Effects of Gel Teat Cleaning and Sanitizing on Raw Milk Quality and Udder Health.

Kasimu Hudu Ingawa

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Effects of gel teat cleaning and sanitizing on raw milk quality and udder health

Ingawa, Kasimu Hudu, Ph.D.
The Louisiana State University and Agricultural and Mechanical Col., 1990
EFFECTS OF GEL TEAT CLEANING AND SANITIZING ON RAW MILK QUALITY AND UDDER HEALTH

A DISSERTATION

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Dairy Science

by

Kasimu Hudu Ingawa
B. S., Louisiana State University, 1981
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Thirty lactating Holstein cows were divided into three groups of ten each and assigned to three treatments. The first treatment required using a gel teat sanitizer cleaner (GEL) and paper towels, no water to clean teats prior to milking. The second used only water (WASH) and paper towels, and the third used water, paper towels, and predipping (PREDIP) with 0.5% iodophor solution. Individual cow samples of milk were aseptically collected weekly from weigh jars for ten weeks. Bacteria counts were determined. Microorganism counts were also monitored from individual cow teat swabs. Treatment effects on daily milk yield, fat and protein percentages, udder health, milk iodine residue, and parlor efficiency were investigated.

Raw milk microorganism counts were 1184, 2481 and 1119 organisms/ml for GEL, WASH and PREDIP. Teat swab counts were 10388, 28558, and 9205 organisms/ml for GEL, WASH and PREDIP. Preliminary incubation counts were 2048, 4583 and 2527 for GEL, WASH and PREDIP. The GEL and PREDIP counts were lower than WASH counts. No differences existed between all counts of GEL and PREDIP treatments. Treatment effects were similar for production traits: fat percent, protein percent, a.m. milk yield, p.m. milk yield, and daily milk yield. Milk iodine content in WASH
was 0.002 and 0.001 ppm lower than GEL and PREDIP, but GEL and PREDIP treatments did not differ.

The GEL group had lower SCC than WASH and PREDIP. There was no clinical mastitis in the GEL group while 17.24 and 10.34% of cows had clinical mastitis in WASH and PREDIP groups. Cultured organisms from the WASH group included Klebsiella specie, Staphylococcus aureus, Streptococcus bovis, and Streptococcus dysgalactiae. Pathogens from PREDIP could not be identified in two cases and Escherichia coli was isolated in one case.

Premilking udder preparation time least-squares means were 1.58, 1.10, and 1.77 min for GEL, WASH and PREDIP. Parlor throughputs were 55, 51, and 43 (cows/hr) for GEL, WASH, and PREDIP.

Results showed the GEL procedure to be superior to WASH and PREDIP methods of premilking udder preparation.
INTRODUCTION

The subject of premilking udder preparation has been investigated by several studies (1, 26, 27, 28, 47, 72). Effects have mainly been examined relative to milk quality, udder health, and chemical residue in milk. Milk quality is important because consumers demand it and dairy farmers must comply with government rules and regulations (25). Improperly cleaned udders are among the sources of environmental bacteria responsible for milk contamination. Effective premilking udder hygiene is essential for production of high quality milk (72). An udder hygiene program is comprised of different steps that could have either direct or indirect effects upon microorganism populations in milk. Factors studied have included how dry and clean udders and teats were at cluster attachment (26, 28), type of drying towel used (28), type and concentration of premilking sanitizer (28, 35, 47), and duration of sanitizer contact with teats (28).

Mastitis control is perhaps the most important factor responsible for the increase in premilking udder hygiene studies. Several of these investigations (19, 23, 30, 63,
71, 88) have examined the effect of udder hygiene on bacterial populations. Results generally indicate a decline in udder infections with improved hygiene.

Inflammation of the mammary gland is usually caused by pathogens invading the udder. Organisms are generally found in the cow's environment from where they contact the udder either during milking or some other management activity. The teat orifice provides the most common passage for bacteria into the udder. Decreased exposure of teat ends to environmental pathogens is one recommended approach to mastitis control (71). Generally, mastitis causes a significant reduction in milk yield, and possible losses from discarded milk and culled cows (75).

A high SCC indicates abnormal conditions in the udder (75) and a possible high bacterial populations in the milk. Milk quality can be lowered when enzymes, produced by the bacteria, degrade certain desirable milk components (6, 75). Chemical residue in milk is highly undesirable and regulated by the government. Milking equipment and udder sanitizers contain chemicals that can contaminate milk. Iodine residues in milk have been researched more intensively than residues of other active ingredients from teat dips and equipment cleaners and sanitizers (72). This does not mean noniodine sanitizers are safer or do not form residues in milk, milk may be contaminated by application of any sanitizer before or
Studies (14, 15) have shown absorption of iodine through the skin to be the principal mode of contamination rather than suction from teat surface by milking machines. Other sources responsible for increases in iodine in milk include dairy rations (15, 29, 34, 79) and iodized animal medications (14, 18).

Premilking udder preparation is important to any effective milking management program. Several steps of the milking procedure have been automated due to technological advancement. Automation can increase production costs especially when pre-installation cost analyses are ignored. Results of parlor efficiency studies (3, 4, 5, 10, 11) have shown parlor performance differences due to milking procedures. The recommended procedure is to determine work routine time which can be used to calculate number of cows milked/hr (5).

A milking management program with effective udder hygiene procedures should lower microorganism populations and SCC in milk. Such programs could also improve milk quality and udder health.

The objectives of this study were:

1. To compare and contrast, using raw milk bacterial count, the traditional method of udder preparation (i.e. washing with water and drying with towels) to a new method using a gel teat cleaner and sanitizer, and paper towels with no water.
2. To determine if and to what extent, iodine used as the sanitizer in the gel, gets into harvested milk.

3. To evaluate the relationship between udder health and method of udder preparation as shown by somatic cell count (SCC), mastitis incidence, and types of pathogens present.
Introduction

The effects of premilking udder preparation procedures on milk quality have been the subject of several studies (1, 26, 27, 28, 47, 72). Milk quality is important because consumers demand it and dairy farmers must comply with government rules and regulations (25). Improperly cleaned udders are among the sources of environmental bacteria responsible for milk contamination. Effective premilking udder hygiene is essential for production of high quality milk (72). An udder hygiene program is comprised of different steps that could have either direct or indirect effects on bacterial populations in the milk. These factors include the wetness and cleanliness of teats and udders (26, 28), type of drying towel used (28), type and concentration of premilking sanitizer (28, 35, 47), and sanitizer contact time with teats (28).

Mastitis control and milk quality are important factors responsible for the increase in premilking udder hygiene studies. Several investigators (19, 23, 30, 63, 71, 88) have examined the effect of udder hygiene on bacterial populations on teats, udder, and adjacent
anatomy. Results indicate fewer mammary infections with improved hygiene.

Inflammation of the mammary gland is usually caused by pathogens invading the udder. Organisms are found in the cow's environment from where they contact the udder either during milking or some other management activity. The teat orifice provides the most common passage for bacteria into the udder. One recommended approach to mastitis control was decreased exposure of teat ends to environmental pathogens (71). Udder inflammation also leads to a significant reduction in milk yield, possible losses from discarded milk, and culled cows (75).

High SCC indicates abnormal conditions in the udder (75) and possibly high bacteria populations in the milk. Bacteria can produce enzymes capable of degrading desirable milk components (6, 75) resulting in lower quality milk.

Presence of chemical residues in milk is highly undesirable and regulated by the government. Milking equipment and udder sanitizers contain chemicals that can contaminate. Iodine residues may seem more important than noniodine residues, probably because there is no residue data available for noniodine sanitizers (72). This does not mean noniodine sanitizers are safer or do not form residues in milk. In a recent literature review on udder hygiene, Pankey (72) reported that milk is contaminated by
application of any sanitizer before or after milking. Studies (14, 15) have shown absorption of iodine through the skin to be the principal mode of contamination, instead of suction from teat surface by milking machines. Other sources responsible for increases in iodine presence in milk include dairy rations (15, 29, 34, 79) and iodized animal medications (14, 18). Although all products used for teat and equipment sanitizing must be approved by the Food and Drug Administration (FDA), caution should be exercised when sanitizers are used.

Udder Stimulation and Hygiene

The two main purposes of premilking udder preparation are: 1) proper stimulation to induce adequate milk ejection and 2) to minimize the number of organisms on the teat skin. Premilking udder stimulation has been shown to cause the release of oxytocin from the posterior pituitary gland into the blood. This hormone causes the contraction of myoepithelial cells surrounding alveoli and mammary gland ducts, ejecting milk into the glandular cavities (20, 58, 60, 81, 83). Other stimuli capable of causing oxytocin release include suckling and all activities which the cow can associate with milking (21, 83, 98).

Some studies on adequate stimulation have shown an increase in milk and fat yield (99), completeness of milk removal and lactation maintenance (97), and increased milk
flow rates and shorter machine time (58). Other studies (82, 93, 99) have reported no significant difference in milk production between cows given premilking stimulation and those not stimulated.

A study of the effect of teat stimulation on udder sympathetic tone was conducted by Lefcourt (49). Milk removal may be affected significantly by a decrease in sensitivity to sympathetic agents in the udder (24). Breed, parity, and milking management routine can affect premilking stimulation.

Premilking udder hygiene is an important component of an effective milk quality program. Such programs should be evaluated by their effects on milk quality and incidence of mastitis (72).

There are many sources of microorganisms that can contaminate teats including wash water, bedding, soil, hands, milking equipment, contaminated milk, udder cloths, etc. (75). It would be difficult to implement a milk quality program which would require sanitizing these sources individually. If such a program were possible, it would not be economically feasible. A program with a primary goal of minimizing teat end bacteria would be effective and more realistic.

Similar germicides are used as pre- and postmilking teat dips. However, formulation for concentration of active or other ingredients may vary. Schultze and Smith
(87) studied the relative efficacy of three postmilking teat dips. Chlorhexidine reduced teat end staphylococcal population by 95%, iodophor 87% and hypochlorite (4% available chlorine) 67% (87). Hogan and Smith (37) took a different approach to test four commercial teat dips. They determined whether prolonged in vitro exposure could enhance bacterial resistance to teat dips. Eight strains of *Staphylococcus aureus* were exposed to 4% sodium hypochlorite, 1.94% linear dodecyl benzene sulfonic acid, 1% iodophor, and 0.5% chlorhexidine. Results generally showed no alteration of germicidal tolerance of *Staphylococcus aureus* by prolonged exposure to commercial teat dips.

Type and concentration of sanitizer are important aspects of premilking udder hygiene. In a controlled study, Pankey et al (71) obtained results that showed a decrease in number of pathogens when iodophor concentrations of 0.1 to 0.5% were used immediately before milking. The study was conducted on four commercial dairy herds where percent reduction of major pathogens across the herds ranged between 45.3 and 61.5%. Different types of sanitizers were also studied by Galton et al (28) as premilking teat dips. Dodecyl benzene sulfonic acid (DDBSA) was found to be less effective in reducing coliform count than other disinfectants. Some studies (61, 74) have indicated premilking dips were more
effective than udder wash sanitizers because dips contain more germicide.

