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Techno-Economic Approach to Hydroponic Forage Crops: Use for Feeding Dairy Cattle Herd

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ABSTRACT

This paper aims to study hydroponics technique in Algeria through: (i) assessing the nutritional value of forage, (ii) impact of use of the green on milk production and finally, (iii) estimate the economic value of this technique. The results obtained have shown the multiplication of the fresh weight of the green by a factor of 6, relative to the weight of the seed. Total Nitrogen Content (TNC) was higher in green plant (27.10%) than in roots (12.92%). The nutritional value greatly conspicuous by increased digestible intestinal protein permitted by nitrogen (DIPN) during the 6th and 8th days, also in green part respectively: 76.23; 99.30; 175.67 g/kg and digestible intestinal protein permitted by energy (DIPE): 100.57; 133 and 112.32 g/kg. Unlike milk fodder units (UFL) that experienced a decrease (1.01; 0.89 and 0.91). The results of the physic-chemical analyzes of milk samples showed no significant differences ($p> 0.05$) in the useful matter of milk in two lots of cows. For the Fat concentrate between the control group and the experimental group (4.31; 4%) and for protein content(2.66 ;2.62%).While milk production was increased in experimental group. Economically, it turned out that hydroponics can't compete with the culture of fields remains the least expensive since the cost of a kg of green feed is 1.12 DA (DA: Dinar Algérien≈ 0.01 €), while the hydroponic fodder is 15 DA (≈ 0.13 €).
KEYWORDS: Forage biotechnology - nutritive value -dairy cows -economic result.

INTRODUCTION

Algeria, like other countries of the Maghreb, is facing since independence to a continued rise in demand for dairy products, due to a strong demographic dynamics and urbanization of populations [1]. Local milk production is far from able to meet this growing demand. Feeding level of dairy cows in farms and inadequate feed supply are major limiting factors that antagonize the development of milk production and livestock in general [2,3,4]. Diet is the most important parameter in operating expenses in milk production, but also one of the most effective tools for controlling milk production, either in quantity or quality [4,5].Hydroponic methods were used for a long time with regard to plant crops, mainly vegetables, but hydroponics is now used in many countries to reduce the pressure on land and grow forage for livestock. This method of forage production has many benefits for farmer, economy and environment[6].However, the expansion of production of green fodder for water conservation for other sectors is very important mainly for the arid and semi arid countries [7].Several research studies have been conducted on hydroponics whose main purpose was to determine the nutritional value of its forage. Indeed, the inclusion of hydroponic oats in feeding sheep seems to improve the milk production and welfare of animals[8]. While a loss of 2% of gross energy was recorded after comparing barley grass with the original grain [9].Barley hydroponic forage when it was included in the diet feeder calf set, no difference in the performance of the calves finishing was noted. However, the cost of food was 24% greater than the control diet because of the additional expenditure required for the production of green fodder[10].In this context, the present paper aims to study hydroponic technique in Algeria through (i) assessing the nutritional value of forage, (ii) impact of use of the green on milk production in quantity and nutritional quality and, (iii) estimate the economic value of this technique.

MATERIALS AND METHODS

The experiment was conducted in demonstration farm (Ruminant Station) at Technical Breeding Institute (ITELV). The test was performed on 12 dairy cows divided in two groups: control group with six dairy cows with a ration (oat hay: 15kg + concentrate: 9kg) and an experimental group whose feed consists of concentrate (9kg), oat hay (5kg) and hydroponic barley(10kg). The refusal is weighed every morning to determine the amount ingested. The choice of lots was done taking into account the physiological stage of the animals, level of milk production of each cow and dairy breed (Holstein Pie Noire). The average age of the cows from the control

