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ORAL PRESENTATION

Comparison among actual and estimated milk yields in dairy goats

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Abstract

In dairy goats milk production can be affected by remarkable daily variations in consequence of the incidence of environmental, seasonal and sanitary factors. Usually during lactation animals milk yields are estimated through monthly functional tests operated by the National Breeders Association using specific calculation algorithms. Main limit of this procedure is that lactation milk yields are estimated through few data. Therefore, despite the introduction of special correction factors, milk productions can be over- or underestimated inducing evaluation errors in flock management.

At the experimental farm of the University of Milan 24 Saanen dairy goats (lactation: 1-3; DIM: 10 ± 5) were milked between February and October 2007, and individual milk yields were recorded at each a.m. and p.m. milking session by electronic milk meters (AfiFree™ S.A.E. AFIKIM) and a flock management software (Afigoats™ S.A.E. AFIKIM). Daily milk yields were used to calculate actual milk yields at 100, 210 and 227 days in milking (end of experimentation).

Moreover, for the same group of animals and for the same lactation stages milk yields were estimated following the procedures provided for dairy goats by the regulations of functional controls operated by the National Breeders Association (ICAR AT4 protocol and Fleischmann estimation method).

A comparison among real and estimated milk yields was carried out.

Estimated milk yields showed an underestimation at 100 DIM (-3%) and an overestimation respectively at 210 and 227 DIM (+5% and +2%) in comparison with actual milk yields

Measuring actual animals milk yields through electronic milk meters instead of estimating them through calculation algorithms enable breeders to improve flock management (instantaneous sensing of animals milk yields, proper feed plans formulation, grouping animals on real production levels during milk sessions).

Keywords: milk meter, milk yield, lactation curve, dairy goat.

Introduction

In dairy goats milk production can be affected by remarkable daily variations in consequence of the incidence of environmental, seasonal and sanitary factors. On equal terms, however, milk production can be described by a lactation curve with a quite regular profile.

Usually during lactation milk yields are estimated through functional tests performed monthly by field officers of the National Breeders Association. Many official milk recording methods (A4, AT4, B4, E) are used in ICAR member Countries and among these methods the alternate morning and evening testing scheme (AT method), that is based on weighing and sampling one milking alternated between a.m. and p.m. on monthly basis, has been regarded as an efficient way to achieve good accuracy at convenient cost. But when the yield of a single milking is recorded and animals are milked twice a day, daily and total milk yields have to be estimated. In dairy science several mathematical models have been proposed to

predict milk yield and the factors affecting it (Smith and Pearson, 1981; Wiggans, 1981; Lee and Wardrop, 1984; Delorenzo and Wiggans, 1986; Grossmann and Koops, 1988; Gipson and Grossman, 1990; Cassandro et al., 1995; Lee et al., 1995; Pool and Meuwissen, 1999; Basdagianni et al., 2005) although when only the yield of a single milking is recorded on the test-days, total lactation milk yields can be over- or underestimated inducing evaluation errors in herd or flock management.

Current technologies allow the automatic measurement and recording of milk production at every milking reducing costs and human errors related to the milk recording procedures. Presently various automatic milk recording systems are available on the market for dairy goats (Afimilk, 2007; DeLaval, 2007; WestfaliaSurge, 2007), but only few commercial farms have implemented them due to high costs of the equipment required for automatic animal identification (ID) and for recording of milk volume or milk flow (Ait-Saidi et al., 2008).

Aim of the study was to compare actual milk yields, recorded through electronic milk meters, with milk yields estimated by the Fleischmann's method at different lactation stages in dairy goats.

Materials and methods

A total of 24 Saanen dairy goats (lactation: 1-3; days in milking: 10 ± 5), located at the experimental farm of the University of Milan (North Italy) were used. Goats were milked twice a day at 5 a.m. and 5 p.m. between February and October 2007 in a rapid exit parallel milking parlor (16+16 stalls) equipped with a low milk pipeline, 16 milking units on each side, automatic cluster removers (ACRs), electronic milk meters and automatic head lockers. The milking machine was set up to provide 90 pulsations/min in a 50:50 ratio with a vacuum level of 42 kPa.

Goats were random split into two groups of 12 animals. One group was milked with an ACR switch point of 70 g/min and a delay time of 10 s while the other one was milked disabling the ACR. Reattachment of milking units to goats was discouraged.

Individual milk yields were recorded at each a.m. and p.m. milking session through electronic milk meters (AfiFree™ S.A.E. AFIKIM) and a flock management software (Afigoats™ S.A.E. AFIKIM).

Calculation of actual milk yields

Actual milk yields at 100, 210 and 227 days in milking (end of experimentation) were calculated using individual milk yields recorded at each a.m. and p.m. milking session by electronic milk meters and flock management software. Erroneous milk yield records (equal to 0 kg or greater than 6 kg/milking session) due to failed or incorrect measurements operated by milk meters were not used in the calculation of actual milk yields and an average value between the previous and the next record was considered.

Estimation of milk yields

During the experimental period milk recording was performed monthly by field officers of the National Breeders Association using the ICAR AT4 method. Under such scheme, morning milk yields were recorded in one month then the evening yields were recorded in the following month and so on up to the end of the field test.

Milk yields of each animal at 100, 210 and 227 days in milking were estimated using the Fleischmann's method:

$$\text{Milk yield [kg]} = L_1 \cdot \text{int}_1 + \sum_{i=2}^n \left(\frac{(L_i + L_{i-1})}{2} \cdot \text{int}_i \right) + L_n \cdot 14$$

where:

- L_1 = milk yield of the 1st monthly test;
- L_i = milk yield of the i^{th} monthly test ($i = 1, \dots, n$);
- L_n = milk yield of the last test;
- int_1 = number of days from kidding to 1st monthly test;
- int_i = number of days between monthly tests ($i-1$) and i ($i = 1, \dots, n$);
- n = total number of monthly test for a specific animal.

Statistical analysis

Statistical analysis was performed using the Proc GLM of SAS (SAS, 2000). The following model was used:

$$Y_{ijk} = \mu + CR_i + LN_j + MM_k + CR*MM + \Sigma e_{ijk}$$

where:

- Y_{ijk} = milk yield;
- μ = general mean;
- CR_i = effect of cluster remover ($i = 0,1$);
- LN_x = effect of lactation number ($j = 1,2$);
- MM_k = effect of measurement method ($k = 1,2$);
- $CR*MM$ = effect of cluster remover-measurement method
- Σe_{ijk} = random error term with zero mean and variance.

The parameters NL, TM, CR were dropped from the model since they did not affect it.

Results

Milk yields at 100, 210 and 227 days in milking averaged respectively:

- $212,5 \pm 17,3$ kg, $427,2 \pm 33,4$ kg and $456,0 \pm 35,3$ kg, when calculated using individual milk yields recorded at each a.m. and p.m. milking session by electronic milk meters;
- $208,2 \pm 17,3$ kg, $447,0 \pm 33,4$ kg and $464,6 \pm 35,3$ kg, when estimated using the Fleischmann's method.

No differences ($P > 0.05$) were detected in actual and estimated milk yields at different lactation stages (Table 1). Anyway the calculation of milk yields by Fleischmann's method entailed a slightly underestimation at 100 days in milking (-2,0 %) and an overestimation at 210 and 227 days in milking (+4,6% and +1,9%) in comparison with actual milk yields (Figure 1).

Table 1. Comparison of estimated and actual milk yield in dairy goats

	Measurement method		SEM	P
	Fleischmann	Electronic milk meter		
MY-100 ¹ [kg]	208,2	212,5	± 17,3	> 0.05
MY-210 ² [kg]	447,0	427,2	± 33,4	> 0.05
MY-227 ³ [kg]	464,6	456,0	± 35,3	> 0.05

¹Milk yield at 100 days; ²Milk yield at 210 days; ³Milk yield at 227 days;

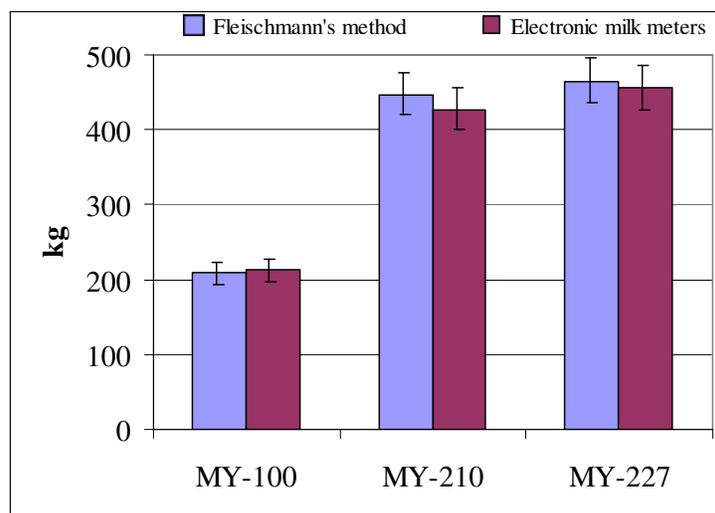


Figure 1 Estimated and actual milk yields at 100, 210 and 227 days in milking

Conclusions

The comparison between milk yields estimated by Fleischmann's method and actual milk yields calculated using individual milk yields recorded at each a.m. and p.m. milking session by electronic milk meters did not highlighted significant differences at anyone of the lactation stages considered. Although only slightly underestimation (-2%) and overestimation (+5% and +1,9%) of milk yield were observed respectively at 100, 210 and 227 days in milking, the main limit of Fleischmann's estimation method is that it considers a constant daily milk production between two records and equal to this two records mean, which doesn't describe the real variation of milk secretion during lactation (Pereira and Oliveira, 2006). On the contrary, measuring animals milk yield on a daily base through milk meters enable breeders to monitor constantly the individual milk production that is an important factor closely related with the health status of animals and their reproduction performance.

Automated systems to record individual milk weights of animals at each milking are widely used on many dairy cows farms in Europe and the US while they are not still common on dairy goats. With the regular use of milk meters, the farmer can select high producing animals for future breeding purposes or low producing ones for culling or that require

attention. By knowing animals milk production, the farmer is better equipped to assess supplementary feed requirements and to formulate proper feed plans. In addition, variation in daily milk yields can be used by management programs in efforts to detect health problems such as mastitis (Hogeveen et al. 1995). Individual milk yields can be used also in grouping animals during a milking session on the base of the actual production levels, improving the milking parlor throughput and reducing the unit cost of milking.

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Performance, labour and economic aspects of different farrowing systems

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Abstract

Pig farming is undergoing significant changes. Animal welfare is gaining importance in our society and the long-term future of the pork industry depends upon production methods being accepted by consumers and retailers alike. Farmers have to find economically viable systems as an alternative to farrowing crates that must also be competitive. There are several different farrowing systems available on the Austrian market today. They can be roughly divided into two categories: pens and farrowing crates allowing various degrees of freedom of movement and nest building of sows and litters.

The eight systems studied differed in design, space allowance, door opening and closing devices; as well as wall, feeder, crate and creep area design. These differences created variations in performance, work time requirements and gross margin. The number of piglets weaned per litter and sow (from 8.87 to 9.73 piglets) differed significantly among the systems investigated. The system related differences in average piglet weight at weaning time were as high as 4.7%. The system related labour requirements (not including work time requirements for management) ranged from 4.2 to 6.0 hours annually per sow. Labour requirement times varied up to 42.7%. According to these differences, the outputs and gross margins were lower for free farrowing pens than for farrowing crate systems. The system-related differences in gross margins annually per sow were as high as 29.3%, the highest variations were found between sows kept in sow pens and those in farrowing crates. Among the different farrowing crates, system related gross margin differences per sow and year were less than 8%.

Keywords: piglet, time requirements, farrowing systems, gross margin, litter.

Introduction

Animal welfare concerns increasingly gain importance in our society. The interest in farrowing accommodations that do not restrict sow movement or nesting behaviour is growing. Farmers are searching for alternatives that assure efficient operation methods and acceptable financial performance. This means weaning a high number of piglets per litter while maintaining, or even minimising, production costs, labour costs in particular. The transition to a more animal friendly system can require changes in farm set up and management, which result in increased costs. In the past, for example, some pen designs have resulted in higher piglet mortality.

Recently, several farrowing crate and pen systems with more or less animal friendly designs have become available on the Austrian market. Eight of them have been chosen for evaluation in an interdisciplinary study.

The farrowing crates aim to make management as easy as possible. This is achieved by using a crate to control sow movement, which reduces the risk of crushing piglets and protects the stockperson from sow aggression. The pens give sows more freedom, allowing them to turn around and also express a higher level of maternal behaviour (Taylor et al. 2006).

Differences in housing design affect not only labour time requirements, but also sow and piglet performance and therefore profit. In order to identify these differences, similar environmental conditions and data collection methods are necessary to ensure a high degree

of accuracy. This accuracy enables objective comparison and therefore results that can be applied to improving ecological and economic innovation potential and hence existing techniques. These demands require precise measurement and documentation, for example using digitally based methods.

Material and Methods

Performance, labour time requirements and the economic aspects of eight different pen systems, three farrowing pens and five farrowing crates, were investigated on a large-scale piglet farm in Austria, as part of a project subsidized by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management.

The stables held around 600 sows and were equipped with eleven rows of ten different farrowing accommodations. In the farrowing unit, the work processes, climate control, and birth management were optimised for keeping sows in farrowing crates.

To determine litter performance variation, the performance data of each sow during the birth and suckling phase was collected with software developed specifically for the collection and analysis of sow reproduction data. The relevant per sow parameters were litters per year, percentage of sows replaced annually and the number and weight of birthed, piglet losses and weaned piglets related to each farrowing accommodation.

The performance of around 600 sows was recorded over 17 months. System effects on the number of piglets per litter, the weight of piglets weaned and piglet losses were evaluated using data from the 1,436 litters born into the eight investigated systems.

In order to objectively measure the system related time requirements and identify differences, the system related work processes were broken down into small, measurable episodes, or work elements. Measurements of these work elements were repeated to gain representative standard times usable for planning purposes (Schick 2005).

Physical and monetary data regarding variable costs and output per sow and system were collected for gross margin calculations. The measured time requirements and collected performance data were pooled in SAS for statistical analysis. The differences in system related performance were tested by GLM (Generalized Linear Model) and GENMOD (Generalized Model) models. The GLM model was used for continuous data, work times (element related) and weight of piglets. The GENMOD was used for categorical data litter size at weaning and the piglet losses in percentage.

Results and Discussion

The different designs of the five farrowing crates and three sow pens in this study influenced litter performance (piglet mortality, litter size, body weight at weaning), work time requirements and, consequently, gross margin results.

Performance variation

On average, each sow bore 2.23 litters and weaned 2.17 litters per year. Around 44 % of the sow stock was replaced each year. The medium group of the Austrian and Saxon large-scale farms obtained similar results (Gerner et al. 2007; Mewes 2006).

System type, sow group, litter number class, management, litter size, piglet weight after birth and genotype of the sow had significant impacts on the system related number of piglets weaned and piglet mortality. The GLM model used was adjusted to allow for these factors.

Piglet weight, measured using the GENMOD model, was significantly affected by system type, sow group, parity number, litter size, piglet weight after birth and suckling days. The

data on the reproductive performance parameters in the different systems, sow pens and farrowing crates, are presented in table 1.

Table 1. System related piglets weaned per litter, weaned piglet weight, and percentage of piglet losses for 1.384 litters (2005-2007)

System	Piglets weaned per litter	Weight weaned per piglet	Piglet losses in percent
FS1 (FT)	8.87 a	6.08 ab	23.12 a
FS2 (JY)	9.05 ac	6.26 a	20.96 ac
FS3 (IK)	9.29 a	6.10 ab	19.09 ab
KS1 (SM)	9.68 b	6.08 ab	15.75 b
KS2 (SA)	9.43 bc	6.10 ab	17.91 bc
KS3 (BD)	9.56 b	5.98 b	16.10 b
KS4 (HM)	9.62 b	6.09 ab	15.54 b
KS5 (LT)	9.73 b	6.04 ab	18.83 b

The number of piglets per litter was partly significantly affected by the holding system. The number of piglets per litter ranged from 8.87 to 9.73 piglets, a difference of up to 0.86 piglets. The lowest number of piglets weaned per litter and sow was found in the sow pens, especially in the structured FS1. Significant differences regarding litter size consisted between the two sow pens FS1, FS2 and the five farrowing crates. In the sow pen FS2, sows achieved a litter performance similar to that of the farrowing crate with the poorest litter size weaned, the KS2. There were no significant differences in the number of piglets weaned per litter for the five different farrowing crates, differences being up to 0.3 piglets weaned per litter. Different results were obtained at Swiss farms, where the same litter sizes at weaning were achieved in both sow pens and farrowing crates. In both farrowing systems 9.6 piglets per litter and sow were weaned, independent of the farrowing system (Weber 2007). The litter sizes of Austrian working team farms producing piglets mainly in farrowing crates were 8.9 to 10.5 piglets weaned per litter (Gerner et al. 2007).

For piglet weight, differences of up to 0.28 kilograms per piglet were found. Piglets in the sow pen FS3 and the farrowing crate KS5 achieved the maximum difference, this also being the only significant one. Johansen et al. (2004) identified the most important risk factors as being low piglet birth weight, arthritis, diarrhoea, other infections, forelimb-skin abrasions on a piglet, weak pasterns of sows on concrete slats, poor milking of the sow, low birth weight and gender; and not farrowing system construction differences.

Piglet losses per litter were relatively high on this farm, varying between 15.5% and 23.1% per sow and litter. There were significant differences in piglet losses per litter for sows in the structured sow pen FS1, up to 8.84%, or 0.86 piglets. Sow had partly significant higher piglet losses in the sow pens FS2 and FS3 over the farrowing crate systems. Within the farrowing crate systems there were no significant differences in piglet loss per sow and litter.

Usually, losses are lower than 15%. For example, the piglet losses of Austrian working team farms were 10.9% to 13.1% per litter and sow (Gerner et al. 2007). The assumed reasons for

higher losses on the trial farm include the high frequentation of the farrowing unit by pupils, lecturers and students, and low labour input.

Weber (2007) determined piglet losses of 12.1% per litter on surveyed Swiss farms and no significant piglet loss differences between sow pens and farrowing crates, although there were significant differences between the various causes of loss. The number of crushed piglets in sow pens was 1.1% higher than in farrowing crates (Weber 2007), but in the farrowing crates piglet mortality in crates was mainly due to runts (Weber et al. 1996).

Work load time variation

Routine tasks, such as feeding and mucking, handling litter and health checks, occurred almost daily. Work tasks responsible for significant time differences in routine work were the cleaning of troughs and pens, opening and closing of doors and supplying of rooting material to the creep area.

The total of all routine work tasks for one sow pen or farrowing crate area caused system related time requirements of 3.23 to 16.9 minutes per sow and cycle. The highest requirements were for the structured sow pen. The differences between the other sow pens and farrowing crates were minor; maximum variation was 20%. Overall, 1.97 to 2.95 working hours per sow and year were needed for system related routine work tasks.

Special tasks are tasks that are done once or only few times during a birth and suckling cycle. The special tasks for the sow that caused system related differences in time requirements were moving sows in and out of their stalls, medical care and birth assistance. Time differences were caused by door latching mechanisms, door and crate width, wall height, and fixation bar placement.

Special tasks for piglets included medical care, tail docking, teeth clipping, setting of ear tags and mycoplasma vaccination prior to weaning. The setting of ear tags and mycoplasma vaccination took place in the sow pen or farrowing crate and all other activities outside the pen. There were time differences between the sow pens and farrowing crates for the handling of piglets and entrapment tasks. This was due to the different entering, exiting and catching behaviours caused by system design.

Special tasks for the sow pens and farrowing crates were sweeping, washing and disinfection. Their time requirements were influenced by system size, material and design.

The total time requirements for special tasks in and around sow pens and farrowing crates were 28.1 to 33.6 minutes per sow and cycle. The differences varied only marginally since most main special tasks were executed independently of sow pen and farrowing crate design. The system related time requirement of the special tasks per sow and year differed from between 1.85 and 2.38 working hours per year. The highest time requirement was for the structured sow pen and the farrowing crate KS3, which caused extremely high washing expenses in comparison to the others.

Monitoring tasks included feeding and daily health checks, some routine task elements, farrowing checks during the birth phase, some special task elements. Monitoring tasks restricted to the pen area required 4.9 to 12.6 minutes per sow and cycle. Time requirements were higher for the sow pens FS1, FS2 and FS3 and lower for the farrowing crates, which varied up to 8.5 minutes per sow. The total monitoring work per sow and year was between 0.33 and 0.66 working hours per sow, system and year, a 100% variation.

The total system related work time requirements (excluding management tasks) were 4.2 to 5.99 working hours annually per sow (table 2). The highest time requirements were for the structured sow pen. Time differences between sow pens were as high as 22.3%. There were minor differences in work time requirements between non-structured sow pens and farrowing

crates as well as within them. The maximum work time variation between sow pens and farrowing crates was 42.7%. The work time required during group housing in the dry and pregnant periods accounted for 1.54 hours annually per sow. Overall, these are low time requirements. Reasons were the efficient operations, quality equipment and large stock size.

The work time requirement annually per sow (not including piglet breeding) of Austrian planning data was 16.4 hours annually per sow (Bundesministerium für Land- und Forstwirtschaft, Umwelt- und Wasserwirtschaft 2004). Upper Austrian farms with more than 100 sows and including piglet breeding measured an average 18.1 hours annually per sow (Blumauer 2004). Handler et al. (2006) reported average working time requirements of 34.4 hours for piglet production on Austrian farms. Riegel et al. (2006) published similar figures for Swiss farms with around 60 sows, kept in both sow pens and farrowing crates. Their work time requirements, including management tasks, varied between 23.6 and 39.2 hours annually per sow (p. 61). Haidn (1992) determined work time requirements of 6 to 37 working hours annually per sow for Bavarian farms. The time requirements differed extremely depending on the operation and stock size.

Differences in economic results

Generally, annual output per sow depends on the price per kilogram for piglets, piglet weight at weaning, number of piglets per litter, annual litters per sow, proportion of sows replaced and the per piglet refund for mycoplasma vaccinations. The system related annual average output per sow varied between 960 EUR and 1.039 EUR for the different systems examined during the research time. The average gross price per piglet during this period was 7.19 EUR per kilogram, 4.1% higher than the average price for the three-year period 2003 to 2007. The main reasons for the system related output differences were variation in piglet number and weight, as highlighted above. The output for the piglets differed by as much as 8.32% per sow, system and year. The lowest overall outputs were achieved by sows housed in sow pens. Output differences of up to 41.7 EUR per piglet were found between the different sow pen systems. The farrowing crate KS1 achieved the highest output. The difference to the lowest output (FS1), was 76.4 EUR, or nearly two piglets. Differences of up to 26.6 EUR were found between farrowing crate systems.

The annual direct costs per sow consisted of replacement, feed, veterinary care and medication, insemination, contributions, energy costs and miscellaneous costs for water, straw, cleaning, disinfectant and marking material. Major costs were replacement, feed, veterinary care and medication, which made up more than 75% of the total direct costs and varied between 551 EUR and 559 EUR annually per sow. The differences between the investigated systems were marginal and caused by variations in feed, medicine and contribution costs due to the number of piglets per litter and piglet weight. Similar direct costs were verified by the Saxon large scale farms (Mewes 2007)

Other annual variable costs per sow were for machines and allocable labour costs. Machinery costs were 26.6 EUR annually per sow. Allocable labour costs differed between 44.9 EUR and 64 EUR annually per sow, caused by the identified system related differences in labour time requirements. Overall, labour costs were relatively low due to efficient and extensive work operations supported by synchronisation of group farrowing, medical induction of labour and part time labour. The work time requirements, including management work times, accrued costs of at least 78.8 EUR for the minimum of 10 hours annually per sow on Saxon farms (Klemm et al. 2004).

The system related gross margins, calculated by subtraction of direct and other variable costs from the output, were 318 EUR to 412 EUR annually per sow, or 16.5 to 19.6 EUR per piglet

sold. The gross margin differences between sows kept in the different systems investigated were as high as 29.3% (table 2)

Table 2. Annual gross margin per sow and per piglet sold, gross margin differences in percent and work time requirements by system

Systems	FS1	FS2	FS3	KS1	KS2	KS3	KS4	KS5
Gross margin/sow/year	318	375	377	412	391	382	404	403
Gross margin/piglet sold	16.5	19.1	18.7	19.6	19.1	18.4	19.4	19.1
Gross margin differences in percent /sow/year (related to KS4, ($\Delta = 0$))	-29.3	-9.7	-9.3	0	-5.4	-7.7	-1.9	-2.0
Working time requirements* (h/sow/year)	5.99	4.66	4.71	4.24	4.35	4.58	4.20	4.47

* Without management

The highest differentiation was between sows kept in the structured sow pen and the most economic farrowing crate, the KS1. Gross margin differences between sow pens were as high as 20%. The gross margins for sows kept in the FS1 system were worse than in the other sow pens. Sows kept in sow pens FS2 and FS3 obtained similar gross margins, not much lower than the gross margins of sows kept in farrowing crates. The differences were under 10% and the gross margin per piglet sold was akin to that of piglets kept in farrowing crates. Differences within the farrowing crates varied up to 7.7%. Variations in gross margins were mainly caused by design effects responsible for differences in the number of piglets, in piglet weight and in work time requirements. These results imply, as Appleby (2005) mentioned, that higher animal welfare in pig production requires premium prices.

Conclusions

Eight farrowing accommodations on the Austrian market, three sow pens and five farrowing crates, were evaluated for performance, work time requirements and financial efficacy. Their designs varied in space allowance, door opening and closing devices, walls, feeder, crate and creep area.

Design differences in the farrowing accommodations influenced litter performance, which had an impact on work time requirements and financial results. Significant differences were determined for litter size, piglet mortality and piglet weight, especially between the sow pens and the farrowing crates. The number of piglets per litter varied between 8.87 and 9.73 piglets. Cushing of piglets was highest in sow pens, especially in the structured one. The differences in piglet losses between the sow pens and farrowing crates were up to 8.84 % or 0.86 piglets per litter. The weight differences of up to 0.28 kilogram per piglet were rather low.

Sow pens had the highest time requirements for routine, special and monitoring tasks, in particular the structured sow pen, which had another manure removal system, litter, a non-perforated floor and more floor area. Within the sow pens and farrowing crate systems, work time variations were caused by the size of the farrowing accommodation, door latching mechanisms, floor and door material, door and crate widths, crate and feeder design, wall heights, position and design of the creeps and arrangements of the fixation bar. The system related total work time requirements (measured and calculated by the time element method),

were 4.2 to 5.99 hours annually per sow. The maximum differences existed between sow pens and farrowing crates, up to 42.7% annually per sow. The work time differences among the sow pens were as high as 22.3% and among farrowing crates less than 10%. This variation indicates an existing work transaction optimisation potential within both groups of systems.

The work time during group housing, in the dry and pregnant states, was 1.54 hours annually per sow. Overall, these are low time requirements for both units. Reasons were the efficient work operations, ensured by grouping of sows, large stock size and part time employees.

The output per sow or piglet varied with litter size and piglet weight. Among sow pens, the output difference was as high as one piglet per year; and between sow pens and farrowing crates the difference was nearly two piglets annually per sow. The system related differences in direct costs were marginal, to the highest being 1.34%. The other variable costs varied according to allocable labour costs, which are tied to the system related time requirements. The system related gross margins were from 318 EUR to 412 EUR annually per sow; or 16.5 to 19.5 EURO per piglet sold. There were remarkable gross margin differences of up to 29.5% for keeping sows in the investigated systems, caused by the above-mentioned design differences. Within the sow pens, gross margin differences of up to 20% were recorded; within the farrowing crates up to 7.7%. Differences in gross margin between the non-structured sow pen and farrowing crates were less than 10%.

These results imply that the sow pens recently available on the market cannot guarantee the same productivity and financial performance as farrowing crates. Short term alternatives to offer free movement and more space to animals are higher producer prices for animal friendly produced piglets, or government subsidies. There is a potential for optimisation and minimisation of the current considerable differences in performance and work load, which would better meet customer and farmer needs.

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Daily and seasonal patterns of lying and standing behaviour of dairy cows in a freestall barn

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Abstract

To examine the influence of environmental parameters on animal behaviour, an experimental programme was set up at a farm where anomalous behaviour of cows had been previously noted. The research was carried out in a free-stall barn (75 cows) where cow behaviour has been recorded by a time lapsed video system from June 2004 until June 2005.

This paper aims to investigate daily behaviour pattern in a herd and to examine cows' response to different environmental conditions through the analysis of the data related to four weeks in different climatic conditions (August, October, December and January). The behaviour of cows has been expressed through indices based on number of cows involved in different activities (standing, lying, eating and drinking). Simultaneously temperature and humidity within the cowshed have been recorded using dataloggers and Temperature Humidity Index (THI) has been calculated.

The comparison of behaviour in different hours of the day shows a strong diurnal pattern, while the behaviour at the same hours of different seasons highlight a significant difference only in daylight hours, despite the difference in temperature. The behavioural indexes in summer and autumn differ significantly only one hour in the day (3 pm) while THI values are widely different (mean values of 73.26 and 62.17; standard deviation of 3.85 and 2.41, respectively for the two periods).

The results obtained suggest that THI values are not sufficient to explain the influence of the barn on cows' behaviour.

Keywords: THI, animal behaviour, dairy cow housing.

Introduction

Several authors have emphasised how environmental conditions of livestock buildings can significantly affect animal welfare and productivity (Armstrong, 1994; Bouraoui et al., 2002; D'Archivio and Zappavigna, 2007; Kadzere et al., 2002; West, 2003). Temperature, humidity and ventilation contribute to changes in environmental conditions and may have a significant effect on the physiological response of animals. Dairy cows are, in fact, able to adapt to a wide variety of environmental conditions, but the best performances can be obtained only in the area of thermal neutrality, to maximise the energy available for the production of milk. According to Kadzere and colleagues (2002), genetic selection for increase in milk production is related to increased heat produced by cows, which makes animals more susceptible to heat stress.

Most of the studies use the Temperature Humidity Index (THI) to measure thermal comfort and a $THI \geq 72$ is usually considered the upper limit for dairy cows. Above this level cows generally reduce the milk yield because of heat stress (Igono et al., 1992; Ravagnolo and Misztal, 2002).

