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Performance of Feedlot Calves Fed Hydroponics Fodder Barley

H. Fazaeli[1]*, H. A. Golmohammadi[2], A. A. Shoayee[2], N. Montajebi[2], and Sh. Mosharraf[3]

ABSTRACT

This experiment was conducted to evaluate the effect of barley green fodder produced by hydroponics system on the performance of feedlot calves. In a completely block randomized experiment, 24 cross bred (Holstein×Local) male calves were assigned randomly to one of the two treatments (diets) that were either control (grain barley) or hydroponic barley green fodder (BGF) that was included to provide 22.8 percent of the total diet on dry matter basis. Seed grade barley was grown in a hydroponics chamber system where the growth period was adjusted for 6 days. Body weigh gain was not significantly different between the treatments, but the animals that had received the control diet had higher (P< 0.05) dry matter intake than those fed BGF diet. There was a tendency (P= 0.199) toward differences in feed efficiency due to dietary treatments. From economical point of view, feed cost increased up to 24 percent when the calves were offered BGF, because of the costly production of hydroponics green forage. Although the mass production of fresh fodder was about 4.5 times per kg of barley grain, this was due to water absorption during germination and growth period. Nevertheless, the dry matter obtained was less than the initial barley grain and further dry matter losses were found in the green fodder. These findings suggest that green fodder had no advantage over barley grain in feedlot calves, while it increased the cost of feed.

Keywords: Barley, Feedlot calves, Hydroponics green forage.

INTRODUCTION

Sprouting grains for human consumption has been used for centuries in Asian countries to improve food value (Resh, 2001). Germination and sprouting activates enzymes that change the starch, protein, and lipids of the grain into simpler forms, for example, starch changes to sugars. There are some arguments about the sprouting grains for convenience of green forage production in hydroponics system to compensate the feed resources for animals (Rajendra *et al.,* 1998; Tudor *et al*., 2003). The hydroponics green fodder is produced from forage grains, having high germination rate and grown for a short period of time in a special chamber that provides the appropriate growing conditions (Sneath and McIntosh, 2003). Development of this planting system has enabled production of fresh forage from oats, barley, wheat and other grains (Rodriguez-Muela *et al.*, 2004). Depending to the type of grain, the forage mat reaches 15 to 20 cm high where production rate is about 7 to 9 kg of fresh forage equivalent to 0.9 to 1.1 kg of dry matter (Mukhopad, 1994). This technology may be especially important in the regions where forage production is limited (Mukhopad, 1994; Bustos *et al.,* 2000). Generally, the seeds are allowed to germinate and grow for about one week when a forage mat made up of the germinated seeds, their interwoven white

[1] Animal Science Research Institute, Karaj, Islamic Republic of Iran.
* Corresponding author, e-mail: hfazaeli@gmail.com
[2] Agricultural Research Center of Golpaygan, Islamic Republic of Iran.
[3] Agricultural and Natural Resources Research Center of Isfahan Province, Islamic Republic of Iran.

roots, and the green shoots is obtained (Cuddeford, 1989). The whole product is then fed to the animals and the empty space in the chamber is used to germinate a new set of seeds (Mukhopad, 1994).

Limited research has been conducted to determine the feeding value of hydroponically sprouted grains (Thomas and Reddy, 1962; Peer and Lesson, 1985a). These authors noted that the dry matter intake of green fodder by feedlot cattle and dairy cattle were low due to its high moisture content. However, Tudor *et al.* (2003) reported an improvement in the performance of steers when given restricted hay diet plus 15.4 kg fresh hydroponics green fodder (about 1.8 kg added DM). It can be concluded that the biological and economical viability of production of hydroponics green forage will depend on sprouting systems, type and quality of the grain, particularly the germination rate, culturing conditions, management, and the local conditions that merits further investigation. Hence, this research was conducted to compare the cost and nutritional value of hydroponically sprouted barley with barley grain offered to feedlot calves.

MATERIALS AND METHODS

Green Forage Production

A growing plan was conducted using a steel hydroponics chamber measuring 4.0×3.0×2.6 m equipped with automatic sprayer irrigation and ventilation apparatus with a capacity of 100 polyethilen trays sized 70×30 cm each. Conditions inside the chamber were controlled to get a range of working temperatures from 18℃ to 21℃ and the relative humidity was adjusted at about 70% using an air circulation. Fluorescent lighting tubes with watertight appliances were arranged on the walls in vertical position to provide 1,000 to 1,500 microwatts cm^{-2} during 12 to 14 hours of daily light. Clean seeds of barley (*Hordeum vulgare* L.) were washed and soaked in tap water for 20 hours, and were then distributed in the trays, with a seed rate density of 4.5 kg m^{-2}.

