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Research Paper

Evaluation of fodder biomass yield of hydroponically-grown barley and oats and the effects on intake, digestibility and weight gain of Washera sheep when fed as a supplement to a basal diet of natural pasture hay in Ethiopia

Rendimiento de biomasa, consumo y digestibilidad de cebada y avena cultivadas en medio hidropónico y su efecto en la ganancia de peso vivo de ovejas Washera en Etiopía

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Abstract

The feasibility of using hydroponically-grown (HGF) barley and oats forage as a supplement to natural pasture hay (PH) for sheep-feeding was investigated. Twenty-five intact Washera male lambs were used in both a 90 day feeding trial and a 10 day digestibility study. The treatments compared were: 100% PH (control, = T1); PH + a concentrate mix (CM) (= T2); PH + HGF barley (= T3); PH + HGF oats (= T4); and PH + 50% CM and 50% HGF mixture of barley and oats (= T5). Chemical composition of diets and refusals, feed intake and digestibility of DM and nutrients were recorded. The average HGF fresh biomass yields from 1 kg grain were 5.21 and 6.32 kg for barley and oats, respectively. The CP, NDF, ADF and ADL concentrations in HGF were 13.2, 45.6, 34.8 and 6.7% for barley and 13.7, 46.8, 36.6 and 7.6% for oats. All supplemented treatments had higher total DM intakes (12–21%) than the control (P<0.05) and all supplements produced marked substitution effects for PH (35–51%). Animals on the PH diet lost weight (17 g/d), while all supplemented groups gained weight (58–65 g/d). Partial budget analysis showed that the highest net return was for T5 followed by T2, T4 and T3. Hydroponically-grown oats forage could have potential to replace a commercial concentrate for supplementing sheep on native pastures, but both HGF and concentrates are probably unaffordable for the majority of smallholder farmers engaged in sheep production. Establishment of farmer cooperative hydroponic facilities could spread the overhead costs of the capital infrastructure and this approach should be investigated.

Keywords: Biomass yield, chemical composition, economics, substitution effects.

Resumen

En Bahir Dar, Etiopía, se investigó la viabilidad del uso de forraje de cebada y avena cultivadas hidropónicamente (HGF) como suplemento de heno de pasto nativo (PH) para la alimentación de ovejas. Se usaron 25 corderos Washera enteros en un ensayo de alimentación de 90 días y un estudio de digestibilidad de 10 días. Los tratamientos fueron: 100% PH (control, = T1); PH + una mezcla de concentrados (CM) (= T2); PH + HGF de cebada (= T3); PH + HGF de cebada (= T4); y PH + 50% CM y 50% mezcla de HGF de cebada y avena (= T5). Se evaluaron la composición química de las dietas y del forraje rechazado, el consumo del forraje y la digestibilidad de la MS y de los nutrientes. Los rendimientos promedio de biomasa fresca de HGF de 1 kg de grano fueron 5.21 y 6.32 kg para cebada y avena, respectivamente. Las concentraciones de CP, NDF, ADF y ADL en HGF fueron 13.2, 45.6, 34.8 y 6.7% para cebada y 13.7, 46.8, 36.6 y 7.6% para avena. El consumo total de MS fue para todos los tratamientos suplementados (T2–T5) más alto (12–21%) que para el control (P<0.05) y todos los suplementos mostraron marcados efectos de sustitución para PH (35–51%). Los animales

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con la dieta PH perdieron peso (17 g/día), mientras que los de los grupos suplementados aumentaron de peso (58–65 g/día). El análisis del presupuesto parcial mostró que el mayor rendimiento neto fue para T5 seguido de T2, T4 y T3. HGF de avena podría tener el potencial de reemplazar un concentrado comercial como suplemento para ovejas en pasturas nativas, pero tanto el HGF como los concentrados probablemente no sean asequibles para la mayoría de los pequeños agricultores dedicados a la producción de ovejas en Etiopía. El establecimiento de instalaciones hidropónicas en cooperativas de agricultores podría considerarse como mecanismo para dispersar los costos de capital necesario y este enfoque debería investigarse.

