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REGULAR ARTICLES

Effects of substituting concentrate mix with water hyacinth (*Eichhornia crassipes*) leaves on feed intake, digestibility and growth performance of Washera sheep fed rice straw-based diet

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Abstract

The objective of this experiment was to determine effects of substituting concentrate mixture (CM) with water hyacinth (*Eichhornia crassipes*) leaves (WHL) at different inclusion levels of feed and nutrient intake, digestibility, and growth performance of Washera sheep. Twenty yearlings intact male sheep with initial body weight of 24.1 ± 1.68 kg (mean ± SD) were used in both 90 days of feeding and 7 days of digestibility trials. The experimental animals were arranged into four blocks of five animals based on their initial body weight. The dietary treatments used in the experiment were 100% concentrate mix (0WHL-T1), 50% WHL and 50% CM (50WHL–T2), 75% WHL and 25% concentrate mix (75WHL-T3), and 100% WHL (100WHL-T4). Rice straw was given ad libitum. The crude protein (CP) content of water hyacinth leaf is 14.4%. Dry matter digestibility was greater ($p < 0.001$) for 0WHL and 50WHL followed by 75WHL. The average daily weight gain was higher for 100% concentrate mix followed by 50 and 75% water hyacinth leave supplemented sheep. Therefore, wilted water hyacinth leave can safely substitute concentrate mix up to 75% and result in the optimum growth of Washera sheep from the feeding regime employed in this study.

Keywords Water hyacinth leaf · Rice straw · Body weight · Digestibility · Washera sheep

Introduction

Water hyacinth (*Eichhornia crassipes*) is a free-floating perennial aquatic plant which is a widely prevalent and enormously fast-growing aquatic weed in almost all tropical nations (Adeyemi and Osubor 2016). Water hyacinth (WH) multiplies rapidly and forms dense mats; it produces seeds in large quantity which may remain viable for up to 30 years (Simpson and Sanderson 2002) which interfere with waterways, decimate aquatic wildlife, create ideal conditions for diseases and its vectors, etc. (Kushwaha 2012). It has been recognized as the most damaging aquatic weed in Ethiopia since its first presence in 1965 (Stroud 1994; Rezene 2005). Its presence in Lake Tana has been recognized in 2011 (Tewabe 2015). Since its sighting, several efforts have been done to control and eradicate the weed in collaborated approaches. Unfortunately, it was not successful because of its fast expansion rate and invasive behavior of the plant (Wassie et al. 2014).

When we looked from a resource angle, it appears to be a valuable resource with several unique properties. There are potential benefits from WH such as animal fodder, water purification, fiberboard, biogas, fertilizer, and paper production (Lindsey and Hirt 1999; Chhay et al. 2007). In Malaysia, Indonesia, Philippines, and Thailand, water hyacinth is used as feed for pigs, ducks, and fish (Jianbo et al. 2008). Jianqing et al. 2001 reported that during the 1950s–1970s, water hyacinth was widely used for animal food in China, as at that time, the economy in rural areas was very depressed and there was great shortage of food for animals. As indicated by Oguniade et al. (1988) because its dry matter has high crude protein (18%) and low acid detergent fiber (33%) contents, the water hyacinth has potential as a roughage source for ruminants. Researchers also evaluated WH as a feed source to cattle (Thu 2011), goats (Hira et al. 2002), and sheep (Abou-

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Raya et al. 1980). Livestock in the tropics is still facing the challenges of poor nutrition, as the available crop residues are of low nutritive value. One way to alleviate this feed shortage would be the development of new technology for the utilization of aquatic plants as livestock feed. Water hyacinth could provide an accessible feed resource for livestock that is considered as one of the more effective physical control methods (Ho Thanh 2015). Rajib and Balen (2004) also reported that WH can be an inexpensive source of animal feed. So, proper and large-scale utilization could serve as a positive approach to the control of WH (Anushree 2007).