One sixth of the trays were planted every day and, after six days from the starting point, green fodder carpets were removed. Therefore, a 6-day cycle of working plan was needed to acquire continuous daily harvesting of the green fodder. Fifteen trays of the prepared green fodder were removed from the growing chamber every day. After weighing, the green fodder carpets were removed from the trays and shredded by hand, 2 hours before mixing with the experimental diets. Samples of the green fodder were taken weekly to determine the DM and nutrient contents. To estimate the feeding cost, the price of barley grain, electricity, water and labor were recorded per kg of the green fodder production and feeding.

Feeding Trial

Twenty four cross bred (Holstein×Glpayegani local) male calves with initial average body weight of 193.1±14.75 kg and 9 months age were purchased from local farms and delivered to the agricultural research station. After a three week adaptation period, the animals were weighed and ranked according to live weight. Then, they were grouped in blocks by weight. Four blocks of 3 calves of similar weight were defined and kept in free stall housing for a 3- months trial. Within these groups, each calf was randomly allocated to one of the two treatments diets that were:

1) Control: 35.5% roughage (alfalfa hay, wheat straw, and corn silage)+64.5% concentrate (barley grain, corn grain, cotton seed meal, canola meal + supplement).

2) Experimental diet: 35.5% roughage + 41.7% concentrate + 22.8% BGF.

The experimental diets (Table 1) were formulated to meet the nutrients requirements (NRC, 2000) for 1,200 g d^{-1}

Table 1. Formulation and composition of the experimental diets (DM basis).

Feeds ingredients (% DM basis)	Diets Control	Green Fodder
Alfalfa hay	15.00	15.00
Wheat straw	5.50	5.50
Corn silage	15.00	15.00
Hydroponic fodder barley	0.00	22.80
Barley grain	34.3	12.35
Corn grain	10.00	13.00
Wheat bran	10.00	10.00
Cotton seed meal	4.50	2.75
Canola seed meal	4.50	2.75
Urea	0.50	0.25
Calcium carbonate	0.50	0.40
Sodium chloride	0.20	0.20
Total	100	100
Composition of the diets		
Metabolizable energy (Mcal kg^{-1} DM)	2.55	2.54
Crude Protein (g 100 g^{-1} DM)	14.4	14.5
NDF (g 100 g^{-1} DM)	34.5	36.8
ADF (g 100 g^{-1} DM)	19.0	20.6
Calcium (g 100 g^{-1} DM)	0.52	0.53
Phosphorus (g 100 g^{-1} DM)	0.40	0.39

expected daily body weight gain of the animals used.

Diets consisted of chopped (2-3cm) alfalfa hay, wheat straw and corn silage as roughage components, while barley grain, corn grain, wheat bran, cotton seed meal, canola meal, urea and mineral supplements were used as concentrate part of the rations (Table 1). The concentrate ingredients were prepared and combined weekly, while the roughage and concentrate were mixed manually every day and fed as total mixed ration (TMR) continuous access for approximately 5% feed refusal. The amounts of feed offered and refused were measured daily. All animals had free access to salts stone and fresh water during the experiment. Dry matter intake (DMI) was estimated from voluntary feed intake (VFI)× percentage of DM. Weekly samples of green forage, diets and orts were collected and kept frozen until chemical analysis. Samples were grounded through a 1 mm-screen hammer mill and analyzed for DM (at 70ºC) and nutrients composition (CP, Ca and P) according to AOAC (1999) and cell wall constituents using the procedure of Van Soest *et al.* (1991). The metabolizable energy (ME) content of the feeds was estimated from NRC Tables (2000), except for the barley green fodder that was estimated according to Menke and Steingass (1988). Body weight changes were determined by monthly weighing of the individual animals. Feed and water was removed in the afternoon of the day prior to weighing. The total body weight gain and average daily gain were calculated from the body weight changes. Feed conversion ratio was estimated based on the amount of DMI per kg of live weight gain.