Teat end microorganisms can be reduced by improving udder hygiene (1, 26, 27, 28, 35, 41, 57, 63, 73, 74, 75, 88). Galton et al (27) conducted various studies on premilking udder preparation procedures. In one experiment, 16 different treatments were applied to teats and udders of 39 Holstein cows. Treatments included complete lack of udder preparation, varying degrees of udder and teat wetness, use of sanitizers, and different sanitizer-contact time with teats and udder (27). Milk samples were collected from weigh jars and plated for Standard Plate Count (SPC), coliform, Staphylococcus specie and psychrotropic organism counts. Coliform count samples were preincubated for 6 hours at 37° C before plating. Treatments with: 1) no preparation of udder at all and 2) wet, sanitized, no drying of udder and teats, showed highest bacterial counts (27). Lowest counts were obtained when only teats were water hosed, sanitized and dried (27). These results emphasized the importance of udder dryness like other reports (28, 57, 75).

Similar conclusions on bacterial counts were reported earlier by Galton et al (26) using a different method. They collected teat rinses before and after machine attachment. There was no overall treatment difference in SPC of teat rinses between samples collected before and
after machine attachment. Milk SPC indicated that udder surfaces needed to be dry and teat surfaces should be clean and dry before machine attachment. Increased drying time of udder and teats was found to reduce bacteria on teat skin. Results were confirmed with a later study (27).

Galton et al (28) reported that SPC did not differ between treatments where different paper towels were used before machine attachment. They concluded that manual drying of teats was more important than the type of paper towel used. Similar results from other studies (26, 27) have shown no difference between wet towel and water hose with adequate manual drying. Restricting water to the teats is more important.

**Bacterial Contamination of Raw Milk**

Standard Plate Count is recognized in the Pasteurized Milk Ordinance (25, 76, 79) as a standard method for monitoring bacteriological quality of raw milk. The legal limit of bacteria count in Grade A raw milk is $10^5$/ml/farm or $3 \times 10^5$/ml in a mixed sample from more than one farm (25). Standard Plate Count is a direct method of estimating bacteria population. Therefore, it can be used to detect sources of contamination for specific equipment used to pasteurize milk and process nonfermented milk products (78). The plating medium for SPC is tryptone
glucose extract agar diluted in phosphate buffered distilled water. Plates are incubated for 48 ± 3 h at 32 ± 1° C (78). Some studies (7, 45, 48, 77) have reported inconsistencies associated with the SPC method. In one study (45), the researchers reported that incubation temperature is not adequate for some microorganisms that can produce heat-resistant enzymes responsible for off flavor in finished products. Other investigations (48, 53) found insufficient nutrients in the SPC medium for some groups of bacteria. These microorganisms do not grow in the SPC agar.

Technological advancement has produced a comparable procedure to the SPC. The 3M Petrifilm™ is made up of a base film covered with a Standard Methods culture medium which contains nutrients, overlaid with a polyethylene film and coated with a gelling agent that is soluble in cold water. A tetrazolium dye (Triphenyl Tetrazolium Chloride or TTC) is added for easy counting of bacteria colonies (55). Reduction of TTC occurs as colonies grow and a red color shows (56). Only 1 ml of diluted or undiluted sample is inoculated on the film using a single pipette or a continuous pipetting syringe. (31, 52). Unlike SPC, this procedure does not require preparation and sterilization of media, or pouring agar into plates.

Comparison of the SPC and 3M Petrifilm™ procedures has been the subject of several studies (32, 84, 31). The
two methods were compared using 108 raw milk samples in duplicates and a correlation coefficient of 0.95 was reported (32). In another investigation, Sandoval (84) modified and studied the two methods using raw and pasteurized milk samples. As a modification step, the 48-hour incubation period of plates and petrifilms was divided in half. Plates and petrifilms were stored for 24 h at 4.4° C and re-incubated. Bacteria count did not significantly differ between SPC and Petrifilm or their respective modified versions (84). Correlation coefficient between SPC and Petrifilm for raw milk samples was 0.89. Correlations between petrifilm and modified petrifilm, and SPC and modified SPC were 0.91 and 0.87 (84). These investigators concluded that 3M Petrifilm™ and SPC methods are similar and 3M Petrifilm™ could be used instead of SPC (84, 32).

Preliminary Incubation (PI) of raw milk samples selectively promotes the growth of certain group of microorganisms associated with unsanitary conditions at the farm. This group primarily consists of psychrotrophic contaminants (17, 42, 43, 78). Psychrotrophs grow mostly at refrigeration temperatures of 2 to 7° C but their optimal growing temperature ranges between 20 and 30° C (78). A recent study (54) has shown that the PI method has similar impact on all microorganisms regardless of group type.
The PI procedure requires an 18-hour incubation period of samples at $12.8 \pm 1^\circ C$ (17, 78). Temperatures above $13^\circ C$ increase bacteria count several fold (42). A comparison study between SPC and PI was conducted by Ryan et al (80). Results indicated PI was a more accurate test for raw milk bacteriological quality.

There are three general sources of bacteria found in milk: 1) mammary gland interior, 2) udder and teat exterior or environment, and 3) milk storage handling, and milking equipment (13, 51, 72, 90). Adequate hygiene during milking can reduce bacteria populations in milk. Maintaining a low count requires properly designed and functioning equipment used for milking and milk storage. Temperature and vacuum fluctuations must be avoided and farmers must effectively clean and sanitize all equipment that comes into contact with milk.

Most organisms found in the interior of the udder are infectious. Mastitis, or inflammation of the mammary gland, occurs in two forms: 1) subclinical and 2) clinical. A cow suffering from subclinical mastitis rarely shows any symptoms at all. Such a cow, however, can be responsible for up to $10^5$ organisms/ml in the milk. Clinical mastitis is characterized by visible abnormalities of the milk and udder. A cow with this condition can have more than $10^8$ organisms/ml of milk (94).
Several types of microorganisms originating from the udder and teat exterior, or environment, have been found in milk (13, 48, 78). Pankey (73) has categorized these organisms as follows: 1) contagious organisms which include Staphylococcus aureus and Streptococcus agalactiae, they grow primarily on teat skin and wounds of infected cows; 2) environmental organisms, e.g., Streptococcus uberis and coliforms, this group of microorganisms is found on the teat surface and primarily originate from bedding material, soil, and manure; and 3) normal teat microflora like Staphylococcus epidermitis, Staphylococcus hyicus, and Corynebacterium bovis, while rarely causing clinical cases of mastitis, their presence raises both somatic cell and bacteria count in raw milk (73).

Raw milk contamination from milk storage and milking equipment is imminent when the equipment is inadequately cleaned and sanitized, improperly designed, or malfunctioning. Bacteria population can be kept low if storage and transportation are done properly. Examples include adequately maintaining milk storage tank temperature, or comingling only milk with uniform quality and temperature (90). Several techniques for reducing bacteria populations on milking equipment have been examined (73). They range from disinfecting clusters with hot water to backflushing milking systems (73). Palmer
(68) reported a contamination rate of $10^4$ organisms/ml from improperly cleaned and sanitized milking equipment. Management practices must include an effective equipment maintenance program and a policy of closely observing all cleaning and sanitizing instructions.

Several studies (26, 27, 28, 41, 44, 71, 75) have been conducted to examine the relationships between premilking udder hygiene and organisms in milk. Traditional premilking udder preparation is done by washing the udder with water from a hose, drying and machine attachment. Pankey (73) recently reported other commonly used procedures: i) washing with water, no drying, 2) washing with a paper towel or disinfectant-soaked cloth, then drying with a single use paper towel, 3) washing with water containing udder disinfectant and drying with single use paper towel; and 4) wipe dry teats with a single use paper towel. Another method becoming popular is predipping teats in a sanitizer before machine attachment.

Premilking teat dips contain the same bactericide found in postmilking teat dips. Iodine is the most commonly used active ingredient in predips with 0.1 to 0.5% titrable iodine (73). Other germicides used in pre- and postdips include sodium hypochlorite, linear dodecyl benzene sulfonic acid, chlorhexidine, and quaternary ammonium compounds (37).
Effective premilking udder preparation requires a completely dry udder. Results of studies (26, 27, 41, 44) have shown that water laden with bacteria drains into teat cups after machine attachment. This contaminated water from improperly dried udders and teats gets into the milk and increases bacteria populations.

Galton et al (28) examined the effect of 13 udder preparation procedures on SPC and coliform count in milk. A reduction in SPC was observed in preparations that included manual drying after wetting teats either with water or disinfectant dip. Premilking dipping with subsequent drying was adequate to reduce bacteria count (28). Earlier findings (26, 27, 28) were similar. Tolle (94) reported that bacteria count in raw milk can be lowered to less than $5 \times 10^3$/ml by eliminating reverse flow of milk and complete drying of teats after washing with a disinfectant. Effective udder preparation significantly lowers total bacteria count in raw milk and improves milk quality.

Psychrotropic and Gram negative rod shaped organisms are commonly found in soil, water, and on improperly cleaned or sanitized milking equipment. *Acinetobacter, Alcanigenes, Arthrobacter, Enterobacter, Flavobacterium* and *Pseudomonas* are the common genera of psychrotrophs found in raw milk (78, 96). Gram positive psychrotrophs include some *Bacillus, Clostridium*, some micrococci, and
streptococci types (78, 94). Psychrotrophs can cause off-flavors in milk by producing heat-resistant enzymes that degrade milk solids (78). Rancid flavors and odors occur under storage conditions due to milk fat hydrolysis by lipase which is produced by the organisms (2). The species of Pseudomonas and Flavobacterium can produce proteolytic enzymes that are heat resistant and can cause bitter flavor by degrading casein and whey (16). Although most psychrotrophic organisms are destroyed by pasteurization, keeping their numbers low should improve milk quality. Most of these microorganisms can produce enzymes capable of destroying milk constituents. Effective cleaning and sanitizing of milk storage and milking equipment, as well as maintaining equipment in proper working condition should keep bacteria populations low in milk. Bacteria count can also be kept low by storing milk on the farm for no longer than 48 h.

Another group of microorganisms that contaminates raw milk consists of thermoduric bacteria which include the genera Streptococcus, Microbacterium, Lactobacillus, and Micrococcus. Corynebacteria, Clostridium and Bacillus, are also included. These organisms have a high tolerance for heat and are from the same source with psychrotrophs. They can also be found on improperly cleaned and sanitized udders (78). Thermoduric bacteria survive but do not grow at pasteurization temperature, their primary effect is
reducing the shelf life of pasteurized milk (78). The most effective way of avoiding milk contamination with thermoduric bacteria is proper execution of production procedures aimed at minimizing raw milk contamination.

