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Effect of the Incorporation of a High Food Value Fodder Ration on the Cheesemaking Quality of Milk

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ABSTRACT

Background: The aim of this study was to investigate the impact of incorporating high value fodder on the productive performance of experimental Prim Holstein cows in lactation.

Methods: This supplementary feed ration is composed of a mixture of green grass silage and meadow hay. The effect of this incorporation on milk production and cheesemaking quality was studied on a batch of twenty-five high-lactation cows in experimental stalls.

Result: Physico-chemical analysis showed that concentrate and hay are energy-dense feeds, with the highest dry matter and crude cellulose content However, the fodder ration is richer in crude protein and minerals. Evaluation of the chemical composition of milk in the high-lactation phase revealed a significant difference between the experimental batch and the control batch in terms of protein, dry matter and urea content, but no difference was observed in terms of fat, lactose and mineral content. Analysis of production performance data clearly showsed that the fodder ration significantly improved milk production and technological milk quality. The use of green fodder remainsed effective in improving milk production performance and the cheese-making quality of the milk. Technological milk coagulation times have been optimized to ensure the correct orientation of the targeted cheese matrices.

Key words: Cheese quality, Experimental cows, Fodder ration, Milk production.

INTRODUCTION

Animal feed is one of the main factors affecting milk composition and consequently the quantity and quality of dairy products (Grelet *et al.,* 2013).

Improving the efficiency of dairy systems based on studied diets is a major challenge to achieve dairy potential and meet the needs of a demanding dairy industry (Bir *et al.,* 2015). Moreover, global demand for dairy products is high and set to rise further due to population growth and economic prosperity (Bayesa *et al.,* 2020; Legato *et al.,* 2014).

Algerian milk production fluctuates by region, due on the one hand to feeding constraints for dairy cows and on the other hand to feeding practices and unstudied rationing through the anarchic use of concentrated feeds.

The use of feed resources, employed in Europe and throughout the world, would be costly for Algerian dairy farms. It would therefore be advisable to find another naturally rich local food source, as an alternative that would improve the physico-chemical properties of milks with the aim of improving these technological and nutritional qualities (Matallah *et al.*, 2017).

To improve national milk production, fodder autonomy is an essential issue for Algerian dairy farms. Achieving fodder self-sufficiency, *i.e.* having the capacity to cover the herd's needs with forage produced on the farm, is therefore an important pillar for the economic profitability of any livestock farm (Remane *et al.,* 2016).

It is in this context that this work was carried out on a dairy farm in western Algeria in order to assess the suitability of a dairy herd's feed ration for quantitative and qualitative milk production.

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MATERIALS AND METHODS

Location

This study was carried out on a dairy farm in western Algeria, located in the region of Mostaganem, Algeria, from October 2022 to January 2023, with a dairy herd consisting of 25 Prim Holstein dairy cows divided into 05 lots of 05 cows.

Animals

The study involved 05 batches of lactating cows. One control (designated T) and the other experimental group (designated

E1, E2, E3 and E4) calved in autumn 2022. Calving date of experimental dairy cows was between September 03, 2022 and September 28, 2022. The average live weight of the dairy cows 550 Kgs with an average milk production, in high lactation, of 32 kgs per day.

Experimental conditions and feeding

The animals were kept in experimental stalls and fed the ration prepared for each batch of cows individually and ad lib (Table 1).

To help the animals adapt to the experimental diets, a one-month habituation period was adopted. Feed was gradually distributed twice a day. Water was provided ad lib, with a daily average of 60 litres.

At the end of this phase, the animals were subjected to an experimental phase lasting 04 months, the high-lactation period, during which the dairy cows were rationed according to the formulation set out in the Table 1. These feed quantities correspond to the average ingestion capacity of each animal and to the coverage of its needs.

Feed formulations

Two diets, one established according to the farm's feeding practices and the other according to the formulation based on green fodder. Diet formulations are illustrated in the Table 1.

Physico-chemical analysis of feeds

Physico-chemical feed analyses were carried out using the Near-Infra Red FT-NIR Thermo Scientific Antaris Animal Feed II Analyzer (reference FL52069-E09/14M of the year 2018). The results taken were the average of 05 repetitions of analyses performed.

