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RESEARCH ARTICLE

Effects of substitution corn silage with hydroponic barley forage on the variability of milk production, weight gain, and nutritional quality of cow's milk from the Holstein breed

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ABSTRACT

In the case of dairy cattle breeding, the hunt for substitute resources is imperative due to the skyrocketing cost of concentrate feed and the poor nutritional value of the basic rations that Algerian breeders typically use. Hydroponic green barley, which has been used as animal feed since the 18th century, satisfies the requirements for new fodder resources. The main objective assigned to this work is to study the effect of substitution of 50% hydroponic barley on bodyweight gain, milk yield and nutritional quality of milk from cows reared in Mostaganem region pastures. Sixty Holstein cattle, weighing 450 ± 55 kg on average live weight were divided into two groups; one contains dairy cows fed through a diet with hydroponic barley, the second fed with corn silage. The results based on the diets offered to dairy cattle revealed variations in the biochemical composition between the two batches studied. The nutritional increase in crude protein and minerals was consistently observed in hydroponic fodder, being 31.64% and 12.07%, respectively. On the other hand, low dry matter content was noted, depending on the type of grain and shelf life. Cows fed hydroponic barley and concentrate (group1) recorded greater final bodyweight gains than those fed on silage (100 Kg vs 83 Kg. $p<0.05$). Hydroponic forage feeding improves the rate of milk production through increased nutrient intake and digestibility. Depending on the type of diet, a significant effect ($p<0.05$) was noted at the level of all the physicochemical parameters of milk, with the exception of density. Acidity is high in the milk from the group, made from hydroponic barley (17.73°D). The results obtained show variations in the composition of the milk depending on the type of diet. Incorporation of hydroponic barley into the batch ration; contributed to produce milk with higher crude protein and ash contents. The use of hydroponic barley is very interesting for the breeding of dairy cattle and makes it possible to obtain milk recommended by nutritionists and of attractive hygienic quality.
Keywords: Acidity; breeding system, cow, hydroponic barley, milk; nutritional quality

INTRODUCTION

For an urban society experiencing rapid population increase and changing dietary preferences toward higher-quality foods, milk is an essential source of animal protein. Algeria is projected to consume more than 6 billion liters annually (Leduc et al., 2022). Feed is the primary factor restricting dairy cow output on dairy cattle farms. The limited amount of land sown, the scarcity of water, and the uncontrolled cultivation methods all contribute to the herd's inadequate feed supply (Tudor et al., 2003).

In Algeria, feed is mostly purchased for all farms that appear to be penalized by the limited amount of land available for fodder crops

(not only a dependency on concentrates, but also fodder during tough periods) (Belhadia et al., 2014). The issue of selecting the type of concentrate for dairy cows has come up more and more in the last few years. This decision may have been made for technical or economic reasons: cost, usability, and nutritional content (Yurtseven et al., 2020). However, the use of protein supplements such as hydroponic barley makes it interesting to integrate it in greater proportions in the diet of dairy cattle (Sharma et al., 2021). According to Fazaeli et al., (2011), hydroponic green fodder is made from fodder grains with a high germination rate and is grown quickly in a specialized chamber with ideal growth conditions. The creation of this planting method has made it possible to produce fresh fodder from grains such as wheat, barley, and oats (Rodriguez-Muela et al., 2004). An alternate approach to cultivating feed for farm animals

is the use of hydroponic technology (Naik, 2014). Livestock feed can be obtained naturally from fodder (Jemimah et al., 2018). Dairy animals should be fed it on a regular basis to ensure sustainable milk production (Jemimahe et al., 2022). In light of this and the requirement to lower feed costs, we felt it would be fascinating to examine how dairy cows reacted to the addition of hydroponic barley in contrast to concentrate feed and corn silage. Based on these findings, the main objective assigned to this work is to study the substitution effect of 50% hydroponic barley on growth performance, monthly milk production and the nutritional quality of milk from cows raised in the Fornaka region of the wilaya of Mostaganem.

MATERIAL AND METHODS

Hydroponic barley forage production

The study was conducted from February to May 2022 on a pilot farm for intensive dairy cattle breeding named joint stock company SPA Mosta Boustane in the wilaya of Mostaganem, more precisely in the commune of Fornaka. The latter is located in the southwest of Mostaganem, also called the Mostaganémois plateau. It is bordered by the Mediterranean Sea and Stidia to the north, by Sidi Abdelmoumen to the south, Ain Nouissy to the east and by the confluence of the Macta to the west (Enb et al., 2009).

