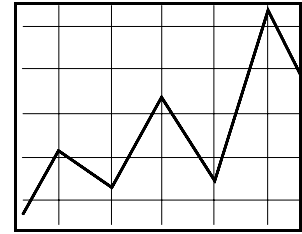


MARKETING AND POLICY BRIEFING PAPER



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RETHINKING DAIRYLAND:

MILK COMPOSITION, QUALITY AND PRODUCTION EFFICIENCY: WHERE DOES WISCONSIN STAND?¹

What is the ideal milk composition for cheese manufacture? How close is Wisconsin milk to that ideal, and how does it compare with milk from other leading dairy states? What can Wisconsin's dairy farmers and cheese processors do to ensure that milk produced in the state improves the state's cheese industry from farm to wholesale product? These questions are addressed in this report, which supports *Rethinking Dairyland* leaflet No. 8

WHAT COMPOSITION AND QUALITY OF MILK DO CHEESE PROCESSORS NEED?

The ideal milk for making a whole milk cheese, e.g. Cheddar, would contain 14-15 percent total solids and have a casein-to-fat ratio of about 0.7. This would typically be milk with about 4.2 percent fat and about 3.6 percent true protein. Few, if any, cows produce milk of this composition. So cheese makers standardize their milk using a variety of processes. Fat content may be reduced through cream separation. Solids content may be increased through vacuum pasteurization or by adding additional nonfat milk solids to the raw milk in the form of condensed skim milk, nonfat dry milk or ultrafiltered milk concentrate.

Basically, the two main ingredients of milk that a cheese maker needs are casein and fat. The amount of fat that can be used in a cheese make procedure is limited by the amount of casein present to hold the fat in a stable system. Thus, the casein to fat ratio is a critical one determining the cheese making potential of a milk supply. The final composition of a cheese will dictate what amount of casein and fat are required to make that cheese. Ideal casein to fat ratios (based on recommendations from the WI Center for Dairy Research) for some varieties of cheese are shown in Table 1.

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Table 1. Ideal casein to fat ratios for selected varieties of cheese

<i>Cheese variety</i>	<i>Casein: Fat Ratio</i>
Cheddar	.70
Low Moisture Part Skim Mozzarella	1.05
Swiss	.85
Parmesan	1.10
Havarti	.60
Brick, Muenster	.70
Gouda	.70

The most realistic goal for milk composition would be to have a casein to fat ratio of 0.70 which would be ideal for Cheddar, Brick, Muenster, Gouda and several other varieties of whole milk cheese. Milk would then only have to be standardized for other varieties of cheese with fat in the dry matter specifications of less than 50 percent.

In 1997, Wisconsin was reported to be 8.6 percent “deficient” in total protein for cheese manufacture (Natzke, 2000). What this means is that the total amount of cheese made in the state contained 8.6 percent more protein than the milk used to produce it — the “deficit” was made up in added protein, mostly from out-of-state sources. This amounted to over 50 million pounds of casein needed to balance out the surplus fat that the cheese plants purchased.

Up to now, cheese makers have mostly used nonfat dry milk, condensed skim milk, or UF milk concentrate to supply the additional casein. Milk protein concentrate (MPC) has recently been used as a source of functional casein for standardizing milk for cheese that does not have a Food and Drug Administration (FDA) Standard of Identity. Rennet casein and acid casein are not acceptable sources of functional casein for standardizing cheese milk.

Cheese makers sometimes complain about poor cheese yield from milk coming from southern and southwestern states. This is especially true when the milk is produced during a period of heat stress. Typically, for every 10°F above 70°F, the fat content of milk will drop .2 percent and protein will show a proportionate drop. During the summer hot spells in Wisconsin, cheese makers see as much as a 10-15 percent drop in milk protein and a corresponding drop in cheese yield.

WHAT IS THE COMPOSITION AND QUALITY OF WISCONSIN MILK?

Milk Composition

Sources of information about milk composition vary according to comprehensiveness and method of collection. The most comprehensive source is Federal Milk Marketing Orders, which collect and report composition and quality for all milk “pooled” within orders. Table 2 shows federal order data for the marketing order areas that encompass part or all of the top ten dairy states except California (which is not included in any federal order).

Table 2. Characteristics of producer milk by federal milk order marketing area, 2001

Marketing Area	Top Ten States included in Marketing Area	Butterfat	True Protein	Other Nonfat Solids	Somatic Cell Count
			<i>percent</i>		<i>1,000/ml</i>
Upper Midwest	WI, MN	3.72	3.02	5.70	344
Northeast	NY, Southeastern PA	3.68	3.00	5.69	NA
Mideast	MI, Western PA	3.68	3.02	5.70	359
Western	ID	3.61	3.06	5.71	NA
Pacific Northwest	WA	3.66	3.04	5.70	NA
Southwest	TX, NM	3.62	3.05	5.67	354

NA - Not available; producer payments are not adjusted for somatic cell count in these markets.

Source: Milk Marketing Order Statistics, Agricultural Marketing Service, USDA,
http://www.ams.usda.gov/dyfmos/mib/rcpts_milk_ytd.htm

The federal milk order data show that milk in the Upper Midwest market has the highest butterfat test among the 6 orders, more than a point (tenth of one percent) above the lowest ranking Western order. Protein tests exhibit smaller variability among orders. But the Upper Midwest lags the three orders in the west by .02 to .04 percentage points. Other (nonfat) solids are practically the same across orders. Differences in somatic cell count are also small.

The Dairy Herd Improvement (DHI) program reports average milk composition by state for all herds enrolled in DHI testing. These data allow more direct comparison across states than the federal marketing order data and also include California. Their deficiency is in their coverage

and representativeness — not all dairy farmers subscribe to DHI testing and those that do tend to be higher technology producers.²

DHI data related to milk composition in the top ten U.S. dairy states are shown in Table 3.³ These data represent only a subset of all cows in the DHI program: Only cows whose records include sire identification or otherwise qualify for the national genetic evaluation program are represented. The percentages of all cows in the respective states included in these DHI data are shown in the right-hand column of the table.

Table 3. Milk composition for the ten leading dairy states, DHI, 2000-01^{1/}

State	Rank ^{2/}	Fat	True Protein percent	Protein breeds ^{3/}	All cows ^{4/}
				<i>percent</i>	
California	1	3.63	3.07	8.0	22.5
Wisconsin	2	3.71	2.99	3.6	16.8
New York	3	3.71	2.98	3.8	24.3
Pennsylvania	4	3.67	2.98	4.4	28.9
Minnesota	5	3.71	2.99	2.4	26.1
Idaho	6	3.62	3.10	10.0	8.5
Texas	7	3.69	3.12	16.4	10.1
Michigan	8	3.80	2.98	3.2	21.0
Washington	9	3.65	3.03	6.1	15.0
New Mexico	10	3.57	3.03	1.5	5.0
US		3.69	3.02	7.0	19.0

^{1/} Powell, R. L., and A. H. Sanders. 2002. State and national standardized lactation averages by breed for cows calving in 2000. Animal Improvement Programs Laboratory, Agricultural Research Service, US Department of Agriculture. <http://aipl.arsusda.gov/docs/dhi/current/2.html>.

^{2/} Rank based on total milk production.

^{3/} Brown Swiss and Jersey cows as percent of cows among the three leading breeds in the USDA–DHI genetic evaluation program.

^{4/} Cows of the three leading breeds included in the USDA–DHI genetic evaluation program as percent of all dairy cows in the state.

² A third source of information on milk composition by state is USDA’s National Agricultural Statistics Service (NASS). NASS only reports butterfat content.

³ Milk composition averages for DHI herds in the leading dairy counties of Wisconsin are in Appendix Table A1.

The DHI data tell a somewhat different story than the federal milk marketing order data. Butterfat tests in Wisconsin rank high, but are exceeded by nearly a point in Michigan and tied in New York and Minnesota. Compared to California, Wisconsin's chief rival in cheese production, Wisconsin milk has about .07 percent higher fat content

The DHI data show a larger spread among states with respect to protein percentages. Wisconsin is among five states with protein content just below 3 percent. All of these five states are in the great lakes and northeast regions. The western and southwestern states have protein percentages above 3.0 percent and ranging up to 3.12 percent.

Protein differences among states appear to be due in part to the higher prevalence of high protein breeds (Jersey and Brown Swiss) in the western and southwestern states. The one exception to this is New Mexico, which has the lowest percentage of Jersey and Brown Swiss cows, but has an intermediate protein content. Among Holstein cows in the ten leading dairy states, protein content ranges from 3.03 to 3.06 in the western and southwestern states, and from 2.96 to 2.98 in the great lakes and northeastern states (data not shown). Apparently Holstein producers in the western and southwestern states have given somewhat greater emphasis in sire selection to protein than producers in the great lakes and northeastern states. Compared to California, Wisconsin is .08 percent protein lower for all milk and .06 percent lower for milk from Holsteins.

