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PAPER

Typologies of dairy farms with automatic milking system in northwest Spain and farmers' satisfaction

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Abstract

The aim of this study was to determine the characteristics of the dairy farms that installed an automatic milking system (AMS). A survey of 38 dairy farms with AMS, in Galicia (Spain), collected information on quantitative and qualitative variables. Following elimination of redundant variables, categorical principal component analysis identified 4 factors accounting for 43.7% of the total variance. Using these factors, the farms studied were subjected to hierarchical cluster analysis which differentiated 4 types of farms: (A) farms with more leisure and quality of life where the AMS covered the expectations of farmers (29%); (B) farms that removed cows more often due to AMS and farmers with more stress (34%); (C) farms with little leisure and farmers with no successor (21%); (D) large farms with many full-time employees (FTE) where the AMS had covered farmer's expectations the least (11%). Generally the farms were based on a family structure with a high percentage of FTE. With the adoption of AMS these farms sought to increase milk production, save labour and have more flexibility. With 87% of farms with free cow traffic the activity that took the most of the farmer's time was fetching cows for milking (1 h/day). Nearly 58% of farmers were completely satisfied with their AMS, although this value reached 91% in farms with herd sizes below the average which were better adapted to the use of one AMS.

Introduction

Over the last 20 years, the European dairy sector has suffered a profound adjustment in its production structure, having lost two thirds of the dairy farms in the European Union of 12 member states. The major adjustment corresponded to Spain, where only 17% of the farms that existed in 1988 are now operative (Sineiro *et al*., 2009) and these have tripled the number of dairy cows. In 2010, cow milk production in Spain amounted to 6357 million Tm, the greatest contribution being from Galicia (Spanish autonomous community located in the North West of the country).

Over the last decades, both labour and land prices have increased, whereas the price of milk has decreased, making it necessary to increase productivity per hour and per hectare (de Koning, 2004). Furthermore, the elimination of the quotas planned for 2015 creates a new scenario, so that in the near future it will be the market that will regulate milk production, which will result in greater price instability (Sineiro *et al*., 2009). New developments and technologies in the different fields of dairy production have come into play, facilitating the work in the farms and increasing their productivity. One of them is the automatic milking system (AMS), a system that not only reduces the amount of work required, but it also makes it more flexible, which is the main reason for installing this system (Hogeveen *et al*., 2004). Dairy farming is a very demanding activity, the number of hours required being determined by the dynamics of the dairy farm, especially the milking routine. The milking is a process that has to be done at least twice a day, every day of the year, and it demands long hours and specialized labour. Dairy farming can be an activity that ties down to the point that no holidays or free weekends can be taken. The potential successors notice the hard, demanding labour that their parents carry out, a labour that sometimes does not get enough return for all the efforts involved, which discourages them from following their parents' footsteps. The AMS could be part of the solution, as farms with an AMS use 29% less labour than farms with conventional milking systems (Bijl *et al*., 2007). For a dairy farm, the implementation of an AMS means an important innovation that provides advantages; however, it is not free of difficulties. Besides adaptation of the cows, the farmer will need to acquire higher level management skills for cows, business and technology to optimize the investment in automation (Reinemann, 2008). In some countries in Northern Europe, a large proportion of the farmers who introduced an AMS changed their grazing strategy after AMS adoption, using stable feeding instead (Mathijs, 2004). In spite of the higher cost of AMS technology compared with the conventional systems for harvesting milk, many dairy farmers are willing to pay a premium for the improved quality of life offered by AMS (Reinemann, 2008). The goal for the future is to reduce production costs, improving productivity per employee and labour conditions (Sineiro *et al*., 2009) to make it more attractive and similar to other sectors. Studies that look into socio-economic aspects of AMS and into motivations for adopting this system instead of a conventional milking parlour were carried out in North America (de Jong *et al*., 2003), where dairy farms have different dynamics of expansion, and in Northern Europe, where AMS was already developed and adopted many years ago (Hogeveen *et al*., 2004; Mathijs, 2004). Furthermore, some different socio-economic aspects were expected, see for example data about farms with AMS described by a Dutch accounting agency (Bijl *et al*., 2007) which is different from Galician data (total land use, pasture, milk quota, total labour, *etc*.). Considering the importance of the dairy sector in northwestern Spain and the recent introduction of AMS in this area, the objective was to determine the structural characteristics and operations of the dairy farms that installed an AMS, as well as to find out the main reasons farmers had for deciding to invest in an AMS, and knowing the implications that its adoption had.

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Key words: Automatic milking system; Farm structure; Farm typology; Farmer satisfaction.

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Materials and methods

Area of study

Continuing with the study initiated by our research group concerning the efficiency of AMS in dairy farms in northwestern Spain (Castro *et al*., 2012), data was collected by conducting an in-person survey that covered all the farm owners within the Autonomous Community of Galicia that had AMS installed in their farms. Galician dairy farms contributed with 37.9% of the total Spanish cow milk production in 2010. Galicia occupies an area of 29,343 km^2, with an average population density of 93.6 inhabitants/km^2. In May 2011, there were 328.821 dairy cows in Galicia, representing two fifths of the country's total (MARM, 2011). In 2009, livestock unit per hectare was 2.89 and milk production per hectare was 17,253 kg milk per year (Barbeyto and López, 2012). Milk yield data published from 2010 from Galician herds showed an average milk yield per cow in 305 d of 8971 kg with 3.76% fat and 3.17% protein (AFRICOR, 2010).

Data collection

Firstly, a questionnaire was designed. For that purpose, other studies were consulted on the implementation of AMS in other regions, management practices, social aspects and motivations of farmers for installing AMS (Alibés *et al*., 2002; de Jong *et al*., 2003; Hogeveen *et al*., 2004; Mathijs, 2004; Kristensen and Noe, 2004). These studies col-

Table 1. Active variables considered divided into main topics.

Topic	Variable
Characteristics of farms	Size of farms and number of cows
	Milk quota, kg/year
	Contracted agricultural labours out to professionals
	Total full time employed in the farm
	Contracted full time employed in the farm
Characteristics of farmers	Age of the farmer interviewed, years
	Education level of farmer
	Contracted farm service for management of farm
	Existence of successor in the farm
	Who cooperates with labour on the farm
Statements of farmers	It is important to have new technologies at an early stage in the farm
	It is important to have some free time and take a holiday every year
Reasons to install an AMS	As the first option, why have you installed an AMS?
	Reasons to adopt an AMS
AMS adopted	Number of AMS installed
Implications of AMS in barn	Did you make any change in the barn to install the AMS?
	Position of the AMS in the barn
	Area of corridors per cow, m^2
	Stalls per cow
Implications of AMS in strategies before and after adoption of the AMS	Milking labour time before installation of the AMS, min
	Milking labour time after installation of the AMS, min
	Start milking labour in the morning before installation, a.m.
	Start milking labour in the morning after installation, a.m.
	Start milking labour in the afternoon before installation, p.m.
	Start milking labour in the afternoon after installation, p.m.
	Milking in parlour after installation of the AMS
Implications of AMS on health	My physical health has improved
	My mental health has improved
	My sleeping quality has improved
Implications of AMS on leisure and quality of life	I have more time for my family
	I have more time for hobbies
	The quality of life of our family has improved
Adaptation of cows	Selected traffic of cows
	Time until adaptation of the cows to AMS milking, when cows were milked voluntarily, days
	Any cows were removed due to AMS problems
Adaptation of farmers	The AMS covered your expectations
	Previous experience with computerized management systems
	Farmer were satisfied with data of AMS software
Hours worked	Checking of alarm lists and problems with AMS and computer, min/d
	Cows had to be fetched, min/d
	AMS maintenance; changed teat cup liners; cleaning the robot etc., min/d
	Checking information cow data, writing reports, min/d
	Other labours, min/d
Other implications of AMS	Contracted maintenance service
	Periodically review

