

Food Animal Economics

Economics of feeding pasteurized colostrum and pasteurized waste milk to dairy calves

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Objective—To estimate the marginal contribution of pasteurization of waste milk and colostrum to gross margin per calf at weaning and to estimate the minimum number of cattle on a dairy farm for pasteurization to be profitable.

Design—Randomized, controlled, clinical trial.

Animals—300 Holstein calves.

Procedure—The performance of calves fed pasteurized colostrum and waste milk was compared with the performance of calves fed nonpasteurized colostrum and waste milk. Costs, revenues, and gross margins for the 2 groups were compared.

Results—Calves fed pasteurized colostrum and waste milk were worth an extra \$8.13 in gross margin/calf, compared with calves fed nonpasteurized colostrum and waste milk. The minimum number of cattle for which feeding pasteurized colostrum and waste milk was calculated to be economically feasible was 315 calves/d (1,260-cow dairy farm).

Clinical Implications—An economic benefit was associated with feeding pasteurized colostrum and waste milk. Additional benefits that may accrue include higher mean weight gain and lower mortality rate of calves as well as calves that have fewer days in which they are affected with diarrhea and pneumonia. (*J Am Vet Med Assoc* 1996;209:751–756)

Milk from dairy cows treated with antibiotics, commonly referred to as waste milk, is discarded or fed to calves.^{1–6} Although feeding waste milk to calves reduces feed costs,⁷ many producers avoid this practice for fear of increased calf mortality attributable to pathogenic organisms,^{6,8–10} morbidity,⁶ and reduced weight gain.¹¹ Many investigators have examined practical methods of storing and handling waste milk, such as fermentation or chemical treatment, to increase its feeding value.^{6,12–15} It has been reported that calves fed pasteurized waste milk and colostrum have a lower

risk of developing diarrhea and better weight gain than those fed nonpasteurized waste milk and colostrum.⁸

The reasons that dairymen have not adopted pasteurization to treat waste milk may be because of the high initial investment associated with purchasing pasteurizing equipment or because they believed the quantity of waste milk they produced was too small for pasteurization to be economical. In the central valley of California, where nearly 70% of dairies have 200 or more milking cows,¹⁶ production of waste milk can be substantial. In an effort to provide producers with information on the potential of pasteurization as a means to treat waste milk and colostrum, economic evaluation of the contribution to overall farm income of pasteurization of waste milk and colostrum needs to be performed.

Several approaches have been used to examine the economics of animal health on livestock production programs (eg, cost-benefit analysis,^{17–20} partial farm budgeting,^{21–23} gross margin analysis,^{24–25} and marginal product analysis^{26–30}). The approach that measures marginal economic impact of each input component through production-function analysis probably gives the most valuable information for economic decision making.²⁹ Specifically, marginal analysis by use of marginal gross margin (ie, profit before fixed costs) to assess the economic contribution of each input used in an animal health or production improvement program (eg, milk pasteurization) has not been reported.

The greatest appeal for use of marginal gross margin is its ability to directly measure the effect of changes of each variable input component on profitability of multiple-enterprise operations without requiring that fixed costs be known. The typical dairy farm in the central valley of California may be involved in the production of milk, forage, replacement heifers, beef, or combinations of these enterprises. Fixed costs (associated with capital investment on housing and equipment, rent of land, building and equipment depreciation, interest on investment, and corresponding property tax and insurance on buildings and equipment) are shared by many enterprises, and, hence, allocating fixed costs for each enterprise on a farm may be difficult. Fixed costs are fairly small, however, compared with variable costs such as feed, labor, and health-related expenditures.³¹ Use of gross margin to assess the economic benefit of introducing on-farm pasteurization, which involves substantial variable

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costs, may best quantify the association between pasteurization and variable inputs.

The objectives of the study reported here were to estimate the marginal contribution of pasteurization of waste milk and colostrum to gross margin per calf at weaning and to estimate the minimum number of cattle on a dairy farm for pasteurization to be profitable.