Cow behaviour is considered a good indicator of animal welfare (Overton et al. 2002). Therefore, the analysis of daily behaviour patterns has been used by several authors to study

the benefits of different bedding and housing solution (Haley et al., 2000, Fregonesi et al., 2007).

Animal behaviour is considered one of the indicators of animal comfort and indices based on the time cows spend in different activities (lying, standing, eating, drinking) have been used by several authors (Cook et al., 2005; Overton et al., 2003). Some studies have raised the possibility that cow stress can be related to THI values below the heat stress and occurs also in temperate climates (Bluett et al., 2000; Kendall et al., 2006).

To evaluate the performance of the housing and management system of a herd, the observation of cows' behaviour in a limited number of days might give a partial information. In fact, the differences among seasons and the effect of external environmental conditions (temperature, humidity, etc.) affect the daily behavioral pattern of the herd (St-Pierre et al. 2003). As a preliminary step to long term observation of cows' behaviour, some information on the consistency of daily pattern and the variability due to the seasonality has been collected and analysed.

This paper aims to 1) investigate the consistency of daily behaviour pattern in a herd and the more representative time of the day to examine cows' response to environmental conditions 2) study cows' behaviour to examine its seasonality and 3) give indications on the methodology to evaluate the effect of the housing system on cows behaviour.

Materials and methods

This study has been carried out in dairy cattle farm in the province of Lodi, Italy, in a free stall cowshed, from June 2004 until June 2005. The reinforced concrete precast structure has a rectangular layout of the dimensions 52 x 17.6 m with a north-south longitudinal axis and asymmetric gable roof, parallel to the longitudinal axes of the cowshed, and open ridge. The west pitch slope is 7%, while the east one is 5%. The building is without outside main wall and borders on the east side with another building partially closed.

Figure 1 shows the microclimatic sensors and video cameras installation scheme in the barn, provided with 74 stalls placed on two lines head to head. The data loggers for the measurement of the temperature have been installed between the stall rows at a height of about 1.2 m from the animals floor to measure the air temperature as close as possible to the animals, but without being affected by the closeness of the animal self. The temperature and humidity sensors (weather stations Heavy Weather WS) have been installed over the feed manger using plastic pipes fixed to the roof beam to bring them at a height of 2 m from the animals floor, so that they can not be reached by the cows. All parameters were continuously measured and recorded every 30 minutes. The black-and-white cameras are provided with a sheltered container and a 3.6 mm lens. The mini lens provides a shot angle of about 67° and uses a CCD sensor of 1/3 inch. The cameras were connected to a 4 channel video capture card DVR 4200 integrated in a personal computer to perform an analogue to digital conversion of the signal for the subsequent storage on a hard disk. The digital video recording parameters has been set, thanks to the suited control software with a capture frequency of a frame per second. This value has been chosen as compromise between the possibility of maintaining a good comprehension of the animals movement and the size of the information to save.

Local weather conditions were used to be compared with the internal microclimatic data obtained by the described instrumentation.

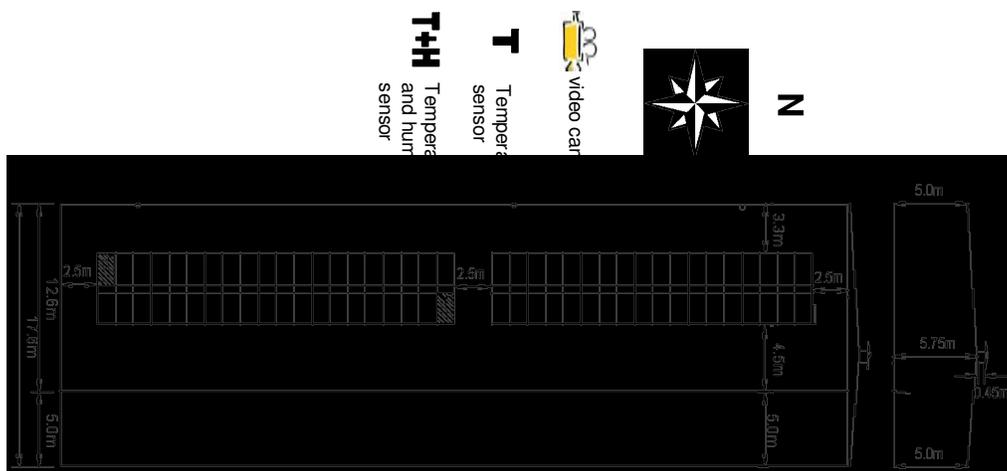


Figure 1. Plan and cross section of the cowshed with the position of the sensors and of the two video cameras with related shoot angles

Data from the two regional agency for environmental protection network weather stations of Sant'Angelo Lodigiano and Cavenago d'Adda were used for this purpose, which report hourly: temperature, relative humidity, global sun radiation, wind speed and direction, rainy condition. The analysis of the video recording data consisted in the evaluation of the number of dairy cows engaged in the different activities (feeding or drinking, resting, inactive standing) for the two sides (north and south) of the structure.

The time base to be used for the video analysis to extract the animals behaviour has been analyzed by Mitlohner et al. (2001) who have pointed out that to measure short time events (e.g. the drinking) it is necessary to use limited scanning periods (10 minutes), but that other behaviours, such as resting, can be adequately explained with scanning to 30-60 minutes. On the base of these experiences, the videotape have been analyzed hourly.

During the analysis, the hours connected to the cowshed management (milking and feeding) that influence the animals behaviour have been excluded. For the further processing of the collected data, some microclimatic and animals behaviour indices have been defined. Concerning the climatic aspects the Temperature Humidity Index (THI), widely utilized in bibliography, has been used to consider jointly temperature and humidity. It was calculated with the relation suggested by ASABE (ASABE, 2006):

$$THI = t_{ba} + 0.36t_{pr} + 41.2$$

Where:

t_{ba} = dry bulb temperature ($^{\circ}C$)

t_{pr} = dew point temperature ($^{\circ}C$)

Some indices have been used for the analysis of the data related to the behaviour. The first of this index is related to animals resting in the stall:

$$\text{Cow Lying Index} = \frac{\text{cows lying in stalls}}{\text{total cows}}$$

It represents the index of animal comfort and it is connected to the number of animals in the stall in comparison with the total number of heads (Cook et al., 2005).

Likewise are defined the index for the standing animals and the one that measures the cow tendency to move to the northern part of the building:

$$\text{Cow Stress Index} = \frac{\text{cows standing}}{\text{total cows}}$$

To consider the stall use by animal that are not engaged in other activities (eating and drinking) a further index has been calculated (Overton *et al.*, 2002):

$$\text{Eligible Cow Lying Index (ECLI)} = \frac{\text{cow lying in stalls}}{\text{total cows} - \text{cows eating or drinking}}$$

Finally, to consider the use of the different areas of the barn Crowding Index (CI) calculated as the absolute value of the complement to one of the number of cows in a sector of the barn divided by the expected number of cows in that sector.

To study the seasonality of cow behaviour, four periods has been selected, according to the daily mean THI values.

As can be noticed from table 1, reporting the start and date of the periods and the number of hours analysed, there are some missing values due to management operation affecting cows (milking, feeding, litter renewal, video recording malfunctioning).

In particular, the hours from 5 to 8 in the morning and 16 to 19 in the afternoon have not been considered. Missing data has been removed for all the parameter analysed.

Table 1. Periods, number of observations and average daily THI

Period	Starting date	Ending date	Number of hours analysed
August	01/08/2004	07/08/2004	112
October	20/10/2008	26/10/2008	108
December	09/12/2004	15/12/2004	111
January	09/01/2005	15/01/2005	111

A simple statistical descriptive analysis was carried out to find mean and standard deviation values of the hourly behavioural indices and THI for each period and for all observations. The different periods were studied by the application of a one-way Analysis of The Variance (ANOVA). Tukey's HSD test was used to test the multiple comparisons.

Hourly values have been compared graphically for the four periods reporting the mean values and the amplitude of variability expressed as twice the standard error of the mean.

Results and discussion

Table 2 reports the mean values, standard deviations and ANOVA significant differences obtained from the analysis of the four periods.

It can be noticed how all behavioural indices show significant differences ($P < 0.01$) between periods. Only CLI remain the same in October and December. The THI vales do not differe significantly in December and January.

Table 2. Mean standard deviation and significant differences for the behavioural indices and the THI for the four period of observation

	August		October		December		January		All	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
CLI	.54c	0.27	.64b	0.25	.65b	0.16	.80a	0.08	0.66	0.22
ECLI	.61d	0.26	.73c	0.21	.78b	0.1	.89a	0.05	0.75	0.20
CSI	.31a	0.2	.21b	0.15	.18c	0.06	.10d	0.04	0.20	0.15
CI	.45a	0.46	.33b	0.37	.13c	0.15	.08d	0.08	0.25	0.34
THI	73.26a	3.85	62.17b	2.41	47.42c	4.38	46.46c	2.79	57.33	11.69

The overall mean of the four periods of observation for the CLI and ECLI show a relative good use of the stalls but this results is influenced by the very good results obtained in January. The August values (54% and 61%, respectively) are lower and considered below the expected in a comfortable situation although the average THI values have a mean below the threshold value for heat stress of 74 reported by several authors. CSI shows a clear decrease from August to January not always justified by THI. The mean value of 20% of cows in the 24 hours in considered higher than the advised good practice, especially taking into account that the hours just after milking have not been observed. CI an unexpected high average value (25%) highlighting a strong preference of cows for the north side of the building all the year although there is a strong variation in the different periods of the mean values and a very high variability is reported by the standard deviation values.

Considering the differences expressed as percentage of the mean values of the four periods, the relative change of the indices have different patterns (figure 2). CLI and ECLI have a maximum variation of 20% and are practically the same in October and December. CSI and CI have higher variations, over 50% and 85%, respectively and show a strong reduction from December to January that cannot be explained by the variation of THI that does not have significant variation in this two periods.

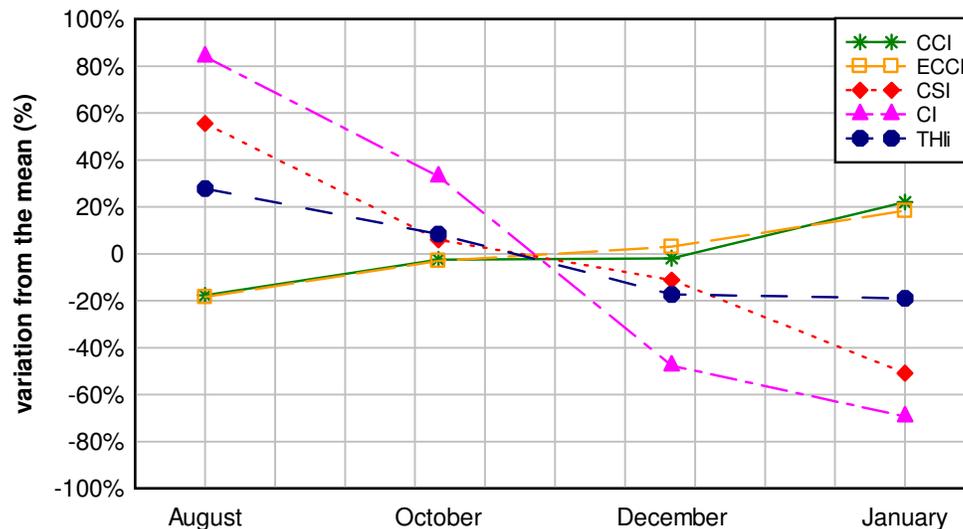


Figure 2. Relative variation of different behavioural indices and THI for the four periods of observation

The difference of the average values for the four period of observation can be better explained by the hourly analysis. Figure 3 reports the average values for each hour of the day for the behavioural indices. As can be noted, there is a clear diurnal patten and the differences among periods are minimised during nighttime. Slightly higher differences are shown in the evening, after the evening milking. This can be probably explained by the difference of THI and also by the daylight duration.

The night behaviour expressed by the four indices utilised show a good use of the stalls (ECLI is almost always over 80) and, as obvious consequence, a limited number of cow standing. The distribution of cows is regular in all the periods, and the CI index never reach the value of 10%.

During the day (from 9 to 15 hour), cows behaviour vary significantly in the different periods. CLI and ECLI show a similar pattern with a increasing values from August to

January. While The differences are always significant between January and the other periods, December differs from October just in some hours and August is for many hours similar to October.

CSI, as expected, result in an increase of values during the central hours of the day. It can be noticed that the maximum values are, for different periods at different hours: at 12 for August; 12 and 13 for October; 15 for December and January. It is also clear there are significant differences in the same period at different hours of the day.

The pattern of CI is following in some way the CSI although in August the values during the daytime are always very close to 100% as all cows are in the north part of the barn. The peak values in December and January are also for this index at 15 and significant differences between hours are reported.

The daily pattern of the behavioural index in the different periods is not always directly explained by the hourly values of THI (figure 4). The large variation of THI from August to October does not seems to be reflected in the behavioural index while the THI values in December and January are very similar with the exception of some hours. The hours with maximum values of THI in this two periods correspond to those of the CI and CSI. On the contrary in August and October, while the THI report a maximum value at the same hour (15), the behavioural index have their peak values around 12.

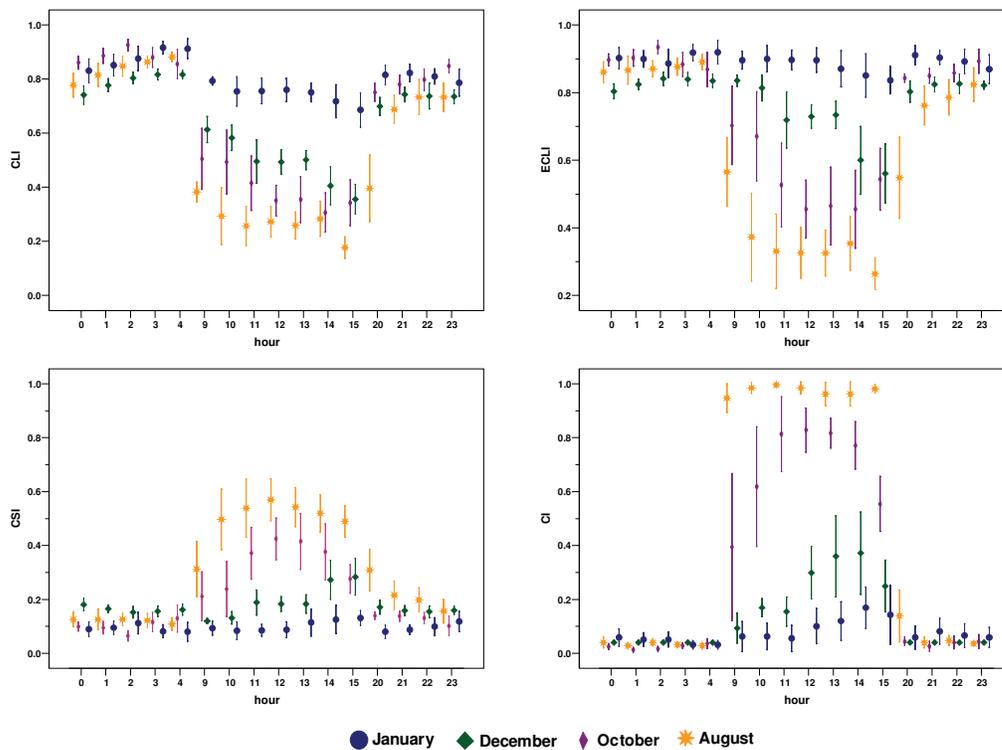


Figure 3. Average hourly values of the behavioural indices for the four periods of observation. The vertical bar represent twice the standard error of the mean

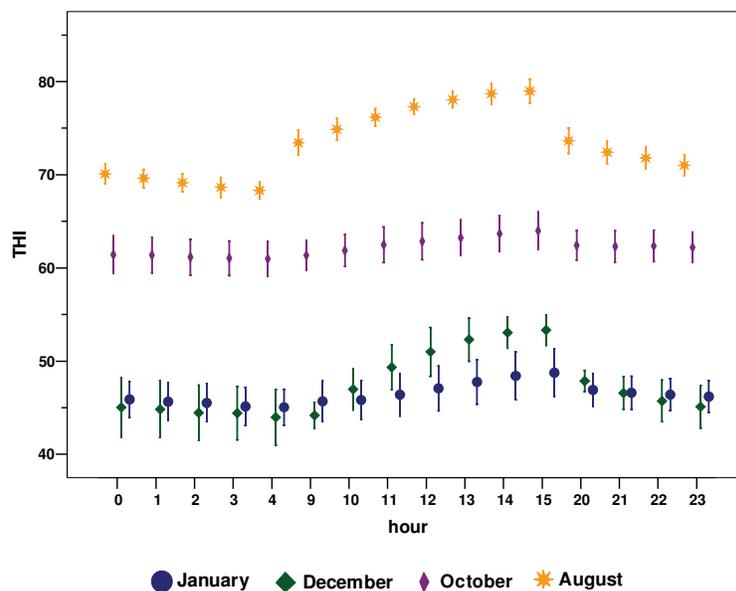


Figure 4. Average hourly values of the THI for the four periods of observation. The vertical bar represent twice the standard error of the mean

Conclusions

In the observed herd, the hourly pattern has shown a clear diurnal behaviour. Cows activity is limited during night and does not seem influenced by seasonality or THI. Thus, few information can be obtained observing the night time. During the day, cow behaviour varies significantly. The observation of the herd in only one hour of the day bring to results that might be not representative of the daily situation. The best period of observation seem to be from one hour after the morning milking to the start of the second one, but the observation of some hours after the second milking might improve the accuracy of the results.

Cows behaviour has resulted to be linked to the period of observation more than to THI. This aspect should be further investigated, but indicates that the evaluation of the influence of the barn and environmental conditions on cows behaviour must take into account also the seasonality.

CLI and ECLI indices are strongly correlated probably also because the observations have excluded the time soon after the milkings, and the use of one index or the other does not to improve the results.

The preference of cows to stay in one side of the barn should be considered to evaluate properly cow behaviour. Moreover, groups of animals in different side of a barn might show a different behaviour and therefore direct comparison might not give correct results.

Although more investigation is required to confirm the results obtained, it seems that experiments aiming to the evaluation of the influence of the barn on cow behaviour should not be short term observations (few days) and not referring of groups with few cows. Seasonal effect and crowding tendency should be taken into consideration to obtain results that can be transferred into practice.

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Optimal evaporative cooling system configuration for livestock building

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Abstract

The efficiency of ventilation and evaporative cooling systems usually depend on the system configuration, air distribution and cattle layout. From a thermo-fluid dynamics point of view, local recirculation zones could be present, reducing significantly the advantages of evaporative cooling. Furthermore, while for hot and dry climates such advantages are in general quite evident, in Italy the temperate and moderately humid summers make uncertain the cost-benefits ratio.

Previous results show that such systems are convenient even for temperate climates. In order to get an efficient implementation an optimal location of EC panels is required. From this point of view a double target is required: i) to reduce the indoor dry bulb temperature; ii) to keep low the increasing humidity due to the direct evaporative cooling effect.

Keywords: CFD, dairy cattle comfort, THI.

Introduction

The thermal exchange between cattle-breeding body surface and the surrounding environment influences growing, birth-rate and in general all the animal activity. As an example, in the case of dairy cattle the thermo hygrometric stress can cause a significant reduction of milk production (Armstrong, 1994; Collier et al., 1982; Ravagnolo, 2000; Ray et al., 1992). In this direction, an important parameter to investigate in order to assess the discomfort is the Temperature Humidity Index (*THI*) (Thom, 1958; Buffington et al., 1981; Igono et al. 1992, Bohmanova et al., 2007)

The bovine stress conditions can be reduced by using different methods: either increasing the animals thermal dissipation, and/or obtaining an improvement of the environmental conditions.

In case of dairy cattle the first experiences in the 1940s demonstrate that cooling obtained by direct water spraying on bovines increase milk production. Other studies show that wetting and shadowing cattle result in a significant reduction of respiration rate and body surface temperature (Seat & Miller, 1948), although the presence of the drawback of an increased percentage of possible cattle injuries due to the slippery floor.

The indoor environmental conditions can be improved by using traditional HVAC systems, with remarkable operating costs. In this framework, the use of Evaporative Cooling systems (EC). In case of dairy cattle the first experiences in the 1940s demonstrate that cooling obtained by direct water spraying on bovines increase milk production. Other studies showed that wetting and shadowing cattle result in a significant reduction of respiration rate and body surface temperature (Seat & Miller, 1948), although the presence of the drawback of an increased percentage of possible cattle injuries due to the slippery floor.

The indoor environmental conditions can be improved by using traditional HVAC

systems, with remarkable operating costs. In this framework, the use of Evaporative Cooling systems (EC) (Wang, 2001) could be more suitable.

In this paper the optimal layout of such panels is investigated by using a 3-D numerical simulations based on the CFD approach, considering a complete thermo-dynamical model including air buoyancy effects due to the natural convection, fan forced convection, sensible heat and humidity production due to the animals and the external solar radiation at the Sicilian latitude and in general at the temperate climate zones.

Materials and methods

The simulated domain has the following dimensions: 12,0 m (front width), 6,4 m (length of represented stable zone), 6,70 m (maximum height).

Perimetrical walls are made by 20 cm brickwork covered by 1,00 cm plaster. Four windows are present in the computational volume. Simple 3,00 mm glass is considered for each window, having a 2,25 m² surface area. The roof is composed by rain coated wood with air hollow space, insulation and plaster.

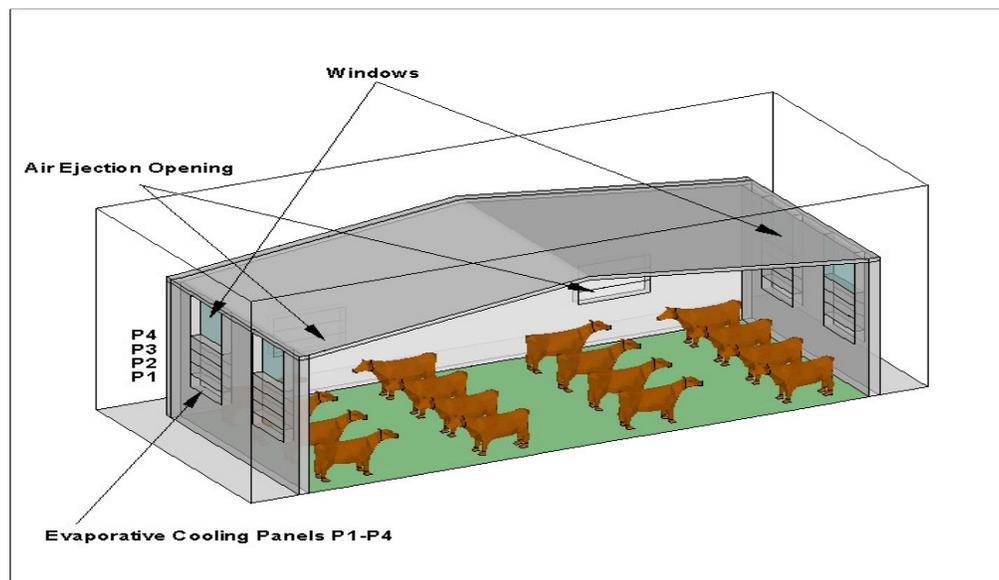


Figure 1. Simulation domain

Numerical methods

The Navier-Stokes equations for a compressible fluid were solved by computing the unsteady discrete solution of continuity, momentum and energy equations:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0 \quad (1)$$

$$\frac{\partial (\rho \mathbf{v})}{\partial t} + \nabla \cdot (\rho \mathbf{v} \otimes \mathbf{v}) = -\nabla p + \nabla \cdot (\bar{\bar{\tau}}) + \rho \mathbf{g} \quad (2)$$

$$\frac{\partial (\rho E)}{\partial t} + \nabla \cdot (\mathbf{v}(\rho E + p)) = \nabla \cdot (k \nabla T + \bar{\bar{\tau}} \cdot \mathbf{v}) \quad (3)$$

where: E is the total energy ($E = e + v^2/2$), v is the air velocity, T is the temperature, $e = C_v \Delta T$ is the internal energy, p is the static pressure, $\bar{\tau}$ is the strain tensor, ρg is the gravitational force and C_v the constant volume specific heat.

Air buoyancy effects due to the natural convection were modelled by the Boussinesq approximation, where in the momentum equation the density ρ is substituted by the term:

$$\rho(T) = \rho_0(1 - \beta(T - T_0)) \quad (4)$$

being β the air thermal expansion coefficient, and ρ_0 the density at the reference temperature T_0 (288 K).

A CFD commercial code was used, based on control volumes approach for the balance equations in conservative form with space and time second order accuracy; the computational domain was suitably discretized in about 700'000 control volumes.

Turbulence was modelled by using a realizable $k - \varepsilon$ model, using for the dissipation rate ε a transport equation derived from an exact equation for the transport of the mean-square vorticity.

A progressive variable time step in the range from 0,1 to 1 s was used for a global time simulation of 1 hour. In order to get shorter simulation times only a quarter of the whole livestock volume was modelled imposing a transversal symmetry condition. The reference stable was located at 37°N with a South exposed front.

The dynamic nature of the external cooling operating load was taken into account: following the hourly outdoor air dry bulb temperature of TRY (Test Reference Year, 1985); in particular, considering the Italian climatic area of the south Tyrrhenian Sea coast, the considered time interval is 12:00 ÷ 13:00 of the warmest summer day at this latitude (July 21th), and using a numerical time-varying solar ray tracing algorithm for the daily solar radiation (Fluent Inc. 2006).

The supply airflow rate \dot{V} (19 m³/s) of the evaporative cooling system was designed by using the following expression [20]:

$$\dot{V} = \frac{\dot{Q}_{sen} \cdot v_s}{c_p (t_{in} - t_s)} \quad (5)$$

where: $\dot{Q}_{sen} = 58,5$ kW is the maximum seasonal sensible cooling load.

The outdoor rate was calculated according to the CLTD method (Cooling Load Temperature Difference, ASHRAE 2005), while the indoor one, due to the cattle presence, was computed by considering the metabolic load for each bovine equal to 914 W for 600 kg of body weight at 26°C (Yeck et al, 1959), , where v_s is the specific volume of the supply air, C_p is the constant pressure specific heat, $t_{in} = 26^\circ\text{C}$ is the design indoor air temperature and $t_s = 23,5^\circ\text{C}$ is the design supply air temperature.

The latter was obtained using a direct evaporative cooler starting from a design dry bulb temperature and relative humidity respectively of 32°C and 45%.

Thermal model

The thermal load for the cattle was computed using a formulation based on the model developed by McGovern and Bruce (2000).

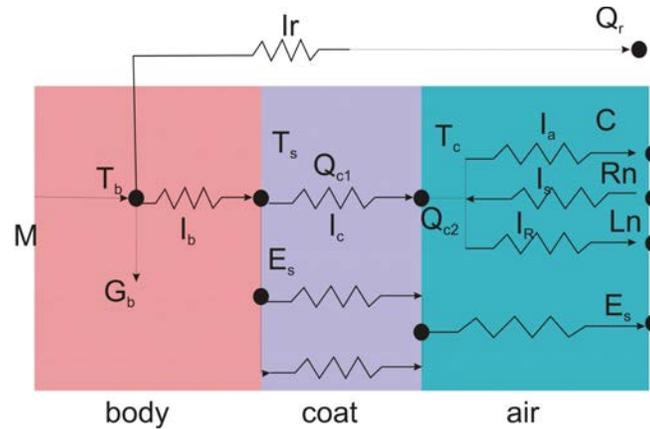


Figure 2. Schematic diagram of modelled heat flows following McGovern and Bruce (2000)

In this work the heat flows are modelled as shown in fig.1:

$$Q_b = M - Q_{r,b} - G_b \quad (6)$$

$$Q_{c,1} = Q_b - E_s \quad (7)$$

$$Q_{c,2} = C + L_n - R_n \quad (8)$$

where Q_b , $Q_{c,1}$, $Q_{c,2}$ are the heat fluxes from the body core to the skin, skin to the coat and coat to the air surrounding the simulated animal, respectively, $Q_{r,n}$ is the net heat flux from the respiration system, M is the metabolic heat production, G_b is the stored heat, E_s is the latent heat loss from the skin; C is the convective heat flux from the coat surface; L_n is the long-wave heat exchange with the surroundings and R_n is the short-wave radiation, with all variables expressed in W/m^2 of surface area of the simulated animal.

The heat flux from the body to the skin can be computed using the thermal resistance of the body tissue I_b as

$$Q_b = \frac{(T_b - T_s)}{I_b} \quad (9)$$

where T_b and T_s are the temperatures of the body and the skin of the simulated animal expressed in $^{\circ}C$.

Combining Eqns (6) and (9) and solving for the skin temperature we obtain

$$T_s = T_b - I_b (M - Q_{r,b} - G_b) \quad (10)$$

where the normal body temperature of cattle is taken as $39^{\circ}C$.

The combined effects of temperature and humidity are considered by using the following expression for the respiratory water loss ($g s^{-1}$), (Berman,2006):

$$Rwl = 0.41 - 0.02 * Ta + 0.0005 * Ta^2 - 0.004 * RH + 0.00004 * RH^2 \quad (11)$$

where Ta is the air temperature in $^{\circ}C$ and RH the relative humidity (%)

The THI index

The *THI* represent the stress cattle condition index in relation to the combined effect of air dry bulb temperature and humidity. For dairy cattle, the following relationship can be considered (Bohmanova et al.,2007):

$$THI = T_{db} + 0,36 T_{dp} + 41,2 \quad (12)$$

where: T_{db} and T_{dp} [°C] are the dry bulb and the dew point temperatures of the local environment.

Results

Two different set of simulations were performed: the first one computing the THI index on a daily base, comparing results obtained with evaporative cooling panels in position P1, and evaporative cooling ceiling diffusers (not shown in Fig.1), and natural ventilation.