Fecal matter, dirt, and the intestinal tract are some of the primary sources of coliform bacteria. Improperly cleaned equipment and utensils are also sources because coliform bacteria can colonize milk residues adhered to equipment. The genera of the coliform group include Enterobacter, Escherichia, and Klebsiella. This group also includes all aerobic and anaerobic, gram negative, nonspore-forming rods. They are capable of producing acid and gas by fermenting lactose at 32° C within 48 h (22, 78). Bedding material forms a significant part of a cow's environment. It is directly related to many primary sources of coliform bacteria.

Fairchild et al (22) compared total coliform and Klebsiella counts from different bedding materials. The investigators used green softwood sawdust, with and without added lime as bedding materials. Similar number of organisms were found on teat ends when the two bedding materials were compared for bacterial count (22). The same study reported results of a second trial where tie-stalls were bedded with either green sawdust or lime. Total coliform and Klebsiella counts on teat ends of cows using stalls bedded with lime were lower. Hogan et al
(36) used nine commercial dairies to study bacteria populations between organic and inorganic bedding materials. Coliform and Klebsiella species were included among the organisms studied. Results were similar to those obtained by Fairchild et al (22). Both studies concluded that organic bedding materials have significantly higher moisture content and bacteria population than inorganic materials. Hogan et al (36) further reported more gram-negative bacteria and coliforms in the winter than summer and fall. Recycled newspaper, wood shavings, and pelleted corn cobs were also recently studied for bacteria counts by Hogan et al (39). Results indicated coliform, gram-negative bacteria, and streptococcal counts in chopped newspaper and pelleted corn bedding to be similar. Pelleted corn cobs were higher than chopped newspaper in staphylococcal counts. Counts for gram-negative, staphylococcal, and coliform bacteria were lower in chopped newspaper than wood shavings (39). These findings indicate that microorganism populations differ between both types of bedding material and seasons of the year (36, 39). Management should utilize this information to implement housing capable of reducing teat end bacteria and consequently raw milk contaminants.
Udder Health

Annual loss from mastitis in the United States dairy industry is estimated to be millions of dollars. Mastitis is defined as an inflammation of the udder (75). It occurs at two levels of intensity—clinical and subclinical. Clinical mastitis is an individual cow problem characterized by identifiable abnormalities of the milk and udder. It is usually of short duration since farmers can isolate infected cows for treatment or disposal in acute and chronic cases. Subclinical mastitis usually precedes the clinical form, some of its characteristics include: longer duration, harder to detect (because milk looks normal on gross eye examination), more prevalent, and a significant decrease in milk production. Dairy farm losses due to mastitis can become large due to increased production costs and culling of cows. Also, the amount of discarded milk increases with increased number of treated cows. Drug and veterinary bills represent another source of lost income. The majority of mastitis problems are a result of deficient management and it is useless to attempt to control mastitis by treating clinical mastitis alone (75). Improving management activities to reduce subclinical cases should also reduce chances of clinical mastitis. Effective udder hygiene is one of these management activities.
Although over 100 types of organisms are known to cause mastitis, the following four are known to cause most of the cases: *Staphylococcus aureus*, *Streptococcus agalactiae*, *Streptococcus dysgalactiae* and *Streptococcus uberis* (75, 76, 94). Other organisms implicated are *Escherichia*, *Enterobacter* and *Klebsiella* species (76, 94). *Corynebacterium bovis* and *Staphylococcus epidermis* are organisms that can cause mastitis but to a lesser degree (94).

The presence of bacteria in milk can adversely affect milk quality because the organisms cause a decrease in butterfat, protein, sugar, calcium, phosphorus and potassium (50, 76). Microorganisms also cause an increase in unwanted milk constituents like lipase, sodium, whey proteins, blood serum proteins, and chlorine (50, 76). Pathogens can change cell counts in milk. Normal milk contains about $10^5$ somatic cells, 75% are leukocytes and 25% epithelial cells produced by the udder tissue.

Nine commercial dairy herds with low SCC were surveyed for clinical mastitis by Hogan *et al* (38). Results showed only 6% of quarters were infected at calving and drying off. Identified pathogens were environmental streptococci and coliform organisms. Less than 1% of quarters and 0% quarters were infected with *Staphylococcus aureus* and *Streptococcus dysgalactiae*, (38). The report further indicated coliforms, other gram
negative and environmental streptococci were responsible for 82.3% of all clinical cases (38).

Leukocytes increase in number due to an infection or injury, while epithelial cells are found as a result of infection or injury (75). A certain type of leucocytes known as neutrophils are responsible for producing enzymes that degrade milk lipids and proteins, reducing raw milk quality (50). The United States Department of Agriculture (USDA) sets a legal limit on SCC in raw milk at $10^6$ cells/ml (25). Lower SCC count is desirable for both mastitis control and milk quality.

Reducing infections should be one of the goals of an effective udder hygiene program. In a recent review of studies on premilking udder hygiene, Pankey (72) pointed out that reduction of bacteria populations on teat ends is desirable. There is a positive correlation between number of bacteria on teat ends and udder infections, especially when the most common passage for bacteria into the udder is through the teat orifice. Some studies (19, 23, 30, 71, 73) have reported a reduction of intramammary infections by premilking hygiene. Other reports (19, 57, 89) have obtained results where some pathogens were difficult to control by udder hygiene.

The literature contains reports on numerous mastitis studies. Major factors studied include: milking machine (73, 91), therapy (66, 67, 86), postmilking teat dipping
premilking teat sanitizing (26, 30, 71, 89), and some specific aspects of management like bedding material (22, 36, 39), overmilking (62), and milking frequency (95).

Most milking machine studies include cow to cow transfer of pathogens. The milking machine serves as a perfect carrier of organisms from one cow to another during milking (91). New intramammary infections (IMI) have been recognized as the method of investigating the spread of mastitis. Different results of pathogen studies on teat cup liners under natural and challenged IMI situations have been reported (91). Other milking machine factors associated with mastitis are vacuum fluctuation and pulsation failure. Irregular vacuum level was reported to be responsible for higher SCC and clinical mastitis (91). Blood congestion due to pulsator malfunction can lead to poor teat and udder health. In general, the milking machine may be a big factor in clinical mastitis. Chances of mastitis can be reduced if effective maintenance of milking machines is part of a control program.

Intramammary infusion of antibiotics is the commonly used method of clinical (67) and subclinical (86, 66) mastitis therapy. Antibiotic treatment is used on cows with clinical cases and culling is the best method of dealing with chronic cases. Since several different
organisms can cause mastitis, a variable of response to
treatment should be expected. Only a few types of
organisms are responsible for most cases (75, 76, 94).
Staphylococcus aureus seems to be the most difficult
organism to control. Researchers (67) infused quarters of
S. aureus infected cows with $10^6$ U of penicillin G and 150
mg of novobiocin. They collected milk and tissue samples
(67). Mean penicillin concentrations for single and
double infused quarters were 0.013 and 0.057 U/mg,
respectively. Novobiocin concentration for both
treatments was 0.06 IU/mg. Comparison of parenchyma
tissue analysis between S. aureus-infected and uninfected
quarters showed an increase in connective tissue area and
a decrease in luminal area of infected quarters. The
investigators suggested poor drug distribution was due to
reduced milk space and changes caused by inflammation
(67).

Subclinical cases were treated as indicated by high
SCC in Virginia (86). Results showed a 70% cure for
infected quarters when subclinical treatment was applied
versus 50% cure with no subclinical treatment. Owens et
al (66) combined intramammary and intramuscular treatments
to study efficacy of therapy regimens for S. aureus
infection. Reported results showed 51.4% cure of quarters
and 48% of cows when intramammary and intramuscular
treatments were applied together. Only 25% of quarters
and 30.4% of cows were cured with intramammary infusion alone (66). Mastitis therapy studies have shown the importance of identifying organisms responsible for the infection. Prevention of infection is better than cure, therefore, a mastitis control program should primarily aim at controlling subclinical mastitis. This form of mastitis is more prevalent and precedes clinical.

A mastitis control program with an inadequate postmilking teat dip practice will be ineffective. Immediately following milking, the teat is moist and the streak canal is not tightly closed. This exposes the udder to pathogenic invasion. The importance of postmilking teat dipping was reported in a review by Pankey et al (70). Disinfection is the primary purpose of both pre- and postmilking teat dips. Sodium hypochlorite is one of the first compounds used in postmilking dips. Quaternary ammonium compounds appeared later. The most widely used germicides today include iodophor and chlorhexidine, although linear dodecyl benzene sulfonic acid is becoming popular (73). Different concentrations of bactericides in postdips have been studied (12, 64) to determine their efficacy. Nickerson et al (64) examined the effectiveness of two teat dips on teat canal infections. The teat dips used were 0.18% iodophor and lactic acid plus fatty acid teat dips. Results showed a 90% effectiveness in preventing *S. aureus*
infection and a 95.6% effectiveness in reducing its progress. Lactic acid plus fatty acid teat dip reduced persistence of infection due to \textit{S. aureus} by 39\% (64). Boddie and Nickerson did not find teat skin irritation by 0.18\% iodine teat dip (12). Postmilking teat dip in a polymer gel was studied by Oliver \textit{et al} (65). These University of Tennessee researchers investigated effectiveness of chlorous acid and chlorine dioxide in a polymer gel as a postmilking teat dip. Reported results are as follows: the experimental teat dip reduced \textit{S. aureus, Streptococcus dysgalactiae, Streptococcus uberis, Corynebacterium bovis}, and coagulase-negative staphylococcal infections by 67.4, 63.8, 27.8, 45.8, and 38.7\%, respectively. The dip also achieved an overall efficacy of 52.2\% against organisms causing most mastitis cases (65). The idea of postmilking teat dip in a gel form is promising. Theoretically, gelling a post dip may keep the bactericide on the teat skin longer than a liquid dip. This will provide the udder with longer and more complete protection against pathogen invasion.

Certain dairy farm management practices are directly or indirectly related to causes of mastitis. Type of housing and its management (especially bedding material), overmilking, and frequency of milking are some examples. Hogan \textit{et al} (36) have recently reported that bacteria counts in bedding material is directly related to rate of
clinical mastitis. Results of a study on how overmilking affects udder health have shown an increase in rate of cross infection with increase in machine-on time (62). An increase in physical abuse to teat and mammary tissue will increase susceptibility to IMI. Milking three times per day does not appear to affect udder health (95). In Tulare County, California, Goodger et al (33) studied management practices of 91 large dairies. Results indicated a need for education programs in better preventive medicine for producers, and better tools to analyze and evaluate economic gains of preventive medicine. The study also reported the existence of inadequate application of recommended milking procedures such as maintaining treatment records, use of paper towels, attending liner slips, efficient parlor usage measured by throughput, and careful teat dipping (33). Management of milking procedures is an important practice that relates to mastitis infections. Findings of Goodger et al (33) should be closely examined.

