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Effect of hydroponic barley supplementation on production and physicochemical composition of milk from Normande cows

Efecto de la suplementación con cebada hidropónica sobre la producción y composición fisicoquímica de la leche de vacas Normandas

Efeito da suplementação com cevada hidropónica na produção e composição físico-química do leite de vacas da raça Normande

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Abstract

This study explores the potential of hydroponic barley as an innovative feed strategy to address shortages in intensive livestock production, with a focus on small-scale landless farms. Twelve three-parous Normande cows, averaging 717 ± 34 kg, were allocated into two homogeneous groups based on body weight, calving date, and previous lactation performance. Both groups received identical total mixed rations (TMR), while the experimental group was supplemented with 10 kg of hydroponic barley per cow per day. Over the lactation period, cows in the experimental group exhibited higher daily dry matter intake (20.62 ± 1.21 vs. 19.13 ± 1.14 $kg.d^{-1}$) and milk production (22.17 vs. 18.91 $kg.d^{-1}$), resulting in a 17.25 % increase in total lactation yield (6,760.80 vs. 5,765.68 kg). Feed efficiency improved by 9.09 %, and milk composition analysis revealed elevated fat (40.13–42.49 $g.kg^{-1}$) and protein (32.21–34.87 $g.kg^{-1}$) concentrations. Daily fat and protein yields were also significantly higher in the experimental group (942 and 758.06 $g.d^{-1}$, respectively) compared to the control (777.76 and 609.09 $g.d^{-1}$). No significant differences were observed in body weight or body condition score between groups. These results suggest that hydroponic barley supplementation can enhance both milk yield and quality by improving nutrient intake and digestibility. However, to fully understand the mechanisms underlying these benefits, further investigations are needed to assess its effects on rumen metabolism and gut microbiota. Overall, this study highlighted the practical potential of hydroponic barley as a sustainable, high-value feed supplement in modern dairy systems.

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Resumen

Este estudio explora el potencial de la cebada hidropónica como una estrategia innovadora de alimentación para abordar la escasez en la producción ganadera intensiva, con especial atención a las pequeñas explotaciones agrícolas sin tierra. Doce vacas Normandas de tres partos, con un peso promedio de 717 ± 34 kg, se asignaron a dos grupos homogéneos según su peso corporal, fecha de parto y rendimiento de lactación previa. Ambos grupos recibieron raciones totales mixtas (TMR) idénticas, mientras que el grupo experimental se complementó con 10 kg de cebada hidropónica por vaca al día. Durante la lactación, las vacas del grupo experimental mostraron un mayor consumo diario de materia seca (20,62 ± 1,21 frente a 19,13 ± 1,14 kg.día^{-1}) y mayor producción de leche (22,17 frente a 18,91 kg.día^{-1}), lo que resultó en un aumento del 17,25 % en el rendimiento total de la lactación (6760,80 frente a 5765,68 kg). La eficiencia alimenticia mejoró en un 9,09 %, y el análisis de la composición de la leche reveló concentraciones elevadas de grasa (40,13–42,49 g.kg^{-1}) y proteína (32,21–34,87 g.kg^{-1}). Los rendimientos diarios de grasa y proteína también fueron significativamente mayores en el grupo experimental (942 y 758,06 g.d^{-1}, respectivamente) en comparación con el control (777,76 y 609,09 g.d^{-1}). No se observaron diferencias significativas en el peso corporal ni en la puntuación de la condición corporal entre los grupos. Estos resultados sugieren que la suplementación con cebada hidropónica puede mejorar tanto la producción como la calidad de la leche al mejorar la ingesta de nutrientes y la digestibilidad. Sin embargo, para comprender completamente los mecanismos subyacentes a estos beneficios, se necesitan más investigaciones para evaluar sus efectos sobre el metabolismo ruminal y la microbiota intestinal. En general, este estudio destaca el potencial práctico de la cebada hidropónica como un suplemento alimenticio sostenible y de alto valor en los sistemas lecheros modernos.

Palabras clave: cebada, vaca lechera, alimentación, producción de leche.