AMS, automatic milking system.

lected interesting variables that we took into account when developing our questionnaire. This would also allow us to compare the results of the other regions with our own. The final questionnaire included both quantitative and qualitative variables belonging to the following topics: owner and owner family profile, farm structure, statements by farmers, reasons for installing an AMS, implications of AMS (on health, quality of life, strategies before and after the AMS introduction, barn design), adaptation of the cows, adaptation of the farmers, hours worked and AMS adopted. Firstly, a telephone survey was conducted to assess the willingness of farmers to participate in the study. If confirmed, an in-person interview was organized. During each visit, in addition to the interview, a layout of the barn with the AMS was drawn. Finally, all the owners who had an AMS in Galicia by September 2009 (n=38; 46 AMS) accepted the in-person interview. The census of farms with AMS was maintained until 2012.

Data analysis

The survey contained 78 variables to characterize the farms that invested in AMS. The information provided by the variables was both quantitative and qualitative. Sometimes a quantitative variable does not provide more information than a qualitative variable (Grande and Abascal, 2005). Also, in order to be able to analyze many variables simultaneously, they must all be of the same typology. Therefore, quantitative variables were transformed into 3 classes, using its quantile position with respect to the mean. This provided the frequencies of observations that were within the quantiles: <25%, between 25 and 75%, and >75% of the mean value for a chosen variable. It provided the frequencies of observations within each of the classes for each qualitative variable. Then a categorical principal component analysis (CATPCA) was performed to identify the factors that best accounted for the variations between the farms considered. This procedure quantifies categorical variables simultaneously, thereby reducing the dimensionality of the data (Meulman and Heiser, 2010) and allowing us to detect the factors that best characterized the farms. The criterion followed to select the number of dimensions consisted in taking a number that was small enough for the interpretations to make sense. The analysis was carried out using IBM SPSS Statistics 19 (SPSS, 2010). Information provided by the analytical variables and considered in the present study was redefined and coded into nominal, ordinal or binary variables that summarized the data from the survey. The 45 active variables finally considered in the CATPCA – divided into main topics – are defined in Table 1. Simultaneous analysis of all the variables is difficult to interpret so it is important to choose an active topic, *i.e.*, those variables that form a homogeneous unit. In this study the attention was focused on determining the degree of satisfaction of farmers that had installed an AMS, taking into account the variables which in our view may affect this satisfaction. All other variables are illustrative; that is, those variables that are not used for obtaining the analytical results, but which are related to these and facilitate their interpretation. There are many variables that can be considered to contribute to each of the dimensions; but only the variables with factorial loadings greater than 0.55 were selected in each dimension. Once the CATPCA has been carried out with the active variables, the first factors found will be used for classifying the sample of farms in homogeneous classes. This is done by means of a hierarchical cluster analysis. A cluster analysis allowed grouping the farms that were similar. Other classification techniques were used by researchers to study the different typologies of dairy farms, but the discriminate analysis may be used to validate this methodology (Riveiro-Valiño *et al*., 2009). The characteristics of each group in the active topic as well as the rest of the illustrative variables collected in the survey were then statistically described. The differences between the groups of farms obtained were contrasted with regards to the quantitative variables by a one-way ANOVA with Student-Newman-Keuls mean comparison and, with regards to the qualitative variables, by a Pearson chi-square test of contingency tables.

Results

Automatic milking system farms typology

Table 2 shows the results of the CATPCA. From the beginning we chose 4 dimensions: 43.7% of the total variance is accounted for by these 4 dimensions with eigenvalues greater than 3, a fairly high proportion for an analysis involving such a large number of variables. Cronbach's alpha for all of the dimensions is greater than 0.7, which means that the test for these samples of farms has a good reliability. A fifth dimension would have a Cronbach's alpha close to 0.7 which would decrease the reliability. The first dimension, or principal component, accounts for almost 14.8% of the total variance. With the 7 variables that are considered to contribute to this dimension, it can be referred to as the *amount of labour with AMS*. The second principal component accounts for 11.5% of the total variance with 4 contributing variables and can be referred to as the *implications of installation of AMS*. The 4 variables that can be regarded as associated with the third dimension helped in referring to it as

Table 2. Results of the categorical principal component analysis.

Dimension (combination of variables grouped)	1	2	3	4	Total
	(milking labour time before AMS; size of farm; milk quota; contracted FTE; cows that had to be fetched; my physical health has improved; number of robots installed)	(position of the AMS in the barn; area of corridors per cow; stalls per cow; checking of alarm lists and problems with AMS and computer)	(contracted agricultural labours out; my mental health has improved; any cows were removed due to AMS problems; education level of farmer)	(successor; I have more possibilities to spend time with my family; age of the farmer)	
Score dimensions	0.70; 0.68; 0.66; 0.66; 0.61; -0.58; 0.56	0.87; 0.85; 0.85; -0.56	0.80; -0.61; 0.61; -0.57	0.62; 0.58; 0.56	
Cronbach's alpha	0.869	0.824	0.782	0.739	0.971
Eigenvalues	6.66	5.15	4.25	3.61	19.67
Variance, %	14.81	11.45	9.44	8.01	43.70

AMS, automatic milking system; FTE, full time employee.

farmer's level of professionalism. Of the many variables that contribute to the fourth dimension, we only considered three and these variables suggest that this dimension may be appropriately referred to as *future of the farm*.

After the CATPCA, an aggregative hierarchical cluster was carried out from the farms in the sample on the basis of the four emerging dimensions, which allowed us to classify them into four classes or groups of farms. Figure 1 shows the dendrogram obtained from the farms studied. We considered it appropriate to make a cut at reference level 10 so that four classes were obtained, because with fewer groups it is easier to interpret. The four types of farms consisted of 11, 13, 8 and 4 dairy farms, and they were classified as type A, B, C, and D, respectively. However, this cut produces a loss of 2 farms, which we believe necessary to be able to separate the farms into well differentiated groups.

As a result, mean values of main qualitative and quantitative variables for each typology group of farms are showed in Tables 3, 4, 5, 6 and 7. The main active characteristics of all of the farms that allow more discrimination between groups ($P<0.05$) were: contracted FTE; I have more time for my family; any cows were removed due to AMS problems; milk quota; I have more time for hobbies; farm size; previous experience with computerized management systems; number of AMS installed; my mental health has improved; AMS maintenance, change teat cup liners, cleaning the robot. So with these variables, the 4 groups found, can be defined.

