cows, type of housing, cost and availability of skilled labor. The selection of the best programmed-breeding system for an individual herd also depends on that herd's rate of heat detection. Those herds with excellent heat expression and(or) heat detection may be served best by programs with less hormonal intervention.

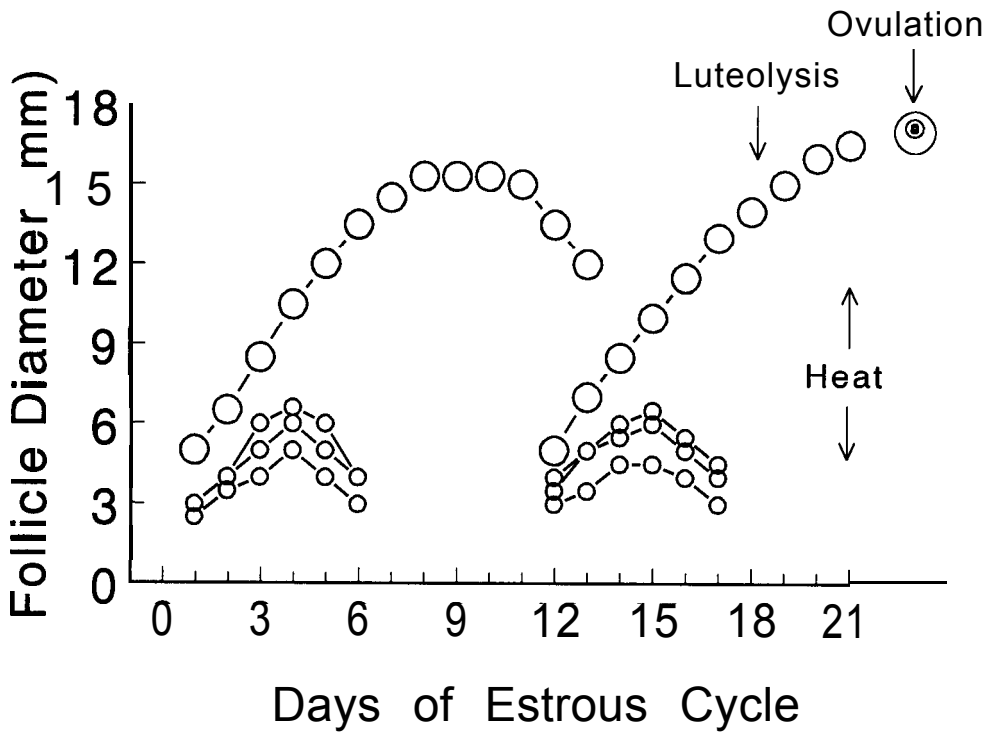


Figure 1. Follicular Wave of a "Two-Wave" Cow during the Estrous Cycle.

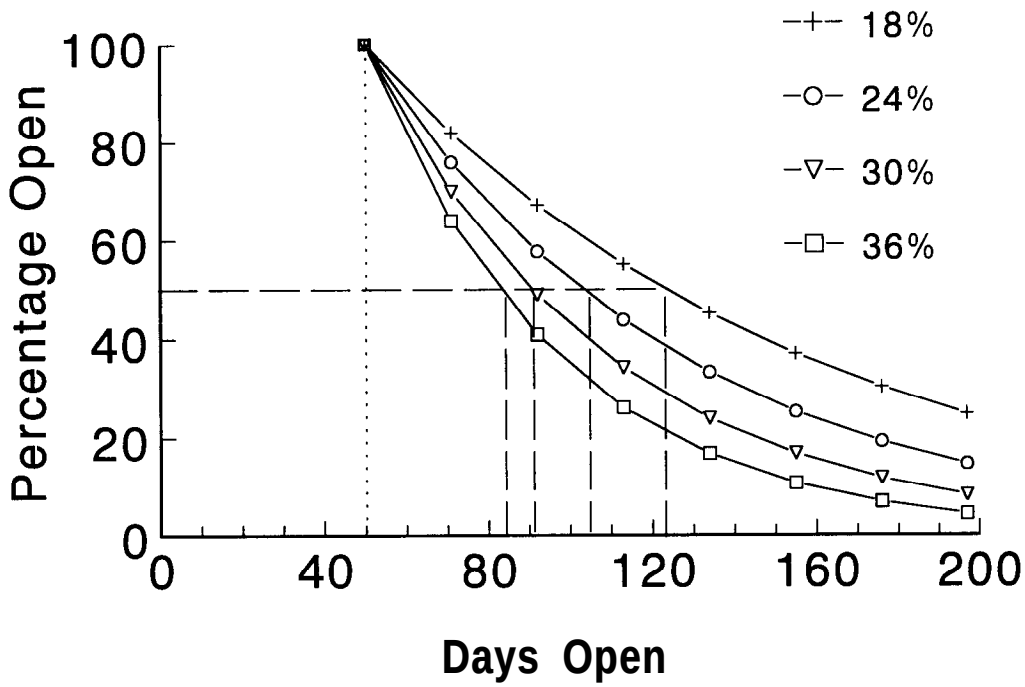
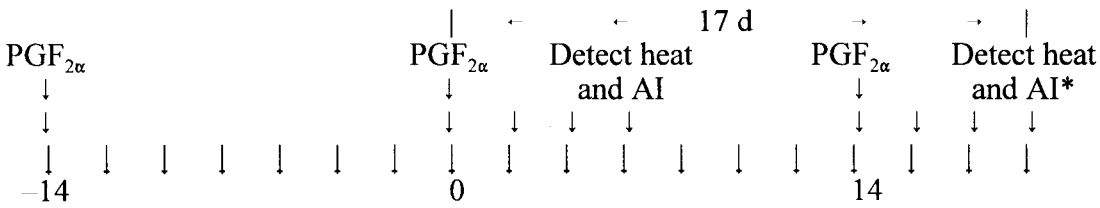


Figure 2. Pregnancy Rate Curves with Estimated Days Open.



Days from the end of the EWP (d 0)

***In the absence of detected estrus, AI at 80 hr after $PGF_{2\alpha}$.**

Figure 3. Targeted Breeding® Program.

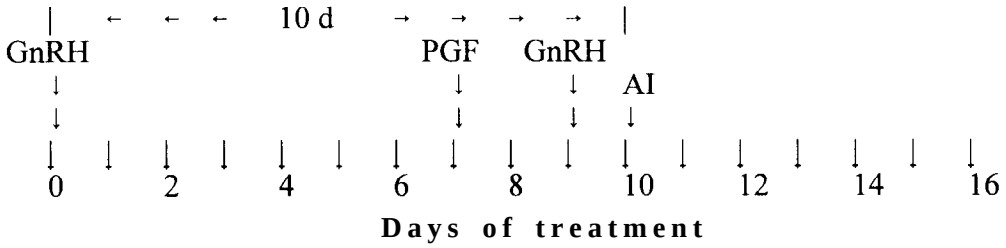


Figure 4. Ovsynch.

Table 1. Hours to Estrus after $PGF_{2\alpha}$ Injections at Various Stages of the Cycle

Study	Short Days 5-8	Long Days 8-11	Medium Days 12-15
A	48	–	60
B	49	–	61
C	44	71	53
D	54	70	–
Unweighted average	47	70	58

Table 2. Definitions of Heat Detection, Conception, and Pregnancy Rates

Heat detection rate (HDR)	=	number of cows inseminated / number of cows synchronized
Conception rate (CR)	=	number of pregnant cows / number of cows inseminated
Pregnancy rate (PR)	=	number of pregnant cows / number of cows synchronized
PR	=	HDR × CR

Table 3. Examples of 21-Day Pregnancy Rates

Heat Detection		Conception Rate		Pregnancy Rate
HDR	×	CR	=	PR
60	×	30	=	18
60	×	40	=	24
60	×	50	=	30
60	×	60	=	36
40	×	50	=	20
50	×	50	=	25
60	×	50	=	30
70	×	50	=	35

Table 4. Pregnancy Rates Achieved with Traditional Heat Detection[1] and Ovsynch[2] Programs During 21 Days

Item	Traditional	Ovsynch
No. of cows attempted for AI in 21 days	100	100
No. of cows submitted for AI (heat detection rate), %	70	100
Conception rate, %	50	50
Pregnancy rate[3], %	35	50

[1] Observation for estrus and no hormone use or estrus-synchronization program.
[2] See Figure 4.
[3] PR = HDR × CR.

Table 5. Comparison of AI Breeding Costs of Ovsynch and a Traditional Heat Detection Program without Hormonal Intervention

Per Cow	Traditional	Ovsynch
Hormones[1], $	0	13
Labor, $	0	5
Semen + AI[2], $	20	20
Total costs, $	20	38

Per 100 Cows	Heat detection rate, %			
No. of cows inseminated	50	70	100	100
No. of pregnancies[3]	20	28	40	40
Cost for 100 cows[4], $	1000	1400	3800	3800
Cost per pregnancy[5], $	50	50	95	95
Increased no. of pregnancies by Ovsynch[6]			+20	+12
Total cost of additional pregnancies[7], $			2800	2400
Per cow cost of additional pregnancies[8], $			140	200
Value of additional pregnancy[9], $			274	253
Semen + AI labor, $			50	50
Additional days open at $1 per day			84	63
Replacement cost, $			140	140
Net return per additional pregnancy, $			+134	+53

Source: Adapted from Hoard's Dairyman, September 10, 1998, p. 662.

[1] Cost of $PGF_{2\alpha}$ = $3 and two doses of GnRH = $5.

[2] Cost of semen = $15 and insemination = $5.

[3] No. of pregnancies or pregnancy rate = heat detection rate × conception rate (40%).

[4] No. inseminated (50, 70, or 100) × cost per cow.

[5] Cost per 100 cows divided by the number of pregnancies.

[6] Compared to 50% and 70% heat detection rates, respectively.

[7] Difference in cost for the traditional and Ovsynch programs at each heat detection level.

[8] Cost of additional pregnancies divided by the number of pregnancies.

[9] Cost of 2.5 more services (40% conception rate) + average of 63 or 84 days open to impregnate successfully 80% of the 12 or 20 remaining open cows (not pregnant after first service in the traditional program), respectively, + the cost of replacing 20% of open cows with replacements valued at $1200 each and cull cows worth $500.

PERFORMANCE OF LACTATING DAIRY CATTLE IN THREE DIFFERENT COOLING SYSTEMS

M. J. Meyer, J. F. Smith, J. P. Harner III[1], J. E. Shirley, and E. C. Titgemeyer

Summary

Ninety-six Holstein multiple-lactation cows averaging 115 days in milk (DIM) and 60 Holstein first-lactation cows averaging 97 DIM at the initiation of a 10-wk study between June 10 and August 22, 1998 were used to evaluate the effectiveness of three different cooling systems. Thirty-two multiparous cows and 20 first-lactation cows were assigned to each of three pens that contained different cooling systems. The three cooling systems consisted of : 1) a single row of 36-inch fans, spaced at 24-ft intervals over the freestalls and over the feed row, 2) 56-inch ceiling fans spaced at 12-ft intervals over the freestalls, and 3) polytube longitudinal cooling over the freestalls. Each of the three cooling systems utilized similar sprinkler systems located over the feed line. Dry matter intake, respiration rates, milk production, and body condition scores were measured. Cows cooled with overhead 36-inch fans produced more milk and had lower respiration rates than those cooled with other methods. The cows cooled with ceiling fans tended to produce more milk than those cooled via the polytube. Dry matter intake also tended to be greater for cows cooled by overhead 36-inch fans.

(Key Words: Heat Stress, Dairy, Milk Production, Cooling.)

Introduction

Elevated temperature and humidity during the summer months have dramatic effects on milk production of dairy cows. Heat stress occurs when the cow's heat gain is greater than her capacity to lose heat. Her heat load increases as the summer temperatures and relative humidity increase, whereas her ability to dissipate heat decreases. Cows regulate body temperature by increasing respiration rate, water consumption, and sweating and by decreasing feed intake. These combined events depress milk production and limit reproductive performance because of the shift in energy from those functions to body temperature regulation. The primary way dairy cows dissipate heat during heat stress is by evaporative cooling. Cooling occurs when sweat or other moisture is evaporated from the skin or respiratory tract. This explains why dairy cattle sweat and have higher respiration rates during heat stress. High humidity limits the ability of the cow to take advantage of evaporative cooling. By providing fans with sprinkler systems, the amount of evaporative cooling and the rate at which the cow dissipates heat are increased.

The objective of this study was to evaluate the effectiveness of three different cooling systems to reduce heat stress in lactating dairy cows. Cost of operation, initial investment cost, and milk production were used to evaluate the economics of the systems.

Procedures

Ninety-six older and 60 first-lactation cows were paired by DIM, milk production, and lactation number. Four pens with 100 Holstein cows per pen were housed within a 4-row freestall barn at a commercial dairy near Palmer, KS. The dimensions of the open-sided, east-west aligned barn were: length 420 feet, width 100 feet, eave height 13 feet, roof pitch 4:12, and ridge row width 30 inches. Each of the

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three pens contained 20 first-lactation and 32 multiparous cows monitored for this study plus other nonexperimental cows. Pens that housed cows in this study were located in the southwest, northeast, and northwest sections of the barn. Fans in all three systems were activated automatically at 72EF.

The first cooling system (FF) in the southwest section of the barn consisted of 14, 36-inch diameter circulation fans with 0.5 horsepower motors. A single row of fans was mounted every 24 ft over the freestalls and feed line and angled down at a 30E angle. Airflow delivery rates per fan ranged from 10,000 to 11,500 cfm.

The second cooling system (CF) in the northeast section of the barn used 14, 56-inch ceiling fans with 0.1-hp motors and a rating of 21,000 cfm. Fans were mounted 12 ft on center with a downward air movement.

The third cooling system (PT) located in the northwest section of the barn used four, 36-inch fans with 0.5 hp motors. Large polytubes were attached to the fans, and when turned on, the fans inflated the tubes. The fans and tubes were mounted 8 ft above the freestalls. The polytubes had 3-inch holes at the five and seven o'clock positions at 2-ft intervals.