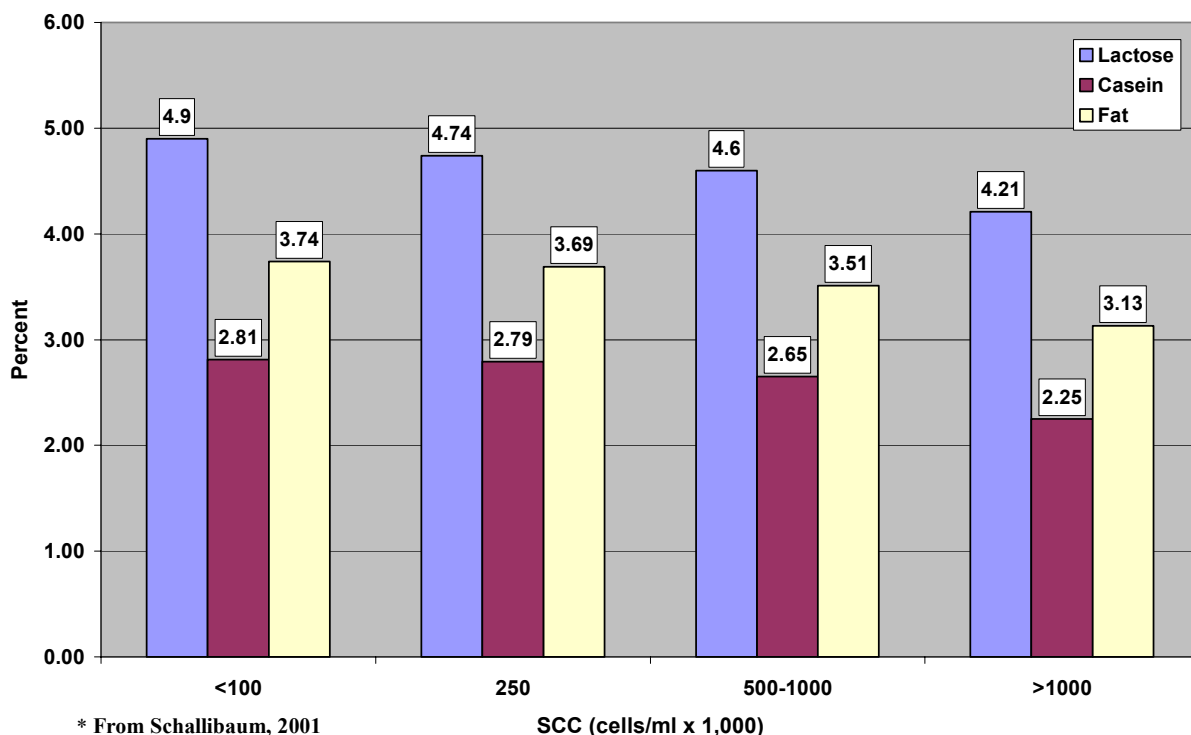
These small differences in fat and protein percentage do not indicate Wisconsin milk is inferior for cheese production compared to California milk. Although Wisconsin milk is slightly lower in protein content, it is slightly higher in fat content than California milk. Using milk from the two states to produce cheddar cheese (without standardization) results in almost exactly the same yield.

Milk Quality and Food Safety

Milk quality is usually defined by the *somatic cell count (SCC)* and the *bacterial count* of pre-pasteurized bulk tank milk. The largest factor that influences the SCC of milk is mastitis (Harmon, 2001). The SCC of a cow that is not infected with mastitis is usually less than 200,000 cells/ml and many cows maintain SCC values of less than 100,000 cells/ml. A SCC of greater than 200,000 cells/ml is almost always caused by mastitis.

Milk processors prefer milk with low SCC and many processors offer financial incentives to producers for high quality milk. High SCC milk reduces the shelf life of dairy products and diminishes the quality and quantity of milk protein, thereby reducing cheese yields (Barbano, et al., 1991). Even modest increases in individual cow SCC (>100,000/ml) have been shown to reduce cheese yields (Figure 1; Schallibaum, 2001). Infection with a mastitis pathogen causes injury to secretory cells and reduces the synthesis of lactose, fat and protein.

Figure 1: Effect of SCC on Milk Composition*



Subclinical and clinical mastitis infections also increase the permeability of cell membranes and allow the leakage of blood components into milk, further reducing product yields and quality.

Milk quality data are available from three of the federal milk marketing orders (Table 2) and from DHI (Table 4). DHI herd average SCC by county in Wisconsin are in Appendix Table A1. SCC results are reported only in milk marketing orders that provide increased producer payments for milk with lower SCC. Market order SCCs include all herds in the order area. The SCC summary from DHI includes only cows whose records are used in the national genetic evaluation program. It has been shown that the SCC from these cows does not differ from cows in DHI herds that are not in the genetic evaluation system. The SCC in DHI herds is lower, on average, than all herds.

Differences in SCC among the milk marketing areas are small and of no practical significance. Two milk quality measures are reported from the DHI summary (Table 4): Average SCC and percent of herd test days with SCC >400,000 cells per ml. The percentage of DHI herds >400,000 is likely higher than the percentage of DHI bulk tanks above the 400,000 cells/ml threshold: Milk of individual cows with high SCC is included in the DHI statistics, but milk from some of these cows is withheld from the bulk tank. Herds with SCC above 400,000 cells/ml should focus greater attention to managing for lower SCC. These herds are losing significant milk quality premiums and reduced milk production due to a large percentage of infected cows.

Table 4. Milk quality in the ten leading dairy states ^{1/}

State	Somatic Cell Count	Herd test days with SCC >400,000
	<i>1,000 cells/ ml</i>	<i>percent</i>
California	298	21.0
Wisconsin	297	25.4
New York	280	22.7
Pennsylvania	317	27.2
Minnesota	420	48.5
Idaho	320	24.7
Texas	342	32.0
Michigan	287	23.4
Washington	275	13.5
New Mexico	311	29.5
US	322	31.1

¹ Miller, R. H., and H. D. Norman. 2002. Somatic cell counts of milk from Dairy Herd Improvement herds during 2001. Animal Improvement Programs Laboratory, Agricultural Research Service, USDA. <http://aipl.arsusda.gov/docs/dhi/dhi01/scc01.htm>.

The state of Washington clearly sets the pace for producing high quality milk. California and Wisconsin are both intermediate for average SCC, but California has a slightly smaller percentage of herds in the undesirable, high SCC ranges. Overall, Wisconsin milk is similar to California milk in terms of milk quality, but a higher percentage of Wisconsin herds are in need of special attention for improving milk quality. We conclude that Wisconsin cheese makers are neither disadvantaged nor are they favored in terms of milk quality.

Dairy product safety is an additional concern related to milk quality (Ruegg, 2002). There is ample evidence that increased prevalence of subclinical mastitis in a dairy herd (as demonstrated by high SCC) is indicative of management practices associated with reduced food safety. Monthly BTSCC values were higher in herds where verotoxigenic *E. coli* and *Listeria monocytogenes* were cultured from bulk tanks as compared to herds negative for these pathogens (Steele, et al., 1997). Hygienic practices on herds with higher SCC values are generally poorer than hygienic practices on herds with lower SCC values (Barkema, et al., 1998). Milking facilities, cow housing areas, and the udders of cows from herds with higher SCC values have been demonstrated to be dirtier and more soiled with manure as compared to cows and facilities from herds with lower SCC values (Barkema, et al., 1998). High SCC have also been linked to

the occurrence of other indicators of poorer milking management. The risk of incurring a violative antibiotic residue is 2 to 7 times higher for herds with SCC values above 400,000 cells per ml as compared to herds with SCC values of less than 250,000 cells per ml (Ruegg and Tabone, 2000).

HOW CAN WISCONSIN IMPROVE THE COMPOSITION AND QUALITY OF MILK FOR CHEESE?

First, it should be noted that no cow produces the ideal milk for cheese in terms of the casein: fat ratio. Cheeses vary in their composition, so the ideal milk for one cheese would not be ideal for another. Fat content relative to casein is higher in milk than in nearly all cheese. The disparity is small for high fat varieties of cheese such as cheddar, but it is magnified for the low fat cheeses like mozzarella. Matching casein:fat ratios in milk to ideal levels in cheese is economically beneficial to cheesemakers.

Second, the leftovers from cheese production include whey proteins, lactose and minerals. The economic well being and competitiveness of the cheese industry, therefore, depends in part on capturing as much value as possible from each of these non-cheese components of milk. That Wisconsin is regarded as deficient in milk protein has little to do with the protein content of the milk produced here. Rather, Wisconsin's protein deficit is due to the fact that nearly all milk has an excess of fat for cheese making and over 80 percent of the state's milk is converted to cheese. Furthermore, milk fat sold in the form of cheese usually has a higher value than fat sold in butter other commercial butterfat products. Cheesemakers attempt to balance milk composition by adding dry milk powder or other dairy protein sources to capture as much fat as possible in the form of cheese. It's simply in the nature of milk and in the nature of cheese that fat is in excess for milk made into cheese.

In addition, it must be recognized that protein, whether for the human diet or animal diet, is the most costly of the macro-nutrients. High energy feeds, such as shelled corn and forage, are comparatively lower in cost than protein-rich feeds. A study of the cost of feeds to support marginal increases in the yields of the milk components illustrates the point (Dado et al., 1994): Feed cost per pound of milk protein production was twice the cost for milk fat production and four times the cost for lactose production. Protein synthesis by the cow requires that she be fed protein-rich feeds that are higher in cost than energy-rich feeds. Synthesis by the cow of milk fat and lactose demands very little protein from the diet, but does require energy-rich feeds. Cheese is a protein-rich food. It is inescapable that milk used for cheese production must compensate producers for the higher cost of producing protein.

When consumers buy a package of cheese in the grocery store, they buy it by the pound and they have no concern about whether that pound of cheese was derived from 9 lbs or 11 lbs of milk. The implications for cheese processors are that the benefit of higher milk component percentages occurs in the manufacturing process and that processing efficiencies in milk with high component percentages should be shared with producers as an incentive toward producing milk with high component levels. The implication for producers is that management should focus on producing pounds of protein and fat rather than percentages of the components. While higher

component percentages result in higher prices per hundred pounds of milk, the milk check depends both on how much milk is shipped and how much fat and protein is in the milk. Milk price per 100 lbs is meaningless until it is multiplied by the amount of milk shipped. This message is made more clearly to producers when milk payments are shown in the form of price per pound of protein, fat, and milk volume or 'other solids' multiplied by the pounds of protein, fat, and milk or shipped.

What Can Cheese Processors Do?

Because raw milk accounts for 85-90 percent of the cost of manufacturing cheese, cheesemakers are extremely interested in milk composition and especially the concentration of fat and casein in the milk. With whole milk cheeses, e.g., Cheddar, the primary concern is recovering the maximum amount of cheese per cwt. of milk. With reduced-fat cheeses, e.g., Mozzarella, the cheesemaker must determine if it is more profitable to sell the surplus fat (cream) to creameries for butter production or to purchase additional casein in the form of NDM or condensed skim milk to recover the fat in the form of additional cheese. The ultimate decision as to where the milk components go is determined by prices in the butter and cheese markets.

