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Feed Management: Impacts on Dairy Cow Welfare, Metabolic Health and Milk Quality: A Review

L. Doubbi Bounoua[1], A.A. Dahou[1], H. Tahlaiti[1], Z. Meskini[1,2], M. Homrani[1], A. Homrani[1]

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ABSTRACT

In dairy production, rigorous herd management is essential to ensure the well-being of cows, their metabolic health and ultimately, the quality of the milk produced. This study compares two types of dairy farms: Modern farms (Category 1) and resource-limited farms (Category 2). The objective is to assess the impact of feeding practices on the health and welfare of dairy cows by measuring metabolic parameters *via* blood sampling and behavioral observation. At the same time, milk quality is analyzed, both in terms of hygiene and physicochemical properties, using techniques such as lactofermentation tests and infrared spectroscopy. Finally, the study examines livestock infrastructure and its correlation with zootechnical performance, based on criteria defined by the World Organisation for Animal Health (WOAH). A statistically significant comparative study ($P<0.05$) highlights that optimized feeding practices on modernized category 1 farms lead to high cow welfare (65/100) and increased milk production (25.75 kg/day). In contrast, category 2 farms with stressful practices exhibit poor well-being (21/100), metabolic issues like low sugar (1.09 g/L) and triglyceride (0.86 g/L) levels, decreased production (19.67 kg/day) and reduced milk protein content (< 3%). The study confirms that the rearing environment, high-quality feeding practices and animal welfare are intrinsically linked to cow health, quality milk production and farm sustainability. Investment in these areas, particularly herd hygiene and welfare, directly translates into robust health, improved animal welfare and increased milk production, thereby justifying the implementation of necessary adjustments for farms.

Key words: Animal welfare, Feeding practices, Metabolic health, Milk quality, Sustainability.

Dairy farming requires a holistic approach to sustainability by integrating efficient, environmentally friendly management with excellent animal welfare and health (Pullin *et al.,* 2022). Challenges include balancing economic performance, environmental impact and animal welfare, which can be achieved through optimal farm design and management. A sustainable future for dairy depends on improving conditions to prevent stress and disease, thereby enhancing metabolic health, productivity and milk quality (Fraser *et al.,* 2013; Linstädt *et al.,* 2024; Porcher, 2003; Wankhade *et al.,* 2019).

Dairy cows' physical and mental health, productivity and milk quality are significantly impacted by both their housing environment and farming practices, including diet, space and ventilation (Harvey *et al.,* 2025; Vapnek and Chapman, 2010). Well-designed buildings and access to pasture improve health and reduce stress, while respectful practices ensure a balanced diet and comfortable environment, directly contributing to metabolic health, optimal milk production and higher fat and protein content in milk. Sustainable dairy farming requires integrating animal welfare, metabolic health, production and milk quality, as these factors are interconnected and their optimization is key for responsible, efficient and profitable dairy operations (Deghnouche *et al.,* 2019; Tewari *et al.,* 2018).

Dairy farming in northwestern Algeria faces significant hurdles, including heavy reliance on costly imported concentrated feeds and a critical lack of quality native forage and pasture, which are essential for healthy diets and robust milk production. This inadequacy, coupled with poor feed management, results in widespread metabolic issues like ketosis and mastitis, reduced immunity, diminished zootechnical performance and ultimately, threatens the economic sustainability of local dairy farms (Meskini *et al.,* 2023).

Dairy farmers in western Algeria face challenges including a lack of knowledge about suitable forage species, insufficient forage quantity and quality and poor feed management. These issues contribute to nutritional

[1]Laboratory of Sciences and Techniques of Animal Production, Faculty of Natural and Life Sciences, Abdelhamid Ibn Badis University, Mostaganem, 27000, Algeria.
[2]Department of Agricultural Sciences, Faculty of Natural and Life Sciences, Ahmed Zabana-Relizane University, Relizane, 48000, Algeria.

Corresponding Author: A.A Dahou, Laboratory of Sciences and Techniques of Animal Production, Faculty of Natural and Life Sciences, Abdelhamid Ibn Badis University, Mostaganem, 27000, Algeria. Email: abdelkader.dahou@univ-mosta.dz
ORCIDs: https://orcid.org/0009-0008-1762-7631, https://orcid.org/0000-0001-6640-3169, https://orcid.org/0000-0003-3545-7425, https://orcid.org/0000-0002-2906-9330, https://orcid.org/0000-0001-7265-516X, https://orcid.org/0000-0002-5486-3050

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deficiencies and metabolic diseases such as ruminal acidosis, ketosis and mastitis, ultimately reducing animal health and productivity (Boukhechem *et al.,* 2019).