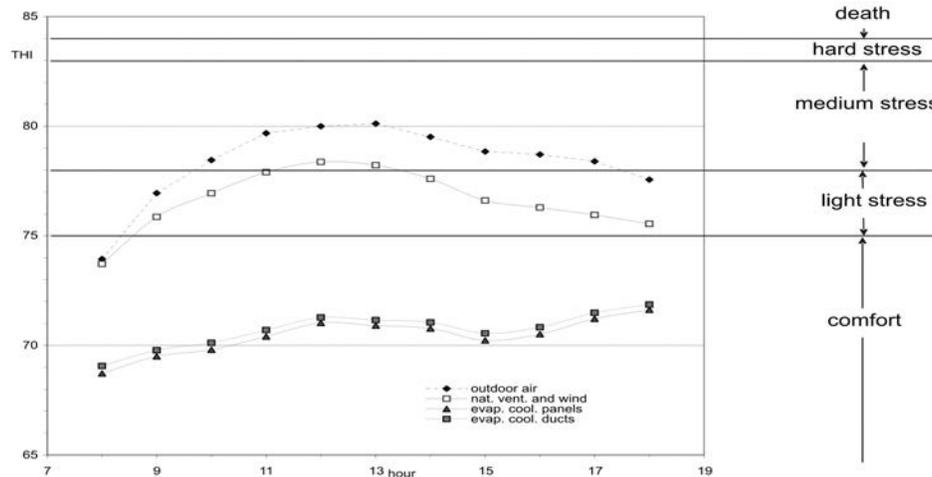


Figure 3. Simulated hourly THI

In Figure 3 the hourly average *THI* profiles, for the simulated cases, in the horizontal α -plane are reported. On the right side of the same figure the *THI* levels related to comfort conditions are shown too.

It is possible to observe that in both EC configurations the *THI* profiles are entirely in the comfort zone ($THI=70$ in the average). In the case of natural ventilation and wind a light stress is detected while for cattle without shadow the worst condition appears.

In Figure 4 the local *THI* index computed with EC panels in positions P1,P2,P3,P4 is shown after 10 m on a longitudinal plane positioned at 1.2 m from the pavement, highlighting the dominance of the thermal effects respect to those caused by the relative humidity, and suggesting that the best position for the EC panels is just over the bovine shoulders.

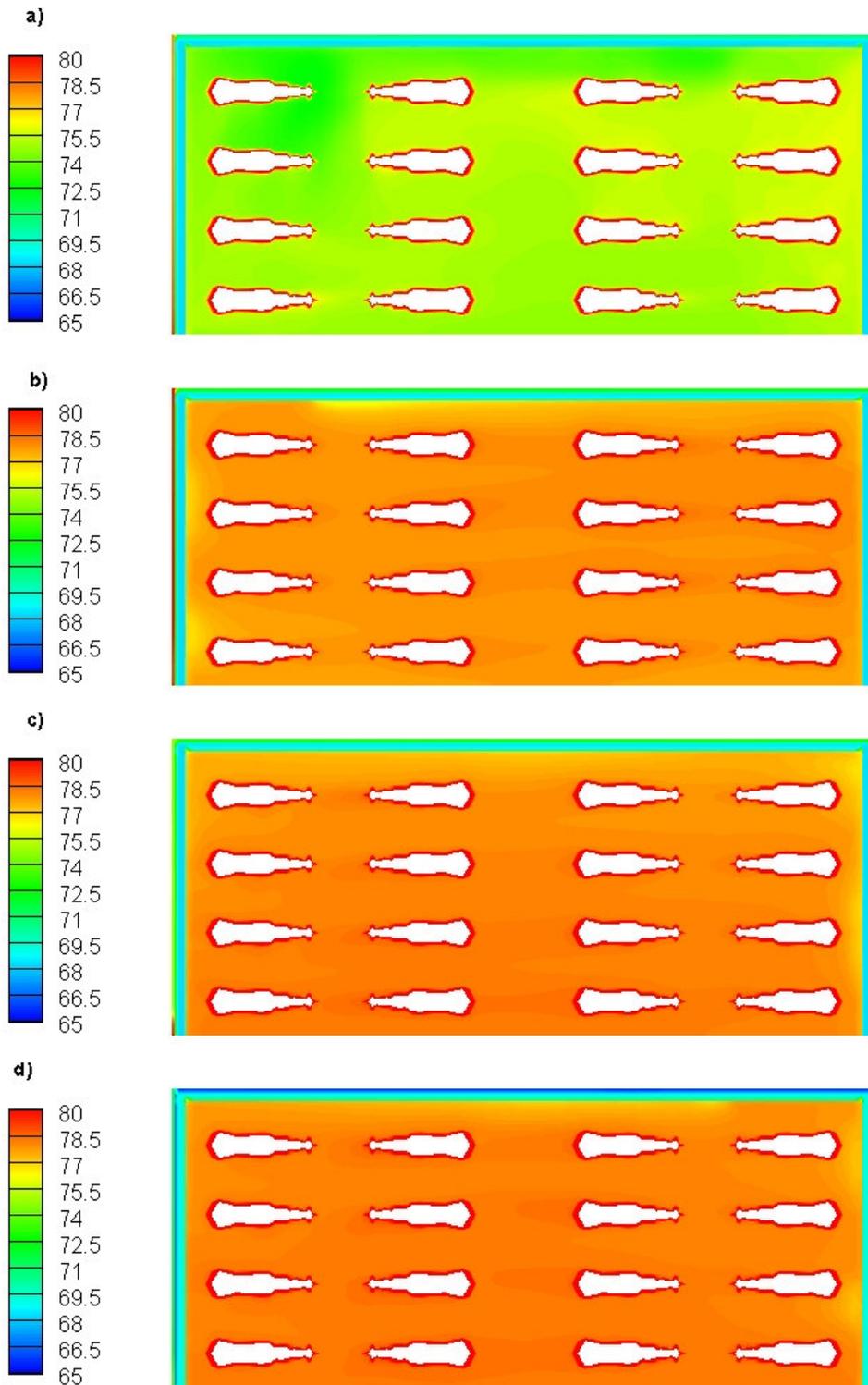


Figure 4. THI distribution for evaporative cooling panels positioned in: a) P1 b) P2 c) P3
d) P4

Conclusions

The Computational Fluid Dynamic approach provides a powerful tool to investigate local effects like temperature and relative humidity distributions, which constitutes a critical point in the use of evaporative cooling for heat stress relief for dairy cattle.

Particularly, the combined temperature and humidity, coupled with buoyancy effects seem to suggest that the best position for the EC panels seem to be just above the animal.

The stratification effects due to the metabolic heat production in the lower zone of the stable tends to contrast the cooler air descent in the P2:P4 positions, resulting in a higher THI index.

A same level collocation of EC panels should be avoided in order to reduce the air velocity disturbance on the animals, due to the presence of evaporative cooling fans.

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Energy use and management in dairy farms

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Abstract

This study aimed to investigate the energy demands in dairy cow farming to define the energy intensity of different categories of farms by efficiency indicators, identifying the critical operations and suggesting technologies that could be appropriate for energy savings. The electricity consumptions of a set of fourteen dairy farms, ranging from 40 to 300 milking cows, were analysed for one year with reference to the main operations (milking, milk cooling, lighting, ventilation, manure handling) and the equipments used. The overall electricity consumptions accounted for 466 kWh/cowyr, ranging from 314 to 630 kWh/cowyr. Milk productions, which ranged between 270,000 and 3,030,000 kg/yr per farm, required on average 5 kWh/100 kg/yr. The highest energy demands were associated to milk harvesting (refrigeration and milking procedures) which account for 41% of total, while lighting showed the lowest.

Keywords: efficiency, electricity, milk production.

Introduction

The analysis of the overall energy flows involved in agricultural processes is the basic tool to evaluate quantitatively the energy efficiency and the sustainability of a production process. Agriculture contributes for about 3% to the national primary energy consumption and about 11% of agricultural final energy uses is due to electricity (Enea, 2006). In recent times the role of agricultural sector in the world energy scenario has been emphasized because it can contribute to improve energy balance as producer of bio-energies. On the other side the energy management of agricultural activities plays a strategic role for the future of agriculture by reducing the production costs and supporting the sustainability of rural development.

Animal farming is evolving to more energy demanding forms of management which result in higher economic and environmental costs. Intensive mechanization has reduced the incidence of labour requirement for livestock activities and increased the utilization of electricity, natural gas and other fuels. The evolution of energy prices in this last years has affected the production costs, reducing process profitability and farmer's net income. A survey on bovine milk production costs in some Italian regions found that the rates of direct energy and water increased of 12-13% in the period 2004-06 (Ismea, 2008).

Proactive strategies for lowering the operating costs and reducing the consumptions require the assessment of the overall energy uses in a farm.

This study investigates the electrical energy demands in dairy farming with the aim of defining the energy intensity of different categories of cow farms by efficiency indicators, identifying the critical operations and suggesting technologies that could be appropriate for energy conservation.

Materials and methods

The investigation has been carried on in Sardinia region, where economical and productive performances of dairy farms were found to be similar to the northern Italy ones (*Ismea, 2008*). The electricity consumptions of a set of fourteen dairy farms, ranging from 40 to 300 milking cows, were analysed for one year with regard to the main procedures: milking, milk cooling, lighting, manure handling and ventilation. The energy audit was performed in each farm on the basis of a questionnaire where data about organization, structure characteristics, equipments and ways of management were analytically described. Some information were collected by interviewing the personnel directly involved in farming operations, while data about electrical power, consumption and expenditure were obtained by the monthly energy bills. Household uses have been excluded from the computation considering the number and the consistency of families. Detailed consumption of specific equipments (as vacuum pumps equipped by variable speed drivers) have been measured by an using electrical energy meter

The farm efficiency figures were expressed by mean of energy utilization index (EUI), namely the amount of electrical energy used per cow (kWh/cow yr) and per mass of milk produced (kWh/100 kg·yr), calculated either on annual or daily base (*Edens at al., 2003; Ludington, 2003*). The incidence of electricity cost on milk income was also estimated as well as the proportion of the most demanding activities on the total energy requested.

Results and discussion

Table 1 summarizes the technical characteristics and the energy performances of the audited farms grouped in two size categories, <100 cows and >100 cows, which correspond to a total milk production less and over 10^6 kg/yr. Livestock management techniques were similar in all farms. The producing animals were housed in free stall barns and milked twice a day in herringbone milking parlours, except in one case where a rotary platform milking machine was installed. Direct refrigeration milk tank coolers were used in all farms, most of them equipped by a heat recovery system for producing hot water for milking center utilizations. Animal feeding was based on total mixed ration distributed on through by mixer trailers.

Livestock manures, after mechanical removal from cowsheds and storage in unroofed structures, were utilized for land application as fertilizers; equipments for slurry collection and treatment, like pumps and centrifugal separators, were installed only in three farms. Climate control systems were present in 6 farms, based mainly on forced ventilation inside milking areas and in cowsheds and only in one case on nebulisation by water sprinklers.

Electricity was entirely provided by energy distributing companies; none of the investigated farms had installed facilities for self-producing energy as photovoltaic systems or anaerobic digesters. Most of the farmers had signed a supplying contract with the main national energy operator, while 5 of them had chosen two other distribution companies. Power supply per farm varied between 11 and 62 kW, corresponding to an average value of 0.27 kW/cow. As expected, due to economy of scale in larger farms, this value was lower in farms sized >100 cows (0.22 vs 0.30 kW/cow).

All energy contracts were based on a constant kWh tariff applied all day, with variable fare calculated for blocks of monthly consumptions. The charge of fixed quota differed in relation to the farm power supply, mainly when it was lower than 16.5 kW. In some cases a discount was offered when annual consumption were more than 20,000 kWh.

Table 1. Overall electricity consumption related to dairy farming

Herd Size	Total Heads (N°)	Cows (N°)	Milk Production (1000 kg/yr)	Electricity demand (kWh/yr)	Power supply (kW)	Energy Utilization Index		Energy cost (€/100 kg milk)
						(kWh/cow yr)	(kWh/100 kg milk)	
>100 lactating cows	770	300	3,030	167,917		559.72	5.55	0.95
	600	260	2,340	127,542	47	490.55	5.45	0.94
	450	210	2,352	75,699	30	360.47	3.22	0.55
	450	170	2,300	100,452	62	590.89	4.37	0.75
	256	128	1,300	56,712	25	443.06	4.36	0.75
	252	121	1,270	71,601	33	591.74	5.64	0.97
	235	115	1,016	53,878	27	468.50	5.30	0.91
<100 lactating cows	190	98	1,000	35,169	11	358.87	3.52	0.60
	180	90	900	37,320	16.5	414.67	4.15	0.71
	156	78	820	24,548	25	314.72	2.99	0.51
	160	70	570	43,970	38	628.14	7.71	1.33
	140	70	679	33,524	16.5	478.91	4.94	0.85
	70	40	330	25,270	16.5	631.75	7.66	1.32
	60	37	270	13,334	11	360.38	4.94	0.85

Considering the whole annual expenditure, the final price paid by farmers for the energy consumed varied between 0.162 and 0.176 €/kWh, corresponding to an average value of 0.172 €/kWh, including taxes and additional fees. The average price of electricity paid in Italy for non household uses results about 24% higher than the average European price and this can put Italian dairy farmers at a disadvantage when competing on international markets.

The comprehensibility of the monthly energy reports that retailers sent to the users was in some case rather inadequate, particularly when the consumptions were presumed and not registered for a long time.

Electrical consumptions and efficiency indicators

The total amount of energy consumed in the audited dairy farms was comprised by 13,334 and 194,917 kWh per year, the highest levels related to the largest livestock (Fig. 1).

Monthly electrical consumptions, calculated as average values for the two reference categories of farm size, are depicted in figure 2. Milk was produced through all year and the associated amount of electricity averaged between 2570 and 5430 kWh per month, respectively for herd sized <100 cows and > 100 cows. The slight increase during summer period (about 1.2 times compared to winter) was due to a larger usage of water pumps and climate control systems.

While the regression analysis showed a direct relation between herd size and kWh consumed per year, there was a wide variation in the annual energy demand per cow because of the numerous variables, like type of facilities and operative choices, influencing the energy intensity of the productive process.

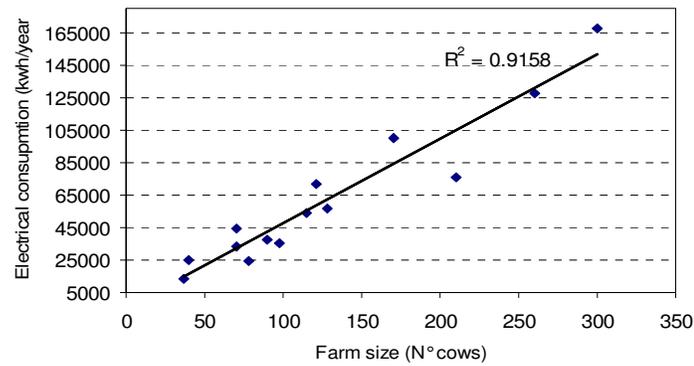


Figure 1. Total annual electricity demand per farm

These values, referred to overall consumptions, ranged from 314 to 631 kWh/cow · yr, lower than EUI reported in previous studies for US dairy farms (Lundigton, 2003; Edens et al., 2003) and similar to the data recorded in France (Dolle and Duyck, 2007). The average EUI was 10% higher for the category >100 cows (500 kWh/cow · yr) than for <100 cows (455 kWh/cow · yr). Based on these data, the daily cost of electricity can be estimated about 0.23 € per lactating cow, varying from 0.15 €/cow day in the most efficient farm and doubling to 0.35 €/cow in the less efficient one.

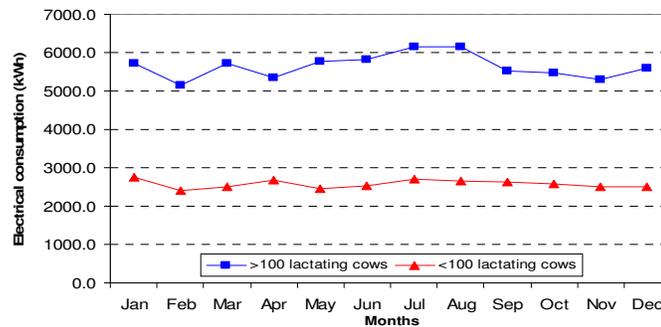


Figure 2. Average monthly electrical consumption

Referring the annual energy demand to the quantity of milk, which ranged between 270,000 and 3,030,000 kg/yr per farm, the EUI resulted on average 5 kWh/100 kg·yr (50 Wh/kg). Individual values started from a minimum of 3 kWh/100 kg rising to a max value of 7.7 kWh/100 kg in two farms sized 40-70 cows.

The related costs varied between 0.50 to 1.31 €/100 kg of milk and considering an average milk sale price of about 0.38 €/kg, the rate for the electricity weigh on average 2.2% upon milk gross income.

Energy demands by equipment categories

The main operations absorbing electrical energy in the audited farms have been grouped as follow: milking, milk cooling, manure handling and lighting. Equipments that were not

present in all farms or which consumptions could not be accounted because a lack of reliable information about the actual use, have been included in the category miscellaneous. Depending from the farm organization this category could comprise facilities for climate control, ventilation, slurry separation and water pumping. Differently from other surveys, water heating was excluded from the computation because in 80% of farms it was based on refrigeration heating recovery systems, with an average reservoir capacity of 500 dm³, while only three farms used conventional gas heaters.

The four major categories of electrical usages accounted for 55% of the total demand in farms sized <100 cows and 48% in farms sized >100 cows, where the higher technological level has a bearing on explaining the largest miscellaneous quota (Fig.3).

The largest energy demand was associated to milk harvesting -refrigeration and milking procedures- which accounted for 36-46% of total consumptions, depending on herd dimension.

Except for the case of rotary milking machine, milk cooling was the prevalent energy consumer in all farms with conventional milking parlours. In this cases refrigerating milk to 4°C required on average 96.7 kWh/cow·yr and 1.1 kWh/100 kg, corresponding to a share of 23% of the total electric energy absorbed.

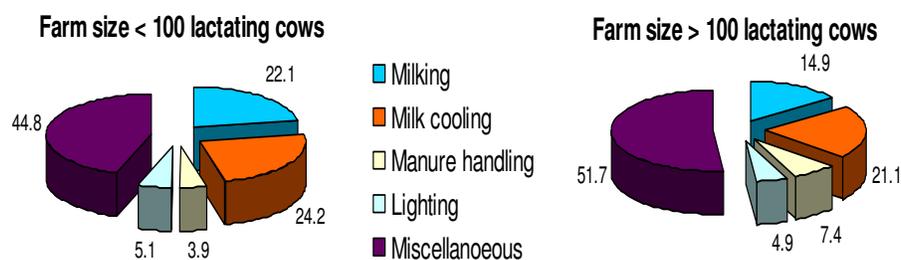


Figure 3. Annual electricity use by equipment category

About 65% of farms used two cooling tanks instead of one, which increases specific energy consumptions and costs. Analysing for each installation the ratio between daily milk production and tank nominal volume, the annual average filling coefficient varied between 0.58 and 0.98. In 5 farms it was lower than 0.75, this last value being considered as the limit for a rational utilization of tank capacity.

Only 20% of the dairies had installed a plate heat exchanger to pre-cool milk with well water before entering the tank, reducing in this way the energy required for milk refrigeration.

The energy demand for milking operation was dependent mainly from the vacuum pump size. The average EUI account for 84 kWh/cow·yr with a nominal vacuum pump capacity of 208 l/min per milking unit; the values recorded in all installations ranged from 124 kWh/cow·yr to 52 kWh/cow·yr.

The best efficiency results (52-58 kWh/cow year) were found when the vacuum pump was equipped by a variable frequency drive (VFD) that adjust the pump capacity with the actual need of air removal during milking. This technology allowed to reduce of about 60% the pump capacity per milking unit (85-94 l/min·unit) as well as the kW/milking unit (from 0.4 to 0.2 kW/unit), cutting off the half of the milking energy consumptions (Figure 4).

Manure removal from cowshed was generally performed by automatic scrapers driven by electricity while 35% of farmers used a tractor equipped by a frontal blade; slurry

treatment was made by using electrical agitators in five farms and only three of them used pumps and separator. Electricity demand for manure handling was about 23 kWh/cow yr, weighing on average 5.6% of total consumptions till a maximum value of 12% in those farms where pumps were used for slurry transport.

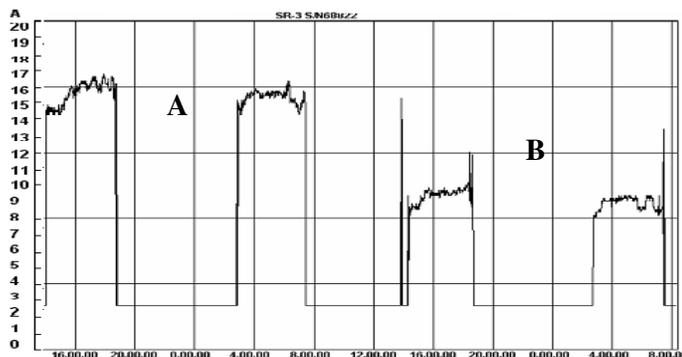


Figure 4. Milking electricity demand profile: (A) vacuum pump and conventional regulator; (B) vacuum pump equipped with variable frequency drive

In the audited farms 95% of light points inside the milking area and the cowsheds mounted 36-45 Watt tubular fluorescent lamps, while incandescent and halogen lamps were used in external areas. Fluorescent lighting systems require less power and have a longer life if compared to the other type of lamps, providing a better energy efficiency and lower operating costs. Lighting consumption accounted for 5% of total energy demand, with an average EUI= 21 kWh/cow year.

Conclusions

Dairy farmers should apply proactive measures for energy conservation, by integrating efficient technical solutions and effective management strategies.

According to the results of our investigation the quantity of electricity required in dairy farms vary widely with the herd size, the technological level and the type of management. Energy efficiency indicators were not related with herd size and large margins of improvement subsist.

Applying the best EUI found for each group of farms, a potential energy saving of about 180,000 and 61,000 kWh/year can be estimated respectively for the total of herds >100 cows and <100 cows. Based on these estimate energy saving, the annual cost reduction per farm would roughly result of 4,000-1,550 €/year.

Energy efficiency of milk production relies on numerous and different factors which have to be carefully assessed and combined to improve farm performances. For each facility the power demand, the hours of use, the electrical rate do influence the extent of energy savings that can be realized as well as the daily peak energy use.

Milking and milk cooling are the critical operations for reducing the farm energy intensity. Equipments like VFD both reduce energy demand and lower the farm power load, realizing an economical benefit as bigger as the vacuum pump capacity is over-dimensioned respect to the actual need. This technology can also be used for milk pump motor. Considering the increasing trend of electrical tariff and some state financial support for energy saving, the investment for VFD installation can be easily repaid.

The results indicates the convenience of heat recovery from refrigeration for water heating using systems that, at the same time, improve the performance of the refrigeration unit by removing heat from the refrigerant. Lowering milk temperature to 18 °C by pre-coolers had reduced the energy requirement for milk cooling and, as a consequence, could allow the installation of smaller compressors. Another active measure for reducing the power of the refrigeration units is the use of more energy efficient compressors like the scroll type, that was installed only in one of the investigated farms.

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Assessment of work organisation and analysis of energy consumption in mechanical milking and donkey milk processing

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Abstract

It is well known that donkey milk is becoming increasingly important in the diets of newborn babies who are allergic to normal milk proteins. For this reason in the last year the number of donkey breeders are going up and up.

Milking is prevalently carried out by mechanical machines similar to those used for sheep and goats. Following milking, the milk is filtered and refrigerated even occasionally pasteurised and thus sold directly to the public.

The aim of this research is to examine the work organisation according to standardised methodologies and energy consumption by means of electrical metering, during the usual routines of milking and milk processing in the milking parlour.

The study were carried out in two different breeder both with predominantly breed 'ragusana' and with a milking machine of 0.6 kW. The first breeder milks twice a day, pasteurises it at 78°C and then refrigerates it at 4°C. The second, milks just once a day, refrigerating it at 4°C.

The results show that the efficiency and work capacity of milking are quite low because waste of time significantly impinges on the whole operation. The Mechanisation Indexes demonstrates that a better organization due also by a rational mechanization allows to reach higher levels of efficiency in terms of a reduction of working time with consequently a rise productivity.

It is possible to observe that the total energy consumption and Energy Utilisation Index are significantly lower with respect to other livestock and thus the incidence of energy consumption is not exorbitant in the total amount of the operating costs.

Keywords: mechanisation index, work efficiency, energy consumption, donkey breeder

Introduction

In recent years the necessity to protect a species in danger of extinction and to reassess the function of donkey milk has led to increased interest in donkey species (Signorello et al., 2004). As is well known, the availability of hypoallergenic milk biochemically similar to human milk is extremely important for newborn babies suffering from various forms of allergies to casein and other elements contained in cow milk. The use of donkey milk is not limited to the paediatric field: it is, in fact becoming more and more often used in geriatric nutrition and in the cosmetic industry.

In Italy there are only a few scores of donkey farms with a total of about 35,000 animals used for milk production. 7% of these are in Sicily where there are 2,500 animals (ISTAT, 2007; Zarbà and Maltese, 2006).

Donkeys are rustic animals with few requirements. They adapt easily which means in most cases they can be reared in a semi-wild state, this reducing initial investment costs and expenditure.

Milking is mainly carried out using machinery usually adopted for sheep and goats (Murgia and Pazzona, 2001; Pazzona, 1999) and suitably adapted, thanks to the

morphological characteristics of the udders, which are very similar in the two species. After milking, to keep the milk hygienic, usually it is pasteurised thermally and refrigerated. It can then be kept in refrigerators at 4°C until the fourth day after milking.

Donkey milk must be sold and bought out outlets situated in the production site (Regio Decree 994/29), this meaning that normal distribution channels cannot be used and restricting trade.

It is clearly of fundamental importance that the work in the milking parlours and processing plants should be organised efficiently with the use of limited energy and labour and that productivity should be kept high, the quality of the milk guaranteed, production costs scaled down and the well-being of the animals considered. Even if donkey milk is a niche product there is reason to expect the market to get bigger.

The aim of this work was to examine the various milking and processing phases in order to highlight the organisation during these operations and find any critical points or time wasting. Experimental results relating to use of energy for the machinery and the organisation of labour were obtained from two different farms and three different models of labour organisation were analysed.

Materials and methods

One of the farms considered is situated on the slopes of Mt. Etna and the other near the town of Ragusa. Both rear mainly the Ragusa species in a semi-wild state and use a milking machine. On the first farm milking is carried out twice a day and the milk is pasteurised at 78°C and then refrigerated at 4°C. In the second milking is carried out only once a day and the milk refrigerated at 4°C.

On the first farm data was recorded at two different times (2006 and 2008) with two different organization models referred to as A and B (Figure 1). The third model (Figure 2) which relates to the second farm and is different from the other two is referred to as C (Table 1).



Figure 1. Milking parlour models (A and B)

In models A and B, the milking and processing operations begin with the transferral of the jennies from their stalls to the milking parlour. In the passage way between the positions taken up by the jennies, the worker turns on the milking machine, milking one animal at a time having first cleaned the udder with a dry paper napkin. The milked animals are taken out of the milking parlour and other animals spontaneously take their places.

The first milk of the day (morning milking session) is filtered and poured into the pasteuriser and cooled to a temperature of 4°C. In the afternoon, the second milk of the day is added to the pasteuriser, again after filtration. The milk is all subsequently pasteurised at a

temperature of 78°C for about 1 minute and then again refrigerated at 4°C, to keep it hygienic. While the morning refrigeration and the afternoon refrigeration-pasteurisation phases are taking place, the milking parlour is cleaned. Then the milk container and funnel are washed with water and disinfectant and cleaning of the milking parlour completed. Once the refrigeration process is complete, the milk is poured into 1, 0.75 and 0.5 litre bottles previously washed with detergent and a brush. These are placed in a fridge where they are kept until they are sold directly to the customer.

The last operation of the day is the washing of the pasteurisation tank. First it is washed with just water and then with water and disinfectant heated to a temperature of 45°C. Finally it is emptied and rinsed.



Figure 2. Milking parlour model (C)

In model C milking begins with the transferral of the jennies from the grazing ground or stall to the milking parlour. Here all the jennies to be milked (a total of 11-12) are tied up by one worker and fed with food concentrate in a trough by another. Milking of one donkey after the other proceeds with modest pauses mainly for moving the milking machine from one animal to the next and once the vacuum tube attached to the machine. Once milking is complete, the milk is poured into the refrigerator tank. Not all the milk is cooled to a temperature of 4°C as sometimes it is sold before it reaches this temperature. After milking the jennies are freed together and join their young.

The milking machines used (Figures 3 and 4) on the two farms are fairly similar (Table 2), while the milk processing equipment differs both because that used in organisation models A that B can also pasteurise the milk and because the energy absorbed and the tank capacity are different (Table 3).

Table 1. Organisation models in the milking and processing stages

Model	N° workers	N° stand	Distance covered to milking parlour	Site cleaning	Milking machine cleaning	Milk tank cleaning	Bottle type
A	1	2 × 2 animals	200 m	2/day	2/day	yes	glass
B	1-2	2 × 3 animals	0 m				
C	2	1 × 11-12 animals	300 m	1/day	1/day	separatedly	plastic



Figure 3. Milking machine and teat group in model A and B



Figure 4. Milking machine and teat group in model C

Table 2. Work parameters and characteristics of the milking machines

Model	Power	Vacuum pump pressure	Pulse number	Tank capacity	Teat groups used	Trolley
	(kW)	(kPa)	(n./min)	(l)	(n.)	(yes/no)
A	0.6	-35	60	30	1	yes
B					1-2	yes
C	0.6	-35	50	15	1	no

Table 3. Work parameters and characteristics of the pasteuriser-refrigerators

Model	Power	Tank capacity	Refrigeration	Pasteurisation	Tube cleaning
	(kW)	(l)	(°C)	(°C)	(yes/no)
A	4.5	30	4	78	yes
B					
C	0.3	60	4	no	no

The data relating to the work organisation was collected with standard methods and that relating to energy consumption using electricity meters. All data was recorded in the milking parlour and processing room during routine work times.

Results

The results obtained in the three models are quite different both for animals milked and production of milk, because the number of jennies to be milked is determined by the regular customer request (Table 4).

The TT is greater in C model than others, and the value is referred to one milking per day. In the A and B models the values should be calculated by multiplying for two milking per day. In this way the B and C models become similar (about 70 min per milking vs 62 min). The work organisation of A model is already outdated and substituted by B model. Now it is very rational but although the movement phase of animals and the movement and draining phase of milk tank are decreased (TAt), the site and milking machine cleaning phases (TMIt) significantly affect the total time taken to complete the operation. Certainly, this greater waste of time is necessary to ensure adequate hygienic conditions for human and animal health.