Statistical Analysis

Data on chemical composition and conversion ratio of the green fodder yield was analyzed based on the completely randomized block design including 2 treatments with 6 blocks. Performance data from feeding trial including DMI and feed conversion ratio were analysed based on the following statistical model:

$$Yij= \mu+Ti+Bj+eij$$

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Where, *Yij* is the general observation, μ the general mean, *Ti* the effect of *i*th treatment, *Bj* the *i*th block and *eij* the standard error term. Data from the body weight changes and daily gain were processed according to the below model:

Yij= μ+Ti+Bj(Ak)+eijk

Where the statistical items are same as the above mentioned but each animal per block [*Bj(Ak)*] was considered as one observation. All statistical analysis was conducted using the GLM procedure of SAS (SAS Institute, Cary, NC, 1996), based on the critical *p*-value of 0.05. Means were contrasted using Duncan test.

RESULTS AND DISCUSSION

Green Fodder Yield and Composition

Fresh weight of green fodder increased about 4.5 times of the original seed weight, after sprouting barley grain for 6 days. This increase in fresh weight of forage was due to the large uptake of water during germination, but, numerically some dry matter losses (DML) was found in the green sprout compared to the original grain dry matter (Table 2). The conversion ratio was significantly (P< 0.05) increased for crude protein (CP), although this increase was mostly non-protein nitrogen and not true protein. The production conversion ratio, based on the amount of fresh fodder produced per unit of the seed grain, ranged approximately 4 to 8 times (Peer and Lesson, 1985b; Morgan *et al.,* 1992). This ratio could be affected by several factors such as type of grain, variety, management factors, irrigation, nutrients solution, temperature, humidity, lights, density of seeds on each tray and the number of growing days (Bull and Peterson, 1969; Trubey *et al.,* 1969).

The chemical composition of both barley grain and green forage is presented in Table 3. There was a large difference between the two feeds in DM concentration, which was more than 90 percent in the initial barley grain and less than 20% in the green forage. Crude protein, neutral detergent fiber (NDF), acid detergent fiber (ADF) and Ca increased, but non-fiber carbohydrates (NFC) decreased in the green forage compared to the barley grain on a DM basis. Such changes in nutrients profile are misleading since they only describe the alterations in the proportion of nutrients during sprouting of barley grain. Morgan *et*

Table 2. Nutrients conversion performance of barley grain to green fodder.

Item	Barley [a] grain (g)	Greed [b] fodder (g)	CR [c]	Significance
Fresh weight	1000.00	4590.13	4.50	*
DM weight	941.70	895.07	0.95	ns
Organic matter	909.69	863.32	0.95	ns
Crude protein	98.39	122.69	1.25	*
True protein	66.91	69.78	1.04	ns
Non protein nitrogen	31.57	52.91	1.68	*
Neutral detergent fibre	211.93	280.18	1.32	*
Acid detergent fibre	83.86	128.88	1.54	*
Non fibre carbohydrate	579.64	457.40	0.79	*
Water soluble carbohydrate	35.43	64.48	1.82	*

[a] Dry mater and nutrients per 1000 g of barley grain used for green fodder production; [b] Green fodder and nutrients yield per 1000 g of barley grain, [c] Conversion ratio= Amount of nutrients yield per unit of nutrients used.

ns= Non significant, * (P< 0.05).

Table 3. Chemical composition (Mean±SE) of barley grain and barley green fodder (DM basis).

Composition (%)	Feeds	
	Barley grain	Green fodder
Dry matter	90.40 [a] ±0.10	19.26 [b] ±1.11
Moisture	9.60 [b] ±0.10	80.74 [a] ±1.11
Ash	3.40 ±0.12 [a]	3.65± 0.15 [a]
Organic matter	96.6 ±0.12 [a]	96.35 ±0.15 [a]
Ether extract	1.9 ±0.08 [b]	2.25 ±0.14 [a]
Crude protein	10.45 ±0.14 [b]	13.69 ±0.18 [a]
Non protein nitrogen	3.35 ±0.11 [b]	5.89 ±0.14 [a]
True protein	7.10 ±0.09	7.79 ±0.11
Neutral detergent fiber	22.50 ±0.40 [b]	31.25 ±0.60 [a]
Acid detergent fiber	8.90 ±0.25 [b]	14.35 ±0.21 [a]
Non fiber carbohydrate	61.55 ±0.56 [a]	49.03 ±0.64 [b]
Calcium	0.26 ±0.02 [b]	0.32 ±0.10 [a]
Phosphorus	0.35 ±0.03	0.43 ±0.01
Potassium	0.45 ±0.10	0.37 ±0.01
Magnesium	0.18 ±0.02	0.21 ±0.01
Fe (mg kg^{-1})	125 ±12.3 [b]	237 ±24.8 [a]
Mn " " "	19.0 ± 1.80	18.5 ±1.03
Zn " " "	18.0 ± 1.12	21.11 ±1.7
Cu " " "	8.0 ± 0.16	7.67 ±0.12