Determination and calculation of feed gross energy value

The basic formula used by the LSTPA laboratory to calculate the gross energy value of a food is as follows:

Gross energy GE value=

$$(\% \text{ carbohydrates} \times 4 \text{ Kcal}) + (\% \text{ lipids} \times 9 \text{ Kcal}) + (\% \text{ proteins} \times 4 \text{ Kcal})$$

Observations

- Carbohydrates represent at the food level: crude fibre and starch.
- Lipids represent at feed level: crude fat.
- Proteins are the food's crude proteins.

Chemical analysis and cheese-making properties of milk

Fresh milk samples were collected under strict hygiene conditions, immediately cooled to 4°C and analyzed within 24 hours. Each sample was separated into two aliquots.

The first was preserved with bronopol and analyzed by MIR spectrometry (Milko Scan FT2, Series N°8100), Foss Analytical, Hillerød, Denmark. The Milko Scan FT2 was used to determine the chemical composition of milk in terms of total dry extract, protein rate PR, butyrate rate BR, lactose, pH, mineral content and urea content.

The second was used to measure cheese aptitude using laboratory reference methods as described by Hurtaud *et al.* (2001) and Tahlaiti *et al.* (2020). Before coagulation parameters were measured, the milk was standardized for pH by lactic fermentation. Coagulation and acidification parameters were measured for two typical cheese technology models : fresh paste (FP) and soft paste (SP). Each milk sample was coagulated by lactic action of the milk's native flora, by enzymatic action (by adding rennet) or by mixed action using two different protocols. Coagulation parameters were measured on 10 ml of milk at 30°C.

Cheeseability was determined by measuring flocculation time and setting time using the method of (Grelet *et al.*, 2013).

Flocculation time is the time interval between renneting and the appearance of the first casein flakes visible to the naked eye on a milk sample heated to 30°C in a water bath (Grelet *et al.*, 2013).

The setting time is the moment when the first droplets of whey appear (start of whey exudation) on the surface of the gel, also known as coagulum, which becomes rigid and no longer runs down the walls of the experimental tube (Tahlaiti *et al.,* 2020).

For any coagulation, the setting time is generally about twice the flocculation time. Thus, for a normalized flocculation time of 5 minutes, the setting time is 10 minutes (Tahlaiti *et al.,* 2020).

Statistical analysis

The study of the similarity between the averages of diet formulation results and the quality produced by the milk collected was made possible by using a statistical test in systat software myatat 13.

RESULTS AND DISCUSSION

Feed chemical analysis

The basic ration of energy concentrate, wheat hay and barley grain (Table 2) is rich in dry matter and complex non-parietal sugars (starch and crude fibre), which, through anaerobic fermentation, lead to the ruminal production of acetate, butyrate, propionate and gases (carbon dioxide and methane). According to Sauvant *et al.* (2011), these feeds should not be fed in excess, as this would lead to acidosis, fibrousness and dietary transition.

The basic ration (R1) of dairy cows, influenced by the energy concentrate, provides high proportions of crude lipids > to 6%. In the same comments of Legato *et al.* (2014), such a practice is often accompanied by metabolic and nutritional disorders that alter the composition of the milk produced, more specifically the butyrous rate, increase the rate of long fatty acids and decrease the proportion of medium fatty acids. When the lipid content of the ration (Table 3) is controlled (feeding of R2, R3, R4 and R5 diets), the butter content of the milk is controlled; saturated fatty acid content decreases in favor of trans and polyunsaturated fatty acids of high nutritional value (Ferlay *et al.,* 2013). This proves that a balanced diet is an important lever for ensuring feed efficiency and increasing the quality of processable milk. In this approach, feed efficiency in dairy cows was observed according to the three criteria defined by Hulsen, (2010) and (Zaaijer and Noordhuizen, 2003), rumination time, rumen fill score and faeces. In practical terms, the R5 diet is best suited to lactating dairy cows, with a rumen filling score of 4 out of 5 (score scale defined by Hulsen, 2010) giving good digestive transit without metabolic disorders and an ideal rumination time of 08 hours. The faecal assessment score was 1 out of 5 (on the score scale defined by Zaaijer and Noordhuizen, 2003), an ideal score for lactating cows, giving bright faeces with a homogeneous consistency. No undigested elements were visible or palpable. This shows that the supplementation of the R5 ration ensured that the rumen flora functioned properly.