All of the pens had identical sprinkler systems. The nozzles were rated to deliver 2.5 gal/hr and were spaced 78 inches on center. The sprinklers were set for a 15-min cycle with 3 min on and 12 min off and were activated when the temperature was above 80EF. The designed application rate was 0.02 inches/ft^2 of surface area, which consisted of 12 ft^2/headlock or 24-inch feeding space. The overall application rate was 50 gal/cycle (0.5 gal/24 inches of feed line space) or 16 gpm/pen when a sprinkler system was on.

All eligible cows received rbST at 14-day intervals. Daily milk production data were collected on days –15, 1, 30, 32, 38, 62, 72, and 74 of the study. Body condition of all cows and heifers was evaluated at the beginning and end of the study. Respiration rates were collected weekly on 10 older and 10 first-lactation cows in each treatment. Cows were group fed, and each group received the same total mixed ration. The amounts of feed fed and refused were weighed and recorded daily. Daily dry matter intake values represented the summer averages of all cows per pen and not specifically the 52 experimental cows per pen that were monitored during our study.

Results and Discussion

At the initiation of the study, no difference in the level of production, stage of lactation, or body condition score existed among the three treatments (Table 1). Average milk production of all cows is shown in Table 1. Cows in the FF pen produced an average of 5.5 lb more ($P<0.05$) milk than CF cows and 6.7 lb more milk than PT cows. Milk yield of multiparous cows appeared to be affected more dramatically by the different cooling systems than that of first-lactation cows. Cows housed in FF produced an average of 93.3 lb of milk, whereas CF and PT cows produced 87.3 and 82.3 lb, respectively. First-lactation cows in the FF pen produced 5.1 and 2.4 lb of milk more than CF and PT cows, respectively. Older cows housed in FF produced 6 and 11 lb of milk more than CF and PT, respectively.

Throughout the summer, cows in FF had an average respiration rate of 8.3 breaths/min less ($P<0.05$) than CF and 7.1 breaths/min less ($P<0.05$) than PT cows. The respiration rates of cows in CF and PT tended to be similar, with a difference of only 1.3 breaths/min.

Total amount of feed fed and refused and number of cows per pen were recorded daily. This information was used to calculate dry matter intake per cow per day. Because this information represented averages of all experimental and nonexperimental cows in the pens, statistical analysis could not be completed. Higher dry matter intakes were consistent with increased milk production and reduced respiration rates (Tables 1 and 2).

Body condition was evaluated at the beginning and end of the study (Table 1). Cows in FF, CF, and PT gained averages of 0.32, 0.22, and 0.18 BCS points, respectively. Changes in body condition for mature and first-lactation cows are shown in Table 2. Mature cows

exposed to FF gained more (P<0.01) condition than those in PT.

Table 3 provides an economic analysis of the different cooling systems. This analysis was performed assuming a 20% reduction in milk production if cooling was not provided. The returns on investment for FF, CF, and PT were $84, $50, and $34 per stall, respectively. Sensitivity analysis showed increased milk production to be the biggest single factor affecting economic return.

Conclusion

All of the cooling systems studied had a positive net return on investment, but FF provided the highest return. Cows in FF produced more milk on a daily basis, maintained lower average respiration rates, and tended to have higher daily dry matter intakes.

Table 1. Milk Yield, Respiration Rates, Body Condition, and Feed Intake of Dairy Cows in Three Cooling Systems

	Cooling System[1]			
Item	FF	CF	PT	SEM
Initial milk, lb	94.9	94.3	95.4	1.1
Initial days in milk	105.7	105.8	105.7	1.0
Average milk, lb	88.4[a]	82.9[b]	81.7[b]	1.8
Respiration rate, breaths/min	75.3	83.5	82.3	1.9
Dry matter intake, lb	44.7	42.1	42.1	-
Change in body condition	+0.32	+0.22	+0.18	0.036

[1]FF = Fans over freestalls and feedline, CF = ceiling fans over freestalls, PT = polytube cooling over freestalls, and SEM = standard error of mean.

[a,b]Means with uncommon superscript letters differ (P<0.05).

Table 2. Effect of Lactation Number on Cow Performance in Three Cooling Systems

	Cooling System[1]							
	Mature cows				First-lactation cows			
Item	FF	CF	PT	SEM	FF	CF	PT	SEM
Initial milk, lb	109.1	108.0	109.4	1.4	80.6	80.6	81.4	1.8
Initial days in milk	114.0	115.2	115.6	1.3	97.4	96.4	95.8	1.6
Average milk, lb	93.3	87.3	82.3	2.28	83.5	78.4	81.1	2.73
Respiration rate, breaths/min	74.6	83.6	82.4	2.71	76.0	83.6	82.2	2.69
Change in body condition	+0.31	+0.21	+0.13	0.048	+0.32	+0.23	+0.23	0.055

[1]FF = Fans over freestalls and feedline, CF = ceiling fans over freestalls, PT = polytube cooling over freestalls, and SEM = standard error of mean.

Table 3. Economic Analysis of Three Different Cooling Systems

	Cooling System[1]		
Item	FF	CF	PT
Number of fans per pen	14	14	4
Fan size (hp per fan)	0.5	0.1	0.5
Number of days cooling system used	100	100	100
Hours of operation during summer	1200	1200	1200
Electrical demand charge ($/kW)	10.65	10.65	10.65
Electrical energy charge ($/kWh)	0.0585	0.0585	0.0585
Milk price ($/cwt)	12	12	12
Number of stalls per pen	84	84	84
Annual demand charge for fans ($)	519	104	148
Annual energy charge for fans ($)	368	74	105
Total cost of electricity for fans ($)	886	177	253
Lb of milk needed to pay electricity cost (lb/stall/yr)	87.91	17.58	25.12
Total sprinkler water usage (gal)	66000	66000	66000
Rural water cost per 1000 gallons ($)	1.6	1.6	1.6
Cost of water for sprinklers ($/pen/yr)	106	106	106
Lb of milk needed to pay water cost per year (lb/stall/yr)	10.48	10.48	10.48
Daily milk production (lb/cow/day)	95	95	95
Production loss due to heat stress w/o cooling (%)	20	20	20
Production loss due to heat stress w/ cooling (%)	6.9	12.7	14
Milk production w/o cooling (lb/cow/day)	76	76	76
Milk production w/ cooling (lb/cow/day)	88.4	82.9	81.7
Cooling response (lb/cow/dy)	12.4	6.9	5.7
Feed cost ($/ton)	120	120	120
Extra production due to cooling (cwt/stall/yr)	12.4	6.9	5.7
Total extra income due to cooling ($/pen)	12544.56	6990.48	5745.6
Cost per fan ($/fan)	260	89	450
Expected fan life (yrs)	7	5	4
Total fan cost per pen ($/pen)	3640	1246	1800
Installation of fans in a pen ($/pen)	2838	1462	1462
Fixed and installation costs of sprinkler ($/pen)	500	500	500
Expected sprinkler life (yrs)	5	5	5
Total fixed cost of cooling systems ($/pen)	6978	3208	3762
Fixed fan cost ($/pen/yr)	925.43	541.60	815.50
Fixed sprinkler cost ($/pen/yr)	100.00	100.00	100.00
Variable cooling cost ($/pen/yr)	992	283	359
Feed cost ($/pen/yr)	2903.83	1618.17	1330.00
Interest rate if money was invested (%)	8.00	8.00	8.00
Interest ($/yr)	558.24	256.64	300.96
Gross income due to cooling system ($/pen/yr)	$12,545	$6,990	$5,746
Operating cost due to cooling system ($/pen/yr)	$5,479	$2,799	$2,905
Net income due to cooling system ($/yr/pen)	$7,065	$4,191	$2,840
Return on investment ($/stall/yr)	$84	$50	$34

[1]FF = Fans over freestalls and feedline, CF = ceiling fans over freestalls, PT = polytube cooling over freestalls, and SEM = standard error of mean.

SAMPLING TECHNIQUES FOR AND INTERPRETATION OF MILK UREA NITROGEN CONCENTRATION

J. E. Shirley, M. V. Scheffel, A. F. Park, J. F. Smith, T. G. Rozell, and J. S. Stevenson

Summary

Representative MUN values can be obtained by testing a milk sample before milking, at AM or PM milking, or with an in-line siphon sampling device. MUN values obtained from homogenous milking strings are as accurate as an average MUN value obtained by sampling each cow in the string. Bulk tank sampling is not advisable because of the variation in MUN caused by stage of lactation. Small herds that feed a single TMR should use the average MUN from cows between 60 and 200 days in milk. Monthly sampling is recommended to build a database. The effect of diet changes on MUN can be assessed within 7 days.

(Key Words: Milk Sampling, Milk Urea Nitrogen, Blood Urea Nitrogen.)

Introduction

Milk urea nitrogen (MUN) is a reasonable estimate of blood urea nitrogen (BUN), which, in turn, is a reasonable predictor of the protein status of the dairy cow when used in conjunction with other herd information such as diet, age of the cow, sampling time after feeding, days in milk, stress due to weather, exercise or health status, and method of sampling. Blood urea nitrogen is a by-product of ammonia clearance from the blood in order to maintain blood pH at 7.0. This detoxification event occurs in the liver where two amine groups (NH_2) are bonded to a ketone (C=O) to form urea for excretion primarily in the urine or to be recycled back into the rumen via the salivary glands to serve as a nitrogen source for rumen microorganisms. The urea nitrogen in milk is in equilibrium with that in the blood; thus, milk samples provide a convenient method of determining BUN.

The origin of BUN is primarily ammonia absorbed from the rumen with lesser amounts from protein (or amino acid) metabolism to provide glucose or energy during periods of negative energy balance. The latter source is relatively minor when compared to the ruminal contribution. Therefore, BUN levels provide a reasonably accurate reflection of dietary effects on rumen function. Our work clearly demonstrates that BUN is strongly influenced by feed intake. Figure 1 depicts the changes in blood serum concentrations of urea nitrogen during advancing days in milk and also demonstrates that sampling only a few cows in the herd, without regard to stage of lactation, could provide misleading information.

The purpose of our study was to assess various sampling techniques in order to provide dairy producers with the most convenient method of obtaining MUN values that accurately reflect management changes in the herd.

Procedures

Cows at the Kansas State University Dairy Teaching and Research Center were used to evaluate various milk sampling techniques for MUN analysis. The MUN analyses of all milk samples were conducted at the Heart of America DHIA Laboratory located in Manhattan, KS. Data were collected to determine: 1) if a single quarter sample of milk obtained immediately after prepping and before attaching the milking unit provides an accurate MUN value; 2) if the MUN concentrations in AM and PM samples agree with each other and with an AM/PM composite sample; and 3) if a single string sample accurately reflects the average MUN values of the individual cows within the string. Other data also were collected to illus-

trate effects of the relationship between days in milk and diet changes on MUN values.

Results and Discussion

All dairy producers do not have access to devices that permit them to obtain a homogenous milk sample from each cow nor are they members of a DHIA program. Thus, if MUN levels are to be used as a management tool, it is imperative that a low-cost sampling technique be available to all producers. Further, many DHIA members use the AM/PM program that provides a homogenous sample of either AM milk or PM milk but not a composite sample of both. This study was designed to provide information on various sampling techniques and determine their accuracy relative to composite AM/PM samples.

Milk samples obtained from 104 cows (Table 1) indicate that either AM or PM samples provide a reasonable estimate of an AM/PM composite sample and were within 1 mg/dl of each other. The difference in the two values is not large enough to impact the on-farm decision-making process. Producers that do not participate in DHIA and do not have homogenous sampling devices can utilize a sample of milk from one quarter to evaluate the MUN level in their herd. Table 2 depicts the relationship among quarter samples taken immediately before the milking unit was attached and composite samples obtained after the cow was milked. Samples among quarters contained essentially the same MUN and were within 1 mg/dL of the composite sample. Again, this is well within the tolerance necessary to support management decisions.

Herd managers that group their cows by production or stage of lactation need to know the average MUN level of the group in order to facilitate decisions relative to diet components. An in-line sampling device that continuously siphons a small amount of milk throughout the milking process is being marketed (Heart of America DHIA, Manhattan, KS) as a means of obtaining a representative string sample without having to sample each cow in the string. The value of such a technique is obvious, because it would reduce sampling time and analytical cost. Cows at the Kansas State University dairy were divided into seven strings. One string contained 27 cows, and the other 6 strings contained 24 cows each (Table 3). Individual cows were sampled, and the average MUN values within a string were compared to the appropriate string composite sample. The variation between the two values was less than 1 mg/dL. Therefore, a single string sample provides a reasonable estimate to use in making decisions relative to dietary changes. We should note that this technique should be used only for reasonably homogenous groups. Bulk tank samples for an entire herd will not provide an accurate value because of the variation in feed intake across days in milk as indicated by the variation in MUN values in Table 4. Cows less that 60 days in milk generally have a lower MUN value than cows over 60 days in milk because they eat less. MUN levels tend to decline after 200 days in milk because of a decline in feed intake.

Sampling small herds that feed a single total mixed ration can be accomplished in one of two ways. All cows in the herd can be sampled and sorted by days in milk to provide a herd profile, or cows between 60 and 200 days in milk can be sampled and the average MUN value used to make decisions relative to dietary adjustments. When the entire herd is sampled, the MUN value for cows between 100 and 199 days in milk would be the most appropriate one to use, if at least 25% of the herd falls in this group. If not, then the average value should be used for cows in the 41 to 99 and 100 to 199 days in milk groups.