Palabras clave: Análisis económico, composición química, economía, efecto substitutivo, producción de forraje.

Introduction

Ethiopia has the largest livestock population in Africa, with an estimated 59.9 million cattle, 30.7 million sheep, 30.2 million goats, 56.5 million poultry and 1.23 million camels (CSA 2018). The livestock sector contributes significantly to the economy of the country, producing about 47% of agricultural gross domestic product (Behnke 2010). Livestock products and by-products in the form of meat, milk, honey, eggs, cheese and butter provide animal protein for the local human population. In addition, other items, such as live animals, meat, hides and skins, are exported to earn foreign exchange for the country and play a significant role in the social and cultural values of society (Tegegne et al. 2010).

However, livestock productivity in Ethiopia is still far below its potential, as animals are mostly left to graze on degraded pasture land and crop residues, which do not supply the nutrient requirements for maintenance of animals (Gebremedhin et al. 2009). As a consequence, livestock productivity in Ethiopia is one of the lowest in the world, with average carcass weights of 108, 10, 8.5 and 0.8 kg/head for cattle, sheep, goats and chickens, respectively (Negassa et al. 2011). In addition, Hagos and Melaku (2009) reported that the steady increase in the human population has resulted in grazing and browsing areas being converted to arable farming areas for food crop production, which further aggravates the scarcity of feed resources. Even the existing natural grazing land is characterized as overgrazed, poor in botanical composition, low in biomass yield (1.5–2 t DM/ha/yr) and of poor nutritive value. These grazing lands produce biomass only during the rainy season (July–October) and there is no green fodder in the remaining 8 months. Irrigation development for forage production is not widely exploited. Utilization of concentrate feeds in developing countries like Ethiopia is largely impractical as they are very expensive and not easily accessible by smallholder farmers.

Alternative fodder sources are needed if production levels are to increase. Green fodder production through hydroponic technology is one possible solution. Hydroponic fodder production is simple and easy (Uddin and Dhar 2018) and could be economically feasible in Ethiopia as the seed, construction of the plantation structure and management costs could be relatively inexpensive compared with costs of concentrates. The required materials for the construction and raw materials for growing fodder are available at the smallholder farmer's level. As climatic conditions in the country are suitable for fodder production through hydroponic technology, this production system should not incur significant costs (Bakshi et al. 2017). The materials used for hydroponic technology could also be varied based on the producer's investment capability.

Therefore, the majority of smallholder farmers could possibly establish this system using local materials, while urban and peri-urban dwellers could focus on a 'high tech' setup. Hydroponic fodder is targeted at supplementation of mainly highly-productive animals, not as the basal diet. However, information on possible production levels and utilization as a supplement for animals is quite limited.

This study was designed to assess the production of hydroponically-grown barley (*Hordeum vulgare*) and oats (*Avena sativa*) forage and the benefits from feeding this material as a supplement to sheep fed a basal diet of natural pasture hay.

Materials and Methods

Description of the experimental area

The study was conducted at the Zenzelema Campus of the College of Agriculture and Environmental Sciences of Bahir Dar University (11°37' N, 37°27' E; 1,900 masl), near Lake Tana, Ethiopia. Zenzelema is located at about 573 km northwest of Addis Ababa and 8 km north of Bahir Dar town. The average daily minimum and maximum temperatures are 7 °C and 29 °C, respectively, and mean annual rainfall is 1,445 mm.

Seed preparation before planting

Barley and oats grains were purchased from the local market and screened to remove debris and other foreign materials. The grains were washed using tap water and lemon juice soap at least 3 times and soaked in tap water for 4–6 hours. Seeds were then sterilized by soaking for 30 minutes in a 20% sodium hypochlorite solution with tap water to control the formation of mold growth. Before planting, soaked grains were stored in a gunny bag in a dark room for 24 hours until a root mat emerged.

