Precision Dairy Monitoring Technology Opportunities & Challenges

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Introduction

Technologies are changing the shape of the dairy industry across the globe. This rapid introduction of new technologies should come as no surprise given the technological culture shift in every facet of our society. In fact, many of the technologies applied to the dairy industry are variations of base technologies used in larger industries such as the automobile or personal electronic industries. Undoubtedly, these technologies will continue to change the way that dairy animals are managed. This technological shift provides reasons for optimism for improvements in both cow and farmer well-being moving forward. Many industry changes are setting the stage for the rapid introduction of new technologies in the dairy industry. Across the globe, the trend toward fewer, larger dairy operations continues. Dairy operations today are characterized by narrower profit margins than in the past, largely because of reduced governmental involvement in regulating agricultural commodity prices. Consequently, small changes in production or efficiency can have a major impact on profitability. The resulting competition growth has intensified the drive for efficiency resulting in increased emphasis on business and financial management. Furthermore, the decision making landscape for a dairy manager has changed dramatically with increased emphasis on consumer protection, continuous quality assurance, natural foods, pathogen-free food, zoonotic disease transmission, reduction of the use of medical treatments, and increased concern for the care of animals. Lastly, powers of human observation limit dairy producers' ability to identify sick or lame cows or cows in heat.

Precision Dairy Farming

Precision Dairy Farming is often used to describe many technologies aimed at improving dairy management systems. Bewley (2010) described Precision Dairy Farming as the use of technologies to measure physiological, behavioral, and production indicators on individual animals to improve management strategies and farm performance. Eastwood et al. (2004) defined Precision Dairy Farming as "the use of information technologies for assessment of fine-scale animal and physical resource variability aimed at improved management strategies for optimizing economic, social, and environmental farm performance." Spilke and Fahr (2003) stated that Precision Dairy Farming, with specific emphasis on technologies for individual

animal monitoring, "aims for an ecologically and economically sustainable production of milk with secured quality, as well as a high degree of consumer and animal protection." With Precision Dairy Farming, the trend toward group management may be reversed with focus returning to individual cows through the use of technologies (Schulze et al., 2007). Technologies included within Precision Dairy Farming range in complexity from daily milk yield recording to measurement of specific attributes (e.g. fat content or progesterone) within milk at each milking. The main objectives of Precision Dairy Farming are maximizing individual animal potential, early detection of disease, and minimizing the use of medication through preventive health measures. Precision Dairy Farming is inherently an interdisciplinary field incorporating concepts of informatics, biostatistics, ethology, economics, animal breeding, animal husbandry, animal nutrition, and engineering (Spilke and Fahr, 2003). The ideal Precision Dairy Farming technology explains an underlying biological process that can be translated into meaningful action with information readily available to the farmer and a reasonable return on investment. Additionally, the best technologies a flexible, robust, reliable and demonstrated effective through research and commercial demonstrations.

The list of Precision Dairy Farming technologies used for animal status monitoring and management continues to grow. Because of rapid development of new technologies and supporting applications, Precision Dairy Farming technologies are becoming more feasible. Many Precision Dairy Farming technologies including daily milk yield recording, milk component monitoring (e.g. fat, protein, and SCC), pedometers, automatic temperature recording devices, milk conductivity indicators, accelerometers for monitoring lying behavior, rumination monitors, automatic estrus detection monitors, and daily body weight measurements are already being utilized by dairy producers. Despite its seemingly simplistic nature, the power of accurate milk weights should not be discounted in monitoring cows, as it is typically the first factor that changes when a problem develops (Philpot, 2003). Other new Precision Dairy Farming technologies have been introduced to measure jaw movements, ruminal pH, reticular contractions, heart rate, animal positioning and activity, vaginal mucus electrical resistance, feeding behavior, biological components (enzymes, antibodies, or microorganisms), odor, glucose, acoustics, progesterone, individual milk components, color (as an indicator of cleanliness), infrared udder surface temperatures, gain analysis, and respiration rates. Unfortunately, the development of technologies tends to be driven by availability of a technology, transferred from other industries in market expansion efforts, rather than by need. Relative to some industries, the dairy industry is relatively small, limiting corporate willingness to invest extensively in development of technologies exclusive to dairy farms. Many Precision Dairy Farming technologies measure variables that could be measured manually, while others measure variables that could not have been obtained previously.