Type A: farmers with more leisure and better quality of life where the automatic milking system covered their expectations

This group corresponded to 11 AMS dairy farms (29%) with the smallest average herds (61.6 cows) (Table 3) and with 1 AMS/farm. These are dairy farms with an average owned area of 29.4 ha. As we can see the rented area did not show significant differences between groups but this fact may be interpreted as a difference if we consider the farm size in each group. So the area available per cow could indicate differences. On these farms grass crop (32.2 ha) is more common for silage than corn. All of the farms contracted out some agricultural labours to professionals, the preparation of the total mixed ration (TMR) being the labour least contracted out (9%). Around 46% of farms are general partnerships with no difference in total FTE compared with other groups but with 0.4 contracted FTE. The farmers in this group are young representing the overall average age. It is a group of farmers with the same percentage of primary, university and agricultural education levels (27%). A successor is not guaranteed in 45% of these farmers. All of these farmers have dairy farming as their main profession. These are the AMS users who agreed the most that their mental health had improved (64%). All of them considered that their physical health had improved and more than half of them said that their sleeping quality had not changed. All of these farmers agreed that they had more time for their family and more time for hobbies. Almost all the farmers (91%) had previous experience with computerized management systems and in the same percentage the AMS covered their expectations, and is almost significantly different to the other groups ($P=0.054$).

Type B: farms that removed cows more often due to automatic milking system and farmers with more stress

Thirteen farms (34%) formed this AMS group with a herd size of 71.5 cows. They are the group that contracted out the most agricultural TMR labour (62%), as well as the total agricultural labours. More than half the farm-

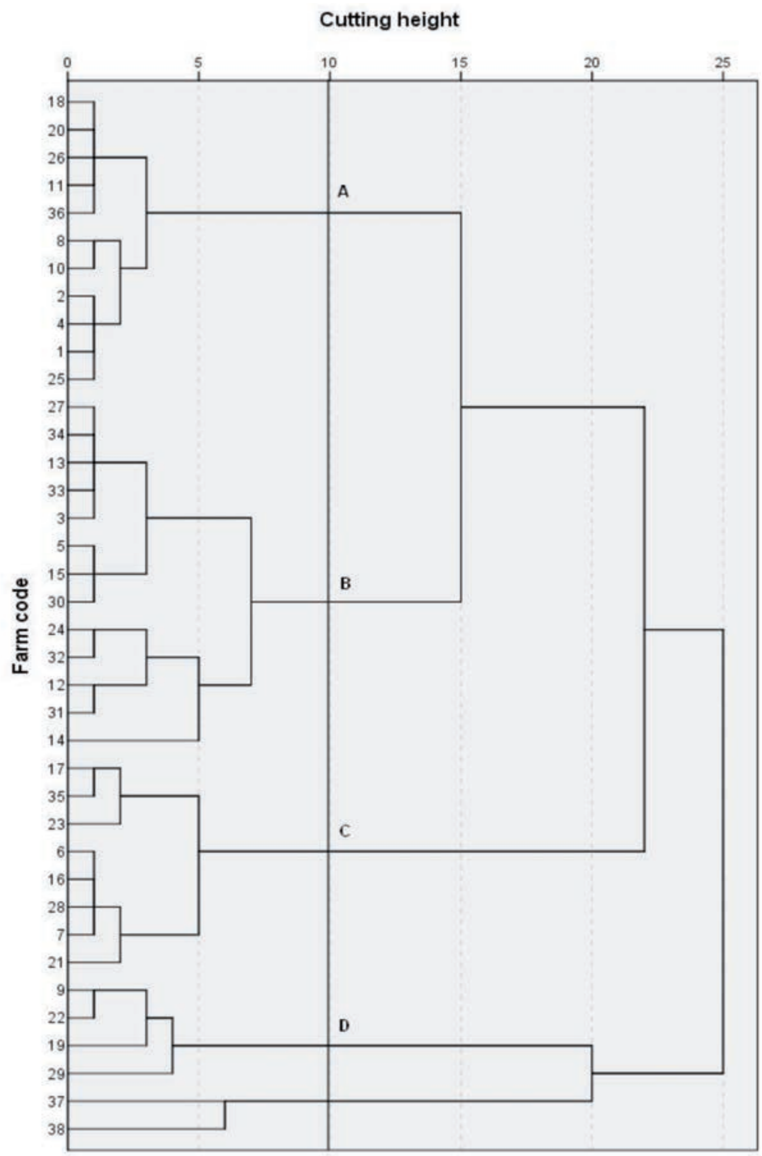

Figure 1. Dendrogram for 38 farms with automatic milking system showing the results of hierarchical clustering and the four classes (A, B, C and D).

Table 3. Structure and characteristics of farmers for each group of dairy farms with automatic milking system obtained in the cluster analysis.

Variables	Overall (n=11)	Type A (n=13)	Type B (n=8)	Type C (n=4)	Type D	P
Characteristics of farms						
Farm size, cows	75.4	61.6[b]	71.5[b]	72.9[b]	140.0[a]	0.005
Type of enterprise, %						0.246
Family farm	31.6	36.4	15.4	50.0	25.0	
Cooperative	5.3	9.1	7.7	0.0	0.0	
Agricultural transformation society	28.9	9.1	46.2	25.0	25.0	
General partnership	31.6	45.5	30.8	25.0	25.0	
Limited liability company	2.6	0.0	0.0	0.0	25.0	
Own area, ha	34.9	29.4[b]	34.3[b]	27.0[b]	72.8[a]	0.021
Rent area, ha	11.0	12.8	10.3	13.0	7.3	0.729
Corn area, ha	25.3	17.9[b]	24.7[b]	22.9[b]	56.0[a]	0.011
Grass area, ha	25.4	32.2	22.0	24.1	23.0	0.431
Others forages area, ha	3.4	0.0[b]	4.2[b]	1.5[b]	16.3[a]	0.029
Forages bought, kg	62,579	45,272	50,846	66,125	172,500	0.309
Milk quota, kg	720,847	588,363[b]	651,815[b]	713,125[b]	1,481,250[a]	0.001
Milk quota is enough, %	55.3	36.4	53.8	37.5	75.0	0.514
Contracted agricultural labours out to professionals, %						
Nothing	2.6	0.0	0.0	0.0	25.0	0.042
Harvesting silage	94.7	100	92.3	100	75.0	0.250
Tilling the land	55.3	72.2	46.2	37.5	50.0	0.432
Slurry	21.1	18.2	38.5	12.5	0.0	0.300
TMR	36.8	9.1	61.5	50.0	0.0	0.018
Others	10.5	0.0	23.1	12.5	0.0	0.287
Total FTE, n	2.8	2.7	2.9	2.5	3.4	0.441
Contracted FTE, n	0.6	0.4[b]	0.4[b]	0.4[b]	2.8[a]	0.000
Tractors per farm, n	2.5	2.6	2.4	2.6	2.8	0.853
Other machinery, n	5.6	5.4	4.9	6.9	6.8	0.208
Characteristics of farmers						
Sex farmer owner interviewed, %						0.298
Man	89.5	100	84.6	75.0	100	
Woman	10.5	0.0	15.4	25.0	0.0	
Age of farmers, years	38.9	36.5[ab]	33.8[ab]	46.1[b]	28.8[b]	0.044
Education level, %						0.028
Primary school	36.8	27.3	23.1	75.0	25.0	
Secondary school	13.2	18.2	15.4	12.5	0.0	
Agricultural education	31.6	27.3	53.8	12.5	0.0	
University	18.4	27.3	7.7	0.0	75.0	
Contracted farm services, %						
Reproduction	81.6	81.8	76.9	87.5	100	0.728
Milk quality	60.5	72.7	53.8	50.0	75.0	0.647
Feeding	92.1	90.9	92.3	100	100	0.782
Others	18.4	9.1	23.1	12.5	25.0	0.768
Successor, %	44.7	54.5	61.5	0.0	50.0	0.038
Labour in co-operation in the farm, %						0.201
Wife or husband	18.4	27.3	7.7	37.5	0.0	
Single person	5.3	0.0	0.0	12.5	0.0	
Person employed	39.5	36.4	30.8	37.5	100	
With child, laws or parents	28.9	27.3	46.2	12.5	0.0	
Partner	7.9	9.1	15.4	0.0	0.0	
Dairy farming is the main profession, %	97.4	100	100	100	75.0	0.042
Nature of other enterprises, %						
Products made of milk	5.3	0.0	0.0	0.0	50.0	0.001
Vegetables, forages, grains and fruit	7.9	9.1	0.0	12.5	25.0	0.419
Other livestock	10.5	9.1	15.4	12.5	0.0	0.849
Contract work for others farmers	5.3	0.0	15.4	0.0	0.0	0.290
Veterinary and advisory services	5.3	9.1	0.0	0.0	25.0	0.223
Other enterprises	13.2	9.1	15.4	12.5	25.0	0.882
Statements of farmers						
It is important to have new technologies at an early stage in the farm, %	76.3	63.6	84.6	87.5	50.0	0.334
It is important to have some free time and to go on holiday every year, %	94.7	100	100	100	75.0	0.042
It is important what other farmers think of me, %	10.5	18.2	0.0	25.0	0.0	0.236