The impact of diet on MUN is related primarily to the contents of ruminally available protein and carbohydrates and feed intake. Changes in dietary ingredients that result in an increase or decrease in ruminally available protein and carbohydrates usually increase or decrease MUN, if feed intake remains relatively constant. Effective management of MUN levels in the herd requires a knowledge of feedstuffs with respect to their content of ruminally available protein and carbohydrate because of the variation in rumen-undegraded protein and nonstructural carbohydrates among feed grains and common by-product feedstuffs. Further, plant and(or) animal fats generally are included in diets to increase energy density; thus, they are substituted for carbohydrate. This substitution

reduces the amount of energy available to rumen microbes and usually results in an increase in MUN. This is particularly true when grain sorghum is the primary grain source, because it is inherently low in rumen soluble carbohydrates. We observed positive effects on milk yield and milk protein and negative effects on MUN when wheat was substituted for 30% of the grain sorghum in diets on an equal weight basis. The positive effect of wheat was most pronounced when the diets contained approximately 5% fat. Increasing the rumen-undegraded protein from 35 to 40% of total protein by substituting expeller soybean meal for solvent soybean meal in the diet reduced our herd average MUN from 19 mg/dL to 16 mg/dL. This drop in MUN was observed within a week after the diets were changed.

These are a few examples that illustrate the effect of diet on MUN and support the potential benefit of using MUN as a management tool. Routine (monthly) MUN analysis will provide a herd baseline over time that will be useful in the decision-making process and can be supplemented with spot checks approximately 1 wk after diets are changed.

Table 1. Mun Values in AM, PM, and AM/PM Composite Milk Samples from 104 Cows[1]

Time	MUN(mg/dL)	R^2	
AM	16.26	AM to PM	.72
PM	15.18	AM to AM/PM	.89
AM/PM	15.67	PM to AM/PM	.94

[1]Cows fed between 7 and 8 AM and 1 and 2 PM. Feed available at all times.

Table 2. MUN Values in Quarter and Composite Samples from 26 Cows[1]

	Sample				
Item	LR	LF	RF	RR	Composite
MUN (mg/dL)	19.74	19.58	19.58	19.68	20.27

[1]Quarter samples taken after predipping by hand milking into a DHIA sample vial. Composite sample taken from the weigh jar after milking.

Table 3. MUN Values for Individual Cows vs. String Milk Samples

	Strings						
Item	1	2	3	4	5	6	7
No. Cows	27	24	24	24	24	24	24
Composite [1]	20.58	18.92	18.33	19.29	18.06	18.20	18.63
Individual [2]	20.17	18.13	18.00	19.27	18.16	18.37	18.94

[1] Composite sample for each string collected with an in-line sampling device.
[2] Individual samples obtained from weigh jar and represent the average of the cows in a string.

Table 4. MUN Herd Profile by Days in Milk

DIM	**No.** of cows	Milk, lb	Fat, %	Protein, %	MUN, mg/dL
0 - 40	14	61.3	4.60	3.20	12.7
41-99	48	93.6	3.20	2.85	16.6
100 - 199	64	80.0	3.55	3.15	16.0
200 - 299	58	70.0	3.65	3.35	15.7
300+	29	53.0	3.95	3.65	14.3
Herd Average[1]	213	75.4	3.58	3.21	15.6

[1]Weighted average based on the number of cows per group.

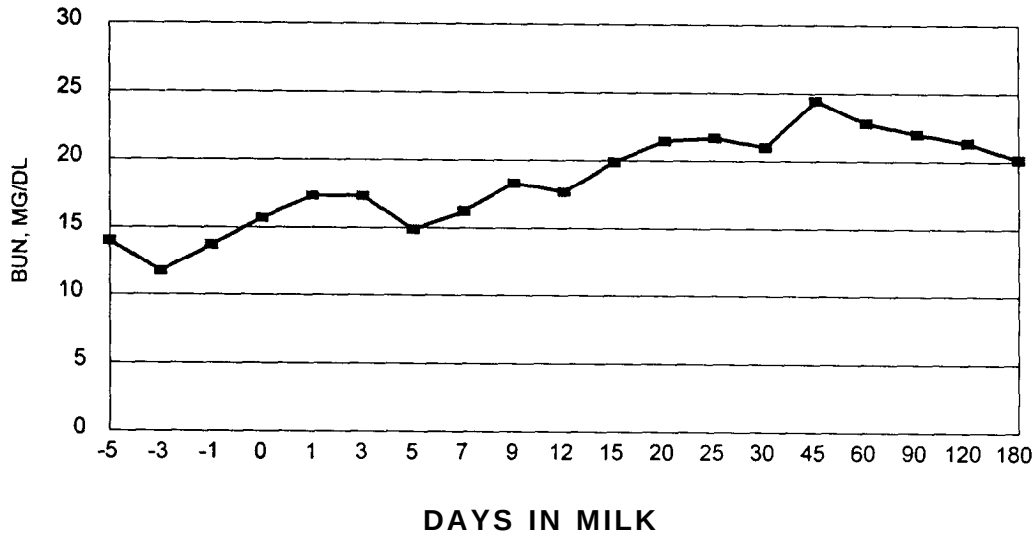

Figure 1. Relationship between Blood Urea Nitrogen and Days in Milk.

FREESTALL BARN DESIGN AND MANAGEMENT FOR COW COMFORT

W. G. Bickert[1] and J. F. Smith

Summary

Proper design, construction, and care of freestalls are essential to cows using the stalls and realizing their potential benefits for comfort and health. Freestall dimensions depend upon particular designs and are compromises between ensuring optimum cleanliness and providing a spacious area for the ultimate in cow comfort. Freestalls designed to meet these fundamental needs will be most used. Most likely, no perfect freestall design exists. Rather, several freestall designs may satisfy the basic requirements of the cow perfectly well!

(Key Words: Freestall, Cow Comfort, Bedding.)

Introduction

A freestall is an integral component of a complex system that can be used to enhance profitability on a dairy farm. The freestall itself is a system made up of individual parts that function together to become a vital element of the cow's environment. Therefore, understanding relationships between the cow and the freestall as well as the interactions among individual freestall components is important to design.

Basis for Freestall Design

Cleanliness and comfort are two basic prerequisites that must be satisfied in freestall design and construction. Cleanliness relates to clean, dry conditions, especially the stall bed in the vicinity of the udder. Comfort means a comfortable bed and roomy dimensions to accommodate the cow's ability to move easily in and out of the stall and allow her to lie comfortably therein.

In simplest terms, the main purpose of a freestall is to reduce exposure of the teat ends to mastitis-causing organisms. So every effort is made to provide a clean, dry place for the udder on the freestall bed. Then we expect the cow to choose a freestall for a place to lie down. An effective freestall must be sufficiently appealing to a cow to cause her to choose to lie in a stall 10 to 14 hr per day.

A freestall should enable a cow to rise and lie down naturally (See Figures 1 and 2 for illustrations of the rising movements of a cow). A 1400-lb cow requires 66 inches for body space and about 18 inches for head space. This adds up to 84 inches (7 ft), a commonly recommended freestall length.

Freestalls also must provide lunge space for cows. This space ranges from 10 to 22 inches added to the combined 84 inches for body and head space. Or, the space is 28 to 40 inches measured ahead of the foreknees. Accounting for this lunge space is the first and most important aspect of stall design. It is the key to providing stalls that cows will use readily.

Whether the lunge space is provided either forward or to the side determines both the type of partition to use and the overall length of the stalls. If the forward lunge is to occur within the stall envelope, the recommended length overall is at least 8 ft. Or, if space for the lunge is provided to the side into an adjacent stall space, overall stall length need be only 7 ft. Other

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alternatives are to allow the cow to lunge forward into a stall space opposite the cow or into an adjoining alley or even to the outside of the barn itself.

Types of Freestalls and Components

Depending upon provisions for the thrust of the cow's head during the lunge, freestalls may be in one of two categories—forward lunge or side lunge. Figure 1 shows two examples of forward-lunge stalls and Figure 2 illustrates side-lunge stalls. Certainly, other designs may satisfy the concepts and principles of freestall design equally well. Therefore, an evaluation of a particular freestall begins with assessing its merits in meeting the basic needs of the cow from the standpoint of comfort and cleanliness.

Side-lunge and forward-lunge freestalls differ in partition shape and in stall base design at the front. Designs are similar at the rear of the stall. To reduce injury, both types provide space beneath the lower rail to minimize contact with the hip and pelvic area of the cow.

In a side-lunge freestall, the cow turns and thrusts her head into an adjacent stall space as she rises. The lower rail of the partition is either high enough in the front to allow the cow to thrust her head under the lower rail or low enough to allow the cow to thrust her head over the lower rail without interference. If the cow thrusts her head under the partition rail, the bottom partition rail should be installed a minimum of 28 inches above the stall surface. If the cow thrusts her head above the bottom rail, the bottom partition rail should be a maximum of 7 inches above the stall surface. In the figures, these values are greater, because the dimensions are measured from the top of the back curb, a more stable reference point especially in sand-based freestalls.

In a forward-lunge freestall, additional stall length is needed to allow the cow to lunge forward—either within the stall envelope or through an open front to space beyond. If the lunge is within the stall envelope, the stall must be at least 8 ft long. If the lunge is through an open stall front, provide a minimum of 21 inches of open vertical space.

The brisket board defines the space for the body of the lying cow and discourages her from moving too far forward into the stall when she is in a lying position. A brisket board is essential in a stall where space for the lunge is provided ahead of the cow.

A neck rail across the top rail of the stall partition is important to maintaining stall cleanliness. The neck rail encourages cows to back up when rising and stops cows from moving too far forward when standing without being a nuisance to them. A neck rail that is too low hinders the rising movement. Neck rails should be 66 inches ahead of the alley side of the curb and at least 40 inches above the stall bed.

With side-lunge stalls, make sure that cows have easy, natural access to the lunge space. When the recommended freestall length is used, the partition is mounted such that the cow can easily reach the lunge space. However, making the freestall longer than necessary, say 7.5 ft vs. 7 ft, positions the lunge space 6 inches farther forward in the stall, well ahead of where it should be for cow comfort. Without a brisket board, the cow will move too far forward in the stall, increasing the likelihood of her defecating and urinating in the stall. A brisket board will help position cows to prevent dirty stalls. But cows will still have to reach forward awkwardly to use the lunge space in a longer stall.

Recommended Dimensions

Dimensions chosen for freestalls represent a compromise between cow comfort and cow cleanliness. Stalls must enable cows to lie down and get up naturally and comfortably. Stalls should be wide enough that cows normally do not contact stall partitions in any way that could cause injury or that could damage the partitions. But stalls that are too wide may allow cows to turn around in them or lie diagonally. Stalls that are too long may allow lying too far forward, unless brisket boards are used. All of these conditions increase the possibility of manure being deposited on the stall bed.

Table 1 shows a range in the recommended stall widths and lengths. In our opinion, the lower values of the ranges in the table represent a livable compromise between cow comfort (high rate of stall usage) and cow cleanliness. The upper values, which provide for wider and longer stalls, favor cow comfort over cleanliness and will result in more time being spent in stall maintenance.

Table 1. Suggested Freestall Dimensions

Cow Weight	Freestall Width[1]	Freestall Length[2]		Neck Rail Height above Stall Bed	Neck Rail and Brisket Board Distance from Alley Side of Curb
		Side-lunge	Forward-lunge		
- - - lb - - -	- - inches - -	- - - - - - - inches - - - - - - -		- - - inches - - -	- - - - inches - - - -
800-1,200	42 to 44	78	90 to 96	37	62
1,200-1,500	44 to 48	84	96 to 102	40	66
over 1,500	48 to 52	90	102 to 108	42	71

[1]Width: "center-to-center" with 2-inch pipe partitions.

[2]Length: alley side of the curb to the front of the stall.

With two rows of freestalls placed head-to-head and designed for space-sharing, stall partitions usually are mounted on posts. This allows for unrestricted open space for the forward lunge into the adjacent stall space. When a row of building support posts is located down the center of the two facing rows, spacing between the support posts must be a multiple of the freestall width, 45 inches on center for typical Holstein herds. Otherwise, building support posts will be located periodically in the forward lunge space needed by the cow. Freestall width should determine building post spacing, not vice versa.

In hot climates, consideration to heat buildup in the freestall area may lead to wider freestalls of 48 inches. Although, in a well-ventilated building equipped with cooling fans, the advantage of wider freestalls has not been established.

Freestall Base and Bedding

The stall base and bedding act together to provide a resilient bed with a clean, dry surface. Of all the factors that discourage use of freestalls, the condition of the bed is likely the most important. Avoid beds that are too hard (concrete, concrete with a rubber mat, compacted earth). Swollen hocks and knees result from a bed that does not provide sufficient cushion. Avoid beds with mounds, lumps, or holes. Such conditions reduce comfort for the cow, but, worse yet, can cause difficulties for the rising cow. Lack of comfort and difficulty in rising both discourage freestall use.

Slope the base upward 4% from the rear to the front. Use a curb that puts the stall beds 6 to 10 inches above the alley. The curb must keep scraped manure or flush water out of stalls.

Bedding material added on top of the base absorbs moisture and manure tracked into the stall. It also adds resilience, making the stall more comfortable, and reduces the potential for injuries. Possible materials are straw, sawdust, wood chips, sand, composted manure, ground limestone, shredded newspaper, rice hulls, corn stalks, and peanut hulls. Choice of bedding material may influence selection of a manure handling and storage system. Too much straw or other organic material can build up a substantial crust in a storage area, creating problems with agitation at emptying. The use of

short, fine bedding material reduces the amount dragged into the manure alley.

Two methods have emerged as top candidates: i) mattresses with bedding on top and ii) a deep layer of sand. In our opinion, sand can be considered as the gold standard for a freestall base and bedding. If other materials are to be considered as alternatives and are to be evaluated on the basis of cow comfort, sand is the basis for comparison. The only logical reasons for not using sand would be the difficulty it adds to the manure system or limited availability of high quality sand.

As a cushion or for resilience, loose sand conforms to the shape of body components, e.g., knees or hocks. This reduces pressure on projecting bones and body parts by distributing downward force or weight over a larger area. This is important to the lying cow—her total weight is transferred to the lying surface via the contact point of her body.

