

Potential for Segregating Milk: Herd Differences in Milk Value for Fluid and Five Manufactured Products

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ABSTRACT

Herd differences in value of milk for fluid use, nonfat dry milk, and Cheddar, Swiss, Mozzarella, and cottage cheeses were determined. Data were 1988 herd average records from the National Cooperative Dairy Herd Improvement Program that included milk, fat, and protein yields from 50,608 herds (3.8 million cows) that produced 28.8 billion kg of milk. Values of annual yield were calculated both on a per cow and total herd basis for fluid milk based on skim and milk fat pricing and for each of the five manufactured dairy products based on end product pricing. Mean value of annual yield was \$1961 per cow and \$145,700 per herd. Effect of milk pricing on yield value was similar among cheeses. Largest differences in yield value were between Cheddar cheese and fluid milk. Differences between herds in annual yield value for Cheddar cheese compared with skim and milk fat pricing ranged from -\$297 to \$123 per cow and from -\$306,800 to \$91,000 for total herd income. Within-county SD were 68 to 75% as large as overall SD, which suggests that milk segregation might be

feasible with little additional hauling cost.

(Key words: milk value, herd difference, multiple component pricing, end product pricing)

Abbreviation key: C:F = casein to fat ratio, EPP = end product pricing, NCDHIP = National Cooperative Dairy Herd Improvement Program, P:F = protein to fat ratio, SMFP = skim and milk fat pricing.

INTRODUCTION

Methods of pricing milk have undergone sweeping changes in the last decade. Attention has been directed to value of milk components other than fat because over 60% of milk produced today is used for manufactured dairy products (14). Multiple component pricing (assigning a value to one or more components in addition to fat) has been implemented in several forms, frequently as premiums or differentials for either protein or SNF. Often payment for these extra components has been tied to milk quality requirements (SCC or standard plate count), primarily because of their influence on cheese yield. One multiple component pricing method currently used by many cheese plants is "end product pricing" (EPP), also called "product yield pricing". This method prices milk based on its predicted yield and value in manufactured products (10). This predicted yield can be affected by a number of individual components (such as fat, protein, lactose, or SCC). With EPP, a milk producer is

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compensated according to value of the milk to the processor for the individual products manufactured. The basis for EPP is that the contribution of each component of milk toward market value can be determined for any given product.

Kosikowski (13) reported that Van Slyke first described a formula in 1894 that could be used to predict yield of Cheddar cheese from milk of known fat and casein composition. In 1952, Van Slyke and Price (18) presented an updated formula. Ernstrom et al. (11) noted that Van Slyke and Price's formula "is remarkably accurate in plants where good cheese making practices are followed," but such accuracy is not achieved for most plants. Ernstrom (10) suggested a reduction in the coefficient for fat recovery from 93 to 90% for Cheddar and used the same approach to develop formulas for Mozzarella and Swiss cheeses. Continued development of improved formulas for product yield for traditional and specialty cheeses is likely to result in expanded use of these tools in milk pricing (5).

Management of the milk supply so that milk from individual herds is delivered to the processing plants where it generates the greatest returns could benefit both producer and processor if accomplished without increasing hauling costs beyond the benefit gained. Some studies (7, 8, 17, 19) have shown that milk differs in value depending on its composition of milk fat and protein. Knowledge of herd differences in value of milk produced for various products is necessary to determine the potential benefit of segregating milk. The objective of this study was to determine the distribution of herd differences in milk value for fluid use, nonfat dry milk, and various cheeses.

MATERIALS AND METHODS

Data

The Animal Improvement Programs Laboratory, ARS, USDA, receives yield data of individual cows from nine dairy record processing centers for all herds enrolled in milk recording plans of the National Cooperative Dairy Herd Improvement Program (NCDHIP). In addition, these processing centers provide herd averages that represent the annual yield

summary of all cows in the herd, i.e., all milk produced during the 365 d prior to reporting. Yield data used in this study included 1988 averages from herds enrolled in all official NCDHIP plans (2) and averages from herds in all other management plans except milk only, component averaging, trimonthly testing, or basic management. Only herds with averages for milk, fat, and protein yields were included. Amount of milk reported by NCDHIP probably deviated from amount shipped by each herd because of differences in farm use, discarded milk, and sampling methods.