Reduction of pathogen populations at the teat end is important in minimizing mastitis. In a recent update on mastitis, Pankey (73) reported that highest concentration of pathogens on the teat are found immediately before milking. This contamination depends upon how clean the cow's environment is between milkings. Effective management practices are desirable in keeping cows clean
especially where housing is used. There are various methods of premilking preparation. Each has a different degree of effectiveness, as Galton et al (27, 30) and Pankey (73) reported. Perhaps the most important point of emphasis is how dry and clean the udder and teats are before machine attachment. Several reports (8, 26, 30, 40, 41, 44, 47, 71, 73) have shown an increase in intramammary infections due to udder surface drainage of contaminated water into the teat cups.

When predips were used before machine attachment, Pankey and Nickerson (69) discovered that the type of disinfectant used may make a difference in reducing bacteria counts. The researchers also found DDBSA to be less effective on some organisms than iodophor or sodium hypochlorite solutions as a premilking dip. It was more effective as a post milking dip in reducing the rate of new infections (69).

In two separate investigations, Galton et al (27, 28) examined the presence of microorganisms on teats using teat swabs and rinses. Teat ends were swabbed using four motions with equal pressure across the surface of the teat end. Swabs were immediately preserved in sterilized test tubes containing nutrient base media. Samples were then transported on ice to the laboratory (28). In the other experiment (27), the investigators rinsed the right front and left rear teats before udder preparation and left
front and right rear teats after udder preparation. Finally, all teats were rinsed following machine removal. Only the ventral 2 cm. of each teat was rinsed in a nutrient base media (27). Treatment differences for SPC and coliform counts before machine attachment were obtained in both experiments (27, 28).

An efficacy study on effectiveness of three commercial iodine teat dips was conducted by Pankey et al (71). The three teat dips contained 0.1, 0.25, and 0.55% available iodine, respectively. Udder preparation procedures used by the investigators were as follows: 1) teats and base of udder were washed with a disinfected single use paper towel; 2) visual examination of foremilk; 3) teats of predip groups were dipped in one of the test products; 4) a minimum of 30 s contact time was allowed; and 5) teats of all groups were thoroughly dried with single service paper towels. Milking followed and all teats were dipped in the same premilking dip after machine removal (71). Results showed that mastitis infection was reduced by at least 50% and predipping did not reduce IMI caused by coagulase negative staphylococci (71, 73). Premilking hygiene can be a valuable component of a mastitis control program. It could significantly contribute to reduction of IMI.

Pankey (72) reported a need to evaluate the effectiveness of predipping on incidence of udder
infection caused by environmental pathogens (72). Currently, there are only two controlled studies (30, 71) in the literature on this subject.

**Chemical Residues in Milk**

The dairy industry is becoming more concerned with chemical residues because iodine content in milk has been increasing in the last 15 years (12). Perhaps large losses in dairy revenue due to mastitis are responsible for the intensified study of germicides in search of a solution to this problem. Iodine teat dips are the most widely used products today. The current level of iodine in milk should not cause an immediate concern to human health but continuous intake as iodine residues increase in milk may be of concern (12).

Iodine is one of the natural components of milk. Its concentration can be influenced by organic iodine added to feeds (9). A survey of feeding and management practices of 175 dairy herds in Wisconsin showed a relationship between increase in milk iodine and use of iodine supplements in dairy rations (79). Up to 11% of the bulk tank milk samples obtained from farms contained greater than 1000 µg/L. The average iodine content was 466 µg/L (79). Results of a recent study (92) showed a quick increase in milk iodine content when moderate changes are introduced in the diet of lactating Holsteins. Feeding 1,
2, and 4 mg/kg of iodine as potassium iodide increased milk iodine concentration from 205 ng/ml to 404, 477, and 757 ng/ml, respectively. Ethylenediamine dihydroiodide (EDDI) fed in the same proportion raised iodine concentration in milk to 467, 535, and 869 ng/ml from 205 ng/ml (92). Ruegsegger et al (79) also fed EDDI to lactating Holstein cows. Iodine content in milk increased from 210 µg/L to 6225 after a two-week feeding period at 1 g/d (79). Results of these investigations (79, 92) indicated the significance of quantity and type of iodine added to the diet of dairy cows relative to milk iodine content.

Teat dips containing iodophor have been found to increase iodine residue in milk. Several studies (14, 27, 29, 70) have been conducted on this subject. Udder sanitizers and disinfectants may contain ingredients that serve different purposes, e.g., a teat dip may contain skin moisturizers, surfactants, stabilizers, viscosity regulators, dyes, etc. These ingredients form residues in milk (72).

Most teat dips and sanitizers contain either chlorine or iodine, unfortunately there is currently no available residue data on noniodine compounds (72). Studies (27, 29) have been conducted on the concentration of iodine in pre- and postmilking dips. Results obtained by Galton et al (27) indicated that the higher the iodine concentration
in teat dips, the higher the residues in milk. A 0.5% iodophor teat dip contributed less iodine in milk than a 1% iodophor teat dip (27). The researchers discovered that drying of teats becomes more important in reducing residues when the teat dip contains higher iodine concentrations. Same results were later obtained by Pankey et al (71) and Galton et al (29).

Conrad and Hemken (14) reported that iodine residue in milk can be increased between 80 and 100 μg/L when 1% iodophor teat dip is used. In comparison, Galton et al (27) indicated up to 8.8 μg/100 ml of iodine can be added to milk when iodophor is used as a teat dip. The higher the concentration of iodine in a dip, the more it is absorbed. Other reports (71) showed similar results. Iodine absorption through the skin surface seems to be the principal method of uptake rather than contamination from milking machine liners (14, 29). Postmilking dips should be a more significant source of iodine residue in milk than premilking dips. A postdip stays on the teat skin longer than a predip and post dips have higher iodine concentrations. The literature also suggests this point as reported by Pankey (73) in a recent update on mastitis.

Dairy rations and animal medications combine to constitute another source of iodine residue in milk (14, 15, 18, 29, 34, 79). As feed intake increases iodine
content in milk decreases (29) perhaps due to a dilution factor from increased milk yield.

There seems to be a consensus in the literature that premilking udder preparations may affect iodine residue in milk. The concentration of iodine in pre- and postmilking disinfectants determines residue amount in milk (27). Manufacturers of these compounds should compile data and provide safety and residue information to farmers on each product of this nature. The literature indicates an iodine concentration range of 0.1% to 0.5% as desirable. Within this range, the germicide is effective with little to no residue found in milk. The remaining components of the hygiene program should not be neglected.

Milking Parlor Performance

Technological advancement has automated several steps of the milking procedure. Modern parlors have machines that can automatically perform some milking activities from washing the udder to cluster removal at the end of milking. Automation results in higher production costs, therefore, producers need to analyze parlor changes to determine their effects before implementation. Parlor performance is a method that can be used for this analyses. The time required to milk a herd may have a direct effect on production costs as it is affected by equipment installed or milking procedure implemented.
Several studies (3, 4, 5, 10, 11, 98) have been conducted on parlor efficiency with different methods of data collection. The recommended method of determining parlor efficiency in the literature is by determining average work routine time (WRT). It can be used to calculate the maximum number of cows milked per hour using the formula 60 min/average WRT (5). Armstrong and Quick (5) have defined WRT as the total series of operator activities for each cow at each milking. Elements of WRT include several of the following steps of the milking procedure: cow entry, feeding, washing udder, drying udder, foremilk check, attaching cluster, detaching cluster, postdipping or spraying of teats, cow exit, and miscellaneous. Activities like waiting for cows to complete milking, reattaching cluster, adjusting cluster, washing cluster between groups, time out of parlor, and washing floor between groups are considered miscellaneous (5).

Blake and McDaniel (11) examined the management aspects of milking efficiency and also reported that milking time per cow is a function of the following steps of milking procedure: cow entry, udder wash, grain feeding, machine attachment, machine time, stripping time, machine removal, and cow exit. These steps are similar to those outlined by Armstrong and Quick (5). Since WRT contains several elements, it is likely to contain many
sources of variation. Some of the sources have been outlined by Armstrong and Quick (5), they include types of milking parlor, milk production, parlor mechanization, milking procedures, parlor design, and milking equipment malfunction. The elements making a WRT are chosen by the researcher to fit conditions under which the experiment will be conducted.

The double herringbone parlor is the most commonly found design in the US (5). Armstrong et al (4, 3) examined different elements of milking procedure using this type of parlor. Micke and Appleman (59) simulated herringbone and side-opening milking parlors to study milking operations.

Although the literature has given some suggestions on methods of collecting data for parlor efficiency and throughput, the experimenter can design a method (within the given guidelines) to fit conditions surrounding the experiment. This flexibility should increase accuracy in obtaining information.

Summary

In general, all studies have reported an advantage in practicing premilking udder hygiene. There is an improvement in milk quality due to a reduction in bacterial populations in the milk. The fewer bacteria found in the milk the lower the degradation of important
milk solids by microorganisms and the enzymes they produce. Poor quality milk is the principal source of off-flavor in milk products and can shorten shelf life.

Perhaps the most important advantage of premilking udder hygiene is minimizing mastitis cases by reducing the number of microorganisms on the teat skin and teat end. Dairy farm losses due to mastitis can be substantial when cows are culled and milk from treated cows is discarded. In addition, there are medication and veterinary expenses. There is a concern about iodine and other chemical residues in milk, several investigations have reported methods of minimizing these contaminants. Mechanization of milking equipment is responsible for a closer examination of parlor efficiency to determine the worthiness of automating some steps of milking the procedure. Parlor efficiency and throughput studies should fit parlor situations. Finally, when a milking management program is designed, it should be effective enough to minimize contamination of milk with bacteria or sanitizer and disinfectant residues. The program should also improve udder health and minimize production costs of milk harvest.
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Effects of a Gel Teat Cleaning and Sanitizing Agent on Raw Milk Quality and Udder Health

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Effects of a Gel Teat Cleaning and Sanitizing Agent on Raw Milk Quality and Udder Health

ABSTRACT

Thirty lactating Holstein cows were divided into three groups of ten each and assigned to three treatments for ten weeks as follows: 1) prepare for milking a gel teat sanitizer cleaner and paper towels, no water (GEL), 2) use only water and paper towels (WASH), and 3) use water, paper towels, and predip with 0.5% iodophor solution (PREDIP). Individual cow milk samples were aseptically collected from weigh jars and bacteria counts determined for ten weeks. Counts were also monitored from individual cow teat swabs. Treatment effects on daily milk yield, fat and protein percentages, udder health, milk iodine content, and parlor efficiency were investigated.