Resumo

Este estudio explora el potencial de la cebada hidropónica como una estrategia innovadora de alimentación para abordar la escasez en la producción ganadera intensiva, con especial atención a las pequeñas explotaciones agrícolas sin tierra. Doce vacas Normandas de tres partos, con un peso promedio de 717 ± 34 kg, se asignaron a dos grupos homogéneos según su peso corporal, fecha de parto y rendimiento de lactación previa. Ambos grupos recibieron raciones totales mixtas (TMR) idénticas, mientras que el grupo experimental se complementó con 10 kg de cebada hidropónica por vaca al día. Durante la lactación, las vacas del grupo experimental mostraron un mayor consumo diario de materia seca (20,62 ± 1,21 frente a 19,13 ± 1,14 kg.día^{-1}) y mayor producción de leche (22,17 frente a 18,91 kg.día^{-1}), lo que resultó en un aumento del 17,25 % en el rendimiento total de la lactación (6760,80 frente a 5765,68 kg). La eficiencia alimenticia mejoró en un 9,09 %, y el análisis de la composición de la leche reveló concentraciones elevadas de grasa (40,13–42,49 g.kg^{-1}) y proteína (32,21–34,87 g.kg^{-1}). Los rendimientos diarios de grasa y proteína también fueron significativamente mayores en el grupo experimental (942 y 758,06 g.d^{-1}, respectivamente) en comparación con el control (777,76 y 609,09 g.d^{-1}). No se observaron diferencias significativas en el peso corporal ni en la puntuación de la condición corporal entre los grupos. Estos resultados sugieren que la suplementación con cebada hidropónica puede mejorar tanto la producción como la calidad de la leche al mejorar la ingesta de nutrientes y la digestibilidad. Sin embargo, para comprender completamente los mecanismos subyacentes a estos beneficios, se necesitan más investigaciones para evaluar sus efectos sobre el metabolismo ruminal y la microbiota intestinal. En general, este estudio destaca el potencial práctico de la cebada hidropónica como un suplemento alimenticio sostenible y de alto valor en los sistemas lecheros modernos.

Palavras-chave: cevada, vaca leiteira, alimentação, produção de leite.

Introduction

The shortage of traditional fodder in Algeria poses a significant challenge to the development of dairy cattle farming (Bir *et al.*, 2015). A comparison of fodder requirements and availability in Algeria reveals a substantial deficit that exceeds 50 % of national needs. This gap has further widened due to the increasing numbers of all animal species, leading to the accelerated degradation of rangelands and the decline in the floristic composition of meadows, resulting in decreased production (Bouzida *et al*., 2010). As a result, breeders are compelled to seek alternative solutions to supplement the rations provided to their animals to some extent (Bir *et al.*, 2015).

Because highly productive species may be cultivated in artificial conditions, hydroponic fodder production may be an alternative to conventional fodder production in this specific situation. In addition to improving the nutritional value of the food rations that were delivered, this would enable the reduction of this shortfall.

Hydroponic barley is a type of fresh fodder that can be grown in special chambers under ideal conditions of light, humidity, and temperature for a brief period of time. The result is incredibly tasty and palatable sprouts that were 15–20 cm tall and can be supplied year-round, regardless of climate or land (Farghaly *et al.,* 2019; Ali *et al.,* 2019).Thus, by producing year-round green fodder with high nutritional content, hydroponic fodder production has the potential to boost milk yield and quality on farms in addition to addressing the main issues with traditional fodder crops (Nemzer *et al.,* 2019, Niroula *et al.,* 2019, Ma *et al.,* 2023, Pastorelli *et al.,* 2023). The nutritional advantages of hydroponic barley in ruminant diets, particularly dairy cattle, have also been shown in a number of studies (Mohsen *et al.,* 2015, Abouelezz *et al.,* 2019, Pastorelli *et al.,* 2023, Wu *et al.,* 2024, Masucci *et al.,* 2024). But rather than adding barley to the rations that were given out, the authors of these tests utilised it to replace concentrates.

This study evaluated the use of hydroponic barley as a supplement on milk production and physicochemical characteristics, as well as its effect on consumption, production yield, milk quality and body condition in Normande cows.

Materials and methods

The experiment was conducted in accordance with local legislation and the Animal Care of the Al Anfal cooperative (Accreditation Number of 19/03/11 of October 25th, 2022). The study was carried out at the experimental farm of the El Anfel multipurpose agricultural cooperative, situated in the southern part of the wilaya of Sétif in northeastern Algeria (35.58.50N and 5.32.50E), served as the study's site. The climate of this area is semi-arid, with less than 250 mm of precipitation falling there each year.