To ensure usefulness of herd average data, a minimum herd size of 10 cows was required. Herd average yield per cow was restricted (unless verified) to between 1815 and 12,700 kg of milk, 70 and 545 kg of fat, and 55 and 455 kg of protein. Component percentage was restricted (unless verified) to between 2.5 and 7.3% for fat and 2.5 and 4.5% for protein. These edits are those used for calculation of NCDHIP herd averages (20). Data were from 50,608 US dairy herds with 3.8 million cows that produced 28.8 billion kg of milk. Means and SD of milk, fat, and protein herd averages are in Table 1 by breed.

Six values for gross income were computed from the annual milk yield of each herd based on possible utilization in fluid milk under skim and milk fat pricing (SMFP) (i.e., values assigned to skim and milk fat), and utilization for nonfat dry milk, Cheddar cheese, Swiss cheese, Mozzarella cheese, and cottage cheese. This required estimating product yields from each herd and assigning economic values to each. Income values also were calculated on a per cow basis for each of the six utilization formulas.

Estimation of Product Yield

Product yields were estimated with yield formulas similar to those currently used by some milk manufacturing plants in the US (3, 6, 11, 18). In practice, yield formulas need to be modified to be appropriate for each plant's specific product and manufacturing procedures. Standardized milk available at the 1988 average price was assumed to be the alternative source for making each product. Although little information is compiled on a national basis through the processing industry on the average protein percentage of milk, NCDHIP herds included in this study averaged 3.2%.

TABLE 1. Numbers of herds and cows and means and SD of milk, fat, and protein production per cow by breed of herd.

Herd breed	Number of herds	Number of cows	Milk yield		Fat percentage		Fat yield		Protein percentage		Protein yield	
			— (kg) —		— (%) —		— (kg) —		— (%) —		— (kg) —	
			\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
Holstein	45,297	3,445,161	7829	1112	3.65	.24	286	43	3.19	.09	250	35
Jersey	1931	137,990	5400	814	4.78	.26	258	41	3.79	.13	205	31
Guernsey	836	41,723	5628	865	4.59	.25	258	40	3.57	.12	201	30
Brown Swiss	541	25,571	6435	979	4.04	.20	260	42	3.56	.11	229	35
Ayrshire	366	17,047	6064	870	3.92	.19	238	36	3.38	.10	205	30
Milking Shorthorn	77	2801	5851	1050	3.64	.30	213	43	3.33	.09	195	35
Red and White	62	3413	7497	969	3.70	.20	278	37	3.20	.08	240	30
Mixed	1498	85,518	6632	1262	3.81	.36	253	45	3.30	.18	219	38
All herds	50,608	3,759,225	7669	1243	3.70	.34	283	44	3.22	.16	247	37

Therefore, "average milk" available for processing was assumed to be 3.2% protein. Yields of each product and excess cream from average milk were determined so that these yields could be used in assigning economic values.

To give each specific type of cheese the proper qualities, cheese making often requires removing cream from producer milk to obtain a "cheese milk" with the desired ratio of casein to fat (C:F) (13):

$$C:F^* = \frac{C\%_{milk_{ch}}}{F\%_{milk_{ch}}} = \frac{(C_{milk_{prod}} - C_{cream})}{(F_{milk_{prod}} - F_{cream})}$$