Producers are very responsive to premiums added to milk prices. Premiums for milk with low somatic cell count have driven improvement in milk quality more than any other single factor. Producers are keen to take advantage of any opportunity to increase revenue and will manage their herds accordingly. To the extent that higher protein and fat contents reduce the cost of cheese manufacture, premiums for higher levels of milk components must be offered. The benefits of higher percentages of milk components must be shared between the processor and producer. These premiums are a tangible mechanism for processors to communicate to producers what they want in milk composition.

Premiums are often paid to producers based on the volume of milk shipped. Changing the payment system from volume of milk to pounds of cheese or pounds of protein would continue to reward the high volume producers, but also provide incentive to produce milk with higher cheese solids content. This strategy would also more often reward producers with high protein breeds of cattle.

One problem the cheese plants in Wisconsin have had in the past is the structure of the milk pricing system that is influenced by the federal milk pricing system. In the past, this system was heavily influenced by the fluid market. Prior to January 1996, dairy producers were not paid on a component basis, but rather on a fat-skim milk basis (Cropp et al., 1999). On average, 60 percent of the milk value was based on water (volume), 34 percent on butterfat, 2 percent on protein, and 4 percent on other solids.

From 1996 through 1999, a multiple component pricing (MCP) system was put in place. Under MCP pricing, the average value of protein represented 44 percent of the value of milk, butterfat 34 percent, and other solids 22 percent. In January 2000, further changes were made to the MCP and protein then represented an average of 58 percent of the value of milk, butterfat 39 percent and other solids 3 percent. However, with the fat value being tied to the butter market and

protein to the cheese market, sometimes the value of fat could be equal to or greater than the value of protein. This sends mixed signals to the producers as to the overall value of each of the milk components. If cheese plants wish to encourage producers to produce milk with an ideal composition for cheesemaking, they will need to establish a milk pricing system based on cheese yield that provides a consistent signal for production of higher protein milk.

What Can Producers Do?

Three areas of herd management are considered as ways that producers might improve the composition and quality of milk for cheese production: Dairy cattle feeding and nutrition can affect milk composition with almost immediate gains. Animal health can impact both milk quality and milk composition, also with immediate results. The best long term strategy for effecting changes is through genetics.

Dairy Cattle Feeding and Nutrition

The cow's diet can have a major impact on milk yield, composition, and component yields. The multiple-component pricing (MCP) system is based on absolute yields of fat, protein and other solids, and not on individual component percentages per se. Therefore, a change in a cow's diet that increases component percentages, but also reduces milk yield, may or may not increase component yields or gross income depending on the relative magnitudes of change. An example of this scenario would be the feeding of lower grain diets with the aim of increasing milk fat test. On the other-hand, a slight depression in component percentages due to a change in the cow's diet could be favorable for the dairy producer if offset by enough of an increase in milk yield. An example of this scenario would be the feeding of supplemental fat with the aim of increasing milk yield, while knowing that a depression in milk protein test is to be expected. Finally, a change in a cow's diet that increases milk yield while maintaining component percentages will increase the yields of all components and gross income. An example of this scenario would be the feeding of a more highly digestible forage source that allows for a higher intake of the diet by the cow.

Dairy producers are being paid for yields of components — not to produce milk of a specific composition most favorable for producing a specific type of cheese. Despite all the concern and discussion about a protein deficit for cheese manufacturing, pay prices per pound of protein at or below the pay price per pound of fat does not send the right economic signal to dairy producers or their nutritionists to focus on milk protein percentage or yield, especially if it were to compromise fat percentage or yield. The recent interest in cheese yield pricing systems may be a step toward providing the proper economic signals at the producer level.

Milk protein yield can be increased through increases in milk yield or increases in milk protein percentage. The latter, unless depressed by feeding an unbalanced diet, is difficult to increase more than 0.10 to 0.15 percentage units by a change in diet. Moreover, this small change in protein percentage usually comes at a high cost, for example by using lysine formulations or ruminally-protected methionine).

Relatively low grain and byproduct prices experienced recently have made the feeding of minimum forage diets common. Over the last decade corn silage has increasingly replaced alfalfa silage in milking cow diets. These trends, along with a “yield” based milk-pricing system, continue to drive us, from a feeding standpoint, toward the high-volume production of milk that is right at the point of fat test depression. In fact, the NRC (2001) fiber “requirements” are merely minimum guidelines aimed at maintaining normal ruminal pH and fiber digestion and milk fat test above 3.4 percent in Holstein cows, and preventing digestive upsets (i.e. subacute ruminal acidosis/laminitis and left displaced abomasums). The good news is that these types of diets do, from a level of carbohydrate standpoint, maximize milk protein percentage and yield.

Thus, we will explore how milk protein might be increased for diets where the production of protein and energy (volatile fatty acids) by ruminal microbes and milk protein has been maximized from a level of dietary carbohydrate standpoint.

Forage and TMR Particle Size. Finely-chopped forages and (or) finely-processed total mixed rations (TMR) have the effect of increasing milk yield and milk protein percentage and yield, but milk fat test depression is a problem. Further, without sufficient coarse fiber to maintain chewing activity digestive upsets may develop. Because of the feeding of chopped silages with minimal hay in relatively low forage diets, there is little opportunity for the industry as a whole to further exploit this avenue for increasing milk protein. However, many individual producers could benefit from adopting this practice.

Supplemental Fat. Supplementation of milking cow diets with 1 to 2 lb. per cow per day of added fat is a common practice with the aim of improved body condition, fertility, and milk production. Assuming that some of the energy goes to body condition and that the added fat displaces some starch from grain in the diet, we expect a 3 to 4 lb. increase in milk yield per pound of supplemental fat. Since we supplement with whole oilseeds rather than free oils, relatively saturated animal tallow and (or) rumen-inert fats, milk fat test is usually not altered appreciably. However, feeding supplemental fat reduces milk protein percentage about 0.1 percentage units per pound of added fat. The reasons for this fairly consistent protein depression in response to feeding supplemental fat is not fully understood and therefore cannot be alleviated at this point.

Why would a dairy producer supplement fat when it reduces milk protein⁴ percentage, which isn't positive for the cheese maker? Because fat supplementation increases milk fat and other solids yields with no change in milk protein yield due to the increase in milk volume. Combined with similar pay prices per pound of milk protein or fat, this makes this feeding strategy profitable for the producer. Better body condition (i.e. improved milk persistency and/or fertility) is an extra potential benefit of supplemental fat feeding.

From the perspective of cheesemakers, farmers' use of supplemental fat reduces the amount of protein per hundredweight of milk. In turn, this requires more protein added to the cheese vat to achieve optimal casein-to-fat ratios. Cheesemakers could capture an extra 0.10 to 0.20 units of milk protein *percentage* at the same milk fat *percentage* if farmers eliminated supplemental fat

⁴ The term, protein, in this paper refers to true protein (non-nitrogen) as opposed to total milk protein.

feeding . But to capture this added protein, cheesemakers would need to provide an economic incentive in the form of relatively higher protein payments compared to butterfat payments.

Dietary Protein. Underfeeding dietary protein relative to the cow's requirement reduces milk yield and milk protein percentage and yield (National Research Council [NRC] 1989, 2001) There is a major economic disincentive to under-feeding protein, especially at the low to moderate protein supplement prices experienced recently. Overfeeding dietary protein relative to the cow's requirement (NRC, 2001) does not increase milk yield or milk protein percentage or yield. Consequently, there is both an economic and an environmental disincentive to over-feeding dietary protein.

The NRC (1989; 2001) has provided rumen degradable and non-degradable protein guidelines for milking cow diets and tabular values for protein degradability of feedstuffs. Using these guidelines, diets can be formulated to meet the protein needs of the ruminal microbes for production of protein and energy (volatile fatty acids) and the cow's production of milk protein. Because this area has been a major focus of the feed industry and consulting nutritionists for the last two decades, there is little opportunity for the industry as a whole to further exploit this avenue for increasing milk protein. However, there are many individual producers who could benefit economically from adhering to NRC guidelines.

The NRC (2001) has provided amino acid guidelines for lysine and methionine to maximize milk protein percentage and has also distributed computer software to estimate dietary amino acid status. The formulation of dairy cattle diets for amino acids is very much in its infancy stage. Dietary lysine status can be improved in a reasonably cost effective fashion by formulating diets for rumen non-degradable protein using high-lysine protein supplements such as ruminally-protected soy products and blood meal, rather than low-lysine supplements, such as distillers-dried grains or corn gluten meal.

To achieve maximum milk protein percentage, the NRC (2001) guidelines for methionine and lysine:methionine ratio must also be addressed. This is difficult to do unless ruminally-protected methionine products are supplemented at a cost of about 10 to 20 cents per cow per day. The expected benefit of this feeding practice is a 0.10 to 0.15 percentage unit increase in milk protein percentage with no change in milk yield or other components. Assuming a milk protein pay price of \$2.00 per lb., the gross returns from this sort of milk protein percentage response is 15 to 20 cents per cow per day at 70 to 80 lb./cow/day milk production levels. Consequently, the profit potential for the dairy producer is marginal, especially since there is a risk that the anticipated milk protein percentage response may not be observed in all situations. An extra 0.10 to 0.15 percentage units of milk protein at the same milk fat percentage can be captured by cheese manufacturers if milk protein were given a sufficient economic value to promote routine feeding of ruminally-protected methionine. This feeding practice would result in an increase in milk protein yield.

Milk Quality and Animal Health

Multiple benefits accrue to improving milk quality. Among them are improved cheese yield, improved dairy food safety, and improved production per cow. Dairy product safety and milk quality are closely related (Ruegg, 2002). There is ample evidence that increased prevalence of subclinical mastitis in a dairy herd (as demonstrated by high SCC) is indicative of management practices associated with reduced food safety. Monthly bulk tank SCC values were higher in herds where verotoxigenic *E. coli* and *Listeria monocytogenes* were cultured from bulk tanks as compared to herds negative for those pathogens (Steele, et al., 1997). Hygienic practices on herds with higher SCC values are generally poorer than hygienic practices on herds with lower SCC values (Barkema, et al., 1998). Milking facilities, cow housing areas, and the udders of cows from herds with higher SCC values have been demonstrated to be dirtier and more soiled with manure as compared to cows and facilities from herds with lower SCC values (Barkema, et al., 1998). High SCC have also been linked to the occurrence of other indicators of poorer milking management. The risk of incurring a violative antibiotic residue is 2 to 7 times higher for herds with SCC values above 400,000 cells per ml as compared to herds with SCC values of less than 250,000 cells per ml (Ruegg and Tabone, 2000).