The nutrient content of a ration, as well as its structure, are important for good digestion and a healthy metabolism. A good feed ration must compensate for any energy deficits that dairy cows need to maintain their bodily functions. In addition, a controlled protein intake increases lactation requirements and improves milk quality. Fig 1 shows a difference in the proportions of energy and protein provided by the feed components used to formulate our rations. On the one hand, the high-energy base ration, made up of wheat hay, concentrated energy feed and barley grain (with a gross energy intake of between 237.96 and 303.65 Kcal). Secondly, the protein-rich forage supplement, made up of green grass silage and green meadow hay (with a protein content of between 11.45 and 17.5%).

In this study, excess energy intake of the basic ration has been substituted with a protein amendment provided by meadow hay and green grass silage.

These assessments concur with those of Legato *et al.* (2014), Nozieres *et al.* (2007) and Pawar *et al.* (2018) especially in the approach that dairy cattle require pasture forages rich in essential nutrients and low in energy. In amended rations, dairy cows break down the crude proteins in their feed (meadow hay and first-cut green grass silage) to build up their own proteins to maintain body mass and good lactation.

For example, the quality of the green feed given to dairy cows, combining green grass silage and green meadow hay, for organic farming and feeding (Chaudhary and Thakur, 2021; Santhosh, 2022) is reflected in the fine composition of the milk, which is preserved during cheese processing. This is a major improvement, as it guarantees the processor consistent milk quality right through to the finished product.

Chemical analysis and cheese-making properties of milk

Management of the fodder available on the farm and its use in a complementary ration (composed of green meadow hay and green grass silage) and the adoption of a period of acclimatization to improved diets, significantly conditioned the rise in milk production from 148.75 kg/day to 163.10 kg/day per experimental batch, *i.e.* from 29.75 kgs to 32.76 kgs per milked Holstein cow (Fig 2).

Table 1: Formulation of feed rations.

Diet	R1	R2	R3	R4	R5
			A		
A1 (kgs)	7.5	7.5	7.5	7.5	7.5
A2 (kgs)	9	6.75	4.5	2.25	0
A3 (kgs)	4.5	4.5	4.5	4.5	4.5
			B		
B1 (kgs)	0	1.125	2.25	3.375	4.5
B2 (kgs)	0	1.125	2.25	3.375	4.5
A+B (kgs)	21	21	21	21	21

R1: Basic ration (in kgs), R2: Basic ration amended to 25% (in kgs), R3: Basic ration amended to 50% (in kgs), R4: Basic ration amended to 75% (in kgs), R5: Basic ration amended to 100% (in kgs), A1: Wheat hay, A2: Concentrated energy feed, A3: Barley grain, B1: Green grass silage, B2: Green meadow hay, A+B: Complete ration.

Table 2: Average chemical composition of food components in the basic ration.

Designation	Moisture %	Crude fibre %	Crude protein %	Crude fat %	Mineral matter %	Dry matter %	Starch %
A1*	13.18±0.02	47.85±0.01	3.73±0.02	1.08±0.05	6.15±0.03	87.82±0.02	5.48±0.04
A2*	7.65±0.05	31.18±0.03	0.52±0.01	15.05±0.03	6.08±0.02	88.58±0.05	10.35±0.04
A3*	14.25±0.04	5.32±0.02	9.72±0.02	1.75±0.02	8.12±0.02	84.72±0.04	50.2%±0.03

*Significant at P<0.05; A1: Wheat hay, A2: Concentrated energy feed, A3: Barley grain.

Table 3: Average chemical composition of the feed in the supplementary ration.

Designation	Moisture %	Crude fibre %	Crude protein %	Crude fat %	Mineral matter %	Dry matter %	Starch %
B1*	52.85±0.03	22.38±0.02	11.45±0.05	0.18±0.01	10.12±0.03	43.65±0.03	12.65%±0.04
B2*	48.72±0.05	27.15±0.03	17.52±0.02	0.24±0.04	8.88±0.02	81.32±0.05	2.8%±0.05

*Significant at P<0.05; B1: Green grass silage, B2: Green meadow hay.

The aim of our study was to produce milk with the highest possible PR/BR ratio (>0.9 on average). Protein content is positively related to the general level of feeding (Grelet *et al.,* 2013). In present study, an increase of around 0.6 g of protein was observed per kg of milk produced (Fig 2). Dietary formulations have been made by shifting rumen fermentative orientations (volatile fatty acids) towards a reduction in the ratio of acetic and butyric acids to propionic acid and by improving nitrogen nutrition (Grelet *et al.,* 2013; Sauvant *et al.,* 2011). In practical terms, the R5 diet best suited to the needs of dairy herd. Average milk production and chemical quality of milk from the different batches have been presented in Table 4.

