

Milking management and udder health of Brown Swiss cows raised under an intensive production system

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Abstract

This study assesses Brown Swiss cows' milking management and hygiene (n=40) in Tunisia. Milk production, quality, and udder health were examined during 12 months (2021-2022). Cows were milked three times daily, and their cleanliness was evaluated before morning milking on a 1–4 scale (1: very clean, 4: extremely dirty). The duration of udder preparation (T1), the interval between the final udder preparation and cup attachment (T2), and the total milking duration (T3) were recorded. After milking, the residual milk (RM) fraction was evaluated after an oxytocin dose. Results showed that the percentages of cows with an udder scores of 3 and 4, a hind leg score of 3 and 4, and a flank and thigh scores of 3 and 4 were respectively 15, 35, and 28% of the total number of tested animals. The somatic cell content (SCC) of cows classified 3 and 4 was 46% higher than that of milk from cows graded 1 and 2. Cow's cleanliness before mechanical milking is not fully respected, resulting in an estimated milk loss ranging from 3.44 to 10.04%. At 305 days of lactation, the average milk production (Kg), milk fat and protein contents (%), and SCC (10^3 cells/mL) were 5719 ± 439 , 3.79 ± 0.36 , 3.54 ± 0.18 , and 474 ± 76 ; respectively. Multiparous cows produced more milk than primiparous cows, with higher peak lactation yields (27.1 L/d) and a lower persistency coefficient (94.8%) than primiparous cows (97.1%). Mean values for T1, T2, and T3 were 0.97; 1.07 min, and 6.22 min, respectively. The residual milk fraction accounted for 22.0% of total milk production. These results suggest that enhanced milking management and cow hygiene can greatly improve production performance of Brown Swiss cows raised under an intensive dairy production system in Tunisia.

Keywords: animal hygiene; Brown Swiss cows; milking management; milk performance

Introduction

In Tunisia, dairy cattle production presents numerous constraints at various levels such as insufficient cow productivity, average milk quality, and often high production costs (Ayadi & Ben Salem, 2023). As a result, improving dairy production remains a critical factor in raising the profitability of dairy cattle farming. The total dairy cattle population is 388,000 female units, of which 237,000 (58%) are pure imported breeds, with an average milk of 5,100 kg per 305-days lactation for herds belonging to the organized sector (OEP, 2022). Milk production is affected by multiple factors, including genetic, nutritional, and numerous endocrine and environmental factors. Indeed, milking can influence changes in milk production in cattle (Marnet, 2013; Ayadi, 2019). Therefore, it is critical to identify milking systems that maximise quantitative and qualitative production while minimising labour restrictions. There is limited evidence available on the efficiency of mechanical milking of dairy cows in Tunisia (M'Sadek et al., 2014; Ayadi et al., 2020). Mechanical milking efficiency is mostly described as milk yield per minute of box time (Løvendahl et al., 2014). The highest milking efficiency is achieved with the best ratio between a cow's high milk yield and the short time that a cow spends in a robot (Odorčić et al., 2019). According to Labussière (1993), the efficiency of mechanical milking is defined as the ability to produce maximum milk quickly and thoroughly, while preserving the mammary gland health.