Materials and Methods

A clinical study was conducted on a dry-lot dairy farm in the central valley of California.^a The dairy had 5,000 cows and a 5-year rolling herd average of about 10,900 kg of milk/cow. Newborn female (n = 150) and male (n = 150) Holstein calves that were born between May 28 and June 28, 1993, were enrolled in the study. A thorough physical examination was performed to exclude clinically sick, deformed, or injured calves. Sample size was chosen to accommodate logistic and time constraints and to cause the least interference with the existing calf management protocol of the farm. Calves were assigned to treatment and control groups on the basis of their dam's ear-tag number.^a Calves in the treatment group received 2 to 4 L of pasteurized colostrum (warmed to about 38 C) 2 to 3 hours after birth, and calves in the control group received a similar amount of nonpasteurized colostrum. Treatment- and control-group calves were separated from their dams to prevent suckling and were moved to a central calf-rearing area, where they were housed in rows of hutches that contained treatment and control calves, respectively. While in the hutches, calves in the treatment group were fed 4 L of pasteurized waste milk twice daily for the first month, followed by 4 L once daily until weaning at 10 to 12 weeks of age. Calves in the control group received nonpasteurized waste milk at a similar rate of intake. Water and calf-starter pellets (22% crude protein, 2.5% crude fat, and 8% crude fiber, determined on a dry-matter basis) were provided ad libitum from the third day after birth until weaning. Pooled colostrum was pasteurized by use of a high-temperature short-time method, and waste milk was pasteurized by a batch-pasteurization method.³²

All calves were observed for about 2 hours twice daily after each feeding for signs of inappetence, dullness, diarrhea, and respiratory disease. A standardized scoring method was used to record clinical signs. Diarrhea and pneumonia were treated by a caretaker, using medications as instructed by the farm veterinarian. Calf weights were approximated on arrival at the calf hutches and were determined every week thereafter by use of a calibrated heart-girth tape.^b Calves were evaluated from birth to weaning. At the time of weaning, calves weighed 80 to 90 kg. After weaning, female calves were raised in group pens to become replacement heifers, and male calves were fattened and sold when they weighed approximately 140 kg.

Variable costs of production—All variable cost information on feed (eg, calf-starter pellets, colostrum, and waste milk), medication for maintenance of health (eg, vaccines, disinfectants, antibiotics, antibacterials, and electrolyte mixtures), and labor (feeding, cleaning of hutches, and treating sick calves) were obtained concurrently from farm records (Table 1). Cost information collected on pasteurization included initial capital investment on pasteurization equipment (including erecting a structure to house the pasteurizer), annual depreciation, loan interest, insurance, and operational costs such as labor, energy, and maintenance.

Variable definitions and calculations—Average revenue was the market value at the time of weaning of a female calf sold as a replacement heifer or a male calf sold for beef.

Table 1—Variable input costs during the preweaning period for calves on a 5,000-cow dairy farm that were fed pasteurized or nonpasteurized waste milk

Variable	Cost
Feed	\$/unit
Grain (calf-starter pellets; kg)	0.31
Milk, including first colostrum (L)	0.09
Labor (per feeding or per treatment)	
Feeding	0.08
Treatment for diarrhea	
Spectinomycin	0.56
Erythromycin	0.28
Gentamicin	0.28
Treatment for pneumonia	
Tylosin	0.28
Oxytetracycline	0.28
Penicillin	0.28
Health-related expenses (per treatment)	
Diarrhea medication	
Spectinomycin	1.12
Erythromycin	0.70
Gentamicin	0.79
Electrolytes	0.07
Pneumonia medication	
Tylosin	0.36
Oxytetracycline	0.09
Penicillin	0.36
Vitamins A and D	0.04
Vaccines	1.20
Pasteurization-related cost (per day)	¢/unit
Capital costs*	
Depreciation†	1.02
Interest‡	0.52
Repairs and maintenance§	0.39
Taxes	0.08
Insurance¶	0.10
Labor	3.04
Energy	0.19
Total	5.35

*Annual cost obtained from amortization of capital costs (ie, pasteurizer, heating equipment, and building) during a 5-year period was considered to be a variable cost in the context of this study. †Depreciation was determined on the basis of a 15% annual rate for milking equipment and building. ‡Assumed interest rate was 7.6%/annum. §Mean annual rate of milk equipment repairs of \$600 for the farm for the past 5 years. ||Property taxes were \$2.00/\$100 of market value. ¶Insurance was 1.5% of value for equipment and building.