Means with different superscripts within a row are significantly (P < 0.05) different.

al. (1992) conducted a series of sprout production experiments and concluded that it was not possible to produce a DM gain in just 6 to 8 days. They recorded DM losses ranging from 7–18%, which was mostly from non-fiber carbohydrates portion. On the other hand, the structural carbohydrate increased in the sprouted green forage. These changes could affect the proportion of other nutrients such as protein, which could be increased on a percentage basis of barley green forage (Peer and Lesson, 1985a; Morgan *et al.*, 1992).

Feeding Trial

Feed Intake

As shown in Table 4, the total means of dry mater intake was significantly (P< 0.05) lower (6.6 vs. 7.2 kg d^{-1}), in calves fed green fodder than those fed the control diet. Although the expected ME and CP were similar for both diets (Table 1), the fiber contents (NDF and ADF) were relatively higher in the BGF than in the control diet (36.8 *vs.* 34.5 and 20.6 *vs.* 19.0 percent in dry matter, respectively), with limited effect on feed intake. In addition, the very high water content in the green fodder made it bulky, which may have limited dry matter intake of calves fed the green fodder (Hillier and Perry, 1969; Myers, 1974). However, with the hydroponic sprouting systems, type and quality of grain, particularly the germination rate, and the culturing conditions and management may affect the palatability of the product (Trubey *et al.,* 1969; Tudor *et al.,* 2003). There was no information concerning the intake and the palatability of hydroponics green forage in ruminant nutrition.

Body Weight Changes

The final live weights were 303.9±17.6 and 312.3±14.9 kg and the total body weight gain during the 90 day experimental period averaged 113.28±8.31and 116.72±7.42 kg for the control and treatment groups, respectively. These weights were not significantly different for the two diets

(Table 4). Moreover, when daily live weight gain was calculated from the body weight changes by month, no significant differences were detected in the different months when the calves received either control diet or the dietary treatment. However, calves fed the control diet had numerically higher means of daily gain during the experimental period as compared to those fed green forage diet (1,297 *vs.* 1,259 g d^{-1}, P= 0.199). In general, live weight gains from the current study were similar to the results of Goonewardene *et al.* (1998), who found an average daily gain of 1.22 kg in crossbred steer calves during the finishing period of 100 days, fed with either whole or rolled barley.

Live weight gain depends on several factors such as breed characteristics, age, initial live weight, nutrition, and management practice (Baker *et al.,* 2002; Restle *et al.,* 2003; Berry *et al.,* 2004). In this study, these factors were similarly controlled for both groups of animals, except for the form of barley (grain *vs.* sprouted green forage), resulting in a similar body weight gains. Therefore, no advantages in daily gain of calves were found as a result of the green forage consumption.

Limited research has been conducted to evaluate the feeding value of sprouted grain. Early workers found lower weight gain when pigs were fed 10-day sprouted maize relative to ground maize, but, when beef cattle were fed with hydroponics green fodder, an average of 200 g higher daily gain was obtained in comparison to those fed with a maize-control diet (Leitch, 1939). Peer and Lesson (1985a) found lower growth rate in pigs when fed sprouted barley than ground barley. Farlin *et al.* (1971) found no difference in performance of the cattle fed sprouted or non-sprouted grain.

We expected that feeding vitamin-rich green forage that could activate some enzymes (during sprouting) and change the starch, protein, and lipids into simpler forms, might affect the animals performance (Mayer and Poljakoff-Mayber, 1975; Kruglyakov, 1989). However, BGF probably did not have higher bioavailability of nutrients for fattening the calves in this experiment.

Feed Efficiency

At the individual measurement periods and over the entire duration of the experiment, no significant differences were found between the control diet and BGF diet for feed conversion ratio (FCR), (Table 4). Generally, FCR depends on the feed intake, growth rate of the animals, and nutrients concentration in the diet (Goonewardene *et al.,* 1998; Loerch and Fluharty, 1998; Fernandez and Woodward, 1999; Baker *et al.,* 2002). However, results in this experiment could be similar to those obtained by Restle *et al.* (2002; 2003) and Berry *et al.* (2004).