Indeed, several parameters can affect the cow's adaptability to machine milkings, such as milk production level, udder morphology, and different milking machine settings (Mein, 1992; Lee & Choundhary, 2006; Marnet, 2013; Gadzhiev et al., 2021). The milk fractions obtained during mechanical milking are: machine milk (MM), machine stripping milk (MSM), and residual milk (RM) (Ayadi et al., 2018; Bueso-Ródenas et al., 2022). Increasing the MM fraction and reducing the RM fraction is essential to improve the efficiency of machine milking in dairy cows (Labussière, 1993; Ayadi et al., 2020). These milk fractions vary depending on lactation stage, lactation number, and milking interval (Knight et al., 1994; Ayadi et al., 2003). On the other hand, the milking process used during mechanical milking indirectly impacts milk quantity and quality (Lollivier et al., 2002; Sannino et al., 2018). The RM increases with the length of time between milk ejection and milking completion (Labussière, 1993). Milk ejection depends on several factors, such as the milker (Rushen et al., 1999), pre-stimulation and feeding during milking (Johansson et al., 1999). According to Hernandez et al. (2016), leaving 30% residual milk in the udder suppresses milk yield, increases somatic cell count (SCC) and decreases the lactose content of the milk. Adequate teat stimulation before milking is essential to facilitate efficient milk harvest and minimize the milking machine impact on teat tissue condition (Wieland et al., 2020; Singh et al., 2023). This stimulation includes tactile stimulation of the teat and the timing of milking unit attachment (NMC, 2016). Teat tactile stimulation initiates the release of oxytocin into the bloodstream by the pituitary gland (Bruckmaier & Blum, 1996). The time between the beginning of tactile stimulation and the attachment of the milking unit must be sufficient to allow this hormone to reach the mammary gland and the ejection of alveolar milk into the gland cistern before the cisternal milk has been evacuated (Bruckmaier et al., 1993). In addition, poor milking and hygiene practices can affect udder health in cows and cause mastitis (Breen et al., 2009; Abebe et al., 2023). Mastitis, an inflammation of the udder commonly caused by intramammary infection, is one of the most prevailing and prominent diseases occurring in dairy cows (Farre et al., 2022). Its impact on the productive life of cows is significant, given the magnitude of the economic losses, risks to human health, and transformation issues in the dairy industry (Raboisson et al., 2020). Udder health in cows depends partly on good milking hygiene (Bartlett et al., 1992). Contamination of the teat orifice can easily occur by bacteria present on teat surface or on the contact surfaces of milking equipment (Hovinen et al., 2005). Therefore, keeping udders and limbs clean and healthy prevents harmful microorganisms from entering the udder canal and causing mastitis. By observing which parts of the cow are dirty, farmers can determine which barn areas need better cleaning or management (Lévesque, 2004). It is within this context that the present study is conducted to evaluate the milking management and udder health of Brown Swiss cows raised under intensive production system in Tunisia.

Materials and methods

Ethical approval

The procedures and animal manipulation in this experiment were authorized by the Official Animal Care and Use Committee of the National Institute of Agronomy of Tunisia (Protocol No. 5/15).

Animals and Management

A total of 40 Brown Swiss cows with different ages and stages of lactation were used. The cows belonged to a "Société de Mise en Valeur et Développement Agricole (SMVDA)" located in the delegation of Sidi Thabet in the governorate of Ariana, northern Tunisia (36° 34' 26" N and 8° 47' 50" E).

Cows were kept in loose housing with a straw bedding. They were given a basal diet consisting of 4 kg of oat hay (88.9% dry matter (DM), 9.3% crude protein (CP), and 0.40 Milk Forage Units (UFL)) and 20-25 kg of

green berseem (*trifolium alexandrinum*) (16.5% DM, 20.3% CP, and 0.69 UFL). To support milk production, the cows were also fed 8-10 kg/cow/day concentrate feed (91.5% DM, 20.6% CP and 0.96 UFL) four times each day. Cows had a free-access to fresh water.

Assessing cow cleanliness before machine milking

Cow cleanliness was assessed before morning milking (10:00), on four occasions (once a fortnight during November and December 2022), using the Lévesque (2004) evaluation method. It consists of evaluating, on a scale of 1 to 4 (1: very clean and 4: very dirty), in the milking parlor, and just before the cups are placed: (i) the cleanliness of the udder (rear and sides), which is an indicator of the hygiene of the cubicles and bedding (ii) the cleanliness of the hind legs, which is an indicator of the hygiene of the alleys and outdoor and waiting areas and (iii) the cleanliness of the flanks and thighs, which is an indicator of the hygiene of the bedding and the manure consistency.

Mechanical milking assessment

Cows were milked three times a day (2:00, 10:00, and 17:00) in a Heringbonne (2×5) high-line milking parlor. Milking machine was set at 50 kPa, 60 pulses/min, and 60:40 pulsation ratio, while milking routine included teat washing, teat drying with paper towels, machine milking, machine stripping and finally teat dipping with iodine-based disinfectant solution (Polycide, Laboratoires Interchem, Tunis, Tunisia). In addition, the duration of udder preparation (washing and massaging) (T1, min), the time between the end of udder preparation and teat cup attachment (T2, min), and the total milking duration (T3, min), which corresponds to the time elapsed between teat cup attachment and removal, were recorded by stopwatch, during morning (10:00) and evening (17:00) milkings, for all cows four time during 2 months (November and December 2022).

