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Effect of production mode on productivity, chemical composition and nutritive value of hydroponic barley fodder

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Abstract

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This study aimed to compare productivity, chemical composition and nutritive values of hydroponic barley fodder (HBF) in two different systems, inside a hydroponic chamber (HBFI) and outside in natural non-controlled condition (HBFO), after 8 days of cultivation. The trays (70 x32x 5cm) were shelved in modules made of aluminium. In the hydroponic chamber, temperature and humidity were adjusted between 18° to 24°C and 55 to 65% respectively. Outside the chamber, the hydroponic barley was grown from April to May where the temperature and hygrometer are 11° to 24° and 39% to 77% respectively. In both conditions, barley grain (BG) was first chemically analyzed and HBF samples were analyzed at 8 days culture and the nutritional values (energy and nitrogen values) were estimated. The results showed that barley grain presented higher ($P < 0.05$) dry matter (DM) than HBFI and HBFO with values decreasing sharply after germination with 89.04±1.61% vs 12.23±1.78% and 14.14±2.44%, respectively. However, crude ash (CA), total nitrogen content (TNC) and crude fiber (CF) were significantly higher in both HBF culture. When comparing HBF condition culture, broadly no important differences were observed between HBFI and HBFO and even HBFO showed highest values for CA and EE 5.12±0.86 vs 4.32±0.27 and 3.63±0.54 vs 2.8±1.16 respectively. The results showed that HBF culture enhanced protein content (DIPA and DIPN 24.54±1.00 vs 27.68±3.04; 27.10±2.39 and 64.99±3.69 vs 78.10±12.43; 75.34±9.82 respectively) with no significant difference between HBFI and HBFO. The current results showed that HBF culture in natural conditions could be an interesting alternative in animal feeding with no important investment.

Keywords: Hydroponic barley fodder; productivity; production technique; nutritional quality

Introduction

The scarcity of the animal feed is a worldwide concern with non-availability of constant fodder quality around the year with consequent limitation of sustainable dairy farming (Naik et al., 2015). Traditional production of green grass requires large-scale land, plenty of water, plow, different fertilizers with several management challenges (Devendar et al., 2020).

It is shown that hydroponics culture could be an alternative in green fodder production for livestock in many countries (Sneath & McIntosh, 2003; Rodriguez Muela et al., 2005; Shit, 2019), especially those situated in arid and semi-arid regions and with no access to agriculture lands (Emam, 2016). Concerning water consumption, it is reported that about 1.5-2 litters are needed to produce 1kg of green fodder hydroponically in comparison to 73, 85 and 160 litters to produce 1kg of green fodder of barley, alfalfa and Rhodes grass, respectively, under conventional practices (Al-Karaki, 2010).

Hydroponic system is a technique of germinated many forages crops such as barley, maize, wheat in a hygienic environment without chemicals and artificial growth promoters (Jensen & Malter, 1995; Al-Hashmi, 2008). Fodder production hydroponically does not require high-quality arable land but only limited surface with short growth period 7-10 days (Cuddeford, 1989; Mooney, 2005). This technique ensures constant production of high quality of green forage throughout the year (Ata, 2016). Depending on the type of used grain, the forage produced under hydroponics system can reach 15 to 20 cm in high (FAO, 2001; Morales et al., 2009; Kaouche-Adjlane et al., 2016) with 7 to 9 kg of fresh forage (Mukhopad, 1994). This green fodder contains high protein and metabolic energy levels lightly digestible by most animals (Emam, 2016).