Improvements in milk quality relate directly to improved production efficiency. Production losses due to subclinical mastitis on U.S. dairy farms have been estimated to cost the US dairy industry \$1 billion dollars annually (Ott, 1999). Milk quality (as measured by the SCC) is important to the dairy producer because of the well-documented relationship between subclinical mastitis (as measured by SCC) and milk yield. A recent review concluded that each 2-fold increase in SCC above 50,000 cells/ml resulted in a loss of 0.9 and 1.3 lb of milk per day in primiparous and multiparous cows respectively (Hortet and Peeler, 1998). It is estimated that total lactational milk yield is reduced by 180 lb for primiparous and 260 lb for multiparous cows for each 2-fold increase in the lactation geometric mean SCC over 50,000 cells/ml. Wisconsin research has estimated that these losses are 200 lb for primiparous and 400 lb for multiparous cows (Raubertas and Shook, 1982).

Dairy Cattle Genetics

Casein Genotypes. Early studies on the impact of genetic variants of κ -casein on cheese yield indicated as much as a 10 percent increase in cheese yield with the BB variant of κ -casein (Aleandri et al., 1990; Marziali and Ng-Kwai-Hang, 1986). Initial reports credited the increase in cheese yield to an increase in protein in the BB milk. Australian researchers (McLean et al., 1984) also reported a slight increase in casein in BB milk but further characterized a major increase in the κ -casein content of BB milk as shown in Table 5.

Table 5. Milk composition for κ -Casein genotypes

<i>Component</i>	<i>AA κ-Casein</i>	<i>AB κ-Casein</i>	<i>BB κ-Casein</i>
Fat [g/L]	48.9	47.6	47.5
Crude protein [g/L]	36.3	36.3	36.2
Casein [g/L]	28.1	28.3	28.5
Casein: Fat Ratio	.575	.595	.600
κ -Casein [g/L]	3.0	3.6	3.7

More recent studies have shown only small yield differences between the AA and BB variants (Bremel et al., 1998; Gibson, 1989; Stasio et al., 2000). The casein to fat ratio of the milk from BB cows was higher than the AA cows and there was a better protein recovery from the BB milk (Bremel et al., 1998). However, AA cows produced more fat and slightly more protein than BB cows. Results of Cheddar cheese trials at the Wisconsin Center for Dairy Research are shown in Table 6. Fat retention was higher in cheese made from milk from BB genotype cows which translated into cheese with higher fat in the dry matter (FDM). Milk from the BB cows clotted faster and reached desired firmness at cutting much quicker than milk from AA cows (19 vs. 33 minutes). Only in high throughput, highly automated cheese plants running around the clock would this difference in clotting time result in an economically worthwhile increase in production efficiency. There were no significant sensory or melt differences between cheeses from the two milk genotypes.

Table 6. Milk Composition and Cheddar Cheese Yields for κ -Casein Genotypes

<i>Component</i>	<i>AA κ-Casein</i>	<i>BB κ-Casein</i>
Fat percent	3.59	3.39
True protein percent	3.06	2.96
Casein percent	2.49	2.42
Casein: Fat Ratio	.69	.72
Cheese yield percent	9.89	9.60
Fat recovery in cheese percent	88.50	91.30

Low moisture, part-skim (LMPS) Mozzarella cheese was also made from AA and BB milk. The milk from AA cows clotted slower than milk from BB cows similar to the Cheddar cheese trials. Other researchers have also reported faster coagulation by rennet in the milk from BB cows (Schaar, 1984; Horne et al., 1997). The primary reason for increased cheese yields from BB milk was a higher fat retention in the cheese (Bremel et al., 1998; Nuyts-Petit, et al., 1997). With higher fat retention, the FDM in cheese will increase and the body of the cheese will become softer. If the FDMs are too high, the cheese may be too soft to shred or slice. In such a case, the increased fat retention of the BB milk would not provide any significant advantage over AA milk.

At the present time, there does not seem to be a significant advantage in selecting BB milk since the BB cows tend to produce milk with slightly lower fat and total solids content that contributes to cheese yield. If the fat and casein levels of BB milk could be increased to match the AA milk, the BB milk would be preferred for cheese making because of the faster renneting time and increased fat retention. However, at present there would no advantage in including milk protein genetic variants among selection criteria for producers (Bremel et al., 1998; Gibson, 1989; Stasio et al., 2000).

Cattle Breeding. The opportunity to manipulate milk composition through breeding is limited by the biological associations among the milk traits. Two examples are the relationships of protein percentage with fat percent (Figure 2) and with milk yield (Figure 3). Each point in these figures depicts the genetic values for two traits of an individual bull or small group of similar bulls. In Figure 2 it is shown that bulls with high PTAs for protein percent also tend to have high PTAs for fat percent. Relatively few bulls fall into the quadrant with high protein percent and low fat percent. Because of this association, breeding cattle with high protein to fat ratios is practically impossible. Progress toward such a goal would be slow and economically undesirable.

The association between milk yield and protein percent is moderately negative; i. e., bulls with high genetic values for milk yield tend to have low values for protein percent (Figure 3). This makes it difficult to simultaneously increase milk production (necessary for profitable dairy farming) and the percentages of the milk components (desirable for cheese manufacture). The balance between genetic improvement for milk yield and protein percent is dictated by the prices paid for milk volume and protein. In fact, a penalty for milk volume would be necessary to favor selection for protein content over milk yield. Later it will be shown that selection indexes are widely used in the industry to facilitate the choices between bulls with high protein compared to high milk.

Figure 2. Scatter plot of Predicted Transmitting Ability (PTA) for protein percent and fat percent for AI Holstein bulls available August 2002

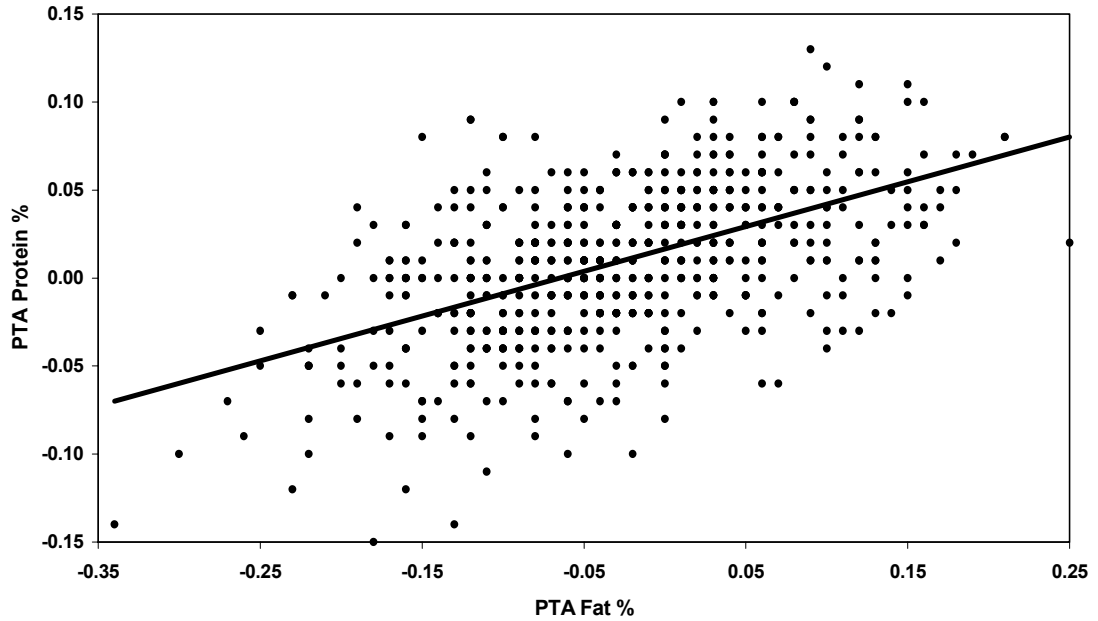
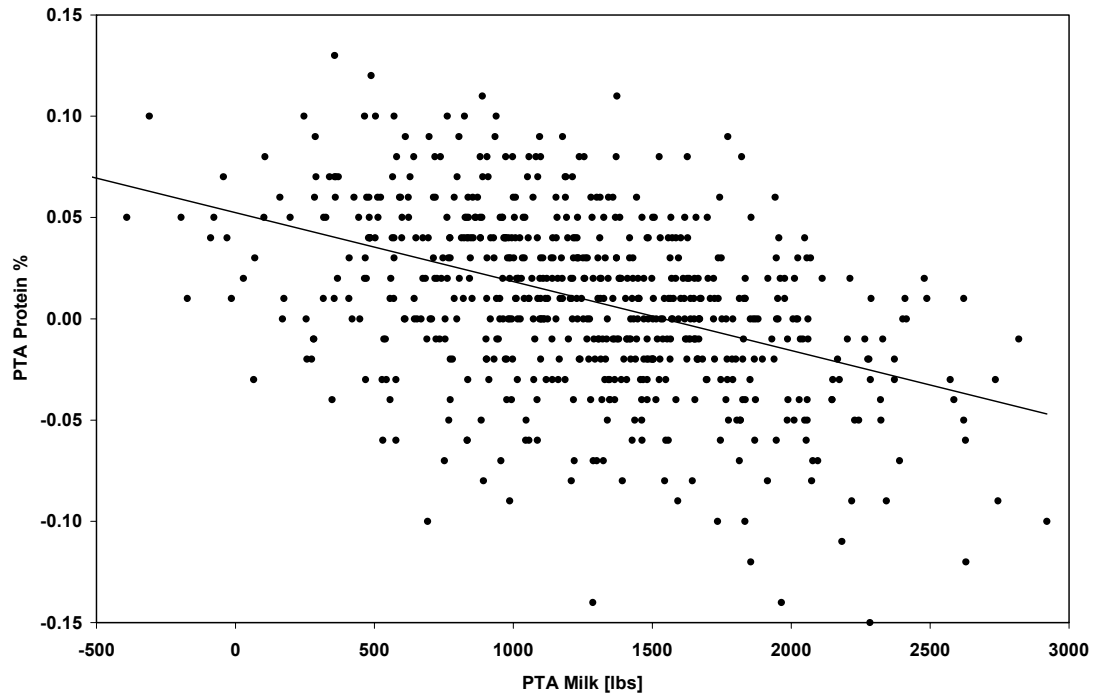


Figure 3. . Scatter plot of Predicted Transmitting Ability (PTA) for protein percent and milk yield for AI Holstein bulls available August 2002



The two primary opportunities to change milk composition by breeding are the selection of sires within breed and by changing breed composition of the dairy cow population. Dairy cattle genetic resources are truly national because breed improvement programs, genetic evaluation of animals, and semen distribution are all conducted nationally. This discussion will take a national perspective.

