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RESEARCH

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# An evaluation of a Browse-aid at the doorsteps of (agro)pastoralists to improve consumption of in situ browses and shrubs and prevent animal deaths during droughts

Harinder Makkar[1], Abay Bekele[1], Yosef Seyoum Mulugeta[2], Andinet Adamu[1], Redwan Getachew Asfaw[2], Wesinew Adugna Bekele[2], Abdinur Ali Warfa[2], Degefa Wayessa[3], Merkeb Belay[1] and Genene Regassa[1*]

## Abstract

**Background** Thousands of animals die in Ethiopia during droughts due to unavailability of feed. Large amounts of browses are available during droughts, which animals do not consume because of the presence of tannins. The hypothesis of the study was that the provision of small amounts of Browse-aid (polyethylene glycol-4000) to animals at farmers' doorsteps would increase browse consumption and body weight gain, and prevent deaths during droughts.

**Methods** A field study was conducted at two sites in Ethiopia to assess the dietary inclusion of the Browse-aid (daily 5 g and 10 g for shoats; and 15 g and 30 g for cattle) to farmers' sheep, goats and cattle in areas devoid of grasses during a very dry spell.

**Results** Inclusion of the Browse-aid to sheep and goats significantly increased the percent body weight gain, and improved the body condition score, skin coat appearance and shine in eyes when compared with those of animals not given the Browse-aid. Similar results were observed in cattle. The foraging frequency of the animals also increased. Nutrient availability to the animals from the increased consumption of browses also increased. Furthermore, the body condition scores of the animals given the Browse-aid were greater than those of the animals that did not participate in the trial but were grazing in the same area.

**Conclusion** Browse-aid made a positive impact on the production of animals during periods of severe feed scarcity. This strategy of providing the Browse-aid (daily 5 g for sheep and goats, and 15 g for cattle) to animals during droughts is highly cost effective; additionally, compared with currently used feeding strategies, the cost in late 2023 was 60% and 90% lower for sheep and goats, and cattle respectively to prevent animals from dying during droughts. A large number of animals can be prevented from dying during droughts, at a much-reduced cost by the dietary inclusion of a small amount of the Browse-aid. The implications of the study are not restricted to Ethiopia but extend to countries in the Horn of Africa. This is the first study that has investigated the effect of the Browse-aid at the farmers' doorsteps in the field.

*Correspondence:
Genene Regassa
genene@vsfg.org
Full list of author information is available at the end of the article

**Keywords** Livestock deaths, Polyethylene glycol-4000, Browses, Shrubs, Droughts, Dry season, Rangeland, Browsing, Grazing

## Introduction

The biomass obtained through natural grazing/browsing is the largest feed resource for livestock in Ethiopia (FAO 2018) and other East African countries, e.g., Kenya, Sudan, Uganda and Somalia (ICPALD-IGAD-FAO 2022). The communal grazing/browsing lands are utilized throughout the year. The quality of forages on grazing lands varies depending on the season. The gains in animal body weight are lost during the dry season due to the unavailability of sufficient feed. This results in poor reproductive efficiency, high mortality and morbidity, and low overall productivity. Hundreds of thousands of animals die during droughts in many African countries due to shortages of feed (WFP 2023).

During droughts and dry seasons, the only greens available on the rangelands are browses, shrubs and trees (hereafter termed browses). The grass disappears. Notably, even under normal conditions, the biomass from browses is 4–5 times greater than that from grasses on the soil (ICPALD-IGAD-FAO 2022). Browses can form alternative feed resources during times of critical feed shortages (dry and drought seasons). However, these animals do not consume them due to the wide presence of polyphenolics (commonly termed tannins) (Ben Salem et al. 2005; Degen et al. 1995, 2000; Getachew et al. 2002, 2005; Motubatse et al. 2008; Rogosic et al. 2008), which produce dry, puckerish and bitter tastes in the animal mouth. Additionally, their consumption can cause digestive problems. These effects are attributed to the high affinity of polyphenols for proteins. They bind membrane proteins and inhibit enzymes because they are also proteins. Polyphenolic-protein complexes are poorly degraded in the gastrointestinal tract, decreasing protein availability. Polyphenols also bind to minerals and decrease their availability to animals. The crude protein content of browses is very high (15–23% on a dry matter basis), but the presence of polyphenols decreases their availability to animals (Feedipedia 2023; SSA Feeds 2023).

In droughts, large amounts of feed are transported from the Ethiopian highlands to drought areas in the lowlands of Ethiopia. The high transport cost of feed makes feed provision to affected areas very expensive (DRM/AFT 2023). Moreover, the emergency feed provided to farmers for their animals is not sufficient for all the animals, and the emergency feed does not reach all the pastoralists. A large number of animals die because of feed shortage. Utilization of browses present in situ in drought areas can save animals from dying, provided the polyphenolics present in these browses can be neutralized or their effects mitigated. The use of this in situ feed by ruminant animals could help reduce the amount of feed transported into the affected areas. The provision of feed in affected areas is expensive, mainly due to high transport costs. Several studies have been conducted at research stations showing the benefits of the inclusion of the Browse-aid (polyethylene glycol 4000) in diets containing high amounts of polyphenols. The benefits ranged from an increase in the digestibility of crude protein to an increase in body weight gain and milk production (Kemboi et al. 2021). A number of on-station research studies in which Browse-aid inclusion with polyphenolic compound-containing diets had beneficial effects on animals have been published. Landau et al. (2000) showed that Quebracho tannins from *Aspidosperma* decreased feed intake and duration of eating bouts. After the incorporation of Browse aid (250 g/day), the animals' feed intake and duration of eating bouts increased. No adverse effects of the Browse aid were observed. Bhatta et al. (2004, 2005) showed that feeding polyethylene glycol-6000 (PEG-6000) for 3 months at the 5% level in a diet containing tannin-containing foliage from *Prosopis cineraria* increased protein availability and body weight gain. Gilboa (2013) observed an increase in the productivity of goats grazing on Mediterranean woodland and scrubland supplemented with polyethylene glycol (Browse-aid). On feeding 50 g of the Browse aid per day to goats along with foliage from lentisk (*Pistacia lentiscus* L.), increased protein digestibility and milk production were observed (Decandia et al. 2000). Ben Salem and Tisserand (2000) and Ben Salem et al. (2000) introduced 6, 12, 18 and 24% of the Browse-aid in olive cake-based feed blocks to sheep fed tannin-rich *Acacia cyanophylla* foliage. Linear increases in acacia foliage intake, and digestibilities of organic matter and crude protein were recorded. Also increased utilization of tanniniferous foliage by ruminants was observed. An improvement was evident in the nitrogen value of the diet, as reflected by an improved nitrogen balance and increased rumen microbial nitrogen supply. An increase in the nutritive value of diets resulted in increased growth in sheep. Since the responses obtained with 18 and 24% of the Browse aid in the feed blocks were similar, the authors recommended limiting the level of the Browse aid to 18% to obtain an optimal positive effect from feed block use. The slow release of the Browse aid, and therefore the synchronized consumption of tannins and PEG, is probably the main explanation for the beneficial effect of PEG-containing feed blocks. This hypothesis was corroborated in vitro by Getachew et al. (2001), who reported that the introduction of PEG into an in vitro rumen fermentation system by splitting rather than single doses gave rise to the greatest microbial nitrogen synthesis from some tannin-rich fodder shrubs.