After analysis of variance, the results found in this study for dry matter content, protein content, butyrate, lactose and mineral matter showed significant differences ($p<0.05$). This shows that green feed supplementation had an improving effect on protein content (3.38%) and total milk solids (12.78%). Milk protein concentration was high in the batch of cows on the R5 diet with 100% green feed supplementation. The average protein values of the bovine milk samples analyzed were estimated at 2.82% for batch T and increased from 2.88% in batch E1 to 3.38% in batch E4 (Fig 2). These results are in line with the mean values obtained by Tir *et al.* (2015) and lie within the variation range of Matallah *et al.* (2017) (from 2.7 to 3.4%). Improving diets with protein-rich green fodder significantly improved the PR of milk of technological interest, an indicator of good experimental herd management and applied feeding practices.

The milkfat content is controlled within a range of 2.5 to 3%, which is an appropriate technological parameter for a cheese standardized in fat on dry matter (F/D of 40 to 45%), giving the cheese typical organoleptic characteristics

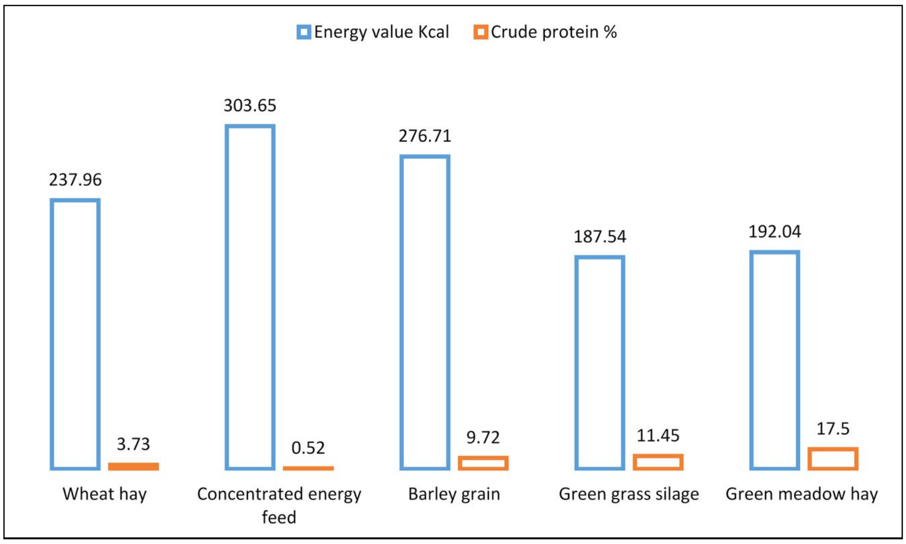

Fig 1: Energy and protein content of foods.

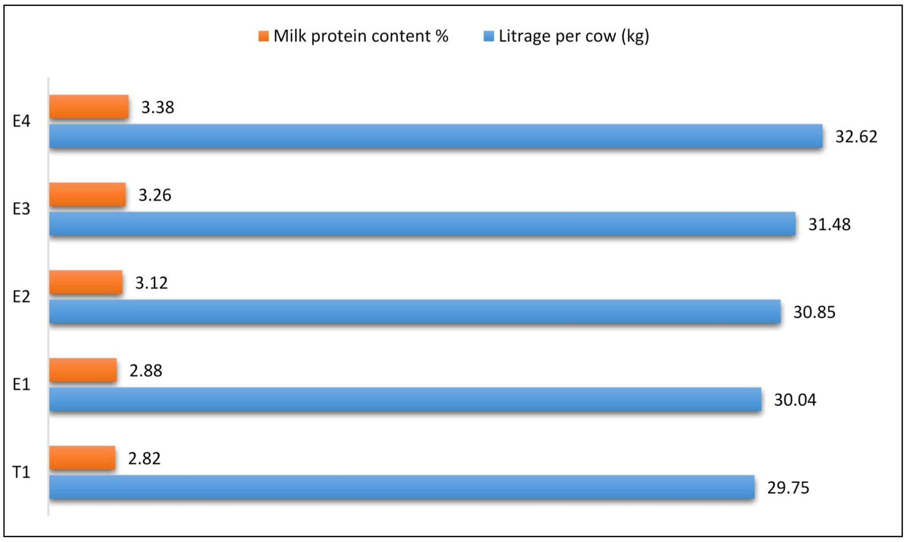

Fig 2 : Milk production and milk protein content per batch of cows studied.