Dairy farms in western Algeria are caught in a vicious cycle where high feed costs and poor animal performance reduce milk production and increase healthcare costs, threatening their economic viability. Studies show that the combination of these factors directly impacts farm profitability, highlighting the urgent need for solutions to counter these challenges (Boukhechem *et al.,* 2019; Medjahed *et al.,* 2024).

The study aims to compare modern dairy farms with those with limited resources in western Algeria in order to identify sustainable improvements and propose strategies to increase milk productivity and quality to meet the needs of processing and regional competitiveness. The analysis focuses on cow performance, health and welfare in order to optimize practices and ensure the sustainability of farms.

Location and period of the study

This scientific study, conducted in two phases by the Laboratory of Animal Production Sciences and Techniques LSTPA, examined, over a period of 291 days of lactation (from August 18, 2024, to July 5, 2025), how farm structure (herd size) and feeding practices influenced the performance of Prim' Holstein cows in the wilaya of Mostaganem, a coastal region in western Algeria. Data on milk production, milk composition, metabolic health and animal welfare were collected from small and large herds to determine the key factors in the efficiency and sustainability of dairy farms.

The preliminary survey analysis highlights a clear division between first-category and second-category farms, with the former featuring superior equipment and larger operations for livestock and production, while the latter are less equipped and less productive. First-category farms average 60 cows, utilize 0.17 hectares of land per cow for forage and feed a mixed ration that includes forages, silage and concentrates, supplemented by grazing. In contrast, second-category farms have smaller herds (45 cows), rely heavily on straw, chaff and crop residues with concentrates and have no dedicated land for growing forage or for grazing, depending instead on fallow land and stubble.

Study procedure

Animal welfare assessment

The methodology used in this study is based on the Welfare Quality® protocol, which is internationally recognized and validated by the World Organization for Animal Health (WOAH, 2022). It assesses animal welfare based on four fundamental principles: physical comfort, health, environmental quality (housing) and appropriate behavior. To collect the data, direct observations were made on each farm, enabling quantifiable measurements to be obtained. The data was analyzed using an assessment form developed by INRAE, 2021 (French National Research Institute for Agriculture, Food and the Environment), which assigns an average score to each farm. This score is determined according to a specific scale for each level of the protocol and expressed as a percentage rating (Table 1).

Biochemical blood parameters in dairy cows

To monitor the metabolic health of dairy cows, blood samples taken from clinically healthy cows at the beginning and end of lactation were analyzed to determine their cholesterol, triglyceride, blood glucose, creatinine, albumin, urea and mineral macromolecule levels using a SIEMENS HEALTHINEERS ATELLICA analyzer. The samples were collected by caudal vein puncture, placed in vacuum tubes and then the plasma was separated by centrifugation and stored at -20°C for analysis. This process follows the recommendations of Vapnek and Chapman (2010), which are supported by the International Dairy Federation (IDF, 2018).

Milk quality

Milk sample collection and preparation for analysis

Milk samples were collected in accordance with the approved laboratory protocol in two stages to determine milk quality: one immediately after morning milking and the other after evening milking. The samples, which represent a mixture of both milkings, were immediately refrigerated in an insulated cooler to prevent any deterioration due to ambient temperature during transport to the laboratory. The samples were analyzed within five hours of collection.

Hygienic quality

The lactofermentation test was the method used to assess the hygienic quality of the milk and its suitability for processing. It is based on the acid coagulation of milk due to protein flocculation, allowing the impact of microbial growth at 37°C to be observed. The appearance of the coagulum formed reveals the presence of spoilage flora and provides an indication of the overall microbial load, as well as the milk's ability to acidify (IDF, 2018).

Physicochemical quality

Infrared spectroscopy analysis, performed with a Lactoscan (reference ZKN001, 2023), was used to determine the following physicochemical parameters: fat (F), density (D), ash content (C), dry matter (S), protein (P), temperature (T), pH, freezing point (FP) and lactose (L).

Statistical processing of results

The results from the animal welfare, blood metabolism, milk production and milk quality indicators were subjected to statistical analysis. A descriptive analysis was used, with

Table 1: Assessment scale for the welfare of inspected herds (WOAH, 2022).

Scores	Assessments
100 ≥ Score > 80	Excellent
80 ≥ Score > 55	Good
55 ≥ Score > 20	Acceptable
20 > Score	Poor

IBM SPSS software (version 29), supplemented by a correlation analysis performed with Excel 2013.

