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Research article

Natural mineral spring water (*hora*) and surrounding soils in southwestern Ethiopia: farmers' feeding practices and their perception about its nutritional roles on animal performance

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ABSTRACT

Natural mineral water (termed hora in Afan Oromo) and surrounding soils are the most important source of mineral supplement traditionally used for livestock in many parts of Ethiopia. However, limited information exists on feeding practices and the impact of hora on animal performance. Thus, the present study aimed to assess farmers' feeding practices and perceptions about the role of hora and surrounding soils on animal performance. Data were collected from 385 households in four districts (Bedele, Dabo, Gechi and Boracha) through face-to-face interviews using a semi-structured questionnaire with the help of the KoboCollect application. Data were analyzed using SPSS version 26. The majority (72.3 %) of respondents reported hora as an important source of mineral supplement for livestock. About 78.1 % of respondents in Boracha routinely supplement their animals compared with farmers from other districts. Large ruminants were given first priority in supplementation with hora compared to other livestock. Interviewed farmers trekked their animals a distance of 6.5 ± 0.2 km to access hora twice a year during the dry season. The majority of the farmers (68.1 %) believed that hora supplementation improved animal performance, while 35.1 % noted negative impacts such as abortions, birth defects, delayed puberty, decreased conception rates and paralysis due to excessive consumption. This study underscores the perceived importance of hora as a natural source of mineral supplementation for livestock health and productivity. It emphasizes the need for improved management and conservation practices to ensure sustainable utilisation and mitigate negative impacts associated with excessive consumption. Moreover, to validate local farmers' perceptions regarding the importance of hora mineral water in animal nutrition and health, further research is needed to determine mineral composition of hora and livestock responses under controlled feeding trials.

1. Introduction

Optimal livestock production – including both intensive and extensive (grazing) systems – depends upon consumption of nutritionally balanced rations to meet requirements for growth, reproduction, and immune system development through appropriate

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intakes of protein, energy, vitamins, and mineral nutrients [1,2]. However, various factors such as poor husbandry practices, inadequate and/or nutritionally imbalanced feed and water sources, the prevalence of animal diseases, poor extension services, inadequate infrastructure, and limited markets are affecting livestock production and productivity [3,4]. Livestock in many parts of the world consume diets that contain insufficient nutritional balance to meet dietary requirements, with minerals a critically important component. Herbivores presumably obtain a high proportion of dietary minerals from the forages and/or other feedstuffs consumed, with mineral intakes often determined by environmental and production factors underlying the mineral content of plants and their seeds [5]. Common inorganic sources of dietary mineral supplements for livestock include limestone, dicalcium phosphate, common salt and calcined magnesite to provide calcium, phosphorus, sodium, chloride and magnesium, respectively [6].

Traditionally, Ethiopian farmers in specific regions seek to meet mineral needs of hoof stock (cattle, sheep, goats) through exposure to naturally-occurring mineral spring water (commonly called *hora*) and accompanying soils, often travelling extensive distances to locate these resources [7,8]. The word "*hora*" literally translates as "water discharged from underground". *Hora* sites are found in different Ethiopian regions including Bale, West Shawa, Ilu Aba Bora, Buno Bedele and East Wollega districts [7,8]. Additionally, Chiodi [9] identified about 47 *horas* in Bale Mountain National Park and the Harenna Forest, which are located in separate, smaller districts. *Hora* water or soil consumption is thought to enhance feed intake and fattening, milk yields, milk fat content, increase fertility, and provide ethno-veterinary medicinal properties [8,10]. Furthermore, local communities use *hora* mineral water for livestock and mineral supplementation and a honeybee attractant – the latter by painting traditional beehives with mineral soil found around *horas* (Local farmer, personal communication 2022). In addition to mineral supplementation, farmers in the study area use *hora* components as traditional medicine to treat different diseases such as rabies.

Although many *horas* are located in different parts of Ethiopia, they have, in general, not been well integrated into livestock feeding systems due to lack of awareness of their potential use or effectiveness. While culturally significant, the documented role/nutritional importance of such waters in livestock feeding seems to be a new area of research. Few scholars have investigated mineral nutrition in extensive grazing systems in Ethiopia, with existing studies focusing primarily on synthetic and common mineral supplements with low bioavailability [11]. Compared to minerals found in manufactured or natural feedstuffs integrated within complex bio-matrices, minerals present as free ions in water may offer considerable considerably higher bioavailability [12].