The work capacity, in terms of number of milked animals and litres of produced milk is always greater in the model B, showing a best work organisation (Table 5). Also the Mechanisation Index demonstrates that a better organization due also by a rational mechanization allows to reach higher levels of efficiency in terms of a reduction of working time with consequently a rise productivity.

Table 4. Milking phases

Model	Animals	Milk	TE _m ¹	TE _t ²		TI _t ³	TAt ⁴	TMIt ⁵		TT ⁶	
	(n.)	(l)	(s)	(s)	(min)	(s)	(s)	(s)	(min)	(s)	(min)
A	17	10	73	1222	20	689	134	735	12	2780	46
				44%		25%	5%	26%		100%	
B	15	12	54	820	14	160	27	1081	18	2088	35
				39%		8%	1%	52%		100%	
C	11	19	186	2115	35	908	83	606	10	3712	62
				57%		25%	2%	16%		100%	

¹TE_m = "Tempus Efficientiae" mean (milking phase of one animals)

²TE_t = "Tempus Efficientiae" total (milking phase of all animals)

³TI_t = "Tempus Itineris" total (movement phase of animals)

⁴TAt = "Tempus Adiuvandi" total (movement and draining phase of milk tank)

⁵TMIt = "Tempus Morandi Inevitabilis" total (site and milking machine cleaning phase)

⁶TT = "Tempus Totali" (sum of all phases)

In the model C the milking machine works more than in the others and the total consumption seems to rise higher levels in comparison with model A and B with reference to milking and cleaning activities. But it is also necessary to underline that this difference it is reducible significantly if farm milking is carried out twice a day instead of once a day (like data showed in Table 6).

To less time of milking machine work corresponds less energy consumption such as in the model B case. This means the work organisation is strictly correlated to the energy demand. So, also Energy Utilisation Index in terms of kWh/donkey day and kWh/l day are affected by the same constraints that could be removed by a more intensive milking processing activity with more quantities of produced milk, efficiently sustainable using a mechanical process.

Table 5. Work capacity (Wc) and Mechanisation Index (MI)

Model	Wc -1	1/Wc	Wc-2	1/Wc	MI ¹
	(n./h)	(min/n.)	(l/h)	(min/l)	(%)
A	22	2.7	12.5	4.8	55
B	26	2.3	21.5	2.8	91
C	11	5.6	18.4	3.2	57

¹ MI = Mechanisation Index (mechanical and human work ratio)

Table 6. Energy consumption of the milking machine

Model	milking	cleaning	Total consumption	EUI-1	EUI-2
	(min)	(min)	(kWh)	(kWh/donkey day)	(kWh/l day)
A	18.5	5.1	0.3	0.042	0.074
B	10.5	2.6	0.2	0.026	0.032
C	40.9		0.6	0.055	0.032

Although the data of energy consumption of the milk processing concerning the model A and B are not available in this paper, it is anyway possible to observe that the total energy consumption of model C are only 1 kWh/day and Energy Utilisation Index in terms of kWh/donkey day and kWh/l day are, respectively 0.0040 and 0.0023. With respect to other livestock productions (e.g. cows, sheep and goats) these values are significantly lower, it is derived that the incidence of energy consumption is not exorbitant in the total amount of the operating costs.

Conclusions

In general it was found that the milking yield and work capacity were rather low as accessory work times greatly affected the total time taken to complete the operation with respect of other livestock productions. The Work capacities and the Mechanisation Indexes demonstrates that a better organization due also by a rational mechanization allows to reach higher levels of efficiency in terms of a reduction of working time with consequently a rise productivity.

It is possible to observe that the total energy consumption and Energy Utilisation Index are significantly lower with respect to other livestock and thus the incidence of energy consumption is not exorbitant in the total amount of the operating costs.

Further investigations are carrying out in order to study specific strategies able to improve the donkey milk production in terms of work capacity, yield and operating costs.

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Safety in equestrian exhibitions

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Abstract

The world of equestrian exhibitions aims most of its attention on the overall image and glamour, without focusing organizational strains on safety among public, workers and horses. Preventing accidents on workplaces means protecting the safeness of people and animals. The not easy definition of risks in the equestrian range rises from the extreme variability and arduous foreseeing of working states and from the considerable number of activities which are often simultaneously performed.

The sphere of these risks concern:

Safety of people:

constraint of dangerous animals, buildings and structures authorized by firemen, sound fences and enclosures around rings, trial and competition fields, safety distance from public and horses, moving carriages and equipments, visible signals of routes equipped for horses.

Safety of workers:

specific training and information for horse managing employees, equipments and individual protective devices according to regulations, good acquaintance of expositive dynamics.

Horses' physical and psychical safety:

sound and wide stalls so that horses may be stabled in the most comfortable conditions; doors, gangways and transit paths free from dangers, obstacles and unevenness that may wound horses; removal of stress from excessive lighting, ceaseless presence of noisy public, scanty moments of relax through daytime, close presence of more stallions, separation of foal from mare.

As conclusion, to reach a real optimization of safety in equestrian exhibitions, fairs and expositions it is necessary to develop a level of attention in the three areas mentioned above so that a good degree of protection can be reached in a global and commensurate way. Only applying some simple but basic rules, it will be possible to grant a complete and effective safety in the framework of every respectable equestrian show.

Keywords: safety, equestrian exhibitions.

Preliminary statement

If analysis and definition of risks involves great difficulties due to the presence of horses in permanent structures, we can easily imagine what happens when, along with all the daily problems, you have to struggle with those added by precarious situations, new places and boosting noises, provoked from an unknown environment in a sport or show event.

In these contexts there are rules for sanitary provisions and location of stalls, but almost nothing in terms of safety of people, workers or horses. Rules in force in these situations points out only the responsibility of the expositors, who must be considered responsible in case of damages to people or objects, but on the other side the organization does not refund any damage, of any kind, that has taken being inside the event.

Even in important international events you can very often see horses being rode among crowds of people, animals without a keeper, safety exits badly indicated and sometimes obstructed and fire disposals absolutely insufficient.

To expose our work giving some indications related to the necessity of applying the safety rules in force on working places in the specific sector of horse events (shows, fairs, competitions, ecc) and horse centres and stalls, horse breeding centres and therapeutic centres for horse rehabilitation, it is necessary to take a look to the law outline in which we have to move about nowadays.

The application of the *Testo Unico sulla Sicurezza*

Issued in April 2008 and operative since May 15th 2008, it includes all the preceding laws related to safety in working places and it is applied without differences in all the private and public activities, prescribing the necessary measures related to wellness and safety of workers in their working places. The Testo Unico founds a total and compulsory application, with the institution of those roles referred to safety that the precedent laws (D.Lgs.626/94 and following modifications) already had created in the so called "chain of safety".

Once the safety roles have been indicated and instituted, with a specific nomination formally accepted by the singles, it is necessary to carry out the duties and the responsibilities provided for each one. The violation or the inobservance of these duties brings on, also for the worker as for the other subjects involved, very heavy administrative sanctions and penalties, related to the importance.

For a correct "evaluation of risks" (not always to be done in a script modality) defined by the formula: risk = probability x importance (magnitudo), law prescribes to identify the fonts of risks, make a valuation of exposure to the risks and only after these paces the employer, by himself or with the help of the responsible of prevention and protection service, put hand to the actions that will reduce or eliminate the identified risks.

That means that risk is not identified by the legislator, but by the employer: relating to the activities, to the working conditions and to the working places. Relating to this, in the risk evaluation document, he defines the map of existing risks, determining the measures suitable to eliminate risks or to reduce them to a minimum acceptable level and then controlling their application.

Projecting safety

At the moment of projecting and installing spaces and structures for events, if safety rules would be held in consideration, following the guide lines indicated below, surely something could be improved, without great difficulties and even without great expenses.

As a general rule, during events it is important to grant:

- a) Safety of people
- b) Safety of workers inside the event
- c) Horses' physical and psychical safety.

Safety of people:

For what concerns safety of people and horses' moving among people (which is surely important being a horse show were everyone wants to appear as much as possible) few basic rules are enough:

- no dangerous animal should be placed near visitors or be rode outside a ring;
- not authorized people must not accede to rings, competition and trial fields;
- it is necessary to maintain a safety distance from public and horses, moving carriages

- and equipments;
- it must be forbidden for people, with fences and by personal control, to stay or walk along routes equipped for horses, which must be well pointed: alternative paths must be lined out and well indicated;
- a contemporary transit of cars, trucks, trailers and horses along the same paths must be forbidden;
- every building where people can enter without restrictions must be controlled and granted by firemen, when the specific fire laws require it, and safety exits must be well identified, not more than 40 meters long and without obstacles and unevenness.

Safety of workers:

For what regards safety of workers, all the indications that have a value “at home” must be respected even in these situations. Besides these, it is necessary that:

- working places, even if temporary and precarious, must grant structures with the same safety conditions of the steady ones;
- dangerous objects or people who can disturb workers must not be present on working places;
- specific training and information must be provided to horse managing employees, above all to those temporary workers who usually have other jobs and so have no experience with horses; it is important that these workers be supported by skilled ones and have only duties that they are able to struggle with;
- specific equipments and individual protective devices, according to regulations, must be provided to all workers;
- workers must have a good acquaintance of expositive dynamics and programmes and have to be able to manage th horses in this context;
- to grant the best working conditions, each worker must not have too many horses to attend (1 worker each 5-6 horses);
- if there are dangerous horses, not broken or difficult to manage, workers must be informed about this and only really skilled workers, who have received a specific training, should manage them.

Horses’ physical and psychical safety:

For horses’ physical and psychical safety, on which so often safety of people depends, it’s necessary that:

- horses be stabled in the most comfortable conditions, in solid and wide stalls, with a thick and soft litter and no lack of water or food;
- doors, gangways and transit paths must be large, broad and preserved free from dangers, obstacles and unevenness that may wound horses and workers;
- stable doors must be wide and have a fast and easy opening lock, for any kind of emergency;
- it is important to remove as much stress as possible deriving from excessive lighting, ceaseless presence of noisy public, scanty moments of relax through daytime;
- a horse show is not the best place to operate separation of foal from mare, which would cause nervousness among all horses;
- the close presence of many stallions might cause competitiveness among horses, raising risk level.

Safety in competitions

Other matter to consider in the world of sports competition, particularly in saddle-horse events or morphology shows, is their location inside the structures who give hospitality, often inadequate or not suitable to receive, for a short and concentrated space of time, a heavy load of people, horses and trucks. Otherwise to what happens in race-courses for flat racing or trotting-races, where structures are projected and realized specifically for that kind of competition and where there are physically separated areas for working people and for the public, the equestrian centres live a normal daily mixture of horses, riders, workers and public. To this mixture you have to add, during competition days, an overwhelming chaos created by the greater human and animal inflow in structures usually unknown to the most.

In these situations, the least to be done is that:

- rings, trial and competition fields must be raised far away from paddocks for mares and foals;
- stallions should be stalled separately from mares;
- horses must not be ridden among the public.

Conclusions

A correct application of the rules contained in the "Testo Unico sulla Sicurezza" imposes a new projectual approach in equestrian competitions, shows and fairs, increasing safety levels without bearing heavily upon costs. Even the improvements in horses' performances are due to animals' balance and calmness, which comes also from a correct training and information given to the workers who should learn to manage horses with the strength of technique rather than with the technique of strength.

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Safety at work in livestock and poultry farms in South-eastern Sicily

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Abstract

The present study analyses the standard of adjustment to the rules concerning health and safety at work in the livestock and poultry farms in Sicily, with specific reference to ones sited on the Hyblean Plateau.

We examined nineteen farms having at least one employee which is the prerequisite condition to be liable to guidelines of the Italian legislative Decree n. 626/94, recently substituted by the Italian legislative Decree n. 81/2008. Employers and workers were given four check lists that aimed to identify the standard of "objective" adjustment concerning conditions of buildings and facilities.

The results have highlighted that the livestock and poultry farm conditions are highly unsatisfactory in terms of adjustment of the building, as well as the correct way of using them and the knowledge of procedures as for the workers.

Therefore, it is important to find strategies to train employees and employers about health and safety at work.

Keywords: livestock farms, risk prevention, check list.

Introduction

In Italy, for some years now, there is a gradual reduction of accidents at work in agriculture (fig.1). This trend is confirmed also in the reduction of cases of accidents recorded in Sicilian farms (fig. 2). In the same period, the accident rate (ratio between the number of accidents reported and number of employed in agriculture) are decreasing in Sicily, from 3.2 in 1999 to 2.2 in 2006 and in Italy from 8.1 to 6.7. It isn't sure if these positive results can actually be attributed to the adjustment of the farms to the rules about health and safety of workers and to the employers' awareness of safety problems (Salvati, 2003). In particular, although for many years there have been specific rules (Italian legislative Decree n. 626/94; Italian legislative Decree n. 547/55) imposing the necessity of achieving adequate safety and health levels, in most small farms the work is not always carried out with awareness of the risks and with adequate knowledge of prevention and protection measures that limit those risks.

The objective of this work was to verify the current level of adjustment of livestock and poultry farms to the safety regulations. In this respect, it was identified a sample of livestock and poultry farms in an area representative for the characteristics and the size of livestock farms in Sicily. The considerations set out below focus the fields where the problems in workplaces are larger.

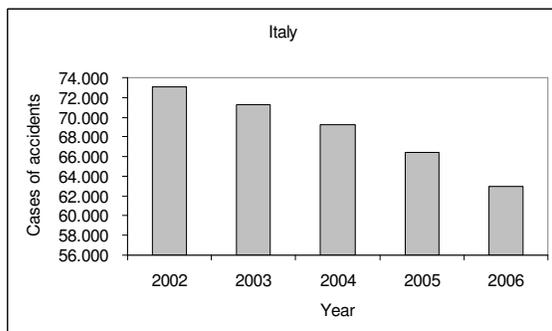


Figure 1. Trend of agriculture work accidents in Italy

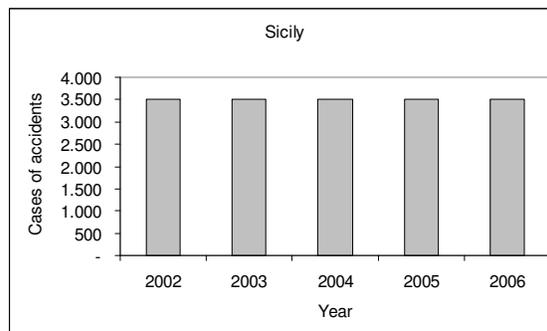


Figure 2. Trend of agriculture work accidents in Sicily

Materials and methods

The study was conducted during the year 2004 on a sample of nineteen livestock and poultry farms, located on the Hyblean Plateau. This area of investigation was chosen for the strong agricultural vocation of South-eastern Sicily where, in particular, there is the largest number of livestock farms of the island. Most farms sited on the Hyblean Plateau have small dimensions in terms of number of bred animals and of available farm land. Furthermore, those farms are managed by a single farmer who carries out all activities to the management of the farm (ISTAT, 2002). Since this characteristic excludes farms from their obligations of safety rules, in this study were selected only the farms with at least one employee (Soprani, 2003), taking care of forming a representative sample of animal species bred in the examined area. Then, the sample selected consists primarily of dairy farms, while in a lesser extent there are herds of pigs and laying hens.

Check lists are frequently used to identify potential sources of risk to workers and to design rational prevention programs of accidents in workplaces. The check lists contain statements and/or questions involving two possible responses: true or false. They are effective for the recognition of non-compliance regulations and techniques, as well as for the planning of good safety management systems. In addition, experience has shown that the use of check lists reduces the human commitment and the economic resources for risk analysis and supports the control and the update of prevention and protection interventions (Enama, 2002).

To obtain the data needed to achieve the objectives of this work three check lists have been used (Cascone *et al.*, 2004; Zappavigna *et al.*, 2006).

The check lists were compiled through surveys and direct interviews to managers and workers. Their use made it possible to analyze three different areas: the typology of the farm, the general features of the farm, the prevention and the protection against risks, the buildings and the installations.

The check list "Farm typology" contains data on animal breeding and animal housing, on the management of feeding and manure, on crops and on the use of machines.

In the checklist "General data" three main areas of interest were grouped: the form of management, the staff employed and the organisation of the Service of Prevention and Protection against Risks (SPPR).

The check list "Buildings and Facilities" examines the safety conditions of the buildings and of the relative installations. To simplify the filling of the check list, the entries were organized in the following groups: access and viability, doors and gates, flooring and walls, stairs, raised platforms, lighting and microclimate, roofing, tanks, silos, barns, machine shops, electrical equipments, noise, biological contaminations, manipulation of objects.

To each item of those three check lists was given a numerical value that measures the level of risk to which workers would be subject in the case of non-compliance with safety requirements expressed by the same voice. The possible levels of risk are three: low, medium and high. To the lower level of risk 1 point have been assigned, to the average level 3 points and to the higher level 9 points (Brugnoli *et al.*, 1999). On each item to the answer (true or false) is given a null score if it expresses the condition of conformity (true); on the contrary, if the answer expresses the condition of non-compliance (false) it is given a rating equal to the level of risk. Therefore, for each filled check list it is possible to associate to the surveyed farm a triple scoring method: a "reference score", which corresponds to the maximum achievable score, obtained by adding the scores of all voices of the checklist, excluding those not filled as not relevant or related to elements not present; an "absolute score", determined by the sum of the scores actually obtained from all the voices that express a non-conformity; a "relative score", obtained by the ratio between the absolute score and the reference score.

Results and discussion

During the first part of the survey, it was filled the part of the check list through the information obtained from interviews of the owners, concerning the "General data". This preliminary interview allows also to assess the level of detail of subsequent phases of the visit in order to compile the other check lists.

Using the relative scores expressed as a percentage it was possible to make some considerations on the overall conditions of the analysed sample, to analyse one by one the situation in each area of investigation and to compare the different farms in the sample (CSA 2000; Zappavigna *et al.*, 2002). In addition, conducting a sectorial building analysis it has been possible to identify priorities in actions.

General data and farm typology

In all farms of the sample it is carried out simultaneously livestock activity and cultivation, intended mainly to pasture and forage crops; in several cases, for special mechanised processes, farms undertake outsourcing.

Of the nineteen farms in the sample, sixteen have a legal form of ordinary partnership company directly conducted by the owner, with an average of two family components that work within the farm. The remaining three, two are joint-stock companies and one is a limited company. These last three farms, in particular, are the only that rear chickens and pigs and, therefore, less rooted in local livestock traditions.

Another important aspect emerging from the analysis of the data included in the "Farm typology" check list regards the total lack, in most farms, of the Service of Prevention and Protection against Risks (SPPR). In particular, among the ordinary partnership companies no one have established a SPPR and only in two farms the employers have attended a course concerning the issue of the safety management. The participation to that course, although not followed by any information activities and worker training, has contributed to make the worker awareness of the need of preventive and protection measures, at least for the performance of some specific activities. This leads the employers to provide their employees with Personal Protective Equipment (PPE), which are essentially: gloves, masks and boots. In all other fourteen farms organized in the form of ordinary partnership company, the problem of worker safety is almost completely ignored, thus highlighting the most serious lack common to the whole sample: the lack of information on rule duties and on the possibility to comply with the rules.

Farms which employ more than one employee not belonging to the owner's family, (the three farms that are not directly conducted by the owner) have tried to comply with the Decree n. 626/94 conducting risk assessment and creating a SPPR with the help of an external consultant who also plays the role of head of the service itself. However, the attention given to the issue of safety at work was primarily dictated by the need of being complying with the rules in case of a possible inspection by the supervisors, rather than a real need oriented to ensure adequate working conditions.

Buildings and facilities

The analysis of checklists "Buildings and Facilities" has led to a table that presents for each farm the absolute scores, the relative scores and the reference scores. Table allows to make some considerations on the level of complying with the rules for the safety of workers. In fact, the reading of data from each farm allows to understand if it was conducted a risk analysis that allows only the identification and possible resolution of the most critical situations, or if it was conducted a deeper analysis which leads to the design and implementation of prevention interventions needed.

Table 1. Number of non-compliant items, number of relevant items and percentage of non-compliant items resulted from the compilation of check lists "Buildings and Facilities"

Farm	Number of non-compliant items			Number of relevant items			Percentage of non-compliant items		
	Level of risk			Level of risk			Level of risk		
	low	medium	high	low	medium	high	low	medium	high
1	7	8	13	15	21	23	47%	38%	57%
2	7	7	7	15	17	16	47%	41%	44%
3	6	4	4	19	22	21	32%	18%	19%
4	6	7	5	16	17	20	38%	41%	25%
5	7	6	7	14	19	16	50%	32%	44%
6	7	11	5	16	19	13	44%	58%	38%
7	5	7	7	13	19	18	38%	37%	39%
8	6	8	5	15	21	14	40%	38%	36%
9	8	9	7	15	22	18	53%	41%	39%
10	7	7	5	14	18	19	50%	39%	26%
11	7	9	7	15	23	18	47%	39%	39%
12	5	7	5	15	22	22	33%	32%	23%
13	9	9	7	18	24	23	50%	38%	30%
14	6	6	6	13	17	14	46%	35%	43%
15	6	7	4	14	22	17	43%	32%	24%
16	6	6	5	14	19	16	43%	32%	31%
17	4	4	4	14	19	17	29%	21%	24%
18	7	10	10	13	20	18	54%	50%	56%
19	3	7	3	10	17	9	30%	41%	33%
Average	6,3	7,3	6,1	14,6	19,9	17,5	43%	37%	35%

With reference to the whole sample, it comes that the major defaults in complying with rules are six on average, with a minimum of three and a maximum of thirteen; these data assume greater significance when compared with the number of relevant items. Indeed, in the farm with three serious non-compliances was possible to evaluate only nine entries with a high risk. The three non-compliant items represent, therefore, one third of the total relevant items, thus highlighting a high percentage of serious inadequacies.

The most interesting result is the relative score that gives an overview of the real situation through the percentage of non-compliances which on this latter table is on average about 35%, for the level of risk "high". Only the farm n. 3 shows a percentage of defaults of about 20% compared to all the relevant items. However this latter result is a high value in order to express a positive view on safety conditions for workers. Finally, nine farms in the sample reach a score higher than average. Subsequently, data by sectors were observed, as they were indicated in the check list, in order to identify those farms which require priority actions and those farms which, in general, guarantee sufficient security levels.

Access to the farm and internal viability

The control of the outside of the buildings aims to verify their dimensions which represent a crucial aspect for reducing the risk of accidents between workers and means of transport circulating in the farm.

With regards to the easy accessibility and the possibility of movement, the 84% of the farms is in satisfactory condition, and only in three cases the situation presents significant inadequacy, since the visibility conditions in both directions is insufficient and the space for manoeuvres are limited.

The presence of subsidences and holes on the roadbed, and the consequent difficulty in removing the rainwater, is a problem common to all farms in the sample. To that issue farmers still give little importance, assuming that the experience gained in the use of machines is sufficient to ensure the safety of workers, even in situations that could become dangerous.

Doors and passageways, flooring and walls

The first clear lack in this sector is the total absence in all the farms of emergency exit in pens with presence of free animals. They are required in case of unmanageable animals, even if that risk is extremely rare in the opinion of all farmers interviewed. The doors and gates also are lacking is systems that prevent the sudden shutting for accidental causes. The most inadequacies were found for the sliding gates that in none of the reported cases have devices against the diversion.

To analyse the characteristics of flooring and wall finishes, it is necessary to distinguish the different rooms of the farm. The milking rooms are satisfactory. They, in fact, are generally equipped with non-slippery floors and walls covered with tiles to ensure the safety of milkers and adequate level of hygiene during milking routine (Failla *et al.*, 2001). However, in the breeding and outdoor areas there is a lesser degree of attention especially highlighted by the frequent presence of pavements that become slippery when wet.

Ladders and over raised floors

Ladders are frequently (68% of farms) in bad conditions. In detail, the ladders found in sixteen farms are old and rickety and should be immediately replaced with new ones satisfying the current security arrangements.

Only in a farm there are over raised floors not protected by parapets and with too sloping access ramps often travelled in reverse by car travelling. In this case, therefore, adequate protective parapets are needed in order to minimize the risks during operations on ramps and platforms.

Lighting and microclimate

Microclimatic and lighting conditions are very important because frequently are cause of occupational diseases (Frazzi and Lodigiani, 1996). In all farms natural and artificial lighting and micro-climate are satisfactory. There is only one machine shop with poor lighting, and this is probably attributable to the very rare use of such. The lamps for artificial lighting, in general, have a good level of functioning but they require more accurate maintenance. In no cases, however, there are emergency lamps.

Tanks and cisterns – Silos and barns

Only in seven farms there are cisterns for collecting water. The maintenance of these facilities is generally neglected and in all cases there are no elements of protection that guarantee the minimum levels of security against the risk of falling for the operators.

The state of silos, both horizontal and vertical, is largely satisfactory in all the farms visited. The horizontal silos are built up and are generally well proportionate compared to the loads they are called to endure. The vertical silos are prefabricated structures that require assembly and maintenance clearly defined for the security guarantees of the operators. During the survey it was verified the observance of the assembling procedure with most cars for the fixing to the ground.

The barns require more attention especially as regards the disposal of round bales. In 75% of the farms, round bales are filled overlapped, with consequent risk for the bales to fall down hurting not only workers but anyone in the proximity of the barn.

Machine shops

Only three farms are equipped with a room used as a machine shops for ordinary maintenance of machines. Properly because of their rare use, garages visited are not subject to adequate maintenance and they show lack of appropriate hardware equipment, PPE, boxes for medication and insufficient lighting.

Electrical equipments

Eighteen of the farms have electrical installations complying the rules, but only three carry out regularly the necessary periodic checks and to ensure the maintenance of all elements of the electrical installation in terms of integrity and cleaning. In just one farm, however, does not exist adjustment and maintenance of electrical installation, resulting a substantial risk of electric shock for the operators.

Noise

The problems caused by noise are among the most neglected: in no farms the overcoming of noises thresholds are evaluated, nor adequate ear protectors are used. This attitude is attributable mainly to two reasons: firstly the lack of farmer awareness of damage caused by excessive exposure to noise, with consequent underestimation of the importance of prevention; secondly the limited use of noisy machinery that induces operators to reject ear protectors.

Biological Contamination / zoonosis / sanitation

The hygienic conditions of the livestock building were investigated only by two entries in the check list: a voice analyzes the level of ventilation of the rooms, always positive checked in all farms in the sample, and a voice verifies regular cleaning of bedding and shelters, which in one case it is not respected.

All animals are subjected to regular veterinary checks and vaccinations, thus offering good guarantees in terms of prevention of possible cases of zoonoses.

Handling of objects

The problems related to manual handling of objects are neglected by employers and operators. In 90% of farms, workers are not engaged in activities that require excessive physical efforts. In the only farm in which the issue assumes importance, the employer provided mechanical means of transport for solid foods in order to reduce the physical commitment of employees.

Personal protective equipment (PPE)

The use of PPE is limited to boots and, in a few cases, to work gloves; in none of the farms examined operators wear gloves and masks for the operations in the livestock building and field or during the application of garrison sanitary. In three farms employers have purchased to workers masks and gloves, whose use remains however sporadic.

Conclusions

The analysis of check lists compiled during the survey to a sample of farms sited on Hyblean Plateau has supplied information concerning the adjustment of farms themselves to existing regulations on safety and health of workers, and to distinguish areas that need immediate attention from the one that may be considered satisfactory. The adjustment to these regulations is generally unsatisfactory, all farms have obtained high absolute scores in the compilation of checklists. Indeed, taking as maximum acceptable two major defaults, the results reported express a general situation of serious inadequacy. It is clear, then, the widespread non-compliance to existing regulations on health and safety of workers, although most farms have the characteristics for being subjected to the rules contained in Italian legislative Decree n. 626/94.

The buildings situation is critical, probably because too few checks have been carried out in order to led employers to achieve the necessary adjustment. The latter, moreover, are very expensive and farmers are not encouraged to come to them also in view of the lower frequency of serious accidents that occur inside buildings compared to those caused by improper use of agricultural machineries. It follows, therefore, the urgent need for a targeted training of employers and workers to enable them to gain awareness of the problem of safety and to understand the importance of specific interventions. Institutional authorities and trade associations must be involved to act in a capillary way in the territory, creating opportunities of meeting and confrontation among workers aimed at encouraging the culture of prevention and safety. The objective can not be simply to obtain the rules compliance of the rules by the farms, but must be to achieve especially awareness of the problem of all those involved in the production process.

Finally, the situation analyzed is representative of farms that have at least one employee. On the Hyblean Plateau, however, there are many family farms without employees, and therefore not subject to the requirements set by the Italian legislative Decree n. 626/94. That fact, however, must not promote working conditions that do not guarantee minimum safety requirements. It becomes necessary, then, to remove the conviction, unfortunately very widespread, that the safety and health of workers are simply a legal obligation and it is necessary to plan activities to spread the general awareness of the problem even among those

who will be never checked but who have as well the duty to ensure an environment of work appropriate even only for himself.

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Transportable prototypes for milking and dairy processing in wild or transhumant flocks

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Abstract

The aim of this research was the experimentation of a transportable integrated system for milking and dairy processing in wild or transhumant flocks. This system is made up of three elements: a module where a mechanical sheep and goat milking plant is installed; a module containing dairy machinery to transform the milk produced; and a lorry, type approved as an agricultural tractor, to transport, one at a time, the two modules following the transfers of the flock.

The prototypes were designed following the introduction of the EEC 92/46 and 92/47 directives, which regulate milk production and dairy products. In fact, also the shepherds who rear flocks in the wild and operate in protected areas or those who practise transhumance must have suitable premises and equipment to keep selling milk, cheese and ricotta in accordance with consumer protection regulations. The system meets the requirements of the law and can operate without direct connection with the water, gas or electricity mains supply, in the open field near the flocks and with only one operator to manage it.

The experimentation shows the functionality and suitability of the two prototypes for the production processes also in conditions where there are no infrastructures (water, roads, etc.) with optimal performances. The times taken to complete the milking operation and the dairy processing are comparable or shorter than those taken by the shepherds with the traditional methods. Moreover, the vehicle is able to transport a module off road in the predictable operative conditions.

Keywords: typical cheese, sheep farming, protected areas.

