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Automatic Milking System Occupation Rate Analysis and Optimization Applied to Mediterranean Buffaloes

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The Automatic Milking Systems (AMS) are well studied in dairy cows applications, but not on Buffaloes (Bubalus bubalis). Though, a few applications to the species can be found in literature. This study was carried out in a farm located in Paestum (SA), Southern Italy. It has about 230 lactation animals and to the best of our knowledge it is the first farm in the world that introduced the AMS in the case of buffaloes. The objective of this study was to optimize the AMS occupation rate in order to use it with Buffaloes. The experimental trial has been two years long. During the first year, a functional screening of barn with 4 AMS has been done. During this year, operational and functional aspects, such as number of buffaloes, milkings and rejections per AMS/year have been analysed. The working time and milking downtime per AMS/year have been calculated and additional number of buffaloes per AMS/year has been evaluated. It has been estimated the number of buffaloes that could be added and could be milked during the year per AMS (19 ± 3). During the second year, the occupation rate of one AMS has been increased. 70 buffaloes, chosen randomly among primiparous animals, have been added in the same AMS where the year before there were 51 primiparous buffaloes. The random chosen buffaloes, with DIM of 5 ÷ 10 days, have been bred with similar alimentation rates (TMR) and management proprieties as the previous year, as well as DeLaval AMS robot parameters (42 kPa vacuum; 60 cycles/min; 7 h between two milkings). In order to evaluate AMS functionality to an increase of buffaloes number, they have been determinated: 1) functional parameters of AMS during the observation year such as working times, occupation rate, number of milkings made by AMS and milkings distribution during 24 h; 2) productive parameters such as milking frequency e milk production rate per AMS during the observation year. Furthermore, milk quality during the second year has been compared with milk quality of previous year in order to evaluate if the buffaloes number increase could affect stress and uneasiness within the group, and then milk quality. Milk composition parameters have been evaluated: % fat; % protein; % casein; % lactose. Results have been validated using an analysis of variance (ANOVA), setting the significance level (α) to 0.05. Buffaloes number increase in AMS during one year caused an increase (+18 %) of milkings compared to previous year; an increase of total milk production (+55 %), a decrease (-27 %) of AMS not working time during a year; an increase (+15 %) of system occupation rate. Statistical analysis showed no significative difference of this increase on daily milking frequency in AMS during one year and daily milk production per buffalo in AMS during one year.

1. Introduction

The AMS (Automatic Milking System) is a robotic milking system which distinguish itself from the traditional mechanic milking, where the farm animals are simultaneously milked in groups which are mostly big at fixed schedules. The main difference is that the animal willingly goes to the milking station in a sufficient number of times so that a production increasing is satisfied, without additional costs (Hogeveen et al., 2001; Svennersten-Sjaunja and Pettersson, 2008; Jacobs and Siegford, 2012), and that the teatcup attachment is automatic. The AMS for cows has been introduced in the Netherlands in 1992. Since then, the number of factories using it has quickly increased (Svennersten-Sjaunja and Pettersson, 2008), making this technology