TMR, total mixed ration; FTE, full time employee. [a,b]Different letters in the same row denote significant ($P \leq 0.05$) differences among means.

ers in this group (54%) have agricultural training and it was this group that resorted the least to contracting an economic management service for their farms before and after of the installation (8%). 77% of them had to remove some cows due to problems associated with the AMS. This can influence the fact that these farmers are who least agreed that their mental health had improved (8%). Also these farms are a minority regarding the fact that their sleeping quality had not changed (15%). However, they are the group whose succession is the most guaranteed (62%). All of them believe that the AMS is the future and a challenge for their farms and for this reason they adopted this machine. They were the farms that spent the most time on milking with AMS, including the time spent on fetching the cows to be milked (72 min/day).

Type C: farmers with little leisure and without successor

This group consisted of eight farms (21%) with a herd size similar to group *type B* (72.9 cows). Half of them are family farms. Only 13% of these farmers have more time for their families and for hobbies. They are the group of farmers with the lowest level of education with 75% of them having studied primary education. None of these farmers has a successor and they are also the group with the highest average age (46.1 years). They felt that they did not have more time for their family and hobbies (87%). Also, 13% of them had to remove cows with problems when they installed the AMS. Furthermore, the AMS covered the expectations of about 50% of the farmers. Only a quarter of the farmers had previous experience with computerized management systems. They were the farmers that spent the least time on AMS maintenance, *e.g.*, changing teat cup liners or cleaning the milking robot (7.5 min/day). Moreover, the time spent on fetching cows was about 75 min per day.

Type D: large farms with many contracted full-time employees and where the automatic milking system covered the expectations of the farmers the least

This group includes 11% of farms and is composed of large farms with a herd size of 140 cows. This size can influence other characteristics such as milk quota (1,481,250 kg), number of AMS installed (2), area of corn crop (56 ha). They are farms that had more contracted FTE (2.8). In 25% of these dairy farms, dairy farming is not the main profession. Also 50% of them make other dairy products. These are farms that contracted out the least amount of agricultural services, for example none of these farms contracted out the preparation of the TMR. They are the group of farmers with the highest level of education (75% of them have a university education). Despite being large dairy farms, only 50% of these farms are sure to have a successor, maybe because they are the youngest farmers (28.8 years), them being the actual successor. In contrast to other groups ($P<0.05$) 25% of these farms do not believe that it is important to have some free time and to go on holiday each year and also, the AMS only covered the expectations of a quarter of them.

Once categorized by typology, the farms being studied were described based on different sections.

Table 4. Reasons to install an automatic milking system for each group of dairy farms obtained in the cluster analysis.

Variables	Overall	Type A (n=11)	Type B (n=13)	Type C (n=8)	Type D (n=4)	P
Reasons for installing an AMS						
Already knew some farmer with AMS, or personal contact with an AMS farmer, %	57.9	63.6	53.8	50.0	50.0	0.928
Farmer considered buying a milking parlour before by an AMS, %	36.8	54.5	38.5	12.5	50.0	0.297
As the first option, why have you installed an AMS?, %						0.734
It's a saver labour	2.6	0.0	0.0	12.5	0.0	
To expand the farm	2.6	9.1	0.0	0.0	0.0	
To increase milk production	57.9	63.6	46.2	62.5	50.0	
To reduce production costs	5.3	0.0	7.7	12.5	0.0	
For the future	2.6	0.0	7.7	0.0	0.0	
Other	28.9	27.3	38.5	12.5	50.0	
Reason to adopt an AMS, %						
Labour reduction	81.6	63.6	92.3	87.5	100	0.193
Labour flexibility	92.1	90.9	92.3	100	75.0	0.533
Get rid of hired labour	28.9	27.3	15.4	12.5	75.0	0.083
Improving technical parameters	65.8	54.5	84.6	50.0	75.0	0.291
It's a future challenge	78.9	81.8	100	50.0	75.0	0.046
Other activities	78.9	72.7	92.3	75.0	75.0	0.612
AMS adopted						
Number of robots installed	1.3	1^{b}	1.3^{b}	1.3^{b}	2.1^{a}	0.010
Why have you installed this brad of AMS?, %						
Finance	5.3	0.0	7.7	12.5	0.0	0.630
Operation washing, techniques arm	55.3	63.6	53.8	62.5	25.0	0.578
Good and bad publicity of other brands	7.9	18.2	0.0	0.0	25.0	0.190
After sales service technical assistance	31.6	27.3	38.5	25.0	50.0	0.781
Considered as the best brand	36.8	27.3	30.8	50.0	50.0	0.674
Other	15.8	9.1	23.1	12.5	25.0	0.768

AMS, automatic milking system. [a,b]Different letters in the same row denote significant ($P\leq0.05$) differences among means.