Among PEGs of various molecular weights, PEG-4000 and PEG-6000 have been found to have the highest ability to neutralize polyphenols (Makkar et al. 1995). PEG, with a molecular weight of 4000 Da, has several applications in the cosmetic, pharmaceutical and food industries and hence is available in abundance on the market. Therefore, PEG with a MW of 4000 Da was selected for the current field trial. The structure of PEG-4000 is commonly expressed as $H-(O-CH_2-CH_2)n-OH$. It is a synthetic compound and is inert, water soluble and tasteless; therefore, animals can easily consume it. Because of their inertness and lack of skin irritation, PEGs are widely used in pharmaceuticals, e.g., in the preparation of ointments, suppositories, tablets, and solvents for injection, as well as in cosmetics, e.g., creams, lotions, powders, cakes, and lipsticks. PEG is also available as a bowel prep for colonoscopy procedures and as a laxative. PEG-4000 is a laxative available over-the-counter and is named Miralax. PEGs have low toxicity, are miscible with aqueous fluids in all proportions, and dissolve many poorly soluble aqueous compounds. Compounds with poor aqueous solubility and resulting poor bioavailability and considerable individual variability in absorption were shown to provide exceptionally high bioavailability and to reduce intersubject variability in plasma concentrations when dosed as solutions or suspensions in PEGs (Gullapalli and Mazzitelli 2015). It is a part of several medicines (Dave 2008).

Against the above background, we evaluated the effects of dietary inclusion of the Browse-aid (polyethylene glycol, PEG-4000) on animals at two different sites during the peak dry spell, where feed and water were very scarce. The field trials were conducted in the second half of 2023. During the trials, the sites were devoid of any grasses. Browses were present at both sites. The hypothesis of the field trials was that PEG-4000 (Browse-aid) at low levels of inclusion in diet would be effective at enhancing the consumption of browses present in the rangeland and providing nutrients to animals from these in situ present feed resources. In on-station research, inclusion of PEG-4000 or PEG-6000 in diets was at high levels, with the aim to neutralize most of the dietary polyphenolics; however, in the field trials conducted in this study the aim was to evaluate whether low levels of PEG-4000 that could prevent death of animals during droughts. Studying low levels of PEG-4000 was important for decreasing the cost of the treatment and for providing benefits to a large number of animals, thus helping to save the livelihood of a large number of pastoralists and agro-pastoralists during droughts.

## Materials and methods

The field trials were conducted by two organizations (the VSF-G and VSF-S) at two different sites.

### Study area of the VSF-G field trial

The trial was conducted in the Nakiya *Kebele*, Dassenech district, in the former South Omo zone, Southern National Nationalities and People (SNNP) region state of Ethiopia. The Nakiya kebele is located 27 km north of Omorate town and 5 km away from the main tarmac road to Turmi. Dassenech district is bordered by Kenya in the South, Salamago Woreda in the North and Hammer Woreda in the East. This district is classified as a livestock maize/sorghum livelihood zone and is also known for its high sheep and cattle population.

### Study area of the field trial by VSF-S

Anokulul kebele (GPS, Lat: 6.08629 and Long: 43.54588) of Gode Woreda was found to be ideal for the trial. The kebele is located 16 km north of Gode town on the main tarmac road to Kebridahar.

Hereafter, these sites are referred to as Site 1 and Site 2. Additionally, a general term, 'livestock farmers', used at several places in the article refers to pastoralists and agro-pastoralists. The key criteria for the selection of both sites were as follows: (1) no grass on grazing land during the short dry season, (2) vulnerability to recurrent droughts, (3) minimum mobility of the animals to other areas, (4) willingness of the community to participate in the trial, (5) no provision of supplementary feed to animals during the trial by the farmers, and (6) availability of different browse and shrub species during the dry season. The trials were conducted in August, September and October 2023, during the peak dry spell in the area when feed and water were very scarce at the sites. At both sites, the study commenced after two months of dry spell in July and August 2023. The timing of the study was deliberately planned for September and October 2023 as this is the emergency stage of the drought cycle and emergency livestock feeding is normally conducted in Ethiopia during this time. The precipitation was zero at both the sites during these months.

It was ensured through the field officers conducting the trial on daily basis that the farmers would not feed any supplementary feeds to the test animals.

### Selection of the farmers and number of animals in each group

At both sites, the field team, together with assigned development agents, discussed the objectives, importance of the work, procedures and requirements of the trial with the community. This approach helped the team convince them and gain their consent to participate in the trial. The trial was conducted in the field using farmers' animals and under natural conditions in which the animals are reared. The criteria used for the selection of animals for on-station studies, for example, similar animal body weights, same sex and physiological stage, could not be adhered to, and these yardsticks must not be adopted if the aim is to evaluate the impact of a treatment under farmers' conditions.

At Site 1, the study was conducted on sheep and cattle. A total of 60 sheep and 30 cattle, voluntarily provided by community members, were included in the study. Both the sheep and cattle were distributed into three categories (Table 1). Each animal was ear tagged. The trial was concluded on day-45 because of the commencement of the short rainy season in the area.

For Site 2, one household for the sheep and goat trial (39 sheep and 21 goats; Table 1) and three households for the cattle trial (10 cattle each) participated in the study. The target animals were marked near the head for Level-1, at the middle back for Level-2 for the Browse-aid groups, and at the back tail for the Control group, using traditional dye 'Hinna'. Individual animals had to be given specific marks using numbers at the stated part of the animal to differentiate animals during subsequent weighing and observation. The trial was conducted for 50 days because the rains started on day-50.