Market values were obtained from review of the regional market at the time of expected sale.³³

Feed costs were associated with feeding colostrum, waste milk, and calf-starter pellets during the preweaning period. Waste milk was fed at the previously described rate throughout the preweaning period, and calf-starter pellets were offered daily at the rate of 0.45 kg of pellets/d during the first month, 1.36 kg/d from the first month until about the third month, and 2.26 kg/d from then until weaning. The daily amount of waste milk and calf-starter pellets fed to each calf was estimated by the caretaker. Labor cost associated with feeding was calculated as:

$$\frac{\text{number of hours a caretaker spent feeding calves per day} \times \text{mean wages per hour}}{\text{number of calves fed per day}}$$

Health maintenance costs consisted of total expenditures on vaccines, chemicals, and drugs used on calves, including labor cost associated with product administration. Labor cost associated with health maintenance was calculated as follows:

$$\frac{\text{mean amount of time required for a caretaker to treat a calf for a particular condition} \times \text{average daily wages of caretakers on the farm (including costs for overtime and health benefits)}}{\text{number of calves treated}}$$

Pasteurization costs were associated with establishing a pasteurization unit and included capital investment for a pas-

Table 2—Values (mean $\pm$ SD) of calf characteristics, costs, and revenue, stratified by sex, for groups of calves fed pasteurized or nonpasteurized waste milk on a 5,000-cow dairy farm

Variable	Males		Females	
	Pasteurized waste milk (n = 75)	Nonpasteurized waste milk (n = 75)	Pasteurized waste milk (n = 75)	Nonpasteurized waste milk (n = 75)
Total variable costs (\$)	74.39 ^a $\pm$ 9.36	71.22 ^b $\pm$ 11.24	70.45 ^b $\pm$ 8.55	73.37 ^a $\pm$ 12.74
Feed costs*	64.69 ^a $\pm$ 6.72	59.66 ^b $\pm$ 9.55	61.23 ^b $\pm$ 7.08	61.09 ^b $\pm$ 11.96
Grain (calf-starter pellets)	32.85 ^a $\pm$ 4.10	29.79 ^b $\pm$ 5.83	30.74 ^b $\pm$ 4.33	30.66 ^b $\pm$ 7.30
Waste milk (including first colostrum)	25.92 ^a $\pm$ 2.13	24.32 ^b $\pm$ 3.03	24.82 ^b $\pm$ 2.24	24.78 ^b $\pm$ 3.79
Labor on feeding	5.92 ^a $\pm$ 0.49	5.55 ^b $\pm$ 0.69	5.67 ^b $\pm$ 0.51	5.66 ^b $\pm$ 0.87
Health costs†	6.07 ^a $\pm$ 5.64	7.36 ^b $\pm$ 6.75	5.74 ^a $\pm$ 5.40	8.09 ^b $\pm$ 6.30
Drugs for diarrhea treatment	3.22 ^a $\pm$ 3.91	3.73 ^a $\pm$ 4.38	2.91 ^a $\pm$ 3.51	3.80 ^a $\pm$ 3.92
Drugs for pneumonia treatment	0.55 ^a $\pm$ 1.14	0.96 ^b $\pm$ 1.76	0.60 ^a $\pm$ 1.30	1.39 ^b $\pm$ 2.12
Labor on diarrhea treatment	1.03 ^a $\pm$ 1.27	1.19 ^a $\pm$ 1.42	0.93 ^a $\pm$ 1.16	1.20 ^a $\pm$ 1.28
Labor on pneumonia treatment	0.26 ^a $\pm$ 0.56	0.47 ^b $\pm$ 0.89	0.29 ^a $\pm$ 0.64	0.69 ^b $\pm$ 1.07
Loss associated with mortality	0.00	4.19 [‡]	0.00	4.19 [§]
Miscellaneous	1.01 [§]	1.01 [§]	1.01 [§]	1.01 [§]
Pasteurization cost	3.75 ^a $\pm$ 0.31	0.00	3.60 ^b $\pm$ 0.32	0.00
Total revenue (\$)	241.25 ^a $\pm$ 29.43	224.26 ^b $\pm$ 36.83	191.11 ^c $\pm$ 23.86	186.28 ^d $\pm$ 33.86
Calf value at birth (\$)	92.05 ^a $\pm$ 9.69	90.76 ^b $\pm$ 9.15	86.82 ^b $\pm$ 8.48	87.49 ^b $\pm$ 9.06
Gross margin (\$)	74.81 ^a $\pm$ 24.66	62.28 ^b $\pm$ 31.14	33.83 ^c $\pm$ 16.98	25.42 ^d $\pm$ 27.16