Spreading the cow's weight over a larger area also protects her front knees during rising. A cow rising from a lying position lunges forward, transferring the weight of her body forward so she can more easily rise on her hindquarters. The knees act as the fulcrum for this teeter-totter action, and the stall bed provides the cushion for the knees. During the lunge, the weight transfer process increases the downward force on each knee from 350 lb (about 25% of her weight) to 500 lb or more—on each knee! As the sand conforms to the shape of the knee, increasing the area over which this downward weight is distributed, it lowers the potential for injury to the knee.

Loose sand serves to distribute consistently the downward weight probably better than any other material or combination of materials currently in use. Thus, loose sand represents the standard of comparison when evaluating stall beds of various materials for their cushioning effect.

Good footing in the freestall is essential to the cow's ability to lie down and rise easily. In this case, "footing" means not only reducing the tendency to slip, but allowing the cow to more-or-less embed her foot in the surface so as to provide good leverage. When a cow can rise more confidently, rising time is reduced. In addition, the tendency to rock back and forth is lessened, and rising is accomplished more smoothly, reducing trauma to the legs. Loose sand provides excellent "footing". Beds of other materials must be equivalent

A bed of loose sand (6 inches minimum) maintained in the stall area acts as both base and bedding. Sand contributes to cow comfort, good udder health, and cleanliness. In addition, sand kicked into the alleys improves footing. However, the sand should not contain small rocks or pebbles, which could cause damage to the hoof or lameness.

Every 1 to 4 wk, sand should be added to the front of the stall bed, allowing the cow to work it toward the rear of the stall. Sand should be replenished before the front of the stall bed becomes lower than the rear, a condition that makes it difficult for cows to rise and causes them to lie diagonally in the stall. This tends to put more manure in the stalls and leads to dirtier cows.

Sand bedding has many advantages for cow comfort and health, but it may greatly complicate the manure-handling system. Good planning—including selection of a handling system, storage needs, and equipment—is essential.

A dry surface is essential to minimize bacterial growth. The surface of a sand bed stays dry through its infiltration capacity. Dryness of the surface of a bedding mattress is assured only by the presence of dry bedding, e.g., chopped straw or sawdust. Thus, dry bedding on the surface is an essential aspect of a mattress system.

Bedding mattresses, 3 to 4 inches thick, placed over hard stall bases such as concrete or well-compacted earth can provide a satisfactory cushion. A bedding mattress consists of bedding material sandwiched in a fabric—heavyweight polypropylene or other material. Various materials are used as filler—long or chopped straw, sawdust, shavings, and shredded or ground rubber. Mattresses need to be covered with bedding to

reduce friction and to keep them dry. Small amounts of bedding (chopped straw) maintained on top of the mattress help keep the surface dry and improve cow comfort.

When the lying cow tends to slide around while lying down, the friction between her hide and the lying surface can be abrasive. Chopped straw or similar material on a bedding mattress acts as a lubricating layer to reduce abrasions to the skin. Sand sliding over sand has a similar positive effect.

The search goes on for the ultimate freestall bed. Meanwhile, a bed of loose sand and rubber-filled mattresses with organic bedding on top are two methods for satisfying the requirements for freestall beds that promote cow comfort and good udder health. Sand appears to have the advantage. However, either system, properly installed and maintained, can contribute to a desirable environment for the dairy cow.

Freestall Care

Proper freestall care includes daily inspection and removal of wet bedding and manure, besides adding dry bedding periodically. Neglected freestalls with excessive moisture or accumulations of manure can lead to an increased incidence of mastitis.

For stalls with bases such as sand that must be replenished, upward slope of the base toward the front always should be maintained. This upward slope helps position cows more squarely in the stall when lying down, and this contributes to cleaner stalls and cleaner cows.

Selecting and Locating Freestall Barns

Selecting the type of freestall housing is an important decision that should be made with the lactating cow in mind. Several options are available when selecting freestall housing for lactating dairy cows. Some of the options include 2-row, 3-row, 4-row, or 6-row freestall barns. Access to feed and water is reduced by 33% if the length of the feedline and the number of waterer stations are not increased. The advantage of 2-row or 4-row freestall barns is access to feed and water. The advantage of 6-row barns is cost; however, producers should be concerned about the level of heat stress and the limited feeding area. Producers building 6-row barns should seriously consider cooling systems during periods of heat stress.

Proper ventilation is essential in a freestall barn. Freestall housing should be constructed to provide good natural ventilation. Sidewalls should be 12 to 14 ft high to increase the volume of air in the housing area. The sidewalls should have the ability to open 75 to 100%. Fresh air should be introduced at the cow's level. Curtains on the sides of freestall barns allow greater flexibility in adjusting the environment around the cow. Because warm air rises, steeper sloped roofs provide upward flow of warm air. Roof slopes for freestall housing should range from 4/12 to 5/12. Roofs with slopes less than 4/12 may have condensation and higher internal temperatures in the summer. Providing openings on the end walls in addition to alley doors will improve summer ventilation. Gable buildings should have a continuous ridge opening to allow warm air to escape. The ridge opening should be 2 inches for each 10 ft of building width. Naturally ventilated buildings should have a minimum of 100 ft between structures. In the midwest, freestall barns are typically oriented east to west to take advantage of sun angles and provide afternoon shade. Producers who construct barns north to south will find an overhang on the west side desirable to produce shade for stalls on the west side of the barn during the afternoon. Freestall barns should be located as close to the milking center as possible without restricting ventilation. The goal is to reduce the distance that cows have to walk to and from the milking parlor. Field observations indicate that the distance from the gate of the housing area to the gate of the holding pen should be a maximum of 1000 ft for 2x milking, 700 ft for 3x milking, and 500 ft for 4x milking.

Water Availability

High-producing dairy cows can consume between 30 and 50 gal of water/day. Water should be provided to cows leaving the milking parlor. In parlors that are double 25's or smaller, one 8-ft trough is usually sufficient. In freestall housing, water should be located at

every crossover. There should be one waterer or 2 ft of tank perimeter for every 10 to 20 cows.

The water system must be able to provide 75 to 100 gal/cow/day. Peak flow rate is determined by number of waterers, assuming 100% utilization or milk parlor usage during cleaning. A minimum size well is probably 10 gpm, with 20 to 30 gpm, being preferred.

How Many Crossovers Are Needed?

Crossovers should be provided every 120 to 160 ft, or every 30 to 40 stalls. Crossovers are typically 10 to 12 ft wide. However, if a waterer is located in the crossover, consider increasing the width to 14 ft to allow passage behind other cows that are drinking. Producers often will reduce the number of crossovers in freestall barns to reduce construction costs. This is not a good alternative from a cow's point of view. Reducing the number of crossovers limits access to feed and water. It also reduces the total length available to construct the feedline. Very few producers stock freestall barns at one cow per stall. The tendency is to overstock freestall facilities. Therefore, reducing the number of crossovers or the width of crossovers restricts access to feed and water and limits the space for cows at the feed line. The bottom line is that the cows suffer when the number of crossovers is reduced.

Groups of Cows

Typically, large dairies have eight strings or groups of milking cows. They also would have pens for slow milking cows, mastitis cows, fresh cows, dry cows, and springers. The slow milking pen would have capacity for 2% of the milking cows. The fresh pen and mastitis pen would each have the capacity for 1% of the milking cows. Also, a minimum of two dry-cow pens and one pen for springers usually is constructed.

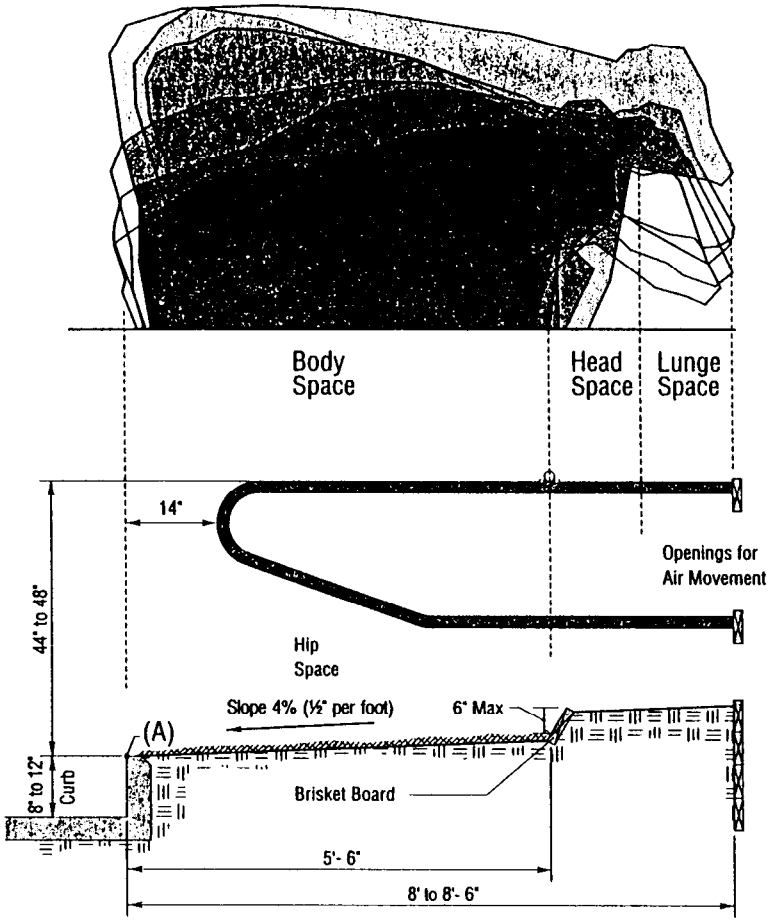

Figure 1a. Single loop partition.
A longer free-stall partition allows the Cow to thrust her head forward.

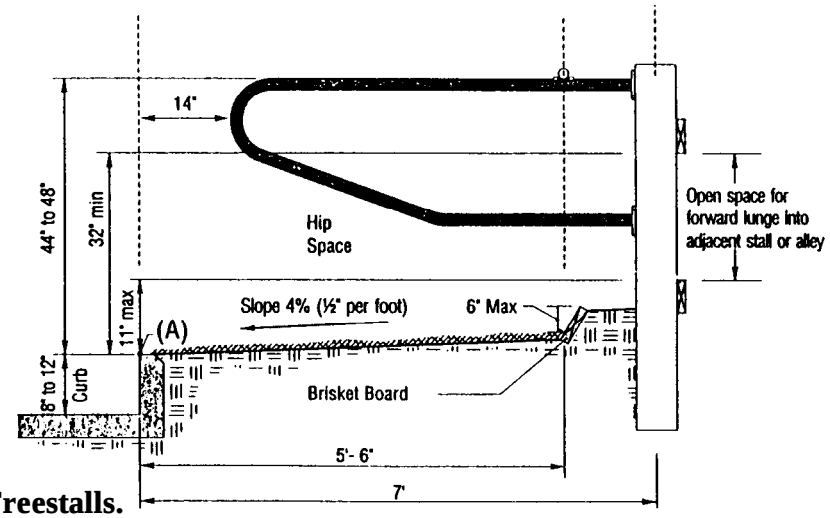

Figure 1b. Head-to-head partition.

Partitions are mounted on posts and the cow thrusts her head forward using the space left open between facing freestalls or into an adjacent alley.

Figure 1. Forward-Lunge Freestalls.

Top of curb (A) is used as the primary reference point for measurements, except when the stall bed is elevated. When the stall bed is elevated, the apparent top of the stall bed at the curb is the reference point. Dimensions are for a 1,400 lb cow. Refer to Table 1 for proper freestall size. This page is adapted from Dairy Freestall Housing and Equipment, MWPS-7, Sixth Edition, 1997, MidWest Plan Service, Ames, IA. Original drawings by W.G. Bickert.

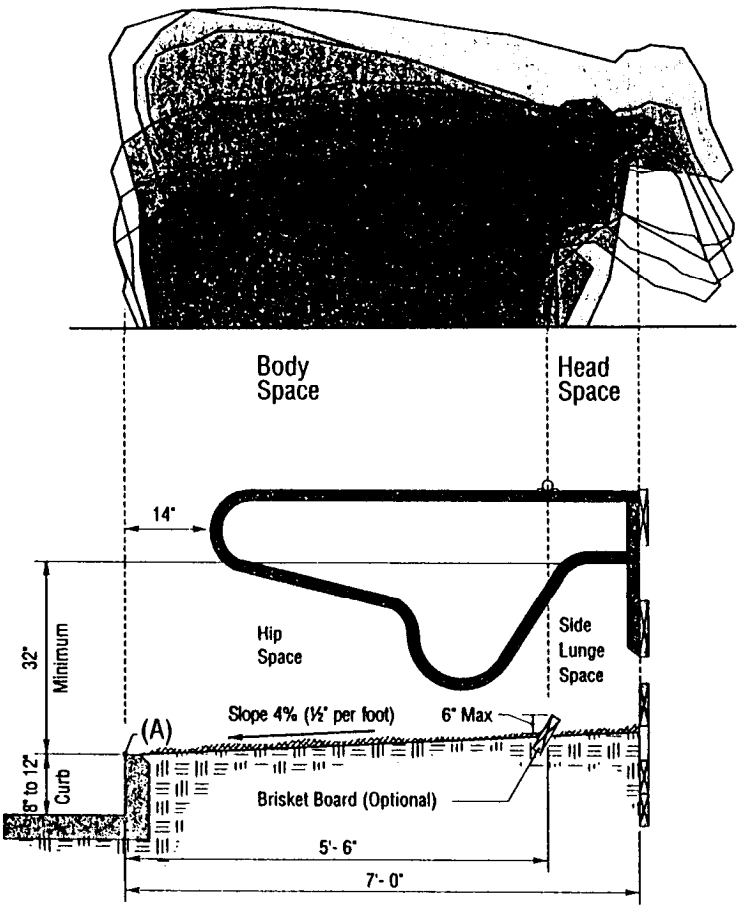

Figure 2a. Side lunge partition.
Cow thrusts her head under the lower of the partition into the adjacent free stall space.