Introduction

With the introduction of the EEC 92/46 and 92/47 directives, which regulate the production of milk and dairy products, and were applied in Italy by means of the D.P.R. (Presidential Decree) no. 54 of 14th January 1997, also the shepherds who rear flocks in the wild and operate in protected areas and those who practise transhumance must have suitable premises and equipment to continue selling milk, cheese and ricotta in accordance with the consumer protection regulations. For this reason it is necessary to set up dairies with milking sheds that conform to the regulations. These solutions, however, are not consonant with the conditions under which shepherds who practise this form of sheep farming work. For these shepherds, in fact, the construction of buildings is not possible, because both of landscape constraints and their type of transhumant farming, which involves frequent movement of the flocks during the lactation period, so they must greatly modify the ways they produce and transform milk. Most shepherds, therefore, have found that they can no longer transform milk. Consequently, sheep farming has been abandoned as the shepherds, no longer being able to realise a profit from transforming the milk they produce, are obliged to sell it to the large dairy companies (Istat, 2005 and 2006), who deal with collecting it but fix disadvantageous prices. A great reduction in the number of sheep farms occurred between 1990 and 2000

(-40.5%); furthermore, the number of sheep fell sharply between 1999 and 2000 (-38.2%), a drop only partially made up for in 2001 (+22%). From 2001 to this date there has been a stability in the number of animals (Istat, 2005 and 2007).

The consequence is that some typical products are disappearing as, given they depend on pasturing, they cannot be guaranteed by the large companies. At the same time the protection and safeguard of the territory represented by the shepherds is coming to an end, particularly in fringe areas, which will soon be unpopulated.

In an attempt to limit this phenomenon, an integrated system to carry out sheep milking and dairy processing to produce *Pecorino* cheese and ricotta was designed.

Material and Methods

The system

In order to enable shepherds to produce and to transform milk in suitably hygienic conditions and in conformity with the current regulations, and to keep alive some traditions and foodstuff production an integrated system was designed and realised. It is made up of three elements: a module where a mechanical sheep and goat milking plant is installed; a module containing dairy machinery to transform the milk produced; and a lorry to transport, one at a time, the two modules following the transfers of the flock.

The system, intended for flocks of 200-400 animals, was designed in such a way as to be managed by a single shepherd, who should be able to carry out the milking, the transformation of the milk and, with the help of the vehicle (when free of the containers), the transport of anything necessary both for the functioning of the equipment (water, Diesel fuel, GPL, etc.) and for the needs of the flock and shepherd (fodder, feed, dairy products, food, etc.) as well as the periodic transfer of the containers.

The modules containing the milking and dairy processing equipment (fig. 1) are containers realised with sandwich panels, insulated with polyurethane and with smooth, washable, stainless sheet steel internal surfaces. These are anchored to a framework of rectangular steel pipes that have the function of both sustaining the equipment installed and making the structure rigid. At the corners of the framework there are four telescopic legs, commanded by means of hydraulic jacks connected in parallel, which have the double function of raising the container in order to permit a single operator to load and unload the transport vehicle and of making it possible to level the floor, even if the ground is not perfectly flat. The decision to carry and not tow the modules, on one hand makes progress and manoeuvres on tortuous and dug up tracks easier, on the other it set limits on their dimensions. In fact, in order to remain within the limits established by the highway code, the modules were kept down to a width of 2.2 m and a length of 3.1 m and it was, moreover, necessary to make the roof of the milking container telescopic – on installation at the milking site this can be raised 60 cm higher with respect to its transport position. Moreover, in order to avoid duplication of equipment, a milk refrigerator tank, a water tank and a heat generator were installed only in the dairy processing module. Finally, there is only one generator set, driven by a Diesel engine and capable of supplying 5.5 kW of electric current, designed to meet the needs (at different times) of the two modules.

The vehicle (fig. 2), constructed for the transport of the milking and dairy processing modules, is classifiable as a tipping lorry but type-approved as an agricultural tractor, and is, therefore, subject to the specific regulations governing its maximum speed. It has a 2,068 cm³ and 35 kW Diesel engine, one reverse and five forward normal gears, a two-speed transfer case, as well as the possibility of using 4WD (2WD can be disconnected). It can, therefore, be driven over loose earth with a steep slope and is thus suitable for use in the hilly fringe areas

where there is most pasturing. The vehicle, when it is free of containers, has a dump body with hydraulic hoist and four side boards; it also has a tow hook to attach an operating machine that can be powered by p.t.o.



Figure 1. The container



Figure 2. The vehicle with a module

As regards the milking module (fig. 3), the dimensions of the container permit the installation of a small milking plant with an eight place auto-blocking system realised with galvanised steel section bars and complete with feeder and troughs in stainless steel. The sheep enter and exit by means of ramps with railings. The rear doors, which during transport close off the animals' entrance space, constitute the first part of the ramps and are connected to the final sections, which, when the plant is not in use and during transport, can be kept inside the container. In order to control the entrance and exit of the sheep or goats at the sides of the auto-blocking system there are two sliding gates while, in order to reduce obstructions in the plan, the gangway to the stands is retractable, so that, while the animals are going in or out of the container, the operator is obliged to stay outside as the retractable gangway occupies his workspace. Once the gangway has been closed he can enter the module by two doors along the side of the container and proceed with the milking. The gangway, the two sliding gates, the feed doser and the block device are controlled pneumatically by jacks set in motion by means of a 1.5 kW electro-compressor and operated from a panel installed on the door near the animals' entrance gate; on the same door there is the general electrical panel.

The milking plant is a low milk line with four milking units and an automatic washing installation. Stainless steel was used both for the 40 mm diameter milk pipes and the milk terminal 32 dm³ container. The milk pump (0.66 kW), with both the rotor and casing also in stainless steel, was installed immediately below the milk terminal. The vacuum circuit, made up of 42 mm diameter galvanised steel tubes is kept in depression by means of a vacuum pump, which, powered by a 2.2 kW electric motor and provided with a 55 dm³ tank, is capable of aspirating 750 l/min of air at 50 kPa. A servocontrol is installed in the circuit making it possible to keep the vacuum constant. The pulsation of the milking units is maintained by two pneumatic pulsers regulated at a frequency of 100 pulsations per minute with a 50% ratio. The milking area is also provided with two douches, connected to the water supply by means of flexible tubes. These can be used to wash the animals' teats before the attachment of the milking units.

The equipment was placed under the floor of the auto-blocking system, which for the convenience of the operator was raised 90 cm higher than the floor of the container. It was isolated from the milking area by creating compartments in galvanised metal sheets in order to create separate areas for milking - milk area (milk pump, milk terminal, hygienic separator,

plant washing tank) and for the vacuum pump. This guarantees maximum hygiene for the milk area and, at the same time, reduces the surfaces to be washed.

The milking module is integrated with the dairy processing module and the milk can be sent either to the refrigerator tank or the processing tank in the second module.

In the dairy processing module there is a processing tank for the dairy processing of 200 litres of milk per cycle. The entire production cycle of pecorino cheese and ricotta can be realised in this, including the thermal treatment of the milk. The heating of the milk or the whey it contains is brought about by circulating hot water, produced by a GPL heat generator, in the interspaces of the processing tank, while to cool down the milk from the pasteurisation temperature (75 °C) to that required for the cheese making process (38 °C), water from an 800 litres tank is circulated in the same interspaces. The tank is equipped with a refrigerating plate to guarantee the prototype's constant performance also with a smaller volume of water.

According to the traditional pecorino making process, the formation of the cheese moulds involves removing the curd manually from the processing tank and takes place on a dripping table, equipped with a container for the collection of the whey drained from the cheese (fig. 4). Subsequently the same table is used to fill the baskets of ricotta. The dairy processing equipment is completed by one sink accessible from inside the container and another from outside, fed by a 12 Vcc autoclave, a 100 litres refrigerator and a cupboard for tools and detergents. All the liquid waste is collected in plastic tanks placed under the container: there is the possibility of separating washing water from the whey, which can be used as food for the sheep and goats. This would satisfy the requirements of decree no. 152 of 11th May 1999 and of executive decree 7th April 2007 on the protection of the waters from pollution which, however, in certain cases, provides for an agronomical use of liquid waste.



Figure 3. The milking module



Figure 4. The dairy processing module

Besides the entrance door, the container is also provided with two big windows with mosquito nets, which let in sufficient natural light. This can, however, be integrated in case of need by an artificial light plant functioning at 12 Vcc by means of an electrical accumulator, kept charged by a battery charger. There is also an aspirator installed in the roof, also this functioning at 12 Vcc. The electrical apparatus, powered at 220 V (heat generator, circulation pump, refrigerator, battery charger, etc.), is controlled from a general electrical panel, which in its turn can be connected, by means of a connection outside the container, either to the electricity mains supply, if this is available, or to a generator set.

By positioning the two modules strategically (fig. 5), the area in front of the entrances to both the milking and the dairy processing modules can be protected with a blind and it turns into a service area separated from the flock.

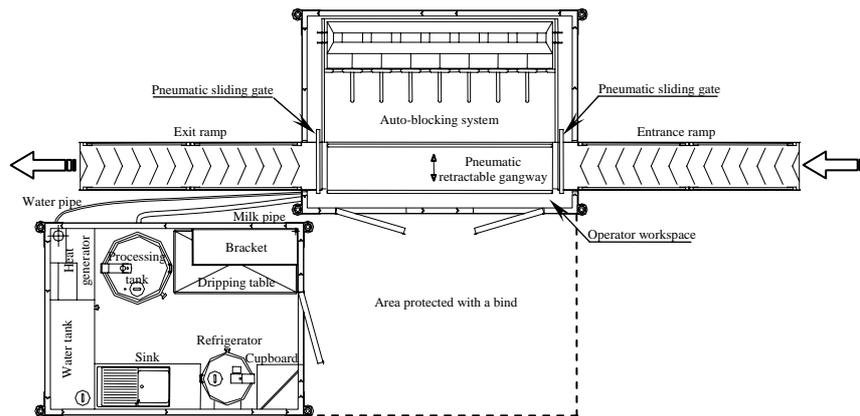


Figure 5. Plan of milking and dairy processing modules

The experimental trials

As the milking module was realised in a different research project from the one for the vehicle and the dairy processing module, during the experimentation it was not possible to carry out trials with the two modules connected. However, the suggestions of technicians and operators received in the course of numerous demonstration days were considered. Moreover, several trials were carried out to assess the functionality and the performance of the three elements.

As regards the vehicle, trials were carried out on this, both unloaded and loaded with the dairy processing module, which represents the most difficult load as regards both weight and height, in order to assess the traction control and identify the transversal stability limits in the conditions in which it would normally be used. In fact, transfers were carried out to determine fuel consumption on the road and to verify manoeuvrability and traction on tracks. Furthermore, loading and unloading operations were carried out with different soil conditions to assess whether only one operator would be able to complete the procedures.

Instead, the milking module was positioned for an autumn-winter-spring season in the pen of a flock consisting of about 100 sheep of the Comisana breed. Once the shepherds were familiar with the equipment, trials were carried out to measure the times taken to carry out the different elementary phases into which it is possible to break down the milking operation. In particular, the following times were considered: the time taken for groups of 8 sheep to enter the container and each take up a place in the auto-blocking system; the time taken for the operator to take a milking unit from its support and attach it to the teats (attachment time), to remove a unit from a sheep and attach it to another one (detachment/attachment time) and to remove the unit from a sheep and put it back on its support (detachment time); and the time taken by a group of milked sheep to leave the container and permit the start of a new milking cycle. Other times considered were: the massage time, which is the time taken for the shepherd, before detaching a milking unit, to manually facilitate the emptying of the udders; times in which the operator rested; dead times, essentially including the times necessary to verify the presence of dry sheep and the positioning of the milking units to facilitate the attachment operation. Another element considered for each 8 sheep milking cycle was the number of dry sheep.

Once the data had been collected, the average values for each of the times considered was calculated and the cycle time necessary for the milking of a group of 8 sheep was also calculated. This was done by summing the average times for entrance, exit and rest with the dead times and the average attachment, detachment/attachment and detachment times,

multiplied by four, this being the number of units installed, and 8 times the average massage time minus the percentage of dry sheep found in the year. Moreover, the data relative to the milking cycles where there were no dry sheep was extrapolated in order to determine the ideal cycle time and to find out whether the separation of lactating sheep from dry ones before milking might significantly reduce the time necessary to complete the milking of the entire flock. Finally, for each day on which the times were measured, the percentage number of fewer cycles that would have been necessary had the dry sheep been prevented from entering the milking module was calculated.

After all the flock had been milked, the quantity of milk produced was checked as well as the amount of water used to wash the plant and quantity of Diesel fuel required by the generator set that powered the equipment. As the dairy processing module was not available, the milk produced was collected in buckets or milk cans, the water supply was obtained by connecting the container to the water mains, while to produce the hot water necessary for washing the plant, an electric boiler powered directly from the mains was installed so as not to influence the consumption of the generator set.

As regards the dairy processing module, numerous processing trials were carried out with both 200 litres and 100 litres of milk per cycle to verify the flexibility of use. In some cases, moreover, two processes were carried out one after the other, even if this would not normally happen, in order to assess performance also when there is an overload of work. During the trials the time taken for each phase of the work was monitored as well as the changes in temperature of the milk during pasteurisation, of the whey used for the production of ricotta and of the water in the heater and inside the tank respectively during the phases of heating the milk or whey and of cooling the milk from the pasteurisation to the cheese making temperature. Other data collected regarded the consumption of GPL for the heat generator, the consumption of Diesel fuel for the generator set and the total water consumption for the process and the washing of the plant.

Results and Discussions

The trials carried out on the three elements of the system, showed that a single operator is able to manage the whole system. However, the results for each element are reported here.

Vehicle. It is manageable in manoeuvres also during the transport of a container and it is remarkably stable both on the road and on tracks (a limit of a transversal slope of 22% was identified). So it is able to carry out transfers along mountain tracks typical of the internal areas. On asphalted roads, on average 4 km were covered with a litre of Diesel fuel, while on bare tracks the traction control was excellent as regards both power available and the adherence of the wheels (the vehicle went up 30% slopes fully loaded). Certainly, as regards transport over long distances the maximum speed was penalised – on various occasions round trip distances of 500 km were covered, but these distances are very unusual in transhumance.

The loading and unloading of the modules onto and off the vehicle was found to be fully satisfactory: even on sloping ground not previously prepared, the shepherd-driver was able in just a few minutes to single-handedly load or unload the module from the loading platform without ever meeting any type of problem.

Milking module. In the flock with which the trials were carried out, on average 18% of the sheep were dry during the trial period. This led to the need for 17.5% milking cycles more than would have been necessary if the dry sheep had been prevented from entering the container. Figure 6 shows the times taken into account to complete the milking of 8 sheep both with and without dry sheep. The great difference in time is in the entrance time due to the presence of the dry sheep in the group, which slow down the entry phase. Without dry

sheep the attachment, detachment, rest and massage times are also shorter because the shepherd has less time to complete the operation. Only the dead time is greater.

The cycle time was 4.5 minutes/head when the dry sheep were also present and was reduced to 4.2 minutes/head when all the sheep were in lactation. These results indicate hourly capacities of 107.8 and 114.4 sheep/hour milked respectively with an increase in productivity in the latter case of 6.1%. This increase, considered with the 17.5% fewer cycles that would have been carried out if the dry sheep had been prevented from entering the milking module cannot be considered negligible. Finally, the time required to prepare the plant for the washing procedure after milking was on average 5 minutes. The washing time was 40 minutes but this does not require the presence of the operator as it is automatic.

The water consumption for the post milking wash was 230 litres, while the fuel required to power the Diesel-electric set was 1.3 kg. Although the water consumption may seem high, it cannot be reduced as it is this quantity of water that guarantees the elimination of traces of detergent from the milking tubes. Moreover, the 800 litre capacity of the water tank in the dairy processing module guarantees autonomy for an entire day. Besides, a frequent change of water ensures that the water will not become stagnant and therefore unsuitable for use in preparing food. Finally, the concentration of pollutants in the waste water is reduced and it should therefore be possible to discard it on agricultural land if there is no public drainage system available, as is likely, given the type of flock the plant has been designed for.

Dairy processing module. The plant was subjected to a wide range of tests with reference to the productive cycle used by shepherds for the production of *Pecorino Siciliano* cheese and ricotta. Overall the transformation of 200 litres of milk took, on average, about 3.3 hours, using 2.5 kg propane gas for the heat generator and 1.8 kg fuel for the Diesel-electric set. The incidence of each phase of dairy processing to produce cheese and ricotta is shown in figure 7.

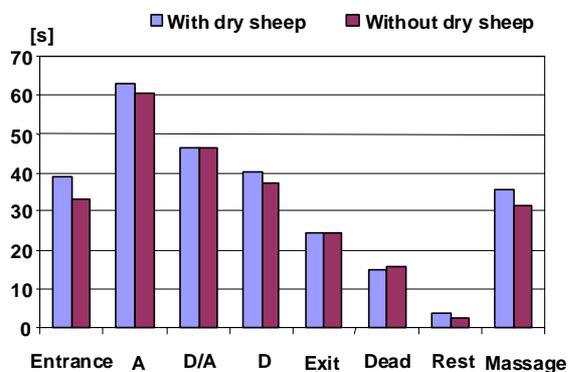


Figure 6. Times taken for each phase of milking operation

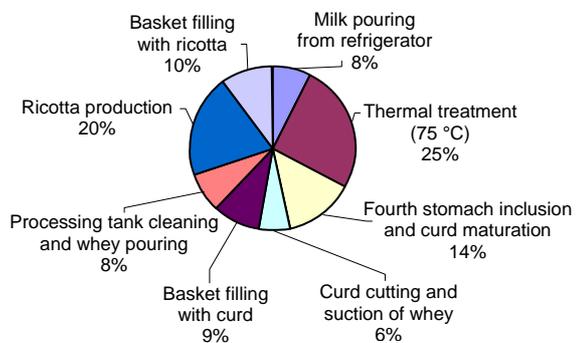


Figure 7. Incidence of each phase of dairy processing procedure

The longest time is taken by the thermal treatment (about 50 minutes: 25 minutes to heat the milk to the pasteurising temperature of 75 °C and 25 minutes to cool the milk from this temperature to the cheese making temperature of 38 °C using the 800 litre tank installed). So, the time to complete the dairy process, if shortened by the time necessary for pasteurisation, is comparable with the time currently taken by Sicilian shepherds to carry out the same process in the traditional manner. Clearly, both the consumption of gas and that of Diesel fuel can be markedly reduced if pasteurisation is not carried out, while the execution of thermal treatment of the milk at 65 °C did not appear to lead to a significant difference.

If the dairy processing is carried out only in the morning, it is necessary to keep the milk produced in the evening in the refrigerator and another 2,2 kg fuel is needed for the Diesel-electric set. Finally the water consumption to wash the plant was about 170 litres per cycle.

Conclusions

Since the introduction of community regulations 92/46 and 92/47/EEC, there has been a tendency to abandon the pastures and consequently inland and fringe areas. This has had serious repercussions both of a social nature, above all in areas where unemployment is high, and on the environment, given that the protection given by shepherds to the territory is no longer guaranteed. In order to limit this phenomenon, it was decided to intervene, realising suitable structures that would make it possible to continue following traditions and producing typical cheeses while also complying with current regulations. The study has demonstrated that this is possible: in fact, even if there are no infrastructures (water and electricity mains supply, buildings, roads and so on), the prototypes of the vehicle and the modules for milking and dairy processing realised can meet the requirements of shepherds with sheep or goats in the wild or transhumant flocks. Their operational simplicity has also been demonstrated, one person being sufficient for all phases of the work. The performance is optimal in that it is clearly superior to that obtained at present by shepherds.

The system proposed in this work could moreover also be used – if suitably powered and re-dimensioned – by shepherds with small non-migratory flocks. Instead of building or adapting existing buildings at great cost, they could use these ready made modules, connecting them directly to the water and electricity mains for water and power and to the drainage system for the disposal of liquid waste.

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Farm Welfare Index for assessment of wellbeing in swine farms

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Abstract

Animal welfare in swine farms can be evaluated by means of different methodologies. An Italian research team has recently developed a new methodology to assess animal welfare in cattle farms. The same methodology has been now applied to pig farms.

The system called FWI (Farm Welfare Index, Italian letters IBA) is based on a specific check list for each different category of animals in the farm. The check list data are elaborated to give a farm score on the basis of limited and objective parameters to be recorded during the farm visit. In such a way the score is given taking into account both well-established technical parameters experimentally tested by specific researches or derived from experience of farmers and advisors and the legislation in force.

The assessment of welfare using FWI is in progress in 80 pig farms located in the North of Italy. The assessed swine farms will be scored according to the FWI methodology by a total score on general farm inputs and by partial scores referring to the housing systems used for different pig categories; in addition non conformity to current regulations will be reported.

At the end of the process, every farm has to be classified by the total FWI score. The index can allocate the farm in one of the 6 different classes with an increasing level of welfare from 1 to 6.

Keywords: animal welfare, welfare assessment, Farm Welfare Index, pig housing.

Introduction

The welfare of farm animals is a current issue. Defined by Hughes (1976) as that "*state of complete mental and physical health in which an animal is in harmony with its environment*", it is required not only for ethical reasons but especially to have healthier animals able to provide more wholesome food.

Employees and farmers in particular must consider animals' welfare as a great opportunity to improve farming techniques and structures to develop productive services, reduce health issues and add value to farm products.

One of the most important aspects for the welfare and health of animals is the farm environment, defined as all the elements around the animal that condition the life and behaviour of the housed animals. Thus, it is not by chance that the environment is the main subject that almost all the current animal welfare evaluation systems focus on.

Among the most important elements that contribute to defining the farm environment is the microclimate (temperature, humidity, air velocity), light, gas and dust concentration, noise, the type of housing (single or collective, fixed or free, open or closed), the living space for each animal, the type of flooring (full, slatted, with litter), the shape and distribution of the farm areas, hygiene conditions and the microbial environment, the feeding system (size and type of equipment to supply feed, location of feeding areas), the water distribution system.

To evaluate the aforementioned aspects, the subjects related to farm construction must be studied in particular, paying special attention to the farm and housing systems, structures, equipment and farm facilities and the environmental control in the buildings.

Systems to evaluate animal welfare

The systems to evaluate animal welfare can be subdivided into the following categories:

- systems based on functional farm equipment and facilities tests in order to verify performance and correlation with animals' welfare (for example, the German test DLG);
- diagnostic systems based on welfare "indicators" for individual animals (for example, productive parameters or behavioural, health and physiological aspects);
- on-farm index systems that estimate the potential of farming methods and structures to provide animals with a certain level of welfare.

On-farm evaluation index systems, the ones only that interest us at this time, are characterized by basic criteria that can be summarized as follows:

- highlighting the most serious mistakes concerning farm system and structures;
- emphasizing the most relevant aspects for farm animals' welfare;
- rapidity of the evaluation (farm visits and then assigning points) and training evaluators and then lowering evaluation costs;
- increased repeatability of points for objective and measurable parameters (in the case of evaluations repeated at different times or by different evaluators).

These criteria provide the general set up of the applicable approach to evaluate the welfare of raised pigs and rely on consolidated technical parameters, set up through research, experimentation and the experience of farmers and technicians as well as, obviously, current legislation.

For this last point, the following regulations enacted by the European Community and in Italy regarding pig prevail:

- the general regulation dealing with protecting farm animals (*Regulation 98/58/CE* enacted by *Legislative Decree nr. 146* of 26/03/2001);
- the specific regulation to protect pig (*Regulation 91/630/CEE*, *Regulation 2001/88/CE* and *Regulation 2001/93/CE*, enacted by *Legislative Decree nr. 534* of 30/12/1992 and by *Legislative Decree nr. 53* of 20/02/2004).

The primary limitation of these evaluation systems is that they cannot rely heavily on scientifically tested criteria, like, for example, possible tests to be carried out on animals (Leeb *et al.*, 2004) or possible laboratory analyses which would involve costs and timeframes that are not compatible with the investigation methods in question.

Another possible critical evaluation point is the time of the farm visit. From this point of view, it is preferable not to establish or give too much importance the evaluation parameters that can vary considerable from season to season. In this regard, an example is the discovery of toxic gas concentrations in farms which, relying heavily on ventilation and moving waste, can vary from summer to winter and from one day to another.

Among the different on-farm evaluation index systems, *ANI* is particularly noteworthy (*Animal Needs Index* or, in the original German, *TGI- Tier-Gerechtheits-Index*). The original and creative idea of creating an animal welfare evaluation index comes from Bartussek, who proposed an animal welfare index as part of the Austrian regulations on factory farming (1985). This index was subsequently drafted and improved to arrive at the current version called *TGI 35 L* (or *ANI 35 L*), applicable to cattle, laying hens and fattening hogs (Amon *et al.*, 1999).

The farm visit is based on the evaluation form where the range of scores assigned are listed based on environmental conditions, technical and technological prerequisites and the measures regarding the way the farm is managed for different functional areas that have an impact on the animals' health and welfare.

TGI 35 L is essentially based on technical farm system requirements, like the availability of space and the quality of flooring and considers 30-40 verification criteria, including: the possibility of moving; the possibility of “social “interactions among animals of the same species; flooring types and conditions; light and air conditions; characteristics of staff working in the barn.

The system purposely leaves out aspects regarding feeding since it is considered that supplying appropriate animal feed is a *sine qua non* condition not so much for wellbeing as the farm's profitability.

The scores given initially varied between one and seven points for each functional area of the farm, for a maximum of 35 points. With subsequent changes, the points were further differentiated, including negative and maximum points over those initially proposed (from -9 to + 45.5). Now, this system takes into account that animals can counterbalance negative influences in functional areas with positive aspects.

In Austria, the *TGI 35 L* has been used since 1995 for organically certified farms. The minimum score needed to obtain certification is 21 for current structures and 24 for new or renovated buildings. Based on the species in question, the system gives “importance” to different variables considered.

Based on this concept, another model was developed by Sundrum *et al.* (1994). Created as a contribution for public calls for tender, it provides a simplified method to evaluate animals' welfare on calves, pigs and hens farms.

TGI 200 (or *ANI 200*) considers 60 -70 evaluation criteria and, in particular, emphasizes factors that impact animals' health. The points assigned are within a variable range from zero to 200. The reason for such a high score is due to the possibility of various special features occurring in various functional categories. For this reason, based on the type of species and the purpose of the farm, it is not always possible to reach the maximum number of points in terms of excellent care and health.

Methodology

A group of researchers at the Research Centre on Animal Production in Reggio Emilia and the Department of Agricultural and Forest Engineering of University of Florence fine-tuned an evaluation system for farm animals' welfare as part of the activities carried out for a project funded by Emilia-Romagna Region.

The project aimed at providing and testing the check lists and experimentally evaluating them with a significant sample of pig farms to verify how they comply with regulations and reference technical requirements for animal welfare.

Below, the main activities carried out for the project are summarized:

- codifying the FWI evaluation system, singling out macro survey areas and aspects of the farm to emphasize;
- arrangement of checklists and defining how they are tested at the farms;
- filling out the checklists at pig farms;
- creating an appropriate spreadsheet (an *Excel* file) to input the data collected and automatically assign points and a FWI class;
- checking and validating the data collected and inputting them on a spreadsheet created for that purpose;

- correcting the pending spreadsheet and validating it;
- classifying the farms using the FWI system, processing sample data and conclusions drawn.

The evaluation system called FWI (Farm Welfare Index, Italian initials IBA) is based on a checklist that allows points to be assigned based on wellbeing, starting with a limited number of objective parameters that are easily measured during the farm inspection. Nevertheless, in some cases, subjective evaluations must be used because aspects such as the internal surface areas of barns and the cleanliness of troughs would require time and special equipment to be evaluated in a way that can then be used. Additionally, it is unanimously agreed that evaluating animal welfare cannot be completely objective.

Different variants of the checklist can be used for all types of pig farms (breeding/fattening farms, breeding farms, fattening farms) with housing of animals inside the buildings.

The parameters studied refer to the following main themes:

- farms systems and barn structures;
- environmental control;
- feed and drinking water;
- animals' hygiene, health and behaviour;
- checking animals, equipment and facilities;
- farm staff.

The checklist for assigning the FWI is subdivided into different parts (table 1). For each farm unit, a general form must be filled out (form A), a form for each farm building (form B) and a form for each type of animals kept inside each building (forms C, D, E and F). Different functional areas are considered for each building and for each type of animal: resting area, feeding area and exercise area.

For instance, in the case of a farm with a building including a room for pregnant sows and several rooms for farrowing sows and with a building divided in different rooms for post-weaned piglets, the following forms have to be drawn up:

- n. 1 form A - General Part;
- n. 3 form B - Building;
- n. 1 form C - Mating/pregnancy;
- n. 1 form D - Farrowing/lactation;
- n. 1 form E - Weaning.

To make it easier to fill out, all questions that have to be answered by the head farmer have been placed in the General Part of the form while the remaining forms in the checklist can be only filled out by the surveyor through observation, measuring and evaluation. The surveyor is equipped only with a compass, an 8-m flex meter and a laser diastimeter.

Types of questions and assigning points

One of the most complex aspects in defining an evaluation method for welfare is certainly assigning points to the individual questions and the groups of similar questions by type. In fact, it is important to carefully weigh the different parameters in question in order to create a reliable and sufficiently objective classification grid that fulfils the goal of evaluating farm animal welfare. There are essentially four types of questions on the checklist:

1. free response or description;
2. yes/no answer;
3. codified answer;
4. numeric answer.

Several type 1 questions do not assign points and are only included to more precisely characterize the farm and to allow further cross-checks with other types of questions.

Assigning points must be varied based on the relative importance given to individual questions; in fact, always using the same points is not helpful (for example, 0-3 points or -1 to +1) as shown by several evaluation systems that are used, because the same importance is given to aspects that can have very different significances.

In short, by defining the classification system, the following basic criteria were respected:

- assigning higher maximum scores and minimum negative scores for the most important and easiest aspects to evaluate like, for example, the type of housing or farm surface area;
- assigning the lowest maximum scores to detailed, or less important, aspects and more uncertain evaluation parameters, like those that require a more subjective evaluation by the surveyor;
- setting up an adequate program to calculate points that take into consideration the type of questions and how they interact and provide for different possibilities in terms of the number of forms to fill out.

FWI score

The FWI score is made up of the sum of 3 partial scores:

- *GENE* score, for general data;
- *BUIL* score, for buildings;
- *CATE* score, for pig categories.