*Costs of grain, milk, and labor associated with feeding. †Costs of drugs and labor associated with administering treatment for diarrhea and pneumonia, vitamin supplements, and vaccines, dehorning, and cleaning of hutches. ‡Value determined for 74 calves. §Standard deviation not calculated. ¶Value determined for 71 calves.
Means within the same row with different superscripts differ significantly ($P < 0.05$).

teurizer, water heating equipment, and a building to house the pasteurizer; annual depreciation on all capital expenditures; interest from borrowed capital; repair and maintenance costs; taxes; and insurance premiums. An annual depreciation rate of 15% was used for the pasteurizer and heating equipment (as is typically used for depreciation of milk-processing equipment), and an annual depreciation rate of 10% was used for the building.³⁴ Depreciation was calculated by use of the declining-balance method.³⁵ An interest rate of 7.6%, which was applied on capital borrowed to establish the pasteurization facility, was determined on the basis of the current interest rate charged by a local bank were for dairy equipment purchases. Repair and maintenance costs determined on the basis of mean yearly farm expenditures on milk-processing equipment. An annual property tax of 2% was applied on pasteurization facilities (equipment and housing). Total capital expenditure on pasteurization was amortized during a 5-year period to obtain mean annual cost of pasteurization. Other variable costs associated with pasteurization included labor to operate the pasteurizer.

Enterprise gross margin per calf was calculated by determining the difference between total revenue for each calf at weaning and average total variable costs (Table 2).

Statistical analysis—Group differences for calf characteristics, morbidity, costs, revenue, and gross margin were assessed, using a two-way ANOVA,³⁶ whereby the effects of treatment, sex, and the treatment-by-sex interaction were evaluated. The gross margin function was estimated by use of multiple-regression analysis,³⁷ whereby the dependent variable was the gross margin per calf and independent variables were variable costs associated with feed, labor, health maintenance expenses, and pasteurization (treatment). The model controlled for the effects of sex and birth weight. An all-possible-subset regression procedure³⁸ was used.³⁹ Models with a subset of variables that maximized the coefficient of determination (R^2) were chosen as appropriate, after assessment for normality and residual analysis to satisfy the Gauss-Markov conditions.⁴⁰ In addition, highly correlated variables (tolerance < 0.02) were excluded. Differences were considered significant at $P < 0.05$.

Economic analysis—Estimates obtained from the regression analysis were used to estimate the value of the mar-

ginal gross margin or the marginal return to gross margin on a dollar invested for all the variable inputs. A positive coefficient was interpreted to mean that increasing use of the variable input resulted in a benefit, and a negative coefficient meant that the variable input increased the net cost.

The minimum number of cattle on a dairy farm for pasteurization to be profitable was determined by computing the break-even point for pasteurization. First, mean pasteurization cost in the preweaning period for various pasteurization capacities (defined as number of calves fed pasteurized waste milk per day) was determined. Second, a cost function was generated by plotting mean cost of pasteurization versus number of calves fed pasteurized waste milk per day. The break-even point (number of calves raised annually) for use of pasteurization was obtained when the gross margin function equaled the mean cost function. Number of cows on a dairy farm was calculated by multiplying the number of calves fed pasteurized waste milk per day by a factor of 4 (eg, 5,000/1,250 = 4, assuming a 5,000-cow dairy farm producing 5,000 calves/y, of which 1,250 calves would be fed pasteurized milk on any given day).