Realistically, the term "Precision Dairy" should not be limited to monitoring technologies. Perhaps a more encompassing definition of Precision Dairy Management is the use of automated, mechanized technologies toward refinement of dairy management processes, procedures, or information collection. This definition incorporates monitoring technologies, automated milking systems, automated calf feeding systems, and precision feeding systems. Automated milking systems have already been widely adopted in Europe.

Adoption rates in North American have increased in recent years. The introduction of robotic milking components to rotary parlors will increase mechanization of milking in larger farms in the near future. Automated calf feeding systems have created a paradigm shift in how to raise dairy calves. Despite initial concerns of increased disease transmission, the benefits to automated calf feeding seem to outweigh the drawbacks when managed properly. New options for monitoring total mixed ration delivery and consumption will also improve how lactating dairy animals are fed. This is a particularly important economic and social concern given increased feed prices and concern for dairy efficiency and greenhouse gas emissions.

Benefits

Perceived benefits of Precision Dairy Farming technologies include increased efficiency, reduced costs, improved product quality, minimized adverse environmental impacts, and improved animal health and well-being. These technologies are likely to have the greatest impact in the areas of health, reproduction, and quality control (de Mol, 2000). Realized benefits from data summarization and exception reporting are anticipated to be higher for larger herds, where individual animal observation is more challenging and less likely to occur (Lazarus et al., 1990).   As dairy operations continue to increase in size, Precision Dairy Farming technologies become more feasible because of increased reliance on less skilled labor and the ability to take advantage of economies of size related to technology adoption.

A Precision Dairy Farming technology allows dairy producers to make more timely and informed decisions, resulting in better productivity and profitability (van Asseldonk et al., 1999). Real time data can be used for monitoring animals and creating exception reports to identify meaningful deviations. In many cases, dairy management and control activities can be automated (Delorenzo and Thomas, 1996). Alternatively, output from the system may provide a recommendation for the manager to interpret (Pietersma et al., 1998). Information obtained from Precision Dairy Farming technologies is only useful if it is interpreted and utilized effectively in decision making. Integrated, computerized information systems are essential for interpreting the mass quantities of data obtained from Precision Dairy Farming technologies. This information may be incorporated into decision support systems designed to facilitate decision making for issues that require compilation of multiple sources of data.

Historically, dairy producers have used experience and judgment to identify outlying animals. While this skill is invaluable and can never be fully replaced with automated technologies, it is inherently flawed by limitations of human perception of a cow's condition. Often, by the time an animal exhibits clinical signs of stress or illness, it is too late to intervene. These easily observable clinical symptoms are typically preceded by physiological responses evasive to the human eye (e.g. changes in temperature or heart rate). Thus, by identifying changes in physiological parameters, a dairy manager may be able to intervene sooner. Technologies for physiological monitoring of dairy cows have great potential to supplement the observational activities of skilled herdspersons, which is especially critical as more cows are managed by fewer skilled workers (Hamrita et al., 1997). Dairy producers with good "cow

sense" are the ones who will benefit the most from technology adoption. Those who view technologies as a way to do something they don't like to do will likely struggle.

Adoption

The list of Precision Dairy Farming technologies used for animal status monitoring and management continues to grow. Despite widespread availability, adoption of these technologies in the dairy industry has been relatively sparse thus far (Gelb et al., 2001, Huirne et al., 1997). Perceived economic returns from investing in a new technology are always a factor influencing technology adoption. Additional factors impacting technology adoption include degree of impact on resources used in the production process, level of management needed to implement the technology, risk associated with the technology, institutional constraints, producer goals and motivations, and having an interest in a specific technology (Dijkhuizen et al., 1997, van Asseldonk, 1999). Characteristics of the primary decision maker that influence technology adoption include age, level of formal education, learning style, goals, farm size, business complexity, increased tenancy, perceptions of risk, type of production, ownership of a non-farm business, innovativeness in production, average expenditure on information, and use of the technology by peers and other family members. Research regarding adoption of Precision Dairy Farming technologies is limited, particularly within North America.