GEL and PREDIP procedures significantly improved milk quality over WASH method. Experimental GEL had a significant advantage over WASH and PREDIP in SCC, parlor throughput and reduced mastitis. The WASH group had highest SCC, bacteria in milk and teat swabs, and more mammary infections. Milk iodine content was comparable for the three treatments. There was no clinical mastitis in the GEL group throughout the trial. Daily milk yield, fat and protein percentages were not affected.
The GEL procedure was a superior method of premilking udder preparation compared to WASH and PREDIP and as determined by lower SCC, fewer intramammary infections and parlor efficiency.
INTRODUCTION

Several methods of premilking udder preparation are commonly used by producers. These procedures have been extensively studied (1, 7, 8, 9, 19, 23). The most widely used method usually requires washing teats and udder with water or a wash cloth, drying of udder and teats with a paper towel followed by machine attachment.

Milk quality and mammary gland health can be affected by premilking udder hygiene (7, 8, 9, 11). Effective udder hygiene is essential for reducing bacteria populations on the teat skin. Improperly cleaned udders are among the sources of environmental bacteria that can contaminate milk. Premilking udder hygiene includes many factors such as the wetness and cleanliness of teats and udders (7, 9), type of drying towel used (9), type and concentration of premilking sanitizer (9, 15, 19), and sanitizer contact time with teats (9).

Perhaps the most important aspect of premilking udder hygiene is how dry the udder is at cluster attachment. Results of several studies (7, 8, 17, 18) have shown that water laden with bacteria drains into teat cups after machine attachment. This contaminated, water from improperly dried udders and teats, gets into the milk and increases bacteria populations. Bacteria populations also
increase at the teat end thereby increasing the chances of mammary gland invasion by pathogens. Effective premilking udder preparation requires a completely dry udder.

Inflammation of the udder is usually caused by pathogen invasion. Organisms from the cow's environment contact the udder between milkings and in the parlor. Abnormal conditions in the udder are indicated by high SCC (24). Generally, mammary infections have been reported to decline with improved hygiene (5, 11, 20, 22, 30). Mastitis leads to a reduction in milk yield and quality. Discarded milk, health costs and culled cows are among possible sources of loss (24).

Teat and udder damage from milking machines can result in unhealthy conditions in the mammary gland. Milking machine factors associated with mastitis are vacuum fluctuation and pulsation failure. Irregular vacuum level was reported to be responsible for higher SCC and clinical mastitis (31). Blood congestion due to pulsator malfunction can lead to poor teat and udder health. Clusters also serve as carriers of organisms from one cow to another during milking (31). Generally, milking machines are a big factor in causing clinical mastitis.

Iodine is a natural component of milk. Premilking udder preparation methods requiring products with iodine as a disinfectant may affect iodine residue in milk.
Contamination is primarily by absorption through the teat skin (2, 3). Other sources of iodine residue in milk include dairy rations and animal medications (2, 3, 4, 10, 14, 27).

A premilking udder hygiene program capable of reducing numbers of microorganisms on teat skin may lower bacteria populations and SCC in milk. Milk quality and udder health may also be improved as a result. The objectives of this study were to evaluate the effects of a gel teat cleaner sanitizer on milk quality, udder health, and milk yield and composition, iodine concentration in milk and parlor efficiency.
MATERIALS AND METHODS

Origin and Description of Data

Cows and facilities at the Louisiana State University (LSU), Baton Rouge, dairy farm were used for this study. Data were comprised of four types: 1) milking parlor measurements, which consisted of a.m. milk weights, p.m. milk weights, and premilking udder preparation times; 2) milk quality observations of bacteria count in weigh jar milk and teat swab samples, and iodine content in milk samples; 3) milk constituents, including somatic cell count (SCC), fat percent, and protein percent; and 4) mastitis pathogen identification. Sample analyses for part 2) were conducted at the Milk and Products Quality Control Laboratory, Department of Dairy Science, LSU. Part 3) data were from samples analyzed at the Dairy Herd Improvement Laboratory, T. E. Patrick Dairy Improvement Center, LSU. Data in part 4) were analyzed at the Division of Bacteriology - Mycology, Clinical Diagnostic Services, LSU Veterinary Teaching Hospital and Clinics.

Cows and Farm Facilities

Thirty Holstein cows were selected and randomly assigned to three treatment groups. Ten cows were assigned
to each group. Two days before the start of data collection, quarter milk samples on the entire herd were cultured to identify any pathogens present. One cow was removed from the study due to a *Staphylococcus aureus* infection. The cow was infected before the study begun.

Housing was identical for all cows regardless of treatment. Cows were housed in a loafing barn where sanitation was poor. Floors were scraped daily, but cows were generally dirty. Cows were milked twice a day starting at 3:00 a.m. and 2:30 p.m., respectively. Milking parlor was a side opening parlor with eight stalls in a double-four arrangement. A weigh jar was present at each stall. Machines were removed by hand. Individual cow milk production was recorded at each milking. Other management factors such as feeding, reproduction, health care, etc, were uniform for all cows on the study.

**Treatments and Animal Assignment**

Animals were assigned to one of the following treatments:

1. **(GEL)**
   
   A gel teat cleaner and sanitizer. Premilking procedure steps included: 1) strip check fore milk for abnormalities, 2) rub GEL on teats only and leave for a minimum of 30 s, 3) wipe each teat
thoroughly with a single use paper towel, and 4) attach milking machine.

2. **(WASH)**

The traditional method of udder preparation using water from a hose with spray nozzle. Procedure steps were: 1) strip check for abnormalities, 2) wash teats with hand and water using a hose equipped with spray nozzle, 3) wipe teats and udder dry with single use paper towels, and 4) attach milking machine.

3. **(PREDIP)**

Premilking dip procedure using 0.5% iodophor solution as predip. Steps used were: 1) strip check foremilk for abnormalities, 2) wash teats with hand and water from a water hose with spray nozzle, 3) wipe teats and udder dry with single use paper towels, 4) dip each teat with 0.5% iodine predip solution and allow 30 s contact time, 5) wipe teats dry with single use paper towel, and 6) attach milking machine.

Immediately following machine removal, all teats of all cows were dipped in a commercial teat dip containing 1% iodophor (Teat-Kote™, Babson Bros. Co.). The active
ingredient in Teat-Kote™ is Nonylphenoxypoly (ethyleneoxy) ethanol iodine complex which provides 1% titrable iodine. Other components of the dip include lanolin and glycerine in a stable pH aqueous base.

The predip solution was a mixture of Teat Kote™ and sterile distilled water in equal proportions.

**Gel Teat Cleaning and Sanitizing Agent**

The experimental GEL was a water based mixture containing 0.5% iodophor as the active ingredient. It also contained 2% detergent, 4.7% glycerin, and 0.75% Carboxymethyl Cellulose (CMC) (Aldrich Chemical Company Inc.) as gelling agent. Several different formulations of these and other ingredients were tried before arriving at the formulation used for the trial. Resulting gels from these different formulations were discarded for different reasons. Examples included coating instead of cleaning dirt and manure on teats, too thick or thin to stay on teats for the minimum contact time of 30 s, and improper viscosity to dispense. Similar problems were also encountered when different ingredients were tried. For example, substituting dihydroxyethyl cellulose for CMC resulted in little gelling despite using seven times more dihydroxyethyl cellulose. Adding polyacrylamide produced a gel that was too sticky and difficult to wash or wipe off, and higher amounts of polyacrylamide gave an unpleasant odor to the gel.
Early trials of mixing the gel were done with 0.5% chlorhexidine diacetate as the germicide. This formulation was satisfactory, but iodine was substituted as the active ingredient for this research since it could be assayed accurately and inexpensively.

The experimental gel had a pH of 5.25 and a freezing point of $-4^\circ$ C. Viscosity and shear analyses of the gel showed an apparent viscosity value between $12 \times 10^3$ and $6 \times 10^4$ centipoise at $25^\circ$ C under normal shear stress. This range depended upon how fast the gel was mixed, moved, or pumped because both the apparent viscosity and rate of shear varied with changing shear stress. Other properties of the gel obtained from this analyses were a flow behavior index of 0.2605 and average fluid consistency index of 556.14 dyne–sec/cm².

Milk and Teat Swab Samples

Individual cow milk and teat swab samples were collected from each cow once a week for ten weeks. Samples were immediately placed on ice and transported to the laboratory for microbiological work.

Aseptic collection procedure employing sterilized syringes, plastic tubes, and plastic vials were used to obtain milk samples from weigh jars. Before drawing each sample, the milk was properly agitated and the spout on each weigh jar was disinfected with a cotton swab soaked in 95%
ethanol. Samples were used to determine bacteria population in the milk.

Duplicate samples were also obtained in vials to determine milk constituents (fat and protein percentages, and SCC). A third set of samples was collected from each cow in sample bags (Nasco's Whirl-Pak™) for iodine residue determination. Enough volume was collected to analyze each sample in duplicate. Samples for milk constituents and iodine analyses were obtained from the Dairy Herd Improvement sampling spout at the bottom of weigh jars following one minute agitation of milk.

Teat swabbing was done by making three complete circular motions with equal pressure over the teat end surface; only the right front teat of each cow was swabbed. Swabs were placed in sterile test tubes containing 5 ml rinse solution and transported on ice to the laboratory. The rinse solution was a mixture of 0.85% NaCl, 0.1% Proteose-peptone, and 0.2% Sodium Thiosulfate. After the preparation of rinse solution, test tubes containing 5 ml of the solution were autoclaved at 121° C for 15 min at 15 psi.

**Microbiological Work**

All samples were plated on 3M Petrifilm™ in duplicates of two dilutions to obtain a bacteria count comparable to the Standard Plate Count (SPC) (13, 28). The SPC method is commonly used to estimate gross contamination
or total microbial population of raw milk (6, 25, 27). A Preliminary Incubation (PI) count was also obtained for each sample in a method similar to SPC. The PI method is an indicator of psychrotrophic bacteria or those organisms that grow rapidly at refrigeration temperatures (2 to 7° C). An aliquot (about 10 ml) of each milk sample was transferred into a sterile vial and incubated at 12.8 ± 1° C for 18 h ± 15 min. Psychrotrophic organisms are commonly found in soil, water, and improperly cleaned or sanitized milking equipment.

Two dilutions of 1:10 and 1:100 were used for both raw milk and PI samples. Teat swab rinses were diluted to 1:100 and 1:1000. The decision to use these dilution factors was based on pre-trial results conducted according to procedures described in Standard Methods for the Examination of Dairy Products (SMEDP) (26). Dilutions studied ranged between 1:10 and 1:10⁶.