The chemical composition of water hyacinth varies considerably according to the location and season (Shafy et al. 2016). Due to its relatively high crude protein (CP) content (5.8–25.6%), WH can be considered as a potential protein supplement for livestock which is commonly fed cereal crop residues whose contribution as a source of feed is increasing in Ethiopia (Shigdaf et al. 2016). This contributes for substitution of concentrate feeds that became costly and inaccessible for protein supplementation of the animals for smallholder livestock production. Therefore, this study aims to evaluate effects of substituting concentrate mix with water hyacinth leaves at different levels on feed intake, digestibility, and growth performance of Washera sheep fed a rice straw-based diet.

Materials and methods

Study area

The feeding trial was conducted at the Zenzelma Campus in College of Agriculture and Environmental Science of Bahir Dar University, around Lake Tana, Ethiopia. Lake Tana, which is invaded by water hyacinth, is geographically located in the north-western part of Ethiopia, between latitude 10° 58`–12° 47′ N and longitude 36° 45`–38° 14′ E. It has a surface area of 3200 km^2, a mean depth of 8 m, and a maximum depth of 14 m with fluctuations due to increasing siltation levels. The lake lies at an altitude of 1840 m.a.s.l. The mean annual rainfall of the catchment of Lake Tana is about 1280 mm. Air temperature shows large diurnal but small seasonal changes with an annual average of 20 °C (Setegn et al. 2011). The Lake Tana watershed consists of 347 *Kebele*s (the lowest administrative units in Ethiopia) and 21 districts in four administrative zones (IFAD 2007).

Description of the aquatic plant and its status in Ethiopian water bodies

Water hyacinth *(Eichhornia crassipes)* belongs to Kingdom-Plantae, Order-Commelinids, and Family-Pontederiacea (Hossain et al. 2015). The family Pontederiaceae has nine genera including *Eichhornia*; only *Eichhornia crassipes* is regarded as a pan-tropical aquatic weed (HoThanh and Udén 2013). The name water hyacinth refers to its aquatic habitat and the similarity of the flower color to that of the garden hyacinth (Parsons and Cuthbertson 2001). Water hyacinths, a free-floating macrophyte, live at the air-water interface and an erect, free-floating, stoloniferous, perennial herb (Khanna et al. 2011).

At present, water hyacinth has become a major invasive alien weed in the water bodies of Ethiopia having successfully established and invaded different water bodies. Most of the lakes of Ethiopia are predominated with high water hyacinth infestation. The incidence and intensity of water hyacinth infestation in Lake Tana are still increasing through fragmentation of established plants and extends towards the southern tip of the Tana (Stave et al. 2017). Asmare (2017) also reported that even if a tremendous amount of human labor, time, and money has been exerted each year by both surrounding community and government, its coverage continues to escalate from 20 ha in 2012 to around 50,000 ha in 2014 that close to more than 30% of the shoreline of the north-eastern part of the Lake. Consequently, it will invade the Blue Nile River starting from its source, and the Great Ethiopian Renaissance Dam (GERD) (Tewabe 2015; Wassie et al. 2014). It also affects the farmlands surrounded the lake and even part of the lake that being cultivated when the water subsides (Kefelegn 2013).

Feed preparation

Water hyacinth leaves were harvested from Lake Tana in the shoreline of Gonder Zuria district of Lemba and Mitirha Aba Warka Kebeles. The freshly harvested water hyacinth leaves were wilted under shade for 24 h before feeding to the sheep. The concentrate mix was purchased from Aba Wengele feed processing enterprise in Bahir Dar Town. The Concentrate mix consisted of noug seed cake (50%), wheat bran (20%), maize grain (29%), and common salt (1%). The basal diet-rice straw was purchased from the farmers around Lake Tana in Fogera Plain.

Experimental animals and their management

Twenty yearlings intact Washera sheep with the average body weight of 24.1 ± 1.68 kg (mean ± SD) were purchased from Adet Market. The age of the sheep was determined by dentition and information from the owners. The animals were quarantined for 2 weeks at the site of the experiment to observe any illness. The animals were vaccinated against ovine pasteurellosis and anthrax. The sheep were also de-wormed against internal and external parasites using albendazole (300 mg/head), tetramizole tablet, and diazinon (60%). The experimental animals were housed in an individual pen in a ventilated shade. The pens were equipped with feeding and watering troughs.