Barley (*Hordeum vulgare* L.) is considered as one of the most interesting crop allowing high fodder yield with simultaneous water efficiency particularly compared to alfalfa, cowpea, sorghum and wheat (Al Karaki & Al-Hashmi, 2010). Barley fodder is a significant source of forage for livestock producers in most arid and semiarid regions (Ghazi et al., 2011). The hydroponic fodder produced in the controlled chamber with regulation of light, temperature, humidity and water for optimum growth of fodder, represent a costly investment, particularly in developing countries with no access to financial resources. In fact, Fazaeli et al. (2011) reported that feeding fattening calves with hydroponic barley increases the feed cost at 24% and in Algeria Kouch-Adjlane et al. (2016) reported that the cost of 1kg of green feed is 1.12 AD (Algerian Dinar), while the hydroponic fodder is 15 AD. In these conditions, it remains difficult to implement hydroponic chambers in animal farms.

Based on the presented background, the current study aimed to compare productivity, chemical composition and nutritive value of two type of hydroponic barley: grown without nutrient solution in natural non-controlled environment or in controlled hydroponic chamber.

Material and Methods

The experiment trial was conducted at production of green fodder KACI Company in Bejaia (Algeria). The experimentation was designed to compare the development of hydroponics barley fodder in two systems, inside a hydroponic chamber (inside) and outside the chamber in natural environment conditions (outside). All the culture conditions (trays, irrigation, aluminums modules …etc.) were similar in the two systems except the fact that barley was grown in the hydroponic chamber (inside) or outside the chamber.

Culture conditions

Inside culture conditions

A growing plan was conducted using a hydroponic chamber (450 m^2) with a daily production potential of 5 t fresh barley fodder. The chamber was equipped with automatic sprayer irrigation of tap water (1 min/4 h) and automatic ventilation apparatus. The chamber's total capacity is 26 aluminium modules, each one with a length of 1.66 m, a height of 2.5 m carrying 20 trays (70 × 32 × 5 cm). The trays were made of food grade polypropylene and had holes at the bottom of the plastic trays to allow drainage of excess water. The temperature and the humidity were adjusted between 18 to 24°C and from 55 to 65%, respectively. Fluorescent lighting tubes were disposed in vertical position between modules providing 750 lumens with red and blue light spectrum during 18 h.

Outside culture conditions

The hydroponic culture was conducted in an open area near the hydroponic chamber under natural environment conditions. The experimentation was conducted from April to May with three replicate. During the experimentation, the temperature varied from 11 to 24°C and the hygrometry from 39 to 77°C.

Cultivation steps

The barley grain of the local variety "Saïda" was purchased from regional market and was then prepared by sieving, washing, soaking for 12 h to 17 h and dripping for 12 h. Then, the grains were weighed and distributed in the trays (Six: three for inside trial and three for outside one) with a rate of 1.5 kg of sprouted barley/tray equivalent to 6.5 kg/m^2. The plant was allowed to grow for 8 days. Samples were analyzed every day for weight and height development using a balance and a graduated rule, respectively. Observations of sanitary conditions and mold infestation were made with the unaided eye.

Chemical analysis and nutritive values

Samples of grain fodder at 8 days and barley grain were analyzed in triplicate according to AFNOR (1985). Dry matter was determined by drying the samples at 105°C in an oven for 24 h. Organic content was determined by ashing in a muffle furnace at 550°C for 5 h. Nitrogen content was determined by Kjeldahl method procedure (AOAC, 2000) and conversion factors of 6.25 was used to converse nitrogen to crud protein. Crud fiber was determined by acidic and basic hydrolysis according to Weend method. The fat content was obtained using Soxhlet extraction hydrolysis chain. Nutritive values (energy and nitrogen value) were assessed according to Zirmi-Zembri & Kadi (2016).

Statistical analysis

Data were statistically analyzed using analyse of variance test (ANOVA) using StatView Software, Version 4, 55 (1992-1996). The different and interaction between treatments were tested for significance using protected least significance difference fisher (PLSD Fisher) to compare means.

Results

The results revealed that in the both experimental conditions, barley fodder grown regularly, appearing healthy with a green colour with no molds development. Height (Figure 1) and weight parameters (Figure 2) showed closer values between inside (HBFI) and outside (HBFO) conditions. At 8 days of culture, no significant difference was observed concerning height values with 19.64±2.10 cm and 14.56±3.56 cm in HBFI and HBFO, respectively (Figure 1).