Animal welfare

The assessment of animal welfare on farms, measured according to WOAH (2022) on four levels (body condition, housing, health and appropriate behavior), revealed a good overall rating (65±3) for category 1 farms. The category 2 received a lower rating (21±1), mainly due to weaknesses in farms 3 and 4 (Fig 1). The score of 65±3 obtained in category 1 indicates a good level of animal welfare in this category, suggesting that farming practices are generally satisfactory. The lower score of 21±1 obtained in category 2 is mainly due to problems encountered in farms 3 and 4. This highlights the need to improve practices in these specific farms. The LSTPA laboratory assesses the welfare of dairy cows using a rating system based on zootechnical and behavioral observations and health indicators, assigning a satisfactory rating (or high score) when cows achieve a score above 65/100 at the end of lactation and up to 70/100 at the start of lactation, indicating good adaptation to the management system and good use of resources. Category 1 farms are distinguished by practices that promote cow longevity and milk production, including limiting the number of cows per stall, access to pasture and regular health checks. These practices contribute to the sustainability of these farms by reducing disease-related losses and improving overall herd productivity.

A comparative study of animal welfare scores in dairy farming categories 1 and 2 reveals a significant difference, with a score of 21/100 for category 2, three times lower than for category 1 (Fig 1). This difference, which reflects less favorable farming practices in category 2, particularly in terms of housing, resting areas and grazing, raises concerns about the impact on cow welfare. Indeed, these conditions lead to negative interactions between dairy cows, such as competition for access to food, disruption of rest periods, or increased stress due to overcrowding. These interactions have significant consequences on milk production, with a decrease in milk yield, but also on the metabolism and sustainability of cows. For example, a recent study showed that housing conditions similar to those in category 2 can reduce milk production by 10% and increase the risk of metabolic diseases. In addition, poor animal welfare can also have a negative impact on the sustainability of livestock farming, increasing greenhouse gas emissions and reducing animal longevity. These observations are corroborated by the work of Fiorillo and Amico (2024) and Priyashantha (2025) specializing in animal production and biotechnology.

Body condition

The assessment, based on Welfare Quality and INRAE (2021) grids, confirmed that both categories maintain a good body condition in lactating cows (NEC body condition score between 2 and 3), indicating good feed management and no starvation. An adequate NEC (Body Condition Score) of between 2 and 3 for farms in categories 1 and 2 indicates that the animals are receiving sufficient feed and show no signs of hunger. A NEC of 2-3 means that the animals are in optimal physical condition, with visible fat and muscle reserves but without excess. This indicates good feed management and the absence of nutritional stress.

Housing

The study, based on the Welfare Quality approach (Bouffard *et al.,* 2017), observed the cleanliness of the cows. In category 1, cleanliness was high, with prevalences of 77% for hind limbs, 95.4% for udders and 89.3% for flanks. In category 2, a higher prevalence of soiled cows was observed (82.45%). Soiling was particularly marked on the hind limbs (81.25%), udders (15.8%) and flanks (79.6%) in category 2. The study also revealed problems with lying comfort in category 2, often related to the design of the cubicles. This assesses ease of movement through the type of housing (free or tethered). In category 1, 18.3% of buildings were tethered, housing 25.1% of cows. In category 2, 78.92% of dairy cows were tethered.

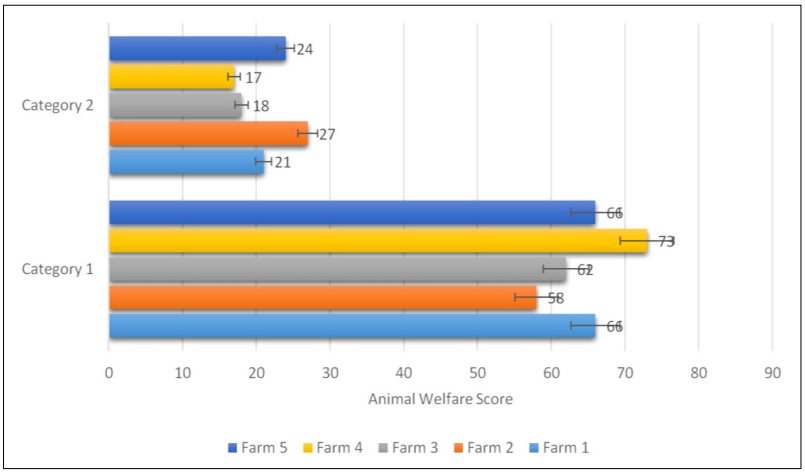


Fig 1: Average animal welfare assessment for the two categories of farms.