Experimental design and treatments

The experimental design was a randomized complete block design with four treatments and five replications. The treatments were then randomly assigned to the sheep in each block. The treatment diets were T1 = 100% CM (0WHL-water hyacinth leaves), T2 = 50% WHL + 50% CM (50WHL), T3 = 75% WHL + 25% CM (75WHL), and T4 = 100% wilted WHL (100WHL). Rice straw was given ad libitum to have 20% refusal. The ration formulation of experimental diets and concentrate mix was done using win feed software 8 (2008). Experimental animals were allowed to adapt to experimental diets for 2 weeks before the commencement of actual feeding trial. The feeding trial lasted for 90 consecutive days.

Feed intake

The amounts of feed offered and refused were recorded daily for each sheep. Daily feed intake was measured as differences between offered and refusal feeds. Samples of feed offer from all diets and refusals were collected each morning prior to offering fresh feed and weighed to measure the feed intake throughout the experimental period. Subsamples were taken and prepared for chemical analysis.

Diets were offered three times per day at morning, midday, and evening. Feed leftovers were weighed daily to adjust voluntary intake.

Digestibility and feeding trials

Each sheep was fitted with fecal collection bags for 4 days of acclimatization period following collection of feces for seven consecutive days. Total feces voided over 24 h was weighed daily for each sheep, and after thoroughly mixing, 20% representative samples were taken and kept frozen at − 10 °C. The daily collected fecal samples were pooled over the collection period for each animal. At the end of the collection period, samples from each sheep were mixed and dried at 60 °C to a constant weight. The digestibility of nutrients was determined as the difference between nutrients intake and that recovered in fecal expressed as a proportion of nutrients intake.

$$\text{The digestion coefficient(DC)} = \frac{[\text{Total Nutrient Intake}-\text{Nutrient excreted in faeces}]}{[\text{Total Nutrient intake}]}$$

Body weight change and feed conversation efficiency (FCE)

The initial and final body weights were obtained by weighing sheep on two consecutive days before feeding and watering using 50 kg digital hanging weighing scale made in Zhejiang, China. Experimental sheeps were subsequently weighed at 10-day intervals during the feeding trial period. The daily weight gain was calculated as the difference between final BW and initial BW divided by the number of feeding days. Feed conversion efficiency was calculated as average daily gain (ADG) divided by feed intake.

Chemical analysis

Representative samples of feeds offered and refusals were collected and the chemical analysis was done at ruminant nutrition laboratory of Shimane University, Japan while fecal sample analysis was done at the Food and Nutrition Laboratory of Bahir Dar Institute of Technology, Bahir Dar University, Ethiopia. Heavy metal content of water hyacinth for its toxicity was detected using flame atomic absorption spectrophotometer in Tottori University, Japan. The dry matter (DM), organic matter (OM), and CP concentration of different parts of water hyacinth were analyzed according to the procedures of AOAC (1990). Neutral detergent fiber (NDF) was analyzed according to the procedures of Van Soest et al. (1991). The organic matter digestibility (OMD) and metabolizable energy (ME) content were estimated by the method of Menke and Steingass (1988). The in vitro gas production technique used to determine ME concentration.

Statistical analysis

The analysis of variance (ANOVA) of data on feed intake, body weight change, and digestibility was run using the general linear model procedure of SAS (2008). Initial BW was used as a covariate for statistical analysis of ADG and FBW. Differences between treatment means were separated using Duncan's multiple range tests when the effect of treatment was significant. A significance level of 5% was adopted for all statistical analysis. Linear and quadratic polynomial contrasts were performed to determine the effects of inclusion levels of the water hyacinth in the diet. The statistical model used for analysis of feed intake, FCE, digestibility, and body weight change was $Y_{ij} = \mu + T_i + B_j + E_{ij}$.

Where:

Y_{ij} observation of body weight in the j^{th} block and i^{th} treatment;
μ the overall mean;
T_i the i^{th} treatment effect;

B_j the j[th] block effect; IBW was used as a covariate for ADG and FBW.

E_{ij} the random error.

Results

Chemical composition of the experimental feeds

The chemical composition analysis of the experimental feed items constituting treatment diets is presented in Table 1. In this experimental diet, the concentrate mix has high crude protein content (24.1%) followed by the water hyacinth leaves (14.4%). As expected, the water hyacinth leaves had more than three times crude protein content than the rice straw (3.9%).