A 120 m² semi-automated production facility at the farm level was used to grow the hydroponic barley green fodder. Electronic units in a nearby room controlled an LED lighting system (24 W), an air conditioner (temperature 19–22 °C, relative humidity 65–70 %), and an irrigation system that used bleach-enriched water (sodium hypochlorite 0.3 $mg.L^{-1}$) to stop the growth of mould. Throughout the eight-day production cycle, the developing fodder received 3-minute misting with a frequency of 8 irrigations per day and continuous lighting. Daily harvests of the hydroponic barley fodder were made to feed the animals directly after harvest. Analyses of the chemical composition of harvested hydroponic barley fodder were carried out (Table 1) according to AOAC (1995). To calculate the nutritional value, the equations used are those of the INRA (2010).

Table 1. Hydroponic barley's chemical composition and nutritional value at 8 days after germination.

Chemical composition (%)	
DM	14.13 ± 0.31
MM (% of DM)	3.7 ± 0.2
OM (% of DM)	94.3 ± 2.6
CF (% of DM)	17.32 ± 0.42
CP (% of DM)	14.59 ± 0.27
Nutritional value /kg of DM	
UFL	0.93 ± 0.14
PDI (g)	99.0 ± 4.0

DM: Dry matter, MM: Mineral matter, OM: Organic matter, CF: Crude fibre, CP: Crude protein, UFL: Milk feed unit, PDI: Digestible proteins in the intestine

Lactating Normande cows' output performance was assessed. Based on their body weight, calving date, and productivity level from their previous lactation (18.86 ± 2.38 $kg.h^{-1}.d^{-1}$), twelve three-parous cows with an average body weight of 717 ± 34 kg at the start of the experiment were split into two homogenous groups, 3.59 ± 0.48 was the average body condition score (BCS) according to Vasseur *et al.* (2013) method.

A single lactation (305 days) was used for the experiment, and both feedlots breeding conditions were the same. The cows were kept in a free-stall barn with semi-automated feed gates and straw bedding. Every cow had unrestricted access to water to drink. There was natural daylight and ventilation. The identical diet, a total mixed ration (TMR), was given to the control and experimental feedlots. The quantities distributed take into account the ingestion capacity of each cow. On average, the quantities distributed per meal are 6 kg of TMR. Nevertheless, a hydroponic barley supplement was given to the experimental feedlot at a rate of 10 $kg.cow^{-1}.d^{-1}$. All of the cows were fed the identical diet during the first five weeks of lactation in order to check and confirm the homogeneity of the milk production performances of the two batches. Refusals were eliminated and weighed every day. According to INRA's nutritional recommendations, to ensure a cow is well-fed, a minimum of 5 % feed rejection is required.

The experimental batch of cows' diet was gradually supplemented with hydroponic barley fodder starting in the sixth week (a transition time of 15 days) in order to better understand the direct impact of hydroponic barley on production performances. Data collection began as soon as the cows gave birth. The total mixed ration was formulated and balanced using the INRA equations (2010), while respecting the recommended nutritional recommendations. The ingredients and nutritional contributions of the TMR were mentioned in Table 2.

Rations were delivered four times a day (07:00, 11:00, 14:00, 18:00), and cows were milked twice a day (at 4:00 and 16:00) in a four-station automated room in compliance with the farm routine. The hydroponic barley feed for the experimental group was consistently distributed at 11:00.

Table 2. Components, chemical composition and nutritional values of Total Mixed Ration (TMR) distributed to cows.

Components	**% of DM**	**Chemical composition and nutritional value**	
Corn	34	DM (%)	87.45 ± 1.18
Barley	8	CF (%)	17.43 ± 0.76
Wheat bran	7	CP (%)	16.18 ± 0.34
Soybean meal	15	NDF (%)	34.27 ± 1.08
Alfalfa hay	12	ADF (%)	26.08 ± 0.94
Wheat straw	17	Starch (%)	24.13 ± 0.93
Molasses	4	UFL	0.91
Calcium carbonate	0.5	PDI (g)	92.21
Salt	0.3		

DM: Dry matter, CF: Crude fibre, CP: Crude protein, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, UFL: Milk feed unit, PDI: Digestible proteins in the intestine.