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group was 3.5 years, while that of the experimental group is 4 years. All cows are on average in the second rank and 2nd month of lactation. Hydroponics barley variety is Saida. Variety highly resistant to drought and it can tolerate up to 300 mm of water. It is resistant to diseases such as rust and smut. Green Yield= 250 quintals/hectare and seed yield=25-30 quintals/hectare. The hydroponic feed production cycle is 8 days. The lighting is artificial and the conditioning unit used to control the temperature inside the growth chamber is maintained at 18 ± 2°C. While the humidity is approximately 70%. The water used is of drinking water supply (Alimentation en Eau Potable: AEP) which is regularly controlled by the relevant department of the municipality. Hydroponics barley is harvested after 8 days of germination, drained, cut into pieces and distributed to the cows of experimental group. Forage analyzes were performed to determine chemical composition during germination for dry, imbibed barley seeds, hydroponic feed barley of the 4th, 6th and 8th days of germination. These analyzes were carried out in triple (3 repetitions) according to [11]. To calculate the nutritional value, the equations used are those of the [12]. Milk samples were also collected to be the subject of a series of physic- chemical analyzes using EKOMILK for the following parameters: temperature, pH, freezing point, density, total dry extract (TDE), solids not fat (SNF), fat and protein contents. All analyzes were performed weekly basis for 2 months. Techno-economic study was conducted by assessing the investment of the machine, cost of seeds and yield or profitability of the unit.

Statistical treatment of data

Data were analyzed using the software XLStat (2013) according to the variance of process analysis (ANOVA). Significance level was set at $p < 0.05$.

RESULTS

The results of chemical analyzes of food distributed are illustrated in table 1. Results of hydroponic barley analyzes showed a difference in chemical composition between the seeds and the barley feed after 8 days of germination. Dry matter (DM) content varies significantly ($p<0.001$) during germination, it fell sharply after seeds soaking for 24 hours in water of 88.86 to 61.96%. This DM declining gradually continues throughout the germination period to reach 16.91%. Total nitrogen content (TNC) has meanwhile also decreased (11.34%) in the dry seeds, 9.22% after dipping and then increased during germination reaching 15.58% on day 8 ($p> 0.05$). Furthermore, crude fiber (CF) increased after soaking the seeds from 7.66 to 16.70%. During 6 days of germination, this content has decreased by about 10% and has increased on day 8 with 19.24%. Hydroponics barley energy value is greater at day 4 (1.02 UFL) than day 8 (0.89UFL). In this study, nitrogen values increased from the 4th to 8th day of germination: 71g of DIPN against 99g and 101g of DIPE against 133g. The DM quantity ingested in the diet is higher (25.43 kg) for the experimental group and 19.18 kg for the control group ($p> 0.05$), where a decrease in milk production before and during the test ($p>0.05$). The average quantity of milk produced per group and the results of physic-chemical analyzes of milk are presented in table 2.

The average amount of milk produced before the test is 14.65 liters / day for the control group and 15.38 liters / day for the experimental group, with ($p> 0.05$). During the test, this amount has increased significantly (16.14 liter / day) for the experimental group; while it decreased in the control group (13.49 liter / day) with $p <0.01$ between the two lots of cows. Increasing the quantity of milk produced by the experimental group was not significant ($p> 0.05$), since some cows milk production has little or no change. Analysis of physic-chemical parameters of milk produced by the cows of the control group and those of the experimental group gave rise to more or less different values (table 2). These values respectively, are slightly different: TDE (11.32% ± 0.52; 11.23% ± 0.82), SNF (6.98% ± 0.16; 6.90% ± 0.15). The same for useful matter of milk with ($p> 0.05$): fat content (4.31%±0.42; 4%± 0.30) and protein content (2.66%±0.05; 2.62%±0.07).

Table 1: Summary of hydroponics barley analyzes.