Feed and nutrient intake

A significant difference was recorded in total dry matter intake among treatment groups (Table 2). The total DM intake declined as the level of WH inclusion increased. The DM intakes as a percent of BW and metabolic BW were higher ($P < 0.001$) for 0WHL and 50WHL than 100WHL. The same trend was observed for CP intake. The total CP intake of 100WHL supplement had a significant difference with 0WHL, 50WHL, and 75WHL; while the CP intake of 50WHL supplemented group was statistically similar to 75WHL.

Apparent digestibility of DM and nutrients

The DM, OM, CP, NDF, and ADF digestibility coefficients of treatment diets are given in Table 3. Significantly higher digestibility of DM ($P < 0.001$), OM ($P < 0.001$), CP ($P < 0.001$), and NDF ($P < 0.001$) were observed among treatments. The apparent digestibility of 0WHL and 50WHL was higher ($P < 0.001$) than 75WHL and 100WHL.

Table 1 Chemical composition of experimental feeds

Parameter	WHL	CM	RS
DM (% ADM)	92.1	91.6	89.3
OM (% DM)	88.1	78.8	86.3
CP (% DM)	14.4	24.1	3.9
NDF (% DM)	42.0	33.4	69.7
ADF (% DM)	28.2	35.8	51.9

DM dry matter. *ADM* air dry matter, *CP* crude protein, *NDF* neutral detergent fiber, *ADF* acid detergent fiber, *WHL* water hyacinth leaf, *CM* concentrate mix, *RS* rice straw

Body weight change and feed conversation efficiency (FCE)

Final BW, ADG, and FCE were significantly affected by WHL supplementation and had a similar trend across treatments (Table 4). Among the supplemented treatments, sheep on 0WHL performed better ($P < 0.001$) in ADG than sheep supplemented by 50WHL and 75WHL.

Discussion

Chemical composition of water hyacinth leaves

The CP content of water hyacinth in the current study is comparable to common leguminous fodders and greater than most grasses available in Africa (Pamo et al. 2007; Hossain et al. 2015) and Ethiopia (Shenkute et al. 2012). Sindhu et al. (2017) indicated that high protein content in the leaves and rapid growth have made WH potential for use as fodder for cows, goats, pigs, ducks, etc. Hossain et al. (2015) also reported that WH can be utilized as feed for animals, especially ruminants, as basal feed resources or supplements, as it contains moderate crude protein content (10.5%). The chemical composition of WH differs according to the region where it is collected and depends on the nutrients available in the environment (de Vasconcelos et al. 2016). It can also assist farmers by ensuring sustainable production with the lowest cost diets for cattle. Thus, water hyacinth leaves may be considered as a valuable supplement for animals fed on low nutrient quality feed such as rice straw and tropical grasses (Cheat 2010).

Feed and nutrient intake

The lowest feed intake by sheep on 100WHL supplementation. This might be associated with high moisture and heavy metal contents that tend to reduce DM intake. Mako (2013) observed DM intake reduction in goats fed with dehydrated WH replacing guinea grass, implying that it could not be used as sole forage or at a high proportion in the diet of ruminants. However, by providing a fiber source (rice straw), Khan et al. (2002) found 67% increase in DM intake of steers. Similarily, de Vasconcelos et al. (2016) reported that DM, OM, CP, and NDF intakes were linearly reduced with the replacement of Tifton-85 hay with WH hay. Aregheore and Cawa (2000) also reported that more than 25% fresh water hyacinth in the feed reduces intake. Substitution of concentrate mix with 50WHL and 75WHL resulted in higher ($P < 0.001$) total DM, OM, and CP intake than 100WHL. Comparable to this result, Abdelhamid and Gabr (1991) stated that wilted water hyacinth replaced up to 50% of the concentrates in complete diets, and Islam et al. (2009) also reported that 50% wilted water hyacinth supplemented diets resulted in significantly higher CP