where C:F* is critical C:F ratio, C%_{milk_{ch}} is casein percentage in cheese milk, F%_{milk_{ch}} is fat percentage in cheese milk, C_{milk_{prod}} is amount of casein in producer milk, C_{cream} is amount of casein in the cream removed, F_{milk_{prod}} is amount of fat in producer milk, and F_{cream} is amount of fat in the cream removed. Critical C:F ratios assumed for this study were .64:1 for Cheddar, .86:1 for Swiss, and 1.1:1 for Mozzarella (1, 3). If the C:F ratio of milk equals or exceeds the critical ratio, the maximum amount of fat in the milk can be incorporated into the cheese. If the C:F ratio is below the critical ratio, a lower percentage of fat will be incorporated into the cheese. This excess fat is assumed to be removed to optimize economic return and to meet the standard of identity for the cheese. The amount of cream to remove from producer milk to prepare cheese milk with the desired C:F ratio was calculated to determine the amount and value of excess fat for each herd. Because protein is assumed to be 78% casein (1, 3, 10),

$$C:F^* = \frac{[.78(P_{milk_{prod}}) - .78(P\%_{milk_{prod}})(1 - F\%_{cream})(c)]}{[F_{milk_{prod}} - F\%_{cream}(c)]}$$

where P_{milk_{prod}} is amount of protein in producer milk, P%_{milk_{prod}} is protein percentage in producer milk, F%_{cream} is fat percentage in cream removed, c is amount of cream that must be removed to obtain C:F*, and all percentages are expressed as decimals. Then,

$$c = \frac{[.78(P_{milk_{prod}}) - (C:F^*)(F_{milk_{prod}})]}{[(1 - F\%_{cream})(.78)(P\%_{milk_{prod}}) - F\%_{cream}(C:F^*)]}$$

Amounts of components to be removed in cream with 40% milk fat to obtain C:F* are .4c for fat and .6c(P%_{milk_{prod}}) for protein.

Nonfat Dry Milk. A formula for expected yield of nonfat dry milk (Y_{nfdm}) is

$$Y_{nfdm} = \frac{[SNF_{milk_{prod}}/(Y_{milk_{prod}} - F_{milk_{prod}})] [Y_{milk_{prod}} - (F_{milk_{prod}}/F\%_{cream})]}{(1 - M\%)} = \frac{[SNF\%_{milk_{prod}}/(1 - F\%_{milk_{prod}})] [1 - (F\%_{milk_{prod}}/F\%_{cream})] (Y_{milk_{prod}})}{(1 - M\%)}$$

where SNF_{milk_{prod}} is amount of SNF in pro-

ducer milk, $Y_{\text{milk}_{\text{prod}}}$ is amount of producer milk, $M\%$ is percentage of manufactured product that is moisture, $\text{SNF}\%_{\text{milk}_{\text{prod}}}$ is SNF percentage in producer milk, $F\%_{\text{milk}_{\text{prod}}}$ is the fat percentage in producer milk, and all percentages are expressed as decimals. The $\text{SNF}\%_{\text{milk}_{\text{prod}}}$ is considered to be the total percentage of protein, lactose, and minerals in producer milk. Average milk available was assumed to be 3.5% fat and 8.6% SNF (3.2% protein and 5.4% lactose and minerals) (9, 16, 21), and 1 kg would be expected to yield .0875 kg of 40% cream and .0847 kg of nonfat dry milk with 4% moisture. After removal of the cream, the resulting skim milk would have 8.91% SNF; in contrast, 1 kg of skim milk would yield .0928 kg of nonfat dry milk with 4% moisture. For individual herds, $\text{SNF}\%_{\text{milk}_{\text{prod}}}$ was unknown but was approximated by $P\%_{\text{milk}_{\text{prod}}} + .054$, where protein percentage is expressed as a decimal.

Cheddar Cheese. For hard cheeses, a formula equivalent to that given by Van Slyke and Price (18) provided the basis for expected cheese yield (Y_{ch}) from cheese milk:

$$Y_{\text{ch}} = [\alpha(F\%_{\text{milk}_{\text{ch}}}) + C\%_{\text{milk}_{\text{ch}}} - \beta](\gamma)(Y_{\text{milk}_{\text{ch}}})/(1 - M\%) \\ = [\alpha(F\%_{\text{milk}_{\text{ch}}}) + .78(P\%_{\text{milk}_{\text{ch}}}) - \beta](\gamma)(Y_{\text{milk}_{\text{ch}}})/(1 - M\%)$$

where α is percentage of fat in the cheese milk that is recovered in the cheese, β is percentage of casein in the cheese milk that is not recovered in the cheese, γ is percentage increase in cheese recovery due to other milk solids plus any salt added, $Y_{\text{milk}_{\text{ch}}}$ is amount of cheese milk used, and all percentages are expressed as decimals. The constants α , β , and γ vary according to type of hard cheese and plant operation.