Structure of dairy farms with automatic milking system: characteristics of farmers

The average herd size for these farms was 75.4 cows (Table 3). Today the farms are enterprises and, as such, they have different mercantile structures. Basically, they can be categorized as family farms (32%), general partnerships (32%) and agrarian transformation societies (29%). The farm area amounts to 45.9 ha, 11.0 of which is rented land. Most farms grow corn for silage (25.3 ha/farm) as well as grass (25.4 ha/farm) or other winter forage. The forage cultivated was not sufficient in the farms as the forage bought exceeded 62 tonnes per farm and year. A large proportion of the farms with AMS had a milk quota of between 500,000 and 700,000 kg, and the group with a quota of more than 1,000,000 kg is also an important one. Less than half of the farmers consider that their milk quota is not sufficient.

They contract many labours out to professionals, such as the harvesting of silage

Table 5. Implications of automatic milking system for each group of dairy farms obtained in the cluster analysis.

Variables	Overall	Type A (n=11)	Type B (n=13)	Type C (n=8)	Type D (n=4)	P
Implications of AMS in barn						
Did you make any change in the barn to install the AMS?, %						0.400
New barn	15.8	0.0	0.0	12.5	0.0	
Nothing	2.6	72.7	76.9	37.5	75.0	
A lot	13.2	9.1	7.7	37.5	0.0	
A few	68.4	18.2	15.4	12.5	25.0	
The internal distribution of the barn was changed	5.3	0.0	7.7	12.5	0.0	0.630
Position of the AMS in the barn°, %						0.290
POU	44.7	63.6	46.2	37.5	25.0	
PIC	10.5	0.0	15.4	12.5	25.0	
POC	2.6	0.0	7.7	0.0	0.0	
PIU	10.5	9.1	7.7	25.0	0.0	
LIU	2.6	0.0	7.7	0.0	0.0	
LOC	5.3	27.3	7.7	0.0	25.0	
LOU	15.8	0.0	7.7	25.0	0.0	
Unknown	7.9	0.0	0.0	0.0	25.0	
Area of corridors, m^2/cow	5.4	5.4	5.5	5.6	3.8	0.360
Stalls per cow	1.1	1.1	1.1	1.1	0.8	0.281
Implications of AMS in strategies before and after adoption of the AMS						
Grazing before, %	18.4	27.3	15.4	12.5	25.0	0.827
Grazing after, %	0.0	0.0	0.0	0.0	0.0	
TMR before, %	92.1	90.9	92.3	87.5	100	0.905
TMR after, %	97.4	100	92.3	100	100	0.611
Free barn before, %	94.7	90.9	100	87.5	100	0.573
Free barn after, %	100.0	100	100	100	100	
Milking labour time before, h	4.0	3.8	3.9	4.1	5.3	0.110
Milking labour time after, h	2.1	1.6	2.7	1.8	2.8	0.134
Start milking labour on the morning before, a.m.	7.6	8.1	7.3	7.5	7.3	0.429
Start milking labour on the morning after, a.m.	8.5	8.5	8.4	8.4	8.1	0.901
Start milking labour on the afternoon before, p.m.	21.5	21.9	21.3	21.5	21.9	0.493
Start milking labour on the afternoon after, p.m.	20.8	21.0	20.4	20.8	21.3	0.238
Size herd before	71.2	58.6^{b}	68.4^{b}	68.5^{b}	127.5^{a}	0.005
Economic management before, %	36.8	45.5	7.7	50.0	75.0	0.041
Economic management after, %	36.8	36.4	15.4	50.0	75.0	0.126
Milking parlour before, %	92.1	90.9	100	87.5	100	0.573
Milking parlour after, %	26.3	27.3	23.1	25.0	50.0	0.763
Implications of AMS on health						
My physical health has improved, %	81.6	100	84.6	62.5	50.0	0.077
My mental health has improved, %	34.2	63.6	7.7	12.5	50.0	0.013
My sleeping quality has improved, %	39.5	63.6	15.4	25.0	50.0	0.079
Implications of AMS on leisure and quality of life						
I have more time for my family, %	68.4	100	84.6	12.5	25.0	0.000
I have more time for hobbies, %	63.2	100	69.2	12.5	25.0	0.001
The quality of life of our family has improved, %	71.1	81.8	76.9	62.5	25.0	0.169

AMS, automatic milking system. °Locations of AMS in the barn: P *vs.* L, orientation of AMS longitudinal axis perpendicular (P) or longitudinal (L) to the longitudinal axis of the barn or hallways; I *vs.* O, farmer access to the AMS located inside (I) or outside (O) of the cubicle area; C *vs.* U, centered (C) position, with barn surface area almost equally available to both sides, or uneven (U) position, with less or no available barn surface area to one side. [a,b]Different letters in the same row denote significant ($P \leq 0.05$) differences among means.

(95%), tilling the land (55%) or preparing TMR on 37% of farms. Work on the farm was carried out by 2.8 full time employees (FTE). Total FTE can be divided into family members and contracted labourers. In our study the contracted FTE per farm was 0.6. Only 11% of the interviewed farmers, whom we considered to be the farm managers, were women. The average age of these farmers is 38.9 years. Most farmers (37%) had primary education, agricultural specific training (AT) was completed by 32%, and a group of 18% had university degrees.

A dairy farm usually contracts out various important services for the correct performance of the farm, carried out by professionals such as agricultural engineers or veterinarians, feeding services (92% of farms), reproduction services (82%) or such as milk quality in 61% of farms. Most of the farmers performed the normal farm labours helped by employed personnel (40%), by parents, in-laws or children (29%), or by their wives or husbands (18%). The succession is certain in less than half of the farmers (45%). For almost all the farmers (97%) dairy farming is their main activity, however, 37% of the farmers had other businesses of a very diverse nature. They seek to diversify with other productions in order to support the dairy farming activity. The main activity was producing other livestock (10.5%).

The farmers were asked about statements on new technologies, free time and what other farmers think of them, and we wanted to know their opinions about these. About 76% of farmers agreed with the statement *it is important to have new technologies at an early stage on the farm*. Almost all of them (95%) agreed with the statement *it is important to have some free time and go away on holiday every year*. However, 11% of the interviewed farmers said they were sensitive to what others thought of them.

Reasons for installing an automatic milking system

In general, 58% of the farmers already knew another farmer with an AMS, or had personal contact with one before installing the AMS (Table 4). Of the farmers that bought an AMS, just over one third (37%) had considered buying a new milking parlor. The farmers were asked about their main motivation for investing in an AMS. They had to choose the answer that they considered to be the most important from a number of open answers. More than half (58%) of these farmers sought, by installing the AMS, to *increase milk production*. In order to know in more detail and more specifically their reasons for adopting an AMS, the farmers had to indicate their particular reasons from a closed list of options. A farmer could choose one or several answers, the result being the percentage of farmers that chose each option. The listed reasons were: labour reduction, labour flexibility, dismissing labour, improving technical parameters, facing the future, challenge, and other activities. Most farmers (92%) chose labour flexibility and

Table 6. Adaptation of farmers and cows for each group of dairy farms with automatic milking system obtained in the cluster analysis.