Sire Selection. About 50 percent of the yearly increase in production per cow is due to genetics. And more than 90 percent of genetic improvement is due to the selection of sires. Within a breed, the greatest opportunity for changing milk composition is by sire selection. The USDA Animal Improvement Programs Laboratory (AIPL) computes and distributes genetic evaluations of bulls and their daughters from data gathered through the Dairy Herd Improvement program. The measure of genetic merit is called Predicted Transmitting Ability (PTA). The difference between the PTAs of two bulls or two groups of bulls is a prediction of the difference in performance of their future daughters.

Selection indexes are recommended as a means of identifying bulls whose daughters are expected to be most profitable. A bull's index value predicts the milking lifetime net income over feed and health costs for an average daughter when the bull is mated to a breed average cow. The AIPL publishes three selection indexes: Cheese Merit, Net Merit, and Fluid Merit. Producer payment prices assumed for these indexes are shown in Table 7. The index weights for these indexes are shown in Table 8. The indexes differ only in the relative emphasis given to milk volume and protein yield. All three indexes assume a fat price of \$1.15/ lb and milk price of \$12.70 per 100 lbs. for milk with 3.0 percent protein and 3.5 percent fat.

Table 7. Producer milk and milk component prices assumed for US sire selection indices

Index	Milk price	Fat price	Protein price
	<i>\$/lb</i>		
Cheese Merit	-0.008	1.15	3.17
Net Merit	0.010	1.15	2.55
Fluid Merit	.087	1.15	0.0

Table 8. Selection index weights for Holstein bulls in the US ¹.

Index	Predicted Transmitting Ability Traits							
	Milk	Fat	Protein	Productive Life	Somatic Cell Score	Body Size	Udder	Feet and Legs
	----lbs----			months		points	points	points
Cheese Merit	-.029	2.14	6.42	28	-154	-14	29	15
Net Merit	.018	2.14	4.76	28	-154	-14	29	15
Fluid Merit	.224	2.14	-2.06	28	-154	-14	29	15

¹From VanRaden, P. M. 2000. Net merit as a measure of lifetime profit. Animal Improvement Programs Laboratory, ARS-USDA, Beltsville, MD. <http://aipl.arsusda.gov/docs/nm2000.html> (Accessed June 13, 2002).

The choice of index depends on the producer's price received per pound of protein. At protein prices above \$2.85/ lb the Cheese Merit index is recommended. At protein prices below \$1.25/ lb the Fluid Merit index is most appropriate. The Net Merit index is best for intermediate protein prices. During the 36 months of 2000 – 2002, the federal order protein price fell below \$1.25/ lb for only two months, and it never exceeded \$2.70/ lb. Therefore, producers should choose sires using the Net Merit index. Protein prices would need to run consistently at least \$1.00 to 1.25/ lb higher than they have during the past three years to make the cheese merit index an appropriate sire selection criterion.

Notice that the cheese merit index places a negative value on milk volume and the fluid merit index places a negative value on protein yield (Table 8). The weights on somatic cell score and body size are negative because cows with lower values for these traits are more profitable.

Table 9 shows the average Predicted Transmitting Abilities for various groups of Holstein AI bulls available in Fall 2002. Values in the first six rows are the average PTAs of the top 100 bulls chosen on the trait shown in the first column of the table. The last row is the average of all 649 active AI bulls; this serves as a benchmark for comparison for the groups of top 100 bulls shown in the previous rows. Comparisons should be made between rows; comparisons between columns are not valid. Comparisons between rows indicate the expected differences in daughter performance for the different bull selection criteria. For example, compare the rows Protein (lbs) and Protein percent: Daughters of the top 100 bulls selected for protein yield will produce, on average, 1103 lbs more milk, 19 lbs more protein, and \$120 more lifetime net merit, than daughters of the top 100 bulls selected for protein percent.

Table 9. Average Predicted Transmitting Ability of the top 100 Holstein bulls when selection is based on various traits, and average of all active AI Holstein bulls [August 2002 data].

<i>Selection Trait</i>	<i>Average Predicted Transmitting Ability</i>								
	<i>Milk</i>	<i>Fat</i>		<i>Protein</i>		<i>Protein: Fat Ratio</i>	<i>Cheese Merit</i>	<i>Net Merit</i>	<i>Fluid Merit</i>
	<i>Lbs</i>	<i>Lbs</i>	<i>%</i>	<i>Lbs</i>	<i>%</i>		<i>\$</i>	<i>\$</i>	<i>\$</i>
Protein pounds	1960	57	-.05	62	.015	.017	501	491	473
Protein percent	857	42	.05	43	.073	.010	402	371	253
Protein: Fat Ratio	1564	19	-.15	47	.005	.037	364	359	358
Cheese Merit \$	1695	59	-.01	57	.029	.010	535	520	478
Net Merit \$	1776	60	-.02	58	.020	.010	533	521	495
Fluid Merit \$	2000	55	-.07	54	-.020	.010	484	489	535
All AI Bulls	1230	38	-.03	38	.009	.009	345	339	330

With respect to improving milk composition for cheese manufacture and dairy herd profitability, the following conclusions can be drawn from Table 9:

- Selecting bulls using the Cheese Merit index or the Net Merit index produces the highest returns in lifetime profit per animal. The two indexes are essentially equivalent in lifetime profit whether producer payment for protein is similar to that assumed for net merit or cheese merit. Between these two indexes, cheese merit provides slightly more gain in protein percentage; this is due to a lower response in milk yield rather than a higher response in protein yield.
- Selecting bulls using the Fluid Merit index is clearly inappropriate for a cheese market, i. e. if the protein price is greater than 1.25 per pound. Doing so results in substantially lower lifetime profit per animal [as measured by the responses in Cheese Merit and Net Merit], and lower fat and protein percentages.

- Selecting bulls strictly on protein percent, while it produces the greatest gain in that trait, results in substantially lower yields of milk, fat and protein and lower lifetime profit per animal.
- Selecting bulls for protein: fat ratio would result in the greatest improvement in protein: fat ratio but the least improvement in lifetime profit per animal. The high ratios are accomplished more by selecting for low fat yields and percentages than by attaining high yields and percentages of protein. This occurs because the yield and percentage of fat is more variable than the yield and percentage of protein. In other words, the greater variation in fat causes it to have a greater influence than protein on the protein: fat ratio.

The contrast between US and Dutch Holsteins. Table 10 shows mature age Holstein, Brown Swiss, and Jersey breed averages for DHI cows in the US. Shown in the last column is the breed average [at actual age of calving] for Holsteins of North American ancestry in The Netherlands. This comparison is interesting because The Netherlands has a substantial cheese industry and, on average, more than 90 percent of the genes in this sub-population of Dutch Holsteins descend from North American cattle.

The Dutch were highly selective in their choice of North American sires, and their criteria for selecting bulls were quite different from the criteria used by US producers. The Dutch experience illustrates the possibilities for changing a breed from within. Beginning in the 1970s and continuing into the 1990s, Dutch dairy genetics organizations collaborated in an aggressive importation of semen and embryos. Animals with 87.5 percent or higher of North American genes are registered separately in the Dutch Holstein registry.

Dutch Holsteins are about 0.7 percent higher in fat percent, 0.2 percent higher in protein content, and 6,000 lbs lower in milk yield than US Holsteins. These differences are due to differences in the way the yields are expressed and to diet in addition to genetics. Yields in the US averages are adjusted to a mature age basis, while Dutch yield averages are at the actual age of calving. The Dutch yields should be increased by around 5 percent to make them comparable to US yields. The age adjustment has only a small effect on milk component percentages.

**Table 10. Average milk, cheese, and component yields and percentages for
US Holsteins, Brown Swiss, and Jerseys^{1/} and
Dutch Holsteins of North American ancestry^{2/}**

	United States			Dutch Holsteins ^{2/}
	Holstein	Brown Swiss	Jersey	
US records (count)	1,624,058	15,704	106,837	634,568
Wisconsin records (%) ^{3/}	13.4	16.7	5.2	--
Milk (lbs)	24,517	20,300	17,038	18,447
Fat (lbs)	893	814	784	796
Fat percent	3.64	4.01	4.60	4.32
True Protein (lbs)	733	672	610	592
True Protein percent	3.00	3.31	3.58	3.21
Casein percent ^{4/}	2.49	2.75	2.97	2.66
Casein: Fat Ratio	0.68	0.69	0.65	.62
Cheddar Cheese				
Cheese Yield ^{5/}	10.00	11.04	11.83	10.55
30% Cream (lbs)	0.30	0.30	1.33	1.91
Milk value ^{6/} (\$/100 lb milk)	13.24	14.61	15.89	14.33
Total value ^{6/} (\$/ cow/ year)	3,246	2,966	2,707	2,643
LMPS Mozzarella Cheese				
Cheese yield ⁷	9.09	10.00	10.68	9.57
30 percent cream (lbs)	4.49	4.95	6.34	6.35
Milk value ^{6/} (\$/100 lb milk)	13.06	14.38	15.60	14.12
Total value ^{6/} (\$/ cow/ year)	3,202	2,919	2,658	2,605

¹ Powell, R. L., and A. H. Sanders. 2002. State and National standardized lactation averages by breed for cows calving in 2000, Animal Improvement Programs Laboratory, Agricultural Research Service, US Department of Agriculture <http://aipl.arsusda.gov/docs/dhi/current/k2.html>.