Petrifilms™ were prepared and incubated according to the directions for use provided by the 3M Company (Medical Surgical Division, 3M Health Care, St. Paul, MN). The temperature of incubation was 32 ± 1° C for 48 ± 3 h as directed by SMEDP. Bacterial colonies were also counted according to SMEDP (26) directions.
Iodine Residue

Duplicate samples of milk were analyzed for iodine content using an Orion Model 901 Microprocessor Ionalyzer (Orion Research Inc., Laboratory Products Group, Boston, MA) with the following equipment and solutions: a Reference Electrode (Orion Model 90-01), Magnetic Stirrer, Stir Bars, Polishing Strips (Orion Cat. No. 948201), Distilled or Deionized Water, Ionic Strength Adjustor (Orion Cat. No. 940011), Reference Electrode Filling Solution (Orion Cat. No. 900001), and Standard Iodide Solution (Orion Cat. No. 945306).

The Ionic Strength Adjustor (ISA) was used to adjust ionic strength of samples and standards, 5M NaN0₃. Reference filling solution was an equitransferent filling solution of 4M KCl saturated with AgCl, and the concentration of the standard iodide solution was 0.1M NaI.

Electrode Operation (or Slope) was checked, as recommended by the instruction manual, before analyzing samples. Electrodes were also polished with polishing strips whenever appropriate.

Iodine level in each sample was determined in parts per million (ppm) following directions provided by the instrument's instruction manual (21). The procedure steps followed include:
1) Measure 100 ml of diluted standard (0.5 ppm) in a 150 ml beaker. Then 2 ml of ISA were added and the solution stirred thoroughly.

2) Electrodes were rinsed with distilled water, blot dried and placed into the beaker. When a stable reading was obtained, the meter was adjusted to display the value of the standard.

3) Step 1) was repeated with diluted standard of higher concentration (1 ppm).

4) Step 2) was repeated to display the second value of the standard.

5) Finally, milk samples were analyzed by measuring 100 ml of the sample into a 150 ml beaker and 2 ml of ISA were added. The sample was stirred thoroughly. Electrodes were rinsed, blot dried and placed into the sample. Iodine concentration was read from the meter display.

Electrodes were rinsed and blot dried between measurements, and each milk sample was analyzed in duplicate.

**Milk Constituents**

Duplicate samples were taken to the Dairy Herd Improvement Laboratory, T. E. Patrick Dairy Improvement Center, LSU, for determination of somatic cell count (SCC). This data was analyzed as an indication of milk quality and
udder health. Milk fat and protein percentages were also determined from the same samples.

Somatic cell count was determined using a Fossomatic Model 215 automatic cell counter (Foss Food Technology Inc., Eden Prairie, MN). This instrument is an automated microscope. For each sample, a mixture was made containing 2 ml of dye (ethidium bromide), 0.2 ml milk sample, and 1.8 ml of buffer. The mixture was placed into a cup seated on a rotating table that was attached to an electronic stirrer. At stirring speed of 600 rpm, enough force was generated to thoroughly mix the solution and also cause lysis of the somatic cell. This enabled the dye to stain the cells' DNA. The entire mixture was then flushed through a microsyringe except 0.3 ml which was dispensed for 12 sec from a nozzle to a highly polished wheel. The wheel passed under a microscope where a photo eye counted the cells. Data were electronically transferred to a printer and readings were recorded in thousands of cells/ml.

Foss Electric Milko Scan Model 605 (Foss Food Technology Inc., Eden Prairie, MN) was the instrument used to determine fat and protein percentages. Potassium dichromate was used as a preservative in all samples. Up to 6 ml of preserved raw milk was required to go through two stages of homogenization. A beam of infrared light was passed through a cuvette which contained 0.33 ml of homogenized milk then a series of filters arranged on a
wheel passed behind the cuvette at a given interval. Each filter allowed the passage of only one wavelength of light. Milk components (fat, protein, lactose, etc) were each measured at a different wavelength.

Electronic circuitry of a digital analyzer converted the amount of light that passed through the cuvette to a milk fat and protein percent. Data were finally sent to a printer and percentages were printed in two decimal places. All samples were analyzed in dupilicates.

Pathogen Identification

Milk samples from all quarters of cows with clinical mastitis were sent to the Division of Bacteriology - Mycology, Clinical Diagnostic Services, LSU Veterinary Teaching Hospital and Clinics, for prompt identification of bacterial organisms present. Samples were collected on all new cases before treatment was administered.

This procedure consisted of four main steps: 1) milk sample was agitated for two minutes to evenly mix the cream; 2) then 0.1 ml of the sample was immediately streaked on a medium of Blood Agar (Tryptose B. A. Base) and MaConkey Agar; 3) plates were incubated for 24 to 48 hours at 35° C; and 4) identification of colony type by Gram Staining procedure.
Different methods and commercial kits were used to identify the colonies: 1) conventional biochemicals and API 20E (API, Division of Sherwood Products, Plainview, NY) were used to identify gram negative rods; 2) gram positive rods (Norcodia and Mycobacterium) were identified using Acid Fast Stain method. Corynobacterim and Bacillus can also be identified with this procedure; 3) to identify gram positive cocci, a catalase and Hydrogen Peroxide were required. Rapid Mastitis Test™ (Immucell, Portland, ME) and Staph Ident™ (API, Division of Sherwood Products, Plainview, NY) were commercial kits used to identify Staphylococcal organisms. Both procedures required Hydrogen Peroxide and a catalase. Identification of Streptococcal pathogens was done with the Rapid Mastitis Test™, Carbonhydrate Fermentation (Phenol Red), Bile Esculin, and Camp Test.

Premilking Udder Preparation Time and Parlor Throughput

Premilking udder preparation time (preptime) was defined as period from the time a cow entered the milking stall to the time a cluster was completely attached. This measurement was taken weekly during afternoon milking for all treatments.

Parlor throughput information was collected to determine how many cows/hr were milked in each treatment. The LSU dairy herd was divided into three groups of equal numbers. This grouping criteria was used to reduce
variation due to machine-on time between groups. Timing of each group started with the parlor entrance of the first cow, and ended with complete removal of last cluster. Each group was measured twice a day (a.m. and p.m.) for two days. Treatment was then changed and measurements began again following a two-day break. The purpose of the break period was to allow milkers to get used to the new treatment. Fresh and sick cows were excluded. Time and number of cows milked were averaged for each treatment, and cows milked/hr was determined.

Statistical Analyses

All microorganism counts and SCC observations were log transformed and analyzed. Bacteria counts were recorded according to procedures provided by SMEDP (26). Variables were analyzed using least-squares techniques and linear methods of the General Linear Model (GLM) procedure as described by Statistical Analysis System (29). The experimental design used was a split-plot in time, adapted from Gill and Hafs (12).

Statistical model was:

\[ Y_{ijkl} = \mu + \alpha_i + \beta_j(\alpha_i) + \delta_k + \alpha\delta_{ik} + \epsilon_{ijkl} \]
where:

- $y_{ijkl}$ = an observation of a dependent variable
- $\mu$ = effect common to all observations
- $\alpha_i$ = effect due to $i^{th}$ treatment
- $\beta_j(\alpha_i)$ = effect due to $j^{th}$ cow in $i^{th}$ treatment
- $\delta_k$ = effect due to $k^{th}$ week
- $\alpha \delta_{ik}$ = interaction effect between $i^{th}$ treatment and $k^{th}$ week
- $\epsilon_{ijkl}$ = error term, assumed NID $(0, \sigma_e^2)$

Cow was considered a random effect and all other effects, except error were considered fixed. Calculation of least-squares means and test of differences between selected means was done using the GLM procedure of SAS (29).
RESULTS AND DISCUSSION

Bacteria Count

Milk quality was measured by determining microorganism population present in milk. Sources of variation, mean squares, and levels of significance are shown in Table 1. All effects in the analysis were tested against the residual mean square except treatment which was tested against cow within treatment mean square. Treatment was a significant ($P < .05$) source of variation indicating the effect of udder preparation procedure on bacterial contamination of raw milk. Least-squares means, significance levels, and standard errors are presented in Table 2. Premilking udder preparation procedures that included sanitizing teats had significantly ($P < .05$) lower numbers of microorganisms in raw milk than procedure without. GEL and PREDIP treatments had similar raw milk bacteria count and were both less ($P < .05$) than WASH treatment. These results agree with Galton et al (9) and Adkinson et al (1).

Bacteria count from teat swabs followed a pattern similar to raw milk. Mean squares, sources of variation, and significance levels are given in Table 3. Results given in Table 4 indicate that PREDIP and GEL treatments had significantly ($P < .05$) lower bacteria count than the
TABLE 1. Mean squares and significance levels of sources of variation for natural log of raw milk bacteria count.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Mean Square (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT</td>
<td>2</td>
<td>15.5590**</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>1.2121</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>2.5000**</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>1.2342</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>181</td>
<td>0.9378</td>
</tr>
</tbody>
</table>

*Treatment effect was tested using Cow(Treatment) mean square as error term.

**Significant (P < .05)

TABLE 2. Treatment least-squares means, significance levels, and standard errors for natural log of raw milk bacteria count.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean (ln)</th>
<th>Standard Error (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEL</td>
<td>7.0766a</td>
<td>0.1151</td>
</tr>
<tr>
<td>WASH</td>
<td>7.8166b</td>
<td>0.1083</td>
</tr>
<tr>
<td>PREDIP</td>
<td>7.0197a</td>
<td>0.1083</td>
</tr>
</tbody>
</table>

*a,b Least-squares means with different letters are different (P < .05).*
TABLE 3. Mean squares and significance levels of sources of variation for natural log of teat swab bacteria count.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Mean Square (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>29.5010**</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>5.1892**</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>5.3912**</td>
</tr>
<tr>
<td>TREATMENT X WEEK</td>
<td>14</td>
<td>3.6182*</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>177</td>
<td>1.9617</td>
</tr>
</tbody>
</table>

<sup>a</sup>Treatment effect was tested using Cow(Treatment) mean square as error term.

*Significant (P < .05)

**Significant (P < .01)

TABLE 4. Treatment least-squares means, significance levels, and standard errors for natural log of teat swab bacteria count.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean (ln)</th>
<th>Standard Error (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEL</td>
<td>9.2484&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.1665</td>
</tr>
<tr>
<td>WASH</td>
<td>10.2596&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.1602</td>
</tr>
<tr>
<td>PREDIP</td>
<td>9.1275&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.1578</td>
</tr>
</tbody>
</table>

<sup>ab</sup>Least-squares means with different letters are different (P < .01).
WASH treatment. Galton et al (8) reported high bacteria counts also in premilking teat rinses when sanitizers were not used.

Sources of variation, mean squares and significance levels for preliminary incubation (PI) count in milk are given in Table 5. Least-squares means in Table 6 show the WASH treatment had significantly (P < .05) higher PI bacteria count than either GEL or PREDIP. Difference between the GEL and PREDIP treatments was not significant (P < .05).