A farm's *BUIL* score is obtained from the weighted average of the total live weight for the individual scores for each building. The *CATE* score comes from the sum of the points assigned to the various pig categories.

The FWI evaluation system assigns a welfare index for each farm evaluated; the index value places the company in one of 6 prearranged levels:

- Class 1 - Farm does not comply with the minimum welfare requirements;
- Class 2 - Farm with a low level of welfare;
- Class 3 - Farm with a sufficient level of welfare;
- Class 4 - Farm with a fairly good level of welfare;
- Class 5 - Farm with a good level of welfare;
- Class 6 - Farm with an excellent level of welfare.

Assigning the FWI is accompanied by a short technical chart that lists the most serious lacks found in order to allow the company to make those changes aimed at improving the level of its animal welfare.

The assessment of welfare using FWI is in progress in 80 pig farms located in the North of Italy.

Conclusions

The project arranged a new evaluation system for the animal welfare at pig farms. The FWI system (Farm Welfare Index, Italian letters IBA) is based on filling out a checklist that varies based on the type of farm and allows a score to be assigned, starting with a relatively limited number of objective parameters that can be easily measured during the farm visit.

The methodology inspires the on-farm index systems, including the famous Austrian ANI (Animal Needs Index), which provides a general framework for the applicable approach to evaluate wellbeing, relying on prepared consolidated technical parameters, experimentation and the experience of herders and technicians as well as, obviously, current legislation.

The FWI system is characterized by the following basic elements:

- highlighting the most serious system and farm structure oversights, allowing the farmers to receive more useful and specific information to improve animal welfare;
- emphasizing the most relevant aspects for animal welfare;
- the evaluation is relatively quick (a farm visit lasts 2-4 hours, based on the complexity of the farm and the number of buildings);
- training evaluators does not take long, even if it is preferable to use staff with a certain amount of experience on pig management, equipment and structures;
- thanks to the software available, entering data and the evaluation is quick and relatively simple and the possibilities of error are kept to a minimum.

The proposed methodology has to be validated in specific research projects aiming at comparing the FWI scores with physiological, sanitary and behavioural indicators or with productive performances.

Table 1. Parameters included in the FWI system checklist for pigs

FORM	PARAMETERS
A - GENERAL PART	General data on the company and farm, managing animals, checking facilities and registration, staff, structures for isolation, health
B - UNIT/ROOM	Categories of pig present, barn features, environmental control, level of cleanliness and state of the internal areas of the building and of the equipment
C - MATING/PREGNANCY (sows, gilts, boars and mating facilities)	Housing systems, space allocation, feeding and watering systems, features of various functional areas (feeding place, resting place, excretory place), floors, environmental control, hygienic-sanitary and behavioural aspects
F - FARROWING/LACTATION (sows, suckling piglets)	Housing systems, space allocation, feeding and watering systems, features of various functional areas (feeding place, resting place, excretory place), floors, environmental control, hygienic-sanitary and behavioural aspects
E - WEANING (weaned piglets)	Housing systems, space allocation, feeding and watering systems, features of various functional areas (feeding place, resting place, excretory place), floors, environmental control, hygienic-sanitary and behavioural aspects
F - FATTENING/BREEDING (growing / fattening pigs, young gilts, immature boars)	Housing systems, space allocation, feeding and watering systems, features of various functional areas (feeding place, resting place, excretory place), floors, environmental control, hygienic-sanitary and behavioural aspects

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Feeding behaviour of pregnant sows monitored by means of RFID active tags

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Abstract

The main aim of the research was to present the technical features of the electronic identification systems to study animals and to analyze the behaviour of pregnant sows kept outdoor using new remote monitoring system. In a pig farm located in a mountainous area of Tuscan-Emilian Apennine an outdoor enclosure was examined by means of an innovative monitoring system based on the use of RFID technology (Radio Frequency Identification). The behavioural studies are presented in this paper. Active tags automatically send impulses so the animals can be identified by even distant readers. This ability is guaranteed by using a power battery. The experimental trials were carried out in January 2008. Inside the pen 15 pregnant sows were kept. They could freely move in the enclosure, using a closed hut for resting, feeders and drinkers. Two sows were provided with an active tag inserted in a collar. The RFID equipment was arranged to monitor the presence of the sows in feeding area. In this way it was possible to analyze the feeding behaviour of the sows.

As first result of experimental trials it was possible to state that RFID technology based on the use of active tags can be suitable for monitoring animals in mid-size outdoor pens, providing digital data that can be easily computerized.

Keywords: RFID, animal monitoring, animal behaviour, pregnant sows.

Introduction

Animal monitoring in outdoor grazing areas or in small pens was carried out with different methodological and technological approaches. Different survey techniques have been defined during last years in order to solve different drawbacks in instruments and to arrive to a significant improvement in data collection results. Techniques used till today have regarded the use of videotaping equipment or photographic cameras, but in the latest years the possibility to follow the animals from space by means of satellite telemetry, especially with GPS, has become a reality (Barbari *et al.*, 2008). The continuous technological progress has required the use of very complex structures and also the design of more and more reliable devices, adaptable to every animal species.

Recently the spatial identification process of animals (Jansen *et al.*, 1999; Wismans, 1999) has realized a further development thanks to RFID (Radio Frequency Identification) technology and to other wireless technologies which allow the direct observation of a single animal in specific survey-areas (middle size grazing areas, drinking or feeding areas, cooling areas, etc.).

Such systems have initially found wide spreading in diversified fields such as logistics, transports, etc. For example, the Georgia Ports Authority (GPA) has set to begin installing RFID technology at the Port of Savannah, to track shipments being brought in and out of the port (Wang *et al.*, 2006).

With adjustments in size and weight, these devices based on the use of active tags can be suitable for surveys of remote animal monitoring. The system allows to collect digital data on animal position, easily computerizable, even if it does not give detailed information on the behavioural patterns.

The aim of the study was to examine the technical characteristics and to check the application of electronic identification systems for the study of pigs in small outside pens. The presentation of preliminary results can be useful to appreciate the real technical capacities of RFID active tags.

Materials and methods

Specifications of the RFID Technology

The RFID technology is an automatic wireless identification system composed of three units: a transponder (derived from transmitter/responder) or tag, a reader and an antenna. The reader is used to read the information on the tag, which is composed of a memory chip and an antenna. RFID transponders may be active or passive.

Passive tags do not have batteries and work only if they are sufficiently close to electromagnetic impulses. They are inserted on collars, in earrings or in other subcutaneous places using different methods from one species to the other. The tags allow the animals to be identified when they approach the area under survey. In order to collect information on the animals' behavior in the limited study-areas, for example as regarding the use of equipment, the passive tags can adequately fulfill this task.

The system was recently and successfully applied to individual showering cages for pigs (Barbari, 2005) and to groups of cattle close to feeding areas and other functional areas (Eigenberg *et al.*, 2005).

Active tags are very interesting, especially for animal behavior studies. They automatically send impulses so the animals can be identified by even distant readers. This ability is guaranteed by using a power battery. These devices can be used to monitor animals in mid-size outdoor pens, providing digital data that can be easily computerized.

The systems can be based on two different operative concepts: RTLS systems (Real Time Location System) and Marker systems (or "markers" as they are called by company, Identec Solutions ILR[®]). They were described in detail in previous studies (Barbari *et al.*, 2008 a; Barbari *et al.*, 2008 b).

In this paper only information on RFID tags and position marker running is given. When the tag passes the induction loop connected to the position marker, it is "woken up" and records the information of its position. The UHF Reader transmits and receives data by antennas at distances up to 100m. Each reader guarantees identification of a large number of tags located simultaneously within the study's read zone. The high rate of transmission allows communication even with fast moving tags.

Study area

A testing trial was carried out in the month of January 2008 by the Department of Agricultural and Forest Engineering to investigate a possible application of RFID system in a pig farm located in a mountainous area of Tuscan-Emilian Apennines (Figure 1).

The study area is an outdoor completely fenced pen. The surface is about 6.000 m².

The pen is provided with metallic feeders, drinkers and a resting-shading area. Around the feeding area and the resting area markers are placed to collect the presence of animals.



Figure 1. Study area monitored during testing trials

Methods

A rigorous protocol was arranged in order to fully test the methodology and to draw objective conclusions about the potential applications of the system. The protocol was organized in different operational phases:

- (1) setting up of RFID components, like antennas, reader, position-marker for external loop, hub and laptop (Figures 2 and 3);



Figures 2 and 3. Installing antennas and reader for RFID system

- (2) uploading configuration parameters to the RFID active-tags (identification number, the ping-rate of transmission, etc.);
- (3) deployment of the RFID active-tags on the sows;
- (4) capturing the animals and recovering instrumentation;
- (5) processing data on PC.

Five pregnant sows in a group of 15 sows were provided with a RFID tags, inserted inside a plastic box fixed on a neck collar (Figures 4 and 5).



Figures 4 and 5. The active tag is put inside a plastic box and connected to a collar support to be fixed to the neck of the animal

The boxes were painted with different colours to recognize the single head.

During the processing phase we selected two tags (0.380.111.929 and 0.380.001.250) to be the data source for the analysis. Respectively they automatically send impulses to distant readers in regular intervals of 30s and 2s.

The experimental trials went on for 15 days. Three days were chosen for processing, that is from January 20th to January 22nd 2008.



Figure 6. Sows with RFID-collar close to feeding area

Results

The data collected during the experimental trials, immediately available in digital format (xls format), were examined and analyzed (Table 1).

From the analysis of the data significant evaluations in quantitative terms emerged (639 total data). However the qualitative judgment on the position is not positive. From the observation and selection of assessments only the number of presences of animals in the

feeding area was drawn. It was not possible to evaluate the real time presence of the sows inside the area.

Table 1. Data collected by transponder available in spreadsheets

Date	Time	IP address of Reader	ID of Reader	ID of Tag	Tag battery life	Marker data
Jan 20-08	11:00:28 AM	192.168.0.84	0074611309	0.380.001.250	Good	New 1 1576s
Jan 20-08	11:00:48 AM	192.168.0.84	0074611309	0.380.111.929	Good	New 1 8028s
Jan 20-08	11:01:14 AM	192.168.0.84	0074611309	0.380.001.250	Good	New 1 1622s
Jan 20-08	11:01:18 AM	192.168.0.84	0074611309	0.380.111.929	Good	New 1 8058s
Jan 20-08	11:01:30 AM	192.168.0.84	0074611309	0.380.001.250	Good	New 1 1638s
Jan 20-08	11:03:33 AM	192.168.0.84	0074611309	0.380.001.250	Good	New 1 22s

The graph of figure 7 clearly shows how the two monitored sows gave very different results in terms of attendance at the feeding area.

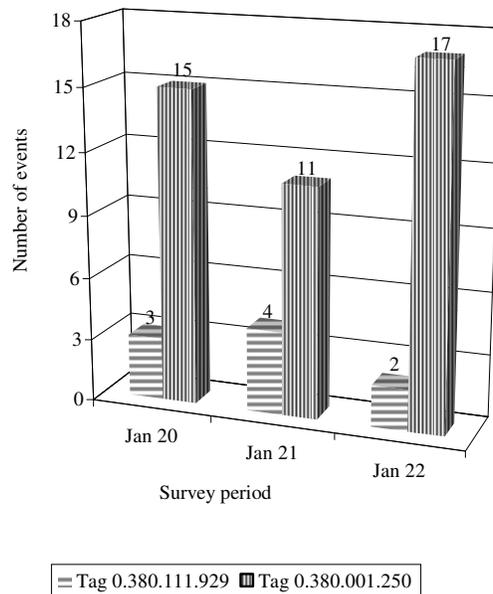


Figure 7. Attending of the feeding area by the two sows

For tag 0.380.001.250 the number of counted events (43) is much higher than for tag 0.380.111.929 (only 9), even if with diversified acquiring times. As a result, we can state that for studies on the behaviour of animals it is much better to use devices with short intervals (e.g. 2s), in order to obtain much detailed information.

During the data processing it was not possible to gather information on the times of attendance of the sows at the feeding area, due to problems on the software for the data management which is at the moment in phase of implementation.

Therefore, especially in this step of hardware and software experimentation it would be useful to support the RFID technology with videocameras in order to compare images with data coming from RFID system and to obtain more information in terms of reliability and real precision in measurements.

Conclusions

The active RFID transponder could provide benefit in the scientific research of animal behaviour. The use of active RFID transponders working together with markers could be an excellent substitute of videocamera survey to monitor animal behaviours for scientific researches.

Further improvements could regard the device installed on the animal (neck collar or other system), that needs to be reduced in size and weight and designed in such a way to reduce lesions on the skin and losses on the ground.

First trials seem to show good results of applicability, considering that the systems are not engineered for this specific purpose. As for the development of passive RFID, the fall of tag size and price of the system will open new opportunities to find application in animal breeding field with regard to rational management of resources, animal welfare and consumer satisfaction. The availability of increasingly cheap RFID systems can encourage the spreading in scientific researches about animal behaviour.

Acknowledgements

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POSTER PRESENTATION

Strategies to reduce heat stress in sheep housing

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Abstract

Three experiments were carried out to assess the effects of ventilation regimens, shading and time of feeding on the welfare and production performance of lactating ewes in summer in a Mediterranean climate. In the first trial we tested the effects of three different ventilation regimens: low (33 m³/h/head; LVR), moderate (66 m³/h/head; MVR) and programmed (operating at 30 °C air temperature and 70% relative humidity; PROGR). In the sheep houses after LVR and MVR treatments were detected higher air concentrations of ammonia and carbon dioxide than after PROGR treatment and sheep of those groups showed higher respiration rate and rectal temperatures. Ewes under the LVR treatment also displayed impaired humoral immune responses and higher plasma cortisol levels than ewes under PROGR or MVR treatment. In the second trial, we tested the effects of two ventilation rates (35 vs 70 m³/h per ewe), two air-speeds (2 vs 4 m/s) and two lengths of ventilation cycles (30 vs 60 min/cycle). Results suggest that proper air speed and length of ventilation cycles, aside from ventilation rate, are required to sustain welfare of housed sheep in summer.

When comparing the effects of providing shaded areas we found that sheep exposed to solar radiation displayed enhanced respiration rate and increased rectal temperature compared with animals protected from solar radiation. Exposure to solar radiation also depressed cellular immune response and adversely affected the hygienic quality of ewe milk. In addition, sheep exposed to direct solar radiation exhibited an increase of inactive behaviours and showed high non-esterified fatty acids plasma concentrations.

Keywords : sheep welfare; heat stress; solar radiation; ventilation regimen.

Introduction

Wide areas of the Mediterranean basin, where dairy sheep are very common, have ambient temperatures in late spring and summer that often exceed the thermal neutral zone (5 to 25 °C) of sheep (Curtis, 1983). Hot climates may induce a rise in body temperature and breath rate, which increases energy requirements for maintenance by 7-25%. Feed intake decreases in heat stressed sheep (Abdalla et al., 1993), especially when they are offered low quality feed (Costa et al., 1992), due to both the effort of reducing heat production and the slower feed transit through the digestive tract. Under these conditions, body reserves of fat and nitrogen are used to supply energy through gluconeogenesis at the expense of the mammary gland, especially in early lactating animals (Amaral-Phillips et al., 1993). High ambient temperatures can also result in plasma mineral imbalance, especially due to reduction in sodium, potassium, calcium and phosphorus and increase in chloride concentrations (Kume et al., 1987; Schneider et al., 1988). Published evidence does not prove that ambient temperature is directly related to udder health, but indicates that it may interact with other predisposing conditions to exert an influence (Klastrup et al., 1987). Beede and Collier (1986) indicated protection from solar radiation and improvement of nutritional management as well as use and genetic development of heat-resistant breeds as the main strategies to improve

productivity in animals raised in hot climates. Ventilation is one of the most important factors in affecting the welfare and production performance of farmed animals, too. Inadequate ventilation systems cannot provide an efficient control of temperature and humidity in animal houses and can lead to increased airborne particulate and gaseous pollutant concentrations, which can represent a significant burden to the respiratory tract of humans and livestock (Rylander, 1986; Hartung, 1994). Previous experiments have shown that poor ventilation is responsible for increased aerial concentrations of viable microbes, ammonia and carbon dioxide, reduced feed efficiency and enhanced aggressive interactions in farmed animals. Three experiments were carried out to assess the effects of ventilation regimens, shading and changing time of feeding to late afternoon on the welfare and production performance of lactating ewes in summer in a Mediterranean climate.

Material and methods

The experiments were conducted at Segezia research station of the Italian Istituto Sperimentale per la Zootecnia (latitude: 41° 27' 6" and longitude: 15° 33' 5"). The climate of this area is Mediterranean, with a rainfall of about 500 mm, a mean temperature of 24.1 °C and a mean relative humidity of 59.4% during summer over the last 40 years. In the first trial 36 lactating Comisana ewes were divided into three groups of 12 and separately housed on straw litter in 8m x 3m and 3.5m high rooms of the same building. Each room was provided with a mechanical negative-pressure system of ventilation, in which 0.28 m² suction fans were placed at 2.5 m from the floor and two 0.36 m² air inlets were placed at the ground level on the opposite wall. Fan speed was kept constant at 4.6 m/s. The three groups were designed low (LVR), moderate (MVR) and programmed ventilation regimen (PROGR). In LVR and MVR rooms, fans provided 10 ventilation cycles of 12.5 and 25 min/h, respectively. In the PROGR room, the fan was connected to temperature and humidity sensors, which provided an on/off two stage control function switching power to the fan. Ventilation system was programmed to operate at 30 °C ambient temperature and 70% relative humidity. A mean ventilation rate of 33, 66 and 173 m³/h per ewe was provided in LVR, MVR and PROGR rooms. The ambient temperature and the relative humidity inside each room were continuously monitored throughout the trial by means of thermo-hygrographs (LSI) placed at a height of 1.5 m from the floor. Air was sampled 0.6 m from the floor twice a week at 0900 (fans switched off in LVR and MVR rooms) and at 16.30 h (fans switched on in all rooms). The concentration of mesophilic micro-organisms, coliforms and yeasts/moulds were sampled using a Surface Air System pump (PBI International, Milan, Italy). Air concentrations of total ($\varnothing > 5 \mu\text{m}$) and breathable ($\varnothing = 2\text{-}5 \mu\text{m}$) dust were recorded twice weekly, using Digit pumps (Zambelli, Bareggio-Milan, Italy). A Lippman cyclone was used for collecting breathable dust. Cellulose nitrate filters having a diameter of 37 mm and pore size of 0.8 μm were used for this purpose. Air concentrations of gaseous pollutants were also recorded twice a week using a Gas Detection Pump (Dräger, Sicherheitstechnik GmbH, Lübeck, Germany), provided with carbon dioxide, hydrogen sulphide, ammonia and methane detection tubes. Respiration rate (RR) and rectal temperature (RT) were monitored in all animals throughout the trial. At 1430 RR was recorded by a trained observer by counting the rate of flank movement and soon after RT was measured with an electronic thermometer having an accuracy to 0.1 °C. Behavioral observations were recorded by two trained observers equipped with video cameras every 15 min from 0930 to 12.30 h once per week. The measurement criterion at each observation period was the number of animals engaged in each of two postures (standing or lying) and of seven behavioral categories, which were eating, drinking, ruminating, walking, self-grooming and idling. The phytohemagglutinin (PHA) skin test was

performed to induce non-specific delayed-type hypersensitivity. At d 3, 20 and 40 of the experiment, 1 mg of PHA (Sigma-Aldrich Italia, Milan, Italy) dissolved in 1 mL of sterile saline solution was injected intra-dermally into the middle of two 2 cm wide circles stamped on shaved skin in the upper side of each shoulder. The skinfold thickness was determined before PHA injection and 24 h after with a caliper. At d 2 of the study, 6 mg of chicken egg albumin (Sigma-Aldrich Italia) dissolved in 1 ml of sterile saline solution and in 1 ml of incomplete Freund's adjuvant (Sigma Aldrich-Italia) were injected subcutaneously in both shoulders of each ewe. A second injection without adjuvant was repeated 9 days later. Antibody titer was determined in blood samples collected in heparinized vacuum tubes immediately before the first antigen injection (2 days) and then at 11, 21, 30 and 40 days of the study period. An ELISA was performed in 96-well U-bottomed microtiter plates. At d 37 ewes were intravenously injected with 2 IU porcine ACTH/kg body weight^{0.75} (Sigma-Aldrich Italia). Blood samples (10 ml) for evaluation of cortisol concentrations were collected in vacuum tubes from the jugular vein immediately before and 1, 2 and 4 h after ACTH injection. Hormone concentration was determined by a radioimmunoassay specific for ovine cortisol. Ewes were milked twice daily (08.00 and 15.00 h) using pipeline milking machines. Milk yield was recorded daily by means of graduated measuring cylinders attached to individual milking units. Milk samples, consisting of proportional volumes of morning and evening milk, were individually collected weekly in 200 ml sterile plastic containers after cleaning and disinfection of teats (70% ethyl alcohol) and discharging the first streams of foremilk. Milk samples were carried in our laboratory by means of transport tankers at 4 °C. The following measurements were carried out in agreement to International Dairy Federation standards, unless otherwise indicated: pH, total protein, fat and lactose content using an i.r. spectrophotometer (Milko Scan 133B; Foss Electric, Hillerød, Denmark), casein content, somatic cell count (SCC) using a Foss Electric Fossomatic 90 cell counter and polymorphonuclear neutrophil leukocyte count (PMNLC), by means of direct microscopic count in milk smears stained with May-Grünwald-Giemsa, renneting characteristics (clotting time, rate of clot formation and clot firmness after 30 min) using a Foss Electric Formagraph. The milk coagulating index (CoI) was calculated as the clot firmness to clotting time + rate of clot formation ratio. At the beginning of the trial, and fortnightly during the study period, the following bacteriological analyses were carried out on milk, according to International Dairy Federation standards: enumeration of mesophilic bacteria, psychrotrophs on plate count agar, total and fecal coliforms. The body weights and body condition scores of the ewes (in a six-point scale with 0=thin and 5=fat) were recorded during the trial.

In the second trial 36 lactating Comisana ewes were divided into three groups of 12 and separately housed in three rooms of the same building as in the first trial. In all rooms, fans provided 10 ventilation cycles per day. Treatments were: low ventilation (LOV-30), moderate ventilation with short ventilation cycles at high air speed (MOV-30) and moderate ventilation with long ventilation cycles at low air speed (MOV-60). In the LOV-30 room 30 min ventilation cycles were provided at a fan speed of 2 m/s. In the MOV-30 room 30 min ventilation cycles were provided at a fan speed of 4 m/s, while in the MOV-60 room 60 min ventilation cycles were provided at a fan speed of 2 m/s. In all rooms, ventilation rate was checked daily by placing a hot wire anemometer (LSI, I-20090, Settala Premenugo, Milan, Italy) over the air outlet and converting readings to m³/h per ewe. The fans provided a mean ventilation rate of 35 m³/h per ewe in the LOV-30 room and 70 m³/h per ewe in the MOV-30 and MOV-60 rooms. Measures taken on air, animals and milk were the same of the first trial.

In the third trial, 40 late-lactating Comisana ewes were divided into four groups of 10 each, which were separately kept in open 5m x 12m pens with mesh-fence boundaries. Shade

was provided by 3m x 8m and 3.5 m high brickwork rooms adjacent to open pens. During the study, animals were either exposed (EXP; not offered shade) or protected from solar radiation (PRO; offered shade). For each solar radiation treatment, feed was offered either in the morning at 10.00 (EXPM and PROM groups) or in the afternoon at 16.00 (EXPA and PROA groups), and the animals had free access to the feed at all times thereafter. Refusals were collected and weighed daily at 10.00, 13.00, 16.00 and 19.00 h. Open pens in EXP groups and shaded rooms in PRO groups were provided with 2 mangers. Averages of daily DM intake were 2.41, 2.25, 2.39 and 2.28 kg/ewe in PROM, EXPM, PROA and EXPA groups, respectively. Water was available at any time for all groups from automatic drinking troughs. Ambient temperature and relative humidity in protected and exposed areas were monitored throughout the trial. Respiration rate (RR) and rectal temperature (RT) were measured in all animals twice weekly. The phytohemagglutinin (PHA) skin test was performed to induce non-specific delayed-type hypersensitivity at d 10, 20 and 32 of the experiment, as described in previous trials. Behavioral observations were recorded by trained observers equipped with video cameras every 15 min from 08.00 to 20.00 h once per week. Jugular blood samples were taken from all ewes at the beginning and at d 21 and 42 of the experiment. Blood sampling was carried out at 07.00 h. Samples were centrifuged for 20 min at 3,500 r.p.m. and plasma was stored at -20 °C, except for a sub-sample which was analyzed enzymatically for plasma concentrations of glucose immediately. The following metabolites and enzymes in plasma were determined within three days from blood sampling: total protein, albumin, bilirubin, NEFA, calcium, inorganic phosphorus, chloride and magnesium, using colorimetric methods, and total cholesterol, urea N, creatinin, aspartate amino-transferase (AST/GOT), alanine amino-transferase (ALT/GPT), gamma-glutamyltransferase (γ -GT), lactate- dehydrogenase (LDH) and alkaline phosphatase (ALP), using enzymatical methods. Sodium and potassium were diluted in a lithium solution and measured by a TRIFLAMM flame photometer (Digiflame, 00100 Rome, Italy). Ewes were milked twice daily (08.00 and 15.00 h) using a pipeline milking machine. Daily milk yield was recorded and milk samples were analyzed as described in previous trials. The body weights and body condition of the ewes were recorded at the beginning and at d 21 and 42 of the study period, after the morning milking but before feeding. All data were subjected to an analysis of variance, using the GLM procedure for repeated measures in the SAS statistical software. When significant effects ($P < 0.05$) were found the Student's t test was used to locate significant differences between means.

Results

First trial. Significantly higher temperature and humidity ($P < 0.001$) were found in LVR than in PROGR room, while both LVR and MVR treatment resulted in higher NH_3 and CO_2 air concentrations than PROGR treatment ($P < 0.05$). LVR and MVR ewes had a higher RT than PROGR ewes ($P = 0.001$). LVR animals also exhibited higher idling compared to PROGR ($P < 0.01$) and lower feeding times than MVR ($P < 0.05$) and PROGR animals ($P < 0.01$). LVR ewes displayed significant lower antibody titers ($P = 0.07$) than PROGR animals (Figure 1) and higher plasma cortisol levels than PROGR ($P < 0.01$) and MVR ewes ($P < 0.05$) 60 min after ACTH injection (Figure 2). LVR treatment resulted in lower yields of milk ($P < 0.01$) and reduced feed efficiency ($P < 0.01$) than PROGR treatment.

Second trial. Averages of maximum THI were about 3 points higher in the LOV-30 and the MOV-30 than in the MOV-60 room, whereas no differences emerged in the air concentrations of dust, gaseous pollutants and microorganisms. Significant interactions of treatment x time ($P < 0.05$) were found for respiration rate, and for the time the ewes spent

lying, idling and eating in the afternoon. Significant effects of ventilation regimen x time ($P < 0.05$) were also observed for milk yield and milk renneting parameters, the LOV-30 ewes giving smaller volumes of milk with a deteriorated coagulating behavior than those of the MOV-60 group during the second half of the trial. When the renneting parameters were gathered in the milk coagulating index (CoI), significant differences ($P < 0.05$) were found between the LOV-30 and the MOV-60 group (Figure 3). No significant differences emerged in ewe immune and endocrine responses.

Third trial. In exposed areas, weekly averages of maximum ambient temperatures were over 30°C throughout the study period and often exceeded 35°C . Maximum ambient temperatures and relative humidities were 3.9 to 6.8°C and 6.3 to 12.3% lower in protected than in exposed areas. During daytime, averages of THI were always near or over 80 in exposed areas, whereas they only exceeded 75 during the second half of the trial. Solar radiation ($P < 0.001$) and the interaction of solar radiation x time of feeding ($P = 0.01$) had significant effects on rectal temperatures (Figure 4). EXPM ewes had higher rectal temperatures than EXPA ewes, which in turn exhibited higher RT compared to PROM and PROA ewes. EXP groups also had significantly higher respiration rates ($P < 0.01$) than PRO groups. Immune response was lower ($P < 0.001$) in EXPM ewes at d 10 and in both EXPM, EXPA and PROM animals ($P < 0.05$) at d 20 compared to PROA ewes (Figure 5). Exposure to solar radiation resulted in decreased plasma concentrations ($P < 0.05$) of alanine amino-transferase (ALT/GPT) ($P < 0.05$), alkaline phosphatase (ALP) ($P < 0.05$), Potassium ($P < 0.05$), Magnesium ($P < 0.05$) as well as in increased levels of NEFA ($P < 0.01$) and aspartate amino-transferase (AST/GOT) ($P < 0.05$). Milk yield and composition were not changed by exposure to solar radiation and time of feeding, but the EXPM treatment resulted in lower yields of casein and fat ($P < 0.05$) and reduced clot firmness ($P < 0.05$) compared with the three other treatments. Milk SCC was similar across treatments, but PMNLC was higher ($P < 0.01$) in EXPM than in PROM and PROA milk. EXPM animals also had the greatest amounts of total and fecal coliforms ($P < 0.01$) and of *Pseudomonadaceae* ($P < 0.05$) as well as the highest number of mastitis related pathogens in their milk.

Conclusions

Our results suggest that a fan ventilation system programmed to operate over upper critical temperature and humidity is not economically attractive in dairy sheep housing. In fact, it involved about a three fold greater energy cost and did not lead to remarkable improvements of ewe welfare and productivity compared to an intermittent regimen split in 25 min/h ventilation cycles during the warmest hours of the day. A further reduction of ventilation cycles to 12.5 min/h resulted in ewe displaying altered behaviour, immune and endocrine responses and giving lower yields of milk. Therefore, our findings indicate that a ventilation regimen, providing ventilation cycles during the warmest hours of the day and the night at a mean ventilation rate of $66\text{ m}^3/\text{ewe}$ per hour may adequately sustain the welfare and production performance of lactating ewes raised in Mediterranean climates during summer.

Doubling air speed from 2 to 4 m/s and ventilation rate from 35 to $70\text{ m}^3/\text{h}$ per animal did not lead to any significant improvement of ewe well-being and performance in the groups subjected to 30 min ventilation cycles. Instead, the ventilation rate being kept at $70\text{ m}^3/\text{h}$ per animal, the group subjected to short ventilation cycles displayed a more intense activation of thermoregulatory mechanisms during the warmest part of the study period compared to the group benefiting from 60 min ventilation cycles.