Variables	Overall	Type A (n=11)	Type B (n=13)	Type C (n=8)	Type D (n=4)	P
Adaptation of cows						
Selected traffic, %						0.476
Free	86.8	90.9	69.2	100	100	
Forced	10.5	9.1	23.1	0.0	0.0	
Guided	2.6	0.0	7.7	0.0	0.0	
Time until adaptation of the cows to AMS milking, when cows were milked voluntarily, days	188.4	183.3	177.0	251.6	188.8	0.854
Any cows were removed due to AMS problems, %	31.6	0.0	76.9	12.5	0.0	0.000
Adaptation of farmers						
The AMS covered farmer's expectations, %	57.9	90.9	46.2	50.0	25.0	0.054
Previous experience with computerized management systems, %	47.4	90.9	30.8	25.0	25.0	0.007
It was easy to understand the AMS software, %	89.5	90.9	92.3	75.0	100	0.520
Farmer was satisfied with data of AMS software, %	73.7	72.7	92.3	50.0	50.0	0.135

AMS, automatic milking system.

Table 7. Labours for each group of dairy farms with automatic milking system obtained in the cluster analysis.

Variables	Overall	Type A (n=11)	Type B (n=13)	Type C (n=8)	Type D (n=4)	P
Hours worked in AMS						
Checking of alarm lists and problems with AMS and computer, min/d	10.5	4.4	8.4	16.3	8.0	0.275
Cows had to be fetched, min/day	69.1	45.0	72.3	75.0	127.5	0.064
AMS maintenance, changed teat cup liners, cleaning the robot, *etc*., min/d	15.8	10.0[b]	18.9[b]	7.5[b]	39.3[a]	0.012
Checking results of information, data cows, to make reports, *etc*., min/d	25.7	28.6	31.9	15.6	21.3	0.387
Other labours, min/d	1.2	0.0	2.7	0.0	0.0	0.518
Other implications of AMS						
Changes in genetic selection, %						0.507
None	78.9	72.7	84.6	87.5	75.0	
Udders	15.8	9.1	15.4	12.5	25.0	
Milking speed	5.3	18.2	0.0	0.0	0.0	
Contracted secure, %	86.8	100	69.2	87.5	100	0.137
Contracted maintenance service, %	26.3	9.1	30.8	25.0	25.0	0.637
Periodically review, %	65.8	45.5	69.2	75.0	100	0.211

AMS, automatic milking system. [a,b]Different letters in the same row denote significant ($P \leq 0.05$) differences among means.

labour reduction (82%) for adopting an AMS.

In the international market there were different AMS industries, the reasons for installing one or another brand of AMS were many and diverse. Thus more than half of the farmers (55%) opted for one particular AMS brand based on *operational reasons, teat washing techniques and the robot arm*. Second most relevant reason (37%) was *consider it to be the best brand* followed closely by *after sales service and technical assistance* in 32% of farmers.

Implications of the automatic milking system on the strategies of the dairy farm

In fact, more than two thirds of farmers (68%) made only a few changes in the barn in order to install the AMS. Only 5% of the farmers modified the inner layout of the barn (Table 5) and there were some farmers who built a new barn (16%). Regardless of whether a new barn is built or an existing one is adapted, installation of the AMS may occupy different positions within the barn. Thus, the positioning of the AMS was based on the combination of three different aspects according to its accessibility by both the farmers and the cows, its final location defined by the way these aspects are combined (Figure 2). The results showed that the majority of new barns adopted a perpendicular position of the AMS to the longitudinal axis of the barn or hallways, located in an area outside the cubicles. We used two variables to define barn space based on two areas; transit area (m^2 hall/cow) and settling area (cubicles/cow). All farms had an average of 1.1 cubicles per cow. We observed that the number of cubicles per cow was higher in new barns than in existing barns (1.4 *vs* 1 cubicles/cow). The average surface area of hallway per cow was 5.4 m^2, also greater in new barns than in existing barns (6.7 *vs* 5.1 m^2/cow, respectively).

Only 18% of the farmers employed grazing before the adoption of AMS, and afterwards none of the farmers did; however, almost all farmers (97%) offered TMR to their cows. Few farms did not employ loose housing before adopting AMS (5%), but they found it necessary to build a new barn in order to install an AMS. In general, the changes in herd size were minor, averaging an increase of 4.2 cows after AMS adoption. After the introduction of the AMS, some farmers still did some of the milking in the old parlor (26%). The farmers estimated that the milking task required on average 4 h per day before installing the AMS, and afterwards just 2.1 h per day. Furthermore, the farmers consider that now with the AMS they go to the barn in the morning later than before (almost 1 h. later), and that in the evening they finish earlier (more than 0.5 h. earlier). Most of them agreed with the statement that their physical health had improved (82%) and that they are now able to spend more time with their families since the installation of the AMS (68%). Almost three quarters of the farmers said that the life quality of their families had improved. However the mental health and sleep quality only improved in 34 and 40% of them respectively.

Adaptation of farmers and cows

Nearly 58% of farmers were completely satisfied with their AMS (Table 6), although this percentage almost reaches 91% in type A farms, however only 25% of type D farms were satisfied with their AMS. Furthermore, milking with AMS implies working with computerized