Good health

The well-being of dairy cows, as observed in a study by Becker *et al.* (2020), is influenced by factors related to physical health, including skin lesions, lameness, mastitis and reproductive problems. According to the study, the diagnoses made, using the same approach as Porcher, (2003) and Seddar-Yagoub *et al.* (2024), reveal significant variations in the prevalence of these problems depending on the type of farm (traditional vs. intensive).

Observation

To evaluate dairy cows, standard scales defined by the LSTPA laboratory research team are used, including the California Mastitis Test (CMT), which detects somatic cells in milk via the formation of a viscous gel. Lameness is assessed by visual observation of gait. Finally, scoring systems for skin lesions evaluate specific areas such as the back, flanks or hocks. These scales generally use a scale from 0 (normal) to 3 (damaged). The scores obtained will be expressed as a percentage of the dairy cattle herd inspected.

Skin lesions

Skin lesions, particularly on the hocks, are more common on category 2 farms (22.3%) than on category 1 farms (0%).

Lameness

Lameness, considered a major welfare issue, is also more prevalent in category 2 farms (26.2%).

Mastitis

The prevalence of mastitis (at a threshold of 2×10^5 cells per ml) is 7.62% in the farms inspected, with an incidence of 8 cases for the 105 cows studied (3 cases for category 1 and 5 cases for category 2).

Appropriate behavior

Animal welfare, particularly appropriate behavior, is crucial in dairy farming. The study showed that the number of agonistic (aggressive) interactions per cow per hour varies depending on the farming system. The category 1 farms have an average of 0.75 interactions (with extremes ranging from 0.35 to 4.30), while Category 2 farms have an average of 1.65 (with extremes ranging from 0.58 to 7.10). It is important to note that tie-stall housing, especially in confined and poorly ventilated spaces, exacerbates cow nervousness. Furthermore, according to the Welfare Quality study (Linstädt *et al.,* 2024), the tolerated frequency of interactions varies from 1.32 to 2.18 interactions per cow per hour, depending on the housing system. Poor management of these interactions negatively impacts the behavior, health, performance and longevity of dairy cows, as well as the sustainability of farms.

Biochemical blood parameters in dairy cows

The results of our study on the blood biochemical parameters of dairy cows showed that the average values of the various parameters do not vary significantly within each category of livestock studied (Table 2). However, significant differences were observed between categories, depending on the feeding strategy adopted. In particular, blood sugar (BS), a key indicator, differs between categories. While category 1 has an average BS level within the normal range (0.77 g/L), category 2 has a higher level (1.09 g/L). This increase in category 2 is clearly linked to a more energy-dense feed ration, as evidenced by the exceeding of normal values in cows from farms 1, 2, 3 and 4 in this category, in the physiological stage considered. During lactation, this high blood sugar level is also due to the high mobilization of glucose for the synthesis of milk lactose. In this context, Linstädt *et al.* (2024) noted in their

Table 2: Average biochemical values of blood constituents.

Dairy farm	Alb g/L	CT g/L	Cr mg/L	BS g/L	TG g/L	U g/L	Pr g/L	Ca mg/L	P mg/L
Standards	18-35	0.5-1.5	9-16	0.5-0.8	0.15-0.75	0.15-0.25	50-75	70-95	30-50
Category 1									
1	20	1.3	9.7	0.65	0.78	0.19	60	80	31
2	19	1.25	10.5	0.62	0.52	0.09	58	73	41
3	22	1.7	11.5	0.85	0.93	0.14	70	81	33
4	19	1.8	9.75	0.82	0.65	0.16	59	74	32
5	25	1.75	8.85	0.91	0.72	0.12	58	82	38
Average	21	1.56	10.06	0.77	0.72	0.14	61	78	35
Category 2									
1	23	1.96	16.08	1.04	0.97	0.16	49	75	27
2	29	1.90	17.18	1.13	1.05	0.14	46	68	33
3	27	1.95	15.85	1.22	0.80	0.16	47	73	34
4	23	1.86	14.54	1.09	0.80	0.14	43	78	29
5	28	1.88	16.25	0.97	0.68	0.15	45	66	32
Average	26	1.91	15.98	1.09	0.86	0.15	46	72	31

Alb: Albumine, CT: Cholesterol, Cr: Creatinine, BS: Blood suger, TG: Triglycerides, U: Urea, Pr: Proteins, Ca: Calcium, P: Phosphore.

research that the needs of the udder, particularly for high-yielding Prim' Holstein cows, are considerable, requiring more than 90% of the energy intake and more than 80% of the protein intake, which increases the demand for glucose for milk production.