Milk production and milk fractionation during milking

Daily milk production of each cow was measured and recorded once a month during the experimental period (September 2021-August 2022) from milk checks carried out by the Office d'Élevage et des Pâturages (OEP, Ariana). The fraction of total machine milk (TMM), which corresponds to the total volume of milk collected by machine (MM) and machine stripping milk (MSM), was measured during the morning (10:00) and evening (17:00) milking. The average milk flow rate was calculated by dividing the TMM volume by the TMM duration (in L/min). In addition, the residual milk fraction (RM) was determined for 40 cows after morning and evening milking, following an intramuscular injection of 6 IU oxytocin/cow. The RM was then collected by mechanical milking. Udder volume (UV) is calculated as the sum of TMM and RM:

$$UV = TMM + RM.$$

Milk composition and somatic cell count

Milk samples were collected on the testing day (once a month) in a 100 mL bottle after each milking (2:00, 10:00, and 17:00) for 12 months for all cows (2021-2022). Analyses of milk chemical composition in fat content (FC), protein content (PC), and somatic cell count (SCC) were performed at the analytical laboratory of the "Office d'élevage et de pâturages" in Sidi Thabet, Ariana using CombiFoss™ equipment (Type FT1, FOSS Electric, Denmark). The SCC in milk is expressed as a concentration (number of cells/mL of milk). A logarithmic transformation (Log) of the concentration is used to ensure a normal distribution of observations before statistical processing. The somatic cell score (SCS) was calculated according to the following formula:

$$SCS = \log_2 (SCC/10^5) + 3 \text{ (Rekik et al., 2008).}$$

In addition, the lactation curve during the 2021-2022 agricultural campaign was determined and the persistence ratio is calculated according to the following formula:

$$\text{Persistence ratio(\%)} = 100 - \text{Milk loss (Gengler, 1996)}$$

With Milk loss = $((MP_n - MP_{n+1})/n)$; MP: milk production and n: control month

Estimating milk losses based on high cell counts

Quantitative losses of milk production resulting from high SCC were only determined from 200 - 500 × 10³ cells/mL according to the following formula (Raguet, 1996; M'Sadak et al., 2015; Atigui et al., 2020) :

$$\text{Losses (\%)} = [(SCC - 200,000) / 100,000] \times 0.02 \times 100$$

Statistical analysis

Statistical processing of the data was carried out using SAS (2012) software. Before analysis, raw daily data were checked for extreme outliers. Outliers in milk yield and milk composition were defined as deviating more than 1 SD from the mean.

Variation factors in dairy performance were analyzed using the following linear model.

$$Y_{ijk} = \mu + C_i + M_j + e_{ijk}$$

Where : Y_{ijklmn} = Milk Performance, μ = overall means, C_i = Cows, M_j = Fixed effect for the month of control (1-12 months), and e_{ijk} = Random residual error

All data are presented as means with standard error of the mean. The level of significance was set at $P \leq 0.05$ and a trend was defined at $0.05 < P \leq 0.10$.

Results and discussion

Milk production, milk composition, and udder health

The average daily milk production (4% fat-corrected milk (FCM), milk production at 305 days of lactation, chemical composition, and somatic cell count (SCC) of milk are presented in Table 1. The average daily milk production obtained in our study is higher (+10.4%) than the national average milk production reported for the Brown Swiss cow (16.8 kg; OEP, 2021). Furthermore, the Brown Swiss cow's average milk production at 305 days of lactation (Table 1) is higher than the average milk production of the Holstein (5106 kg), Montbéliarde (5366 kg), and Tarentaise (3624 kg) cows raised under Tunisian conditions (OEP, 2022). On the other hand, the average fat (FC) and protein (PC) contents of milk from Brown Swiss cows obtained in our study (Table 1) were significantly higher than the national average (FC = 3.59% and PC = 3.15%), as determined by the official milk control program (OEP, 2022). This variation in milk production and composition of Brown Swiss cows may be due to differences in animal genotypes, breeding and environmental conditions (Cak & Yilmaz, 2015).