Daily dry matter intake was calculated by subtracting refusals from the quantities distributed for the TMR. The body weight of the cows was measured at the end of each month.

The milk yield (average daily production ($kg.d^{-1}$) were evaluated every week. Maximum milk production (MPMax) was determined by identifying the highest daily lactation production. The cumulative milk production data gathered over the lactation period was used to compute milk production at 305 days (MP305). Once per week, as soon as the cows were milked in the morning and evening, milk samples were taken for physicochemical studies. Each sample underwent three simultaneous analyses, and the outcomes were averaged. A spectrometric milk analyser (LACTOSCAN, Alpes Industries Services74800) was used to evaluate milk samples. The concentrations of pH, specific gravity, lactose, fat, protein, total solids, and nonfat dry matter were all measured. The formula of Palmquist and Conrad (1978) was used to determine milk yield corrected to 4 % fat (FCM): $Y= 0.4X_1+15X_2$ where Y: milk at 4 % FCM, X_1: milk yield ($kg.d^{-1}$) and X_2: milk fat yield ($kg.d^{-1}$).

The 4 % milk yield (FCM $kg.d^{-1}$) was divided by the total dry matter intake (TDMI $kg.d^{-1}$) to determine feed efficiency (FE). For the control batch, TMR, for the experimental batch TMR + Hydroponic barley.

A set of statistical analysis was conducted. Initially, descriptive measures were calculated. After testing for normality, inter-group value means were compared using Student's tests and Welsh correction according to the situation of equality of variance for the two experimental conditions. The data analysed pertain to the means obtained in the all of experiment. The level of significance was set at $p< 0.05$, all statistics analysis were performed using SPSS 18.

Results and discussion

Diets and nutritional intakes Both rations in this study showed a protein to energy supply ratio ($PDI.UFL^{-1}$) >100, which is consistent with INRA's (2010) nutritional recommendations, they were well balanced. Additionally, it was consistent with the same guidelines for the average amount of DM consumed by each cow. During lactation, the control and experimental feedlots' average total DM intakes were 19.13 ± 1.14 and 20.62 ± 1.21 kg.d^{-1}, respectively, showing a difference (P<0.05). Cattle fed hydroponically grown barley showed an increase in total DM consumption of about 1.49 kg.d^{-1}, or a 7 % increase rate (Table 3).

Table 3. Dry matter ingested and nutritional contributions of the two rations.

Rations	DM (kg)	UFL	PDI (g)	PDI (g). UFL^{-1}
Control	19.13^{a} ± 1.14	17.36^{a} ± 1.03	1 764.91^{a} ± 105.12	101.66^{a}
Experimental	20.62^{b} ± 1.21	18.75^{b} ± 1.10	1,911.94^{b} ± 112.14	101.97^{a}
p-value	0.049	0.045	0.038	0.893

$^{a, b}$ Values with common letters are not significantly different at the 5 % threshold. DM: Dry matter, UFL: Milk feed unit. PDI: Digestible proteins in the intestine.

The excellent palatability of this forage was most likely the cause of this. For these kinds of feed, several authors have noted the same thing (Romero Valdez *et al.*, 2009, Garcia *et al.*, 2013, Masucci *et al.*, 2024). Wu *et al.* (2024) state that by incorporating hydroponic barley into rations, increased palatability and voluntary consumption can be expected due to the conversion of cereal starch into simple sugars and the activation of certain enzymes in the shoots.

Milk production

Table 4 displays the average milk production performance data. For the two control and experimental groups, the cows' daily production at the start of lactation was 16.34 and 15.91 kg, respectively. During the first five weeks of lactation, the average output levels achieved equivalent levels of 22.74 and 22.62 kg.d^{-1} (p>0.05). The two lactation curves show the same tendencies when they are stacked (Figure 1).

Table 4. Effect of hydroponic barley on milk production performance and feed efficiency of lactating cows.