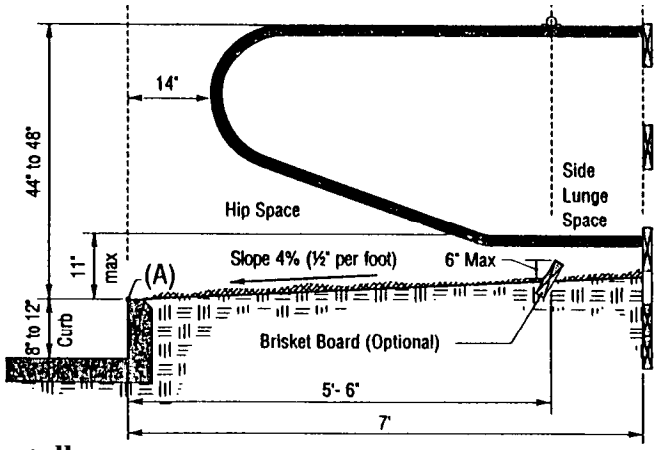

Figure 2b. Wide loop partition.
Cow thrusts her head over the lower rail of the partition into the adjacent stall space.

Figure 2. Side-Lunge Freestalls.

Top of curb (A) is used as the primary reference point for measurements, except when the stall bed is elevated. When the stall bed is elevated, the apparent top of the stall bed at the curb is the reference point. Dimensions are for a 1,400 lb cow. Refer to Table 1 for proper freestall size. This page is adapted from Dairy Freestall Housing and Equipment, MWPS-7, Sixth Edition, 1997, MidWest Plan Service, Ames, IA. Original drawings by W.G. Bickert.

TOWER TANK VALVE FLUSHING SYSTEM FOR DAIRY FACILITIES

J. P. Harner[1], J. P. Murphy[1], and J. F. Smith

Summary

Flushing characteristics of a tower tank valve flushing system with a 12-inch-diameter manual valve were determined. Data were obtained using the outside cow alleys in a four-row freestall barn. The alleys were 12 ft wide and 420 ft long with a 2% slope. The average flow rate exceeded 8,000 gallons per minute (gpm) when the average head was above 30 ft and the manual valve opened 80 degrees. Opening the valve to 90 degrees increased the flow rate to over 9,700 gpm. The velocity of the flushing wave was 8.5 fpm with a flow depth of 3.5 in. The estimated wave duration or alley contact time was 14.6 sec with a 25-40 sec release time from the flush tank. The flow rate ranged from 5,300 gpm to 7,200 gpm when the average head was between 16 and 28 ft.

(Key Words: Flushing, Manure, Water Usage, Freestall.)

Introduction

Flushing systems that collect and transport manure are utilized in dairy operations. They offer the advantage of labor reduction with automated systems, limited scraping requirements, lower operating cost, drier floors, potential reduction in odor, and cleaner facilities. One disadvantage is that an optional method of handling the manure may be necessary during colder weather. Other disadvantages include the water requirements per cow and the initial fixed cost.

Designed flush systems utilize a flush device to release the correct volume of water at the appropriate discharge rate and duration of time. This achieves the designed flow velocity, contact time, and depth of water in the gutter to obtain adequate cleaning.

Daily water requirements for flushing vary depending on the width, length, and slope of the flushed area. Buildings with alleys sloping 2 to 4% will use less water for flushing than alleys with a 1% slope. At an optimal slope of 3%, a minimum flush volume is 100 gal/ft of gutter width for flushing lengths of less than 150 ft. Longer lengths require more water with a suggested maximum release of 175 gal/ft. One study found 40 to 50 gal/cow/flush were required for effective flushing. A study of six dairies found flush water requirements ranging from 240 to 620 gal/cow/day. Another design procedure recommended selecting the larger of two volumes, either 52 gal/cow/flush or 1.35 gal/sq ft of alley/flush.

Most flushing systems utilize purchased components that include pipe line systems using pop-up valves or plates and underground piping. The objective of our study was to develop a tower tank valve (TTV) flushing system that could be incorporated into an existing or new dairy using sand-bedded freestalls. Desired flushing characteristics included a release rate of 9,000 to 10,000 gpm, water usage of 4,200 gal/flush, 30 sec flushing interval, and the ability to move sand-laden manure.

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Procedures

A TTV system was installed at a dairy in north-central Kansas. The freestall building was 420 ft long with a 2% slope. The alleys had a 1-inch slope towards the freestall curb from the outside wall. The four-row barn had 84 freestalls per row. The feed alley was 14 ft wide, and the cow alley was 12 ft wide.

The TTV flush system consisted of open-top flush tanks that were 10.4 ft in diameter and 38.5 ft tall. The flushing system used a 6- to 7-ft section of 16-inch pipe exiting the tank at a right angle. The 16-inch pipe has a 45E slope inside the tank. Another 6- to 7-ft section of 12-inch pipe, which included a 12-inch manual gate valve, then was used to direct the water to the flush alleys. The pipe outlet directed the water along the freestall curb.

Measurements were made using the upper 200 ft of the 12-ft alleys while the cows were in the milking parlor. Except for the first flush, the alleys were free of manure and sand. During the study, the gate valve was opened 80E for the first study and then 90E during the second study.

Tests were conducted at the site on two separate days. Measurements taken during the study used the 12-ft outside alleys, and the data were averaged together based on initial head. The flush water velocity was measured at a distance of 50 ft and 100 ft from a reference point. The reference point was located 90 ft from the outlet of the flush tank. The water front reached uniform flow prior to the reference point. Stop watches were started as the wave front passed the reference point and then stopped as it traveled past the known distance. The flush velocity was determined by averaging the velocities of the wave traveling 50 and 100 ft.

The flush tanks were equipped with pressure gages to measure the water pressure before and after each flush. The difference in pressure was used to determine the drop in water elevation and the volume of water released. The average discharge rate was determined by the water volume release during a given time. The time interval was based on the time the valve was opened. The actual flush time was normally 2 to 3 sec longer to include the time interval required to fully open the valve. The flush valve was closed after the front had traveled 200 ft or approximately 30 sec. The steady-state release volume was not measured. However, based on the Bernoulli equation and using the friction losses of the different components, the estimated steady state rate was 10,500 gpm.

The flow depth was determined at the reference point and at the 50- and 100-ft intervals. The depth was determined by measuring the distance from the top of the curb to the top of the flush water and then subtracting this value from the total curb height. After the flush tanks were filled, the fill valve was closed. Multiple tests were conducted until the tank depth was below 10 ft.

Results and Discussions

Table 1 summarizes the results when the valve was 80E open. The discharge rate was a function of initial head and varied from 8,700 gpm to 5,000 gpm. The initial head varied from 34 ft to 16 ft. The wave velocity ranged from 7 to 10 fpm, with an overall average of 8.5 fpm. The average water depth was 4 inches.

Table 2 presents the results of the second study with the valve opened 90E. Discharge rates increased a minimum of 500 gpm compared to opening the valve only 80E with a similar initial head. Velocity was reduced from 11.5 fps to 6.7 fps as the head decreased from over 30 ft to less than 10 ft. The depth of wave also was reduced about 50% as the initial head decreased.

The water usage based on a 8,500 gpm discharge rate and a 30 sec flush is equal to 0.84 gal/square ft, a flow rate of 700 gpm/ft width of gutter, and a water usage of 350 gal/ft of gutter. Based on number of freestalls and flushing three times daily, the water usage was 48 gal/stall/flush or 140 gal/day/stall. Based on a 30 sec flush three times daily in the milk parlor, the water usage in the milk parlor was 39 gal/stall/day. Visual inspections indicated that the flush system removed the sand and manure from the alleys.

Conclusions

Procedures were developed for determining on-site performance of flushing systems. The flushing parameters of a TTV flush system exceeded current design recommendations. The modifications simplified the construction process and maintenance. If repairs are necessary, the whole system does not have to be drained, unless the pump has to be replaced. The manual valves can be replaced by electric-driven actuators with flush intervals based on time. The TTV flush system also is able to adapt to existing dairies, providing they have room to handle the flush water at the lower end. One disadvantage to a TTV flush system is that more tanks are required. The initial cost appears to be similar to that of pipe line systems using underground piping to equalize the pressure between two tanks.

The flush tank release rate be considered at the upper and lower ends of the alleys. Sand traps and gravity solid settling basins need to be designed to handle higher velocities of flush water. Based on visual inspection of the alleys, we suggest a minimum flush velocity of 7.5 fps and preferably 10 fps for sand-bedded freestalls. Current recommendations on release rates appear to be adequate based on this study and with 400 ft alleys. The water depth at the freestall curb should be a minimum of 3 inches, with 4 inches preferred. The energy of the flush water needs to be directed along the freestall curb rather than in the center of the alley with sand-bedded freestalls. This enables the flushing system to remove sand away from the curbs and avoids having to occasionally scrape the sand away from the curbs. Properly designed flush systems can be utilized for effective removal of sand-laden manure in new or existing dairy facilities.

Table 1. Characteristics of TTV Flushing System with Valve 80 Degrees Open

Initial Head	No. of Observations	Velocity	Flow Rate[1]	Flow Depth	Contact Time[2]
		- - fps - -	- - gpm - -	- - inches - -	- - sec - -
> 30	2	10.6	8,420	4.9	11.5
26 - 30	2	9.8	8,150	3.9	13.9
21 - 25	3	8.5	6,360	4.2	12.2
16 - 20	3	7.8	5,670	3.7	13.0
11 - 15	No measurements taken				
6 - 10	No measurements taken				

[1]Average flow rate based on from opening to closing of valve.
[2]Estimated based on released rate, flow depth, and velocity.

Table 2. Characteristics of TTV Flushing System with Valve 90 Degrees Open

Initial Head	No. of Observations	Velocity	Flow Rate[1]	Flow Depth	Contact Time[2]
		- - fps - -	- - gpm - -	- - inches - -	- - sec - -
> 30	3	11.5	9,740	3.6	11.2
26 - 30	3	10.8	8,630	3.6	11.9
21 - 25	2	9.4	7,760	3.0	13.4
16 - 20	3	8.3	7,390	3.3	15.4
11 - 15	3	7.6	5,940	3.0	16.3
6 - 10	3	6.7	5,010	2.5	20.0

[1]Average flow rate based on from opening to closing of valve.
[2]Estimated based on released rate, flow depth, and velocity.

ASSESSMENT OF MASTITIC INFECTION IN BOVINE MILK USING ATP BIOLUMINESCENCE

M. J. Meyer, K. A. Schmidt, J. E. Shirley, and D. Sukup [1]

Summary

Few choices exist for a mobile, rapid, and nonsubjective assessment of mastitic infection in bovine milk. This project evaluated the effectiveness of using the Biotrace® raw milk quality ATP bioluminescence assay to serve this role. Milk samples with various somatic cell counts (13,000 - 2,500,000) and signs of mastitic infection were obtained from the Kansas State University Dairy Teaching and Research Center. Within 24 hr, raw milk samples were evaluated for microbial numbers and relative light units (RLU). The printed test procedure was modified to evaluate accurately clinical mastitic milk samples. As somatic cell count increased in raw milk, the RLU value increased. In addition, RLU values differentiated among milk samples with various levels of mastitic infection (none, subclinical, and clinical). Repeatability of the ATP bio-luminescence method was very good (CV = 4.76%). These results suggest that the Biotrace® raw milk quality test kit can served effectively as a nonsubjective, rapid assay to determine the degree of mastitic infection in bovine milk.

(Key Words: Mastitis, Somatic Cell Count, ATP Bioluminescence.)

Introduction

Problems with raw milk quality and mammary gland health are among the most costly health concerns on dairy farms. Poor mammary gland health adversely affects a dairy's profitability in two distinct areas. First, milk price premiums and deductions are determined in part by milk quality as indicated by somatic cell count (SCC). Secondly, a lactating cow with a mastitis problem (SCC > 300,000) can show in a 10 to 15% reduction in milk production compared to herd mates without a mastitis problem.

Mastitis is an inflammation of the mammary gland and can be caused by physical trauma or more commonly by microbial infestation of the mammary gland. There are two categories of mastitis: subclinical and clinical. Cows with subclinical mastitis produce milk without physical abnormalities apparent to the naked eye. Subclinical mastitis accounts for 90 to 95% of all mastitis cases. Cows with clinical mastitis produce milk with obvious physical abnormalities, namely, the presence of scar tissue.

To combat the inflammation, the animal's immune system floods the affected area with white blood cells or leukocytes (which make up the majority of the cells in an SCC). As a result, the leukocyte concentration in the milk increases. The degree of inflammation is directly proportional to the leukocyte concentration. This relationship allows the health status of a lactating mammary gland to be determined by enumerating somatic cells in the milk. Unfortunately, nonsubjective rapid assessment of milk SCCs requires the use of large, nonmobile, computer-driven equipment.

The physical environment inside the mammary gland serves as an ideal growth medium for a host of microorganisms, allowing them to flourish and resulting in the immune response previously described. This rapid microbial growth was confirmed recently;

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bacteria had an increased multiplication rate in mastitic milk. Increases in microbial adenosine triphosphate (ATP) seem to correlate well with indicators for mastitis inflammation. The fact that the most common cause of mastitis is microbial infestation of the mammary gland presents the opportunity to evaluate mammary gland health by rapid microbial enumeration procedures, such as ATP bioluminescence.

Our objectives were to determine whether: 1) the Biotrace™ raw milk quality test kit procedure was correlated with raw milk SCC and 2) the Biotrace™ raw milk quality test kit procedure could distinguish among raw bovine milk samples with various degrees of mastitic infection.

Procedures

Milk samples were collected from the complete milking of each cow, stored at 2.8EC, and assayed within 24 hr after collection. With each milk sample, triplicate microbial ATP assays were performed, and duplicate SCC values were obtained.