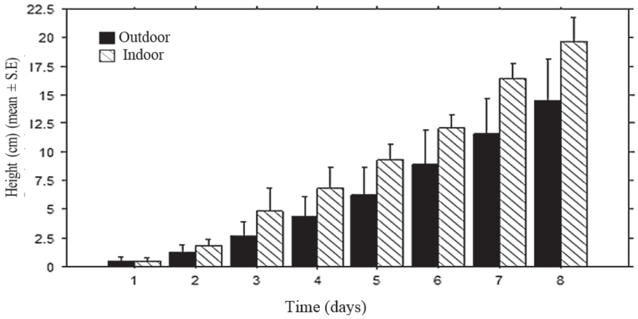

Fig. 1. Evolution of the average height (cm) of hydroponic barley grown inside and outside the chamber

Concerning weight parameter (Figure 2), the difference between HBFI and HBFO conditions was observed from day 4 to the end of the experimental period. At 8 days of culture weight, a significant difference was observed between HBFI and HBFO values with 6.71 ± 0.90 kg and 4.70 ± 0.23 kg, respectively.

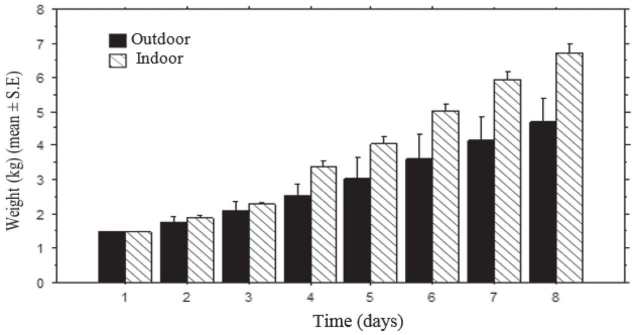

Fig. 2. Evolution of average weights (kg) of hydroponic barley grown inside and outside the chamber

Chemical composition

Chemical composition of barley grain (BG), inside (HBFI) and outside hydroponic barley (HBFO) at 8 days of culture are illustrated in Table 1. As expected, barley grain presented significantly ($P < 0.05$) highest DM values (89.04±1.61 %) when compared to HBFI and HBFO, with 12.23±1.78% and 14.14±2.44% at 8 days of culture, respectively (Table 1). The contents of CA and of CF were significantly lower in Barley grain with 2.14±0.09 % and 5.95±0.5%, respectively, compared to hydroponic culture. OM showed significant differences between the three experimental groups with the highest values in barley grain (97.86 ± 0.09%). No significant difference was found in EE content between HBFI, HBFO and barley grains, even if HBFO seems to present the highest values (3.63±0.54%). Hydroponic culture enhanced TNC content compared to barley grain (10.12±0.58%), no statically difference was observed between HBFI and HBFO with 12.17±1.14% and 11.74±1.53%, respectively.

Table 1. Chemical composition (% DM) of barley grain used, hydroponic barley fodder produced inside and outside the chamber

	DM	OM	Ash	EE	TNC	CF
BG	$89.04{\pm}1.61^{a}$	$97.86{\pm}0.09^{a}$	$2.14{\pm}0.09^{a}$	$2.97{\pm}1.1^{a}$	$10.12{\pm}0.58^{a}$	$5.95{\pm}0.50^{a}$
HBFI	$12.23{\pm}1.78^{bc}$	$95.68{\pm}0.27^{b}$	$4.32{\pm}0.27^{b}$	$2.8{\pm}1.16^{ab}$	$12.17{\pm}1.94^{b}$	$22.57{\pm}1.47^{bc}$
HBFO	$14.14{\pm}2.44^{bc}$	$94.88{\pm}0.86^{c}$	$5.12{\pm}0.86^{c}$	$3.63{\pm}0.54^{abc}$	$11.74{\pm}1.53^{ab}$	$21.10{\pm}2.46^{bc}$

BG: barley grain, HBFI: hydroponic barley fodder inside the chamber, HBFO: hydroponic barley fodder outside the chamber, DM: dry matter, OM: organic matter; EE: ether extract; TNC: total nitrogen content; CF: crud fiber.