Published studies reveal that natural pastures, which provide a major livestock feed resource in Ethiopia, are often imbalanced in

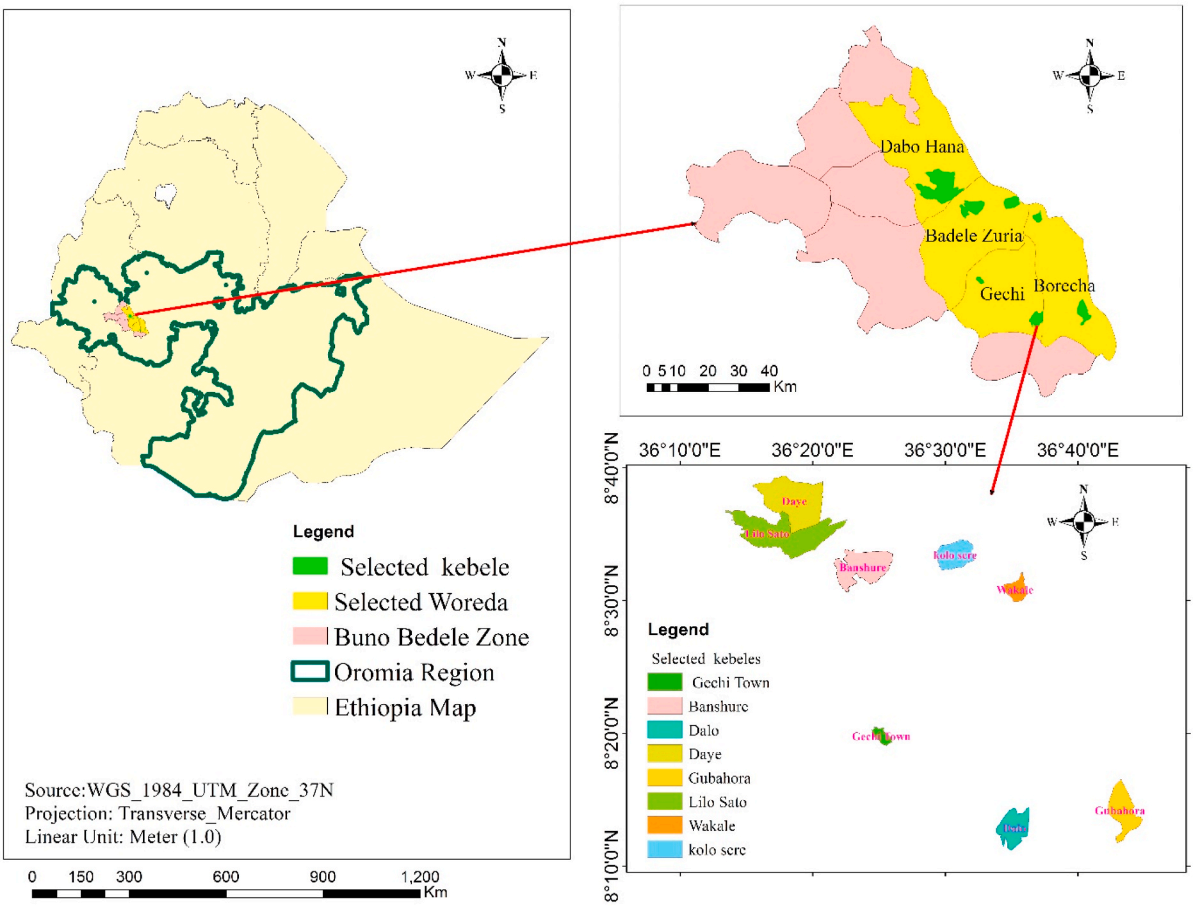

Fig. 1. Sampling district and Village location.

minerals with respect to requirements of cattle, particularly Ca, P, Cu, Mg and Se [13,14]. Among the various suggested strategies to overcome potential mineral deficiencies is supplementing with commercially available mineral sources, which may be cost-prohibitive. Investigation of the use of *horas* as alternative and economic sources of livestock mineral supplementation potentially represents a sustainable solution. Despite *hora* availability in the current study area(s), information on distribution, status, utilisation practices and perception of local farmers with respect to animal mineral supplementation have not been previously detailed. Consequently, assessment of farmers' knowledge and attitudes on the use of *hora* is imperative for generating empirical information on natural supplement availability and utilisation practices, as well as supplementation effects within livestock feeding programs. Such detail will help guide policy makers and livestock development stakeholders to plan proper strategies for efficient management and optimisation of sustainable utilisation of the natural mineral water, contributing to improved livestock productivity and food security. This work also provides preliminary data on the distribution and use of *horas* in livestock feeding in a targeted region within Ethiopia. Overall, this study aims to assess farmers' feeding practices and their perceptions about supplementation effects of natural mineral spring (*hora*) waters and surrounding soils on animal performance.