Seed planting and watering

Sprouted seeds were spread on hydroponic trays which had a volume of 3,500 cm^3 (35×25×4 cm) with holes at the bottom to allow drainage of excess water from irrigation. The seeding rates used in this experiment were about 330–350 g barley and oats grain per tray (about 1–2 cm depth) layer. Tap water containing the nutrient solution was used to irrigate plants twice a day (early morning and late afternoon) throughout the growing period at a fixed rate of 500 mL/tray/day.

Hydroponically-grown green fodder biomass yield estimation

Seven days from planting, total green fodder yields were recorded and production per kg of grain sown was calculated. Representative fresh fodder samples (about 100–200 g) were selected at random and oven-dried at 70 °C for 24 hours to determine dry matter yields and for laboratory analysis.

Purchasing and management of experimental animals

Twenty-five yearling intact Washera sheep with average body weight of 15.2±1.18 kg (mean±SD) were purchased from Sekela local market and quarantined for 3 weeks to allow them to adapt to their new environment and to confirm that they were healthy. The sheep were de-wormed, treated for external parasite control and placed in individual well-ventilated pens. After the adaptation period they were weighed after overnight fasting and allocated by stratified randomization on the basis of initial body weight into 5 groups of 5 animals. Sheep were fed individually throughout the feeding trial.

Experimental design and treatments

The experimental design was a randomized complete block design (RCBD) with 5 treatments and 5 replications. The 5 groups of sheep were randomly assigned to the following treatments: T1 (control group) = 100% natural pasture hay (PH) ad libitum; T2 = PH ad libitum + 300 g concentrate mix (wheat bran and noug seed cake, 1:1 w/w); T3 = PH + 1 kg hydroponic barley (50% DM); T4 = PH + 948 g hydroponic oats; and T5 = PH + 150 g concentrate mix + 250 g hydroponic barley + 237 g hydroponic oats forage. These quantities of hydroponic oats and barley provided similar amounts of nitrogen.

Feeds and feeding management

Natural pasture hay was purchased and chopped to a length of approximately 4–5 cm to minimize preferential selection and wastage, weighed and offered to individual sheep ad libitum as a basal diet. Wheat bran and noug seed (*Guizotia abyssinica*) cake were purchased and mixed in the proportion of 1:1 (w/w) and offered to individual lambs. Barley and oats forage was harvested after 7 days growth and air-dried to 50% DM before feeding the following day. The daily rations of natural pasture hay, hydroponically-grown barley and oats and concentrate mixture were offered in separate troughs. The basal hay ration was fed ad libitum with 10% refusal adjustment every week in the morning and supplements were fed in 2 equal portions in the morning and afternoon. The lambs had free access to clean and fresh water and common salt at all times.

Feed and nutrient intakes

Daily mean basal feed intakes were measured as differences between feed offered and refusals. Natural pasture hay and hydroponic forage refusal samples were taken daily for each animal during both feeding and digestion studies, pooled on a treatment basis, and sub-sampled at the end of the experiment for chemical analysis. Dry matter intake (DMI) was estimated from voluntary feed intake (VFI) × percentage of DM. Intake values for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were calculated by multiplying feed intake by the corresponding percentages for each proximate component.

Bodyweight change and feed conversion efficiency

Animals were weighed at the beginning of the trial and then every 10 days during the 90 days of the feeding trial in the morning after overnight fasting, using a suspended weighing scale with a sensitivity of 100 g. Average daily bodyweight gains were calculated as the difference between final and initial weights divided by the number of feeding days. The feed conversion efficiency (FCE) of experimental animals was calculated as the daily feed consumption divided by average daily bodyweight gain, i.e. g feed to produce a g of bodyweight gain.