: flavor, taste and above all texture. Results concur with those of Vignola and Amiot (2002) and Ferlay *et al.* (2013).

In experiment, there was no significant difference in lactose content. Values ranged from 4.42 to 4.37%± 0.01 for lot T and lot E, respectively. The average lactose content of the cow's milk analyzed was estimated at 4.4%. Lactose, the main sugar present in milk and a lactic fermentation substrate for lactic acid bacteria, is within the normal range for cow's milk, *i.e.* from 4.2% to 5.2% (Grelet *et al.,* 2013).

pH values ranged from 6.68 to 6.73±0.02 for batches T and E, respectively. These values are comparable to those of milk of the same breed from other regions of the country as reported by Maatallah *et al.* (2017); by Remane *et al.* (2016) and by Tir *et al.* (2015). These results are also close to the range (6.5 - 6.85) established by Tahlaiti *et al.* (2020). According to Lij *et al.* (2006), milk pH varies from one diet to another and depends, for a given herd, on the richness of its milk in certain constituents, particularly minerals and insoluble proteins, caseins. In cheese-making technology, any drop in pH below the norm favors the solubilization of minerals and the destabilization of casein micelles, leading to excessive losses in the whey during processing, with a direct influence on the quality of the cheeses produced (Colinet *et al.,* 2013).

The mineral fraction of milk plays an important role in dairy technology and particularly in cheeses. Indeed, any change in mineral distribution has an impact on the technological properties of milk and the rheological properties of coagulum (Grelet *et al.,* 2013). According to the results, the mineral content is 0.59% in the basic ration and rises from 0.64 to 0.85% in rations amended with the progressive incorporation of green fodder (green grass silage and meadow hay). According to some authors, dairy cows with a well-balanced and well-managed diet produce milk, depending on the lactation phase, with variable proportions of mineral matter ranging from 0.6 to 0.9% (Hurtaud *et al.,* 2001). The mineral balance between the colloidal and milky phases depends on pH, ionic strength and temperature. Any failure will result in an imbalance in this mineral fraction.

Measuring urea in milk is another indicator of feed efficiency, making it possible to monitor the protein intake of dairy cows (Nozieres *et al.*, 2007). Interpretation of the results obtained provides information on ration balance. The average urea content of cow's milk in experimental animals fed different diets ranged from 182.35 mg/l to 251.64 mg/l. Low urea levels in milk (< 200 mg/l) may reflect a lack of ammonia in the rumen, resulting on the one hand from low crude protein levels in the base ration and on the other from rumination failure leading to ammonia losses. Rumen microflora are unable to capture ammonia and convert it into protein (Hurtaud *et al.,* 2001). The milk obtained from experimental cow batches E2, E3 and E4, on a diet improved by the incorporation of green forages (green grass silage and meadow hay) combined with good rumination, show urea levels > to 200 mg /l and < to 350 mg/l, showing that the feed ration is balanced. According to Nozieres *et al* (2007), a controlled urea level maximizes protein yield and minimizes the release of nitrogen in the form of urea in the urine.

The results of the analysis of variance showed that there was a significant difference. According to (Bir *et al.,* 2015; Hurtaud *et al.,* 2001; Legato *et al.,* 2014; Matallah *et al.,* 2017), there is a direct relationship between basal nutritional status and the diet improved by green feeding and the ingestion of nutrients with high biological value. The supplementary ration ensured a dietary balance between the protein and carbohydrate fractions in the diet to improve rumen fermentation and the balance of nutrients needed needed to maintain dairy cows in lactation with the production of milk of good technological quality.

Controlling the cheese-making potential of dairy products

Coagulation of milk by lactic acidification and/or enzymatic activity (rennet) is the first stage in cheese-making, which can be considered as the result of a process of concentration of casein and fat after elimination of whey. For the cheesemaker, the behavior of the milk during coagulation plays an important role in the success of the cheese-making process (Lij *et al.,* 2006; Vignola and Amiot, 2002).

In this respect, the technological coagulation time gave an average flocculation time of 12.3 minutes for milk from the control batch, compared with average times ranging from

Table 4: Average milk production and chemical quality of milk from the different batches studied.