### Browse-aid administration

Wheat bran (WB) was used as a vehicle for introducing the Browse-aid. The Control group was given only 100 g of WB. Level-1 and Level-2 for sheep and goats were given 5 g and 10 g of the Browse-aid respectively, along with 100 g WB; while these levels for cattle were 15 g and 30 g respectively along with 100 g of WB.

### Quantitative parameter studied

The quantitative parameter taken for the study was body weight (BW) immediately before the animals were placed in the daily feeding regime and at 10-day intervals using a weighing balance for sheep and Heart Girth Tape for cattle. Since the trial was conducted under field conditions, with farmers' animals, there was little choice over the selection of farmers and animals. As a result, a large initial difference in body weight could not be avoided. This could be considered a desirable feature for the trial wherein the aim was to test the Browse-aid under field conditions. A total of 6 body weight measurements were taken for the sheep and the cattle groups (before the trial; on days 10, 20, 30 and 40). The last measurements were taken on day 45 for Site 1 and day 50 for Site 2.

### Qualitative parameters evaluated

The qualitative parameters included subjective evaluation of the hair coat appearance, shine in the eyes, and foraging frequency and body condition score (BCS). Hair coat and eye shininess are qualitative assessments; however, these are important parameters for herd health and welfare management (Doyle and Moran 2015). These are widely applied in the field and research to assess animal welfare and health status. An element of subjectivity is associated with qualitative parameters. Hair coat shininess and eye shininess are relative assessments observed on the same animals over a period of the experiment, from coarse, shiny to very shiny. This approach of relative assessment helps to minimize the subjectivity associated with these parameters. These subjective parameters were transformed to scores, to allow comparison of the groups in quantitative terms. The basis for the transformation was the number of animals having coarse, shiny and very shiny hair coat and giving them scores as 0, 1 and 2 respectively. As an example, if in a group, numbers

**Table 1** Number and species of the trial groups at Sites 1 (Nakiya Kebele) and 2 (Anokulul kebele)

| Trial groups | Number of animals/species | | | | Marking place |
|---|---|---|---|---|---|
| | Sheep | Goat | Total | Cattle | |
| Level-1 group (daily 5 g and 15 g Browse-aid for small ruminants and cattle respectively) | 13 [20] | 7 [0] | 20 [20] | 10 [10] | Near neck [Ear tagged] |
| Level-2 group (daily 10 g and 30 g Browse-aid for small ruminants and cattle respectively) | 13 [20] | 7 [0] | 20 [20] | 10 [10] | Middle back [Ear tagged] |
| Control group | 13 [20] | 7 [0] | 20 [20] | 10 [10] | Back Near Tail [Ear tagged] |

The values in square parentheses are the number of animals used at Site-1, while those without parentheses at Site 2 of animals having coarse, shiny and very shiny hair coat are 5, 2 and 13 respectively then the score for that group would be $5\times0+2\times1+13\times2=28$). Likewise, for eye appearance the scores given to pink eyes, shiny and very shiny eyes were 0, 1 and 2 respectively.

Foraging frequency was defined as the frequency of foraging during the day (as the animal browse for certain time and then take rest under tree shade, ruminate and then start foraging.

At Site 1, changes in the hair coat and shine in the eyes were recorded before the trial and on days 20, 40 and 45, and the foraging frequency was recorded on days 5, 10, 15, 40, and 45.

At Site 2, hair coat and eye appearances were assessed on days 20, 40 and 50 of the trial.

Another group (20 sheep and 10 cattle) was introduced at the end of the trial to capture the BCS of animals not in the experiment but grazing in the same rangeland. The BCS was measured on a scale ranging from 1 to 5 (Ferguson et al. 1994).

### Statistical analysis

One-way ANOVA was used to determine the relationship between the mean body weight change/gain in the animals that received the Browse-aid and the Control groups. The general equation for one-way ANOVA is shown below:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

where $Y_{ij}$ is the $j$th observation in the $i$th treatment, $\mu$ is the common effect for the whole experiment, i.e., percent body weight change; $\tau_i$ is the $i$th treatment effect; and $\varepsilon_{ij}$ is the random error in the $j$th observation in the $i$th treatment.

## Results

Initially, the results for Site 1 and thereafter for Site 2 are presented.

### Site 1 (Nakiya Kebele)

#### *Body weight changes*

In sheep, the incorporation of the Browse-aid increased the percent gain in body weight. The increase was concentration dependent. A daily dose of 5 g or 10 g of the Browse-aid increased body weight gain by 20% or 32%, respectively, in 45 days, while in the Control group, in which the Browse-aid was not given, the increase in percent body weight gain was only 10% (Table 2). The percentage increases in the body weight gain in the Browse-aid groups were significantly greater ($P<0.05$) than that in the Control group. Additionally, the percent increase at Level 2 was significantly greater ($P<0.05$) than that at Level 1. The Control group received 100 g of WB, which could have contributed to this small increase in body weight gain (Table 2).

For cattle, the increases in body weight gain were 13 and 19% for the daily incorporation of 15 g and 30 g of the Browse-aid, respectively (Table 3). The animals in the Control group lost weight. As for sheep, the percentage increase in the Browse-aid group was significantly greater ($P<0.05$) than that in the Control group. The feed on the grazing land and 100 g of WB given daily did not support body weight gain in the Control animals (Table 3).

Animals of both species that received the higher amount of the Browse-aid had greater percent average

**Table 2** Percentage change in average body weight (ABW) in sheep at Site 1 (Nakiya Kebele)

| Trial group | ABW (kg), initial | ABW (kg), final on day 45 |
|---|---|---|
| *Control Group* (n = 20) | | |
| *Absolute body weight, kg* | 20.3 ± 4.97 | 22.05 ± 4.67 |
| *ABW change (final minus initial), kg* | *1.8* | |
| *ABW, % change* | *10.0 ± 0.10*[a] | |
| Level-1 Group (n = 20), daily 5 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 24.4 ± 6.87 | 28.65 ± 6.77 |
| *ABW change (final minus initial), kg* | *4.3* | |
| *ABW, % change* | *20.0 ± 0.16*[b] | |
| Level-2 Group (n = 20), daily 10 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 22.79 ± 5.54 | 29.53 ± 5.84 |
| *ABW change (final minus initial), kg* | *6.7* | |
| *ABW, % change* | *32.0 ± 0.116*[c] | |

[a, b,c]Means with different superscripts differ at $P<0.05$ (values are mean ± SD), (n = 20)