The Somacount 500 Analyzer (Bently Industries Inc.) at the Heart of America DHIA Lab, Manhattan, KS, was used to perform the SCC assays. Microbial ATP concentration values were monitored using the Biotrace Multi-Lite Milk Bacterial Kit (Biotrace, Bregend, Wales). 1000µL of prewarmed (37EC) Somex-A was added to 1 mL of raw milk, rotamixed for 5 seconds, incubated in a water bath at 37EC for 4 minutes, and then rotamixed again for 5 seconds. Samples were filtered through a 13 mm sterile filter. The filter was rinsed with 5mL of sterile rinse solution. The filter containing the microorganisms then was removed with sterile forceps and placed horizontally into a vial containing 500FL of the microbial ATP extracting enzyme M-Bactex. Contents of the vial were gently mixed and allowed to stand for 1 minute. Then 200 FL of the solution was placed into a sterile cuvette, to which 100 FL of the luciferin/luciferase reagent (Enzyme-MLX) was added.

The ATP bioluminescence assay employs an enzymatic reaction between luciferase and microbial ATP. The light emitted via the luciferase reaction is measured by a Biotrace Uni-Lite luminometer and quantified as relative light units (RLU). The RLU values then can be related to the microbial population of the sample. In order to assay strictly microbial ATP, somatic cell ATP and native milk ATP are removed. Somatic cells are less resistant to physical stress elicited by the Biotrace extractant Somex-A that causes the somatic cells to rupture. The somatic cell ATP and native milk ATP then are flushed away from the intact microbial cells in a filtration step. The extractant and filtration steps finalize the selective removal of all nonmicrobial cells.

Five milk samples (labeled 1 through 5) were prepared from raw milk samples collected from three different cows, each with different mammary health status. These cows were designated 1, 3, and 5. Cow #1 (n = 4) produced milk that showed no physical signs of clinical mastitis and consistently maintained a low SCC (<50,000). This sample represented milk from a healthy mammary gland. Cow #3 (n = 4) produced milk that showed no physical signs of clinical mastitis and consistently maintained SCCs of >300,000 and <1,000,000. This sample represented milk from a cow with subclinical mastitis. Cow #5 (n = 3) produced milk that showed physical signs of clinical mastitis (scar tissue in the milk) and consistently maintained SCCs >2,000,000. This sample represented milk from a cow with clinical mastitis. Sample #2 (n = 4) was prepared by a 50:50 volumetric mixture of milk samples from cows #1 and #3. This sample represented milk produced by a cow with mild subclinical mastitis relative to #3. Sample #4 (n = 3) was prepared by a 50:50 volumetric mixture of milk samples from cows #1 and #5. This sample represented milk produced by a cow with mild clinical mastitis relative to #5.

Experiments were replicated five times. All data were transformed into $\log_{10}$ values before statistical analyses were compared. To determine if SCCs differed among the different milk treatments, SCCs were subjected to analysis of variance.

Results and Discussion

Figure 1 shows the strong correlation (r^2 = .95; P<.05) among the five milk treatments and the SCCs. This assay proved to be highly repeatable across all data points (CV = 4%). Thus, the Somacount 500 SCC assay served as a standard for our investigation.

Figure 2 represents the relationship between the five milk treatments and the ATP assay results (expressed as log RLU). A strong correlation (r^2= .90; P<.05) existed between theATP assay and the samples with various levels of mastitic infection. The ATP assay also exhibited high repeatability (CV = 4.8%).

Average values for the SCC assay and the ATP assay are shown in Tables 1 and 2, respectively. Both assays exhibited similar abilities to distinguish among clinical mastitis (treatment 4 and 5), subclinical mastitis (treatments 2 and 3), and no mastitic infection (treatment 1). The original milk samples (treatments 1, 3, and 5) were distinguished easily from each other. However, we found that both assays lack the ability to statistically differentiate between mild clinical (treatment 4) and clinical (treatment 5) mastitis and between mild subclinical (treatment 2) and subclinical (treatment 3) milk samples. Our results indicate that both assays were equally capable of repeatedly distinguishing among various degrees of mastitic infection.

As a final test, the Pearson correlation coefficient was calculated for the dependent variables, SCC and ATP value. The relationship between the two variables is represented in Figure 3 by a scatter plot of all RLU and SCC data points. A strong correlation (Pearson correlation = .91; P = .001) existed between the microbial load of the milk samples (determined by the ATP assay) and the SCCs.

Conclusion

Statistical analyses of the results obtained during this investigation illustrated the high repeatability of the ATP assay and the high degree of correlation between milk treatments and ATP assay values. Further analysis showed a strong correlation between the ATP and SCC values. The ATP assay also demonstrated the ability to differentiate among milk samples with various levels of mastitic infection: none, subclinical, and clinical. These results suggest that the Biotrace ATP assay could serve as a highly repeatable and mobile alternative to the SCC assay in monitoring bovine mastitic infection. Use of the Biotrace ATP for rapid, on-the-farm, quantitative analyses of mastitic infection deserves further investigation.

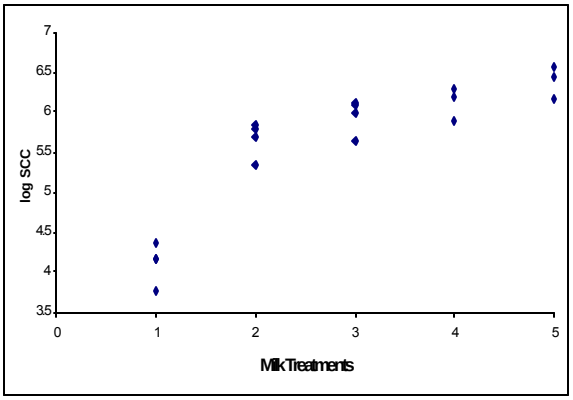

Figure 1. Scatter Plot of Somatic Cell Count (SCC) Values and Milk Treatments (r^2 = .95; P<.05; CV = 4%).

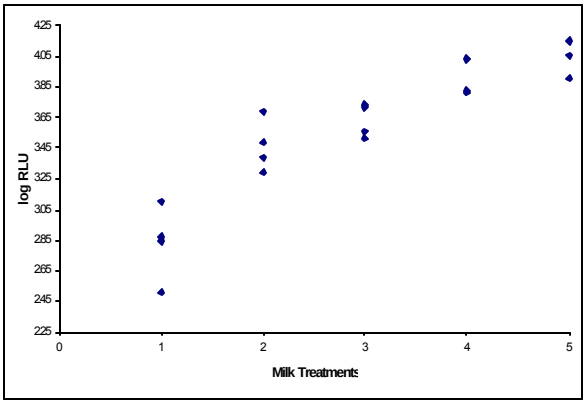

Figure 2. Scatter Plot of Microbial ATP(RLU) Values and Five Milk Treatments (R^2 = .90; P<.05; CV = 4.8%).

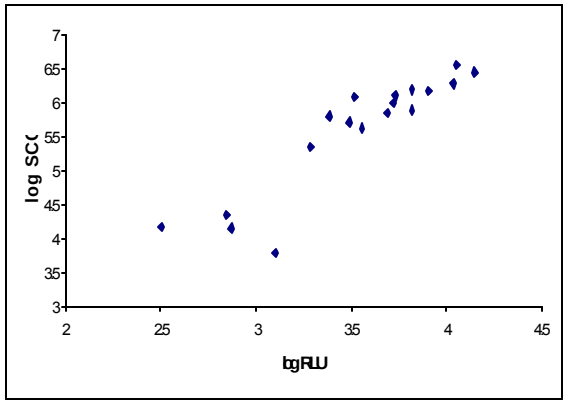

Figure 3. Scatter Plot of Microbial ATP (RLU) and Somatic Cell Count (SCC) Values from All Treatments (r = .91; P = .001).

Table 1. Mean Relative Light Unit (RLU) Values from ATP Bioluminescence Assay

Treatment	Mastitis	No.	RLU
1	None	3	4.0[a]
2	Mild subclinical	3	3.9[ab]
3	Subclinical	4	3.6[bc]
4	Mild clinical	4	3.5[c]
5	Clinical	4	2.8[d]

[a,b,c,d]RLU values with uncommon superscript letters differ (P<.05).

Table 2. Mean Somatic Cell Counts

Treatment	Mastitis	No.	Log SCC
1	None	3	6.4[a]
2	Mild subclinical	3	6.1[ab]
3	Subclinical	4	6.0[bc]
4	Mild clinical	4	5.7[c]
5	Clinical	4	4.1[d]

[a,b,c,d]Log SCC values with uncommon superscript letters differ (P<.05).

COOLING RATE AND STORAGE TEMPERATURE AFFECT BACTERIAL COUNTS IN RAW MILK

I. M. Cox, S. Adapa, and K. A. Schmidt

Summary

Raw milk was obtained from the K-State Dairy Teaching and Research Center and evaluated for quality after being stored under various conditions. Results showed that as storage temperature increased from 35 to 45EF for 0 to 72 hr, total bacterial counts increased, whereas the titratable acidity and pH values remained fairly constant. Changing the cooling rate affected microbial numbers. Cooling to 40EF within 30 versus 120 min reduced microbial counts by 50%. Finally, the preincubation test was shown to be an effective method to document possible psychrotrophic contamination before the milk arrives at the processing facility.

(Key Words: Raw Milk, Cooling Rate, Storage Temperature, Microbial Counts.)

Introduction

Cooling is an important step that can dramatically affect milk quality. The Pasteurized Milk Ordinance specifies that milk must be cooled to 45EF within 2 hr of milking and remain at that temperature or below throughout the distribution system. In some states, if raw milk reaches 50EF or above, it will be downgraded automatically to Grade B. Thus, raw milk temperature can affect the financial status of dairy producers.

In addition to temperature, the rate of cooling also affects milk quality. As the time increases, the milk is exposed to higher temperatures for longer periods. This condition will favor greater microbial growth. Thus, the cooling rate sets the environment that can affect microbial growth.

Several tests are done to evaluate the quality of raw milk. The most common tests include pH, titratable acidity (TA), and total plate counts or standard plate counts. The pH and titratable acidity tests are quick tests that can indicate microbial activity. The plate counts enumerate certain types of microbes that are in the milk but are time consuming. Processors may include a preincubation test on raw milk. This test is designed specifically to evaluate the psychrotrophic contamination level and generally is used to assess on-farm sanitation and hygienic transportation procedures. For the preincubation test, incoming raw milk is placed at 55EF for 18 hr and then plated to determine microbial numbers. Under these conditions, psychrotrophic growth is favored. Psychrotrophs are often the causes of fluid milk spoilage.

Assessing incoming raw milk quality is becoming more important. As milk processing facilities decrease in number, milk must be transported greater distances. This delay in raw milk processing allows microbial growth, which causes deterioration. Thus, this study was conducted to evaluate the effects of storage temperature and cooling rate on the quality of raw milk and to illustrate the use of a preincubation test for determining the acceptance/rejection criteria of raw milk at a fluid milk processing plant.

Procedures

Raw milk was obtained from the K-State Dairy Teaching and Research Center, kept cold (< 45EF), and transported immediately to the K-State Dairy Processing Plant. Milk samples were evaluated for total aerobic plate counts (TPC), pH, and TA. All tests were done in

duplicate, and at least three replications were done for each trial.

Trial 1. **Storage temperature.** Milk samples were incubated at 35, 40, or 45EF for 72 hr. Every 24 hr, samples were evaluated as described above.

Trial 2. **Cooling rate.** Milk samples were cooled to 45EF at each of the following times: within 30 min, within 2 hr, within 12 hr, and within 24 hr. After each test time, samples were evaluated as described above.

Trial 3. **Preliminary incubation test.** Milk was preincubated at 55EF for 18 hr and evaluated as described above.

Results and Discussion

Average values for pH, TA, and TPC were fairly consistent over the 72-hr period at all three temperatures. Slight changes occurred in the TPC. This is significant, because all three storage temperatures are considered "legal" temperatures for raw milk storage. A 72-hr "age" on raw milk before processing is highly likely. Table 3 illustrates that at the higher temperatures, more microbial growth occurs that potentially can spoil the milk. A dairy processing plant, in theory, should accept all three loads of milk. However, because longer shelf lives are desired, the 45EF stored milk would be the least desirable to process into a fluid milk product.

Table 4 illustrates the effect of cooling rate on the quality of raw milk. As the cooling rate increased, pH values decreased, TA values increased, and microbial counts increased. The raw milk that was cooled fastest had lower TPC counts. The TPC count in the quickly cooled milk was half that of the milk cooled within 120 min. Thus, the importance of quick cooling can be easily seen. Although our results suggest that raw milk cooled to 40EF within 12 hr is acceptable from a legal standpoint, it did not meet the cooling criterion of 45EF within 2 hr. Table 4 clearly illustrates the need to cool milk *quickly*, and once it is cooled, to maintain those cooler temperatures (Tables 1, 2, and 3) to preserve the high quality of the fluid milk.

The K-State Dairy Processing Plant uses the following criteria to accept raw milk for fluid milk products: antibiotic negative, pH 6.6 - 6.8, TA .14 - .17%, and TPC < 80,000 cfu/mL. Over the past few years, all incoming raw milk has been accepted. The records from K-State Dairy Processing Plant show that the plant produced high quality fluid milk with a satisfactory shelf life. However, to better evaluate the K-State raw milk, a preincubation test would provide information about possible psychrotrophic contamination.

The test results for three loads of milk clearly show the value of the preincubation test. Incoming milk (before incubation) had acceptable TA and pH values and very low microbial counts. As expected, the preincubation results showed higher TA values, indicating that microbial growth had occurred, which was verified by TPC results. These data indicate that some improvements may need to be made with the on-farm sanitation practices or in the sanitary hauling of milk to the plant.

The preincubation information is invaluable and can strengthen the supplier-buyer relationship. From the preincubation data, a producer can determine where improvements in sanitation, milking practices, or employee actions may be warranted. To make high quality processed milk, high quality raw milk is necessary. Thus, providing direction for possible improvements in raw milk quality benefits everyone -- the producer, the processor, and the final consumer.

Conclusions

The quality of raw milk is affected greatly by handling conditions on the farm and throughout the distribution cycle. This study shows that as storage temperature increases, microbial activity will increase and the quality of milk will decrease. As cooling time increases, raw milk quality will decrease. Thus, it is important to cool milk quickly and to as low a temperature as possible. The preincubation test is an effective

method to determine psychrotophic contamination, which is generally the cause of pasteurized milk spoilage.