Exposure to solar radiation under ambient temperatures over 35°C prevented ewes from maintaining their thermal balance. Provision of shade played a major role in helping the

lactating ewe to minimize the adverse effects of high ambient temperatures on thermal balance and energy and mineral metabolism. Reduction of heat load during the warmest hours of the day through feed administration in late afternoon was beneficial to ewes in minimizing the impact of thermal stress on their immune function and udder health. Both solar radiation and time of feeding had only a minor impact on ewe production performance.

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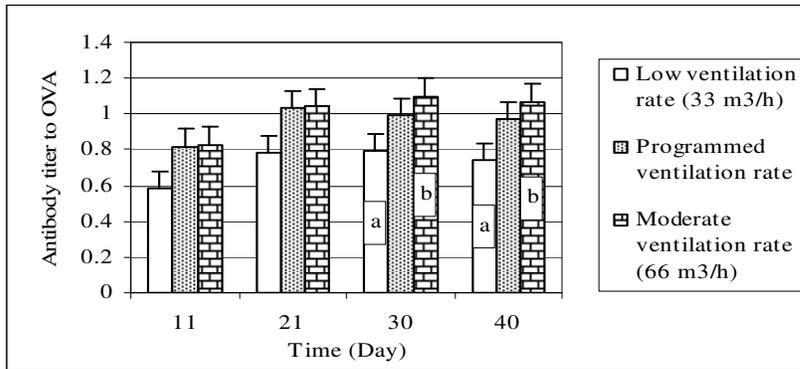


Figure 1. Least square means \pm SEM of antibody response to chicken egg albumin injection in ewes subjected to a low (LVR), moderate (MVR) and programmed ventilation regimen (PROGR)

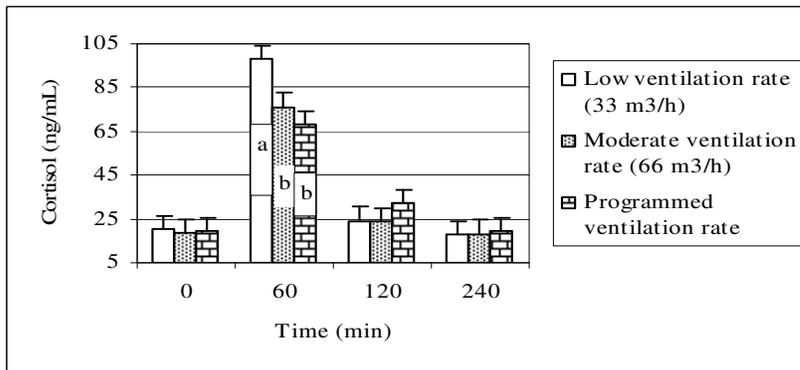


Figure 2. Least square means \pm SEM of plasma cortisol levels after porcine ACTH injection in ewes subjected to a low (LVR), moderate (MVR) and programmed ventilation regimen (PROGR)

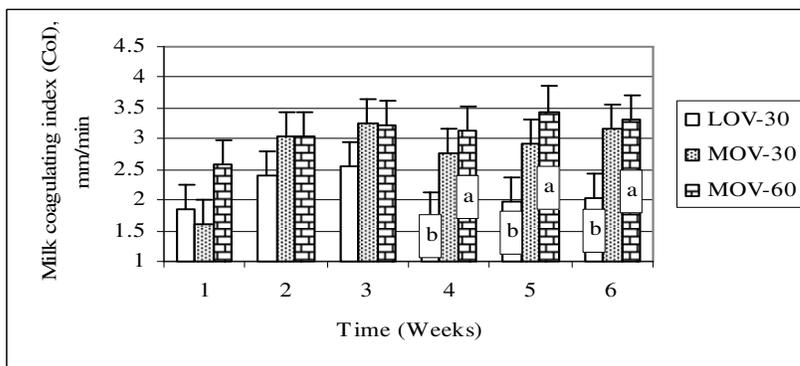


Figure 3. Least squares means \pm SE of coagulating index (CoI) in ewe milk as affected by a low ventilation regimen (LOV-30), and moderate ventilation regimens providing short (MOV-30) and long ventilation cycles (MOV-60)

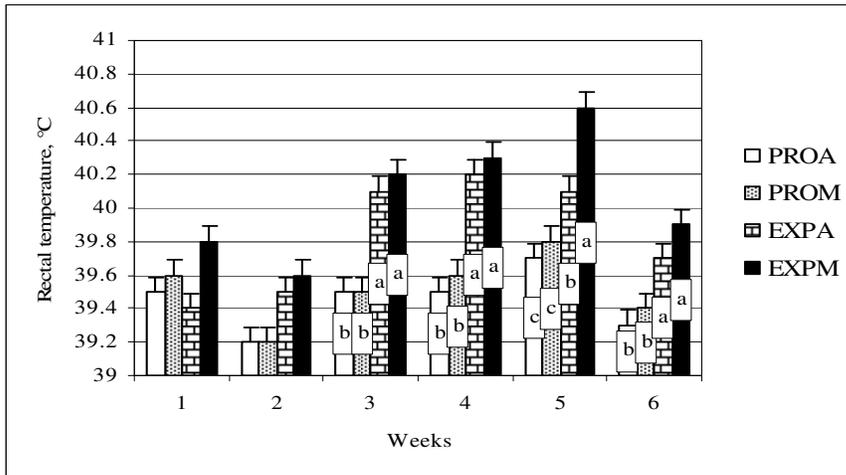


Figure 4. Rectal temperature of ewes when protected or exposed to solar radiation and fed in the morning (PROM, EXPM) or in the afternoon (PROA, EXPA)

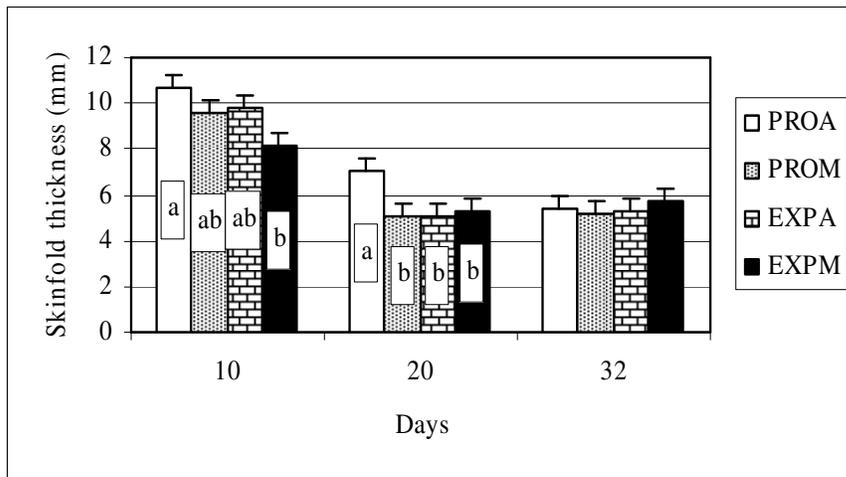


Figure 5. Immune response to PHA injection in ewes when protected or exposed to solar radiation and fed in the morning (PROM, EXPM) or in the afternoon (PROA, EXPA)

Effect of low vacuum on sheep milking

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Abstract

The level of the vacuum in machine milking is one of the principal parameters which influence the integrity of the tissues and the milk quality. Many studies have shown that while raising the level of the vacuum increases the speed of milk emission, it can also generate congestion in the teat, formation of oedema, increase in residual milk and in the number of somatic cells. Thus milking should be performed with the lowest possible level of vacuum which is compatible with not excessively prolonging milking time. In Italy the vacuum level is unjustifiably high - on average 42 - 46 kPa- while in other European countries the usually level is 4-5 kPa lower.

In order to define the milking techniques which best satisfy the physiological needs of dairy sheep, we have compared milking performances at a low vacuum level (28 kPa) and at a standard level (42 kPa). The effects of the working conditions were evaluated by analyzing the milk emission curves and the vacuum fluctuations registered in the milking line and in the short milk tube.

Results showed that using a vacuum of 28 kPa increased the latency time, reduced both average and peak milk flow, and increased the average milking time per head by 17%.

The reduction of vacuum did not produce significant variations in vacuum fluctuations in the short milk tube (10.4 kPa at 28 kPa and 9.0 kPa at 42 kPa) and also in the milking line where the vacuum fluctuations were less than 2 kPa.

Keywords: small ruminant, working vacuum, milking time.

Introduction

The different adjustments of milking machine can modify the milk flow characteristics. Each species of animal has to be milked with suitable operative parameters. However, the level of working vacuum is still very changeable and it depends principally on the country and area.

The level of working vacuum used in Sardinia ranges on average from 41 to 44 kPa, with a maximum level of 50 kPa (Pazzona and Murgia, 2003), while in other countries there has been a tendency to reduce it, operating at about 34 - 36 kPa (Billon, 1999).

High vacuum levels can cause many inconveniences in cows, such as an increase in hyperkeratosis at the apex of the teat (Mein et al., 2003), an increase in stripping milk (Reinmann et al., 2001a), reduction of the machine milk fraction (Mein, 1992) and udder damage (Hamann et al., 1993). Similar negative effects have also been found for small ruminants. High vacuum levels have been associated with an increase in the somatic cell count (Sinapis and I. Vlachos, 1999; Le Du, 1983; 1985; Pazzona and Murgia, 1993) which is also linked to low pulsation frequency (Fernandez et al., 1999). By contrast Peris et al. (2003) reported that in the short term neither somatic cell count of the milk nor teat thickness changes were affected by variations in vacuum level (36 vs. 42 kPa). It is well-known that the application of the vacuum slows down blood circulation in the teat tissue thus influencing its temperature. Recent studies (Stelletta et al., 2007) have shown that the teat returns to its normal physiological temperature more rapidly if the milking vacuum is reduced. The

increase in milking time and the increased frequency of the teat cups falling off are the principal negative factors which have up to now discouraged the use of low vacuum (Spencer and Rogers, 1991).

In line with the current interest in animal welfare in animal husbandry and in order to define milking techniques which best satisfy the physiological needs of dairy sheep, the goal of this study was to evaluate the effects of mechanical milking of dairy sheep at the vacuum of 28 kPa.

Materials and Methods

The milking system used

A prototype milking system specifically designed for low vacuum milking was used in the experiment.

The milking parlour prototype was 24 sequentially gated stalls, with 12 milking units in a low line system. The exit phase occurred simultaneously from the front, with the swing over arms assisting in the rapid evacuation of the milking session. The technical innovation of the prototype was the volume of the milk line. This had an external diameter of 76 mm, so that the volume was more than double that of the 50 mm line normally used for sheep.

The greater volume of the milk line, with the resulting improvement in transport capacity of air and milk, optimised the flow conditions even when air suddenly enters, a very common event during sheep milking due to the short milking time for this species. Stabilising the vacuum in the milk system minimised the possibility of the clusters falling off.

The vacuum regulator was servo-controlled. The sensor is positioned on the main airline near the sanitary trap, in order to guarantee an immediate response when air enters. There was a liquid-ring vacuum pump, with a capacity of 1200 l/min at nominal vacuum. The milking units were assembled from different types of components, chosen from among those most frequently used in sheep milking. When choosing the type of cluster assembly we took into consideration both the suitability of the teatcups for the flock and the weight of the equipment. This was 490 g, the average weight for clusters commonly used in sheep milking which vary between 390-640 g in weight. The cylindrical liners were made of rubber, with an internal diameter of 20 mm and 10.4 cm long. The short milk tube was 8 mm in diameter and the claw capacity was 120 cc. To help the flow of the milk, the long milk tubes (14 mm in diameter) were shortened and mounted with a constant slope towards the milk line. This avoided curves and roses in the tube which could have caused high fluctuations in the vacuum, due to slugs of milk.

Experimental design, equipment used and variables measured

This work was carried out on 48 pluriparous Sarda breed sheep. The animals were randomly divided into two groups of 24, and one group was assigned the working vacuum of 28 kPa (LV) while the other was assigned the 42 kPa (SV). Milking was performed twice daily at 6.00 a.m., and 6.00 p.m.; for the trial the data was recorded one time a day for three months, at the afternoon milking. During milking, ewes received concentrates ad libitum.

Milking routine consisted of attachment of teatcups without previous touching of the udder, and detachment of the cluster without machine stripping. When needed the hook was used in order to have teats at the lowest position.

For the period of the experiment, the milk flow and milk yield data collected with the milk flow apparatus (LactoCorder[®], WMB AG, Balgach, Switzerland) included: maximum milk flow rate; average milk flow rate (machine milk yield/milk flow time); latency time (the

time it takes for milk to begin flowing after the teat cups have been placed on the ewe); milk flow time (milking time – latency time); machine milk yield and milking time (the amount of milk obtained by the machine from time 0 to when milk flow rate fell below 70 ml/min);

Vacuum fluctuations and average vacuum during milking were continuously monitored by a sensor which was directly connected to the milk line and two sensors connected to the short milk tubes of the two different clusters. A computer-based data acquisition system (DAS-M, Star Ecotronics – Milano), equipped with three pressure transducers (Trafag, Mod. 8891.23.3317) with a maximum sampling rate of 100 kHz, was used.

Statistical analysis was carried out by comparing the LV and SV for the milk flow characteristics, using a Mann-Whitney *U* test from the SPSS 15.0 program.

Results and discussion

Analysis of the milk emission curves recorded at low and standard vacuum.

Sample statistics of milk flow, milk yield, milking time in Sarda breed ewes are summarized in table 1.

Table 1. Sample statistics (1) of milk flow, milk yield, milking time in Sarda breed ewes

Trait	LV			SV		
	mean ± stdev	range		mean ± stdev	range	
		min	max		min	max
Maximum milk flow rate (kg/min)	1.07 ± 0.45 ^a	0.20	2.17	1.47 ± 0.44 ^b	0.69	2.51
Average milk flow rate (2) (kg/min)	0.55 ± 0.20 ^a	0.24	1.14	0.64 ± 0.19 ^b	0.30	1.08
Latency time (s)	12.03 ± 6.05 ^c	0	28	9.95 ± 5.99 ^d	0	26
Milk flow time (s)	53.22 ± 15.17 ^a	25	97	45.85 ± 13.20 ^b	23	97
Milking time (s)	65.25 ± 16.83 ^a	33	108	55.79 ± 12.67 ^b	27	113
Machine milk yield (kg)	0.49 ± 0.16	0.20	0.89	0.49 ± 0.15	0.22	0.88

(1) The average of three months evening milkings

(2) Average milk flow rate = machine milk yield/milk flow time.

^{a,b} Within a trait, means with different superscripts differ ($P < .001$)

^{c,d} Within a trait, means with different superscripts differ ($P < .005$)

The representative's flock during an evening milking gave on average 0.49 kg of milk in 55.79 s using an operative vacuum of 42 kPa and a time increased of 17% (9.46 s) using an operative vacuum of 28 kPa ($P < 0.001$). The milking time was divided into latency time and milk flow time. The data obtained showed that both traits were affected by the vacuum. Latency time resulted 12.03 s for the LV test and 9.95 s for the SV test ($P < 0.005$), thought both always in a common value remaining (Marie-Etnacelin et al., 2002). The milk flow time was 7.37 s longer for LV ($P < 0.001$), with an average value of 53.22 s. As a consequence of the results obtained on milking times, the average milk flow rate and the maximum milk flow

rate resulted higher with the standard vacuum (0.64 and 1.47 kg/min) compared with the values recorded at low operative vacuum (0.58 and 1.07 kg/min).

The delay of the milking time for one ewe obtained using the vacuum of 28 kPa should not show so high considering the session milking time. In fact, allowing for milking routine the time that the milker, operating on 6 milking units, needs to execute the movements sequences during mechanical milking of sheep is almost the delay obtained using the low vacuum.

Short milk tube

The results concerning short milk tube fluctuations did not show important differences between the milking at 28 kPa and at 42 kPa (tab. 2), in accord with Murgia and Pazzona (1999). The fluctuations of 9.2 - 9.8 kPa recorded in the short milk tube, with internal diameter of 8 mm, resulted overall lower than the values found in the laboratory with the short milk tube of peer diameter with constant flows of 1.5 l/min (12.9 - 16.6 kPa) (Murgia, Pazzona, 2001).

Table 2 – Average and standard deviation of vacuum level and fluctuations in short milk tube and in milklime during milking

	SHORT MILK TUBE		MILKLIME	
	Vacuum (kPa)	Fluctuation (kPa)	Vacuum (kPa)	Fluctuation (kPa)
LV (28 kPa)	29.1 ± 0.65	9.2 ± 2.03	28.2 ± 0.39	1.0 ± 0.30
SV (42 kPa)	41.8 ± 0.87	9.8 ± 2.35	41.5 ± 0.30	1.4 ± 0.23

Milklime

Testing the milk pipeline during milking, provides valuable information on the technical condition of the milking machine (tab. 2 and fig. 1). According to the technical standards, the milking machine performances are defined in terms of vacuum stability during the milking. The average vacuum fluctuations of 1.0 kPa for the low vacuum system and 1.4 kPa for the standard vacuum system, resulted lower than 2.0 kPa prescribed by the standards, it can be asserted that the milklime of 76 mm guarantees an optimal flow conditions. The best vacuum stability recorded working to low vacuum was mainly due to the speed reduction of the air that entered inside the milking system. However, to evaluate these results it is necessary to consider that the differences in vacuum fluctuations would be accentuated if the milking at 42 kPa was with the traditional milklime (50 mm diameter) instead of the 76 mm diameter.

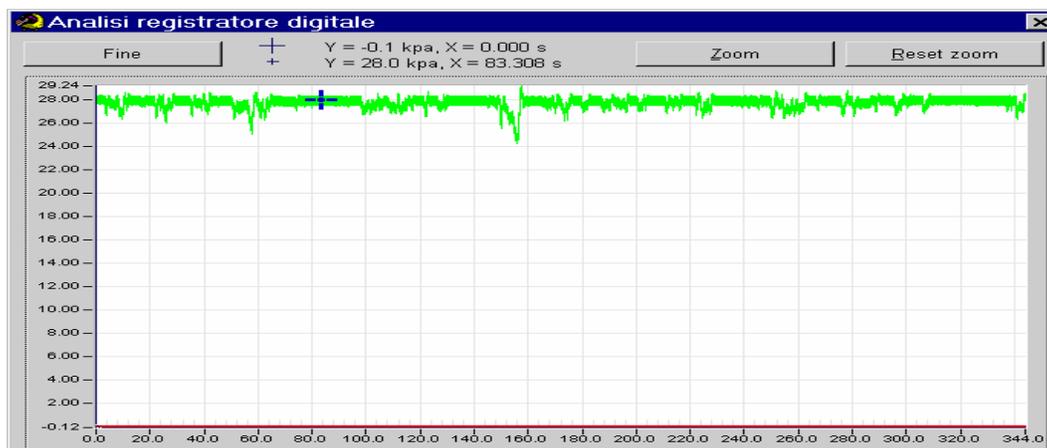


Figure 1. Vacuum dynamics of the milklime 76 cm diameter, during a session sheep milking at 28 kPa

Conclusions

The results of the study clearly showed that the low vacuum level, modified significantly the kinetics of the milk ejection. Working at 28 kPa increased the latency time for the first milk emission, it reduced the average milk flow rate and the maximum milk flow rate and, consequently, it prolonged of about 17% the milking time for the milking of the single ewe. Nevertheless, considering the times of milking routine where the milkers operate contemporarily 6 milking units each one, the milker productivity is reduced in a small degree.

The reduction of the vacuum from 42 to 28 kPa did not produce appreciable variations about vacuum fluctuations in the short milk tube (9,2 kPa for the low vacuum and 9,8 kPa for the standard vacuum). Analogous considerations can make for the milklime where the vacuum fluctuation was on average 1,0 kPa for the low vacuum and 1,4 kPa for the standard vacuum.

The good vacuum stability in the milk system, due to the milk pipeline of 76 cm diameter, positively influenced the milking routine that was not interrupted by liner slips or milking units fall-off.

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Manure management and hygienic conditions of dairy cows in cubicles bedded with separated manure solids

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Abstract

Manure management affects hygiene, animal welfare, work organization and costs on dairy farms. The use of recycled separated manure solids as bedding for loose housed dairy cows is considered cost-effective because avoiding the purchase of bedding material.

The main aim of the research was to improve housing systems and manure management in dairy farms in order to favour better conditions of welfare and hygiene of cows and to reduce costs of dairy farms.

Housing system, equipment, machines, labour and litter usage were considered as well as skin dirtiness, locomotion scores and quality of milk of loose housed dairy cows were assessed and compared among reference dairy farms using and not using separated solids as bedding.

Comparison of dirtiness and locomotion scores showed significant differences among the surveyed dairy farms using different housing systems and different type and amount of bedding in lying area. Lowest dirtiness and locomotion scores were found in barns with cubicles using more than 2 kg/cow.d of straw while the highest scores were found in cubicles using no litter and in barns with sloped bedded floor.

The survey showed acceptable hygienic conditions of dairy cows housed in cubicle barns using separated manure solids even if the assessment of milk quality pointed out relatively high content of somatic cells even if not directly correlated to the use of such bedding. Anyway as bedding may play a role in the cleanliness of the udder, a careful pre milking hygiene routine may be advisable to control mastitis when using separated manure solids.

Keywords: dairy cows, manure management, hygiene, bedding.

Introduction

Manure management affects hygiene, animal welfare, work organization and costs on dairy farms (Barbari and Ferrari 2006; Barbari *et al.* 2007). The use of recycled separated manure solids as bedding for loose housed dairy cows is considered cost-effective because avoiding the purchase of bedding material. Actually this practice is applied by several dairy farms in USA and by a few modern dairy farms in Italy. However there are some resistances from farm advisors and veterinarians because the high bacterial populations in bedding material would influence the level of bacterial counts on udder surface, particularly on teat ends, and would increase the risk of mastitis.

Researches carried out in USA to assess the hygienic feasibility of this practice found that properly composted and dried manure solids, with more than 60% dry matter and no or few coliforms, may be used as free stall bedding in conjunction with stringent mastitis control measures without increasing incidence of coliform mastitis (Allen *et al.*, 1980). Composting manure solids effectively reduces coliform counts to few or to zero but coliform counts can

increase if the compost in the barn becomes moist or is contaminated by external factors, such as feces or urine (Carroll and Jasper, 1978). Therefore dried composting manure was found satisfactory material for bedding of free stalls if it was dried properly before application.

Zehner *et al.* (1986) compared various bedding materials and demonstrated that clean, damp bedding may support bacterial growth; they also suggested that high bacterial counts under barn conditions are influenced by factors more complex than type of bedding used. High moisture levels of organic bedding materials result in rapid growth of environmental bacteria in the bedding contributing to high populations of bacteria on teat ends. Thus the reduction of humidity in manure material is the main consideration of separating dairy manure. However, when bedding materials become mixed with manure and urine, rapid growth of environmental mastitis pathogens starts because of available nutrients (Novàk *et al.* 2004).

Schrade *et al.* (2006) found that bedding material of compost and recycled manure solids is comparable with straw mattresses from the point of view of cubicle maintenance, animal welfare and hygiene.

With regard to the effectiveness of chemical treatments of separated manure solids Hogan *et al.* (1999) compared bacterial counts of untreated recycled manure bedding and those of recycled manure bedding treated with either an alkaline commercial bedding conditioner, acidic commercial bedding conditioner or hydrated lime. The results of this study showed that the use of acidic conditioner in recycled manure has little effect on bacteria in bedding and that alkaline conditioners initially reduce bacterial counts even if the antibacterial effects diminish two days after the treatment. However this kind of treatments may be suggested for herds affected by high rate of mastitis in order to control the fast bacterial growth during the first 2-3 days after bedding.

The main aim of this study is to improve loose housing systems and waste management in dairy farms in order to improve welfare and hygiene of cows and to reduce costs for dairy farms.

Materials and methods

Twelve dairy farms were considered in this study in order to compare hygienic conditions of milking cows in loose housing systems with different lying areas and manure management. The study was focused principally to assess how the practice of using manure solids as bedding influences hygienic conditions and health of milking cows.

Three dairy farms using recycled separated manure solids as bedding in cubicles have been surveyed. In these farms fresh manure solids are spread in cubicles every two weeks just next to mechanical separation without any previous chemical or physical treatments. The dry matter content of manure solids in the cubicles was analyzed two times per farm in summer and winter.

The other farms, except for farm 7, were used to spread organic bedding materials (chopped or whole straw or wood shavings) in cubicles or in sloped floor areas two or three times a week. The nine farms not using manure solids as bedding (from 4 to 12 in table 1) were selected among a sample of forty dairy farms already investigated within a survey on manure management in dairy farms in order to be representative for the most popular and the most modern loose housing systems for dairy cattle in Emilia-Romagna.

In every cowshed skin dirtiness score (DS) and locomotion score (LS) of milking cows were tested and bulk milk somatic cell count (SCC) was recorded.

SCC is one of the indicators of udder health and milk quality.

The DS method was used to analyze five anatomical parts of cows' body: sacro-ischiatic part viewed from the back; back side of the udder viewed from the back; front side of the udder viewed from both sides; legs; feet. The score for each anatomical part varies from 0 to 2 within the following steps: 0 = clean; 0.5 = a few small dirty areas; 1 = less than 50% covered with dirt; 1.5 = more than 50% covered with dirt; 2 = totally covered with dirt. Therefore the total score for each cow ranges from 0 to 10. The number of total scores to be collected in each farm are more than 50% of the number of milking cows in the herd; choice of cows to be scored is random. The mean value of the dirtiness total scores of cows tested in each cowshed expresses the cows' dirtiness score of that cowshed (Houdoy, 1992).

LS is a qualitative index of cows' ability to walk normally (Berry, 1997); it is visually scored on a scale of 1 to 5, where a score 1 reflects a cow that walks normally and a score of 5 reflects a cow that is three-legged lame. LS can also be used to determine the expected milk revenue losses due to lameness.

In each cowshed type of lying area, type of bedding, bedding consumption, manure removal system and type of flooring were considered (Table 1). The following kinds of lying areas were analyzed:

- cubicles bedded with manure solids;
- cubicles bedded with 2 kg . cow⁻¹ . d⁻¹ or more of straw;
- cubicles bedded with less than 1 kg . cow⁻¹ . d⁻¹ of straw or wood shavings;
- cubicles not bedded;
- sloped bedded floor.

Cubicles of farms 5 and 7 are provided with mattresses in order to improve cows' comfort and to avoid or minimize the use of bedding. Farms 1, 3, 4 and 5 are equipped with pumps for flushing; except for farm 5 they are provided with mechanical separator for processing manure in order to separate solids from the liquid manure used for flushing. Cowsheds of farms 8, 9, 10, 11 and 12 are equipped with automatic scraper conveyers.

Table 1. Technical parameters of lying areas, bedding use, type of flooring in passages and manure handling systems in twelve reference cowsheds

Farm	Lying area	Type of bedding	Bedding use kg cow ⁻¹ d ⁻¹	Type of flooring	Manure removal system
1	Cubicles	Manure solids	9.0	Solid	Flushing
2	Cubicles	Manure solids	9.0	Solid	Scrapers
3	Cubicles	Manure solids	9.0	Solid	Flushing
4	Cubicles	Chopped straw	2.0	Solid	Flushing
5	Cubicles - mattresses	Wood shavings	0.7	Slatted	Flushing
6	Cubicles	Wood shavings	0.4	Slatted	Storage pit
7	Cubicles - mattresses	-	0.0	Slatted	Storage pit
8	Cubicles	Straw	3.3	Solid	Scrapers
9	Cubicles	Straw	0.9	Solid	Scrapers
10	Cubicles	Straw	2.3	Solid	Scrapers
11	Sloped bedded floor	Straw	3.0	Solid	Scraper
12	Sloped bedded floor	Chopped straw	2.4	Solid	Scraper



Figure 1. Manure solids and press screw separator



Figure 2. Cubicles bedded with of straw (a); cubicles provided with mattresses and bedded with wood shavings (b); cubicles bedded with manure solids (c)

Results and discussion

Dirtiness scores were collected from 1284 milking cows and lameness score on 1183 heads; the number of cows tested per farm varies from 30 to 431.

SCC analyses of bulk milk were collected for every farm from August 2004 till July 2007, except for farms 1 and 2 (from January 2005 till July 2007), for farm 3 (from June 2006 till July 2007) and for farm 4 (from September 2006 till July 2007).

In cowsheds 1, 2 and 3 the dry matter content of manure solids used in free stalls was 42.1% on average.

Table 2 shows different values of DS, LS and SCC of milking cows in the surveyed cowsheds with different housing systems and with different type and amount of bedding.

Significant differences were found among mean values of DS, LS and SCC (ANOVA one-way) of the three cowsheds where manure solids are used and the other categories of cowsheds (tables 3 and 4).

The average DS of surveyed cowsheds in which manure solids are used was found relatively higher (3.38) than cowsheds provided with bedded cubicles (1.68 and 2.72) but lower than cowsheds provided with not bedded cubicles (4.81) or sloped bedded floor (5.12) in the lying area. The results of this study suggests that the practice of using fresh not treated separated manure solids would not improve cleanliness of cows in comparison with the use of

traditional bedding materials like straw and wood shaving. Anyway the relatively high value of DS for cows bedded with manure solids could be affected by the relatively high water content of this bedding material which was used in the surveyed farms next after mechanical separation without any previous chemical or physical treatments.

LS of farms using manure solids was found higher (1.35) than LS of farms with cubicles bedded with 2 kg cow⁻¹d⁻¹ or more of straw (1.16) but lower than farms with cubicles non bedded (4.81) while it was not found significantly different from cowsheds provided with cubicles and less than 1 kg cow⁻¹ d⁻¹. Although LS of cows is affected by various factors such as the type of flooring, feeding programs and hooves health and care, these results did not show any negative effects of using manure solids as bedding on the health of cows' hooves.