Determining the somatic cell content of milk is an important criterion for assessing udder health (De Haas et al., 2007). The average SCC is 474×10^3 cells/mL, with a somatic cell score (SCS) of 6.68 (Table 1). Such SCC value is lower than those obtained under the national milk recording program for all breeds of cattle (649×10^3 cells/mL; OEP, 2022). Furthermore, the average SCC value reported in our study is lower than the Tunisian standard (NT-14–141-2004) for industrial acceptance of milk (500×10^3 cells/mL). Moreover, it is lower than the international standard for milk collection in the United States (750,000 cells/mL) and Canada (500,000 cells/mL), but higher than that fixed in Europe, New Zealand and Australia (400,000 cells/mL) and Switzerland (350,000 cells/mL; Sharma et al., 2011). To minimize SCC in dairy farms, precautions need to be taken, such as improving milking management, hygiene and barn conditions, milking cows at uniform intervals, feeding cows after the milking and applying a mastitis control program (Koç & Kizilkaya, 2009).

The effect of lactation number on milk production parameters is shown in Table 2. Multiparous cows produced more milk (+13.9%, $P < 0.05$) than primiparous cows. This increase in milk quantity was also observed in Holstein dairy cows in Tunisia by Brahmi et al. (2023) for Holstein dairy cows in Tunisia. Our results are in agreement with the study of Vergara et al. (2019) which showed that third lactation Brown Swiss cows had higher productive performance than first and second lactation cows. In addition, Lee & Kim (2006) showed that the mean milk yield in cows over 305 days increased with increasing parity. Variations in milk production with lactation number can be explained by body condition variation, growth in the volume of mammary tissue during the first gestations, and thereafter by tissue age (Caja et al., 2004).

On the other side, the shape of a lactation curve may be defined using two variables: peak output (kg) and lactation persistence (%). Primiparous cows have lower peak lactation yields ($P < 0.05$) compared to multiparous cows (3rd lactation) (Table 2). Moreover, multiparous cows peak earlier in lactation than primiparous cows. Lactation persistency partly explains why milk production is maintained during lactation. Indeed, it is calculated as the percentage of a given month's production over that of the previous month (Roumeas et al., 2014). According to the results obtained in our study, lactation persistence is higher ($P < 0.05$) in primiparous cows (97.1%) than in multiparous cows (Table 2). This is in agreement with the results of Brahmi et al. (2023) on Holstein cows in Tunisia, reporting that lactation persistence tended to be higher in primiparous cows (97.4%) than in multiparous cows (95.6%). Similarly, Innes et al., (2024) indicated that the lactation curve is often flatter in a primiparous cow, with a lower lactation peak and higher persistence compared to subsequent lactations. Lactation number did not affect significantly ($P > 0.05$) milk fat content and SCC.

Cow cleanliness before milking and udder health

Cows with udder scores of 3 and 4, rear legs scores of 3 and 4, and flanks and thighs grades 3 and 4 account for 15, 35, and 27.5% of the total number evaluated, respectively (Table 3). Lévesque (2004) indicated that cow cleanliness before machine milking is regarded as respected if the number of cows with udder scores 3 and 4 and flank and thigh scores 3 and 4 is less than 10% of the total number of cows tested. On the other hand, the number of cows graded with hind legs 3 and 4 should be less than half (50%) of the total cows assessed.

Animal cleanliness in dairy herds is essential to ensure hygienic milk production, good udder health and animal welfare (Hauge et al., 2012). Indeed, more than 10% of the cows tested in our study had an udder score of 3 or 4, as well as flank and thigh scores of 3 or 4. This can be explained by the fact that the hygiene and quantity of bedding used for each cow (which must be at a rate of 8m² of mulched air/cow) are not strictly respected. This poor udder cleanliness can be the cause of clinical mastitis (Breen et al., 2009). According to Rowe et al. (2021), clinical mastitis rates increased by a factor of 1.4 for every 10% increase in the proportion of cows with poor udder hygiene. However, cows with hind legs 3 and 4 account for only 35% (<50%) of the total

Table 1. Average milk production, fat and protein contents, and somatic cell count in Brown Swiss cows (n=40)

Parameters	Means ±SE
Milk production/cow/day (MP, kg)	18.75 ± 1.45
Milk production at 4% fat (L/d) ¹	18.16 ± 1.24
Milk production at 305 days of lactation (kg)	5791 ± 439
Fat content (FC, %)	3.79 ± 0.36
Protein content (PC, %)	3.54 ± 0.18
Somatic cell count (SCC, 10 ³ cells/ ml)	474 ± 76
Somatic cell score (SCS)	6.68 ± 0.88

¹Milk at 4% fat = 0.4 × Fat content + 15 × MP × Protein content (Gaine, 1969).