2. Materials and methods

2.1. Description of the study area

This study was conducted from March to April 2022, in Buno Bedele Zone of Oromia region, southwestern Ethiopia (Fig. 1). Four districts (namely Bedele, Dabo, Gechi and Boracha) were targeted based on the known presence of *hora* mineral water. The geographical location of the study districts are as follows: Bedele, 8°18′0″–8° 36′0″N, 36°10′0″-36°40′0″ E, Dabo, 8°36′0″–8° 57′0″N, 36°0′0″-36°20′0″ E, Gechi, 8°9′0″–8° 28′0″N, 36°24′0″-36°44′30″ E and Boracha 8°10′0″–8° 30′0″N, 36°30′0″-37°0′0″ E. The average minimum and maximum temperature of the study districts ranges between 13 and 20 °C and 24–28 °C respectively. The mean annual rainfall ranges between 1131 and 1500 mm. The altitude of the Bedele, Dabo, Gechi and Boracha district are 1294–2374, 1268–2267, 1488–2384 and 1332–2292 m above sea level, respectively. The major animal feed over the entire study area is crop residues, followed by natural pasture [15].

2.2. Study design, sampling procedure and sample size

Cross sectional study design was used to assess farmers' feeding practices regarding natural mineral spring water and surrounding soils as supplements, and perceptions about the nutritional role of *horas* on animal performance in the study area. Participants were recruited using a multi-stage stratified random sampling technique. Four districts and two peasant associations (the smallest administrative unit in each a district) in each district were selected based on the availability of *hora* mineral water. Finally, a total of 385 households were randomly selected for interview using a proportional sampling method based on the number of households in each district. The sample size was calculated using the formula of Cochran [16] ($n = Z^2 (pq)/e^2$) where n = sample size, z = level of significance at 95 % CI (=1.96), p = proportion of the study population, q = 1-p and e = the degree of accuracy desired (0.05).

2.3. Data collection methods

Both primary and secondary data were collected. Secondary data including annual rainfall, minimum and maximum temperature and geographical coordinates were obtained from each district agricultural office. Primary data for the study were collected from sampled farmers using a semi-structured questionnaire through face-to-face interviews and focus group discussions with the help of the KoboCollect application. The questionnaire (found in Supplementary Materials) contained both open and closed form questions that were pre-tested by interviewing some households; subsequently necessary modifications were made prior to full interview surveys. Trained enumerators collected the data using the local language, Afan Oromo. The questionnaire was used to collect information on socio-economic characteristics of respondents (age, sex, family size, education, landholding), livestock herd size, farmers' experience and practice in using *hora* as a mineral supplement for livestock, season, frequency and method of supplementation, distance to *hora* point(s) from the homestead, priority of species of livestock supplemented, status and management practices in *hora* use, and farmers' perceptions of the effects of *hora* mineral supplementation on animal performance (including any potential adverse effects/major constraints associated with *hora* utilisation).

2.4. Data analysis

The data collected using the KoboCollect application were rearranged in Excel, coded and analyzed using the Statistical Package for Social Sciences (IBM SPSS, 2019 version 26) statistical software for Windows. Descriptive statistics (mean, standard error of mean and percentages) were used to summarise and present farmers' socio-demographic characteristics and all quantitative data related with farmers' feeding practices and perceptions on *hora* mineral water supplementation. Cross tabulation and ordinal regression were used to test categorical and ordinal data to compare each district separately. Quantitative data comparisons between districts (i.e. age, family size, landholding and number of livestock) were performed using one-way ANOVA. To obtain ranking of *hora* supplementation priority, an index was calculated as: $\sum$ [(4 x number of responses for a first place rank + 3 x number of responses for a second place rank + 2 x number of responses for a third place rank + 1 x number of responses for a fourth place rank)] divided by (4 x total responses for first rank + 3 x total response for second rank + 2 x total response for third rank + 1 x total response for fourth rank).