Table 2. Dirtiness scores, locomotion scores and bulk milk SCC in the surveyed reference cowsheds

Shed	Lying area	Bedding use kg cow ⁻¹ d ⁻¹	DS	LS	SCC ¹
			Mean±SD	Mean±SD	Mean±SD
1	Cubicles	9.0	3.46±1.08	1.36±0.76	328±65
2	Cubicles	9.0	3.59±0.74	1.30±0.54	319±68
3	Cubicles	9.0	2.70±0.93	1.36±0.75	327±112
4	Cubicles	2.0	1.83±0.51	1.17±0.48	333±133
5	Cubicles - mattresses	0.7	2.46±0.53	1.41 ±0.79	248±85
6	Cubicles	0.4	4.77±0.76	1.45±0.74	143±89
7	Cubicles - mattresses	0.0	4.81±0.76	1.68±0.80	515±177
8	Cubicles	3.3	1.41±0.33	1.15±0.41	147±44
9	Cubicles	0.9	2.14±0.68	1.25±0.55	136±29
10	Cubicles	2.3	1.88±0.52	1.16±0.44	190±76
11	Sloped bedded floor	3.0	5.32±0.88	1.18±0.45	489±125
12	Sloped bedded floor	2.4	4.77±0.98	1.41±0.83	359±189

¹⁾ Nr. · ml⁻¹ · 1000

Table 3. Dirtiness scores, locomotion scores and bulk milk SCC in cowsheds with cubicles in lying area

Nr. sheds	Lying area	DS	LS	SCC ¹
		Mean±SD	Mean±SD	Mean±SD
3	Cubicles bedded with manure solids	3.38 ^B ± 1.01	1.35 ^B ± 0.72	323 ^B ± 72
3	Cubicles bedded with more than 2 kg cow ⁻¹ d ⁻¹	1.68 ^D ± 0.50	1.16 ^C ± 0.44	231 ^C ± 126
3	Cubicles bedded with less than 1 kg cow ⁻¹ d ⁻¹	2.72 ^C ± 1.12	1.35 ^B ± 0.69	185 ^D ± 92
1	Cubicles not bedded	4.81 ^A ± 0.77	1.68 ^A ± 0.80	514 ^A ± 177

¹⁾ Nr. · ml⁻¹ · 1000

A, B, C, D) P < 0.01

Table 4. Dirtiness scores, locomotion scores and bulk milk SCC in cowsheds with cubicles bedded with manure solids and in cowsheds with sloped bedded floor

Nr. sheds	Lying area	DS	LS	SCC ¹
		Mean±SD	Mean±SD	Mean±SD
3	Cubicles bedded with manure solids	3.38 ^B ± 1.01	1.35 ± 0.72	323 ^B ± 72
2	Sloped bedded floor	5.12 ^A ± 0.95	1.26 ± 0.62	428 ^A ± 170

¹⁾ Nr. · ml⁻¹ · 1000

A, B) P < 0.01

Bulk milk SCC of cowsheds in which manure solids are used (323000) was found higher on average than cowsheds with bedded cubicles (231000 and 185000) even if lower than cowsheds with not bedded cubicles (514000) and cowsheds with sloped bedded floor (428000). These data showed acceptable health conditions of udders for surveyed cows housed in free stalls bedded with manure solids even if worse than those of cows housed in free stalls bedded with straw or wood shavings. Nevertheless SCC may be affected by other factors which play an important role in the health of udders such as the feeding program, the climate, the milking routine and the maintenance and settings of the milking machine.

Conclusions

The survey showed acceptable hygienic conditions of dairy cows housed in cubicle barns using separated manure solids even if the assessment of milk quality pointed out relatively high content of somatic cells but not directly correlated to the use of such bedding. However, as bedding may play a role in the cleanliness of the udder, a careful pre milking hygiene routine may be advisable to control mastitis when using separated manure solids.

Generally the research highlights the importance of housing systems to keep milking cows in acceptable hygienic conditions. Best hygienic conditions have been assessed in cubicle cowsheds using plenty of straw. Sloped bedded floor in lying area would not be advisable because of the high levels of cows' skin dirtiness and SCC even if LS management cost of cowsheds with sloped bedded floor was found relatively low.

The main advantage of recycling manure solids for bedding is the low material cost which is zero if free available on farm; in this case the estimation of cost savings is 43.6 € cow⁻¹year⁻¹ with reference to labour, machine and material costs in Emilia Romagna Region. The drawback of this practice is the high capital to invest for mechanical separator. For these reasons the purchase of a liquid manure separator for producing manure solids as bedding is only worthwhile for relatively large farms or for collective use.

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Shortening the Length of Dairy Cow Machine Milking Grouping Animal in Function of Milk Extraction Rate

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Abstracts

The aim of the study is to examine the work organisation of routine milking a double herring bone milking parlour of a representative farm in the province of Ragusa (south-eastern Sicily), an area dedicated to quality milk and cheese production, in order to suggest solutions to the notable time losses reported in the literature due to the presence of very slow animals among the groups to be milked.

The farm was chosen on the basis that it represented those in the south east of Sicily, which area, as is known, is very much involved in animal farming. There are about 100 cows, of which during the study about 40% were in lactation while the rest were heifers and calves kept for fattening. The milking operations were carefully observed and subsequently broken down into constituent stages, which were timed. Particular attention was focused on the question of whether group milking times were increased by the presence of exceptionally slow animals.

As reported in the literature, in double herring bone parlours there are prolonged waiting times for cows with shorter extraction times. With regard to this, an elaboration of the data showed that the animals should be grouped according to their extraction rate as this parameter was found to be constant, reliable and independent of the quantity of milk produced. In short, the results indicate that a considerable amount of time can be saved if milking is organised in such a way as to reduce milk extraction times. Savings can be obtained both by establishing a rational way of taking the herd into the parlour for milking and by better work organisation. This represents both a more rational and economical use of the technological innovations (machines, equipment and plants) present on the farm and better work conditions for the operators in terms of greater comfort, safety and free time.

Key words

Herring-bone parlours, herd, work organisation

1. Objectives

The main aim of the research was to examine the work organisation of routine milking in a double herring bone milking parlour in order to suggest solutions to the notable time losses reported in the literature due to the presence of very slow animals among the groups to be milked.

This kind of milking parlour is spread in the province of Ragusa, which plays the role of guide for the rest of the Sicilian farms as it is the province that contributes the most to the dairy production of the island.

2. Materials e methods

The farm was chosen on the basis that it represented those in the commune of Ragusa, which, as

is known, is very much involved in animal farming. It breeds Frisian dairy cows and part of the milk produced goes to an association of producers called "*Cooperativa degli Altopiani*", and part of it is made into cheese according to the procedures dictated by the standards for the production of "*Ragusa Cheese (PDO)*". It has a surface area of about 33 ha (of which about 28 are used for growing grass). The 1000 m² covered area offers free housing in a stall with permanent litter. There are about 100 cows, of which during the study about 40% were in lactation while the rest were heifers and calves kept for fattening. There are no males on the farm and artificial fertilisation is used. The farm produces fodder which is mixed with protein concentrate and fed to the cattle with "*Unifeed*" techniques.

Mechanical milking is carried out using a "double herring bone (4+4)" plant, situated in a parlour which the cattle enter without any pre-established order from an adjacent fenced holding area through two gates manually controlled by an operator. The plant is made up of 8 milking stands and the milker's pit. The passage way to the stands is 1.15 m wide and the stands are inclined at an angle of 30° with respect to the longitudinal axis of the room.

The *milking operations* were studied over a period of a year. The study regarded the productive performance of each animal, including the quantity of milk produced at each milking and the milk extraction rate. Aspects of the work organisation were also studied including routine and milking times with reference to single cows, groups and the herd. Particular attention was focused on the question of whether group milking times were increased by the presence of exceptionally slow animals. In fact, as reported in the literature, this is a drawback to the use of a double herring bone parlour, where the animals enter and leave in groups. Subsequently, after having ascertained the existence of the phenomenon and its frequency by evaluating the *mean milking times* of each cow, it was possible to simulate the formation of groups that were homogeneous as regards milking times, and thus calculate the *simulated cycle times*. The latter were compared with the cycle times that were actually observed in order to establish how much time could be saved by forming homogeneous groups.

3. Results

Parlour Performance

Out of a total of 64 studies carried out during a year, 27 regarded morning milking operations and 37 those in the evening. Each study involved 48 cows in lactation, divided into 12 groups of 4 cows each. Only one operator was present for milking.

The mean milking time of the herd – including all the routine operations from the entrance into the parlour of the first animal until the exit of the last – was on average 88 minutes. This is much less than the sum of the milking times of the 12 groups of 4 animals. In fact, since in the double herring bone plant two groups are milked at the same time, the total milking time for the herd is much lower than the product of the mean cycle time by the number of groups milked. The work capacity of the parlour was found to be 31 heads/h and the mean cycle time (for the execution of all the stages of the milking routine of each group) was 13.3min.

The phase with the longest mean time is represented by milk extraction (9.4 min), which is equivalent to 71% of the cycle time (fig. 1), while the remaining phases take much less time. In order to reduce the routine time and thus increase the double herring bone parlour performance, it might be possible to intervene at the stage when the operator is working. This, however, represents only 29% of the routine itself and does not appear to be reducible. A more realistic

possibility is represented by the possibility of forming groups of animals with the same extraction times so as to reduce the time spent in the parlour waiting for the slowest cow in the group. This has already been suggested in the existing literature. Obviously another indirect way to reduce times would be to increase the presence of cows with faster milking times by means of genetic selection.

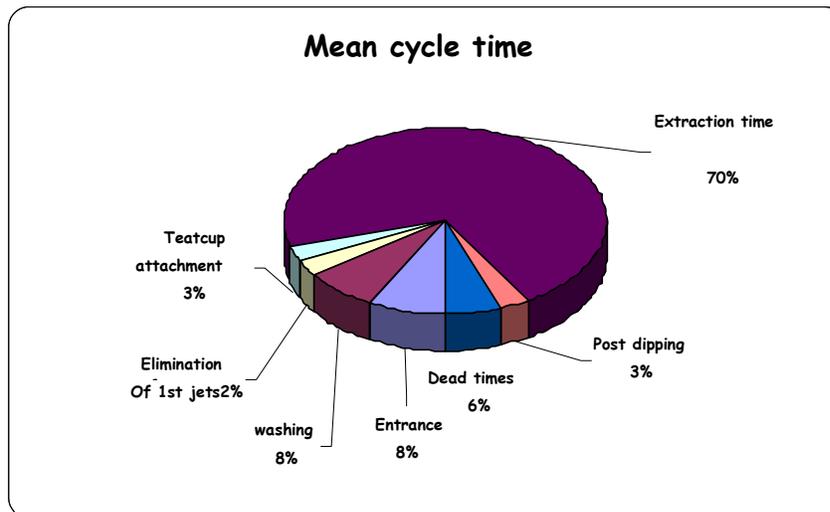


Figure 1

Formation of homogeneous groups

Identification of the parameter. By observing the individual stages of the milking routine, it was found that the parlour performance depends only to a very small extent on the work organisation and the operator's performance and to a much greater one on the milk extraction time, that is to say on the characteristics of the cow being milked. This observation confirms what is reported in the literature: animals that have already been milked remain in the parlour longer than necessary because of the presence of slower cows. An analysis of the data shows that on average about 280s passed from when the fastest cow had already finished being milked to when the whole group could leave the parlour. As a consequence, it was realised there was a need for a constant and reliable parameter that could be used to group the animals according to their milking times. This parameter was identified in the milking rate (l/min). In fact, from an analysis of the extraction times, it is possible to identify cows that are constantly characterised by a correspondence between low capacities and high extraction times or high capacities and low extraction times, regardless of how much milk is produced. Figure 2 shows the high correspondence between milking time and milk flow rate.

Medium-low capacities (1.2 l/min) corresponded with medium-high extraction times (10 min) and medium-high capacities (3.1 l/min) corresponded with medium-low extraction times (3.4 min); the amount of milk produced did not influence these times. From a practical point of view, an elaboration of the data shows that to establish the number of measurements necessary to determine the correlation between capacity and extraction times, the 5 initial observations would have been sufficient (tab. 1). Work in the parlour, therefore, can be organised by studying just a

few milking sessions and then forming homogeneous groups on the basis of extraction rate.

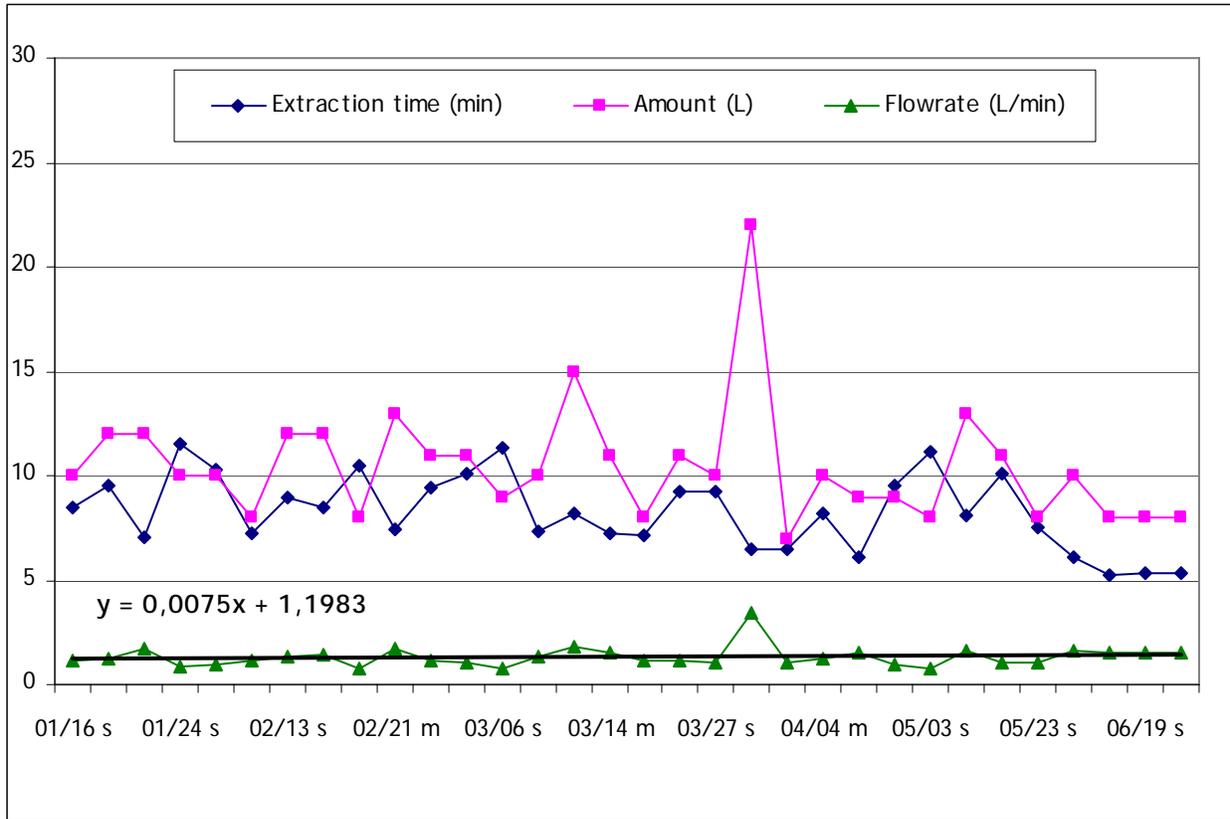


Figure 2

Table 1 - Calculation of extraction capacity based on three milking sessions

Denomination	Milk production (litres)	Extraction time (min)	Extraction capacity (l/min)
Slow cows	10	8,55	1,2
Quick cows	15	5,33	2,8

Simulated milking. Once both the relationship between the extraction times and rate, and the constancy - and therefore reliability - of the rate had been ascertained, it was possible to proceed with simulated milking, forming homogeneous groups on the basis of milking rate. From an elaboration of the data relative to the milking times for such homogeneous groups, it emerges that the mean milk extraction time is about 2 minutes less than that for the groups observed (11.2 as opposed to 13.2 min). Thus, the homogeneous groups took 21% less time to milk than the groups formed randomly. The waiting time of the fastest cow (on average 260s) was reduced to about 25s, representing a saving of 90%. Moreover, the extraction time for the simulated groups represents about 65% of the cycle time, this being less than the percentage calculated (71%) for the groups observed. This saving in time means that forming homogeneous groups for the

extraction stage reduces the cycle time for each group in the herd by about 15%. Moreover, from an elaboration of the data relative to the simulated milking, it was calculated that the parlour work capacity was 45 heads/h as opposed to 31 heads/h, this representing an increase of 45%. When the unit time was considered, the 1.8 min/head for the observed groups was reduced to 1.2 min/head for the simulated groups, this representing a saving of 30%.

Table 2 – Comparison of observed and simulated groups

Milking parlour performance		
	Observed	Simulated
Number of cows milked	46	46
Number of groups	12	12
Milking of the herd (min)	88	61
Work capacity (heads/h)	31	45
Unit time (min/head)	1,8	1,2

3. Conclusions e prospects

The observations made during the course of a year show the influence of various factors on the organisation of the milking, on the various stages of the process and on the execution times.

The results also show the large proportion of the total milking time taken up by milk extraction (71%). This indicates, among other things, that to reduce milking times it is necessary to reduce the milk extraction times, for example by grouping the animals in such a way as to reduce waiting times of cows in the group on completion of milking.

As reported in the literature, in double herring bone parlours there are prolonged waiting times for cows with shorter extraction times. With regard to this, an elaboration of the data showed that the animals should be grouped according to their extraction rate as this parameter was found to be constant, reliable and independent of the quantity of milk produced. In the trial situation, it was found that the results of only 5 milking were sufficient to calculate the extraction rate of each animal.

Also, the trials has showed that:

- measurements have to be started 8 -10 days after birth;
- only healthy herds have to taken in account;
- measurements can't overcome 300 days.

Having identified and quantified the milk extraction rate parameter, a milking session of groups made up of cows with similar extraction rates was simulated. Waiting times were reduced by 90%, with a corresponding decrease equal to 15% of the milking cycle time of each animal

Considering the entire herd, about 30% of the milking time (h/herd) was saved with simulation and the parlour work capacity (head/h) increased by 45%.

In short, the results indicate that a considerable amount of time can be saved if milking is organised in such a way as to reduce milk extraction times. Savings can be obtained both by establishing a rational way of taking the herd into the parlour for milking and by better work organisation. This represents both a more rational and economical use of the technological innovations (machines, equipment and plants) present on the farm and better work conditions for

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Predisposition of Mechanical Milking Plants to Dynamic Test

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Abstract

The main aim of this work is to assess the predisposition of milking plants to dynamic tests with innovative equipment in an area of south east Sicily that is particularly dedicated to milk production in order to see if they conform with the ISO Standards, given that in the future plants that are not suitably equipped will not be able to continue with quality production. The study involved a sample of 125 dairy with parlours and cow milking plants (88 direct inspections and 37 telephone researches). From the inspections carried out at the plants, it emerged that the lack of diagnostic outlets is often caused by the original design being unsuitably modified in order to adapt it to the limits imposed by the structural characteristics of the milking parlour, which generally pre-existed. In these often precarious situations, it emerged that the analogical equipment is more suitable as it consists of small instruments which do not need to be connected to one another. On the other hand, the inescapable requirements of quality production impose the execution of periodic dynamic checks, that is to say tests during milking, and it is therefore necessary to verify that plants comply with Standard UNI ISO 5707 in particular, in both the design and realisation phases. Checks on existing plants are also useful as they focus on the adjustments necessary to regularise the plant. This is indispensable for the rational use of the now available computerised equipment, which is able to guarantee results that cannot be achieved with analogical equipment. Some of the cattle-breeders reached by the telephone researches don't know exactly the mean of "dynamic test", "static test", "diagnostic outlet"; surely, it need more information if we wish obtain more milk quality and more quality in the milking plant.

Key words

UNI ISO 6690, check list, static test, diagnostic outlet

1. Introduction

According to some authors (*Madinelli & Dalvit 2002*), a static test of milking plant is not always sufficient to bring to light any abnormalities in the functioning, while the dynamic test represents a more valid tool as it can provide information regarding both the plant and the milking routine.

Starting from this assertion, the main aim of this work is to assess the predisposition of milking plants to dynamic tests in an area of south east Sicily that is particularly dedicated to milk production in order to see if that plant are conform with the ISO Standards.

The survey starts from a previous study carried out in 2005's [Schillaci] in the same district, in which dairy farm are devoted to milk high quality.

2. Materials and methods

As regulative reference framework we assume the UNI ISO Standards 3918, 5707, 6690 (UNI = Ente Nazionale Italiano di Unificazione – National Italian Unification Board).

UNI ISO 3918 contains the definitions and terms that are used in the official regulations, in research and in the construction and use of mechanical milking plants for

cows, sheep, goats and buffalos ¹.

Standard UNI ISO 5707 sets out the minimum performances and the required dimensions for good functioning of milking machines, besides other requisites regarding materials, construction and installation ². The Standard also provides for three connection points to measure the vacuum level: at the recorder jar or terminal (A_1 , V_m), near the regulator sensor (A_2 , V_r) and near the entrance to the vacuum pump (V_p). A_2 is a connection point near the regulator. To allow measurement of the recovery rate, the Standard provides for a connection (P_e) to the vacuum pump outlet. With regard to the latter the means to isolate it from the rest of the plant must be present.

Standard UNI ISO 6690 specifies the precision requirements for measuring instruments and sets out the mechanical tests to verify an installation's conformity with the requirements of UNI ISO 5707. It contains a description of a static test of a plant and all the individual tests to be carried out for this.

In the fig. 1a, 1b, we can see the diagnostic outlet positions as regard 3 different kind of plants.

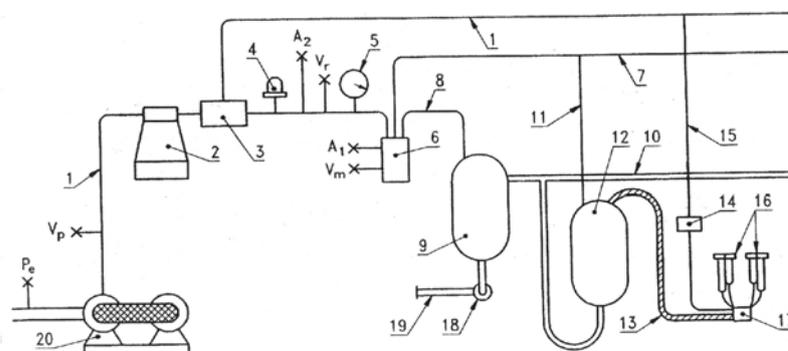


Fig. 1a – Diagnostic outlets (recording jar plant)

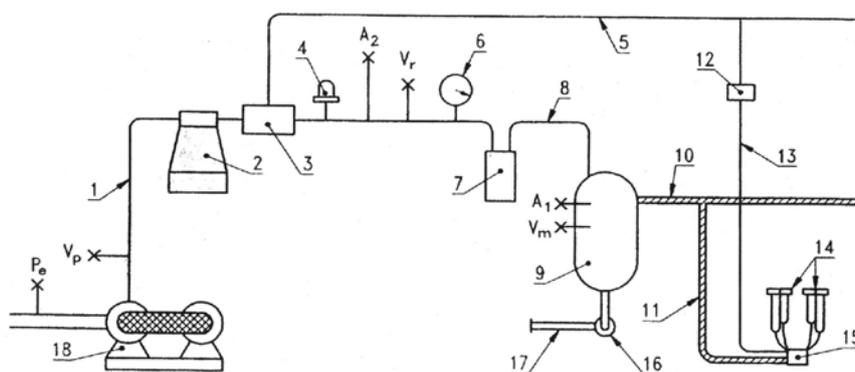


Fig. 1b - Diagnostic outlets (milk pipeline)

¹ UNI ISO 3918 also contains a description of the characteristics of milking plants. It must be pointed out that among the characteristics of the plants described in the Standard in question, there are diagrams of milking machines which also show where testing equipment should be connected.

² UNI ISO 5707 contains the particulars of the plant conformity test, with a description of the connection points for testing equipment (also given in the milking machine diagrams in Standard ISO 3918) to permit measurement of system reserve and unit consumption.

Static control of milking machines.

They are carried out by using an analogical equipment that includes 2 flowmeters, (0 - 1,650 and 0 - 3000 L/min), 1 precision vacuum gauge (diam. 150 mm), 1 revolution counter, 1 pulsograph and various recording instruments. With the flowmeters it is possible to measure the air flow of the vacuum pump, the system reserve and the unit consumption. They are periodically calibrated and are accurate to within $\pm 2\%$ of the true reading.

Dynamic control of milking machines.

It was used a digital equipment that has the advantage of incorporating in one device all the measuring functions that are otherwise carried out by numerous separate analogical tools, thus permitting simultaneous memorisation of the parameters on a laptop. The acquisition of data takes place thanks to a series of transducers, placed at three different points of the plant to be checked and able to convert the various physical entities to be measured (pressures, differential pressures, flows etc.) into electrical signals. This means it is possible to obtain measurements at the same time at different points of the plant, as required by law, and also to operate in both static and dynamic conditions.

An important characteristic of DAS-M is represented by the fact that the tests can be carried out by attaching at least three sensors to the plant, thus collecting values relative to the vacuum fluctuations at different points of the plant – the receiver, the air pipeline near the separator and the milk pipeline– contemporaneously, correlating the results in time.

As methodological aspects, the study by direct inspection was carried out on a sample of 88 dairy farms; others 37 farmers were involved by telephone researches. We asked them some very simple queries, as: if they knew the means of “dynamic test”, “static test”, “diagnostic outlet”, ISO UNI 3918, 6690, 5707”.

All the dynamic tests conducted with computerised equipment included the recording of the presence and arrangement of diagnostic outlets on each type of milking installation. The description and symbols used for the positioning of the diagnostic outlets are those given in the relative regulations.

As regards the dynamic tests with analogical equipment, such notes were not taken. In fact, these tests are always possible given that the diagnostic outlet is obtained by disconnecting the receiver. Considerations on the data, the problems met with and the solutions adopted were made with reference to the current regulations (UNI ISO 6690).

The dynamic and static tests assessed the plant’s functional parameters with bearing on its dimensioning and on the safeguard of the health of the herd and the hygiene of the milk. The parameters considered involved measuring the vacuum fall in the air and milk pipelines, the vacuum pump capacity, the air pipeline consumption, the milk pipeline consumption, the cluster consumption, the pulsation group consumption and the effective vacuum reserve.

All the data collected with the computerised equipment are the result of a calculation system that every 5” integrates the values recorded, obtaining the mean vacuum level, while the highest and lowest values are defined the maximum and minimum vacuum level respectively. A 10 minute recording period was set so as to guarantee reliability and the measurements carried out near the receiver cover the entire duration of the milking of a single animal. Those relative to the vacuum line also include the phases of attachment and removal of the milking groups.



Fig. 2 – Analogical devices



Fig. 3– Computerized devices

3. Results and discussion

With regard to the study of aspects connected to the *static* (“dry”) test, 88 milking plants of various types were visited. Only 27 of these (31%) were all the diagnostic outlets required by law found. Expressing this in more detail - 5 milk pipeline plants out of 16 (31%), 10 bucket plants out of 36 (28%) and 12 recorder jug out of 36 (33%) were found to comply with the law. The remaining installations had only some of the diagnostic outlets necessary for the checks and some had none at all.

Only 31% of the milk pipeline plants had all the diagnostic outlets required to measure the vacuum level (V_m , V_p , V_r); the reverse pressure (P_e) could not be measured in 56% (50%-2005) of the farms and in only 7 (5-2005) cases could the air flow be measured near both the terminal jar (A_1) and the regulator sensor (A_2).

Moreover, as regards the recorder jar plants, it was observed that for the measurement of the vacuum level only 11% installations had all three diagnostic outlets required; with respect to the reverse pressure, in 66% of the cases, measurement could not be carried out; as regards air flow, in 42% (39%) plants the diagnostic outlet was near the sanitary separator (A_1) and 47% (33%) near the regulator sensor (A_2).

Out of 36 bucket installations, in 72% it was not possible to measure the reverse pressure, only 28% had both the outlets required for the vacuum level and in 22% to measure

the airflow it was necessary to dismantle the vacuum pipeline to obtain a suitable connection, this causing notable operational difficulties.

Dynamic tests were carried out on a total of 18 farms, of which 5 had milk pipeline plants and 13 had recorder jar installations (tab. 2). The tests were carried out in each of the plants with analogical (MIBO) and digital equipment (DAS-M).

As stated in the methodology section, the survey of aspects connected with the dynamic testing of milking plants only regarded the tests carried out with DAS-M.

As regards the milk pipe line installations, 1 out of 2 had all the diagnostic outlets required by the equipment software, that is to say near the terminal jar, on the milk pipeline and on the receiver.

As regards the recorder jar plant, 3 out of 5 had all the diagnostic outlets required by the equipment software.

Similarly, in the plant without the three outlets, the three transducers were attached to three collectors of the teatcup groups.

4. Conclusions and prospects

In contrast with the widespread objectives as regards quality, only a limited number of plants in the vast number in the sample was found to conform with the regulations and therefore to be able to carry out routine checks with computerised equipment.

From the inspections carried out at the plants, it emerged that the lack of diagnostic outlets is often caused by the original design being unsuitably modified in order to adapt it to the limits imposed by the structural characteristics of the milking parlour, which generally pre-existed. In these often precarious situations, it emerged that the analogical equipment is more suitable as it consists of small instruments which do not need to be connected to one another. These characteristics permit the use of analogical equipment even in narrow spaces and difficult working conditions, represented by components that can only be reached with difficulty or parts that are hard to see and inspect. On the other hand, the inescapable requirements of quality production impose the execution of periodic dynamic checks, that is to say tests during milking, and it is therefore necessary to verify that plants comply with Standard UNI ISO 5707 in particular, in both the design and realisation phases.

Telephone research shows that several (and very good) farmers of the sample don't know the correct mean of "static test", "dynamic test", "diagnostic outlet" and, overall. They don't know if their plant were equipped with correct diagnostic outlets and because they are very important to obtain quality milk and to increase animal welfare.

The research shows that information about the topic should be spread and that a considerable amount of resources should be utilised to set up milking plant if we really wish obtain high quality milk and cheese.

With this aim during the research a check list was drawn up of each of the three different types of plant studied (milk pipeline, recorder jar and bucket).

By using these, operators themselves will be able to verify in the design and realisation phases whether the plants really comply with the regulations and have diagnostic outlets. The same check lists will be brought to the attention of the technicians working for the technical assistance services for a preliminary assessment of milking plants.

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