Digestibility trial

For the digestibility trial prior to commencement of the feeding study, each sheep was fitted (harnessed) with a fecal collection bag for 3 days as an acclimatization period prior to total collection of feces for 10 consecutive days. Feeding and animal management during the digestibility trial were similar to those in the feeding trial. Feces voided were weighed and recorded every morning, thoroughly mixed and representative samples (20% of feces) were taken, frozen at -20 ºC and pooled over the collection period for each animal. At the end of the collection period, daily samples for individual animals were mixed and dried to calculate DM intakes and digestibility and were used for chemical analysis. The apparent digestibility values for DM, CP, NDF and ADF were determined using the following equations:

$$\text{Apparent DM digestibility coefficient} = \frac{\text{DMI} - \text{fecal DM output}}{\text{DMI}}$$

$$\text{Apparent nutrient digestibility coefficient} = \frac{\text{nutrient intake} - \text{fecal nutrient output}}{\text{nutrient intake}}$$

where:
DMI = dry matter intake.

Chemical analyses of experimental feeds

Experimental feeds were sub-sampled to determine DM concentration and ground to pass a 1 mm mesh sieve for chemical analyses. NDF, ADF and ADL were determined according to Van Soest and Robertson (1985), while CP concentration was estimated by the micro-Kjeldahl method (AOAC 1990).

Economic analysis

All input costs were recorded and the economic feasibility of the various treatments was determined through a partial budget analysis using the procedure of Upton (1979). The partial budget analysis involved the calculation of variable costs and benefits. The same purchase price was applied to sheep in all treatments initially regardless of differences in mean weights of groups. At the end of the study all sheep were sold within various treatments and values recorded. Differences in the values of sheep in each treatment before and after feeding were considered as gross returns (GR) in the analysis. For the calculation of variable costs, expenditures incurred on various feedstuffs were taken into consideration. Feed costs were computed by multiplying the actual feed intake for the whole feeding period by the prevailing market price, including the transportation costs incurred in moving the feeds to the experimental site. Total variable costs (TVC) included the costs of all inputs for the various treatments and net return (NR) was calculated as GR – TVC. The change in net return (ΔNR) was calculated by the difference between the change in gross return (ΔGR) and the change in total variable cost (ΔTVC), which is to be used as a reference criterion for decision on the adoption of a new technology, i.e. ΔNR = ΔGR – ΔTVC. The marginal rate of return (MRR) measures the increase in net income (ΔNR) associated with each additional unit of expenditure (ΔTVC). This is expressed in percentage as: MRR = (ΔNR/ΔTVC).

Statistical analysis

Performance data from the feeding trial including DMI, nutrient intake, digestibility, bodyweight change and feed conversion efficiency were analyzed using GLM procedure of SAS 9.1.3 based on the critical P value of 0.05. Differences among treatment means were tested using Duncan's multiple range test. The statistical model used in the study was:

$$Yij = \mu + Ti + \beta j + eij$$

where:
Yij = the general observation;
μ = the general mean;
Ti = the effect of the *i*th treatment;
Bj = the *j*th block; and
eij = the standard error.

Results

Biomass yields of hydroponically-grown barley and oats forage

The average green fodder biomass yields (50% DM) at 7 days after sprouting were 5.21 (2.61 kg DM) and 6.32 (3.16 kg DM) kg barley and oats per 1 kg barley and oats grain, respectively.

Chemical composition of treatment feeds

The chemical composition of the experimental diets is presented in Table 1. Hydroponic fodders had higher CP concentrations of 13.2 and 13.7% than the grains used to produce them (11.8 and 8.1% for barley and oats, respectively). Natural pasture hay contained 6.4% CP.

Table 1. Chemical composition of experimental feeds and refusals.