**Table 3** Percentage change in average body weight (ABW) in cattle at Site 1 (Nakiya Kebele)

| Trial group | ABW (kg), initial | ABW (kg),final on day 45 |
|---|---|---|
| Control Group (n = 10) | | |
| *Absolute body weight, kg* | 232.3 ± 8.68 | 212.9 ± 8.97 |
| *ABW change (final minus initial), kg* | *− 19.4* | |
| *ABW, % change* | *− 1.0 ± 0.04*[a] | |
| Level-1 Group (n = 10), daily 15 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 152.6 ± 8.04 | 172.9 ± 8.24 |
| *ABW change (final minus initial), kg* | *20.3* | |
| *ABW, % change* | *13.0 ± 0.06*[b] | |
| Level-2 Group (n = 10), daily 30 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 181.1 ± 11.70 | 212.1 ± 12.23 |
| *ABW change (final minus initial), kg* | *31.0* | |
| *ABW, % change* | *19.0 ± 0.06*[c] | |

[a, b,c]Means with different superscripts differ at $P < 0.05$ (values are mean ± SD), (n = 10)

body weight gains throughout the study period than animals that received the lower amount of the Browse-aid or those in the Control group. Similarly, animals that received a lower amount of the Browse aid had greater average body weight gain than did those in the control group (those that received only WB). Taking values at all the days, unlike in the sheep group, the difference between the higher and lower Browse-aid amount groups was not significant ($P < 0.05$). Cattle that did not receive the Browse-aid had a decrease in body weight of 8% over the first 20 days, which remained the same till the end of the study.

The higher amount of the Browse-aid elicited greater beneficial effects in sheep and cattle. The increase in body weight in both groups receiving the Browse-aid was greater than that in the Control group (not given the Browse-aid), suggesting the potential of the Browse-aid to increase the intake of browses and nutrient availability.

The qualitative parameters, with respect to hair coat appearance, shine in the eyes and BCS, were also better in the Browse-aid fed group.

#### *Hair coat*

Four sheep in the Control group had coarse hair coats before the commencement of the trial, and the remaining 16 sheep had shiny hair coats. By day 45, only one sheep had a coarse hair coat, 14 had a shiny hair coat, and the remaining 5 animals had a very shiny hair coat. Among the cattle, 3 animals in the Control group had coarse hair coats before the trial commenced, and 7 out of the 10 animals had shiny hair coats. By day 45, 7 had shiny hair coat, 2 had a very shiny hair coat, and only one had a rough coat. These results suggest a general trend toward hair coat improvement even in the Control group. The improvement in the Control group could be attributed to the delivery of some protein and energy to animals through WB, which would lead to an increase in biomass intake and utilization by the animal.

Four out of the 20 sheep in the Browse-aid Level-1 group had coarse hair coats before the commencement of the trial, 15 had shiny hair coats, and 1 had very shiny hair coats. By day 45, no sheep had a rough hair coat, 3 had a shiny hair coat, and the remaining 17 sheep had a very shiny hair coat. All the cattle in the Browse-aid Level-1 group had shiny hair coats before the commencement of the trial. By day 45, 9 out of the 10 cattle had very shiny hair coats, and the remaining animal had shiny hair coats. It is evident that the coarse coat that was present in sheep at the beginning turned to shiny or very shiny. Additionally, a large number of shiny coat sheep were found to be very shiny after feeding the Browse-aid. Similarly, 90% of the cattle in the Browse-aid groups turned from shiny to very shiny.

All sheep in the Browse Level 2 group had shiny hair coats before the commencement of the trial. By day 45, the hair coats had turned into a very shiny. Similarly, all the cattle in the Browse Level-2 group had shiny hair coats at the start of the trial, and by day 45, the hair coats improved to very shiny.

The Browse-aid at both levels improved hair coats in sheep and cattle. The extent of improvement in hair coats has been higher than in the Control group (Table 4).

#### *Shine in eyes*

Before start of the trial, 1 sheep in the Control group had pink eyes and the other animals had shiny eyes. By day

**Table 4** Changes in hair coat texture and eye appearance, as scores, on feeding Browse-plus (the hair coat and eye appearance subjective analyses were converted to scores, following the procedure given in Materials and Method section)

| | Control | | Level 1 of Browse-aid (daily 5 g per animal) | | Level 2 of Browse-aid (daily 10 g per animal) | |
|---|---|---|---|---|---|---|
| | Initial | After 45 days | Initial | After 45 days | Initial | After 45 days |
| *SMALL RUMINANT* | | | | | | |
| Hair coat score | 16 | 24 | 17 | 37 | 20 | 40 |
| Eye appearance score | 19 | 26 | 17 | 36 | 20 | 40 |
| *CATTLE* | | | | | | |
| Hair coat score | 7 | 11 | 7 | 10 | 10 | 20 |
| Eye appearance score | 8 | 13 | 10 | 20 | 10 | 20 |

Higher the score, better is the response of the Browse-aids

45, 14 out of the 20 sheep had shiny eyes and the remaining 6 sheep had very shiny eyes. Two cattle in the Control group had pink eyes before commencement of the trial and the remaining 8 animals had shiny eyes. By day 45, 7 out of the 10 animals in the Control group had shiny eyes and the remaining 3 animals had very shiny eyes. These results suggest that shine in the eyes improved even in the Control group, similar to what was observed for the hair coat.

Three sheep in the Browse-aid Level-1 group had pink eyes before the commencement of the trial, and the remaining 17 sheep had shiny eyes. By day 45, 4 out of the 20 sheep had shiny eyes, and the remaining sheep had very shiny eyes. Before the commencement of the trial, cattle in the Browse-aid Level-1 group had shiny eyes, and all animals in this group had very shiny eyes by day 45. It is evident that shine in the eyes of sheep at the beginning of the study improved and turned shiny or very shiny. Additionally, the shines of the eyes of a large number of sheep became very shiny when they were fed the Browse-aid. Similarly, the Browse-aid inclusion improved shine in the eyes of all the animals, ranging from shiny to very shiny. The Browse-aid improved the shine in the eyes of both sheep and cattle.

All sheep in the Browse-aid Level-2 group had shiny eyes just before the commencement of the trial, and this also improved to very shiny eyes after the trial. Similarly, all the cattle in the Browse-aid Level-2 group had shiny eyes before the commencement of the trial, which improved to very shiny eyes at the end of the trial.

Both levels of the Browse-aid increased shine in the eyes of both animal species (Table 4). The shine in the eyes of the Control group were also evident, but with the use of Browse-aid, the extent of change to shiny or very shiny eyes was greater.

Both the hair coat appearance (became softer and shinier) and the shine in eyes improved upon incorporation of the Browse-aid in both sheep and cattle. The extent of their improvements was greater than that in the Control group (Table 4).