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accepted by the Netherlands and several European countries, and also in the USA and Japan. At the end of 2009, it has been estimated that more than 8000 factories all over the world employ the AMS (De Koning, 2010). The first AMS was installed in Italy in 1997. This system, though, didn't achieve a high level of support, because of the first experiences' failures. It seems, however, that even in Italy it's happening a turnaround, and the new AMS are being installed. The milking robots' spreading in Italy has predominantly regarded the northern and central areas, and the main beneficiaries of this technology are family-based holdings where the farmer carries out first in line milking activities. Few unities have been installed in Southern Italy, especially in Campania region, dedicated to the breeding of Mediterranean Buffalo (Bubalus bubalis), with more than 260,000 farm animals in production (Pindozzi et al., 2013). The Buffaloes' production is one of the most important agricultural activities of the Campania region, and one of the principal entries of the GDB. Even if it belongs to the family of bovine animals, the buffalo distinguish itself from the cow (Bos taurus) through its physical appearance and productive and behavioural aspects. The reduced milk production and the buffaloes' behaviour are preventing the factories within the field in choosing this system as a suitable alternative. The first buffalo farm which introduced 4 AMS station is located in Piana del Sele, Eboli (SA) (Faugno et al., 2015). The AMS, designed for cows, has not reported experimental evidences which justify its use on buffaloes up to now. In fact, in bibliography, few applications are listed (Caria et al., 2014; Tangorra et al., 2010). There are several reasons which make an AMS installation advantageous. In bibliography, it is widely reported that the AMS introduction in cows stockbreeding implied an increasing from 6 % to 25 % in milk production attributable to an increase in milking frequency (Amos et al.,1985, De Peter et al., 1985, Hogeveev et al., 2001), not to mention the managerial advantages linked to a complete milking automation with a consequent reduction of approximately 29 % of working hours compared to the traditional milking system (Bijl et al., 2007). The most important functional aspects of an AMS are milk yield, milking frequency, milking interval, teatcup attachment, success rate and length of the milking procedure (Gygax et al., 2007). Several criteria must be considered according to the AMS' milking capacity, such as the number of milkings per day, the herd size, the milking frequency and the cow traffic. The AMS' capacity limits may also be affected by changes in milking frequency when milking systems operate with different numbers of cows with varying milk yields. The number of milkings decreased when more than 45 cows were milked per AMS (Artmann, 2004). Also, milk yield and milk flow rate are influenced by milking interval (Hogeveen et al., 2001), and it has been noticed that increased milking frequency led to a milk yield increase (Wagner-Storch and Palmer, 2003; De Koning and Rodenburg, 2004; Speroni et al., 2006). The percentage of hours the AMS is milking per day expresses the capacity of an AMS, in terms of its occupation rate (OR). Even so, the AMS cannot be used for the entire duration of a day, since it needs some time for non-milking visits and for cleaning. Therefore, the total time available for milking should be allocated so that the milk revenues of the AMS are maximized (André et al., 2010). Because of the buffaloes' general behavior, which is very different to the one of cows, and since there is not a bibliographic history concerning the application of this milking system to this species, the aim of this research is to evaluate and optimize the operational capacity of the AMS applied to the mediterranean buffalo.

2. Materials and Methods

2.1 Study site, experimental design and animal management

The study was carried out from May 2015 to May 2016 in the organic buffalo farm “Tenuta Vannulo” located in Campania region, southern Italy. The farm consists of a total of 600 buffalo heads, of which 325 are divided between lactation and dry. Buffalos were fed on total mixed rotation (TMR) based on corn (18 %) and grass silage (24 %), and was distributed once a day (07:30 to 09:00 a.m.). Furthermore, different amounts of commercial concentrates were administered, ranging from 3 to 5 kg/d per buffalo. The farm has a stable with 4 AMS. It consists of 4 sectors (40 m x 32 m) each of them equipped by a robotic milking machine (DeLaval Voluntary Milking System 2007 Tumba, Sweden). The machine working parameters recorded by the management software (DeLaval, DelPro, DeLaval) were 42 kPa vacuum, 60 cycles/min pulsate rate, and 60 % pulsate ratio. Time set between two milkings is 7h.