Item	Chemical composition (% DM)				
	Ash	CP	NDF	ADF	ADL
Feeds					
Barley grain	2.15	11.8	23.2	18.6	3.32
Barley forage	3.26	13.2	45.6	34.8	6.68
Oats grain	3.22	8.1	47.8	38.7	7.57
Oats forage	2.15	13.7	46.8	36.6	7.57
Wheat bran	3.19	14.4	15.6	10.6	2.24
Noug seed cake	7.44	30.1	41.2	29.8	5.58
PH	7.60	6.4	58.7	47.8	13.0
PH refusals					
T1	8.60	5.2	76.7	73.3	18.9
T2	7.60	4.8	71.4	58.7	15.9
T3	7.44	5.4	66.7	55.3	14.5
T4	9.67	5.0	88.8	76.6	20.0
T5	9.67	6.0	71.4	60.2	17.6

ADF = acid detergent fiber; ADL = acid detergent lignin; CP = crude protein; DM = dry matter; NDF = neutral detergent fiber; PH = natural pasture hay.
T1 = natural pasture hay only; T2 = PH + concentrate mix; T3 = PH + hydroponic barley forage; T4 = PH + hydroponic oats forage; T5 = PH + concentrate mix + hydroponic forage (barley and oats).

Daily intakes of dry matter and nutrients

The daily intakes of DM and nutrients in the various treatments are presented in Table 2. All supplements resulted in an increase (P<0.05) in total DM intake but there was no significant difference (P>0.05) in total DM intake between the 4 supplemented treatments (T2, T3, T4 and T5). Significant differences (P<0.001) were observed in intakes of almost all nutrients.

Table 2. Daily intakes (g/hd/d) of dry matter and nutrients by Washera sheep fed a basal diet of natural pasture hay ± supplements of concentrate mix and hydroponically-grown forage.

Component	T1	T2	T3	T4	T5	s.e.m.
Basal DM	453a	293a	221c	245c	225c	9.07
Suppl. DM	-	282c	310b	308b	341a	1.20
Total DM	453b	575a	531a	553a	566a	10.6
CP	33.5d	78.0a	61.6b	58.4c	77.8a	3.25
NDF	204d	214dc	331a	279b	239c	10.7
ADF	128d	164c	253a	216b	180c	9.59
ADL	37.5b	40.7b	52.9a	44.0b	39.0b	1.60

Means followed by different letters within rows are significantly different (P<0.05). ADF = acid detergent fiber; ADL = acid detergent lignin; CP = crude protein; DMI = dry matter intake; NDF = neutral detergent fiber.
T1 = natural pasture hay; T2 = hay + concentrate mix; T3 = hay + hydroponic barley forage; T4 = hay + hydroponic oats forage; T5 = hay + concentrate mix +hydroponic forage (barley + oats).

Apparent digestibility of dry matter and nutrients

Apparent digestibility coefficients for dry matter and nutrients are presented in Table 3. Apparent digestibilities of CP, NDF and ADF for supplemented treatments were generally higher (P<0.05) than those for the control treatment. However, only the treatment fed both concentrate and hydroponically-grown forage produced higher (P<0.05) DM digestibility than the control.

Table 3. Apparent digestibility of dry matter and nutrients (%) by Washera sheep fed a basal diet of natural pasture hay ± supplements of concentrate mix, hydroponically-grown forage (barley and oats) and their mixtures.

Nutrient	T1	T2	T3	T4	T5	s.e.m.
DM	49.7b	61.0ab	59.6ab	57.3b	71.1a	2.00
CP	47.8c	72.3ab	61.1b	55.5c	76.9a	2.66
NDF	43.0c	50.6b	51.7b	49.3b	57.1a	1.45
ADF	41.6b	50.0a	50.4a	47.2a	54.1a	1.10

Means within rows followed by different letters are significantly different (P<0.05). ADF = acid detergent fiber; CP = crude protein; NDF = neutral detergent fiber.
T1 = natural pasture hay; T2 = hay + concentrate mix; T3 = hay + hydroponic barley forage; T4 = hay + hydroponic oats forage; T5 = hay + concentrate mix +hydroponic forage (barley + oats).

Bodyweight change and feed conversion efficiency

Data on body weights and bodyweight changes are presented in Table 4. All supplemented treatments produced better (P<0.05) bodyweight gains and feed conversion efficiencies than the control.