#### *Body condition score (BCS)*

Fifteen percent of the animals in the Control group had BCS 1, while the remaining 60% and 25% had BCS 3 and BCS 4, respectively. Only 15% of the animals in the Browse-aid Level-1 group were of BCS 2, and the remaining 30% and 55% were of BCS 3 and 4, respectively. Animals in the Browse-aid Level-2 had either BCS 3 (32%) or BCS 4 (68%). Thirty-five percent of the sheep in the group that were neither provided WB nor the Browse-aid were either emancipated (BCS 0) or very thin (BCS 1), and the remaining 50% and 15%, respectively, were of BCS 2 and BCS 3.[1] At the end of the trial, the BCS was much better in the two Browse-aid groups than in the Control group. The BCS of the Control group was better than that of the animals that were not given WB or the Browse-aid, suggesting that during droughts, providing the Browse-aid would help improve the BCS of sheep.

An assessment of BCSs showed that 20% of the animals in the Control group had BCS 2, and the remaining 80% had BCS 3. Sixty cattle in the Browse-aid Level-1 group were of BCS 3, while the remaining 40% were of BCS 4. A large number of cattle (80%) in the Browse-aid Level-2 cohort had BCS 4, and the remaining 20% had BCS3. The results showed that the BCS at the end of the trial was much better in the two Browse-aid groups than in the Control group. Analysis of the BCSs of the cattle that were not given WB or the Browse-aid showed that 70% of the animals were in either the emaciated (BCS 1) or thin (BCS 2) category, and only 30% were in the moderate BCS 3 category. The BCS of the animals in the trial groups was better than the BCS of the animals that were not given WB or the Browse-aid.

[1] The study used black head Ogaden sheep breed in all the three groups. This breed is well adapted to the ASALs.

For both sheep and cattle, the BCS at the end of the trial was much better for the two Browse-aid groups than for the Control group. Additionally, on day 45, the BCSs of the animals that did not belong to the trial groups but were grazing in the same area were much lower than those of the animals given the Browse-aid (BCSs 3 and 4), suggesting that during droughts, the provision of the Browse-aid would help improve the BCSs of sheep and cattle.

The foraging frequency for sheep and cattle in the Control group increased from 4.8 and 4.2 times a day on day 5 to almost 6.5 and 4.6 times a day on day 45, respectively. On average, the foraging frequency for the Browse-aid Level-1 increased from 6.6 and 5 times a day on day 5 to almost 8.2 and 8.0 times a day on day 45 for sheep and cattle, respectively. The foraging frequency of sheep and cattle in the Browse-aid Level-2 increased from 4.6 and 5.0 times a day on day 5 to almost 8.5 and 8.3 times a day on day 45, respectively.

Cattle given the Browse-aid Level-2 started browsing shrubs 15 days after receiving the Browse-aid. On the other hand, cattle in the Browse-aid Level-1 started browsing between days 19 and 21 after receiving the Browse-Aid. These observations suggest that the impact of the Browse-aid on foraging frequency was achieved in lesser duration at the higher level of the Browse-aid. Besides for both sheep and cattle, the Browse-aid induces voracious browsing behaviour for the browses and shrubs that are normally not eaten. The animals fed the Browse-aid started consuming *Abutilon Indicum, Arctostaphylos patula, Calotropis gigantean and Acacia* spp., which are shrub species widely found in the East African Rangelands.

Some toxic/invasive plant species, such as *Lantana camara,* exist in East African rangelands. The introduction of the Browser-aid is not expected to enhance their intake because the animals are not new to the area and have grazed in the rangeland since birth. Animals know the toxic plants of the region and avoid them. The consumption of toxic plants such as *L. camara* does not take place even under extreme drought conditions. There has been no evidence that animals that received the Browse-aid started consuming *L. camara.*

### Site 2 (Anokulul kebele)

#### *Changes in body weights*

The percentage change in body weight gains in the sheep and goats were greater following the incorporation of the Browse-aid at both the levels, but greater changes were observed at the lower level of the Browse-aid (daily 5 g/animal) than at the higher level (daily 10 g/animal). At this higher level of the Browse-aid, a considerable increase in body weight was evident only on day 50, although the body weights were greater than those of the Control on all the days of measurements. The lower response at the higher level of the Browse-aid (Table 5) could be attributed to the presence of a high number of lactating sheep and goats (55%) in the Browse-aid Level-2 group (Table 6). The lactating animals were present only in this group. The increased availability of nutrients as a result of the inclusion of the Browse-aid in this group might have diverted the nutrients more towards milk production than towards growth. However, when the

**Table 5** Percentage change in average body weight (ABW) in sheep and goats (not separated into lactating and non-lactating animals) at Site 2 (Anokulul kebele)

| Trial group | ABW (kg), initial | ABW (kg), final on day 50 |
|---|---|---|
| *Control Group* (n = 20) | | |
| *Absolute body weight, kg* | 26.4 ± 5.72 | 31.3 ± 5.41 |
| *ABW change (final minus initial), kg* | *4.90* | |
| *ABW, % change* | *± 0.18*[a] | |
| Level-1 Group (n = 20), daily 5 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 24.4 ± 5.05 | 33.0 ± 3.86 |
| *ABW change (final minus initial), kg* | *8.6* | |
| *ABW, % change* | *35.0 ± 0.23*[b] | |
| Level-2 Group (n = 20), daily 10 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 26.3 ± 5.31 | 32.6 ± 4.68 |
| *ABW change (final minus initial), kg* | *6.30* | |
| *ABW, % change* | *24 .0 ± 0.15*[c] | |

[a, b,c]Means with different superscripts differ at $P < 0.05$ (values are mean ± SD), (n = 20)

**Table 6** Percentage change in average body weight (ABW) in sheep and goats (Level-2 group separated into lactating and non-lactating animals) at Site 2 (Anokulul kebele)

| Trial group | ABW (kg), initial | ABW (kg), final on day 50 |
|---|---|---|
| Level-2 Group (lactating) (n = 11), daily 10 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 27.7 ± 6.23 | 31.8 ± 4.54 |
| *ABW change (final minus initial), kg* | *4.09* | |
| *ABW, % change* | *15.0 ± 0.08*[a] | |
| Level-2 Group (non-lactating) (n = 9), daily 10 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 24.5 ± 3.51 | 33.6 ± 4.95 |
| *ABW change (final minus initial), kg* | *9.00* | |
| *ABW, % change* | *37.0 ± 0.06*[b] | |

[a, b]Means with different superscripts differ at $P < 0.05$ (values are mean ± SD)

lactating sheep and goats were excluded, the percentage changes at both levels were comparable, but the changes at the higher Browse-aid Level-2 were still lower than those at the Level-1. The decrease was non-significant ($P > 0.05$) by 2%, 4%, 3% and 1.5% at day-20, day-30, day-40 and to 50 days of the field trial At Site 1, the higher level of the Browse-aid resulted in greater body weight gain, unlike at this site. This might be due to the different natures of the browses prevailing at the two sites. At site 2, the polyphenol levels and/or the activity of browses consumed by shoats could be low, which were neutralized by the lower levels of the Browse-aid. However, this hypothesis needs to be tested by measuring the polyphenol levels and their activities in the browses at the two sites. In addition, the mix of sheep and goats used at this site might have also contributed to these differences. Even among the non-lactating animals that had a greater growth response to the Browse-aid; consisted of 7 sheep and 2 goats, while at Site 1, the test animal species was only sheep in the small ruminant group.