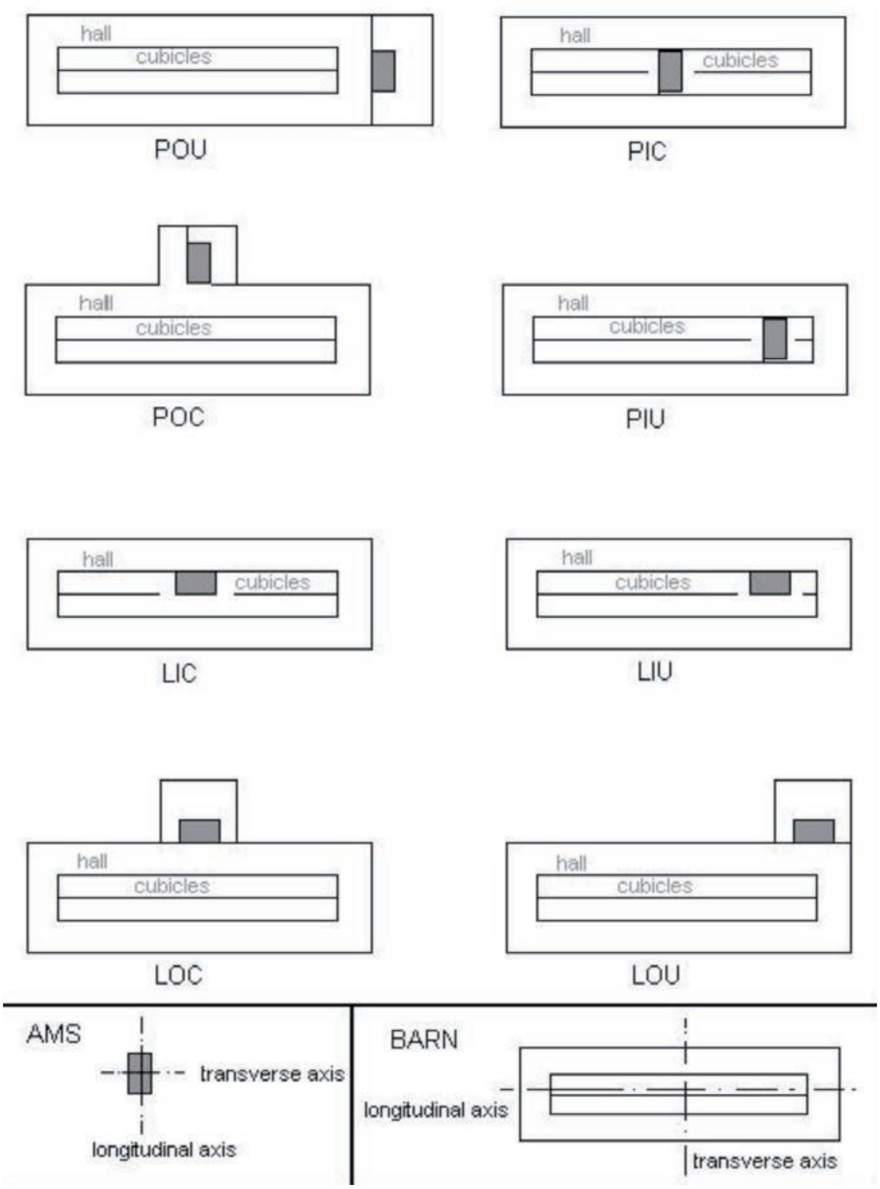

Figure 2. Different positions of automatic milking system (AMS) in the barn. P *vs.* L, orientation of AMS longitudinal axis perpendicular (P) or longitudinal (L) to the longitudinal axis of the barn or hallways; I *vs.* O, farmer access to the AMS located inside (I) or outside (O) of the cubicle area; C *vs.* U, centered (C) position, with barn surface area almost equally available to both sides, or uneven (U) position, with less or no available barn surface area to one side.

management systems and although only half of the farmers had worked with these systems before, many of them (90%) found the AMS software easy to work with. 74% of the farmers also said that they were satisfied with the data offered by the AMS software.

The AMS also has an effect on the welfare of the cows. 32% of the farmers had removed some cows due to morphological problems or mastitis related to installing the AMS. Free traffic was the method most widely used by these farmers (87%). According to the farmers, the adaptation of the cows to the AMS took on average 188.4 days (when cows were milked voluntarily).

Automatic milking system labour

The farmers said that morning milking, afternoon milking and parlor maintenance, took on average just over 4 h per day (Table 7). With AMS we asked about specific activities involving milking with this machine. The activity that took the most time for farmers was fetching cows for milking (1h/day approximately) (Table 7). The second task was checking information, cow data, and writing reports (25.7 min/d.). Most of the farmers (79%) had not changed their selection criteria regarding their cows' genetic parameters. Those who had changed it, tried to achieve an improvement regarding udders (16% overall) and milking speed in those farms (type A, 18%) with their AMS almost at full capacity. Nearly a quarter of the farmers had not contracted a maintenance service with their dealer, and there were many (66%) who periodically did the maintenance reviews themselves. Also, many of the farmers (87%) had contracted an insurance policy for their facility.

Discussion

The characterization of dairy farms is complex because of the large number of variables required to define them. Furthermore, if we consider the implications of a new milk machine like an AMS, this can complicate things more and if we include criteria based on farmer satisfaction, this gets even worse. Riveiro *et al*. (2009) described three types representative of Galician dairy farms using other grouping methodologies but no other previous research was found about classification of dairy farms with AMS. The average farm size in this study is greater than the average dairy farm size in Galicia (25 cows/farm) (IGE, 2010), and also greater than the average dairy farm in Spain (30 cows/farm) (INE, 2009), but smaller than in Dutch farms with AMS (87 cows/farm; Hogeveen *et al*., 2004). The farm area amounts to 45.9 ha and the forage cultivated seems not to be sufficient. Certainly this is a more intensive production model than in Dutch farms, where pasture surface was 80% of the total, as reported by different researchers (Hogeveen *et al*., 2004; Steeneveld *et al*., 2012). The average milk quota of the dairy farms with AMS in Galicia is comparable to that reported by Hogeveen *et al*. in 2004 for Dutch dairy farms with AMS (720,847 *vs* 752,000) but is much lower than that found in a more recent study carried out in The Netherlands by Steeneveld *et al*. in 2012 (897,426 kg). Dairy farmers are becoming more and more specialized in livestock and less so in growing crops. They contract many agricultural labours out to professionals and this will improve milk yield (kg/h). Total work, expressed as FTE, was higher on these farms with AMS than dairy farms in the Netherlands also with AMS and even compared with farms with conventional milking systems (Bijl *et al*., 2007). Succession is guaranteed for more farmers than in the case of German farmers with AMS (30%; Mathijs, 2004). However, this statement depends on the type of farm. For example, type C farms where we observed that the introduction of the AMS did not prove to be quite as successful in terms of leisure because farmers did not have more time for hobbies and their family, are not sure to have a successor. On the other hand, there are farms (type B) which have a guaranteed succession even though their owners confess to being under a certain amount of stress. The succession issue is important and has strong roots in the farmers' mental health, particularly when we are talking about family farms. Sometimes the presence of a successor or not simply depends on that successor having made a definite decision and being able to take early actions on the farm (Macra na Feirme, 2013). One of these actions could be to adopt an AMS. The farmers seek to diversify with other productions in order to support the dairy farming activity, but we do not know to what extent the introduction of AMS helped maintain these activities. The farmers were asked about the same statements as in a previous study about AMS farmers in Europe (Mathijs, 2004). So more of these farmers than the Danish (64%) and German farmers (66%) (Mathijs, 2004) agreed with the statement *it is important to have new technologies at an early stage on the farm*. Perhaps the reason behind this situation is because the Galician farmer has less technology in his farm. Also almost all of them agreed with the statement *it is important to have some free time and go away on holiday every year*. Farmers with large herds and many contracted FTE agree the least with this statement as well as northern European farmers (Mathijs, 2004).

The farmers were asked about their main motivation to invest in an AMS. They had to choose the answer that they considered to be the most important from a number of open answers. More than half of these farmers sought, by installing the AMS, to *increase milk production*. Hogeveen *et al*. (2004) found the higher milk production as a motivation for investing in an AMS for 6 to 11% of the farmers, in research that included farmers in the Netherlands. But when a farmer could choose one or several answers their reasons for adopting an AMS can change the results. Overall, most farmers choose labour flexibility and labour reduction for adopting an AMS as the most important reasons. Mathijs (2004) gives similar results, but differs in their third most important reason, *get rid of hired labour*, which in our study it was the *challenge, future*.

Adoption of AMS can change many aspects in a dairy farm, like the barn, management strategies, feeding, and health of farmer and cows. In principle, almost any free stall barn can be adapted to robotic milking, particularly if it chooses free cow traffic (Rodenburg, 2002). However, of the Dutch farmers who had invested in a new milk parlor, 6% was because their old barns were not very suitable for an AMS (Hogeveen *et al*., 2004). We observed that 16% of the farmers built a new barn when they installed the robot. Of the Dutch farmers who had invested in an AMS, 4% was because they needed to build a new barn (Hogeveen *et al*., 2004). There is a wide flexibility in design when a new barn is built to install an AMS (Rodenburg and House, 2007) but the optimizing facility allocation must be based on cow behavior, welfare needs and facility utilization (Halachmi *et al*., 2003). One indicator related with cow welfare is the number of cubicles per cow. At least one cubicle per cow is recommended (Fregonesi and Leaver, 2002). In our opinion this statement should be emphasized in the case of robotic milking systems, because the milking area is included within the barn. So the result reported in this study (1.1 cubicle per cow) is good.