Table 2. Variation in milk production parameters according to cow parity

Parameters	Parity		P-value
	Primiparous	Multiparous	
Cows (n)	15	25	-
Lactation duration (days)	264 ± 62	294 ± 74	0.063
Milk production at 305 days of lactation (kg)	5495 ^b ± 393	6325 ^a ± 312	0.039
Milk production at lactation peak (kg)	21.9 ^b ± 4.5	27.1 ^a ± 5.0	0.027
Persistence ratio (%)	97.1 ^a	94.8 ^b	0.036
Fat content (%)	3.71 ± 0.35	3.69 ± 0.35	0.315
Protein content (%)	3.45 ± 0.20	3.39 ± 0.20	0.287
Somatic cell count (SCC/ mL)	488 ± 67	479 ± 67	0.462
Somatic cell score (SCS)	6.68 ± 0.78	6.67 ± 0.78	0.612

^{ab}averages on the same line with the different letter are significantly different ($P < 0.05$)

Table 3. Evaluation of the cleanliness of Brown Swiss cows (n=40) before morning machine milking (10: 00)

Parameters	Cow cleanliness evaluation chart				
	1	2	3	4	
	Cows				
Udders (Rear and side)	Number	12	22	6	0
	%	30	55	15	0
Rear legs	Number	2	24	12	2
	%	5.0	60	30	5.0
Flanks and thighs	Number	7	21	10	1
	%	17.5	55	25	2.5

Table 4. Estimation of milk loss associated with high SCC using the cow cleanliness evaluation chart

Cow cleanliness evaluation chart	Score (udder and limb) 1 and 2	Score (udder and limb) 3 and 4
Cow's number	28	12
Somatic cell count (SCC × 10 ³ cells/ mL)	372 ± 72	702 ± 70
Estimated milk losses (%) ¹	3.44	10.04

¹Losses (%) = [(SCC - 200,000) / 100,000] × 0.02 × 100

Table 5. Average milk fractions and milking performance of Brown Swiss cows (n=40)

Parameters	Mechanical milking	
	Morning (10: 00)	Evening (17: 00)
Milk fraction		
Machine milk (MM, L)	7.20 ^a ± 0.15	5.93 ^b ± 0.12
Machine stripping milk (MSM, %)	0.25 ± 0.04	0.15 ± 0.07
Total machine milk (TMM, L)	7.50 ^a ± 0.24	6.10 ^b ± 0.46
Residual milk (RM, L) ¹	1.56 ± 0.08	1.48 ± 0.10
Residual milk (RM, %)	20.8 ± 1.9	23.4 ± 2.6
Udder volume (UV, L)	9.06 ^a ± 1.12	7.58 ^b ± 1.64
Mechanical milking performance		
Average milk flow (AMF, L/min)	1.20 ± 0.09	1.02 ± 0.07
Udder preparation time (T1, min)	0.93 ± 0.02	1.00 ± 0.04
Time from end of udder preparation to the placement of cups (T2, min)	1.15 ± 0.07	0.98 ± 0.03
Total milking time (T3, min)	6.48 ± 1.16	5.95 ± 1.15

¹Residual milk (RM): obtained following intramuscular injection of 6 I.U. of oxytocin per cow.

^{ab}averages on the same line with the different letter are significantly different ($P < 0.05$)

examined. Although the cleanliness of the cows' hind legs is respected before mechanical milking, the observed percentage should be reduced. In this regard, alleyway hygiene (scraping before milking) as well as outdoor and waiting areas must be improved for cow cleanliness. Moreover, the consistency of the dung can have an impact on cow cleanliness (Hauge et al., 2012). The barn must be cleaned regularly. Cleanliness is also an important indicator of cow welfare (Ellis et al., 2007) that could have an effect on productivity.

