PROCEEDINGS OF THE
PRECISION DAIRY CONFERENCE AND EXPO

MAYO CIVIC CENTER, ROCHESTER, MINNESOTA

JUNE 26-27, 2013

Precision Dairy 2013

A Conference on Precision Dairy Technologies

Hosted by the University of Minnesota

The first-ever Precision Dairy Management Conference held in the U.S., the Second North American Conference on Precision Dairy Management, and the Third Robotic Milking Conference

INTEGRATING IT ALL: MAKING IT WORK AND PAY AT THE FARM

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Introduction

With increasing herd sizes, farmers do not have time manage cows individually and tend to optimize decisions at the group level. However, by optimizing decisions at the group level, even when using proper health and reproduction protocols, the individual animal will not be managed optimally. Precision dairy farming (PDF) may assist optimize the performance of dairy cattle held in large groups at the individual cow level. By replacing group management with individual cow management, the cost price of milk can be decreased.

The development of applications for PDF started in the 1970s with the development of electronic cow recognition (Kuip, 1987). Besides the development of individual concentrate supplementation, PDF applications were not implemented at a large scale, although in the 1980s and 1990s work was carried out into PDF applications (e.g., Nielen et al., 1992; Thompson et al., 1995).

Currently, PDF applications are finding their way on dairy farms, although there seem to be differences in the uptake of PDF applications between dairy systems. This paper will describe the factors that make PDF applications work at the farm. Illustrations of these success factors on Northwestern European and American dairy farms will be provided.

Success factors to make precision dairy farming work

Three groups of success factors for PDF applications can be distinguished: System specifications, cost-efficiency and socio-economic factors.

System specifications.
Recently, many new initiatives are taken in the development of PDF applications. Some of these new initiatives are associated with the introduction of automatic milking, where detection of abnormal milk and clinical mastitis could not be done by visual inspection of the milk and/or udder anymore. Many new initiatives, e.g., introduction of automated estrus detection equipment, are not necessarily associated with automatic milking. New initiatives (sensors or other hardware) that are potentially interesting for application on dairy farms often started from engineers. The development of hardware is, however, only a first step in the development of a PDF system, which consists of four stages (Rutten et al., 2013): (1) technique, (2) data interpretation, (3) integration of information and (4) decision making.

A first step in development of a PDF system is the development and description of equipment that measures one or more parameters. Data interpretation is the important second step that transforms data, collected by the PDF systems hardware, into usable information. This is a crucial step, because it involves a clear definition of the animal or farm status that needs to be detected and the gold standard associated with that. Algorithms needs to be developed and validated to transform data into information. This data interpretation can be very tedious

(Hogeveen et al., 2010). For instance, because of the decisions that have to be made on interpretation of sensor output. It is clear that a PDF alert for estrus 4 days after estrus took place will be too late. However, a PDF alert for mastitis 4 days after onset of clinical signs might be in time (dependent on the severity of the mastitis case).

At the third stage, the information obtained from the hardware can be combined with other on- or off-farm information (e.g., non-sensor cow data and economic data) to support decisions. This third step is not a necessary step in PDF systems, but it will improve the value of a PDF system. Stage four is the actual decision making, either by the herdsman or autonomously by the PDF system. Automated concentrate feeders are, for instance, making decisions autonomously.

For a PDF application it is immensely important that it is clear what the application is doing (the golden standard). Applications should at least go to stage 2, data interpretation (alerts). The alerts that a PDF application give, need to be useful for a farmer. Alerts without any appropriate management action or standard operating procedures associated with it, are not useful at all.

Cost-efficiency.

The second success factor for a PDF application is the cost-efficiency of the investment, and this depends on many different aspects of the PDF application. The economic value of a PDF application depends on the type of application. Many new developments are aimed at improved disease situations (e.g., mastitis, metabolic disorders, claw problems). The costs of disease is then an important first element, because in the costs of disease lies the potential economic value of the PDF system. Although for many endemic dairy cattle diseases cost estimates are available (see for instance Hogeveen et al., 2011, Bruijnis et al., 2010 and Ettema et al., 2010), the benefits of the improved management because of PDF applications is often unknown.

Other benefits may be present as well: for example improved production efficiency (e.g., concentrate feeder systems) and reduced labor (e.g., automatic milking). The benefits of improved disease levels, reduced labor, reduced feed costs per kg milk should be weighed against the investment costs of the system. For some PDF systems, economic advantages in the dairy production chain are envisaged. Because the farmer is the one investing, these benefits should be taken out of the equation unless chain partners motivate farmers to invest in PDF systems that benefit the entire chain.

Non-economic factors.