One of the three pilot farms in Mostaganem is the joint stock company (SPA) Mosta Boustane. With over 300 dairy cows in good health and production, it is a modern, intensive system farm with a good herd size of Montbéliarde dairy cattle. This farm is outfitted with sixteen skilled and understanding workers, two veterinarians, a breeding technician, three zootechnical engineers, and a computerized traceability system. It therefore has a modern ration distribution system, a modernized milking parlor of the herringbone milking parlor type, and an appropriate housing system of the free stall type with cubicle building. In addition to using proper cleanliness and prophylactic measures, dairy cattle breeding best practices and techniques are employed. The selection of this study region was predicated on the presence of a sizable population of Montbéliarde cows and the fact that dairy cows' staple diet includes hydroponically grown barley.

Hydroponic barley forage (HBF) can be produced at the farm at up to 1,000 kg/d on a dry matter basis (6,000 kg as-fed) using a fully automated, continuous hydroponic forage production system (EA-38*2, Eleusis International Sau, Spain). Fourteen 38 x 1.5 m polypropylene conveyor belts are stacked in two racks of seven within this chamber, with the belts separated by roughly 50 cm. Two belts, one for each rack, arranged at the same level make up the daily production unit. A solitary electronic device situated in a nearby chamber regulates the environmental parameters. It governs an LED lighting system with 24 W, 3000 Kelvin, and PF 0.50, an air conditioning system with a relative humidity of 70% and a temperature range of 15–18°C, and an irrigation system that uses water enriched with chlorine (hypochlorite 0.2 mg/L) to ward off the growth of mold. The developing fodder is periodically irrigated and lit during the production cycle. Every day, a production unit receives about 1,000 kg of unsoaked barley seed (often 6-row kinds), which is left to develop for seven days.

Experimental design: animals and diets

Animals

The Holstein race's intense breeding program produced the cows used in our experimentation, who are currently starting their second scale lactation. The cows were housed in the same building, under the same environment, for the same amount of time, and fed identical feed under the same breeding method. Our herd was initially split into two groups, each with thirty dairy cows. In the first set, the cows are fed with a pasture, concentrate and hydroponic barley (HB). In the second group, the cows have the same previous ingredients as group 1, together with substitution of hydroponic barley with corn silage added at a daily rate of 50% per cow, as shown in Table 1. Veterinarian supervision is strictly enforced over the cows employed in our study.
In order to assure sufficient representation of the material to be studied, the diet sampling method involved taking two separate random samples of the ingredients such as: pasture, concentrate, silage and hydrponic barley, each weighing around one kilogram. The materials were collected, naturally dried by the wind to remove moisture, ground into a powder, and then kept in storage for further analysis at +4°C.

Growth performance

Using a needle scale with a maximum capacity of 500 kg and with a precision, the live weight of the cattle was measured each month, on each animal. This growth control of the animals made it possible to calculate the average gain (GM) obtained according to the type of diet offered in the basic ration. Weight gain (kg) is calculated by subtracting the starting weight from the end weight of the

experiment.

Milk collection

On February 27, 2023, during the morning milking, a sample of one liter of milk was taken for each batch. The samples that had been labeled were transferred through the laboratory of the Higher School of Agronomy in Mostaganem. To ensure optimal conservation, the samples were stored at -18°C for the different analyses.

Milk yield

Mean milk harvested per hour during a 24-hour period was defined as milking; the amount of milk collected per hour was computed as the average yield from each day's milking divided by the amount of time elapsed since the last milking.

Samples analysis

Diets

Samples were heated in a drying oven for 24 hours at 103 °C and 4 hours at 550 °C, respectively, to determine the levels of dry matter and crude ash (AOAC, 1990). The methodology developed by Folch et al., (1957) was followed in order to extract the total lipid content. Furthermore, the Kjeldahl approach (AOAC, 1990) was employed to quantify crude protein. Furthermore, the total phenolic content in the diets was evaluated based on the method developed by Miliauskas et al., (2004) and crude fiber content was determined using technique described by Van Soest et al., (1991).

Milk pH

Ten milliliters of cow milk sample were fully homogenized with 20 milliliters of distilled water, and the pH of the sample was measured with a pH meter (Mettler Toledo, SevenEasy, USA).

Acidity determination

The standard NFV04-206 (French Association for Standardization, 1969) is used to determine the acidity of milk. It is commonly stated using the following formula (Eq. 1) in grams of lactic acid per liter of milk :

$$\text{Acidity (g/l)} = V \times 0.9 \qquad (1)$$

where V is the 0.1N sodium hydroxide solution's milliliter volume.