For Cheddar cheese, constants derived from those used by Ernstrom (10) were used for expected Cheddar yield (Y_{ched}) from cheese milk:

$$Y_{\text{ched}} = [.90(F\%_{\text{milk}_{\text{ch}}}) + .78(P\%_{\text{milk}_{\text{ch}}}) - .001](1.09)(Y_{\text{milk}_{\text{ch}}}) \\ /(1 - M\%)$$

where $\alpha = .90$, $\beta = .001$, and $\gamma = 1.09$. For Cheddar cheese with 37% moisture, 1 kg of standardized milk with 3.9% fat would yield $[.90(.039) + .78(.032) - .001](1.09)(1)/(1 - .37) = .1022$ kg of Cheddar cheese. Milk standardized to 3.9% fat was used in calculating yield for Cheddar cheese because it had the desired C:F ratio of .64:1. Supplies of milk with C:F ratios higher and lower than the desired C:F ratio can be mixed for optimal economic return in production of Cheddar cheese.

Swiss Cheese. The formula for expected Swiss yield (Y_{Swiss}) from cheese milk was similar to that currently used by the industry (11):

$$Y_{\text{Swiss}} = [.88(F\%_{\text{milk}_{\text{ch}}}) + .78(P\%_{\text{milk}_{\text{ch}}}) - .002](1.10)(Y_{\text{milk}_{\text{ch}}}) \\ /(1 - M\%)$$

where $\alpha = .88$, $\beta = .002$, and $\gamma = 1.10$. Removal of .0156 kg of 40% cream from 1 kg of average milk (3.5% fat, 3.2% protein) to achieve the desired C:F ratio for Swiss cheese of .86:1 removes .0062 kg of fat and .0003 kg of protein. This results in .9844 kg of cheese milk with 2.92% fat and 3.22% protein. For Swiss cheese with 40% moisture, each 1 kg of average milk would yield $[.88(.0292) + .78(.0322) - .002](1.10)(.9844)/(1 - .40) = .0881$ kg of Swiss cheese.

Mozzarella Cheese. The formula for expected Mozzarella (part skim, low moisture) yield (Y_{Mozz}) from cheese milk was based on research at Utah State University (11):

$$Y_{\text{Mozz}} = [.88(F\%_{\text{milk}_{\text{ch}}}) + .78(P\%_{\text{milk}_{\text{ch}}}) - .0005](1.12)(Y_{\text{milk}_{\text{ch}}}) \\ /(1 - M\%)$$

where $\alpha = .88$, $\beta = .0005$, and $\gamma = 1.12$. Removal of .0319 kg of 40% cream from 1 kg of average milk (3.5% milk fat, 3.2% protein) to achieve the desired C:F ratio of 1.1:1 for Mozzarella cheese removes .0127 kg of fat and .0006 kg of protein. This results in .9681 kg of cheese milk with 2.30% fat and 3.24% protein. For Mozzarella cheese with 46% moisture, 1 kg of average milk would yield $[.88(.023) + .78(.0324) - .0005](1.12)(.9681)/(1 - .46) = .0904$ kg of Mozzarella cheese.

Cottage Cheese Curd. Less research has been done to develop yield formulas for cot-

tage cheese than for hard cheeses. However, a formula used by many cheese plants (3, 6) for expected yield of small, dry curd cottage cheese ($Y_{cottage}$) from cheese (skim) milk is

$$Y_{cottage} = 5.5(.78)(P\%_{milk_{ch}})(Y_{milk_{ch}}).$$

As with nonfat dry milk, 1 kg of average milk (3.5% fat, 3.2% protein) would yield .0875 kg of 40% cream. In addition, it yields .9125 kg of cheese milk with 3.32% protein and, therefore, .130 kg of small, dry curd cottage cheese.