Results

Results indicated that male calves in the treatment group generally were weaned later and, thus, were heavier, compared with calves in the control group.^a This was attributed to the fact that many calves in the control group had been enrolled in the study when they were slightly older, but all calves had been marketed at approximately the same date. Calves in the treatment group had significantly higher mean weight gain, compared with calves in the control group. Significant differences for birth weight, age, and weight at weaning between female calves in treatment and control groups were not detected.

Calves in the treatment group had significantly fewer days in which they were affected with diarrhea and pneumonia, compared with calves in the control group. Five control-group calves (1 male and 4 females) died, which resulted in a crude mortality rate of 3.3%.

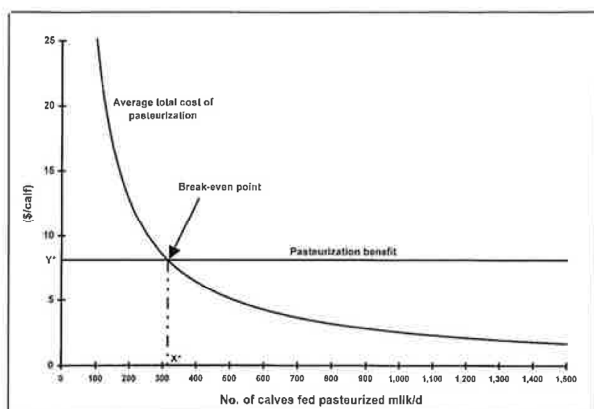


Figure 1—Graph depicting mean cost of milk pasteurization per calf during the preweaning period versus number of calves fed pasteurized milk per day. Break-even point for cost of pasteurization of milk was determined for groups of calves fed pasteurized ($n = 150$) and nonpasteurized ($n = 150$) waste milk on a 5,000-cow dairy farm. Y^* = difference in gross margin between calves fed pasteurized or nonpasteurized waste milk (\$8.13/calf); X^* = minimum number of calves fed pasteurized waste milk per day for pasteurization to be profitable (315 calves).

Crude comparison of variable costs, revenue, and gross margin—For male calves, mean total variable cost was significantly higher in the treatment group, compared with that of the control group (Table 2). The significantly higher mean health cost for male and female calves in the control group, compared with calves in the treatment group, was attributable to the higher cost of pneumonia treatment (Table 2). Mortality losses associated with calves that died included incurred costs for feed, labor, purchase of newborn calves, and medications and loss of the expected profit from sale of calves at the time of death. Total mortality losses were estimated to be \$608.00. Mortality losses were distributed among costs for calves in the control group, which resulted in a mean loss of \$4.19/calf. Costs associated with mortality loss were added to the variable costs. Mean pasteurization cost was significantly higher in male calves than in female calves, and male calves were weaned at a slightly older age than were female calves.

More revenue was earned for calves in the treatment group, compared with calves in the control group, because treatment-group calves were significantly heavier at weaning (Table 2). Similarly, more revenue was earned for male calves than for female calves of a similar age, because males were priced higher than females (\$2.72/kg of body weight for males vs \$2.35/kg of body weight for females). Male and female calves in the treatment group had a significantly higher gross margin (\$12.53 and \$8.41, respectively) than calves in the control group.

Marginal gross margin of variable inputs—After adjusting for confounding factors of birth weight and sex, results of multivariate analyses indicated that calves fed pasteurized waste milk were worth an extra \$8.13 in gross margin/calf, compared with calves fed nonpasteurized waste milk ($P < 0.01$). One dollar spent on feed generated \$0.59 more in gross margin

($P < 0.01$). One dollar spent on treatment for diarrhea or pneumonia was associated with a reduction in gross margin per calf of \$1.62 and \$4.74, respectively ($P < 0.01$). Typically, weaned male calves earned \$35.73 more in gross margin per calf than did weaned female calves ($P < 0.01$). Regardless of sex, calves that were heavier at birth had a higher gross margin (\$0.40/kg of body weight), compared with calves with a lighter birth weight ($P < 0.01$).