	Control	Experimental	p-value
Milk production			
2nd day of lactation (kg.d^{-1})	16.34^{a} ± 2.27	15.91^{a} ± 2.32	0.051
Average at 5 weeks (kg.d^{-1})	22.74^{a} ± 2.52	22.62^{a} ± 2.68	0.058
Lactation peak (kg.d^{-1})	25.85^{a} ± 2.59	29.10^{b} ± 3.14	0.006
Overall average (kg.d^{-1})	18.91^{a} ± 2.28	22.17^{b} ± 2.83	0.001
Milk adjusted to 4 % fat (kg.d^{-1})	18.94^{a} ± 2.29	22.99^{b} ± 2.92	0.001
Total production of 305 days of lactation (kg)	5,767.55^{a} ± 695.4	6,761.85^{b} ± 863.15	0.001
Feed efficiency	0.99^{a} ± 0.12	1.16^{b} ± 0.14	0.001

$^{a, b}$ Values with common letters are not significantly different at the 5 % threshold.

Given the consistency of the cows' production performances over the two batches, A gradual improvement in the experimental batch's milk output was noted as hydroponic barley was added. Production peaks for the two batches were 25.85 and 29.10 kg.d^{-1}, respectively (p<0.01). The production level of the cows in the experimental batch increased further until it peaked around the ninth week of lactation, whereas the control batch hit its lactation peak early in the seventh week (Figure 1).

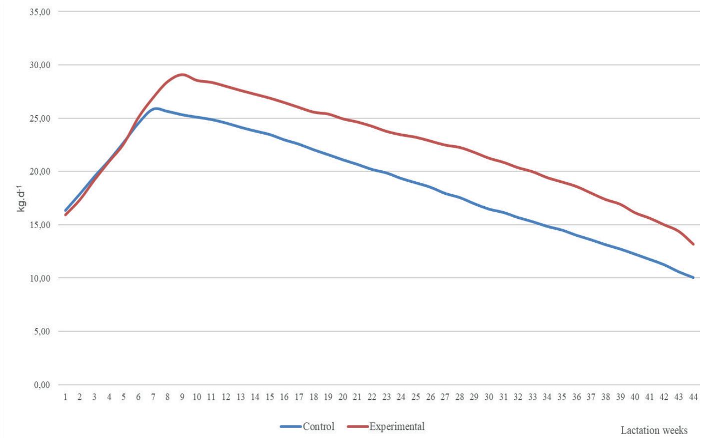

Figure 1. Average milk yield of cows from both feedlots over time (kg.d^{-1}).

The average daily milk production performances for each lactation were 18.91 and 22.17 kg.d^{-1}, respectively (p<0.001), meaning that there was a 17.24 % production difference. Over the course of lactation, the experimental batch produced 6761.85kg, while the control batch produced 5,767.55 kg (p<0.001). The improvement in milk production would have been unquestionably supported by the consumption of total DM, the greater nutritional intakes noted, and the addition of hydroponic barley.

Our findings, which showed a 17.24 % improvement, were comparable to those of Kaouche *et al.* (2016). According to Wu *et al.* (2024), Salo (2019), and Romero-Valdez *et al.* (2009) who supplemented the cows with hydroponic barley, milk output have increased by 7.9, 10.07, and 20 %, respectively. From this, Masucci *et al.* (2024) who replaced corn silage with hydroponic barley, the milk production of cows improved by 7.5 %. Even though the trial batch's milk output was relatively good, it was still less than the breed's genetic potential of 8,626 kg (OS Race normande, 2012).

However, the results we obtained were comparatively better than the production results of traditional dairy cattle farms in Algeria. In fact, Bir *et al.* (2015) reported 4,054 kg at the level of dairy farms in the Sétif region. Bouzida *et al.* (2010) reported (4,074 kg) in Tizi Ouzou region.

Feed efficiency

The experimental batch ration's feed efficiency was further increased by the use of hydroponic barley in this study (Table 4). From 0.99 for the control feedlot to 1.16 for the experimental feedlot (p<0.001), the latter rose by 17 %. Wu *et al.* (2024) also showed an improvement in feed efficiency of roughly 5 %. This study complies with Linn (2006) requirement that a ration's feed efficiency during lactation be better than 1. A contained increase in the availability of proteins, carbohydrates, minerals, and vitamis is frequently the result of the soaking process and germination (Abouelezz *et al*., 2019).

Additionally, an increase in the total concentration of volatile fatty acids (VFA) and propionate at the ruminal level thanks to fermentation from the hydroponic barley diet is observed (Farghaly *et al*., 2019), which would have likely contributed to the increase in feed efficiency of the ration supplemented with hydroponic barley.