Table 4. Bodyweight parameters and feed conversion efficiencies of Washera sheep fed a basal diet of natural pasture hay ± supplements of concentrate mix and hydroponically-grown forage (barley and oats).

Parameter	T1	T2	T3	T4	T5	s.e.m.
IBW (kg)	15.60a	14.60a	15.60a	14.50a	15.70a	0.35
FBW (kg)	14.10b	19.80a	20.78a	19.60a	21.56a	0.7
ADG (g/d)	-16.7b	57.8a	57.6a	56.7a	65.1a	6.02
FCE	27.1b	9.95a	9.23a	9.76a	8.69a	0.01

Means within rows followed by different letters are significantly different (P<0.05). ADG = average daily gain; FBW = final body weight; FCE = feed conversion efficiency (g feed/g bodyweight gain); IBW = initial body weight.
T1 = natural pasture hay; T2 = hay + concentrate mix; T3 = hay + hydroponic barley forage; T4 = hay + hydroponic oats forage; T5 = hay + concentrates + hydroponic forage (barley + oats).

Partial budget analysis

Results of the partial budget analysis of performance of the various groups of sheep is presented in Table 5. Animals in the control treatment lost weight, resulting in a substantial negative outcome financially. All supplemented rations resulted in positive financial outcomes with the highest net returns for the hay + concentrate + HGF treatment and the worst for the barley forage supplemented group.

Table 1. Partial budget analysis of Washera sheep fed a basal diet of natural pasture hay ± supplements of concentrate and hydroponically-grown forage (barley and oats).

Parameter	T1	T2	T3	T4	T5
Purchase price of sheep (ETB/hd)	914	914	914	914	914
Basal diet intake (kg/hd)	40.8	26.4	19.9	22.1	20.3
Concentrate intake (kg/hd)	-	27.0	-	-	13.5
Barley forage intake (as fed, kg/hd)	-	-	55.8	-	14.0
Oats forage intake (as fed, kg/hd)	-	-	-	55.4	13.9
Cost of basal diet (ETB/hd)	20.4	13.2	9.95	11	10.13
Cost of concentrate (ETB/hd)	-	148.5	-	-	74.25
Cost of barley forage (ETB/hd)	-	-	220.2	-	55
Cost of oats forage (ETB/hd)	-	-	-	137.6	34.4
Labor cost (ETB/hd)	150	180	184.2	184.2	182.1
Total variable cost (ETB/hd)	170.4	341.7	414.35	332.8	355.88
Selling price of sheep (ETB/hd)	850	1,469	1,450	1,435	1,510
Gross return (ETB/hd)	-64	555	536	521	596
Net return (ETB/hd)	-234.4	213.3	121.65	188.2	240.12
ΔNR		447.7	356.05	422.6	474.52
ΔTVC		171.3	243.95	162.4	185.48
MRR (ratio)		2.61	1.46	2.6	2.56

ETB = Ethiopian Birr; MRR = marginal rate of return; ΔNR = change in net return; ΔTVC = change in total variable cost. T1 = natural pasture hay; T2 = hay + concentrate mix; T3 = hay + hydroponically-grown barley forage; T4 = hay + hydroponically-grown oats forage; T5 = hay + concentrate mix + hydroponically-grown forage (barley + oats).

Discussion

The forage production per kg of seed in the present study is lower than the 8 kg of hydroponic forage from 1 kg barley seed reported by Badran et al. (2017). Yields are also lower than earlier reports (Al-Karaki and Al-Hashimi 2012; Naik and Singh 2013; Kantale et al. 2017). The ranges of seedling heights of the shoots were 11–17 cm and 10–15 cm for barley and oats forage, respectively. These figures are lower than 18–20 cm for hydroponic barley forage (Al-Hashmi 2008), which was harvested at 8 and 9 days after sprouting. The differences in the biomass yield and length may be attributed to size of the seed, varieties of the grains and the environment where hydroponically grown.