² Wilmink, Hans. Cooperatie Rundveeverbetering Delta, Arnhem, The Netherlands. Personal communication, November 19, 2002.

³ Percentage of US records that were from Wisconsin

⁴ Assumes casein is .83 times true protein.

⁵ Cheese yield [pounds of cheese per 100 lbs milk] is based on Cheddar cheese at 38.0 percent moisture; assumes 96 percent casein retention and 93 percent fat retention in the cheese.

⁶ Milk value assumes cheese at \$1.30/ lb, cream at \$0.75/ lb and whey cream at \$0.70/ lb.

⁷ Cheese yield [pounds of cheese per 100 lbs milk] is based on Mozzarella cheese at 47.0 percent moisture; assumes 96 percent casein retention and 85 percent fat retention in the cheese.

Due to the high cost of concentrate feeds in The Netherlands, dairy rations there are higher in forage content and lower in concentrates than US dairy rations. This dietary difference explains a substantial portion of the difference in milk yield and a moderate portion of the difference in fat percent between the two countries. This dietary difference contributes little to the difference in protein percent. We anticipate that if the Dutch Holsteins were placed in US production systems, that milk yield would increase substantially, fat percent would decrease moderately, and protein percent would remain about the same.

The Dutch sire selection index for milk production is $-0.08 \times \text{milk yield} + 6 \times \text{protein yield} + 1 \times \text{fat yield}$ (Hamming, 2002). This index places a negative economic value on milk volume to the extent that decreasing milk production by 75 lb has the same benefit as increasing protein production by one pound; therefore, it favors high percentages of the milk components, especially protein. Also, an increase of 6 lbs of fat has the same advantage as an increase of one pound of protein. The index places a strong emphasis in favor of high protein percentage, a moderate emphasis on high fat percent and a tendency to favor bulls with low milk yield. Dairy producers in The Netherlands, which is a member of the European Union, fall under quotas based on fat production, so the emphasis on milk protein content is driven more by that fact than by any attempt to match production with the milk composition needs of the cheese industry.

The Van Slyke-Price cheese yield formula was used to determine cheddar cheese yield per cow for each of the breeds (Table 10). The volumes of surplus fat in the form of 30 percent cream are also shown. Cheese and butter market prices will dictate which of the breeds would be the most profitable from the combination of cheese yield plus additional cream for butter production. High solids milk, e.g., Dutch Holstein and Jersey, generates a significant volume of excess cream that traditionally would go to butter production. If we were only interested in cheese production, additional casein would have to be purchased to standardize the fat in cream in order to incorporate that into the cheese make procedure.

Since Mozzarella cheese is becoming the major commodity cheese, with production greater than Cheddar, we also calculated low moisture-part skim (LMPS) Mozzarella cheese yields for each of the breeds (Table 10). By using cream removal to standardize the milk for manufacture of LMPS Mozzarella cheese, there is a significant increase in the amount of excess fat that needs to be handled. Generally, cheese makers would purchase additional casein in the form of nonfat dry milk (NDM) or condensed skim milk to standardize the milk to recover the extra fat in the form of additional cheese. However, if the butter market price is high, it may be more profitable for the cheese maker to sell the cream to a creamery for butter production. Here we have assumed the cream would be sold rather than adding a casein source.

The value of cheese and 30 percent cream derived from 100 lbs milk is more than \$1.00 greater for Dutch than US Holsteins (Table 10). This advantage exists for both cheddar and mozzarella cheese. Should the US dairy genetics industry import breeding stock from the Dutch Holstein breed? The answer is yes, if it's done rationally. Semen from Dutch AI bulls is readily available in the US, and many of these bulls are competitive with US AI bulls. Alternatively, the selection strategy used by Dutch geneticists is available to US geneticists and producers. If the economic signals were correct, it would be possible to produce a sub-population of US Holsteins with cheese yields even greater than Dutch Holsteins. The advantages in milk composition for Dutch

Holsteins were attained at some sacrifice in milk yield and cheese yield per cow (Table 10). Therefore, the choice to use Dutch bulls should consider milk and cheese yield per cow in addition to cheese yield per 100 lbs milk. Finally, it should be observed that US Brown Swiss and Jersey cattle produce more cheese value per 100 lbs milk than the Dutch Holstein. Perhaps a better strategy would be breed crossing among the US breeds.

Breed Selection and Crossbreeding. The most rapid and radical genetic change in milk composition could be accomplished by changing breed composition in commercial, i. e., non-registered, dairy herds. Producers of registered cattle should continue pure breeding in order to continue genetic improvement of the breeds. The 85 percent of herds that do not register their cattle may want to consider crossbreeding. The three breeds with largest cow populations and highest average protein and fat yields are Holstein, Jersey, and Brown Swiss; this discussion will be limited to these breeds.

Crossbreeding has not been widely practiced by dairy producers, but they are showing increased interest in breed crossing. The main advantages of crossbreeding are to utilize the strengths of two or more breeds and to gain the advantage of hybrid vigor. Dairy is the only livestock industry that does not exploit the genetic phenomenon of hybrid vigor. Many herds maintain cows of two breeds, but less often do these mixed breed herds produce crossbred animals.

More than 95 percent of Wisconsin dairy cows are Holsteins. Changing the breed composition of the Wisconsin dairy herd would most likely involve breeding Holstein cows to Brown Swiss or Jersey bulls. Another choice would be to replace Holsteins with purebreds of another breed, but this would be more costly and less profitable in most herds. In producing milk for cheese manufacture, the principal advantages of the Holstein are high yields of milk, fat, and protein per cow and the comparatively high ratio of casein to fat. The Jersey breed has the highest protein and fat percentages, but the lowest casein to fat ratio and lowest component yields per cow. A ranking of the breeds for economically important non-yield traits is shown in Table 11.

Table 11. Comparison of breeds for economically important non-yield traits.

Trait	Holstein	Brown Swiss	Jersey
Calving difficulty	High	Medium	Low
Herd life	Low	Medium	High
Mastitis	Medium	Medium	High
Fertility	Low	Medium	High
Maturity rate ^{1/}	Medium	Low	High
Rearing feed cost	High	High	Low
Feed for body maintenance	High	High	Low

^{1/}Based on first lactation milk yield as a percentage of mature yield

What would be the outcome of having a crossbred herd compared to a herd that is half and half purebred with two breeds? The half and half purebred herd would get the average milk yield and composition of the two pure breeds. The crossbred herd would also expect to get the two-breed average but with an additional benefit due to hybrid vigor. Hybrid vigor is about 5 to 6 percent for lactation milk and component yields, i. e. those measured by weight. There appears to be little hybrid vigor for the milk component percentages. The big news on crossbreeding is that hybrid vigor for survival, herd life, lifetime production, and lifetime net return is 15 to 20 percent above the average of the purebreds. It is for these reasons that producers will begin to practice crossbreeding.

Table 12 compares the lactation production of herds composed of half and half purebred cows against crossbred cows. These calculations assume 5 percent hybrid vigor and are based on the US breed averages in Table 10. The results show the clear advantage for a crossbred herd compared to a herd that is half and half purebred. In most cases the crossbred animals will not exceed Holsteins for lactation production. However, when the benefits of improved fertility, longer herd life, and higher lifetime yield are considered, profitability of crossbred animals may often equal or exceed purebred Holsteins. It remains for individual producers to consider their milk markets and other factors when deciding whether to use crossbreeding. Whether one is pure breeding or crossbreeding, it is most important to select bulls of high genetic value.

Table 12. A theoretical comparison of half and half purebred herds with crossbred herds for Holstein-Jersey and Holstein-Brown Swiss breed combinations^{1/}

Breed composition	Milk	Fat	Protein		Casein	Casein:Fat Ratio	
	<i>lbs</i>	<i>lbs</i>	%	<i>lbs</i>	%		
.5H + .5J	20,777	838	4.03	672	3.23	2.68	.665
H x J cross	21,816	880	4.03	705	3.23	2.68	.665
.5H + .5BS	22,408	854	3.81	702	3.13	2.60	.682
H x BS cross	23,529	896	3.81	738	3.14	2.60	.684

^{1/}Based on the US breed averages in Table 10. Breed cross averages assume hybrid vigor is 5 percent for yield traits and 0 for percentage traits.

HOW CAN WISCONSIN PRODUCE MORE MILK?

The shrinking milk supply in Wisconsin has resulted in an under-utilization of cheese processing facilities. This makes it difficult for cheese processors to compete economically with processors in other regions that operate closer to full capacity. The two obvious strategies for increasing

milk production are increasing the number of cows and increasing production per cow. The number of cows is determined by economic and social factors that are beyond the purview of these authors. Therefore, we focus on production per cow.

Table 13 shows average production per cow for the ten leading dairy states. Milk yields are from two sources: National Agricultural Statistics Service and DHI. Milk production averages by county in Wisconsin are in Appendix Table A2. Among the states, Washington sets the pace by a wide margin in production per cow. The western states lead the northern states. Only Michigan, among the northern states, is among the top half of these ten states. Wisconsin, Minnesota, New York, and Pennsylvania are among the bottom half of these states. Among DHI herds, Wisconsin is near the US average. Of greater concern are the 54 percent of Wisconsin cows in non-DHI herds; their average is substantially below the national average and ninth among the ten leading states.

Table 13. Milk production per cow per year for the ten leading dairy states.