In cattle, increases in percent body weight changes were greater with increasing the Browse-aid intake (30 g/day/animal) (Table 7). The changes observed at the lower level were marginal. For cattle, the lower level of the Browse-aid (15 g/day) does not appear to be sufficient to inactivate substantial amounts of polyphenolics present in the browses. However, this lower level is sufficient to prevent animals from dying during extreme droughts because it increases the consumption of in situ browses and shrubs.

As for site 1, qualitative results observed at Site 2 are presented here.

#### *Hair coat appearance, shine-in eyes and body condition score (BCS)*

As for Site 1, both the hair coat appearance (became softer and shinier) and the shine in the eyes improved in both sheep and goats upon incorporation of the Browse-aid. However, the extent of improvement in the hair coat and shine in the eyes was similar between the two groups.

The average BCS in sheep and goats ranged from 2 to 3 at the start of the trial for the Browse-aid group. At the end of the trial (day 50), the BCS of the Browse-aid sheep and goats ranged from 3 to 4. The BCS of the cattle was near 1 and 2 at the start of the trial. The BCS of the Control group remained the same (1 and 2), while in the test groups (lower and higher Browse-aid inclusion), the BCS ranged between 3 and 4. Therefore, there was

**Table 7** Percentage change in average body weight gain (ABW) in cattle at Site 2 (Anokulul kebele)

| Trial Group | ABW, initial | ABW (kg), final on day 50 |
|---|---|---|
| Control Group (n = 10) | | |
| *Absolute body weight, kg* | 170.3 ± 51.60 | 179.6 ± 45.61 |
| *ABW change (final minus initial), kg* | *9.30* | |
| *ABW, % change* | *7.0 ± 0.09*[a] | |
| Level-1 Group (n = 10), daily 15 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 210.1 ± 60.07 | 221.9 ± 55.00 |
| *ABW change (final minus initial), kg* | *11.80* | |
| *ABW, % change* | *7.0 ± 0.11*[a] | |
| Level-2 Group (n = 10), daily 30 g Browse-aid per animal | | |
| *Absolute body weight, kg* | 145.8 ± 57.30 | 173.9 ± 49.14 |
| *ABW change (final minus initial), kg* | *28.10* | |
| *ABW, % change* | *26.0 ± 0.25*[b] | |

[a, b]Means with different superscripts differ at $P < 0.05$ (values are mean + SD), (n = 10)

improvement in the BCS in both the Browse-aid groups. The BCSs of the animals that were not given WB or the Browse-aid but were grazing in the same area (assessed at the end of the trial to evaluate the effect of WB and the Browse-aid inclusion) showed that the BCS of the non-experimental sheep/goats was less than 2, and the BCS of cattle was 1 on day 50 of the trial.

The poor condition of the non-experimental animals grazing in the same area and the good BCS of the animals given the Browse-aid illustrate the benefits of the inclusion of the Browse-aid during dry conditions.

#### *Browse consumption behaviour*

Although, at this site, daily recording of foraging frequency could not be conducted because of the need for adequate manpower, general eye-observations recording of foraging behaviour showed that the animals in the Control group of all the animal species tested (sheep and goats and cattle) were relatively less active at foraging and spent less time browsing and resting than the Browse-aid Level-1 and the Browse-aid Level-2 groups were. The latter two groups were relatively more active at grazing and browsing. These results also suggest that the Browse-aid improved browse consumption.

### Economics of the Browse-aid application

For saving animals during droughts, daily Browse-aid per sheep or goat is recommended at 5 g, and for cattle, 10 g is recommended. The carrier for browser-aid inclusion could be 50 g of wheat bran instead of 100 g. The Browse-aid is not yet available in Ethiopia. The cost of the Browse-aid was 6.58 US$ per kg.

The two sites at which the Browse-aid trials were conducted are approximately 555 km from Addis Ababa. Generally, drought areas in Ethiopia are approximately 500 km away from Addis. Therefore, for economic analysis, the transport cost of 555 km for the Browse-aid, wheat bran (carrier for the Browse-aid), and the feeds (which are distributed by government and non-government agencies during drought emergencies) was taken into consideration. The costs (2023 August) for comparison were those of (a) 5 g of the Browse-aid for sheep/goat and 15 g for cattle per day, while the inclusion of wheat bran was 50 g per day; versus (b) amount of emergency feed distribution per animal during droughts per sheep/goat and cattle per day.

The combined cost of the Browse-aid and wheat bran was 60% lower for shoats and 81–91% lower for cattle. This cost can be further reduced if a locally available feed resource, cheaper than wheat bran, is used as a carrier. A large number of pastoralist animals can be saved at a low cost. Additionally, providing the Browse-aid to breeding stocks that graze in the vicinity of residential areas containing browses and shrubs would increase their productivity.

### Discussion

To our knowledge, this is the first systematic study that has field-evaluated the inclusion of Browse aid (PEG-4000) in the diet during a dry spell devoid of grasses on grazing land. The only greens available were browses, shrubs and trees. The results revealed increases in body weight gain; hair coat appearance; shine-in-eyes; body condition score; and foraging frequency in shoats and cattle upon the inclusion of very low amounts of the Browse-aid (5 g for shoats and 15 g for cattle per day). The Browse-aid is not absorbed in the rumen, and several studies have shown >97% excretion of this compound in the faeces (Hyden 1955; Ulyatt 1964; Till and Jones 1965). Because of its non-absorption from the gastrointestinal wall and inert nature, it has been extensively used as a marker for estimating the passage rate of liquid and solid phases from the rumen since the middle of the last century (Corbett et al. 1958; Clark et al. 1972). There are more than 1000 publications in which the Browse-aid has been fed to livestock either as a marker or to ameliorate the effects of polyphenols present in browses and agro-industrial by-products. The Browse-aid has been given at a level as high as 250 g per day to small ruminants without any adverse effects (Shaffer and Critchfield 1947). It is a nontoxic compound. In addition, when PEG was injected intravenously into humans, 96% of the injected amount was excreted in the urine within 12 h.