2.2 Data Collection

Data were collected over two different time periods from Dec. 2014 to Nov. 2015 and from Jan. 2016 to Nov. 2016. The study was divided in two phases: the first one during which a screen of system has been done, with all 4 AMS working and the second one, during which the occupation rate of one AMS has been raised. During the first phase, a working time analysis has been carried out in order to optimize the occupation rate of AMS. According to Castro et al. (2012) and Caria et al. (2014), data has been collected using deLaval management software as reported in Table 1

Table 1: Operative parameter of 4 AMS

	DATASET
COUNTER	Average buffalo number per AMS in one year (NB) Milking number per AMS in one year (MAy) Rejections per AMS in one year (RAy) = number of times the buffalo enters the AMS without being milked
TIMES	Time spent on rejects per AMS in one year (hh:mm) (RTy) Cleaning time per AMS in one year (hh:mm) (CTy) Milking time per AMS in one year (hh:mm) (MTAy) Working time per AMS in one year (hh:mm) (WTy) = total time as sum of milking, cleaning and rejection time Not working time per AMS in one year (hh:mm) (MdTy) = *8760 - WTy*
PRODUCTION VARIABLES	Milk production per AMS in one year (kg) (MBAy) Milk production per buffalo in one year (kg) (MYBy) = *MBAy/NB* Milk production per buffalo in one day (kg) (MYBd) = *MYBy/365* Average milking frequency per AMS in one yearr (MF) = *MAy/(365*NB)* Average milk flow per buffalo in one year (kg/m) (MFR)

During the second phase of the study, the occupation rate of one AMS has been raised. With the results of the first phase as reference, 70 primiparous buffalos has been randomly chosen within the AMS 4 barn. During the previous year, in the same AMS, 51 primiparous buffalos has been chosen. The selected buffalos, with DIM of 5 ÷ 10 d, received the same breed (TMR), management and operational parameters of system as previous year (42 kPa vacuum, 60 cycles/min, 7 h minimum time between two consecutive milking).

2.3 Data Selection and Analysis

Working time analysis has been made with first phase operative parameters (Castro et al., 2012; Caria et al., 2014) of 4 AMS. The following functional parameters has been calculated:

Occupation Rate (OR %) per AMS in one year, Eq(1), as ratio between AMS working time (WT_y) and year hours (TT):

$$OR = \left(WT_y/TT\right) * 100 \quad (1)$$

Proportional rejection time rate (PRT), Eq(2), calculated as ratio between rejection time (RTy) and visit time (WTy):

$$PRT = RT_y/(R\,T_y + WT_y) \quad (2)$$

Rate A (ARTy), Eq(3), which is the fraction of time not human dependent because depends on buffalo behavior. It has been calculated as ratio between PRT and RT_y:

$$ART_y = PRT * RT_y \quad (3)$$

Rate B (AMTAy), Eq(4), which is the part of not working time that, in one year, can be optimized to increase the occupation rate of AMS.

$$AMTA_y = MdT_y - ART_y \quad (4)$$

Parameter 1 (AMAy), Eq(5), which allows to estimate the extra number of milkings that AMS can do in one day:

$$AMA_y = (AMTA_y * 60)/(365 * MTB) \quad (5)$$

Parameter 2 (ANB), Eq(6), which allows to estimate the extra number of buffaloes that an AMS can milk in one year:

$$ANB = AMA_Y/MF \quad (6)$$

This process required locating and removing any strange values before calculating the variables. Logical rules were applied; for example, if a certain variable was not recorded for a specific day, this might indicate problem with the AMS on that day and, consequently, data from this day were not taken into account.

During the second observation period, these parameters have been calculated:
AMS operative parameters such as working time, occupation rate, number of milkings and milkings distribution in 24h; other operational parameters such as milking frequency and milk production per AMS during the observation year; quality parameters of milk during observation year in order to evaluate if the increase of buffaloes number could affect milk quality. Milk quality parameters have been compared among the two periods of observation. Milk sampling has been done twice per month for every buffalo. Each sample was 200 mL and It has been analyzed according to International Dairy Federation Standards for fat content, lactose content, protein content and casein content using a spectrophotometer (Milkoscan 133 B Fosseletric). Also, the state of well-being and health of the breast in terms of somatic cells and bacteria content have been evaluated. Data analysis has been done with R-Studio (Version 3.1.1) software and the results validated with variance analysis (ANOVA) with normal distribution and homogenous variances. A significance level of 0.05 (α) has been chosen.