The density is determined by lacto-densimeter according to NF V04-204 August 2004 standard (French Association for Standardization, 2004).

Defatted dry matter determination

The defatted dry matter is expressed in grams /l, calculated according to the following formula (Eq.2):

$$\text{Defatted matter} = \text{total dry matter} - \text{fat.} \qquad (2)$$

Total sugar determination

The method of Dubois et al., (1951) was used to determine the amount of starch and soluble sugars. Five milliliters of sulfuric acid were rapidly added to a test tube containing two milliliters of the solution to be measured and one milliliter of phenol (5%). After 10 minutes, the mixture was vortexed for 30 seconds and allowed to sit for 20 minutes at 25 °C in a water bath. Using a UV-VIS Spectrophotometer Specord plus, the orange-yellow color was measured at 490 nm. The values obtained are computed using a calibration curve built with known glucose concentrations.

Statistical analysis

The statistical relevance of the findings was evaluated by subjecting the study's data to one-way analysis of variance (ANOVA). The Newman-Keuls test was used in these post hoc mean comparisons. A $p<0.05$ was established as criterion for statistical significance.

RESULTS

Composition and physicochemical properties of diets

Table 1 displays the chemical composition of the cow feed that the Mostaganem farm provides. The results showed more protein, moisture and crude ash content in the hydroponic barley feed. The percentages of crude fiber were higher in the hydroponic barley and pasture than in the corn silage and concentrate. However, pasture presented a great amount ($p<0.05$) of polyphenols content

compared to the other feeding ingredients. Furthermore, the data revealed that the levels of total fat were substantially higher and predominant in concentrate-fed as shown in Table 1.

Growth performance

The impact of the replacing silage corn with hydroponic barley on cow growth performance is documented in Table 2. Notable differences ($p<0.05$) were observed in the initial weights of animals across the different rearing systems. The integration of concentrated feeds at varied proportions significantly influenced ($p<0.05$) the final weights at the end of the experiment. After 8 months, cows in the first group exhibited superior weight gains compared to those from the other one.

Milk yield

Figure 1displays the milk production results by type of ration. The acquired results indicate that milk output is significantly influenced by the feeding diet, with increased milk production from cows given 50% hydroponic barley.

Influence of hydroponic barley rate incorporation on the chemical composition of cow's milk

As shown in Table 3, replacing corn silage with hydroponic barley had a significant impact on milk composition, but none on meat pH, density and sugar content. Results showed more intramuscular fat and crud protein in milk from cow's grazed corn silage and receiving concentrated feed in their rations compared to those milk from the other one. However, the analysis of both groups milk crude ash shows a predominance for the hydroponic barley rearing system.

Table 1. Ingredient chemical composition (%, as fed basis) of the experimental diets. (n=4)

Ingredients	**Hydroponic barley**	**Concentrate**	**Pasture**	**Corn silage**	
Group 1 (D_1)	50%	50%	5%	-	
Group 2 (D_2)	-	50%	5%	50%	
Chemical composition					*P* - value
Dry Matter (%)	11.47^{c}	86.40^{a}	70.20^{b}	81.18^{a}	0.001
Moisture (%)	88.53^{a}	13.60^{b}	29.80^{c}	18.82^{b}	0.003
Crude ash (%)	12.07^{a}	02.03^{b}	02.78^{b}	07.90^{c}	0.001
Crude fiber (%)	0.88^{b}	0.45	0.62^{ab}	0.38^{d}	0.000
Protein (%)	31.64^{a}	12.07^{c}	14.80^{b}	08.50^{d}	0.000
Total fat (%)	0.76^{d}	04.73^{a}	02.81^{b}	01.08^{c}	0.002
Polyphenols (mg Eq gallic acid/g DM)	589.13^{b}	211.78^{d}	662.63^{a}	568.24^{c}	0.000

^{a,b,c,d} Superscripts indicate statistically significant differences ($p<0.05$).