State	All cows ^{1/}	DHI cows ^{2/} ---lbs milk---	Non DHI cows ^{3/}	Percentage of cows in DHI ^{4/}
Wisconsin	17,306	20,944	14,207	46
Minnesota	17,777	20,137	15,116	53
New York	17,376	20,841	14,047	49
Pennsylvania	18,081	20,651	14,533	58
Michigan	19,017	22,158	15,747	51
California	21,169	22,150	19,920	56
Idaho	20,816	22,677	19,980	31
Washington	22,644	24,115	22,043	29
Texas	16,480	19,602	14,646	37
New Mexico	20,944	21,961	20,721	18
United States	18,204	20,727	16,055	46

^{1/}Wisconsin Agricultural Statistics Service. 2001. Wisconsin Agricultural Statistics, 2001. Wisconsin Department of Agriculture, Trade and Consumer Protection.

^{2/}These are DHI Rolling Herd Averages and are a good approximation of actual milk produced per cow. Animal Improvement Programs Laboratory. 2002. USDA Summary of 2001 Herd Averages. Agricultural Research Service, US Department of Agriculture <http://aipl.arsusda.gov/docs/dhi/dhi02/k3.shtml>.

^{3/}Calculated from other data in the table.

^{4/}Animal Improvement Programs Laboratory. 2002. DHI Participation as of January 1, 2002. Agricultural Research Service, US Department of Agriculture <http://aipl.arsusda.gov/docs/dhi/dhi02/k1.shtml>.

There is good news in production per cow for Wisconsin. Nearly 10 percent of Wisconsin DHI Holstein herds produce more than 25,000 lbs milk per cow per year (Table 14). These herds account for 20 percent of the milk produced by DHI Holstein herds, and they compete favorably with leading herds anywhere. The table provides other useful insights: Milk quality, measured by somatic cell count, is substantially better in higher producing herds (Table 14). This underscores the point that high producing herds do a better job of managing virtually every aspect of the operation; there is greater specialization and attention to detail. Also, the milk from higher producing herds has lower fat and protein content. This is a well known, almost unavoidable phenomenon: Individual cows, sire daughter groups, and herds with higher milk yield tend to have lower milk composition values, but pounds of the milk components and the cheese derived from those components are higher. In addition, protein: fat ratio increases with production level; this is due the fact that the decline in fat percent is greater than the decrease in protein content as herd average increases.

The higher producing herds tend to be larger (Table 14). But larger, per se, is not the issue. These herds use more technology; more of them milk three times daily; they more often employ herd management, crop management, and other kinds of consultants; their managers and workers are more specialized in their skills and responsibilities. One size does not fit all when it comes to selection of the most profitable technologies. For example, three times daily milking does not fit the management style or labor situation on every farm even though it invariably results in higher production per cow.

It is obvious that a herd averaging 28,000 lbs per cow per year has many economic advantages over a herd that averages 14,000 lbs. Most obvious is that only half as many cows are needed to produce a given amount of milk. A 100 cow herd that averages 28,000 lbs per cow will sell 2.8 million pounds of milk per year. Two hundred 14,000 lb cows would be needed to produce that same quantity. More feed per cow and labor per cow will be used in the higher producing herd. Because fewer cows are needed, less total feed and total labor for the herd is needed to produce the same total amount of milk. Housing and milking costs, also, are substantially less for the higher producing herd. Because revenues are the same for these two herds and costs are lower for the high producing herd, it is clear that a high producing herd is generally more profitable.

This point, while it is so obvious here, seems too often to be overlooked by some producers, their creditors, and perhaps other advisors. We continue to see examples in which herds are advised to increase the number of cows at an unprofitable level of production rather than find ways to increase production per cow. The producer and the creditor in these situations would be well served by solving the fundamental cow management problems before increasing herd size.

Table 14. Distribution and characteristics of Wisconsin DHI Holstein herds by level of milk production^{1/}

Herd average milk/cow	Frequency	No. of milking and dry cows	Fat	True Protein	Prot:Fat Ratio	Somatic cell count^{2/}	% of milk produced^{3/}
1,000#	%		%	%			%
>27	2.9	163	3.66	3.01	.822	88	7.3
25-27	6.2	153	3.68	3.03	.823	93	13.0
23-25	13.3	123	3.72	3.03	.815	94	20.8
21-23	20.8	93	3.75	3.04	.811	101	22.6
19-21	22.9	74	3.82	3.05	.798	110	18.0
17-19	17.9	65	3.86	3.06	.793	122	11.2
15-17	10.2	57	3.93	3.07	.781	143	5.0
13-15	4.2	52	3.94	3.07	.779	162	1.7
<13	1.7	48	3.99	3.05	.764	189	0.5

^{1/}AgSource Cooperative Services. 2002. Herd Summary Averages: Holsteins by Production Level, December 2001. <http://www.agsource.com/hsmavg.htm>.

^{2/}Geometric mean of individual cow SCC which is near the median value and is typically less than bulk tank SCC.

^{3/}Percentage of all milk produced by Holstein cows in DHI herds. Calculated from other data in the table.

The differences in production per cow – whether between states, between DHI and non-DHI herds, or between neighboring herds – are due to the same herd management factors. These include cow health, mastitis control, sire selection, forage quality, ration nutrient balance, reproductive management, cow comfort, milkings per day, and more.

High production per cow is consistent with other measures of efficiency, but by itself is not an adequate measure. A specific production per cow cannot be recommended as most profitable for every herd. We use production per cow here because it is commonly used and readily available. A better measure is cost of production per 100 lbs of milk. In the Wisconsin cheese market, we recommend that the best measure would be cost per pound of cheese – or per 10 lbs cheese because its value would be similar to cost per 100 lbs milk. Cost of production per pound of cheese is appropriate for all breeds of cows and production systems. Each producer must evaluate their individual circumstances to determine their best strategy in reducing production cost per pound of milk or pound of cheese.

References

- Aleandri, R., L.G. Buttazzoni, J.C. Schneider, A. Caroli, and R. Davoli. 1990. The effects of milk protein polymorphisms on milk components and cheese-producing ability. *J. Dairy Sci.* 73: 241-255.
- Barbano, D. M., Rasmussen, R. R., and Lynch, J. M. 1991. Influence of milk SCC and milk age on cheese yield. *J Dairy Sci* 74:369-388.
- Barkema, H. W., Y. H. Schukken, T. J. G. M. Lam, M. L. Beiboer, G. Benedictus, and A. Brand. 1998. Management practices associated with low, medium, and high somatic cell counts in bulk milk. *J. Dairy Sci.* 81:1917-1927.
- Bremel, R., J. Lewandowski, M. Johnson, C. Chen, A. Dikkeboom, B. Tricomi, J. Jaeggi, and M. Zimbric. 1998. Cheese making properties of milk from cows of different genotype. *Pages 75-77* in Center for Dairy Research Annual Report 1998, Wis. Ctr. for Dairy Research, Madison, WI.
- Cropp, R., R. Shaver, and W. Wendorff. 1999. Changes in testing for and paying for milk components as proposed under the final rule of federal order reform: Implications for dairy producers. Marketing and Policy Briefing Paper No. 70. July 1999. Dept. Agric. & Appl. Econ., UW-Madison.
- Dado, R. G., G. E. Shook, and D. R. Mertens. 1994. Nutrient requirements and feed costs associated with genetic selection for milk component yield. *J. Dairy Sci.* 77:598.
- Gibson, J.P. 1989. Altering milk composition through genetic selection. *J. Dairy Sci.* 72: 2815-2825.
- Hamming, Ite. Cooperatie Rundveeverbetering Delta, Arnhem, The Netherlands. Personal communication, November 22, 2002.
- Harmon, R. J. 2001. Somatic cell counts: a primer. Pp 3-9 in Proc. Natl. Mastitis Coun. 40th Annual Meeting., Feb 11-14, 2001 Reno, NV.
- Horne, D.S., J.M. Banks, and D.D. Muir. 1997. Genetic polymorphism of bovine kappa-casein: effects on renneting and cheese yield. *Pages 162-171* in Proc. of IDF Seminar on Milk protein polymorphism. Int. Dairy Fed., Brussels, Belgium.
- Hortet P, Seegers H. Calculated milk production losses associated with elevated somatic cell counts in dairy cows: review and critical discussion. 1998. *Vet Res.* 29(6):497-510.
- Marziali, A.S., and K.F. Ng-Kwai-Hang. 1986. Relationships between milk protein polymorphisms and cheese yielding capacity. *J. Dairy Sci.* 69: 1193-1201.
- McLean, D.M., E.R.B. Graham, R.W. Ponzoni, and H.A. McKenzie. 1984. Effects of milk protein genetic variants on milk yield and composition. *J. Dairy Res.* 51: 531-546.

National Research Council. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. ed. Natl. Acad. Sci., Washington, DC.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Natzke, D. 2000. Milk surge hiding Wisconsin protein deficit. Agri-View, Aug. 3, 2000.

Nuyts-Petit, V., A. Delacroix-Buchet, and L. Vassal. 1997. Effect of the three casein haplotypes (alphas1, beta and kappa) occurring most frequently in the Normande breed on milk composition and suitability for cheesemaking. Lait 77: 625-639.

Ott, S. 1999. Costs of herd-level production losses associated with subclinical mastitis in US Dairy Cows. Pp 152-156 in Proceedings of the 38th annual meeting of National Mastitis Council, Arlington VA. Natl Mast Coun. Madison WI.

Raubertas, R. F., and G. E. Shook. 1982. Relationship between lactation measures of somatic cell concentration and milk yield. J. Dairy Sci. 65:419-425.

Ruegg, P. L. 2002. Practical Food Safety interventions for dairy production. J Dairy Sci., accepted.

Ruegg, P. L., and T. J. Tabone. 2000. The relationship between antibiotic residue violations and somatic cell counts in Wisconsin dairy herds. J. Dairy Sci. 83:2805-2809.

Schaar, J. 1984. Effects of kappa casein genetic variants and lactation number on the renneting properties of individual milks. J. Dairy Res. 51: 397-406.

Schallibaum, M. 2001. Impact of SCC on the quality of fluid milk and cheese. Pp 38-46 in Proc. Natl. Mastitis Coun. 40th Annual Meeting., Feb 11-14, 2001 Reno, NV.