Blood biochemical parameters, particularly triglycerides and cholesterol (CT), are important indicators of lipid metabolism in lactating dairy cows. Studying these parameters has made it possible to assess energy requirements and potential deficits, as well as the quality of farming practices. Oleinik *et al.* (2024) noted that triglyceride levels (TG) increase during lactation, which could be linked to greater mobilization of these lipids by the mammary gland for milk fat synthesis. The lipid metabolism of dairy cows plays a crucial role in meeting their energy requirements and compensating for any deficits at the start of lactation. The TG levels are generally higher in category 2 cows (0.86 g/L) than in category 1 cows (0.72 g/L). The CT levels are also higher in category 2 cows (1.91 g/L) than in category 1 cows (1.56 g/L). According to Deghnouche *et al.* (2019), these differences may indicate variations in husbandry practices and diets, particularly with regard to protected fats, the intake of which can increase cholesterol levels. It is essential to pay particular attention to the health safety of category 2 herds because of these variations.

Regarding nitrogen status assessment, total protein and albumin were the two important parameters used to assess the nitrogen status of dairy cows. The standards established by WOAH (2022) for Prim' Holstein cows in high lactation should indicate blood concentrations of 18-35 g/L for albumin, 15-30 g/L for globulins, 50-75 g/L for total protein and 2-5 g/L for fibrinogen. Albumin and total protein levels varied between the two breeding categories: 21 g/L and 61 g/L respectively for category 1 and 26 g/L and 46 g/L for category 2.

Measuring blood biochemical parameters such as urea, creatinine, calcium and phosphorus in lactating dairy cows has provided valuable information on their metabolic and nutritional health and on the effectiveness of their diet. In this context, WOAH (2022) reports that normal values between 0.15 and 0.25 g/L of blood urea (U) concentration are a good indication of protein balance in the rumen. The observed values of 0.14 g/L for category 1 and 0.15 g/L for category 2 suggest a good protein and energy balance in their rations. Changes in uremia may signal changes in diet, such as a change in the nitrogen/energy ratio, or fluctuations in the nutritional requirements of lactating cows.

Creatinine (Cr) is a product of muscle metabolism and its blood level reflects muscle mass and kidney function. In Prim' Holstein cows in production, normal values are between 9 and 16 mg/L according to the World Organisation for Animal Health (WOAH). The measured values (10.06 mg/L for category 1 and 15.98 mg/L for category 2) are within the normal range, suggesting good kidney and muscle function, as well as a balanced diet. These results also indicate adequate animal health management and prevention of digestive, reproductive and mammary disorders.

Calcium is an essential mineral for bone formation and muscle function, particularly during lactation. The WOAH recommends a range of 70 to 95 mg/L for total calcium in dairy cows. The values observed (72-78 mg/L) in both categories of livestock indicate sufficient calcium intake, which is important from the first signs of calving and throughout lactation.

The plasma phosphorus concentration observed in the two farms studied during lactation (between 31 and 35 mg/L) is in line with the standards recommended by the WOAH, which are between 30 and 50 mg/L. Phosphorus, an essential component of bone matrix, also plays a key role in various metabolic processes.

Milk quality

The quality analysis carried out over the entire lactation period on the 10 farms inspected yielded the following results.

Hygienic quality

The lactofermentation test provided an indicative assessment of the hygienic quality of the milk and its suitability for processing, based on the appearance of the coagulum and the nature of the bacterial flora. The lactofermentation test revealed that category 1 milk had good fermentation quality, with homogeneous gels and a dominant lactic flora, indicating suitability for processing into fermented milk or cheese. In contrast, category 2 milk showed signs of contamination, with irregular gels and spoilage flora, making it unsuitable for lactic coagulation (Table 3).

For category 1, 80% of samples (4/5) produced homogeneous gels, with firm coagulums, little serum and fine gas bubbles. These results indicate a dominance of lactic flora, which is essential for the production of fermented dairy products (yogurts, cheeses). Milk from these farms is considered suitable for biofermentation.

For category 2, 40% of samples (2/5) showed irregular gels, with lumps and serum exudation. 60% of samples (3/5) showed digested curds, with significant serum expulsion, forming pockets. The test also revealed mixed spoilage flora, with a predominance of fungi and butyric acid bacteria, causing processing problems. The milk from these farms is considered unsuitable for lactic coagulation.

These results, established in accordance with IDF (2018) recommendations, imply that category 1 milk can be used for the manufacture of fermented dairy products and cheeses, after possible standardization. Category 2 milk is not suitable for these transformations, as the presence of spoilage flora could lead to quality defects and health risks.

The lactofermentation test assesses the hygienic quality of milk and its suitability for processing, based on the appearance of the coagulum and the nature of the bacterial flora.