The CP concentration in the natural pasture hay in the current study was lower than the 9.9% CP reported by Arefaine and Melaku (2017), and was below maintenance requirements for ruminants (Van Soest 1994) as evidenced by the weight loss recorded in sheep fed only hay.

In contrast, CP concentrations in the barley grain and barley forage in this study were 11.8 and 13.2%, respectively, values lower than the 19.7 and 19.8% reported by Fazaeli et al. (2012). The NDF and ADF concentrations in the barley forage (45.6 and 34.8%, respectively) were higher than the NDF and ADF concentrations of 31.6 and 14.6% reported by Helal (2015). While the oats grain contained only 8.1% CP, which was considerably lower than that of barley grain, the oats forage contained 13.7% CP, which was similar to that of the barley forage.

The increase in total DMI when supplements were fed was not surprising as the basal diet of native pasture hay contained only 6.4% CP, while diets where supplements were fed contained either concentrates or forage with CP concentrations of 13–22% and higher digestibility than the basal roughage. The increased N available to the rumen microorganisms would have increased rate of digestion and rate of passage of the basal diet resulting in increased appetite (Van Soest 1994). While all supplements increased total DMI, all produced a substantial substitution effect on hay intake with supplements containing forage resulting in a higher substitution effect (46–52%) than the concentrate (35%).

With the increased DMI recorded in supplemented groups, coupled with higher digestibility of the ration consumed, the improved bodyweight changes in these treatments were to be expected. Feeding supplements converted a weight loss of 17 g/d to gains of 57–65 g/d. However, the feed conversion efficiency values obtained were disappointing with intake of 10 kg DM needed to obtain a kg of bodyweight gain. The highest average daily gain (65.1 g/d) in T5 for the current study was similar to the 64.6 g/d average daily weight gain for Arsi-bale sheep fed diets of different varieties of faba bean (*Vicia faba*) straw mixed with concentrate (Wegi et al. 2018) and 64.4 g/d for Washera sheep fed natural pasture hay plus 350 g/d concentrate mixture (hulls, wheat bran and noug seed cake) (Mesganaw 2014). Results from this study support the concept of Naik et al. (2014) that hydroponic sprouts can be a rich source of bioactive enzymes and may contain ingredients that improve the performance of livestock. While this confirms the biological feasibility of the process, assessment of the costs and returns is needed to confirm whether or not the procedure is financially viable.

The partial budget analysis of data from this study indicates that feeding any of the supplements produced a positive financial outcome and there were relatively small differences between feeding a concentrate supplement, oats forage and concentrate mixed with barley-oats forage. However, returns from barley forage as a supplement produced a much worse economic outcome than the other supplemented diets. The 21% higher biomass production of oats relative to barley per unit weight of grain under hydroponic conditions combined with a lower unit price of oats grain meant that the returns for the oats forage were more favorable than for barley. This suggests that hydroponic options could be adopted by farmers as hydroponic fodder production and utilization could be a possible option for boosting small-ruminant production by smallholder farmers. We consider it is possible to use low-cost techniques which are easy to operate and maintain and require simple infrastructure and low operational costs. For this intensive forage production strategy to be effectively used in the country, an option could be the production of hydroponic green forage by larger livestock producers as well as farmer-led commercial cooperatives. More studies are needed to confirm that the relative production levels of forage from barley and oats seeds are as found in this exercise.

Conclusions

The results of this study suggest that hydroponic green forage could be grown and fed as a replacement for conventional commercial concentrate mixtures for sheep during the dry season in Ethiopia. However, based on the costs and returns from this study plus the ease of feeding, the net benefits would still favor the concentrate supplements. In any case, unless simple low-cost methods for growing the forage can be developed, for this strategy to be effectively introduced in Ethiopia, hydroponic green forage may need to be produced in farmer-led commercial cooperatives to spread the capital cost.

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