3. Results and discussion

3.1. Socio-economic characteristics of respondents

Respondent socio-economic characteristics are summarised in Table 1. The overall average age of the respondents in the study area was 48.1 ± 0.7 years with no difference among studied districts. The average age of the respondents in the current study is in agreement with the finding of Abazinab et al. [17] who reported 45.6 ± 0.7 years in Gera district of Jimma Zone. On the other hand, Ondieki et al. [18] in Kisii County, Kenya reported that most of their respondents (32.7 %) were between 30 and 39 years of age. The middle- and old-aged respondents are more likely to have a better understanding or more experience regarding the importance of *hora* mineral water in animal feeding. According to Duguma and Janssens [19], the lack of access to land, and the migration of educated youth to large cities for employment in other sectors are the main reasons why young people are not involved in the farming system in Ethiopia.

The overall mean family size of the respondents in the studied districts was 6.6 ± 0.1. This finding aligns with Adejori and Akinnagbe [20] who reported a mean of 6.0 persons from Ondo state, Nigeria. However, it is higher than the value of 4.8 persons reported by CSA [21]. Significantly ($p < 0.05$) larger mean family sizes were found in Gechi district compared to the other districts surveyed. This might be attributed to factors such as the practice of polygamy, limited family planning, and the perception of large families as a source of labour for crop and livestock management. Large family size is a significant source of cheap labour for various farm and livestock production activities. Adimassu et al. [22] and Contzen and Forney [23] highlight the importance of family labour in farm activities such as land preparation, weeding, harvesting, threshing, crop residue collection, transportation, and storage of harvested products. The overall mean land holding of respondents in the study district was 6.3 ± 0.1 ha. This suggests that most of the participants in the current study were small-scale farmers. Our finding was by far higher than the mean of 2.6 ± 0.10 ha in Gera district reported by Abazinab et al. [17]. Farmers interviewed in Boracha district had significantly larger landholding ($p < 0.05$) compared to those in the other districts, likely due to the lower population density in Boracha compared to the available land area.

The overall mean livestock number per household was 24.6 ± 0.6 head. Notably, households in the Boracha district kept significantly more livestock ($p < 0.05$) compared to those in Gechi and Bedele districts. As Table 1 suggests, farmers in Dabo and Boracha with larger land holdings tended to keep more livestock. The majority (~76.0–88.5 %) of the interviewed households were headed by males, with females comprising the remaining 18.4 %. This dominance of male-headed households might reflect cultural norms where men hold primary decision-making power within families and are traditionally responsible for livestock management in Ethiopia. It's also likely that males were more often available for interviews as they typically manage free-grazing animals. The percentages of male-headed households in the current study were lower compared with the findings of Abazinab et al. [17] and Duguma and Janssens [19] who reported that 92.8 % and 95.5 % of the respondents were male in Gera district and around the Gibe Catchment, Southwest Ethiopia, respectively. Conversely, it is higher than the value of 65.4 % in Kisii County, Kenya reported by Ondieki et al. [18].

Regarding the educational background of respondents, around 15.6 % were illiterate and 26.5 % could only read and write across the studied districts. Educational level varied significantly ($p < 0.05$) among the studied districts. Lack of awareness and educational institutions, as well as economic status of the family, were contributing factors affecting educational levels. The proportion of illiterate households in this study was lower than those reported elsewhere in Ethiopia by Mengistu and Kassie [24] (52.8 %) and Abazinab et al. [17] (82.2 %). Conversely, it was higher than the value reported for Kisii County, Kenya (2.6 %) by Ondieki et al. [18] and Ondo State, Nigeria (9.6 % by Adejori and Akinnagbe [20]). Generally, farmers with higher levels of education are more likely to adopt new technologies. This is because they can better understand and adapt to extension messages and agricultural information. However, the practice of *hora* supplementation remained unaffected by the level of education since *hora* supplementation is considered a cultural community practice whereby any household who rears livestock has free access to *hora*.

Table 1
Socio-economic characteristics of respondents in the study district.