Premilking udder hygiene is essential in reducing bacterial contamination of raw milk at harvest. Adequate sanitizing of teats prior to machine attachment is an important aspect of premilking hygiene. Perhaps the most important aspect of premilking hygiene is how dry the udder is at machine attachment. Milk bacteria counts was low in the GEL and PREDIP treatments. These results agree with the findings of Galton et al (7, 8, 9).

Production

Milk yield, fat percent, and protein percent were the production traits examined in this research. As shown in Table 7, only week and cow within treatment were significant (P < .01) sources of variation for all three
TABLE 5. Mean squares and significance levels of sources of variation for natural log of preliminary incubation count in milk.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Mean Square (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT*</td>
<td>2</td>
<td>11.8374**</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>1.7124**</td>
</tr>
<tr>
<td>WEEK</td>
<td>6</td>
<td>4.0292**</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>12</td>
<td>0.5493</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>156</td>
<td>0.7431</td>
</tr>
</tbody>
</table>

*Treatment effect was tested using Cow(Treatment) mean square as error term.

**Significant (P < .01)

TABLE 6. Treatment least-squares means, significance levels, and standard error for natural log of preliminary incubation (PI) count.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean (ln)</th>
<th>Standard Error (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEL</td>
<td>7.6244a</td>
<td>0.1086</td>
</tr>
<tr>
<td>WASH</td>
<td>8.4310b</td>
<td>0.1030</td>
</tr>
<tr>
<td>PREDIP</td>
<td>7.8347a</td>
<td>0.1030</td>
</tr>
</tbody>
</table>

*Least-squares means with different letters are different (P < .01).
TABLE 7. Mean squares and significance levels of sources of variation for milk yield, fat percent, and protein percent.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Mean Squares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Milk Yield (Kg)</td>
</tr>
<tr>
<td>TREATMENT*</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>205**</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>261**</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>15</td>
</tr>
</tbody>
</table>

*Treatment effect was tested using Cow(Treatment) mean square as error term.

**Significant (P < .01)

TABLE 8. Treatment least-squares means and standard errors for milk yield, fat percent and protein percent.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milk (Kg)</td>
</tr>
<tr>
<td>GEL</td>
<td>50.69 ± .66</td>
</tr>
<tr>
<td>WASH</td>
<td>51.10 ± .63</td>
</tr>
<tr>
<td>PREDIP</td>
<td>50.01 ± .63</td>
</tr>
</tbody>
</table>

*Least-squares means with different letters are different (P < .01).
traits. Treatment and its interaction with week were not significant sources of variation. Table 8 contains data indicating no significant differences ($P < .01$) due to treatments for daily milk yield, fat percent and protein percent, respectively.

**Iodine Concentration in Raw Milk**

Least-squares analysis of milk iodine concentration data resulted (Table 9) in similar but different ($P < .05$) means for the GEL and PREDIP treatments and both were higher than the WASH treatment mean ($P < .01$). The overall difference observed between means was only 0.0018 ppm. Such minute amounts of iodine have been reported by Conrad and Hemken (2) and Galton et al (8). Cows in the WASH group had iodine on their teats only as a post dip. Iodine is a naturally occurring component of milk.

Teat skin of cows in the GEL and PREDIP treatments was exposed to iodophor more than that of cows in the WASH group. In addition to the 1% iodophor postdip, both the GEL and PREDIP treatments added another source of exposure (.05% titrable iodine). These results confirm reports by Conrad and Hemken (2) and Galton et al (8). Galton et al (10) and Pankey et al (22) emphasized the importance of drying teats in reducing iodine residues.
Premilking Udder Preparation Time and Parlor Throughput

Treatment and week were significant (P < .01) sources of variation for premilking udder preparation time (PREPTIME). There was a significant (P < .01) difference due to treatments. In Table 10, least-squares means reveal the WASH treatment to have shortest preptime, followed by GEL, and PREDIP. GEL and PREDIP treatments required a 30 sec sanitizer contact time before cluster attachment. The GEL treatment had a significant (P < .01) advantage over the PREDIP because similar effects in reducing teat end and raw milk microorganisms were obtained with shorter preptime. The PREPTIME advantage was also shown by the WASH treatment, this advantage may be undesirable because the treatment had the highest (P < .01) bacteria count in milk and at the teat end. Consequently, poor milk quality and udder health could result.

More cows per hour (P < .01) were milked in the GEL and WASH treatments than the PREDIP treatment. Difference between the GEL and WASH treatments was 4 cows/hr which represents a 7.27% improvement. Both treatments required five premilking udder preparation steps but the GEL treatment had a 30 sec sanitizer contact time. In addition, lower bacteria counts were obtained from the GEL treatment. In comparison to the GEL, PREDIP treatment showed similar effects in reducing bacteria counts at the
### TABLE 9. Treatment least-squares means and standard errors for raw milk iodine concentration.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean (ppm)</th>
<th>Standard Error (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEL</td>
<td>0.0110&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0003</td>
</tr>
<tr>
<td>WASH</td>
<td>0.0092&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.0003</td>
</tr>
<tr>
<td>PREDIP</td>
<td>0.0101&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

<sup>ab</sup>Least-squares means with different letters are different (P < .01).

### TABLE 10. Treatment least-squares means and standard errors for premilking udder preparation time.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean (sec)</th>
<th>Standard Error (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEL</td>
<td>95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.24</td>
</tr>
<tr>
<td>WASH</td>
<td>66&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.07</td>
</tr>
<tr>
<td>PREDIP</td>
<td>105&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.07</td>
</tr>
</tbody>
</table>

<sup>abc</sup>Least-squares means with different letters are different (P < .05).
teat end and in milk. The PREDIP treatment was less efficient since it required more premilking udder preparation steps to give the same milk quality as the GEL. Parlor efficiency data is presented in Table 11.

**Udder Health**

Table 12 presents sources of variation and significance levels for natural log of SCC. Least-squares analysis of the data indicated (Table 13) a significantly (P < .05) lower count for the GEL than either PREDIP or WASH treatments. The WASH treatment had a similar SCC (P < .05) to the PREDIP. Perhaps the PREDIP (0.5% iodophor) was not adequately effective in controlling pathogens that can invade the udder.

The GEL treatment did not require water, therefore, no bacteria laden water was present to drain into teat cups. This may make the GEL a more effective method of premilking udder preparation because bacteria laden water has been reported (7, 11, 17, 23) to increase SCC and cause intramammary infections. Milk quality also deteriorates with increasing SCC. Low SCC is an indication of good udder health and should be an objective of a premilking udder hygiene program.

Pathogens isolated in a herd culture before starting the study included *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Staphylococcus saprophyticus* and
TABLE 11. Treatment least-squares means and standard errors for parlor throughput (number of cows milked/hr).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEL</td>
<td>55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.38</td>
</tr>
<tr>
<td>WASH</td>
<td>51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.38</td>
</tr>
<tr>
<td>PREDIP</td>
<td>43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.59</td>
</tr>
</tbody>
</table>

<sup>ab</sup>Least-squares means with different letters are different (P < .01).

TABLE 12. Mean squares and significance levels of sources of variation for natural log of somatic cell count (SCC).

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Mean Square (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>3.4799</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>4.3782**</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>6.0296**</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>1.9067**</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>178</td>
<td>0.7300</td>
</tr>
</tbody>
</table>

<sup>a</sup>Treatment effect was tested using Cow(Treatment) mean square as error term.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean (ln)</th>
<th>Standard Error (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEL</td>
<td>11.6388&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.1042</td>
</tr>
<tr>
<td>WASH</td>
<td>11.9340&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.0963</td>
</tr>
<tr>
<td>PREDIP</td>
<td>12.0693&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.0955</td>
</tr>
</tbody>
</table>

<sup>a,b</sup>Least-squares means with different letters are different (P < .01).

TABLE 14. Eligible number of quarters, percent quarters infected, and total days treated for clinical mastitis.

<table>
<thead>
<tr>
<th>CLINICAL MASTITIS</th>
<th>TREATMENT</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GEL</td>
<td>WASH</td>
<td>PREDIP</td>
<td></td>
</tr>
<tr>
<td>initial no. of quarters&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>% quarters infected</td>
<td>0</td>
<td>9.48</td>
<td>4.31</td>
<td></td>
</tr>
<tr>
<td>total days of infection</td>
<td>0</td>
<td>43.00</td>
<td>25.00</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Number of quarters available at the start of the study.
**Streptococcus dysgalactiae.** In two clinical mastitis cases that occurred in the WASH treatment during the study, *S. aureus* and *S. dysgalactiae* were isolated. Other organisms isolated in the WASH treatment were *Streptococcus bovis* and some Klebsiella species. One case of clinical mastitis caused by *Escherichia coli* was recorded in the PREDIP treatment. Results of six samples from the WASH and PREDIP treatments were negative; four clinical mastitis cases from the WASH treatment and two from PREDIP. Only one sample was contaminated. No clinical cases were observed in the GEL treatment.

Differences in percent quarters becoming infected between treatment groups were tested using a t-test which approximates a standard Student's t statistic (16). Results showed a highly significant reduction in clinical mastitis by the GEL treatment compared to the WASH and PREDIP treatments. The rate of reduction in new clinical mastitis cases between the GEL treatment and the other two treatments was 100%. New clinical mastitis cases were reduced 54.6% by the PREDIP treatment when compared to the WASH treatment.

Although the GEL treatment did not have any clinical mastitis cases during the research period, results of a mastitis check at the end of the study showed the presence of Coagulase-negative Staphylococcal species in this group. Similar type of organisms were found in the PREDIP
treatment. A Corynobacterium specie and S. aureus were also isolated at the conclusion of the study from the WASH treatment.

A summary of clinical mastitis incidence is presented in Table 14. The WASH treatment had more mastitis cases and cows from this treatment stayed infected longer than cows in the PREDIP treatment. These results emphasize the effect of premilking hygiene on udder health. In comparison to the PREDIP procedure, GEL would be a preferable method of premilking udder preparation. The procedure cleans and sanitize teats without leaving contaminated water to drain into teat cups. Findings here agree with the recommendations reported by Galton et al (8, 11) that udder and teats should be thoroughly dry and clean before machine attachment.

The GEL did not irritate teat skin. Gross visual examination of the skin during and after the trial did not reveal any abnormalities.
SUMMARY AND CONCLUSIONS

This research was conducted to compare and contrast the traditional method of premilking udder preparation (i.e. wash with water and dry with single use paper towels) with a new method that did not include water, and the traditional plus predipping with .05% iodophor. The new method required using a gel that cleaned and sanitized teats. Iodine concentration in harvested milk was examined to determine the extent of contamination by iodophor residue from the GEL. Relationships between milk production, composition, udder health and premilking hygiene procedures were also evaluated. Finally, premilking udder preparation time and parlor throughput were studied to determine parlor efficiency.