Assignment of Economic Value

Until recently, most milk produced in the US (except in California) has been purchased using the SMFP formula: a designated price per hundredweight for milk with 3.5% fat and a differential for each .1% change in fat from the 3.5% base. For this study, the 1988 average prices received by US dairy producers (4) were used: \$24.91/100 kg of milk with a fat differential of \$.3395 per .1% change from a 3.5% base. Using the SMFP formula, value of producer milk (V_{SMFP}) is

$$V_{SMFP} = \$.1303(Y_{milk_{prod}}) + \$.3395(F_{milk_{prod}})$$

where \$.1303 = (\$.2491/kg milk) - (\$.3395/kg fat)(.035 kg fat). The formula also can be written as

$$\begin{aligned} V_{SMFP} &= \$.1303(Y_{milk_{skim}} + F_{milk_{prod}}) \\ &\quad + \$.3395(F_{milk_{prod}}) \\ &= \$.1303(Y_{milk_{skim}}) \\ &\quad + (\$.1303 + \$.3395)(F_{milk_{prod}}) \\ &= \$.1303(Y_{milk_{skim}}) \\ &\quad + \$.3525(F_{milk_{prod}}), \end{aligned}$$

which more clearly shows the value of 1 kg of skim milk (\$.1303) and 1 kg of milk fat (\$.3525). This also shows that under SMFP, one price is paid for skim, regardless of its protein content (12), which is contrary to some industry opinion.

Value of milk for manufacturing 1 kg of various milk products (also the input cost for manufacturing) can be determined using individual product yield formulas and the value of skim and fat calculated from SMFP. The as-

sumption that average milk was the principal alternative source for each of these products set the manufacturing price for the milk. Value of milk (input cost) required to produce 1 kg of nonfat dry milk or 1 kg of each of the cheeses from average milk was derived after accounting for value of any excess fat available for cream. After establishing cost of average milk required for each manufactured product, EPP formulas were developed by combining input values with the yield formulas to determine value of individual producer milk based on actual fat and protein content of the milk. Value of extra fat removed in cream in preparation of nonfat dry milk or cheese milk was credited; value of small differences in protein percentage in cream was ignored. Having both the cost of producing each product and the yield from individual producer milk provided EPP milk values for all herd product combinations.

Nonfat Dry Milk. Value of milk for manufacturing 1 kg of nonfat dry milk (4% moisture) was [(\$.2491/kg milk) - (.035 kg fat/kg milk)(\$.3525/kg fat)]/(.0847 kg nonfat dry milk/kg milk) = \$.12572/.0847 kg nonfat dry milk = \$1.484/kg dry milk. Then EPP milk value for nonfat dry milk (EPP_{nfdm}) is

$$EPP_{nfdm} = \$1.484 (\text{nonfat dry milk yield}) + \$.3525 (\text{fat yield})$$

where nonfat dry milk and fat yields are measured in kilograms.

Cheddar Cheese. Because standardized milk with 3.9% fat was used for determining Cheddar yield, milk with 3.9% fat also was assumed for determining value of cheese milk. The EPP cost of milk to produce 1 kg of Cheddar cheese with 37% moisture was [(\$.2491/kg milk) + (.004 kg fat/kg milk)(\$.3525/kg fat)]/(.1022 kg Cheddar/kg milk) = \$2.576/kg Cheddar.

Milk value for Cheddar cheese depends on whether or not excess fat has to be removed from the milk before making cheese (3, 11). When C:F is below the critical ratio, the fat has two values: that used in cheese priced at one value and that which is excess priced at another. Because the critical C:F ratio for manufacturing Cheddar cheese is .64:1 and protein normally is about .78% casein (3), excess fat

must be removed for milk with a protein:fat (P:F) ratio below .82:1 (such as often found for Guernsey and Jersey herds).