To remedy this, a five-page survey was distributed to all licensed milk producers in Kentucky (N=1074) on July 1, 2008. Two weeks after the first mailing, a follow-up postcard was mailed to remind producers to return the survey. On August 1, 2008, the survey was resent to producers who had not returned the survey. A total of 236 surveys were returned; 7 were omitted due to incompletion leaving 229 for subsequent analyses (21%). The survey consisted of questions covering general farm descriptive demographics, extension programming, and decision making behavior. With regard to Precision Dairy Farming the following question was presented to survey participants: *"Adoption of automated monitoring technologies (examples: pedometers, electrical conductivity for mastitis detection) in the dairy industry has been slow thus far. Which of the following factors do you feel have impacted these modest adoption rates? (check ALL that apply)."* Data were entered into an online survey tool (KeySurvey, Braintree, MA). Statistical analyses were conducted using SAS® (Cary, NC). Surveys were categorized by herd size, production system, operator age, and production level. Least squares means among categories were calculated for quantitative variables using the GLM procedure of SAS®. Statistical differences were considered significant using a 0.05 significance level using Tukey's test for multiple comparisons. For qualitative variables, χ^2 analyses were conducted using the FREQ procedure of SAS®. Statistical differences were considered significant at a 0.05 significance level.

Among the 229 respondents, mean herd size was 83.0 ± 101.8 cows and mean producer age was 50.9 ± 12.9. Reasons for modest adoption rates of Precision Dairy Farming technologies and dairy systems software are presented in Table 1. The reasons selected by the highest percentage respondents were (1) not being familiar with technologies that are available (55%), (2) undesirable cost to benefit ratios (42%) and (3) too much information provided without knowing what to do with it (36%%). The high percentage of producers who indicated they were unfamiliar with available technologies indicates that marketing efforts may improve technology

adoption. Actual or perceived economic benefits appear to influence adoption rates demonstrating the need for economic models to assess technology benefits and re-examination of retail product prices. As herd size increased, the percentage of producers selecting "poor technical support/training" and "compatibility issues" increased ($P < 0.05$), which may be reflective of past negative experiences. In developing technologies, manufacturers should work with end-users during development and after product adoption to alleviate these customer frustrations. Few significant differences were observed among age groups, though the youngest producers were more likely to select "better alternatives/easier to accomplish manually." Prior to technology development, market research should be conducted to ensure that new technologies address a real need. Utilizing this insight should help industry Precision Dairy Farming technology manufacturers and industry advisors develop strategies for improving technology adoption. Moreover, this information may help focus product development strategies for both existing and future technologies.

Table 1. Factors influencing slow adoption rates of Precision Dairy Farming technologies

Factor	N	Percent
Not familiar with technologies that are available	101	55%
Undesirable cost to benefit ratio	77	42%
Too much information provided without knowing what to do with it	66	36%
Not enough time to spend on technology	56	31%
Lack of perceived economic value	55	30%
Too difficult or complex to use	53	29%
Poor technical support/training	52	28%
Better alternatives/easier to accomplish manually	43	23%
Failure in fitting with farmer patterns of work	40	22%
Fear of technology/computer illiteracy	39	21%
Not reliable or flexible enough	33	18%
Not useful/does not address a real need	27	15%
Immature technology/waiting for improvements	18	10%
Lack of standardization	17	9%
Poor integration with other farm systems/software	12	7%
Compatibility issues	12	7%