Results of this research may be summarized as follows:

1. Premilking udder hygiene decreased bacteria count on teat end and in harvested milk. Lowest counts were obtained from the GEL and PREDIP treatments.
2. Experimental GEL treatment maintained udder health and reduced bacterial count in milk without leaving illegal iodine residues. The somatic cell counts were lower for cows on the GEL treatment than those on WASH or PREDIP.
3. There were no detrimental effects of the GEL treatment on production observed in this study.
4. The GEL treatment was more efficient in number of cows milked/hr.

An effective milking management program should include adequate udder hygiene. The GEL indicated numerous benefits, its full potential as a permanent premilking udder preparation should be further explored.
LITERATURE CITED


premilking teat disinfection. J. Dairy Sci. 70:867.


Figure 1a. Treatment least squares means for bacteria counts in raw milk.
Figure 2a. Treatment least-squares means for preliminary incubation counts in milk.
Figure 3a. Treatment least-squares means of teat swab bacteria counts.
Figure 4a. Treatment least-squares means for somatic cell count.
Figure 5a. Treatment least-squares means for daily milk yield.
Figure 6a. Treatment least-squares means for a.m. milk yield.
Figure 7a. Treatment least-squares means for p.m. milk yield.
Figure 8a. Treatment least-squares means for milk protein percent.
Figure 9a. Treatment least-squares means for milk fat percent.
Figure 10 a. Treatment least-squares means for premilking udder preparation time.
Figure 11a. Treatment least-squares means for number of cows milked/hr.
Figure 12a. Treatment least-squares means for iodine concentration in raw milk.
TABLE 1a. Treatment least-squares means and standard errors for a.m. and p.m. milk yield.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Least-squares mean a.m. milk (Kg)</th>
<th>p.m. milk (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEL</td>
<td>26.31a ± .38</td>
<td>24.39a ± .34</td>
</tr>
<tr>
<td>WASH</td>
<td>27.74a ± .36</td>
<td>24.36a ± .32</td>
</tr>
<tr>
<td>PREDIP</td>
<td>26.10a ± .36</td>
<td>23.91a ± .32</td>
</tr>
</tbody>
</table>

*Least-squares means with different letters are different (P < .05).

TABLE 2a. Least-squares analysis of variance for a.m. and p.m. milk yield.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>a.m. milk (Kg)</th>
<th>p.m. milk (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENTa</td>
<td>2</td>
<td>3.84</td>
<td>2.55</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>57.19**</td>
<td>47.27**</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>62.66**</td>
<td>68.74**</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>3.69</td>
<td>2.06</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>4.67</td>
<td>3.82</td>
</tr>
</tbody>
</table>

*Treatment effect was tested using Cow(Treatment) mean square as error term.

**Significant (P < .01)
### TABLE 3a. Least-squares analysis of variance for daily milk yield.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (Kg)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>11</td>
<td>0.05</td>
<td>0.9479</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>205</td>
<td>14.24</td>
<td>0.0001</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>261</td>
<td>18.14</td>
<td>0.0001</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>9</td>
<td>0.61</td>
<td>0.8513</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>231</td>
<td>43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Treatment effect was tested using Cow(Treatment) mean square as error term.

### TABLE 4a. Least-squares analysis of variance for fat percent.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (%)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>0.02</td>
<td>0.01</td>
<td>0.9871</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>1.17</td>
<td>4.25</td>
<td>0.0001</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>0.77</td>
<td>2.79</td>
<td>0.0088</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>0.31</td>
<td>1.14</td>
<td>0.3228</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>231</td>
<td>0.39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Treatment effect was tested using Cow(Treatment) mean square as error term.
TABLE 5a. Least-squares analysis of variance for protein percent.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (%)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>0.03</td>
<td>0.08</td>
<td>0.9251</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>0.38</td>
<td>2.06</td>
<td>0.0033</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>0.62</td>
<td>3.41</td>
<td>0.0019</td>
</tr>
<tr>
<td>TREATMENT X WEEK</td>
<td>14</td>
<td>0.04</td>
<td>0.23</td>
<td>0.9984</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>231</td>
<td>0.21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Treatment effect was tested using Cow(Treatment) mean square as error term.


<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (ln)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>15.56</td>
<td>12.84</td>
<td>0.0001</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>1.21</td>
<td>1.29</td>
<td>0.1675</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>2.50</td>
<td>2.67</td>
<td>0.0120</td>
</tr>
<tr>
<td>TREATMENT X WEEK</td>
<td>14</td>
<td>1.23</td>
<td>1.32</td>
<td>0.2014</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>181</td>
<td>0.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>230</td>
<td>1.16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Treatment effect was tested using Cow(Treatment) mean square as error term.
TABLE 7a. Least-squares analysis of variance for natural log of teat swab bacteria count.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (ln)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT(^a)</td>
<td>2</td>
<td>29.50</td>
<td>5.69</td>
<td>0.0090</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>5.19</td>
<td>2.65</td>
<td>0.0001</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>5.39</td>
<td>2.75</td>
<td>0.0098</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>3.62</td>
<td>1.84</td>
<td>0.0355</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>177</td>
<td>1.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>226</td>
<td>2.79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Treatment effect was tested using Cow(Treatment) mean square as error term.

TABLE 8a. Least-squares analysis of variance for natural log of preliminary incubation (PI) count in milk.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (ln)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT(^a)</td>
<td>2</td>
<td>11.84</td>
<td>6.91</td>
<td>0.0039</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>1.71</td>
<td>2.30</td>
<td>0.0009</td>
</tr>
<tr>
<td>WEEK</td>
<td>6</td>
<td>4.03</td>
<td>5.42</td>
<td>0.0001</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>12</td>
<td>0.55</td>
<td>0.74</td>
<td>0.7113</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>156</td>
<td>0.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>202</td>
<td>1.07</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Treatment effect was tested using Cow(Treatment) mean square as error term.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (ln)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT(^a)</td>
<td>2</td>
<td>3.48</td>
<td>0.79</td>
<td>0.4623</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>4.38</td>
<td>6.00</td>
<td>0.0001</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>6.03</td>
<td>8.26</td>
<td>0.0001</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>1.91</td>
<td>2.61</td>
<td>0.0018</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>178</td>
<td>0.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>227</td>
<td>1.42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Treatment effect was tested using Cow(Treatment) mean square as error term.

TABLE 10a. Least-squares analysis of variance for iodine concentration in milk.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (ppm)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT(^a)</td>
<td>2</td>
<td>0.0001</td>
<td>1.38</td>
<td>0.2696</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>0.0000</td>
<td>6.33</td>
<td>0.0001</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>0.0005</td>
<td>68.31</td>
<td>0.0001</td>
</tr>
<tr>
<td>TREATMENT x WEEK</td>
<td>14</td>
<td>0.0000</td>
<td>1.38</td>
<td>0.1637</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>0.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>231</td>
<td>0.0000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Treatment effect was tested using Cow(Treatment) mean square as error term.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (sec)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT(^a)</td>
<td>2</td>
<td>29,439</td>
<td>30.93</td>
<td>0.0001</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>952</td>
<td>1.44</td>
<td>0.0896</td>
</tr>
<tr>
<td>WEEK</td>
<td>6</td>
<td>4,094</td>
<td>6.20</td>
<td>0.0001</td>
</tr>
<tr>
<td>TREATMENT X WEEK</td>
<td>12</td>
<td>681</td>
<td>1.03</td>
<td>0.4219</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>156</td>
<td>660</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>202</td>
<td>1,086</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Treatment effect was tested using Cow(Treatment) mean square as error term.

TABLE 12a. Least-squares analysis of variance for a.m. milk yield.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (Kg)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT(^a)</td>
<td>2</td>
<td>3.84</td>
<td>0.07</td>
<td>0.9352</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>57.19</td>
<td>12.25</td>
<td>0.0001</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>62.66</td>
<td>13.42</td>
<td>0.0001</td>
</tr>
<tr>
<td>TREATMENT X WEEK</td>
<td>14</td>
<td>3.69</td>
<td>0.79</td>
<td>0.6789</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>4.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>231</td>
<td>12.30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Treatment effect was tested using Cow(Treatment) mean square as error term.
TABLE 13a. Least-squares analysis of variance for p.m. milk yield.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MS (Kg)</th>
<th>F Value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT(^a)</td>
<td>2</td>
<td>2.55</td>
<td>0.05</td>
<td>0.9479</td>
</tr>
<tr>
<td>COW (TREATMENT)</td>
<td>26</td>
<td>47.27</td>
<td>14.24</td>
<td>0.0001</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>68.74</td>
<td>18.14</td>
<td>0.0001</td>
</tr>
<tr>
<td>TREATMENT X WEEK</td>
<td>14</td>
<td>2.06</td>
<td>0.61</td>
<td>0.8513</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>3.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORRECTED TOTAL</td>
<td>231</td>
<td>10.56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Treatment effect was tested using Cow(Treatment) mean square as error term.

TABLE 14a. Mean squares and significance levels of sources of variation for iodine concentration in raw milk as affected by treatment.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Mean Square (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT(^a)</td>
<td>2</td>
<td>0.0001**</td>
</tr>
<tr>
<td>COW (TREATMENT)</td>
<td>26</td>
<td>0.0000**</td>
</tr>
<tr>
<td>WEEK</td>
<td>7</td>
<td>0.0005**</td>
</tr>
<tr>
<td>TREATMENT X WEEK</td>
<td>14</td>
<td>0.0000</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>182</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

\(^a\)Treatment effect was tested using Cow(Treatment) mean square as error term.

\(^\star\star\)Significant at the P < .01 level.
TABLE 15a. Mean squares and significance levels of sources of variation for premilking udder preparation time as affected by treatment.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Mean Square (Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREATMENT</td>
<td>2</td>
<td>29,439**</td>
</tr>
<tr>
<td>COW(TREATMENT)</td>
<td>26</td>
<td>952</td>
</tr>
<tr>
<td>WEEK</td>
<td>6</td>
<td>4,094**</td>
</tr>
<tr>
<td>TREATMENT X WEEK</td>
<td>12</td>
<td>681</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>156</td>
<td>660</td>
</tr>
</tbody>
</table>

*Treatment effect was tested using Cow(Treatment) mean square as error term.

**Significant (P < .01)
Kasimu H. Ingawa was born at Batsari, Katsina State, Nigeria.

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1976
Ordinary National Diploma, Animal Health and Husbandry. National Veterinary Research Institute, Vom, Nigeria.

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Candidate: Kasimu Ingawa Hudu

Major Field: Dairy Science

Title of Dissertation: The Effects of Gel Teat Cleaning and Sanitizing on Raw Milk Quality and Udder Health

Approved:

[Signature]
Major Professor and Chairman

[Signature]
Dean of the Graduate School

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Date of Examination:

September 5, 1990