Stasio, L., G. Masoero, P. Fiandra, and L. di-Stasio. 2000. Milk protein polymorphism and relationship with genetic indices in Aosta Black Pied and Castana populations. Sci. Tecnica Lattiero Casearia 51: 27-37.

Steele, M. L., W. B. McNab, C. Poppe, W. Mansel, W. Griffiths, S. Chen, S. A. Degrandis, L. C. Fruhner, C. A. Larkin, J. A. Lynch, and J. A. Odumeru. 1997. Survey of Ontario bulk tank raw milk for food-borne pathogens. J. Food Prot. 60:1341-1346.

Van Eenennaam, A., and J.F. Medrano. 1991. Milk protein polymorphisms in California dairy cattle. J. Dairy Sci. 74: 1730-1742.

**APPENDIX: MILK COMPOSITION, MILK QUALITY, AND
MILK PRODUCTION LEVELS BY COUNTY FOR
WISCONSIN'S 50 LEADING DAIRY COUNTIES**

Milk Composition and Milk Quality

Milk composition and milk quality measures are from DHI herds, so these results do not characterize the entire milk supply from a county or district. Results are shown in Table A1 for the 50 leading dairy counties based on total milk production from all herds.

Variations in milk composition among counties and regions are rather small. Herds with high or low milk composition are not clustered in specific counties. Based on DHI herds, six counties have average protein tests of 3.1 percent or higher and only one county has protein below 3.0 percent. Three of the high protein counties are in the Northwestern district. Average fat test is 3.9 percent or higher in only two counties and less than 3.7 percent in five counties.

Milk quality, as measured by somatic cell count (SCC), is somewhat more variable than milk composition. The standard for high quality milk is set by four counties with SCC below 250,000 cells/ml. Counties in the south central and southeast districts are uniformly lower than other districts. The 31 counties with SCC above 300,000 indicate that wide regions of the state need improvement in milk quality efforts.

Table A1. Milk composition and milk quality measures by district and county for the 50 leading Wisconsin dairy counties.

District/ County	Total Production ^{1/} <i>1,000 lb</i>	Dairy Herd Improvement Herd Averages ^{2/}		
		Butterfat %	Protein %	Somatic Cell Count
Northwest				
Barron	472,700	3.86	3.12	355
Chippewa	553,000	3.85	3.08	334
Polk	302,270	3.84	3.11	323
Rusk	199,390	3.84	3.15	317
North Central				
Clark	1,051,650	3.84	3.03	333
Marathon	1,027,050	3.76	3.05	301
Taylor	293,560	3.86	3.07	353
Northeast				
Marinette	213,600	3.80	3.03	329
Oconto	382,700	3.73	3.03	311
Shawano	628,350	3.72	3.04	331
West Central				
Buffalo	330,000	3.75	3.02	299
Dunn	349,800	3.76	3.05	339
Eau Claire	177,120	3.89	3.09	348
Jackson	220,570	3.79	3.09	306
LaCrosse	195,880	3.83	3.05	323

Table A1. Milk composition and milk quality measures by district and county for the 50 leading Wisconsin dairy counties.

District/ County	Total Production ^{1/}	Dairy Herd Improvement Herd Averages ^{2/}		
		Butterfat	Protein	Somatic Cell Count
	<i>1,000 lb</i>	<i>%</i>	<i>%</i>	
Monroe	421,200	3.89	3.10	308
Pepin	154,000	3.87	3.06	259
Pierce	320,050	3.75	3.04	256
St. Croix	447,700	3.76	3.03	309
Trempealeau	425,000	3.75	3.02	318
Central				
Green Lake	155,100	3.90	3.04	262
Juneau	161,990	3.76	3.09	195
Portage	228,200	3.99	3.06	319
Waupaca	448,560	3.70	3.06	299
Wood	440,000	3.79	3.07	342
East Central				
Brown	777,000	3.63	3.01	333
Calumet	411,320	3.75	3.01	335
Door	153,640	3.66	3.03	267
Fond du Lac	754,400	3.77	2.99	294
Kewaunee	501,370	3.64	3.01	260
Manitowoc	828,000	3.67	3.03	278
Outagamie	693,230	3.78	3.04	334
Sheboygan	489,180	3.82	3.01	312
Winnebago	251,810	3.74	3.07	372
Southwest				
Crawford	163,300	3.79	3.06	323
Grant	889,200	3.82	3.06	334
Iowa	442,000	3.75	3.05	289
Lafayette	477,400	3.76	3.06	305
Richland	249,000	3.87	3.08	341
Sauk	490,000	3.79	3.10	242
Vernon	397,800	3.87	3.11	319
South Central				
Columbia	278,400	3.74	3.08	222
Dane	930,600	3.73	3.02	263
Dodge	726,700	3.79	3.06	223
Green	507,000	3.74	3.06	284
Jefferson	302,400	3.78	3.07	282
Rock	224,900	3.80	3.09	308
Southeast				
Ozaukee	163,800	3.83	3.00	301
Walworth	219,480	3.68	3.04	293
Washington	274,120	3.85	3.07	262

¹Data from Wisconsin Agricultural Statistics Service

²Data from AgSource Cooperative Services, Verona, WI and Dairy Records Management Systems, Raleigh, NC

Milk Production Levels and DHI Participation

The adage that you can't manage things you don't measure is clearly illustrated in milk production per cow. The motto should go on to say that you can't improve things you don't measure. Table A2 shows production levels and DHI participation by county for the 50 leading dairy counties in Wisconsin. Production per cow per year is around 7,000 lbs higher in DHI herds than non-DHI herds. The data provided by DHI and other production recording programs enables producers to manage for higher levels of production.

The county averages for DHI herds range from a low of 19,194 lbs to a high of 23,092 lbs per cow. The range among county averages is much larger for non-DHI herds with a low of 11,139 to a high of 16,940. Management information such as provided by DHI also leads to a more uniform level of management.

Rates of participation in DHI differ widely among counties. Four of the 50 leading dairy counties have fewer than 25% of cows on DHI programs. Eight counties have 55% or more of cows on DHI, and three of these are above 60%. The use of on-farm computers linked to automated milk weight equipment in the milking parlor has displaced DHI records on some farms. The number of farms using this approach to record keeping has not been documented. Nevertheless, it is clear that increasing the use of performance records on individual cows is an excellent opportunity for Wisconsin herds to increase production and profitability and for the state to recapture lost market share in total production.

Table A2. Milk production levels, Dairy Herd Improvement participation and herd size by district and county for the 50 leading dairy counties

District/ County	Milk production per cow per year			DHI Cows per Herd ²	Cows on DHI ^{3/}
	All herds ^{1/}	DHI herds ^{2/}	Non-DHI herds ³		
		---Lbs---		No.	%
Northwest					
Barron	16,300	21,281	15,138	61	19
Chippewa	15,800	20,185	13,571	69	34
Polk	16,700	20,748	11,649	79	56
Rusk	15,700	19,370	14,494	59	25
North Central					
Clark	17,100	21,195	14,499	65	39
Marathon	16,700	21,770	12,929	76	43
Taylor	16,400	20,827	13,966	60	35
Northeast					
Marinette	17,800	20,533	16,061	120	39
Oconto	17,800	21,924	15,040	108	40
Shawano	17,700	22,359	14,001	93	44
West Central					
Buffalo	16,500	21,094	13,570	89	39
Dunn	16,500	20,623	11,213	75	56

Table A2. Milk production levels, Dairy Herd Improvement participation and herd size by district and county for the 50 leading dairy counties

District/ County	Milk production per cow per year			DHI Cows per Herd ²	Cows on DHI ^{3/}
	All herds ^{1/}	DHI herds ^{2/}	Non-DHI herds ³		
		---Lbs---		No.	%
Eau Claire	16,400	20,402	12,707	62	48
Jackson	16,100	20,030	14,454	64	30
LaCrosse	16,600	19,194	13,698	68	53
Monroe	16,200	20,158	13,072	75	44
Pepin	17,500	19,882	16,408	66	31
Pierce	17,300	21,271	13,542	70	49
St. Croix	18,500	21,615	16,304	79	41
Trempealeau	17,000	20,776	14,437	84	40
Central					
Green Lake	16,500	21,692	14,904	85	24
Juneau	16,700	20,602	13,493	93	45
Portage	16,300	20,389	15,049	73	23
Waupaca	17,800	21,382	13,076	102	57
Wood	17,600	19,823	16,940	67	23
East Central					
Brown	18,500	23,003	13,757	141	51
Calumet	18,200	22,662	15,506	91	38
Door	16,700	21,580	11,730	69	50
Fond du Lac	18,400	22,174	13,276	98	58
Kewaunee	18,100	23,092	14,710	113	40
Manitowoc	18,400	21,889	14,187	113	55
Outagamie	18,100	21,260	15,746	92	43
Sheboygan	18,600	22,002	11,958	105	66
Winnebago	16,900	20,111	13,474	92	52
Southwest					
Crawford	15,300	19,219	13,667	52	29
Grant	17,100	19,579	15,472	74	40
Iowa	17,000	20,632	12,924	74	53
Lafayette	15,400	20,209	12,064	84	41
Richland	16,600	19,784	14,241	66	43
Sauk	17,500	21,545	13,943	83	47
Vernon	15,300	19,818	12,463	68	39
South Central					
Columbia	17,400	21,285	13,291	86	51
Dane	18,800	21,912	16,338	91	44
Dodge	16,900	20,713	13,516	76	47
Green	15,600	20,031	11,139	73	50
Jefferson	16,800	20,932	13,322	78	46
Rock	17,300	21,649	10,075	90	62
Southeast					
Ozaukee	18,200	21,541	14,426	116	53
Walworth	17,700	21,516	11,837	93	61
Washington	17,800	19,697	16,730	82	36

^{1/}Data from Wisconsin Agricultural Statistics Service

^{2/}Data from AgSource Cooperative Services, Verona, WI and Dairy Records Management Systems, Raleigh, NC

^{3/}Calculated from WASS and DHI data.