Calculation of coefficients for EPP milk value was explained by Barton et al. (1) and Norman (15). The EPP milk value per kilogram for milk with P:F < .82:1 ($EPP_{\text{Chedp:F} < .82:1}$) was

$$\begin{aligned} EPP_{\text{Chedp:F} < .82:1} &= -\$0.0045 \text{ (milk yield)} \\ &+ \$3.395 \text{ (fat yield)} \\ &+ \$4.292 \text{ (protein yield)} \end{aligned}$$

where all yields are measured in kilograms. For milk with P:F \geq .82:1 (such as often found from Ayrshire, Brown Swiss, Holstein, Milking Shorthorn, and Red and White herds), EPP milk value per kilogram ($EPP_{\text{Chedp:F} \geq .82:1}$) was

$$\begin{aligned} EPP_{\text{Chedp:F} \geq .82:1} &= -\$0.0045 \text{ (milk yield)} \\ &+ \$4.043 \text{ (fat yield)} \\ &+ \$3.503 \text{ (protein yield)}. \end{aligned}$$

Swiss Cheese. Cost of standardized milk (3.5% fat) for producing 1 kg of Swiss cheese with 40% moisture was [(\$.2491/kg milk) - (.0062 kg excess fat/kg milk)(\$.3.525/kg fat)] / (.0881 kg Swiss/kg milk) = \$.22724/.0881 kg Swiss = \$2.577/kg Swiss. To meet the C:F ratio of .86:1 generally used for Swiss cheese, excess fat must be removed, and the EPP milk value per kilogram (EPP_{Swiss}) (3, 11) was

$$\begin{aligned} EPP_{\text{Swiss}} &= \$2.577 \text{ (Swiss yield)} \\ &+ \$3.525 \text{ (excess fat)} \end{aligned}$$

where Swiss yield and excess fat are measured in kilograms.

Mozzarella Cheese. Cost of milk to produce 1 kg of Mozzarella cheese with 46% moisture was [(\$.2491/kg milk - (.0127 kg excess fat/kg milk)(\$.3.525/kg fat)] / (.0904 kg Mozzarella/kg milk) = \$.20433/.0904 kg Mozzarella = \$2.259/kg Mozzarella. For Mozzarella cheese, fat also must be removed to meet the typical C:F ratio of 1.1:1, and the EPP milk value per kilogram (EPP_{Mozz}) (3, 11) was

$$\begin{aligned} EPP_{\text{Mozz}} &= \$2.259 \text{ (Mozzarella yield)} \\ &+ \$3.525 \text{ (excess fat)} \end{aligned}$$

where Mozzarella yield and excess fat are measured in kilograms.

Cottage Cheese Curd. Cost of milk to produce 1 kg of small, dry curd cottage cheese was [(\$.2491/kg milk - (.035 kg fat/kg milk)(\$.3.525/kg fat)] / (.130 kg cottage/kg milk) = \$.12573/.130 kg cottage = \$.967/kg cottage. Therefore, EPP milk value per kilogram (EPP_{cott}) was

$$\begin{aligned} EPP_{\text{cott}} &= \$0.967 \text{ (cottage yield)} \\ &+ \$3.525 \text{ (fat yield)} \end{aligned}$$

where cottage yield and fat yields are measured in kilograms.

Analysis

For fluid milk, nonfat dry milk, and each of the cheeses, herd milk value based on EPP was derived using herd information on fat and protein contents. Means, SD, and frequency distributions were calculated for annual gross income on a herd and cow basis. Measures of herd variation in yield and product value were calculated overall and within county. The latter should reflect the opportunity for segregating milk without adversely affecting hauling costs for those dairy producers currently having a choice of two or more marketing agencies that want different types of milk but are equal in economic efficiency.