Even if a PDF application is cost-effective, adoption of the technology is dependent on other factors. A large heterogeneity exists among farmers (micro-level behavior) with regard to the adoption of technology. Economic factors such as size effects, risk preference and variation in the availability of labor and/or capital are factors for adoption of new technology. Also timing and investment irreversibility are important factors for adoption of new technology (Sauer and Zilberman, 2012).

Goals of farmers differ and has shown to have an effect on the farmers entrepreneurial behavior (Bergevoet et al., 2004). It might be that behavior with regard to PDF applications also differs between farmers. Preferences of the farmer are often overlooked. Especially on farms where the family provides a large proportion of the labor, goals of farmers go wider than only profit maximization. With, for instance, conjoint analysis, farmers preference for systems can very well be studied (e.g., Mollenhorst et al., 2012). For this type of work, it is necessary to have clear (as SMART as possible) descriptions of the potential PDF applications.

The example of automatic milking

In 1992, automatic milking was first introduced on commercial dairy farms in the Netherlands. Since that time, automatic milking has received lots of interest. However, from an economic point of view, automatic milking is not cost-effective. Several studies have been published on economic consequences of automatic milking using normative models (Arendzen and van Scheppingen, 2000; Armstrong and Daugherty, 1997; Cooper and Parsons, 1999; Dijkhuizen et al., 1997; Hyde and Engel, 2002; Pellerin et al., 2001; Rotz et al., 2003; Wade et al., 2004). Although results of these studies differed substantially, with some exceptions, the general trend in these studies was that automatic milking has negative effects on the economic performance of the farm when compared with conventional milking.

Studies using empirical data are relatively scarce. Table 1 presents the main results of a study that compared farms that invested in an automatic milking system (AMS) with farms that invested in the same year in a conventional milking systems (CMS) (Bijl et al., 2007). Farmers were comparable in terms of size (nr of cows) and intensity (nr of cows per hectare). Milk revenues were higher for CMS farms than for AMS farms (P = 0.003). Although no statistical difference could be found in feed costs, livestock costs and land use costs, these were a little lower for the AMS farms than for the CMS farms. Therefore, the margin on dairy production was nearly identical for both groups of farms. Costs for contractors and costs for gas, water, and electricity were greater for farms with an AMS than for those using a CMS. The AMS farmers used 29% less labor than CMS farms. This might not necessarily only be caused by a reduced amount of labor for milking, but also could be caused by increased use of contractors on the AMS farms. The amount of money available for rent, depreciation, interest, labor and profit (RDILP) was larger (P = 0.046) by € 15,566[1] for CMS farms, caused by the smaller amount of non-accountable costs of these farms. These data were on basis of so-called cash accounting. When actual accounting is used, the difference in financial results between a CMS and an AMS farm is likely to be larger, the investment in an AMS is most probably larger than the investment in a CMS. Moreover, the economic lifetime of an AMS is expected to be shorter than of a CMS.

More recently, a new study using empirical data of Dutch dairy farms found that AMS farms had a slight, non-significant lower efficiency than CMS farms (Steeneveld et al., 2012). Very recent data (not published) of 1,109 Dutch dairy farms, collected to study the effect of grazing on economic efficiency confirmed these results. However, the combination of grazing with automatic milking did give a statistically significant lower efficiency of AMS farms. Based on the same data, also an analysis was made on gross farm income (Table 2). Farm size had a positive effect on farm income, as well as grazing. There was no significant relationship between AMS and gross farm income. However, the interaction between grazing and adoption of AMS showed that farms that combined grazing with AMS had a lower gross farm income.

[1] On April 12, 2013, € 1 = $US 1.30

Table 1. Average revenues, costs, margins, non-accountable costs and RDILP[1] (all in Euros[2] per farm per year) for 31 farms having an automatic milking system (AMS) and 31 farms using a conventional milking system (CMS) in 2003. P-values are given when P<0.10.

	AMS	CMS	P
Revenues (a)	299,248	307,147	NS
Feed costs (b)	54,202	57,120	NS
Livestock costs (c)	18,205	20,559	NS
Costs of land use (d)	11,396	12,948	NS
Total (b+c+d) (e)	83,804	90,626	NS
Margin on dairy (a-e)	215,444	216,521	NS
Gross margin (f)	231,542	232,519	NS
Non-accountable costs (g)	79,614	65,025	0.002
RDILP (f – g)	151,928	167,494	0.046

[1]Rent, depreciation, interest, labor, and profit.
[2]On April 12, 2013 € 1 = $US 1.30

Table 2. Results of a multivariate model on the gross farm income of 1,109 Dutch dairy farms