Physicochemical composition of milk

The experimental batch milk had higher average fat and protein concentrations during lactation than the control one's (Table 5). For fat, they were 42.49 and 40.13 g.kg^{-1}, while for protein, they were 34.87 and 32.21 g.kg^{-1}. As a result, the average daily outputs of fat and protein for milk from cows in the experimental feedlot improved significantly (p< 0.001). These were 778 and 609 g.d^{-1} for the control feedlot and 942 and 758 g.d^{-1} for the experimental feedlot. This improvement is most likely related to the combined impacts of adding hydroponic barley and increasing dry matter intake, which suggests that the cows in the experimental batch were receiving more and better nutrition. However, there was no difference between the two diets' lactose contents (p>0.05). Its low variability in cow's milk may help to explain this (Costa *et al.,* 2019).

Table 5. Effect of hydroponic barley on physicochemical composition.

	Control	Experimental	*p* value
pH	6.64^a ± 0.12	6.68^a ± 0.14	0.245
Fat (g.kg^{-1})	40.10^a ± 1.96	42.49^b ± 2.37	0.047
Protein (g.kg^{-1})	32.21^a ± 0.91	34.87^b ± 1.08	0.013
Fat (g.d^{-1})	758.85^a ± 80.13	942.00^c± 103.07	0.001
Protein (kg.d^{-1})	609.09^a ± 29.31	773.06^c± 37.65	0.001
Density	1,030.08^a ± 0.73	1,031.12^a ± 0.91	0.343
Fat-free solids (g.d^{-1})	89.69^a ± 4.09	89.16^a ± 4.32	0.198
Solids (g.d^{-1})	129.19^a ± 6.13	133.32^a ± 5.07	0.096
Lactose (g.kg^{-1})	47.20^a ± 0.33	46.60^a ± 0.22	0.294

$^{a, b}$ Values with common letters are not significantly different at the 5 % threshold.

According to Farghaly *et al.* (2019), hydroponic barley raised the concentration of propionate and total volatile fatty acids in the rumen. They hypothesised that this might be because there were more vitamins and enzymes available, which function as bioactive catalysts to enhance energy release and promote feed metabolism, improving feed utilisation at the rumen level and ultimately improving milk yield and quality.

Overall, and particularly for the experimental batch cows, the results were comparable to the Normande breed standards (43 g.kg^{-1} for fat and 36 g.kg^{-1} for protein). Additionally, they concur with the findings of Wu *et al.* (2024) and Kaouche *et al.* (2016), who showed how adding hydroponic barley improved the quality of cow's milk, especially its fat content. Other than increasing the protein content, hydroponic barley has no discernible effects, according to a study by Faccusi *et al*. (2024). Nonetheless, Yoon *et al*. (2004), Farghaly *et al.* (2019), and Barros *et al.* (2017) documented a linear decline in the proportion of protein and fat in cows with extremely high production potential in their scholarly publications. They would attribute this decline to the inverse relationship between yield and quality.

Live weight and body condition of cows

Live weight (LW) and body condition score (BCS) did not significantly differ between the two groups at the beginning or end of the trial (p>0.05). The control and experimental groups had average live weights at the start of lactation and at the end of lactation, respectively (Table 6). The two groups' respective averages for the body condition score were 3.62 ± 0.41 and 3.56 ± 0.34 at the beginning of lactation and 3.53 ± 0.27 and 3.42 ± 0.52 at the end. The Normandy breed standard, which calls for an average live weight of 800 kg, was somewhat higher than these results.

Table 6. Body weight and body condition of dairy cows.

Feedlot	Control	Experimental	*p* value
Live weight (kg):			
Lactation start	723.00^a ± 39	711.00^a ± 29	0.367
Lactation end	710.00^a ± 41	691.00^a ± 27	0.171
Difference	-13.00^a	-20.00^a	0.221
BCS (1 to 5):			
Lactation start	3.62^a ± 0.41	3.56.00^a ± 0.34	0.568
Lactation end	3.53^a ± 0.27	3.42.00^a ± 0.52	0.348
Difference	-0.09^a	-0.14^a	0.267

$^{a, b}$ Values with common letters are not significantly different at the 5 % threshold.

Conclusion

According to our findings, adding this forage as a supplement greatly increased the metrics measuring dry matter intake, nutritional intake, milk output, feed efficiency, and milk quality.