Means with the same column with differing superscripts are significantly different at $P < 0,05$

Table 2. Nutritive value (/kg DM) of barley seeds and green fodder produced inside and outside the hydroponic chamber

	UFL	UFV	PDIA	PDIN	PDIE
BG	1.25 ± 0.97^{a}	1.26 ± 0.02^{a}	24.54 ± 1.00^{a}	64.99 ± 3.69^{a}	99.92 ± 0.51^{a}
HBFI	0.97 ± 0.02^{bc}	0.92 ± 0.02^{bc}	27.68 ± 3.04^{b}	78.10 ± 12.43^{b}	87.75 ± 2.70^{bc}
HBFO	0.99 ± 0.03^{bc}	0.94 ± 0.04^{bc}	27.10 ± 2.39^{abc}	75.34 ± 9.82^{abc}	86.86 ± 1.36^{bc}

BG -Barley Grain; HBFI -Hydroponic Barley Fodder Inside the chamber; HBFO -Hydroponic Barley Fodder Outside the chamber; UFL -milk fodder unit; UFV -meet fodder unit; PDIA -Protein Digested in the small Intestine of dietary origins also known as "ruminally undegraded feed protein digested in the small intestine"; PDIN -Protein Digested in the small Intestine when rumen fermentable N is limiting; PDIE -Protein Digested in the small Intestine when rumen fermentable Energy is limiting; Means with the same column with differing superscripts are significantly different at P<0,05.

Nutritive value

The energy value of barley was higher in barley grain ($P < 0.05$) with 1.25 UFL (Unité Fourragère Lait: French unit of energy for lactation, equivalent to 1700 kcal) and 1.26 UFV (Unité Fourragère Viande: French unit of energy for maintenance and meat production, equivalent to 1820 kcal) compared to HBFI and HBFO with 0.97UFL, 0.92UFV and 0.99UFL, 0.94UFV (Table 2). At 8 days, PDIA (Protein Digested in the small Intestine of dietary origins) and PDIN (Protein Digested in the small Intestine when rumen fermentable N is limiting) were enhanced significantly in hydroponic culture. HBFI presented highest values compared to HBFO but with no statistically difference.

Discussion

The hydroponic barley fodder is known for being produced in the special chamber that requires the optimal temperature for maximal seeding and the best rate is situated between 19 to 27°C with humidity between 60 to 70% (Lorenz & Appolonia, 1980; Chavan et al., 1989). These conditions are gathered in some climates in Algeria (Mediterranean climate) especially in spring season. This is why we aimed to test the feasibility of growing hydroponic barley in the open air in comparison to the hydroponic chamber and in both cases without nutrient solution. The green barley fodder with abundant vegetation can be produced in 8 days from plating to harvest using hydroponic technique (Gebremedhin et al., 2015; Emam, 2016; Badran et al., 2017). During seed germination, fresh weight increases due to the large uptake of water (Fazaeli et al., 2012; Mohsen et al., 2015).

The results showed that HBFI presented higher weight and height than that of HBFO due probably to the climate conditions (temperature and humidity) which are the only difference between the two conditions culture. Previously, Kide & Abrha (2016) showed a production of 9 kg of hydroponic barley after 8 days sprouting. In the current study, HBFI and HBFO showed a production of 6.7 ± 0.9 kg and 4.7 ± 0.23, respectively, which are closer to values reported by Kide et al. (2015). The length of HBFI (19.64 ± 2.10 cm) is similar to values reported by Al-Hashmi (2008) and Al-Karaki (2011) ranging between 18.7 and 22.70 cm. Nevertheless, HBFO length (14.56 ± 3.56) is lower when compared to HBFI. As for hydroponic weight, this can be related to better culture conditions especially temperature and humidity. This variation in growth performance is associated to different factors especially type and quality of grain, amount and frequency of irrigation, nutritious solution, humidity and number of days allowed to grow (Molla & Sharaiha, 2010).