	Chemical Composition (% DM)					Nutritional value/kg DM		
						Energy value	Nitrogen value (g)	
	DM	MM	OM	TNC	CF	UFL	DIPN	DIPE
Dry seeds	88.86 ±0.1	4.02±0.43	95.98±0.43	11.34±1.97	7.66±0.65	__	__	__
Soaked seeds	61.96±0.07	4.18±0.06	95.82±0.06	9.22±0.27	16.70±0.92	__	__	__
4 days	22.33±1.59	2.58±0.19	97.42±0.19	11.06±0.14	9.29±1.21	1.02	71.01	101.13
6 days	17.81±1,97	2.89±0.33	97.11±0.33	11.60±0.56	10.85±0.42	1.01	76.23	100.57
8 days	16.91±2.33	5±0.11	95±0.11	15.58±0.14	19.24±0.85	0.89	99.3	133
leaves	8.10±0.14	5±0.00	95±0.00	27.10±0.73	21.40±0.38	0.91	175.67	112.32
Roots	8.09±0.63	4.14±0.22	95.86±0.22	12.92±1.58	24.33±0.45	0.79	82.8	91

DM: dry matter. **MM**: mineral matter. **OM**: organic matter. **TNC**: total nitrogen content. **CF**: crude fiber. **UFL**: milk fodder units. **DIPN**: digestible intestinal protein permitted by nitrogen. **DIPE**: digestible intestinal protein permitted by energy.

Table 2: Summary table of the main results obtained in 2 lots of cows.

	Lots	Control group	Experimental group
Milk production (l)	**Before test**	14.65 ±0.70	15.38 ± 0.19
	During test	13.49 ±1.71	16.14 ± 1.48
	TDE (%)	11.32±0.52	11.23±0.82
	SNF (%)	6.98±0.16	6.90±0.15
	Water (%)	88.68±0.52	86.86±4.29
	Fat content (%)	4.31±0.42	4 ±0.30
	Protein content (%)	2.66±0.05	2.62±0.07
	Density (g/cm3)	3.88±0.09	3.85±0.11
	Freezing point (°C)	-0.46±0.01	-0.46±0.01

TDE: total dry extract. **SNF**: solids not fat.

DISCUSSION

Sprouting from 1 to 1.3 kg of barley seeds produced about 7 kg of green fodder from 15 to 20 cm high with a thick mass of roots that represents 3/4 of the total weight. Note that the mold has developed in the late germination cycle despite seed treatment applied during soaking. It is due to the significant roots development, that led to aeration reduction and prevention of the evacuation of excess water. This mold installation is not only due to the important root development, but also to technical problems such as power cuts, irregular opening of the machine, high plant density, crowding seeds...). This is in agreement with [13], who said that the anaerobic conditions occur when the root mass becomes thick hence the development of microorganisms. Difference in chemical composition between dry seeds and forage at 8 days was highly significant ($p < 0.001$). Analysis of the different parts of the hydroponic barley shows also a highly significant difference ($p < 0.001$) in the levels of dry matter and total nitrogen content between leaves and roots, as crude fiber (CF) with ($p < 0.05$). These rates change has been observed by several authors: [14, 9, 15], but with slight differences in results which are probably due to: variety and quality of seed used, light intensity, quality of the irrigation water and finally, germination time. Loss of DM is probably due to the use of carbohydrates and energy within by seeds for metabolic activities of the growing plant, without adequate replacement by photosynthesis of the young plant. This photosynthesis begins around the fifth day when the chloroplasts are activated. According to [9],who report that during harvesting of a shoot 7 or 8 days, DM accumulation is greatly reduced. Seed germination causes an increase in hydrolytic enzymes activity, total protein content improvements, fat, total sugars, vitamins of group B and a decrease of the dry matter, starch and anti-nutrients [16]. These improvements are the metabolic effects of the germination process. Protein content of germs increases from the time of germination, it is may be related to the complex biochemical changes during the hydration and after seed germination. The reserves are decomposed by enzymes into simple compounds which are used for germination. According to [17], the absorption of nitrates facilitates nitrogen compounds metabolism from carbohydrate reserves which would increase the levels of crude protein. In the sprouted barley, crude fiber - an essential component of cell walls- increase with the carbohydrates synthesis such as cellulose and hemi-cellulose [13].Decrease in UFL is probably due to the increase in crude fiber rate which reduces the digestibility of OM (organic matter). Germinated barley energy value is also lower than that of the seed [9]. It is accompanied by a loss of 2% of crude energy after comparing barley grass with the original grain. The body condition score before and during the test varies respectively between control group (2.20), (2.16) and experimental group (2.33), (2.45), which is probably related to assimilation degrees of food intake that differs from one cow to another ($p<0.05$). Density, water content and freezing point remained almost identical between the two groups, indicating that hydroponics barley has a positive effect only on the quantity of milk produced. Comparing values of this study, there is observed that the values of solids (total and not fat), protein and freezing point of the control group are below the standards presented by [18]. While fat content levels of control milk (4.31%) and the experimental milk (4%) are high comparing to the values indicated by these same authors, respectively: 3.9% and 3.5%. The high fat content associated with low protein levels obtained in this study indicate that the ration given to two lots of the test was low in energy and high in fiber (63% for the control group and 48% for the experimental group). According to [19, 20], increasing energy intake level leads to an increase in milk production and protein content. By against, relatively high cellulose content promotes increased fat content dosage. Part of the milk fat comes from the mobilization of fat reserves in the cow if the diet is deficient in energy.