This study demonstrates that incorporating hydroponically grown barley into the diets of lactating dairy cows can significantly enhance feed intake, milk production, feed efficiency, and milk quality without negatively affecting body weight.

The experimental batch consuming hydroponic barley showed a notable increase in dry matter intake, improved milk yield by 17.24 %, and higher fat and protein concentrations in milk compared to the control group. These improvements are likely due to the enhanced palatability, nutrient availability, and ruminal fermentation associated with hydroponic barley. While overall milk production remained below the breed's genetic potential, the gains observed were substantial relative to traditional dairy practices in Algeria, suggesting that hydroponic barley is a promising dietary strategy to improve dairy cow performance and milk composition sustainably.

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Literature cited

Abouelezz, K.F.M.,Sayed, M.A.M., & Abdelnabi, M.A. (2019). Evaluation of hydroponic barley sprouts as a feed supplement for laying Japanese quail: Effects on egg production, egg quality, fertility, blood constituents, and internal organs. *Animal Feed Science and Technol*ogy, 252,126–135. https://doi.org/10.1016/j.anifeedsci.2019.04.011

Ali, H. S., Miah, A. G., Sabuz, S. H., Asaduzzaman, M., & Salma, U. (2019). Dietary effects of hydroponic wheat sprouted fodder on growth performance of turkey. *Research in Agriculture Livestock and Fisheries,* 6, 101–110. https:// doi10.3329/ralf.v6i1.41392

AOAC, 1995. Official methods of analysis. Association of Official Analytical Chemists (AOAC), 14thEdition, Washington D.C, USA.

Barros, T., Quaassdorff, M. A., Aguerre, M. J., Olmos Colmenero, J. J., Bertics, S. J., Crump, P. M., & Wattiaux. M. A. (2017). Effects of dietary crude protein concentration on late-lactation dairy cow performance and indicators of nitrogen utilization. *Journal of Dairy Sciences,* 100, 5434–5448. https://doi10.3168/jds.2016-1917

Bir, A., Yakhlef, H. & Madani, T. (2015). Autonomie alimentaire des systèmes d'élevage bovins laitiers dans la région semi-aride de Sétif (Algérie). *Fourrages*, 221, 85-91. https://afpfasso.fr/index.php?download=2133&token=c16b0ba6e27c1efb0d74a94026afe433

Bouzida, S., Ghozlane, F., Allane, M., Yakhlef, H. & Abdelguerfi, A. (2010). Impact du chargement et de la diversification fourragère sur la production des vaches laitières dans la région de Tizi-Ouzou (Algérie). *Fourrages*, 204, 269-275. https://afpf-asso.fr/index.php?download=1915&token=c16b0ba6e27c1efb0d74a94026afe433

Costa, L., Lopez-Villalobos, N., Sneddon, N. W., Shalloo, L., Franzoi, M., De Marchi,M. & Penasa, M. (2019). Invited review: Milk lactose—Current status and future challenges in dairy cattle. *Journal of Dairy Sciences,* 102, 5883–5898. https://doi.org/10.3168/jds.2018-15955

Farghaly, M., Abdullah, M., Youssef, I., Abdel-Rahim, I. and Abouelezz K. (2019). Effect of feeding hydroponic barley sprouts to sheep on feed intake, nutrient digestibility, nitrogen retention, rumen fermentation and ruminal enzymes activity. *Livestock Science*, 228, 31–37. https://doi10.1016/j.livsci.2019.07.022

Garcia Carrillo, M., Salas Perez, L., Esparza Rivera, J. R., Preciado Rangek, P., Romero Paredes, J. (2013). Produccion y calidadfisicoquimica de leche de cabras suplementadas con forrajeverdehidroponico de mais. *Agronomiamesoamericana*, 24, 169-176.https://doi:10.15517/am.v24i1.9794

INRA. (2010). Alimentaion des bovins, ovins et caprins: Besoins des animaux-valeurs alimentaires, éd. Quae, 309 p.