The cost of feeding was higher for the animals that received hydroponics green forage diet than those fed barley grain (P< 0.05). The components used for assessing feed cost per unit of body weight gain included feed ingredients, processing and preparing of the rations, and daily feeding practice (Loerch and Fluharty, 1998;

Table 4. Effect of treatments on the animal performance.

Parameters	Treatments			
	Control	Green Fodder	SEM[a]	Significance
Initial weight (kg)	190.6±10.4	195.5±10.5	14.75	ns
Final weight (kg)	303.9±17.6	312.3±14.9	22.90	ns
Body weigh gain (kg)	113.28±8.31	116.72±7.42	4.57	ns
Average daily gain (g)	1259±92	1297±82	19.86	ns
Dry mater intake (kg)	7.20 [a]	6.60 [b]	0.02	*
Feed conversion ratio[b]	5.58	5.29	0.33	ns

[a] Standard error of means, [b] Dry matter intake (kg) per kg of live weight gain.
ns= Non significant; * (P< 0.05).

Fernandez and Woodward, 1999). The feed ingredients used in this experiment were mostly similar. However, by including the green forage in the experimental diet, the proportion of barley grain and protein rich feeds (cotton seed meal and canola meal) were reduced (5.5 *vs*. 9.0%).

When the green forage was included in the diet, no differences in the performance of finishing calves was noted. However, cost of feed was 24% greater than the control diet due to the extra expenses needed for production and feeding the barley green forage i.e. materials and labor for converting barley grain to green fodder and its addition to the diet of the animals.

CONCLUSIONS

Substitution of barley grain with BGF, up to 22.8 percent of the total DMI, showed a similar result in feeding of the finishing calves and there was no difference in the performance of the animals fed with either diet. The feed cost increased when the animals were fed the green fodder diet. Therefore, economically speaking, this system of BGF production is not recommended in feedlot calves.

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عملکرد گوساله های پرواری تغذیه شده با علف جو تولیدی به روش آبکشت

ح. فضائلی، ح. ع. گل محمدی، ع. ا. شعاعی، ن. منتجبی و ش. مشرف

چکیده

این پژوهش به منظور بررسی اثر علف سبز جو تولید شده با روش آبکشت بر عملکرد گوساله های پرواری انجام گرفت. در یک طرح بلوک کاملا تصادفی، ۲۴ راس گوساله نر دورگ (هلشتاین × بومی) با یکی از دو جیره غذایی ۱) جیره شاهد و ۲) جیره حاوی علف جو، تولیدی به روش آبکشت (به میزان ۲۲/۸ درصد کل ماده خشک جیره)، تغذیه شدند. بذر جو در یک اتاق فلزی ، برای دوره های شش روزه کشت داده شد و علف سبز تولیدی در جیره آزمایشی مورد استفاده قرار گرفت. نتایج نشان داد که استفاده از علف سبز جو اثر معنی داری بر تغییرات وزن و افزایش وزن روزانه گوساله ها نداشت. در عین حال، گوساله های گروه شاهد، در طول دوره آزمایش، مقدار ماده خشک بیشتری مصرف نمودند ($p < ۰/۰۵$). ضریب تبدیل غذایی اختلاف معنی داری را نشان نداد اما وجود تفاوت های عددی حاکی از تمایل ($p=۰/۱۹۹$) به کاهش میزان خوراک مصرفی به ازای هر واحد افزایش وزن در گوساله های دریافت کننده علف سبز جوبود. هزینه افزایش وزن در گوساله های گروه آزمایشی ۲۴ درصد بالاتر از گروه شاهد بود که این افزایش ناشی از هزینه بر بودن تولید علف سبز جو با روش آبکشت بود. هرچند که علف سبز تولیدی، به ازای هر واحد دانه جو کشت شده معادل ۴/۵ برابر بود اما نسبت ماده خشک تولیدی کمتر از ماده خشک مصرفی بود. نه تنها بخش اصلی علف تولیدی را آب تشکیل می داد بلکه فرایند جوانه زدن و رشد سبزینه همراه با اتلاف ماده خشک دانه اولیه بوده است. چنین می توان نتیجه گرفت که تبدیل دانه جو به صورت خصیل سبز، طی رشد کوتاه مدت با روش آبکشت، جهت مصرف در تغذیه گوساله پرواری مزیتی نداشته بلکه سبب افزایش هزینه خوراک گردید.

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