Number of cattle for profitable pasteurization—Using break-even point analysis, it was estimated that 315 calves/d should be fed pasteurized waste milk for pasteurization to be economical (Fig 1). The number of cows necessary for 315 calves was estimated to be 1,260 (ie, 315×4 ; assuming that calves were weaned at 10 to 12 weeks of age). Alternatively, assuming the herdsman on the farm used in our study maintained the herd size at 5,000 cows, all factors remaining equal, the cost of pasteurization per calf per day could more than double (from the current value of \$0.0535 to \$0.1167) without producing a negative gross margin.

Discussion

Calves fed pasteurized waste milk had a lower cost for health expenditures and a higher gross margin per calf, compared with calves fed nonpasteurized waste milk. The greatest losses observed in the study reported here resulted from calf mortality, which was associated with feeding of nonpasteurized waste milk. Benefits associated with feeding pasteurized waste milk, however, exceeded costs, even when calf mortality losses were ignored. One of the reasons calves fed pasteurized waste milk performed better than calves fed nonpasteurized waste milk may have been attributed to efficient weight gain associated with reduced morbidity that resulted from consumption of colostrum and waste milk with low numbers of bacteria and low toxin concentrations.⁴

Mean feed cost estimated in our study was comparable to that reported elsewhere.⁴¹ Because feed cost was estimated from the total amount of feed provided to calves by a caretaker, the amount actually consumed by each calf varied. For instance, some feed was wasted when it fell to the ground, and feed contaminated with urine or feces in the feed box often was discarded. Even when these feed losses were ignored, the marginal contribution of feed cost was higher than that reported in another study.²⁹

Marginal return to gross margin should be interpreted with caution. A negative marginal return to gross margin means that the expenditure on disease (eg, diarrhea or pneumonia) treatment was unable to offset the cost of medication and possible disease-related production loss. It should not be interpreted to mean that a producer should not treat a health problem. In fact, one of the basic underlying assumptions is that a producer can make rational decisions and, thus, can institute treatments, because providing treatment is economically preferred to the alternative of not providing treatment. Therefore, it is more likely that disease-related losses were reduced by the treatment

strategies selected. The high cost of pneumonia treatment found in this study was associated with the use of fairly expensive antibacterial drugs, such as tylosin and penicillin.

An alternative interpretation of the results could have been attributable to the physical impact (eg, feed consumption), instead of the economic impact, of feeding pasteurized colostrum and waste milk. The additional cost of grain (calf-starter pellets) for a male calf fed pasteurized waste milk versus a male calf fed nonpasteurized waste milk was \$3.06 (\$32.85 vs \$29.79; Table 2). The cost of grain used in this trial was \$0.3141/kg. Therefore, male calves fed pasteurized waste milk consumed 9.74 kg (\$3.06/\$0.3141/kg) more grain than male calves that were fed nonpasteurized waste milk.

Assuming the same number of cattle as the herd that was used in the study reported here, a producer who spent twice as much on pasteurization would still do better than one who did not embark on the use of pasteurization to treat their waste milk. On-farm pasteurization can be economical for medium and larger dairies, typically the size of those in the central valley of California. Small dairies also may benefit from pasteurizing their waste milk by investing in a pasteurizer with a smaller capacity, pooling of waste milk for several days, or pooling of waste milk with waste milk from other nearby dairies and sharing overhead and operational costs.

Generalization of the positive effect of pasteurization in lowering morbidity and improving weight gain, as reflected by higher gross margin, should be done with caution. Gross margin, which represents an economic index of performance, may be explained by variable input components (as approximated by various variable costs), but also may be explained by a function of changes in management and technologic knowledge. In our study, the degree of management and technologic knowledge that existed at the dairy was quite high, which is typical of large commercial dairies in the central valley of California and, thus, may have had an effect on the gross margin. On smaller dairies, it may not be economical to allocate labor solely to perform pasteurization, which may result in breakdown of the pasteurization process.

*Jamaluddin AA. Effects of feeding pasteurized colostrum and pasteurized waste milk on mortality, morbidity, and weight gain of dairy calves: field trial and economic analysis. PhD dissertation, Department of Medicine and Epidemiology, University of California, Davis, 1995.

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