If we focus on the actual milking, the labour tasks and times for conventional and AMS milking are different (Cooper and Parsons, 1999). For AMS milking, labour tasks and other related activities are different from the routines carried out in a standard parlor system. The farmers said that milking in parlor and maintenance, took on average just over 4 h per day. Under these assumptions, our result can be compared with other research: Cooper and Parsons (1999) reported a value of 4 h/day and Dijkhuizen *et al.*, (1997) assumed milking 125 cows took 3.8 h/day. After the introduction of the AMS, some farmers still did some of the milking in the old parlor, either because the herd size exceeded the capacity of the AMS or because some farmers considered it necessary to milk the cows that were infected or that did not conform away from the AMS. The latter coincides with data shown by Artmann (2002). As already pointed out in the previous section of results, a reduction in milking labour of 50% was observed (almost 2 h/day). This result is similar to that reported by Veysset *et al*. (2001), but the total milking time with AMS is higher than Dijkhuizen *et al*. (1997). Many surveys already pointed to a reduction in labour after investing in an AMS (19.8%; Mathijs, 2004; 29%; Bijl *et al.,* 2007). As long as there is a large increase in the value of milking labour, the reduction of milking labour is where we can improve the net return of automatic milking systems relative to traditional milking (Rotz *et al*., 2003). What the farmers do with the labour saved was difficult to assess. Some of the farmers used this extra time to expand their farm by increasing the herd size (Mathijs, 2004), but in this case the changes in herd size was not significant. Furthermore, an aspect not covered by other studies is that there was a substantial improvement in quality of life for these farmers because they can go to the barn in the morning later than before and in the evening they finish earlier. Milking with AMS means a change from the traditional concept of milking; that is, the process by which the people intervene directly. The farmers need to adapt to this change. More than half of farmers were completely satisfied with their AMS, although this percentage almost reaches the total of farms with smaller herds than other groups and farmers having more time for hobbies and their family (type A). However, there are other farms where the AMS has covered the least expectations, characterized by large herd sizes, with at least two AMS and more use of contracted FTE for work on the farm than other farms in the study. This indicated that the problems were associated with the number of AMS installed. Also when a farm has external workers these don't work as hard as family members. Family members can often work for more than 1 standard FTE (Bijl *et al.,* 2007).

The welfare of dairy cows depends on many factors, such as their social interaction with other cows in the herd and with the farmer, feeding system, barn design, climatic conditions or cow traffic. We considered that with a third of farms that removed some cows due to problems related to installing the AMS is not bad, especially considering that 16% of milkings with AMS can be deficient and 55% of these are often caused by cows (Kaihilahti *et al*., 2007), so many farmers would seek to eliminate cows with some problems. However, one group of farms (type B) differs from the rest, in that the majority of the type B farms (3/4) had removed cows due to AMS problems coinciding with farmers not agreeing that their mental health had improved. Besides, it is the largest group in terms of number of farms. According to the farmers, the adaptation of the cows to the AMS took on average 188.4 days. This mean data shows an adaptation smaller than that reported by Jacobs and Siegford (2012) where 95% of cows were milking voluntarily within a month. This indicated that the transition protocol used may not be that which is recommended by manufacturers of AMS. The cows' stress could be due to the cows becoming uncomfortable with the milking stall, barn environment, and robotic milking equipment or process.

In general three types of cow traffic systems have been developed in AMS: forced traffic, free traffic and controlled or guided traffic. Free traffic was the most widely used by these farmers. Free cow traffic gives the most freedom to the cows but many have to be fetched (Wiktorsson and Sorensen, 2004). So in these farms studied, the highest percentage of labour used corresponds to fetching cows, spending twice as long shown by Donkers (2010; 30 min/day). Although the results showed no association between fetching and satisfaction of farmers, fetching may strain the human-animal relationship (Rousing *et al*., 2006). The reasons for involuntary milking can be new or recent training, udder conformation, clinical mastitis, clinical lameness or cows described as lazy (Rodenburg and Wheeler, 2002). Also it was shown that, in terms of workload, the number of cows milked on the AMS is very important. Thus German farmers like to have a lower burden on their AMS, which means higher system costs, but reduces the number of working hours and improves the behavior of the animals (Artmann, 2002). As discussed above, these farmers spend much time fetching cows because most of them use free traffic. Bach *et al*. (2009) observed that forced traffic can be an effective method to increase the daily number of voluntary milkings compared with free traffic, and therefore reduces labour, but is not likely to improve milk production. But another study (Munksgaard *et al*., 2011) showed that the average number of visits to the robot, either with or without milking, did not differ between the two types of traffic. Furthermore, the palatability of the concentrates offered in the AMS will significantly influence the number of cows that have to be fetched (Madsen *et al*., 2010). Although most of these farms has not changed the criteria of genetic selection, the genetic improvement can contribute to better udder health, mobility of cows, milking efficiency (Gäde *et al*., 2006) or decrease the labour in fetching (Nixon *et al*., 2009). Overall, the second task was checking information, data of cows, and writing reports (25.7 min/d.). Type B and D farms, with medium and large herds respectively, showed the highest milking labour levels. Also in type D farms, the reason behind this situation is the size of the herds and consequently the highest percentage of labour is used in fetching cows and AMS maintenance. In contrast, the high milking labour time reported for type B is not caused by the effect of herd size because other types (C) with similar scales spent the same time fetching cows. Now the main reason is that the farmer spends more time checking results of information, cow data and making reports. They are farmers that contract out more agricultural labours, investing the extra time in management of the farm.

Conclusions

Although the group of farms which adopted AMS was small and despite their apparent homogeneity, we found that dairy farms with AMS are varied as regards to many of the features considered in this study. Based on the results, we identified 4 dairy farm types. Farms with the best results in terms of quality of life and leisure (improving mental health and more time for family and hobbies) seem to be those with 1 AMS and an adequate number of animals adjusted to optimize the use of AMS (61.6), and they are managed by farmers with previous experience in computerized herd management. For these farmers, AMS has fully covered their expectations (90.9%). In farms such as those of type B, in which many cows are removed due to AMS problems and a lot of time each day is spent fetching the cows (in these farms it should be interesting assess the cow factors and housing factors), farmers seem to be more stressed out. Only 7.7% of these farmers highlighted an improvement in their mental health after AMS installation. Farmers with little or no experience in computerized herd management seem to have a lower degree of satisfaction with AMS (farm types B, C, and D). Furthermore, AMS meets less expectations in farms with large herds and with high amounts of contracted out labour. Farmers with lower leisure and education levels show poorer expectations of succession; however, succession is not affected in farms which remove cows more often although this increases the stress level. It is impossible to generalize these results for other regions. Still, we believe that these results are relevant because they measure the non-financial costs and benefits of AMS adoption.

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