Estimating milk losses based on high cell counts

Cow cleanliness has a significant impact on udder health, particularly on the rate of environmental mastitis. Thus, SCC varies according to the cow cleanliness evaluation grid. Indeed, the SCC (10^3 cells/mL) of milk from cows graded 1 and 2, as well as 3 and 4, were 372 ± 72 and 702 ± 70 , respectively (Table 4). Thus, the standard of hygiene in the animals living environment is a significant factor influencing the number of somatic cells in milk (Pytlewski et al., 2022). In Tunisia, the estimation of milk losses according to high SCC is well-documented (M'Sadak et al., 2015; Atigui et al., 2020). Raguet (1996) found that milk is considered normal at a threshold of 200,000 cells/mL, losses are only estimated from $200 - 500 \times 10^3$ cells/mL. In fact, above 200,000 cells/mL of milk, there is a milk loss of 2% per 100,000 cells. According to Hadrich et al. (2018), milk yield loss increased as the number of test days with $SCC \geq 100,000$ cells/mL increased. The milk losses estimated in our work varied according to the cleanliness of the cows before machine milking (Table 4). Cows with udder and limb scores 1 and 2, and scores 3 and 4, lost respectively 3.44% and 10.04% of their expected theoretical milk production. In fact, with average milk production at 305 days of lactation of around 5791 kg, an average loss of 605 kg/cow/lactation can be recorded for cows with a cleanliness score of 3 and 4. M'Sadak et al. (2014) reported that udder and milking equipment hygiene had a significant effect on SCC and udder health. Recently, Atigui et al. (2020) found an average milk loss associated with high SCC of 11.52%, i.e. an average loss of 648 kg/cow/lactation. The milk loss is due to poor milking management, in particular to problems associated with the adjustment of milking machine parameters. Indeed, bad machine settings can significantly modify the milking efficiency and increase the risk of udder aggression (Marnet, 2013).

Milking routine and milk production

The average milk fractions and milking performance are shown in Table 5. Udder preparation (washing and massaging) took an average of 0.93 and 1.00 min during the morning (10:00) and evening (17:00) milkings, respectively. This stimulation time is much longer than that reported in the literature for cattle (10 to 20 seconds; Mein, 1992). However, Rasmussen et al. (1992) have shown that manual stimulation of 10 to 20 seconds is not sufficient for any stage of lactation or level of milk production in Friesian cows. Kergozien & Le Guénic (2007) also reported that reducing udder preparation time increases milking time in Holstein cows. The duration of udder preparation for Brown Swiss cows in our study (Table 5) is consistent with the findings of Ayadi et al. (2020) for local crossbred cows in Tunisia (1.52 min). Indeed, it seems that good udder stimulation allows better milk ejection, thus increasing the fraction of machine milk (MM) reducing the fraction of residual milk (RM), and consequently improving milk production (Ayadi et al., 2016; Singh et al., 2023). On the other hand, we observed a lack of wiping of the cows' udders with a dry cloth immediately after washing during morning and evening milkings of Brown Swiss cows, which can increase the risk of bacteria passing through the teats of the udder and therefore causing subclinical mastitis (Bosquet et al., 2013). According to Marnet (2013), cleaning and drying teats before attaching teat cups helps prevent milk contamination and reduce the bacteriological load on teats. In addition, the use of a bacteriostatic product after milking is recommended in ruminants to reduce pathogen penetration and therefore udder infection (Santos & Fonseca, 2001). The time between the end of udder preparation and cup attachment (T₂) averaged 1.15 and 0.98 min for morning and evening milking, respectively (Table 5). On average, the recorded time is well below that obtained by Ayadi et al. (2020) (2.05 min) for local crossbred cows in Tunisia. During our evaluation of the mechanical milking of the Brown Swiss cow, we noticed that, during the milking routine, the milkers prepare the udders (washing and massaging) of the cows in the same batch (n=10) together, and then go on to attach the milking clusters. Such routine will prolong the cows' waiting time. According to Labussiere (1993), a delay of more than one minute in fitting the milking cluster after the cows' udders have been prepared leads to significant milk losses, up to 30%. Similar observations were reported by Caja et al. (2004) in dairy cows. Similarly, Knight et al. (1994), reported that the longer the period between the end of udder preparation and cup attachment, the greater the increase in intramammary pressure, which consequently leads to relaxation of the alveolar cells and to a significant return of milk to the alveoli. This partial return of milk from the glandular cisterns to the alveolar cells is known as the elastic reflux of milk into the gland (Caja et al., 2004).