Table 2 Daily feed and nutrient intake of Washera sheep

Intake (g/day)	Treatments				SEM	*P* value
	0WHL	50WHL	75WHL	100WHL		
WH DM intake	–	116.3	213.5	445.6	0.68	
CM DM intake	549.6	384.7	274.5	–	0.63	
RS DM intake	228.8^{b}	220.1^{b}	275.1^{a}	281.8^{a}	1.2	< .0001
Total DM intake	787.6^{a}	763.4^{ab}	723.1^{b}	687.4^{c}	1.6	< .0001
DM intake (% BW)	3.3^{a}	3^{ab}	2.8^{b}	2.4^{c}	0.4	< .0001
DM intake (g/kg $W^{0.75}$)	64.4^{a}	53.5^{ab}	44.3^{b}	34.6^{c}	1.0	< .0001
Total OM intake	661.6^{a}	641.3^{ab}	607.4^{b}	577.4^{c}	2.6	< .0001
Total CP intake	86.6^{a}	84.0^{ab}	79.5^{b}	68.7^{c}	1.4	< .0001
Total NDF intake	378.0^{a}	366.4^{ab}	347.1^{b}	302.5^{c}	0.8	< .0001

a, b, c means within a row having different superscripts are significantly different at *** = ($P < 0.001$); 0WHL = 100% CM; 75WHL = 75% WHL + 25% CM; 50WHL = 50% WHL + 50% CM and 100WHL = 100% WHL

WH water hyacinth, *CM* concentrate mix, *RS* rice straw, *DM* dry matter, *BW* body weight, *OM* organic matter, *CP* crude protein, *NDF* neutral detergent fiber, *SEM* standard error mean

consumption. In the other way, Dolberg et al. (1981) reported that the addition of an oil cake (220 g/day) to water hyacinth mixed with straw increased DM intake to 109% over the control group (water hyacinth alone). The higher total DM intake per metabolic body weight ($P < 0.001$) was for 0WHL, 50WHL, and 75WHL which could be attributed to variations in CP content of the supplements especially water hyacinth.

Apparent digestibility of DM and nutrients

There were significant effects of WHL inclusion level on DM, OM, CP, and NDF digestibility, all of which decreased when the level of water hyacinth increased. And yet, values for digestibility were substantially higher than values reported for forages available around Lake Tana (Shenkute et al. 2012). Thus, the inclusion of 75WHL and 50WHL with concentrate proportion supports the potential feed resources in Eastern Africa like rice straw. Dada (2002) reported the utilization of sundried *E. crassipes* by growing goats at up to 40% dietary level of inclusion. As indicated by Jianbo et al. (2008) and Lu et al. (2008), feeding egg-laying ducks with water hyacinth, not only promoted egg laying rate but also increased the level of feed digestion and feed utilization rate.

Body weight changes and feed conversation efficiency (FCE)

The lowest average daily gain recorded in animals supplemented with 100WHL (Table 4). This might be due to the low intake of water hyacinth leaves (Table 2) which could be associated with its high nutrient detergent fiber content (Table 1). Mohapatra (2015) reported that utilization of WH meal as partial fish protein replacement in the diet of *Cyprinus carpio* fry at different levels (0, 10, 20, and 30%) results in growth performance decreases as the level of WH increased. It is also reported that when grass crop (*Ctenopharyngodon idella*) were fed diets containing from 0 to 100% water hyacinth meal, weight gain and protein efficiency ratio decreased as the amount of water hyacinth meal increased (Rezania et al. 2015). However, Kivaisi and Mtila (1995) reported that adding water hyacinth to the diet increased egg weight and consequently increased the eggshell weight.

Table 3 Apparent digestibility coefficients of nutrients of experimental diets

Digestibility	Treatments				SEM	*P* value
	0WHL	50WHL	75WHL	100WHL		
DM	78.6^{a}	72.8^{ab}	69.6^{b}	59.6^{c}	2.10	< .0001
OM	75.8^{a}	73.2^{ab}	71.9^{b}	63.4^{c}	1.14	< .0001
CP	86.2^{a}	79.2^{ab}	70.2^{b}	58.4^{c}	1.56	< .0001
NDF	76.8^{a}	71.8b^{ab}	69^{b}	64.4^{c}	1.98	< .0001

a, b, c means within a row not bearing a common superscript letter are significantly different; *** = ($P < 0.001$); 0WHL = 100% CM; 75WHL = 75% WHL + 25% CM; 50WHL = 50% WHL + 50% CM and 100WHL = 100% WHL