Physicochemical quality of milk

The physical and chemical quality of the milk was assessed and the results are summarized in the Table 4.

Based on the results, we find that the total dry extract (TDE) content of cow's milk is close to the IDF (2018) standards, averaging between 11.5 and 13% TDE and 8.5 and 10% DDE (defatted dry extract). In fact, milk samples tested throughout the lactation period have an average TDE content between 11.88% and 12.10%. Milk from category 1 farms had an average DDE of 8.86% and an TDE of 12.10%, while milk from category 2 farms had an average DDE of 8.5% and an TDE of 11.88%. A balanced diet for dairy cattle influences the TDE content of milk, since its components (mainly carbohydrates, lipids, proteins and minerals) come from feed. However, the average results of the DDE show that the average values do not exceed an average of 8.86%. These results fall outside the range (9 to 9.5%) set by dairy industries specializing in cheese processing and are well within the specifications (8.4 to 8.8%) of dairies producing fatty products (including fresh cream and butter).

For pH, our results show that the pH values of our milk samples are normalised in cows in production and range between 6.66 and 6.69 (IDF standard, 2018: 6.6 to 6.8). The results obtained during our study correspond to the recommended physical and chemical standards for raw milk, which are between 6.6 and 6.8 (IDF, 2018). Also, according to Matallah *et al.* (2017), the pH depends on the milk's casein, mineral salt and ion content, the hygienic conditions during milking, the total microbial flora and its metabolic activity. The same author states that pH is an indicator of milk freshness and nutrient content.

For milk fat MF content, based on the results obtained, we note that the average fat content of our cow's milk samples varies between 3.24 and 3.38%. The standard recommended by the IDF (2018) is between 3 and 3.6%. The extreme values of MF, also known as butterfat content

Table 3: Assessment of the hygienic quality of milk by lactofermentation.

	Lactofermentation test			
Dairy farm	Gel homogeneous score 10	Gel spongy score 6	Gel flakey score 3	Gel digested score 0
Standards	Gel homogeneous	Gel homogeneous	Gel homogeneous	Gel homogeneous
F1/ Category 1	Positive	/	/	/
F2/ Category 1	/	Positive	/	/
F3/ Category 1	Positive	/	/	/
F4/ Category 1	Positive	/	/	/
F5/ Category 1	Positive	/	/	/
F1/ Category 2	/	/	Positive	/
F2/ Category 2	/	/	/	Positive
F3/ Category 2	/	/	/	Positive
F4/ Category 2	/	/	/	Positive
F5/ Category 2	/	/	Positive	/

Table 4: Average values for the physical and chemical quality of milk.

Analyses	DDE %	MF %	TDE %	MP %	Lactose %	Water %	FP °C	MM %	pH
Standards	8.5-10	3-3.6	11.5-13	2.9-3.2	4-5	88-92	-0.52/-0.53	0.7-0.8	6.6-6.8
Category 1 farm									
F1	8.78	3.54	12.32	3.12	4.30	86.90	-0.520	0.68	6.66
F2	8.94	3.12	12.06	3.15	4.42	87.74	-0.525	0.72	6.67
F3	8.85	3.13	11.98	3.16	4.52	88.07	-0.527	0.73	6.66
F4	8.86	3.22	12.08	3.17	4.66	87.10	-0.521	0.71	6.68
F5	8.87	3.19	12.06	3.10	4.70	87.26	-0.522	0.74	6.69
Average	8.86	3.24	12.10	3.14	4.52	87.41	-0.523	0.72	6.67
Category 2 farm									
E1	8.48	3.43	11.91	2.96	4.25	87.10	-0.521	0.68	6.69
E2	8.54	3.39	11.93	2.93	4.40	88.77	-0.531	0.72	6.67
E3	8.48	3.31	11.79	2.95	4.52	86.90	-0.520	0.73	6.66
E4	8.54	3.29	11.83	2.97	4.66	86.73	-0.519	0.67	6.69
E5	8.46	3.48	11.94	2.94	4.67	86.74	-0.519	0.66	6.67
Average	8.50	3.38	11.88	2.95	4.50	87.25	-0.522	0.69	6.68

DDE: Defatted dry extract, TDE: Total dry extract, FP: Freezing point, MF: Milk fat, MP: Milk protein, MM: Mineral matter.

(BC), ranged between 3.48% and 3.54% for the two categories of dairy farms. However, the minimum average values ranged between 3.12% and 3.19%. This MF content, which complies with the standard, makes our milk profitable through standardization and skimming for the production of fatty products (butter and crème fraîche) on the one hand and dairy products with compliant MF/Dry ratios on the other.