3. Result and Discussion

3.1 First observation period

Data from December 2014 to November 2015 is shown in Table 2.

Table 2: Operative parameters of 4 AMS – Dec. 2014 – Nov. 2015

DATA per AMS/y	AMS 1	AMS2	AMS3	AMS4
Buffaloes number (n)	47	40	47	51
Lactation number (n)	3-4	2	3-4	1
Milkings number (n)	38947	33653	33528	36456
Rejections number (n)	3388	3296	3921	4481
Daily milking frequency	2.5	2.3	2.4	2.3
Rejection time (hh:mm)	338:48	329:36	392:06	470:42
Cleaning time (hh:mm)	188:16	188:16	188:16	188:16
Milking time (hh:mm)	4875:37	5601:04	4816:02	5160:10
Working time (hh:mm)	5402:41	6208:56	5396:24	5819:08
Not working time (hh:mm)	3357:19	2551:04	3363:36	2940:52

During this observation period, It is possible to notice that one AMS did 35896 ± 2731 milkings on 46 ± 5 buffaloes in 5113:13 ± 358:13 hours (hh:mm). Considering that during one year an average of 4053 ± 550 rejections per AMS happened, losing 405:18 ± 55:00 (hh:mm) hours for milkings process, there were 3053:12 ± 388:50 hours/year of not working time because no buffaloes came in the AMS.
The functional parameters of 4 AMS are reported in Table 3.

Table 3: Functional parameters of 4 AMS

DATA	AMS 1	AMS 2	AMS 3	AMS 4
Occupation Rate **(%)**	61	65	64	66
Proportion coefficient	0.06	0.07	0.07	0.08
Extra milkings per AMS/y **(n)**	52	50	51	44
Extra buffaloes per AMS/y **(n)**	19.9	17.6	19.7	19.3

The average occupation rate (OR) of one AMS with 46 ± 5 buffaloes was 64 %, lower than the average of 79.02 % obtained by Castro et al., (2012) with AMS on cows. This analysis showed that It is possible to increase, in function of AMS not working time, the number of extra buffaloes (ANB) to add per AMS in one year. It has been calculated an average ANB value of 19 ± 2 buffaloes per AMS/y. According to this results, the second observation period has been planned.

3.2 Second observation period

During this period, from Gen. 2016 to Nov. 2016, occupation rate has been increased. Data from this observation period, compared to first observation period, is shown in Table 4.
Data obtained from comparison of two observation periods have been validated with ANOVA analysis showing that the increase of buffaloes number influenced milkings number per AMS in one year, with an increase of 18 %. Also, the not working time decreased (-27 %) while the occupation rate increased by 15 %.

Statistical analysis showed no significative influence of this increase on daily AMS milkings frequency and daily milk production per buffalo in one year.

Tabella 4: AMS data comparison

One year DATA	AMS_2016	AMS_2015
Buffaloes number (n)	70	51
Lactation number (n)	1	1
Average lactation period (d)	310 ± 20	314 ± 16
Milkings number (n)	47067 [a]	36456 [b]
Rejections number (n)	4707	4481
Average milkings frequency (n/d)	2.3 ± 0,1[a]	2.3 ± 0,2[a]
Average milk production per buffalo per AMS (kg/d)	8.3 ± 1,2[a]	8.5 ± 1,0[a]
Total milk production per AMS(kg)	212065[a]	136119[b]
Rejection time (hh:mm)	470:42:00	333:48:00
Cleaning time (hh:mm)	188:16:00	188:16:00
Milkings time (hh:mm)	6093:42:00	5160:10:00
Working time (hh:mm)	6615:46:00	5819:08:00
Not working time (hh:mm)	2144:14:00	2940:52:00
Occupation rate (%)	76 [a]	66 [b]

[a; b] *Average on the same line with the same letter shows not significative difference*

Figure 1 shows hourly distribution of milkings. Red line (AMS_2015) shows milkings distribution of AMS working with 51 buffaloes, while blue line (AMS_2016) shows milkings distribution of AMS working with 70 buffaloes. It is possible to notice from the graph (Figure 1) how the increase of buffaloes number doesn't affect milkings frequency and how milkings are well distributed on 24 h.