Table 1. Average pH Values of Raw Milk Stored at Different Temperatures[1]

	Incubation Time, hr			
Temperature	0	24	48	72
35EF	6.70 ± .03	6.77 ± .04	6.81 ± .03	6.80 ± .02
40EF		6.76 ± .04	6.81 ± .04	6.80 ± .01
45EF		6.77 ± .04	6.81 ± .02	6.80 ± .02

[1]Mean ± SD.

Table 2. Average Titratable Acidity (TA) Values of Raw Milk Stored at Different Temperatures[1]

	Incubation Time, hr			
Temperature	0	24	48	72
35EF	.15 ± .01	.14 ± .01	.14 ± .02	.14 ± .01
40EF		.14 ± .01	.14 ± .02	.14 ± .01
45EF		.14 ± .01	.15 ± .01	.15 ± .01

[1]Mean ± SD.

Table 3. Average Total Plate Counts (TPC) of Raw Milk Stored at Different Temperatures[1]

	Incubation Time, hr			
Temperature	0	24	48	72
35EF	1.6 ± .49	2.0 ± 1.04	1.8 ± .89	1.4 ± .19
40EF		1.6 ± .83	1.5 ± .45	1.9 ± .93
45EF		2.1 ± 1.16	2.0 ± .75	3.2 ± 2.27

[1]Multiplied by 1,000; results are reported in cfu/ml.
[2]Mean ± SD.

Table 4. Average pH and Titratable Acidity (TA) Values and Total Plate Counts[1] (TPC) for Raw Milk Cooled to 40EF at Different Time Intervals[1]

	Interval to Cooling, hr			
Item	0.5	2	12	24
pH	6.82 ± .04	6.81 ± .08	6.78 ± .03	6.64 ± .01
TA	.13 ± .01	.14 ± .01	.15 ± .01	.19 ± .02
TPC[1]	2.8 ± 2.4	6.6 ± 4.1	190 ± 140	88,000 ± 8190

[1]Multiplied by 1,000; results are reported in cfu/ml.
[2]Mean ± SD.

Table 5. Evaluation of Milk for K-State Dairy Processing Plant

Item	Before Incubation	After Incubation
pH	6.76 ± .07	6.74 ± .01
TA	.16 ± 0	.18 ± 0
TPC[1]	6.3 ± 3.8	62 ± 32

[1]Multiplied by 1,000; results are reported in cfu/ml.

EXTRUDED-EXPELLED COTTONSEED MEAL (EXPRESS™) AS A SOURCE OF PROTEIN AND FAT FOR LACTATING DAIRY COWS

J. E. Shirley, A. F. Park, M. V. Sheffel, and E. C. Titgemeyer

Summary

Twenty-four Holstein cows were used in six 4×4 Latin squares to evaluate the effects of substituting extruded-expelled cottonseed meal (Express™) for whole cottonseed and solvent soybean meal in diets for lactating cows. No differences were observed in milk and milk component yield among treatments. Percentages of fat, protein, solids-not-fat, and lactose in milk were similar among treatments. Replacing whole cottonseed with Express™ tended to reduce milk urea nitrogen but had no effect on milk protein percentage or yield. Cow acceptability of Express™ was excellent throughout the 84-day study conducted between late June and September when ambient temperature exceeded 100EF for 35 days. Long-term storage of Express™ in a commodity barn was not a problem. In vitro analysis of Express™ revealed that it contains approximately 75% rumen undegradable protein (RUP) with an intestinally absorbable dietary protein value of 53.4%. Express™ is an excellent source of RUP, and the protein fraction is highly digestible in the small intestine.

(Key Words: Lactating Cows, Extruder-Expelled Cottonseed Meal.)

Introduction

Whole cottonseed processed through an extruder followed by an expeller results in a product that contains approximately 27% crude protein and 7.5% fat. The extrusion process decreases the ruminal degradability of the protein fraction. The resultant product, extruded-expelled cottonseed meal, has the potential to be a source of high quality rumen undegradable protein (RUP) for dairy cows in addition to its inherent fat content and positive contribution to neutral detergent fiber (NDF) and acid detergent fiber (ADF) in high energy diets.

Use of this product would reduce the number of ingredients needed to formulate diets for high-producing dairy cows and provide an economical source of RUP. Reluctance to switch from whole cottonseed to extruded-expelled cottonseed meal probably has occurred because of a lack of performance data available for the extruded-expelled product.

The objective of this study was to evaluate the effect of extruded-expelled cottonseed meal on milk yield and components when substituted for whole cottonseed and solvent soybean meal in diets for lactating cows.

Procedures

Twenty-four Holstein cows were used in six 4×4 Latin squares. Cows were fed individually diets typical of those used in commercial dairies with all of the cereal grain supplied as corn. The diets differed only in source of protein and amounts of fat. The following combinations were compared: 1) 6 lb of whole cottonseed and 2 lb distillers grains; 2) 3 lb of whole cottonseed, 3 lb Express™ meal, and 2 lb distillers grains; 3) 6 lb Express™ meal and 2 lb distillers grains; and 4) 8 lb Express™ meal.

All diets (Table 1) were fed as a total mixed ration. As Express™ replaced whole cottonseed, a portion of the SBM was replaced with corn in order to keep diets equal in nitrogen (protein) content. Cows were fed each diet for 21 days with feed intake and milk production measured daily. Milk samples were analyzed weekly for milk composition; milk protein, fat, lactose, solids-not-fat, MUN, and

somatic cells were measured by the DHIA Laboratory, Manhattan, KS. Cows were weighed and scored for body condition at the beginning and end of each 21-day period.

Results and Discussion

The response of lactating dairy cows to an extruded-expelled cottonseed meal product with lint (Express™) is shown in Table 2. Substituting Express™ for 50% or 100% of the whole cottonseed in the diet did not affect milk yield or composition, even though the fat content of the diet was reduced from 5.1% of dry matter to 4.5% of dry matter when Express™ replaced 6 lbs. of whole cottonseed in the diet on an equal weight basis. Reduction of dietary fat without a change in milk yield indicates that the additional fat supplied by whole cottonseed was not efficiently utilized by the cows.

The protein fraction of Express™ is approximately 75% rumen undegradable (RUP; Table 3) based on Dr. Marshell Stern's (University of Minnesota) procedure and 55% RUP based on the values provided by Insta-Pro7 Extrusion Technology (Des Moines, IA). We used 55% RUP in our formulation, because that was the value available to us at the initiation of the study. Table 3 also shows that the RUP fraction of Express™ is quite digestible in the intestines, which is critical to its success as an absorbable protein.

Express™ was fed with and without distillers dried grains (Table 2, diets ECSMD and ECSM) to determine if distillers dried grains were beneficial. No difference was observed in production performance between the two diets, suggesting that Express™ provided sufficient amino acids to support the production level observed. The dry matter intake across diets was lower than anticipated and reflected the effect of high ambient temperature and humidity during most of the study period.

The use of diets with elevated RUP is important for cows producing at levels higher than those achieved in this study. Thus, we expect that the extruded-expelled cottonseed meal would improve the performance of cows producing over 70 lb of milk per day. This prediction is based on previous experience using other sources of RUP. The milk urea nitrogen (MUN) content was low across diets because of the low dry matter intakes, but the MUN values tended to decrease as the amount of Express™ in the diet increased.

In summary, extruded-expeller cottonseed meal can be substituted successfully for whole cottonseed and distillers grains in diets for lactating dairy cows. It is an effective source of rumen undegradable protein. Further studies during the cool seasons at higher milk production levels are needed.

Table 1. Experimental Diets

Ingredient	WCS[1]	WCS-ECSM	ECSMD	ECSM
	- - - - - - - - - - - - - - - - % of dry matter - - - - - - - - - - - - - - - -			
Alfalfa hay	27.0	27.0	27.0	27.0
Corn silage	20.0	20.0	20.0	20.0
Shelled corn	31.0	31.9	32.8	32.8
Soybean meal (48%)	6.0	5.1	4.2	4.2
Whole cottonseed	9.0	4.5	0	0
Extruded cottonseed	0	4.5	9.0	12.0
Distiller grains	3.0	3.0	3.0	0
Molasses	1.0	1.0	1.0	1.0
Min./vit. Premix	3.0	3.0	3.0	3.0

[1]WCS = 6 lb of whole cottonseed; WCS-ECSM = 3 lb WCS and 3 lb extruded-expelled cottonseed meal; ECSMD = 6 lb of extruded-expelled cottonseed meal with 2 lb of distillers grains; ECSM = 8 lb of extruded-expelled cottonseed meal.

Table 2. Response of Lactating Dairy Cows to Whole Cottonseed and Extruded Cottonseed Meal during the Summer

	Diets[1]				
Item	WCS	WCS-ECSM	ECSMD	ECSM	SE[2]
Milk, lb/day	55.5	57.0	53.0	54.7	.99
DMI, lb/day	43.3	44.8	40.4	44.0	1.41
Efficiency, milk to feed	1.28	1.27	1.31	1.24	
Butter fat, %	3.60	3.77	3.61	3.58	.075
Protein, %	3.13	3.12	3.15	3.14	.030
Lactose, %	4.91	4.82	4.77	4.85	.052
SNF, %	8.72	8.71	8.66	8.75	.035
Change in body wt, lb	+28	+15	+12	+10	7.2
MUN[2]	14.1	13.8	13.5	13.4	.24

[1]WCS = 6 lb of whole cottonseed; WCS-ECSM = 3 lb WCS and 3 lb extruded-expelled cottonseed meal; ECSMD = 6 lb of extruded-expelled cottonseed meal with 2 lb of distillers grins; ECSM = 8 lb of extruded-expelled cottonseed meal.

[2]MUN = milk urea nitrogen.

Table 3. Protein Availability Estimates for Diet Ingredients

Sample	CP	RDP[1]	Solubility	Rate of CP Degradation	ID[2]	IADP[3]
	(% as	(% of	(% of	(h^{-1})	(% of RUP)	(%)
SBM standard	44.7	83.2	16.6	-.26	85.8	14.4
Extruded full-fat soybeans	37.7	52.3	6.1	-.051	74.7	35.6
Express™	23.6	25.7	11.8	-.011	71.9	53.4
Expeller SBM	42.4	48.7	7.5	-.048	76.8	39.4

[1]RDP = rumen degradable protein.

[2]ID = intestinal digestion.

[3]IADP = intestinally absorbable dietary protein (RDP × intestinal digestion).

PROCESSED GRAIN SORGHUM AND GRAIN SORGHUM COMBINATIONS FOR DAIRY COWS

J. E. Shirley, E. C. Titgemeyer, J. S. Drouillard, A. F. Park and M. V. Scheffel

Summary

Twenty-four Holstein cows were used to evaluate the effects of processing methods on grain sorghum utilization by lactating dairy cows. No difference was observed in the utilization of steam-flaked grain sorghum and pelleted grain sorghum obtained by adding water to finely ground grain sorghum prior to extrusion and oven drying at a temperature of 200EF. Extensive processing (pelleting or steam-flaking) improved feed efficiency relative to dry rolling. Cows fed diets containing more extensively processed grains ate less feed but produced the same amount of milk as cows fed diets containing dry-rolled grain.

(Key Words: Lactating Cows, Processed Grain Sorghum, Dry-Rolled Grain Sorghum.)

Introduction

The nutritive value of grain sorghum for dairy cattle is improved by extensive processing methods such as steam-flaking, which disrupts the starch granules and makes the starch more accessible to rumen microorganisms. In recent years, research at Kansas State University has demonstrated that a processed grain sorghum product generated by grinding, adding water, extruding, and drying (hereafter referred to as pelleted grain sorghum) has a significantly improved energy value when compared to dry-rolled grain sorghum. We also have observed that feed efficiencies (milk produced per unit of feed intake) were slightly better with pelleted grain sorghum than with rolled corn. However, in those studies, feed intake and milk fat percentage were depressed when the pelleted grain sorghum was fed. This implies that the pelleted product may have been fermented within the rumen too rapidly, thus creating a less than ideal fermentation.

One method to reduce this excessively rapid fermentation would be to reduce the degree of processing of the grain. This would be difficult in practice. A simple alternative would be to mix the processed grain with dry-rolled grain. A mixture of extensively processed grains (pelleted or steam-flaked) with less processed grain sorghum (dry-rolled) might provide the benefits of processing without the negative influences of an excessively rapid fermentation. Further, if mixtures were used, only a portion of the grain would need to be processed extensively; this would reduce processing costs for the grain sorghum and make it a more attractive feedstuff for Kansas dairies. The objectives of this study were to 1) compare the feeding value of steam-flaked and pelleted grain sorghum for lactating dairy cows and 2) determine if combining processed grain sorghum (steam-flaked and pelleted) with dry-rolled grain sorghum is beneficial.

Procedures

Twenty-four Holstein cows were used in six concurrent 4×4 Latin squares. Cows were individually fed diets typical of those used in Kansas with all of the cereal grain supplied as grain sorghum (Table 1). The diets differed only in how the grain sorghum was processed. The following combinations were compared: 1) all pelleted; 2) all steam-flaked; 3) ½ pelleted, ½ dry-rolled; and 4) ½ steam-flaked, ½ dry-rolled.

Cows were fed each diet for 28 days, and feed intake and milk production were measured daily. Milk samples (AM/PM composite) were analyzed weekly for composition; milk protein,

fat, lactose, solids-not-fat, and somatic cells were measured by the DHIA Laboratory, Manhattan, KS. Cows were weighed and scored for body condition at the beginning and end of each period. On the final week of each 28-day period, blood samples were collected from the tail vein, and total amino acid and urea concentrations in plasma were measured.

Results and Discussion

The cows responded well to all diets (Table 2). Processing of all of the grain sorghum, either by steam-flaking or by pelleting depressed ($P<0.01$) dry matter intake but improved feed efficiency ($P<0.01$). The addition of dry-rolled grain sorghum to the processed grains improved dry matter intake, but this was not translated into higher milk yield.