For milk protein content (MP), we observed that the milk samples from our dairy cows had acceptable levels for category 1 (3.14%), while those from category 2 farms were < 3% undefined for class A and B milk processing (average of 2.88 to 2.95%). This milk protein content MP is not recommended for either fermented milk production or cheese processing, which require a MP>3%. According to IDF recommendations for milk processing, it is necessary to produce milk with a protein content of around 3.1 to 3.2% MP.

After determining the MF and MP content, the butterfat to protein ratio (MF/MP) is an essential parameter to be monitored in the dairy industry for the processing of milk. This parameter is important in the production of milk-based products. According to the average values calculated, the MF/MP ratio for milk from category 1 farms was 1.03, while milk from category 2 farms had a MF/MP ratio of 1.15. According to the IDF (2018), in the cheese industry, this ratio should not exceed 1.2. A ratio of 1.15 is considered optimal for the dairy industry, *i.e*., the production of fermented milk. The average level of this ratio in our study is acceptable. Indeed, the success of a dairy farm depends on obtaining MF/MP ratios for milk at equilibrium thresholds with values between 1 and 1.15 and without exceeding the maximum value of 1.2.

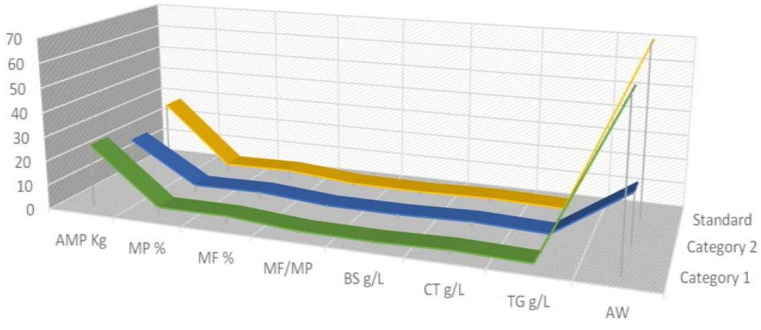
The lactose content in milk, with an average level between 4.5 and 4.57%, complies with IDF (2018) standards, which recommend a level between 4 and 5%. The levels varied slightly depending on the category of farm, ranging from 4.3 to 4.7% for category 1 farms and from 4.25 to 4.67% for category 2 farms. Controlling the lactose level is essential because lactose is a functional element necessary for milk processing (lactic fermentation).

The average mineral content values obtained for the milk studied were below the IDF (2018) tolerable standard for dairy cows on category 2 farms (around 0.69% for a standard of 0.7 to 0.8%). Milk samples from category 1 farms showed a tolerable average over the entire lactation period (0.72%). The mineral fraction of milk plays an important role in dairy technology, particularly in cheese making (coagulation-syneresis and cheese curd texture). Any change in mineral distribution affects the technological properties of milk and the rheological properties of the coagulum (Eck and Gillis, 2006).

The results of the freezing point analyses of the milk samples indicated that, overall, the quality of the milk complies with the expected standards for moisture content. This means that the amount of water added to the milk, if any, remained within acceptable limits. In fact, milk from category 1 farms had an average freezing point value of -0.523°C, compared to -0.522°C (with a slight water content of 0.57%) for category 2. Slight fluctuations were observed between categories and different farms, due to differences in feed on the one hand and differences in watering on the other, which led to slight moisture content rates in category 2 but which remain within the compliance range established by the IDF (2018).

Statistical analysis

Statistical analysis reveals a significant division of dairy farms into two groups: Practices and Potential, justified by a statistically proven difference ($p<0.05$). This implies that the variations observed in management, productivity and sustainability between these groups are real and not



	AMP Kg	MP %	MF %	MF/MP	BS g/L	CT g/L	TG g/L	AW
Category 1	25.75	3.14	3.24	1.03	0.77	1.56	0.72	65
Category 2	19.67	2.95	3.38	1.15	1.09	1.91	0.86	21
Standard	28	3.2	3.6	1.05	0.8	1.5	0.75	70

AMP: Average milk production/cow, MP: Milk protein, MF: Milk fat, BS: Blood sugar, CT: Cholesterol, TG: Triglyceride, AW: Animal welfare.

Fig 2: Comparative simulation of the impact of animal welfare on health and milk production.

random. To fully understand the study, it is essential to consult the explicitly defined results, which should detail the specific characteristics of each group and the differences measured.