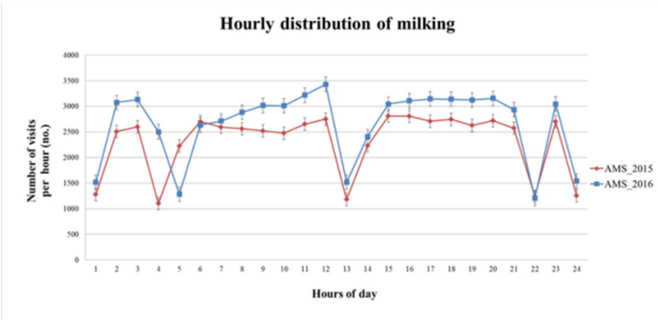
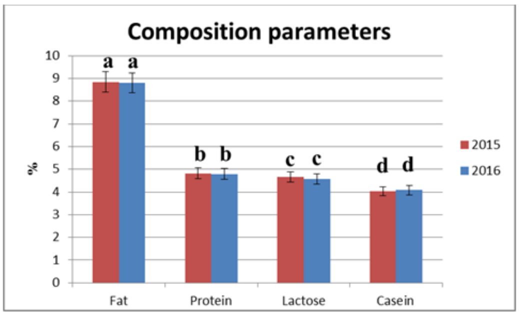


Figure 1: Hourly distribution of milking during one day



Average with the same letter shows not significative difference

Figure 2: Composition parameters comparison

Quality of milk produced by 70 buffaloes during the second year has been compared to quality of milk produced by 51 buffaloes during first year, in order to check if the increase of occupation rate caused stress within the herd affecting milk quality.

Figure 2 shows statistics comparison of milk quality parameters of two buffaloes groups. Red bar (AMS_2015) shows milk parameters of AMS working with 51 buffaloes, blue bar (AMS_2016) shows the milk parameters of AMS working with 70 buffaloes. Average fat content was 8.85 ± 1.36 (g/100 mL) for AMS_2015 and 8.80 ± 1.11 (g/100 mL) for AMS_2016. Both values are in accordance to buffalo milk reference value (8 - 8.5 g/100 mL; Galiero et al., 1996). Average protein content 4.82 ± 0.50 (g/100 mL) for AMS_2015 and 4.79 ± 0.31 (g/100 mL) for AMS_2016. Both values are in accordance to reference values (4-5 g/100 mL; Galiero et al., 1996). Average lactose content was 4.6 ± 0.53 g/100 mL for AMS_2015 and 4.5 ± 0.30 g/100 mL for AMS_2016. Both values are in accordance to buffalo milk reference value (4.5 - 5 g/100 mL; Galiero et al., 1996). Casein content was 4.02 ± 0.31 g/100 mL for AMS_2015 and 4.07 ± 0.33 g/100 mL for AMS_2016. Both values are in accordance to reference value (3.5 – 4.5 g/100 mL; Galiero et al., 1996). ANOVA analysis did not show significative difference for all milk quality parameters analyzed.

4. Conclusion

Automatic Milking System (AMS) application on buffaloes had never been done. This study showed that it is possible to increase the occupation rate up to 20 animals per year, determining an increase of AMS efficiency

with no negative feedback on milk quality. This study shows how AMS can be used also with Mediterranean buffalo, being a valid alternative solution to management issues of farm.
This study can be considered a milestone in AMS adaptation to Mediterranean buffalo showing that can be profitable for buffalo farm managers. Further studies could be taken into account in order to optimize the AMS use on buffaloes.

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