Kaouche-Adjlane, S., Ahmed Serirb, A., Bafdelc, M. & Benhacine, R. (2016). Techno-Economic Approach to Hydroponic Forage Crops: Use for Feeding Dairy Cattle Herd. *Journal of Applied Environmental and Biological Sciences,* 6, 83-87. https://www.researchgate.net/profile/Kaouche-Soumeya-2/publication/299374140_Techno-Economic_Approach_to_Hydroponic_Forage_Crops_Use_for_Feeding_Dairy_Cattle_Herd/links/56f2a42608aee4c8719a0672/Techno-Economic-Approach-to-Hydroponic-Forage-Crops-Use-for-Feeding-Dairy-Cattle-Herd.pdf

Linn J. (2006). Feed Efficiency: Its Economic Impact In Lacting Dairy Cows. *Advances in Dairy Technology,* 18, 19-28. https://wcds.ualberta.ca/wpcontent/uploads/sites/57/wcdsarchive/Archive/2006/Manuscripts/Linn.pdf

Ma, Y., Wang, J., Sun, Y., Dong, Y., Cai, H., Raja, I. H., Guo, T. and Zhang, S. (2023). Effects of compound salt concentration on growth, physiological and nutritional value of hydroponic forage wheat. *Agriculture,* 13,1833. https://doi10.3390/agriculture13091833

Masucci, F., Serrapica, F., Cutrignelli, M. I., Sabia, E., Balivo, A. & Di Francia, A. (2024). Replacing maize silage with hydroponic barley forage in lactating water buffalo diet: Impact on milk yield and composition, water and energy footprint, and economics. *Journal of Dairy Sciences,*107, 9426–9441. https://doi/10.3168/jds.2024-24902

Mohsen, M.K.,Abdel-Raouf, E.M., Gaafar, H.M.A. & Yousif, A.M. (2015). Nutritional Evaluation Of Sprouted Barley Grains On Agricultural By-Products On Performance Of Growing New Zealand White Rabbits. *Archiva Zootechnica* 20:1, 95-113. https://ibna.ro/arhiva/AZ-20-1/08-Mohsen.pdf

Nemzer, B., Lin Y. & Huang, D. (2019). Antioxidants in sprouts of grains. Pages 55–68 in Sprouted Grains. AACC International Press. https://doi10.1016/B978-0-12-811525-1.00003-8

Niroula, A., Khatri, S., Khadka, D. & Timilsina, R. (2019). Total phenolic contents and antioxidant activity profile of selected cereal sprouts and grasses. *International Journal of Food Properties*, 22, 427–437. https://doi10.1080/10942912.2019.1588297

Organisme de sélection Race Normande, (2012). Présentation génétique de la vache Normande. 22P. https://www.lanormande.com/upload/editeur/presentation_generaleLaNormande.pdf

Palmquist, D.L and Conrad,H.R (1978). High fat rations for dairy cows. Effects on feed intake, milk and fat production, and plasma metabolites. *Journal of Dairy Sciences,* 6, 890-901. https://doi.org/10.3168/jds.S0022-0302(78)83667-4

Pastorelli, G., Serra, V., Turin, L. & Attard, E. (2023). Hydroponic fodders for livestock production – a review. *Annals of Animal Sciences*, 24, 645-656. https://doi10.2478/aoas-2023-0075

Romero, V., Córdova D., & Hernández, G,. (2009). Producción de forraje verde hidropónico y su aceptación en ganadolechero. *Acta Universitatis*, 19: 11-9. https://doi.org/10.15174/au.2009.93

Salo, S. (2019). Effect of hydroponic fodder feeding on milk yield and composition of dairy cow: Review. *Journal of Natural Sciences Research*, 9: 1-8. https://doi10.7176/JNSR/9-8-01

Vasseur, E., Gibbons, J., Rushen, J. & de Passillé A. (2013). Development and implementation of a training program to ensure high repeatability of body condition score of dairy cow in animal welfare assessments. *Journal of Dairy Sciences*, 96, 4725-4737. https://doi10.3168/jds.2012-6359

Wu, Z. H., Du, C., Hou, M.J., Zhao,L.S., Ma, L., Sinclair, L.A. & Bu, D.P. (2024). Hydroponic barley supplementation fed with high-protein diets improves the production performance of lactating dairy cows *Journal of Dairy Sciences,* 107, 7744–7755. https://doi10.3168/jds.2023-24178

Yoon, J. T., Lee, J. H., Kim, C. K., Chung, Y. C. & Kim, C. H. (2004). Effects of milk production, season, parity and lactation period on variations of milk urea nitrogen concentration and milk components of Holstein dairy cows. *Asian-Australas Journal of Animal Sciences,* 17, 479–484. https://doi/10.5713/ajas.2004.479