RESULTS

Means and SD of end product value of total 1988 herd yields are in Table 2. Mean dollar value of milk produced was near \$146,000 for all milk products. This consistency was expected because standardized milk at the 1988 US average price was used as the source for manufacture of all products. The SD for herd end product value also was consistent for all products, usually about \$203,000. The SD was larger than the mean, which indicates extreme differences in herd product value largely due to differences in herd size.

Mean end product values for all products on a per cow basis also were nearly equal: \$1961 to \$1979. Small differences in mean product value may result either from a difference in protein percentage for milk produced in the US versus that assumed for standardized milk or from rounding in the product prices assigned.

TABLE 2. Mean and SD of end product value on a per herd and per cow basis.¹

Product pricing	Payment per herd		Payment per cow	
	(\$)			
	\bar{X}	SD	\bar{X}	SD
Skim and milk fat	145,700	202,900	1961	302
Nonfat dry milk	145,700	202,600	1962	299
Cheddar cheese	145,700	203,600	1979	298
Swiss cheese	146,100	202,500	1967	294
Mozzarella cheese	146,000	202,500	1966	295
Cottage cheese	145,900	202,300	1964	295

¹Based on 50,608 herds with 3,759,225 cows. Milk price was \$24.49 per 100 kg with end product values defined in the paper.

For all products, SD of end product values on a per cow basis (about \$300) were similar. Regardless of pricing system, substantial differences existed between herds in average value of yield per cow, largely because of differences in herd management and breed.

No information on payment systems received by individual herds or utilization of milk was available in the data. Although pricing systems are rapidly changing, a large number of herds still are paid using an SMFP system. Therefore, to examine potential for mispayment, EPP value of herd milk was compared with the SMFP method using average US prices (Table 3). Potential for mispayment assumes that milk is used for individual manufactured milk products but paid for with SMFP.

Potential mispayment for nonfat dry milk was smaller than that for the other milk products. The SD for potential mispayment was \$1554, which likely would be important to most producers if they were aware that they

were not receiving full value. Most testing equipment does measure one or more milk components in addition to fat. Therefore, more accurate compensation for actual nonfat dry milk yields usually is possible. If higher solids are not compensated, percentage of solids in the milk supply will likely decrease because production of solids is more expensive than production of carrier water. Potential for mispayment for cheeses was greater than for nonfat dry milk; SD was \$5392 for Cheddar, \$4872 for Swiss, \$4580 for Mozzarella, and \$4349 for cottage cheeses. Within-county SD were 68 to 75% as large as overall SD, which suggests that milk segregation might be feasible with little additional hauling cost. Warner et al. (19) reported that increased assembly costs are minor compared with revenue gains from increased cheese yields.

Although potential for extreme mispayment in milk pricing exists given these SD, possible mispayment in a few cases was much greater than expected. Herds with the greatest differ-

TABLE 3. Potential mispayment between end product pricing and pricing based on skim and milk fat (SMFP) on a per herd and per cow basis.¹

Product pricing	Per herd basis			Per cow basis		
	SD difference from SMFP	Maximum over-payment	Maximum under-payment	SD difference from SMFP	Maximum over-payment	Maximum under-payment
	(\$)					
Nonfat dry milk	1554	42,300	63,500	13	61	87
Cheddar cheese	5392	91,000	306,800	49	123	297
Swiss cheese	4872	121,700	217,800	43	177	285
Mozzarella cheese	4580	115,800	202,700	40	167	266
Cottage cheese	4349	112,600	188,300	38	161	247

¹Based on 50,608 herds with 3,759,225 cows.

TABLE 4. Mean value based on end product pricing (EPP) or pricing based on skim and milk fat (SMFP) on a per herd basis¹ by breed of herd.