Economic evaluation of the price of return of hydroponics:

This economic study was conducted to determine the extent of hydroponics culture with classical fields. Data and results obtained are shown in table 3.

Taking into account the various expenses necessary for the cultivation of fields (tillage, prices of seed, labour,...), the cost of this cultivation is estimated at 45000 DA / ha (DA: Dinars Algériens). Given that1ha brings 400 quintals of green forage per year for the price of 1.12 DA/kg (≈ 0.01 €), while a kg of hydroponic forage is 15 DA (≈ 0.13€). It can therefore conclude that hydroponics is not competitive with the culture of fields. The cost of green fodder is 4 times more expensive than the cost of the seed. Thus, the energy in germinated barley and protein are respectively 3.7 and 2.2 times more expensive than in the original seed. If the seeds are not processed (rolled or chopped), it is estimated that only 60% of the starch is digested. Therefore, the feed may be more economical compared to seeds in the case where they are not processed taking into account the waste due to poor digestibility[13].

Table 3: Table of comparison between different costs back.

Designation	Hydroponics (DA/ ha)	Culture on fields (DA / ha)
Tillage		45 000
Plowing		
Cover - cropage		
Fertilizer application		
Sowing		
Harrowing		
Harvest		
Seed prices		
labour		
Amortization	510 000	/
Barley consumption (seedprice)	441 000	/
Water consumption	2 340	/
Electricity	60 000	/
Labour	216 000	/
Insurance	60 000	/
Various	40 000	/
Total	**1 329 340**	**45 000**
Price of a kg of green feed	**15**	**1.12**

DA: dinars algériens. **Ha**: hectar.

Conclusion

This study has presented the benefit of hydroponic cultivation of barley showing the chemical composition of the green, its food value, effect on milk production and economic interest. The chemical composition differed significantly ($p<0.05$) during germination. The barley hydroponic fodder has presented interesting nutritional values. The energy value was considerable despite its decline during the germination and nitrogen values increased, especially for DIPE. Analyzes of different parts of the barley hydroponic reveal that the leaves are rich in TNC ($p <0.001$) than the roots. The amount of milk produced by the experimental group increased as that achieved by the control group decreased ($p <0.01$). The results of physic- chemical analyzes of milk show no significant difference ($p> 0.05$) in the quality of milk produced by two lots of cows. This study leads to the conclusion that hydroponics can produce long-term highly nutritious green feed, while in economic view point, this culture proves unprofitable.

Nevertheless, Hydroponics may be interesting in times of scarcity; hydroponics may minimize expenditures to cover the needs of the cattle. In order to develop new activities such as seed culture for specially hydroponics which would reduce production costs and in the case of a large-scale production provided by cooperatives aiming to produce and sell green fodder.

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