	Estimate	S.E.	P
Intercept	-29,8153	6,9574	0,000
Farm size (total returns (* € 1.000)	0,5726	0,0126	0,000
Intensity (milk/ha)	-0,6882	0,2340	0,003
AMS (yes/no)	5,7052	4,6551	0,221
Grazing (yes/no)	21,6280	6,2166	0,001
Grazing * farm size	-0,0674	0,0152	0,000
Grazing * AMS	-16,1506	5,5338	0,004
Successor (yes/no)	3,4099	1,9552	0,081
Soil (base=clay)			
Other	-4,0034	4,4942	0,373
Peat	11,5307	4,3243	0,008
Sand	4,9747	2,2407	0,027

Although there is no economic benefit of milking with an AMS, the introduction of automatic milking has gone quite fast in North-western Europe. In 2012, 2,722 Dutch dairy farms (14.5 %) were milking with an AMS. Because there is no direct economic reason that farmers switch from conventional to automatic milking, other factors should be the cause of this rapid adoption.

In a study carried more than 10 years ago (Hogeveen et al., 2004), a random group of 60 farmers who adopted an AMS and a random group of 60 farmers who invested in a CMS, both in 1998 and 1999 in The Netherlands, have been interviewed by the same person about their motivation to invest specifically in an AMS or in a CMS. Of the farmers who adopted an AMS, 26% had seriously considered buying a CMS. There was a large variety in motivations to invest in an AMS system instead of a CMS (Table 3). The most important motivations were related to labor, both in terms of efficiency and flexibility. Factors related to improved milk production or udder health were less important. Although all factors have a relation to the farm's economic situation, economic factors as such were not mentioned. This is in contrast with the farmers who invested in a CMS. Although all CMS farmers did consider an investment in an AMS, the high costs of an AMS were the most important reason not to. Two other important motivations were the dependency on the AMS and the poor growing possibilities. The latter fact is supported by data from Bijl et al. (2007) who also concluded that CMS farms did grow more than AMS farms. Factors such as assumed risks of adopting an AMS, peer group-learning and the positive effects of previous farm-specific innovation experience were found to play a role on adoption of AMS on Danish farms (Sauer and Zilberman, 2012).

Table 3 Most important motivations to invest in an specific milking system

AMS farms	Reason 1	Reason 2	Reason 3	Total	%
Less (heavy) labor	18	10	5	34	21
Flexibility	7	10	4	21	13
Milking more than twice	7	6	5	18	11
Less labor available	7	5	6	18	11
Need new milking system	9	2	4	15	9
Improved udder health	0	4	5	9	6
Higher milk production	0	6	3	9	6
Building new stable	2	4	1	7	4
Future	3	2	1	6	4
Other	7	10	7	25	15
Total	60	59	41	160	100
CMS farms					
Costs AM-system too high	19	7	1	27	29
Dependency on AM-system	6	4	4	14	15
Uncertainty AM-system	1	6	1	8	9
Poor growing possibilities	3	4	0	7	8
2nd milking unit expensive	5	1	1	7	8
Better fit in the stable	4	2	0	6	6
Other	11	9	4	24	25
Total	49	33	11	93	100

When comparing the adoption rate of AMS on US dairy farms, there is quite a big difference. In North America (the US and Canada), approximately 1,000 Lely AMS systems have been sold (Bewley, 2013, personal communication). A large proportion of these AMS are sold in Canada. These figures indicate that the adoption of AMS in the US has been much smaller than in North- western European countries such as the Netherlands.

When looking more specifically to farms milking with an AMS, it seems that these are farms that are working with mostly family labor. By implementing an AMS they are able to increase their farm size without the burden, risks and management difficulties of hiring external labor. Moreover, an AMS provides relief from the routine two times daily, seven days a week labor at inconvenient times. When a farm already is working with hired labor, these advantages will be less prominent. For larger farms, having experience with hired labor, the situation is different. Besides improved economic efficiency, for these farms, there is not much need or motivation to adopt automatic milking. This might explain the difference in numbers of farms working with automatic milking systems between Northwest Europe and the US. However, depending on objectives or the availability of well qualified external labor, also large or very large farms may invest in an AMS, even on a 2,000 cow herd (Hyde et al., 2007).

It is expected that the difference in investment between automatic milking and CMS will decrease over time. The major cost factor of an AMS is not in steel or other materials but in electronics. Price increases will be lower for electronics than for other materials. That means, that in the future, prices of AMS are expected to become relatively lower. Consequently, at a certain moment in time all milking systems will be automatic, because it will be most cost efficient.