Outlook

Though Precision Dairy Farming is in its infancy, new Precision Dairy Farming technologies are introduced to the market each year. As new technologies are developed in other industries, engineers and animal scientists find applications within the dairy industry. More importantly, as these technologies are widely adopted in larger industries, such as the automobile or personal computing industries, the costs of the base technologies decrease making them more economically feasible for dairy farms. Because the bulk of research focused on Precision Dairy Farming technologies is conducted in research environments, care must be taken in trying to transfer these results directly to commercial settings. Field experiments or simulations may need to be conducted to alleviate this issue. Because of the gap between the impact of Precision Dairy Farming technologies in research versus commercial settings, additional effort needs to be directed toward implementation of management practices needed to fully utilize information provided by these technologies. To gain a better understanding of technology adoption shortcomings, additional research needs to be undertaken to examine the adoption process for not only successful adoption of technology but also technology adoption failures. Before investing in a new technology, a formal investment analysis should be conducted to make sure that the technology is right for your farm's needs. Examining decisions with a simulation model accounts for more of the risk and uncertainty characteristic of the dairy system. Given this risk and uncertainty, a stochastic simulation investment analysis will represent that there is uncertainty in the profitability of some projects. Ultimately, the dairy manager's level of risk aversion will determine whether or not he or she invests in a technology using the results from this type of analysis. Precision dairy farming technologies provide tremendous opportunities for improvements in individual animal management on dairy farms. In the future, Precision Dairy Farming technologies will change the way dairy herds are managed.

Literature Cited

Bewley, J.M. 2010. Precision dairy farming: advanced analysis solutions for future profitability. Proceedings of the first North American Conference on Precision Dairy Management, Toronto, Canada.

de Mol, R. M. 2000. Automated detection of oestrus and mastitis in dairy cows. Page 177. Vol. PhD Thesis. Wageningen University, Wageningen, The Netherlands.

Delorenzo, M. A. and C. V. Thomas. 1996. Dairy records and models for economic and financial planning. J Dairy Sci 79(2):337-345.

Dijkhuizen, A. A., R. B. M. Huirne, S. B. Harsh, and R. W. Gardner. 1997. Economics of robot application. Computers and Electronics in Agriculture 17(1):111-121.

Eastwood, C., D. Chapman, and M. Paine. 2004. Precision dairy farming-taking the microscope to dairy farm management.

Gelb, E., C. Parker, P. Wagner, and K. Rosskopf. 2001. Why is the ict adoption rate by farmers still so slow? Pages 40-48 in Proc. Proceedings ICAST, Vol. VI, 2001, Beijing, China.

Hamrita, T. K., S. K. Hamrita, G. Van Wicklen, M. Czarick, and M. P. Lacy. 1997. Use of biotelemetry in measurement of animal responses to environmental stressors.

Huirne, R. B. M., S. B. Harsh, and A. A. Dijkhuizen. 1997. Critical success factors and information needs on dairy farms: The farmer's opinion. Livestock Production Science 48(3):229-238.

Lazarus, W. F., D. Streeter, and E. Jofre-Giraudo. 1990. Management information systems: Impact on dairy farm profitability. North Central Journal of Agricultural Economics 12(2):267-277.

Philpot, W. N. 2003. Role of technology in an evolving dairy industry. Pages 6-14 in Proc. 2003 Southeast Dairy Herd Management Conference, Macon, Georgia.

Pietersma, D., R. Lacroix, and K. M. Wade. 1998. A framework for the development of computerized management and control systems for use in dairy farming. J Dairy Sci 81(11):2962-2972.

Schulze, C., J. Spilke, and W. Lehner. 2007. Data modeling for precision dairy farming within the competitive field of operational and analytical tasks. Computers and Electronics in Agriculture 59(1-2):39-55.

Spilke, J. and R. Fahr. 2003. Decision support under the conditions of automatic milking systems using mixed linear models as part of a precision dairy farming concept. Pages 780-785 in Proc. EFITA 2003 Conference, Debrecen, Hungary.

van Asseldonk, M. A. P. M. 1999. Economic evaluation of information technology applications on dairy farms. Page 123. Vol. PhD. Wageningen Agricultural University.

van Asseldonk, M. A. P. M., A. W. Jalvingh, R. B. M. Huirne, and A. A. Dijkhuizen. 1999. Potential economic benefits from changes in management via information technology applications on dutch dairy farms: A simulation study. Livestock Production Science 60(1):33-44.