Processing did not affect plasma glucose or total amino acids but depressed ($P<0.01$) plasma urea nitrogen (PUN). The decrease in PUN supports the argument that processing improves starch digestion in the rumen. This effect on PUN is interesting, because it demonstrates that diets high in rumen undegradable protein (39.4% of total protein) respond positively to rumen available carbohydrate when dry matter intake is high. Cows in this study weighed approximately 1380 lb and consumed 4.45% of body weight in dry matter on the processed grain diets and approximately 4.6% of body weight on the combination diets (processed and dry-rolled). The depression in PUN probably resulted from both a decrease in dry matter intake and an increase in energy available to the rumen microorganism.

In summary, extensive processing improves the feeding value of grain sorghum in diets for lactating dairy cows. No significant differences were observed between steam-flaking and pelleting.

Table 1. Experimental Diets

Ingredient	Pelleted	Steam-Flaked	½ Pelleted ½ Dry-Rolled	½ Steam-Flaked ½ Dry-Rolled
	- - - - - - - - - - - - - - - - % of dry matter - - - - - - - - - - - - -
Alfalfa hay	27.34	27.34	27.34	27.34
Corn silage	19.5	19.5	19.5	19.5
Whole cottonseed	9.4	9.4	9.4	9.4
Soybean meal	9.0	9.0	9.0	9.0
Distillers grains	3.0	3.0	3.0	3.0
Pelleted grain sorghum	27.6	-	13.8	-
Steam-flaked grain sorghum	-	27.6	-	13.8
Dry-rolled grain sorghum	-	-	13.8	13.8
Molasses	0.85	0.85	0.85	0.85
Dicalcium phosphate	0.7	0.7	0.7	0.7
Limestone	1.1	1.1	1.1	1.1
Sodium bicarbonate	0.87	0.87	0.87	0.87
Magnesium oxide	0.21	0.21	0.21	0.21
Trace-mineralized salt	0.31	0.31	0.31	0.31
Mineral/Vitamin mix	0.12	0.12	0.12	0.12

Table 2. Effect of Diets on Production Parameters of Lactating Dairy Cows

Parameter	Pelleted	Steam-Flaked	½ Pelleted ½ Dry-Rolled	½ Steam-Flaked ½ Dry-Rolled
No. of cows	24	24	24	24
Dry matter intake (DMI), lb/day	61.5[a]	61.7[a]	64.2[b]	63.1[b]
Milk, lb/day	92.6	93.5	93.1	92.4
Butter fat, %	3.41	3.48	3.54	3.47
Milk protein, %	3.06	3.03	3.07	3.06
Lactose, %	4.95	4.94	4.95	4.95
SNF, %	8.73	8.70	8.74	8.74
Butter fat, lb/day	3.14	3.25	3.27	3.18
Milk protein, lb/day	2.82	2.83	2.84	2.81
3.5% FCM, lb/day	91.0	93.2	93.2	91.5
Energy-corrected milk (ECM), lb/day	91.3	93.1	93.2	91.6
ECM/DMI	1.48	1.51	1.45	1.45
SCC, ×1000	199	126	312	114
Body wt change, lb	-0.5	+4.6	+0.3	+7.0

[a,b]Means with different superscript letter differ ($P<0.05$).

Table 3. Diet Effects on Plasma Urea Nitrogen, Total Amino Acids, and Glucose Concentrations of Lactating Dairy Cows

Item	Pelleted	Steam-Flaked	½ Pelleted ½ Dry-Rolled	½ Steam-Flaked ½ Dry-Rolled
Glucose, mg/dL	66.6	67.1	65.8	66.3
Amino acids, mM	2.61	2.46	2.54	2.55
PUN, mg/dL	13.95[a]	13.95[a]	15.24[b]	14.4[a,b]

[a,b]Means with different superscript letter differ ($P<0.05$).

GROWTH AND FEED EFFICIENCY OF GROWING DAIRY REPLACEMENT HEIFERS SUPPLEMENTED WITH RUMENSIN® OR BOVATEC®

J. E. Shirley, M. Scheffel, A. Park, J. F. Smith, and E. C. Titgemeyer

Summary

Ninety Holstein heifers were used to examine the effects of Rumensin® or Bovatec®. Average daily gain and feed efficiency was greater for heifers fed Rumensin® than for heifers fed Bovatec®. Heifers fed Rumensin® consumed more total dry matter per day but slightly less dry matter as a percent of body weight than heifers fed Bovatec®. No differences were observed in body condition score and hip height between dietary treatments. The primary goal of a heifer-feeding program is to obtain a desired rate of gain without fattening at the least possible cost. Results of this study support the use of Rumensin® in diets for growing dairy replacement heifers.

(Key Words: Replacement Heifers, Rumensin®, Bovatec®.)

Introduction

Dairy producers and managers of replacement heifer operations want to improve the efficiency of the growing phase of dairy heifers. The goal of many managers is to have dairy heifers calve by 24 mo of age at a precalving weight of 1360 lb or a postcalving weight of 1200 lb. Several studies indicate that this goal can be achieved, if the rate of gain averages 1.8 lb/day from birth to 24 mo. Increasing the rate of gain to 2 lb/day would result in a similar sized heifer at approximately 22 mo of age. Rates of gain greater than 1.8 lb/day have been discouraged between 3 and 9 mo of age because of the negative effect on future milk production documented in some studies. Others have suggested that the genetically superior heifers available today can grow at 2 lb/day without negative effects on future milk production. A key point for growing dairy heifers may be their body condition prior to puberty rather than daily gain. The second goal of producers is to minimize feed cost per lb of gain. Many of the diets fed to replacement heifers consist of poor quality forages fed free choice and a corn-soybean meal (12 to 14% crude protein) grain mix with assorted minerals and vitamins and an ionophore. Studies using range cattle fed low quality forages suggest that energy supplementation reduces fiber digestion in the rumen; thus, it is not cost effective in many cases. The use of ionophores has increased in dairy heifer replacement programs because of their positive effect on rate of gain and feed efficiency.

Rumensin® (Monensin: Elanco Animal Health) and Bovatec® (Lasalocid: Hoffmann-LaRoche) have claims for increased rate of weight gain in dairy replacement heifers in addition to claims regarding the control and prevention of coccidiosis in calves and improved feed efficiency in cattle fed for slaughter. No study has compared the efficacy of each ionophore in dairy replacement heifers weighing between 250 and 600 lb of body weight. The purpose of this study was to compare growth rate, feed intake, and feed efficiency of dairy heifers fed Rumensin® or Bovatec® beginning at approximately 250 lb of body weight.

Procedures

Ninety Holstein heifers were transported from Cimarron Dairy, located at Cimarron, KS, to the Kansas State University dairy facility in Manhattan on September 24 and 25, 1997. Gooseneck trailers were used to transport the heifers. The trip of 250 miles required 5 hr. All heifers received 1.5 cc of micotil per 100 lb of body weight immediately prior to leaving Cimarron Dairy and again at 5 days after their

arrival. The heifers had free-choice access to prairie hay and water upon arrival. All heifers received a total mixed ration (TMR) consisting of chopped prairie hay and a 16% protein concentrate beginning 12 hr after arrival and continuing for 6 days. Then they received a TMR consisting of chopped prairie hay, corn silage, and concentrate until the treatments were initiated.

Twenty-eight days after arrival, the heifers were ranked by body weight (average of weights on 2 consecutive days) from largest to smallest and alternately assigned to treatment diets containing either Rumensin® or Bovatec®. Within treatments, heifers were assigned to pens by initial weight and remained in the same pen throughout the study. Eighteen pens containing five heifers each were used. Pens were arranged in two rows, and treatment groups were assigned to alternating pens to reduce location effect. The amount of TMR fed was based on the number of calves per pen and the average weight per pen plus 14 lb (2 lb/day projected gain in 7 days). The amount fed was adjusted weekly, and the calves were weighed bimonthly. Treatment pens were paired based on the average body weight per pen; a pen of heifers receiving Bovatec was paired with a pen of heifers with similar average body weight receiving Rumensin. The amount of TMR fed to each of the paired pens was based on the average weight of heifers in the heaviest pen. This procedure was used to ensure that sufficient feed was available to achieve the desired rate of gain. All diets were formulated to provide sufficient energy to support 1.8 lbs of gain/day and sufficient protein to support 2 lb of gain/day in accordance with the values in Table 1 that slightly exceed NRC (1989) recommendations.

The ionophores were delivered as a top-dressing at a rate of 100 mg/head/day for heifers weighing approximately 250 to 400 lb and 150 mg/head/day for heifers weighing >400 lb. The adjustment in the amount of ionophore fed was based on pen average weight. The date of the adjustment was determined by projecting the date when the heifers would weigh 400 lb based on the last weight and projected daily gain. Table 2 lists the daily feed allowance for heifers weighing 250 to 600 lb in 50 lb body weight increments. The amount of each ingredient fed is listed in pounds on an as-fed basis. The dry matter contributed by each ingredient can be calculated using the following dry matter values: alfalfa hay (85% DM); corn silage (34.5% DM); concentrate (87.8% DM); topdressing (88.4% DM). The concentrate mix contained ground shelled corn; trace mineral salt; dicalcium phosphate; and vitamins A, D, and E. The topdressing contained finely ground corn with either Rumensin® or Bovatec®.

Results and Discussion

The response of dairy heifers to Rumensin® or Bovatec® is shown in Table 3. Average daily gain and feed efficiency was greater ($P<0.01$) for heifers receiving Rumensin® than for those fed Bovatec®. Heifers fed Rumensin consumed more ($P<0.05$) total feed dry matter per day but slightly less ($P=0.06$) dry matter as a percentage of body weight than heifers fed Bovatec®. The diets were formulated to provide sufficient energy to support 1.8 lb of daily gain and sufficient protein to support 2 lb of daily gain. The reason for this formulation was to test the ability of the ionophores to improve energy efficiency through their effects on rumen fermentation. Additional protein was included to ensure that it was not limiting. Both treatments resulted in average daily gains above 1.8 lb, supporting the theory that they improved energy efficiency. The use of a control group (no ionophore) would have improved our ability to interpret these results. A criticism of Rumensin® has been that it depresses feed intake. Relative to Bovatec-fed heifers, this effect was not noted because the heifers were limit fed to achieve a desired rate of gain.

The primary goal of a heifer-feeding program is to obtain a desirable rate of gain without fattening at the least possible cost. Rumensin® improved ($P<0.01$) feed efficiency relative to Bovatec® and, thus, supported the desired growth rate at the least cost. No differences were noted between treatments in body condition and increase in stature, as reflected by hip height measurements.

Table 1. Crude Protein and Net Energy Requirements of Dairy Heifers for Projected Gains of 1.8 or 2.0 Lb/Day

	Live Body Weight, lb															
	250		300		350		400		450		500		550		600	
Item	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0
Crude protein, lb	1.19	1.26	1.32	1.40	1.46	1.53	1.55	1.62	1.63	1.71	1.72	1.79	1.85	1.93	1.94	2.02
Neg, Mcal/day	1.77	2.00	2.03	2.29	2.28	2.57	2.52	2.84	2.76	3.10	2.98	3.36	3.21	3.61	3.42	3.85
Nem, Mcal/day	3.14	3.14	3.60	3.60	4.04	4.04	4.47	4.47	4.88	4.88	5.29	5.29	5.68	5.68	6.06	6.06

Table 2. Daily Feed Allowances for Growing Heifers

	Live Body Weight, lb							
Ingredient	250	300	350	400	450	500	550	600
Alfalfa hay	3.8	4.0	4.5	5.0	5.0	6.0	6.0	8.0
Corn silage	8.0	10.0	12.0	12.0	12.0	15.0	15.0	17.0
Concentrate	1.8	1.8	1.9	2.1	3.0	3.1	3.3	2.5
Topdressing	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5

Table 3. Response of Dairy Heifers to Rumensin® or Bovatec®

Item	Rumensin	Bovatec	SE	P-Value
Initial wt, lb	287.40	285.70	0.17	P<0.01
End wt, lb	525.00	508.00	2.81	P<0.01
ADG, lb	2.10	1.97	0.02	P<0.01
Feed efficiency, gain/feed	0.21	0.199	0.002	P<0.01
Dry matter intake	- - - - -- - - - - - - - - - - - - lb/day - - - - - - - - - - - - - - - - - -			
0 - 28 days	8.25	8.22	0.02	P=0.24
28 - 56 days	9.76	9.67	0.07	P=0.36
56 - 84 days	10.80	10.66	0.05	P=0.09
84 - 112 days	11.47	11.27	0.06	P=0.03
0 - 112 days	10.07	9.95	0.035	P=0.04
	- - -- - - - - - - - - - - - - - % of body wt - - - - - - - - - - - - - - -			
Dry matter intake	2.48	2.51	0.0087	P=.06

INDEX OF KEY WORDS

Indexer's note: The numbers indicate the first pages of each article that uses the listed key word.

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BIOLOGICAL VARIABILITY AND CHANCES OF ERROR

Variability among individual animals in an experiment leads to problems in interpreting the results. Although the cattle on treatment X may have produced more milk than those on treatment Y, variability within treatments may indicate that the differences in production between X and Y were not the result of the treatment alone. Statistical analysis allows us to calculate the probability that such differences are from treatment rather than from chance.

In some of the articles herein, you will see the notation "P<.05". That means the probability of the differences resulting from chance is less than 5%. If two averages are said to be "significantly different", the probability is less than 5% that the difference is from chance or the probability exceeds 95% that the difference resulted from the treatment applied.

Some papers report correlations or measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one trait gets larger, the other gets smaller). A perfect correlation is one (+1 or -1). If there is no relationship, the correlation is zero.

In other papers, you may see an average given as 2.5 ± .1. The 2.5 is the average; .1 is the "standard error". The standard error is calculated to be 68% certain that the real average (with unlimited number of animals) would fall within one standard error from the average, in this case between 2.4 and 2.6.

Using many animals per treatment, replicating treatments several times, and using uniform animals increase the probability of finding real differences when they exist. Statistical analysis allows more valid interpretation of the results, regardless of the number of animals. In all the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

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900