Category 1 (n=5)

These are farms with acceptable milk production performance, with an average milk production (AMP) of 25.75 kg/VL/day (for Prim' Holstein dairy cows with high genetic potential). They produced milk rich in TDE of 11.98 to 12.32% with a MP of 3.10 to 3.17%, a MF of 3.12 to 3.54% and lactose of 4.3 to 4.7%. As an indication, the milk was of class A hygienic quality, with lactofermentation compliant in more than 80% of the farms studied. The MF/MP ratio was between 1 and 1.05, which oriented the functional aspect of milk in this class towards fresh or mixed cheese technology.

Category 2 (n=5)

This category of farms has below-average milk production performance, with an AMP of 19.67 kg/VL/day. According to the results of milk tests on the performance of the Prim' Holstein breed carried out by the French breeding institute "INRAE" in 2021, a milk production level below 18 kg/VL/day is the threshold for involuntary culling (for non-compliance in production) of this breed in France and Canada. According to these same results, Prim' Holstein milk must have a MP content of between 3.18 and 3.24% and a MF content of between 3.2 and 4.2%. Despite these milk production performances, this category included milk that was acceptable in terms of chemical components of interest for milk processing (3.29 to 3.48%, 2.93 to 2.97%, 11.79 to 11.94% and 4.25 to 4.67% for MF, MP, TDE and lactose, respectively). The MF/MP ratio is 1.15. The lactofermentation test yielded mediocre results, with 66.67% of fermentations exhibiting a flocculent appearance and 33.33% a digested appearance. The high MF/MP ratio for category 2 is a proven indicator of an imbalance in the nitrogen content of the feed ration. Concentrate-based rations formulated for these farms throughout the lactation period led to an increase in MF content at the expense of MP content.

According to the IDF (2018), for the same Prim' Holstein breed (in a Mediterranean climate), diets based on concentrates (high in energy) increase the fat content of milk much more than those based on fiber-rich forage.

In this case, milk standardization by adjusting its fat content (through controlled skimming) is necessary to align the fat/protein ratio (1 to 1.05) with the standard and adapt its functional profile to the diversification of dairy processing and the typical characteristics of dairy products.

In line with the approach adopted by Bednarski *et al.* (2024), controlled farms must monitor formulated rations and prevent certain metabolic disorders in dairy herds that can affect the two combined chemical indicators of milk quality: MF content and MP content.

The logical way to achieve this, as observed in typical category 1 farms, is to regularly perform real-time biochemical profiling on a large number of cows. In particular, this involves studying variations in milk components. These quickly reflect changes in rations that can have metabolic and pathological consequences. A reasoned approach at the level of category 1 livestock farms, inspired by the experience and work of Pellerin (2021) in Saint-Hyacinthe, Canada, on dairy cows of a similar breed.

In Algeria, Matallah *et al.* (2017) in the northeast and Ouchene-Khelifi *et al.* (2017) in the center reported that milk produced from the same breed varied in quality and quantity. These results were comparable to dairy farming practices and the semi-arid climate of the study region, the western coast. This suggests that local agricultural practices, particularly in terms of dairy cattle breeding and feeding, are adapted to the semi-arid environment of this area.

A simulation based on Excel data (Fig 2) revealed significant differences between the two categories of dairy farms: category 1 farms (advanced methods, forage crops) comply with INRAE standards, while category 2 farms (traditional farming, no forage crops) fall short in areas such as production, milk quality and animal welfare. These differences can be explained by feed, resources, housing and herd management.

The statement asserts that in dairy farms, agricultural practices significantly affect animal welfare (Fig 1) and that farms in category 2, compared to category 1 and INRAE (2021) standards, show different milk production, metabolic health (based on Blood Sugar, Triglycerides and Cholesterol levels) and milk quality (Milk Protein, Fat Content), according to Fig 2.

In other words, farming practices on Category 2 farms appear to have a significant impact on several key aspects of milk production, ranging from animal welfare to the quality of the milk produced.

A constructive approach to animal welfare (AW) in traditional Category 2 farms involves improving feed and housing. This translates into feed enriched with high-quality forage and suitable housing, thereby reducing health problems and negative interactions between cows, which are key factors for the sustainability and longevity of these farms.

The comparative simulation clearly illustrates in the Fig 1 that improving animal welfare is a profitable investment, both for the health and comfort of the cows and for the profitability of the dairy farm.

CONCLUSION

To enhance milk production and quality, dairy farmers must implement integrated management strategies that prioritize metabolic health through optimal feeding and housing, enforce rigorous health monitoring and promote animal welfare. A collaborative approach between researchers and farmers is vital for developing and adopting sustainable practices, supported by technological innovations that enable precision monitoring and feeding, ultimately improving farm profitability, milk quality and environmental sustainability.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare no conflict of interest.

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