In contrast, the residual milk fraction (RM) that remains in the udder accounts for 20.8% and 23.4% of total production in the Brown Swiss cow during morning and evening milkings, respectively (Table 5). On average, this fraction (22.0%) is higher than that found in Holstein cows (10 to 15%) (Labussière, 1993) and local crossbred cows (19.6%) in Tunisia (Ayadi et al., 2020). The difference can be explained by the fact that extending the interval between the end of udder preparation and the attachment of the milking cups in the Brown Swiss cow increased the RM fraction (Labussiere, 1993; Ayadi et al., 2020). This milk fraction, which is difficult to recover during the

next milking, reflects the degree of udder emptying. Therefore, reducing the waiting time of cows is essential to fully benefit from the short and beneficial effect of oxytocin (3 to 4 minutes half-life) on milk ejection and udder emptying. Practically, to improve mechanical milking management and the farmer's income, it is important to reduce the time cows spend in the waiting area before mechanical milking. Moreover, it is recommended to decrease the size of the group of cows to be milked or to move the waiting area further from the milking parlor, if possible. The total milking duration (T3) in the morning and evening is 6.48 and 5.95 minutes, respectively (Table 5). This milking duration is slightly longer than that obtained by Caja et al. (2004) for Holstein dairy cows and by Ayadi et al. (2020) for local crossbred cows in Tunisia. During our evaluation of the mechanical milking management of Brown Swiss cows, we noticed that the detachment of the milking cups is not done on time and according to the end of milking (no milk flow at the milking claw). This can cause over-milking, which is detrimental not only to udder health (teat strangulation and even mastitis) (Rasmussen, 2004) but also to the efficiency of machine milking (increased total milking duration, Vermaak et al., 2022). According to Labussière (1993), increasing milking efficiency involves quickly and completely milking the maximum amount of milk while maintaining the sanitary condition of the mammary gland. The average milk flow rate in Brown Swiss cows is moderate (1.15 L/min; Table 5). Increasing the milk flow rate at which milking is completed can shorten milking time and increase milking efficiency (Hernandez et al., 2016). According to Magliaro & Kensinger (2005), milking time decreased by approximately 0.5 min with higher milk flow take-off level when comparing 0.8 kg/min to 0.6 or 0.48 kg/min. In addition, the milking flow rate is strongly influenced by teat dimensions. A negative correlation was found between teat length and average milk flow rate (Rogers & Spencer, 1991; Ayadi et al., 2020). Indeed, shorter teats are more suitable for mechanical milking than longer teats.

Conclusion

Milking-ability criteria are influenced by a multitude of managerial factors, including milking practices, times of milking, cow and housing cleanliness and udder health. Dairy farmers can improve milking efficiency and maximize milk production from their cattle by enhancing the management of main factors affecting milking-abilities. In our study, the mechanical milking management and cleanliness of the Brown Swiss cows are not fully respected. Implementing a fast and complete milking process can improve the quantity and quality of milk produced by Brown Swiss cows. Additionally, maintaining hygiene in the bedding, corridors, and outdoor areas, as well as in the milking equipment, is essential to improve the cleanliness of the cows and to reduce the incidence of environmental mastitis. Ensuring that the milking process is conducted efficiently and thoroughly is crucial. Delays in detaching the milking cups can result in over-milking, which negatively impacts udder health and milking efficiency. Proper timing and technique during milking can prevent issues such as teat end damage and mastitis, thus enhancing overall milk yield and quality.

The presented results can be used for further research in Tunisia in intensive production system, as there is a potential in breeding and improving the management of dairy farming with regard to udder health and milking efficiency.

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Conflict of interest declaration

The authors declare that they have no conflicts of interest related to the content of this paper.

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