Designation	T	E1	E2	E3	E4	Standard deviation
DMP (in kgs)	148.75	150.22	154.25	157.40	163.10	± 0.05*
TDE %	11.98	12.06	12.28	12.51	12.78	± 0.05*
PR %	2.82	2.88	3.12	3.26	3.38	± 0.01*
BR %	3.41	3.25	3.17	3.12	3.08	± 0.02*
PR/BR	0.83	0.87	0.98	1.05	1.1	± 0.015*
Lactose %	4.42	4.42	4.38	4.39	4.37	± 0.01*
MM %	0.57	0.64	0.69	0.76	0.85	±0.02*
Urea mg/L	182.35	197.58	213.72	229.87	251.64	± 0.03*
pH	6.68	6.65	6.69	6.71	6.73	± 0.02*

DMP: Daily Milk Production, TDE: Total Dry Extract, PR: Protein Rate, BR: Butyrate Rate, MM: Mineral Matter, pH: Hydrogen Potential.
*Significant at $P<0.05$.

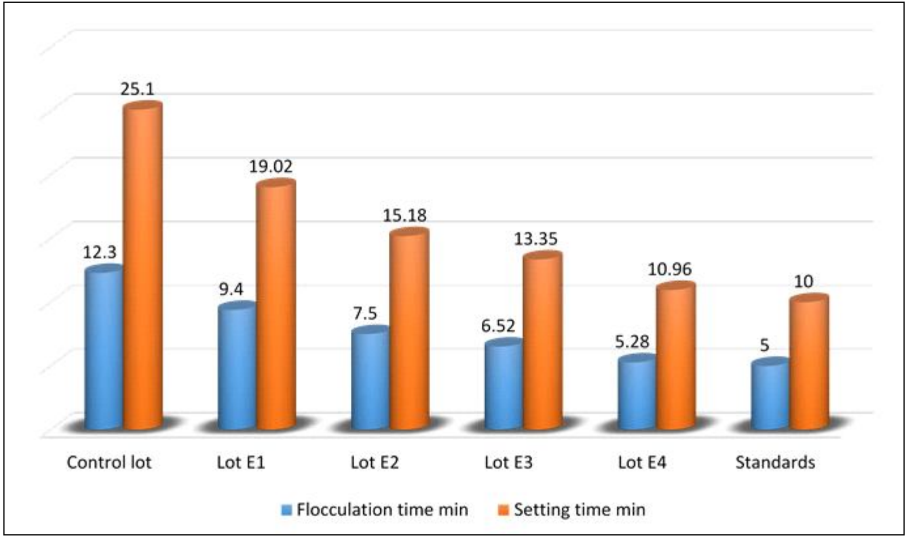

Fig 3: Technological cheesability times for milk products.

5.28 to 9.4 minutes for milk from experimental batches, against an average setting time of 25.1 minutes for the control batch and setting times ranging from 10.96 to 19.02 minutes for milk from experimental batches (Fig 3). The coagulation standard for milk, applicable by the laboratory (LSTPA), should be 5 minutes for flocculation time and 10 minutes for setting time. The results obtained (on Fig 3) are not compatible with milk from the control batch and are consistent with satisfactory to favorable coagulation activity and kinetics for all cheese processing of milk from experimental batches fed diets enriched with high-protein green fodder.

Cheese curds are formed by the agglomeration of caseins (Lij *et al.,* 2006). A good protein content in milk ensures faster curdling (coagulation), a firm gel that holds together better and retains matter better and therefore better cheese yield.

Statistical analysis using Systat Software Mystat 13 to assess the similarity of the averages of the diet formulation results and the quality of the milk produced, yielded significance values with a significant $P<0.05$. The R5 diet formulation was best suited to milk production and the cheesability of the milk obtained. Dairy farming practices substituting energy concentrate with a high nutritional value forage diet based on selected pasture:

- Ensured feed efficiency.
- Maximised the individual performance of prim holstein dairy cows.
- And have given the milk a fine composition with good cheese-making qualities.

CONCLUSION

Present study has shown that high-level dairy cows have specific crude nitrogen requirements that need to be met in order to improve protein utilization efficiency and bring out their full potential. Increasing dairy cow productivity, protein content and the technological aptitude of milk, by combining 02 types of diet with the elimination of energy concentrates, will in the short term provide an effective means of systematically reducing the butyrous content, correcting the PR/BR ratio and improving the cheesability of milk. Intensifying milk production for the cheese industry means adapting the feeding logic to make the most of farm fodder production and implementing compatible and sustainable breeding practices.

Conflict of interest

The authors declare no conflict of interest.

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