CP crude protein, *DM* dry matter, *NDF* neutral detergent fiber, *OM* organic matter, *SEM* standard error of mean

Table 4 Body weight parameters and feed conversion efficiency

BW parameters	Treatments				SEM	*P* value
	0WHL	50WHL	75WHL	100WHL		
Initial BW (kg)	24.2	23.88	23.22	23.92	0.17	Ns
Final BW (kg)	32.8[a]	30.1[ab]	28.0[b]	25.26[c]	0.36	< .0001
ADG (g/day)	96.3[a]	69.1[b]	53.6[b]	14.9[c]	4.27	< .0001
FCE	0.12[a]	0.10 [ab]	0.08[b]	0.03[c]	0.02	< .0001

a, b, c means in the same row having different superscripts are significantly different; ***($P < 0.001$); 0WHL = 100% CM; 75WHL = 75% WHL + 25% CM; 50WHL = 50% WHL + 50% CM and 100WHL = 100% WHL

BW body weight, *ADG* average daily body weight gain, *SEM* standard error of mean

There is higher weight gain and feed conversion efficiency in 50WHL and 75WHL than 100WHL. Islam et al. (2009) reported that wilted water hyacinth supplementation significantly improved the protein conversion efficiency of growing bullocks. The water hyacinth leaf protein concentrate combined with other feeds has been reported to be a good quality protein source for animal feed formulation (Adeyemi and Osubor 2016).

Toxicity and heavy metal content of water hyacinth

The heavy metal analysis result revealed that most heavy metals are present in the water hyacinth leaves such as copper, nickel, zinc iron, chromium, lead, arsenic, mercury, and cadmium except calcium which exceeded the detection limit. The bioaccumulation factor for water hyacinth leaves was found maximum for magnesium (9642.09 μg/g), arsenic (463.25 μg/g), chromium (70.20 μg/g), copper (41.98 μg/g), and lead (17.18 μg/g) in dry wt. These values are in the range of the accepted levels. Wu et al. (2014) reported that the concentrations of common toxic metals including cadmium, lead, platinum, palladium, tin, mercury, barium, silver, stibium, and aluminum in the water hyacinth leaf powder (WHLP) used for the animal feeding test were within their maximum limits in food additives as stated by the World Health Organization. The authors also proved that the WHLP used for the animal feeding test were not acutely toxic. Thus, the level of all heavy metals found in this study was within safe limit (Victor et al. 2016).

In this experiment, toxicity in sheep fed on water hyacinth leaves with rice straw was not detected except their loss of live weight and only one animal (among animals supplemented with 100% WHL) suffered from serious illness. According to the veterinarian diagnosis report, it is difficult to relate the illness with the toxicity of water hyacinth because the other animals in the treatment group did not show such symptom. Mahmoud et al. (1979) reported that Sudan sheep fed water hyacinth leaves did not show any clinical or pathological changes. Similarly, Adeyemi and Osubor (2016) reported that water hyacinth leaf protein concentration is nutritious and acutely nontoxic. Dada (2002) also reported that utilization of sundried *E. crassipes* by growing goats at up to 40% dietary level of inclusion is beneficiary. In addition, Malik et al. (2016) explained that water hyacinth does not contain antinutritional factors to a level that can inhibit the performance of pullet chicks; hence, it can be included up to 15% in the diets of pullet chicks (as a replacement for 75% wheat offal) without any detrimental effects on their carcass characteristics as well as on their hematological and biochemical profile.

Conclusions

Water hyacinth leaves have relatively high CP content and could provide nutrients year-round to be utilized as fodder for ruminant because massive amounts of water hyacinth already exist in Lake Tana. Although wilted WH reduced the intake and digestibility of some nutrients, its concentrate replacement could be economically advantageous for sheep feeding in areas with great availability of this aquatic plant. Wilted water hyacinth leaves can safely substitute concentrate mix up to 75% and result in the optimum growth of Washera sheep. Thus, it can be concluded that wilted water hyacinth leaves can be used for protein supplementation for rice straw-based diet in the dry season.

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