The example of mastitis detection

In the 1980s much research work has been carried out in on-line detection of mastitis (see for an overview Nielen et al., 1992). However, adoption of these systems was low. Partly it was because it was unclear for which purpose these on-line mastitis detection systems could be used. Algorithm development was not aimed at specific goals but merely at generic detection of mastitis (e.g., Maatje et al., 1992). Systems were described as being able to detect clinical mastitis as well as subclinical mastitis. But the associated actions differ between detection of clinical mastitis and subclinical mastitis. The reason to detect clinical mastitis is to treat animals, while the reason for detecting subclinical mastitis is more diffuse. It is partly to have an idea of the herd level of intramammary infections or it might be used for early treatment of mastitis. These differences do require different detection rules (Hogeveen and Ouweltjes, 2003). In order to treat clinical mastitis cases, the alert should be related closely to the onset of clinical mastitis, while for detection of subclinical mastitis cases these requirements are lower. However, even when specifically aimed at the detection of clinical mastitis, detection performance is not great (Hogeveen et al., 2010).Moreover, farmers were already able to detect clinical mastitis. It was and is part of standard milking procedures. For subclinical mastitis, farmers received information through somatic cell count measurements as part of the milk production recording system. In either case, the added value of mastitis detection is unclear.

No economic calculations on the use of mastitis detection systems are available. Automated mastitis detection is not expected to replace labor. The economic value should come from better detection and decision making around treatment of mastitis. The total failure costs of mastitis are approximately € 80 per cow per year (Hogeveen et al., 2011) and improved detection and treatment is not expected to reduce these costs with a large proportion. It has even been shown that cow specific treatment of clinical mastitis does not provide any added economic value (Steeneveld et al., 2012). It is, therefore, not surprising that farmers with a CMS did not adopt automated mastitis detection systems, neither in Northwest Europe or North America.

With the introduction of AMS there was a sudden need for on-line detection of mastitis because visual inspection of the cow and her milk became very laborious. Despite the relatively bad predictive value of the on-line mastitis detection systems, they were needed in AMS and are now widely implemented.

The example of estrus detection

In the late 1980's and early 1990's, research into the use of pedometers to detect estrus was carried out (e.g., Holdsworth and Markillie, 1982; Redden et al., 1993). More recently, 3D-accelerometers are becoming available and are used to detect estrus (Valenza et al., 2012; Lovendahl and Chagunda, 2010). Besides these activity-based automated estrus detection systems, other systems are also available, for instance a progesterone measuring system (Friggens and Chagunda, 2005).

Automated estrus detection systems do have a clear aim: detection of estrus with as associated action the insemination of a cow in estrus. The detection system may be combined with a system to optimize the time of insemination. For some individual cows it can be economically beneficial to extend the time of insemination (Steeneveld et al., 2012). Because of the necessity of timely insemination, the definition of the gold standard in order to evaluate the performance of estrus detection systems is also quite straightforward. Estrus should be detected in time for insemination.

The benefits of automatic estrus detection are twofold. First, automated estrus detection can save labor. Visual estrus detection requires a lot of labor. Dutch recommendations are three times daily 20 minutes of visual inspection of the cows. When this activity is automated, a large proportion of this time is saved. The second benefit lies in an increase in the estrus detection rate. Especially because most farmers do not reach the recommended time of visual inspection. An average estrus detection rate of 50% was assumed (Inchaisri et al., 2010). So when the sensitivity of an automated estrus detection system reaches, for instance, 80%, this can be seen as an improvement of estrus detection. As a consequence the average number of open days and the calving interval will reduce. One study is known on the economic effects of automated estrus detection (Ostergaard et al., 2005). In this normative study it was estimated that the break-even price for an automated estrus detection system, based on in-line progesterone measurements was for an average Danish herd of 120 cows was € 45 per cow per year. The break-even price depended on the differences in the type of estrus detection system and herd reproduction management and varied between € 3 and € 81 per cow per year.

Both in the US as well as in the Netherlands, farmers are starting to implement automated estrus detection systems. It is estimated that in the US 10 to 15 % of the farmers are utilizing automated estrus detection equipment (Bewley, 2013, personal communication). For the Netherlands this is estimated to be 19-20 % (Knijn, 2013, personal communication). Apparently, the adoption rate of automated estrus detection systems is more or less equal for the different dairy systems in the US and North-west Europe. The reasons for this can be that for estrus detection systems there is a clear goal of the system and there are clear advantages both in terms of reduction of labor as well as in improved herd productivity.

Conclusions

In order to be successful, PDF applications need to address a clear problem associated with clear actions or standard operating procedures. Economic advantages of PDF applications either come from reduced (labor) costs (the PDF application replaces something else) or increased returns because of improved herd productivity. For PDF applications the economic advantages are rarely studied. Besides economics, also other aspects may play a role, especially on farms with a large proportion of family labor. These aspects may explain the difference in adoption rate of automatic milking in the US and Northwestern Europe. Because of a lack of (monetary) benefits, automated mastitis detection is hardly used on farms that milk with a CMS. Automated estrus detection is starting to be adopted in both the US as well as the Netherlands. Most probably because of clear (monetary) benefits.

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