Breed	SMFP	EPP				
		Nonfat dry milk	Cheddar cheese	Swiss cheese	Mozzarella cheese	Cottage cheese
		(\$)				
Holstein	151,400	151,300	152,000	151,300	151,200	151,100
Jersey	112,900	115,700	125,500	122,600	121,900	121,300
Guernsey	80,300	81,600	87,000	84,800	84,400	84,100
Brown Swiss	81,300	82,800	86,300	86,000	85,700	85,400
Ayrshire	74,400	75,100	77,100	76,600	76,400	76,200
Milking Shorthorn	54,000	54,400	55,200	55,200	55,100	55,000
Red and White	105,600	105,600	106,300	105,700	105,600	105,500
Mixed	98,300	98,700	100,600	99,900	99,800	99,600
All herds	145,700	145,700	145,700	146,100	146,000	145,900

¹Based on 50,608 herds.

ences between EPP and SMFP differed by 41 to 57 SD, which suggested that these herds may not follow a normal distribution for potential mispayment. Skewness and kurtosis tests confirmed that these potential differences for mispayment did not follow a normal distribution, perhaps because herds were of different breeds and sizes. Maximum potential overpayment would have been \$121,700 if milk was used for production of Swiss cheese but paid for under SMFP; maximum potential underpayment was \$306,800 for production of Cheddar cheese. These extreme cases were for large herds with fat and protein percentages that differed from a typical herd, sometimes because of breed.

On a per cow basis, SD of differences between EPP and SMFP was \$13 for nonfat dry milk and \$38 to \$49 for various cheeses. Po-

tential differences in mispayment on a per cow basis has a more nearly normal distribution.

Potential for mispayment according to breed of the herd is in Table 4. As would be expected, mean payments to Holstein herds would have changed little compared with mean payments to all herds, because most herds are Holstein. Most of the money that would be interchanged between dairy producers as a result of changing pricing systems would be expected to be among Holstein breeders, whose herds represented 90%. This was verified with these data, and 70% of the total dollars in mispayments had shifted among Holstein herds. Holstein herds with high P:F ratios benefited from EPP, whereas those with lower P:F ratios received lower payments. About 40% of the Holstein herds showed income increases using EPP for manufactured

TABLE 5. Mean value based on end product pricing (EPP) or pricing based on skim and milk fat (SMFP) on a per cow basis¹ by breed of herd.

Breed	SMFP	EPP				
		Nonfat dry milk	Cheddar cheese	Swiss cheese	Mozzarella cheese	Cottage cheese
		(\$)				
Holstein	1991	1989	1999	1989	1988	1986
Jersey	1580	1619	1756	1715	1706	1697
Guernsey	1610	1635	1744	1698	1692	1686
Brown Swiss	1720	1751	1826	1821	1814	1807
Ayrshire	1596	1610	1654	1644	1641	1637
Milking Shorthorn	1484	1494	1516	1517	1514	1511
Red and White	1919	1918	1932	1920	1919	1917
Mixed	1722	1730	1763	1751	1748	1745
All cows	1961	1962	1979	1967	1966	1964

¹Based on 3,759,225 cows.

products. Jersey, Guernsey, and Brown Swiss herds usually had increased income from EPP. Some gain also was apparent for Ayrshires and Milking Shorthorns. The benefit for breeds with the highest protein percentages (Jersey and Guernsey) usually was greatest for production of Cheddar cheese. The Brown Swiss breed showed its greatest income gains in the production of Swiss cheese.

Potential for mispayment on a per cow basis according to breed of the herd is in Table 5. In the production of nonfat dry milk, non-Holstein breeds should receive additional payment: Jersey, \$39; Brown Swiss, \$31; Guernsey, \$25; Ayrshire, \$14; Milking Shorthorn, \$10; and mixed breeds, \$8. In the production of Cheddar cheese, additional compensation should be Jersey, \$176; Guernsey, \$134; Brown Swiss, \$106; Ayrshire, \$60; Milking Shorthorn, \$32; and mixed breeds, \$41. Potential for mispayment on a per cow basis is slightly smaller for Swiss and Mozzarella than for Cheddar, but it is still substantial.

Because EPP still is not being used in most manufactured plants, many producers with high percentages of fat and protein continue to receive too little for milk, and others receive too much for milk with low levels of each. In addition, milk composition of the herd should be considered more than is done presently so that milk can be delivered to the plant where its value is greatest for the producer and the processor.

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