#### Mode of administration

Different means of PEG administration have been used to assess the fodder potential of tanniniferous plant species. PEG-4000 was included in concentrated supplements (Ben Salem et al. 1999a; Decandia et al. 2000), dissolved in drinking water (Ben Salem et al. 1999a; David and Ng'ambi 2017), infused orally (Wang et al. 1996; Gilboa et al. 2000) or sprayed in solution on browse foliages (Ben Salem et al. 1999b) given to ruminant animals. The response to PEG supply in terms of intake, digestion and production varied with the mode of PEG application. Ben Salem et al. (1999a) reported a comparison of the three methods of PEG-4000 provision for sheep on *Acacia cyanophylla* Lindl foliage. Based on the improvements in Acacia intake, apparent diet digestibility, rumen fermentation and microbial synthesis, the PEG in the concentrate was the most effective, followed by the PEG in the drinking water and then the PEG sprayed on the foliage. The higher retention time of PEG in the concentrate than in water may be the reason for the greater effects of the former mode of application. In the field trial conducted in this study, the Browse-aid was incorporated in a small amount of a concentrate component, i.e., wheat bran.

### Mode of action of the Browse-aid

The benefits of the Browse-aid are attributed to its ability to form complexes with polyphenols. Its affinity for polyphenols is very high, even higher than that between polyphenols and proteins. Therefore, it has the capability to dislodge the already formed polyphenolic-protein complexes, which enhances protein availability for digestion. Additionally, presence of PEG does not allow the formation of protein-polyphenolic complexes. Enzymes are also proteins and polyphenols decrease their activity. Enzymes retain their activities in presence of PEG enabling normal digestion of feed nutrients. Polyphenols also have affinities for minerals and amino acids, albeit low; the presence of the Browse-aid increases also the availability of minerals and amino acids (Makkar 2003).

### Fate of the Browse-aid in the environment

As stated above, almost 100% of the Browse-aid comes out in animal faeces and is deposited in the soil. However, a number of studies have shown that the Browse-aid is degradable both in the soil and in other environments. PEGs with molecular weights up to 20,000 Da were found to be degraded by soil microorganisms. A strain of *Pseudomonas aeruginosa* has been isolated from soil that is able to use PEG with an average molecular weight of 20,000 Da (Haines and Alexander 1975; Abdalla et al. 2005). In addition, PEGs with molecular weights up to 20,000 Da are biodegradable in the environment. Most PEGs that enter water streams have a molecular weight < 20,000 Da and thus cause no serious environmental pollution. PEGs have also been shown to be biodegradable both under aerobic and anaerobic sludge conditions (Padfield et al. 1990; Kawai 2005; Huang et al. 2005; Bernhard et al. 2008). The delivery of the Browse-aid to soil through animal faeces is not expected to have any adverse effects on the environment.

### Inclusion rates

The Browse-aid inclusion in the diet should be at a level of 5 g/day for sheep and goats, and 15 g/day for cattle to prevent the deaths of animals during severe droughts. For sheep and goats, a daily dose of 5 g of the Browse-aid would also lead to an increase in body weight, while a daily dose of 15 g of the Browse-aid would maintain the body weight in cattle. A higher level of the Browse-aid (10 g/day for sheep and 30 g/day for cattle) would further increase the body weight gain; however, it would incur an additional cost. However, this approach would enable livestock farmers to sell animals during droughts, during dry spells or just after droughts at a higher price. An economic evaluation that considers the additional cost of the Browse-aid inclusion at higher levels and additional monetary gains from selling livestock is needed.

In the present study, wheat bran was used as a vehicle for administration of the Browse-aid. The daily amount of wheat bran taken was 100 g. However, the daily provision of wheat bran can be reduced to 50 g. This would reduce the cost of feeding. Any other locally available cheaper feed could also be offered inplace of wheat bran to reduce the cost of the Browse-aid administration to animals. Water could also be a potential vehicle because the Browse-aid is highly soluble in water and is tasteless. However, during droughts, water is a scarce commodity and is available to livestock farmers at a cost. Additionally, the inclusion of the Browse-aid in water decreases its retention time in the rumen, which might decrease its effectiveness.

### Farmers' responses to, and possible future approach for, use of the Browse-aid

The livestock farmers who participated in the field trials at both sites were overwhelmed by the growth response and overall conditions of the animals. Initial scepticism about the effectiveness of a small amount of the Browse-aid turned into excitement and happiness when the body weights and body condition scores improved, while animals of neighbours that did not participate in the trial lost weight and were in poor body condition. All the livestock farmers in the villages where this trial took place and those in the surrounding villages showed keen interest in using this technology in the future.

The Famer (Pastoralist) Field School could be used to further promote the Browse-aid approach and to test the appropriateness of strategies to deliver the Browse-aid to animals. Short video clips demonstrating cattle and sheep browsing extensively on browses and shrubs prepared during the field trial have helped in disseminating the impressive results to community members, government experts (federal, regional, zonal, and woreda levels), research and nongovernmental organization and donor communities.

The Browse-aid may be considered as a complementary drought management strategy. The drought risk management strategy employed in arid and semiarid lands (ASLs) by communities involves the segregation of herds into *homestead* herds, which include breeding animals (such as pregnant cows/ewes, lactating cows/ewes and calves/lambs); and *satellite* herds (comprising non-breeding animals such as dry cows/ewes and bulls/rams). The satellite herds in the dry season/in drought conditions move away from residential areas to dry season grazing areas found around permanent water points to avoid competition with homestead herds. These animals scavenge available palatable grasses, and at times, they are supplemented with crop by-products or share grazing with wild animals in/near national parks. When the rains start, the satellite herds return to residential areas (wet season grazing areas) so that the dry season grazing areas recover for the next dry season. *The Browse-aid provision to animals could be an important strategy aimed at preventing noncore breeding stock (satellite herd) from dying during droughts, which constitute almost 70% of the herd. In the event of droughts, a large number of these animals die due to starvation.*

The homestead animals remain behind, around residential areas during the dry season and during droughts. Homestead animals were allowed to feed on enclosures. Large quantities of hay and concentrated livestock feed have been transported from the highland region of Ethiopia to drought-affected areas, primarily to protect core breeding stocks. This approach is costly, can introduce parasitic infestations (e.g., liver flukes) to drylands and can have unintended negative impacts on the dairy and beef industries in highlands, mainly due to an insufficient supply of feeds. Furthermore, the feed provided by NGOs and governmental agencies to these breeding animals during droughts is insufficient. During dry seasons and during droughts, grazing land around residential areas also contains browses and shrubs. The inclusion of the Browse-aid into the diets of these animals would also improve the production and health of homestead animals.