DISCUSSION

Table 1 shows that concentrate feed, silage, and pasture all had high dry matter levels. According to Weldegerima, (2018), cereals typically have a dry matter (DM) content of 85% to 87%, while hydroponic fodder typically has a water content of 80% to 85%. However, hydroponic barley, with 11.47%, represents the highest DM content. This content is similar to 11.5%, reported by Soufan (2023), but lower than 18.37% found by Cremilleux et al. (2022). The dry matter content varies according to the stage of development of the plant depending on the morphological composition and the speed of grass growth (Baghdadi et al., 2018), the nature of the cereal used and the form of use of the barley (fresh, dehydrated) (Ouarfli, 2019). Corn silage and concentrate feed, with levels of 18.82% and 13.60%, respectively, had the lowest moisture content. Green fodder yield, grain type and quality, bulk density of seeds per square meter, temperature variations, irrigation frequency, nutrient solution, and growth phase are only a few of the numerous variables that affect moisture (Yousif et al., 2023). The results obtained showed appreciable mineral content. Indeed, corn silage tends to have a high content compared to pasture and feed concentrate. This result is higher than that obtained by Bellagi, (2017), i.e. 7.01% for corn silage. The protein content of hydroponic barley was found to be high and mostly (31.64%). Baghdadi et al., (2018) stated that the germination process alone is responsible for the accumulation of total nitrogenous matter in hydroponic barley, since it results in increased enzymatic activity, a loss of total dry matter, and an increase in total protein.

Table 1 shows that the lipid content of hydroponic barley is the lowest (0.76% vs. 4.73%) when compared to concentrate feed. These results are higher than those found by Fazaeli et al., (2011) and Belbachir et al., (2017), with values of 0.70 vs. 4.01%, and 0.60% vs.

3.55%, respectively. Cows require dietary fiber in order to keep their rumen functioning normally. Consuming fiber promotes chewing, salivation, and rumination. As shown in Table 1, significant differences and predominance are shown by the crude fiber analysis, especially for the hydroponic barley. The results agree with those obtained by Ata (2016). Corn is primarily utilized as an ingredient in the manufacturing of ruminant feed. It is a significant energy source. Usually, importation is expensive. As a result, farmers and researchers are now more motivated to use hydroponic barley as a cornmeal substitute. The data shown in Table 2 indicate that cows fed on hydroponic barley recorded greater final body weight gains than those raised corn silage. These variations are due to the quantity ingested and the digestive efficiency of the ration and its ability to be retained by the body. According to numerous studies, pigs fed a 10-day sprouted barley diet gained less weight than those fed ground corn ; nevertheless, in beef cattle, sprouted barley green feed increased daily gain by 200g over a control diet made of maize (Lim et al., 2020).

Table 2. Effects of hydroponic barley substitution on variation in cow growth performance (n=30).

	D_1	**D_2**	**SEM**	***P* - value**
Cow from 1 to 3 months (Kg)	650	687	0.32	<0.05
Carrier cow (kg)	710	720	0.48	<0.05
Cow from 3 to 6 months (kg)	722	734	0.62	<0.05
Cow 6 to 8 months (kg)	750	770	0.73	<0.05
Weight gain (Kg)	100	83	0.69	<0.05

SEM: standard error mean; D_1: Diet with hydroponic barley; D_2: Diet without hydroponic barley

Table 3. Effects of hydroponic barley substitution on nutritional composition and the physicochemical parameters of cow milk (n=30).

	D_1	**D_2**	**SEM**	**Afnor (1986)**	***P* - value**
Parameter					
pH	06.79	06.71	0.11	6.6-6.8	0.33
Acidity (°D)	17.73	16.60	0.23	15-18	0.000^{**}
Density	1029	1031	1.12	1028-1036	0.028
Chemical composition					
Dry matter (%)	32.70	36.26	01.02		0.000^{***}
Crude ash (%)	0.66	0.50	0.25		0.000^{*}
Crude protein (%)	39.52	28.96	0.19		0.000^{***}
Total dry extract (%)	43.45	60.37	2.38		0.000^{***}
Defatted dry extract (%)	42.15	58.81	1.73		0.000^{***}
Total fat (%)	01.30	01.56	0.14		0.003^{*}
Sugar (%)	04.17	05.07	0.87		0.031

D_1: Diet with hydroponic barley; D_2: Diet without hydroponic barley; SEM: standard error of the mean; * ($p < 0.05$); **($p < 0.01$); *** ($p < 0.001$)

Figure 1 shows a significant increase in milk production in group 1 receiving hydroponic barley over time (from the 1st to the 6th month of rearing) and depending on the composition of the basic ration offered to dairy cattle. These results agree with those reported by Kumar et al., (2021), who claimed that the quality and quantity of milk produced can be enhanced with the use of hydroponic fodder. Similarly, other studies conducted by Heins and Paulson (2016) and Naik et al. (2014) have also shown that feeding hydroponic barley fodder to cows increased milk output by 3.9% and 13.7%, respectively. These results could be explained by the greater digestible nutrient content and crude protein digestibility in the ration (Helal, 2015).