Significant difference was found in DM between the BG, HBFI and, HBFO. The loss in DM content is attributed to the imbibition of water and enzymatic activities, that depleted the food reserves of the seed endosperm (oxidation) without any adequate replenishment from photosynthesis by the young plant during short growing cycle (Sneath & McIntosh, 2003). Also, the decreased in DM and OM may be due to the decrease in the starch content during sprouting, as starch is known to be catabolized to soluble sugars for supporting the metabolism and energy requirement of the growing plant, particularly respiration and cell wall synthesis. Consequently, any decrease in the amount of starch causes a corresponding decrease in DM and OM (Naik et al., 2015). In addition, it is remains impossible to produce a DM grain in just 6 to 8 days culture. The current results are in accordance with the report of Fazaeli et al. (2012) who found that DM was less than 20% in the case of green fodder but about 90% in initial grain. In our study, dry matter of HBFO was higher than HBFI, this is probably due to the increased photosynthetic activity enhancing stage of maturity of the whole plant and leading to higher DM (Kide & Abrha, 2016).

The current investigation showed that hydroponic culture enhanced total nitrogen content. Indeed, soaking and longer germination increase enzyme activity causing a loss in dry weight particularly carbohydrates and increase proteins content (Chavan et al., 1989; Fayed, 2011). Moreover, the nitrogen supplementation and the use of nutrients solution enhances the TNC of the hydroponics barley fodder (Dung et al., 2010a; Emam, 2016) but in our experimentation we have showed an augmentation in protein by using only the tap water. Consequently, PDIA and PDIN values were significantly enhanced in hydroponic culture compared to barley grain. Our results concerning TNC are lower than the findings of Naik et al. (2014) and Mukhopad (1994) with 14.69 and 13.72 respectively, but higher than those reported by Kide & Abraha (2016) in the conventional barley fodder (60 days harvest).

Crude ash and crud fiber were both enhanced in HBFI and HBFO. The increased level of fiber may be due to the increase in the number and size of cell walls with the synthesis of structural carbohydrates such as lignin, cellulose and hemicellulose (Peer & Leeson, 1985a; Azim et al.,1989; Naik et al., 2015). The actual results of CF are higher than the findings of Reddy et al. (1988) and Abouelezz & Hussein (2017) in barley fodder reporting 16.33% and 15.90%, respectively. Concerning ash, Peer & Leson (1985b) reported that the content increases after 4 days of culture corresponding to the extension of roots, which allows minerals uptake. It is evident that ash content of the sprouts increases more if nutrient solution is used rather than tap water (Dung et al.,2010b). The percentage of ash in HBFI and HBFO were higher than those reported by Fazaeli et al. (2011) who found only 3.65%. The results showed that HBFO improved ether extract contents (3.63%). According to Peer & Leeson (1985a), the increase in fat could be due to the increase in the structural lipids and production of chlorophyll associated with plant growth. Our results in HBFO were in line with Kide & Abraha (2016) findings with 3.60% in barley fodder. In hydroponic culture, Fazaeli et al. (2012) reported 3.86%.

Conclusion

To the best of our knowledge, the current results are the first to analyze hydroponic barley performances and nutritive contents grown under natural environment.

The most important findings are that the HBF can be produced in an open area under natural environment without nutrient solution. Indeed, there is generally no great difference compared to Hydroponic barley fodder produced in controlled environment.

The current results showed that HBF culture in natural conditions could be an interesting alternative in animal feeding with no important investment.

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