Both climate change and aridity have created a more conducive environment for certain invasive species, resulting in more and more grassland being converted to rangeland every year (Abduselam and Wudad 2021). This could create more opportunities for use of the Browse-aid to protect needless death of animals due to recurrent droughts without adversely affecting the available browse. The increased use of browses as animal feed as a result of the Browse-aid in one drought is not likely to reduce the availability of browses in the subsequent drought, because the regenerative capability of the browses, between the droughts is very high (Scheiter et al. 2024).

Competing land use patterns and continued encroachment of woody species into non–woody-dominated rangelands have led to the transportation of large volumes of hay and/or concentrated livestock feed from the highland region of Ethiopia to drought-affected areas to protect core breeding stocks at a high cost. Many studies have estimated that the cost of transport is 4–5 times the price of livestock feed. The Harmonized Humanitarian Response Plan for the Anticipated Drought in Ethiopia (Food and Agriculture Organization [FAO] and Disaster Risk Management–Agriculture TaskForce [DRM/AFT 2023]) included 3.5 kg of fodder (bale of hay at 5 US$) and 2.5 kg of concentrate (100 kg at 25 US$) for 90 days for core breeding animals, indicating that the current emergency response covers only a fraction of the animals.

Humanitarian agencies are investing in a number of approaches (e.g., shifting towards adapted browsers such as camels and goats, transporting hay and concentrate feed, and engaging in rangeland rehabilitation and irrigated fodder production, among others) to reduce the impact of feed shortages on livestock assets; however, progress towards achieving these impacts has been slow, expensive, and in some cases not possible. Strategies to safely use shrubs and browses by ruminants on a presently underutilized browsing resource should therefore be sought as an urgent priority. The Browse-aid strategy is cheaper by approximately 60% for sheep and 90% for cattle compared to the available emergency livestock feed options, as shown in this study. It may be noted that the animals that are not allowed free access to browses in the rangeland will not benefit from the Browse-aid. In addition, the Browse-aid will not benefit the animals under conditions where grass is available on the rangelands.

Increasing shrub consumption via the use of a new technology (hitherto not used in droughts in Africa), such as the Browse-aid inclusion in diet, to increase browse and shrub intake, could complement existing strategies, such as shifting to animal species that are more drought resistant, rangeland rehabilitation and irrigated fodder production and its conservation as hay or densified pellets for pastoral and agro-pastoral communities to reduce the losses of animals, maintain income during droughts, and save livelihoods.

## Future research areas

Currently, the Browse-aid is not available in Ethiopia. It needs to be imported. There is a need to establish the Browse-aid supply chain in Ethiopia. Since the Browse-aid approach is useful for all countries in the Horn of Africa, a regional supply chain may also be considered. In addition, future research is needed to identify alternatives to the Browse-aid. Some clays and their derivatives available naturally in Ethiopia and other adjoining countries should be investigated in the laboratory. Based on the laboratory study, the promising candidates should be evaluated in the field on lines similar to those in this study.

Given that the animals given the Browse-aid started consuming a number of browses (e.g., *Abutilon Indicum, Arctostaphylos patula, Calotropis gigantean and Acacia* spp.*)* that were not generally consumed, it would be pertinent to evaluate the nutritive value and polyphenol levels of such browses in the laboratory. This will help in better understanding the extent of nutrient supply to animals from these species. In fact, a larger study to map the browses, shrubs and trees present in rangelands and to assess their nutritive value, including determination of the contents and biological activity of polyphenols, is warranted.

In addition to the survival of animals during droughts, another objective of emergency livestock feeding during droughts is to maintain animal milk production for newborn calves and children. Use of the higher levels of the Browse-aid to address this issue should also be investigated under field conditions.

## Conclusion

From the results obtained at the two sites, it can be concluded that the inclusion of the Browse aid improved (a) the body weights of both the sheep and goats and cattle; (b) the hair coat appearance and softness; (c) the shine in the eyes; (d) browsing behaviour, leading to increased consumption of shrubs and browses; and d) the body condition score. These results support the hypothesis that the Browse-aid enhances the consumption of in situ browses and shrubs when the rangeland is depleted of grasses and other normally consumed browses on rangelands during dry seasons and during droughts. Provision of the Browse-aid to animals during the drought/dry season is a promising strategy not only for preventing deaths during meagre availability of feed but also for maintaining the body weight of the animals. This strategy would decrease the amount of feed needed at drought sites to prevent animal deaths and body weight loss and to maintain the productivity of breeding stocks during these critical periods. From the literature, it is evident that the Browse-aid is nontoxic, inert and degradable in soil and in water channels. No likely adverse effects on the environment or animals are expected when using the Browse-aid. This study has implications for all countries in the Horn of Africa and for areas in other countries that face droughts.

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**Author contributions**

Harinder Makkar, conceptualized, planned, coordinated and supervised the work; took lead in preparing the publication. Abay Bekele and Yosef Seyoum Mulugeta, contributed to paper writing, field support and data Analysis. Andinet Adamau, supervised and conducted field trial work with support from other VSF Germany team (Site-1). Genene Regassa, reviewing report and write up, follow up and in charge of organizing the overall research. Merkeb Belay, in charge of coordinating field work and technical back stopping. Redwan Getachew Asfaw, Wesinew Adugna Bekele and Abdinur Ali Warfa, supervised and conducted field trial work with support from other VSF Suisse team (Site 2). Degefa Wayessa, conducted statistical analysis and coordinated field work n behalf of FAO.

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**Availability of data and materials**

The data are available with VSF-G, VSF-S and FAO.

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**Ethics approval and consent to participate**

Consent of farmers taken.

**Consent for publication**

Taken from all authors.

**Competing interests**

None.

**Author details**

[1]Vétérinaires Sans Frontières Germany (VSF-G), Addis Ababa, Ethiopia. [2]Vétérinaires Sans Frontières Suisse (VSF-S), Addis Ababa, Ethiopia. [3]Food and Agricultural Organization of the United Nations (FAO) Office, Addis Ababa, Ethiopia.

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