Milk pH analysis is crucial to assess its freshness. The pH of cow's milk fed with hydroponic barleyis slightly higher than that of animals provide for with silage (Table 3), but remains within the normal range of variation that corresponds to the standard established by Afnor, (1986). These results are similar to those obtained by Agius et al. (2019) who reported that hydroponic feeding of Holstein cows resulted in higher milk pH. The acidity results from the milks under study are in line with the Afnor standard (1986), which is between 16°D and 18°D. Group 1 which receives hydroponic barley as part of their basic ration has the highest acidity values, at 17.73°D (Table 3), which is comparable to that reported by Boro et al. (2018). However, milk solids content is estimated using milk density (Agius et al., 2019). The statistics shown in Table 3 indicate no significant effect of the diet on density, and a higher value was recorded for cow's milk fed on silage (group 2).

Statistical analysis revealed very clear differences between the main biochemical constituents of milk (Table 3). Compared to milk from the silage-based group, the dry matter content of cow's milk from group 1 that received hydroponic barley was found to be the lowest, at 32.7%. This may be related to the pH of the rumen fluid and the fermentation characteristics. The milk from cows fed

hydroponic barley had the highest mineral content (0.66%). This could be because barley has a high mineral content. This result agree with that found by Agius et al. (2019). According to the data, there is a significant influence of diet on the total dry extract (TDE) ($p < 0.05$), associated with a great level in milk from cows fed on hydroponic barley (Table3).

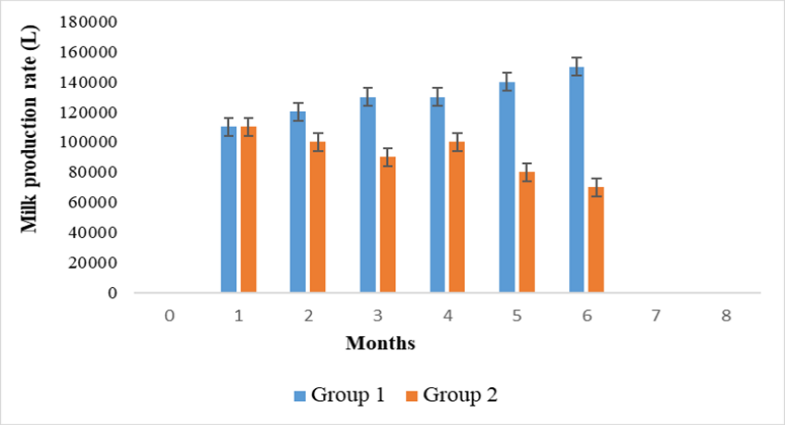

Figure 1. Variation in milk production rate of cows depending on the farming system.

According to Croguennec et al. (2008), the increase or decrease in TDE and DDE is directly related to the variation in protein rate and fat content which are themselves a function of diet. The results of the statistical analysis show a high crude protein and low total fat, sugar contents for the milk of cows fed with hydroponic barley in group 1 compared to that of the other one (Table 3). According to Hassan et al. (2016), breed, genetic variation within the breed, health, environment, managements techniques, and diet are some of the factors that influence the milkcontent.

CONCLUSION

Nutrition plays a crucial role in milk production, animal health and overall profitability of dairy farms. A balanced and appropriate diet for dairy cows is essential to maximize milk production, maintain growth performance and ensure the sustainability of dairy farming. Hydroponic barley is essential for dairy cattle's basic diet in order to improve development and milk output. Because of its low biological value, hydroponic barley provides dairy cows and other domestic species with a good nutritious diet. The addition of this substance to dairy cattle's diet resulted in notable modifications to the majority of milk properties, especially acidity (17.73°D). The total protein content of milk has changed due to the use of hydroponic culture, which is a desirable metric. Significant changes were observed in the fat content, defatted dry extract, and total dry extract based on the kind of ingredient feed. In the event that more research is required, more studies are required, especially those that deal with determining the fatty acid profile and amino acids as well as the sensory quality through a milk tasting test.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Berrighi Nabila, Özlem Aslan. Validation and Software were carried out by BenguendouzAbdenour and Bouterfa Asma. The first draft of the manuscript was written by Berrighi Nabila and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

CONFLICT OF INTEREST STATEMENT

No potential conflict of interest relevant to this article was reported.

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