Variables	Districts					p-value
	Bedele	Dabo	Gechi	Boracha	Overall	
Mean ± SE						
Age (years)	46.8 ± 1.2^{a}	49.7 ± 1.3^{a}	48.5 ± 1.2^{a}	47.3 ± 2.1^{a}	48.1 ± 0.7	0.53
Family size (heads)	7.1 ± 0.3^{b}	5.6 ± 0.2^{a}	7.3 ± 0.3^{b}	6.4 ± 0.2^{ab}	6.6 ± 0.1	0.00
Land size (hectare)	5.5 ± 0.3^{a}	6.6 ± 0.3^{bc}	5.9 ± 0.3^{ab}	7.4 ± 0.2^{c}	6.3 ± 0.1	0.00
Livestock size (Numbers)	22.6 ± 1.3^{ab}	26.9 ± 1.5^{bc}	21.1 ± 0.7^{a}	27.8 ± 1.4^{c}	24.6 ± 0.6	0.00
Sex of the respondents (%)						
Male	77.3	88.5	84.4	76.0	81.6	0.08
Female	22.7	11.5	15.6	24.0	18.4	
Level of education (%)						
Illiterate	13.4	15.6	14.6	18.8	15.6	0.00
Read and write	17.5	14.6	31.3	42.7	26.5	
Primary education	18.6	27.1	20.8	16.7	20.8	
Secondary education	30.9	22.9	19.8	12.5	21.6	
Tertiary education	19.6	19.8	13.5	9.4	15.6	

SE: Standard error; p-values are chi-square probabilities; Means within rows with different superscript letters differ significantly $p < 0.05$.

3.2. Sources of mineral supplements for livestock in the study area

As shown in Table 2, the main sources of mineral supplements for livestock in the study area included mineral water (~33–49 %) and table salt (~21–32 %), both mineral water and accompanying soil (~17.7–28.8 %), and mineral soil only (6–9%). In agreement with this study, Zeleke et al. [10] reported that mineral water was the major mineral supplement for sheep in Humbo Woreda, Wolaita Zone, Ethiopia. Temesgen et al. [25] observed that mineral soil (locally called *addua*), followed by mineral water (*yogua*) were the main sources of mineral supplements for livestock from Wolaita lowlands, Southern Ethiopia. Sources of mineral supplements in this study did not differ significantly across the four districts surveyed. According to Tawa et al. [26], natural salt licks, clay and water are the possible sources of supplemental minerals and detoxification of plant secondary metabolites used by medium and large sized mammals in the tropical rainforest of Belum-Temengor Forest Complex, Peninsular Malaysia.

3.3. Practice and priority of hora mineral supplementation

Table 3 presents practices and priority of *hora* mineral supplementation in the study area. Results revealed that the majority of farmers (73.2 %) practiced *hora* mineral water supplementation for livestock, while about 26.8 % of the participants did not. The practice of *hora* mineral supplementation might be affected by proximity of *hora* sources within each district. A higher proportion (78.1 %) of the respondents in Boracha districts supplement their animals with *hora* compared to farmers from the other districts studied. The average walking distance between the *hora* point and the homestead was 6.5 ± 0.2 km with a significantly ($p < 0.05$) shorter distance in Boracha and Dabo districts compared to those in Bedele and Gechi districts. As the distance between homesteads and *hora* location decreases, the frequency of supplementation of livestock with *hora* mineral water increases.

Overall, about 59.0 % of farmers interviewed reported supplementing livestock with *hora* mineral water as a long-standing practice (cultural practices inherited from their descendants). In line with this study, Edae et al. [8] revealed that utilisation of *hora* traces back to the time when people started herding cattle. The majority of respondents believed that their parents had taught them to supplement livestock diets with *hora* mineral water. In ancient Greece, utilisation of mineral water (sulphurous springs) was recommended due to its beneficial health effects, especially for healing skin diseases and for relieving muscular and joint pain [27].

As indicted in Table 3, a higher priority ranking, with the index value of 0.34, was given for large ruminants (cattle) across the study districts. Farmers from Bedele and Dabo district ranked higher priorities for large ruminants followed by all other classes of animals. On the other hand, farmers from Gechi district gave higher priorities to large ruminants followed by equines. Moreover, farmers from Boracha district supplemented all classes of animals compared to other districts. This might be due to the abundance of *hora* mineral spring in the Boracha district. While it may be more challenging to herd small ruminant animals over long distances, livestock owners often trek their large ruminant animals to find *hora* mineral sources. The economic significance that farmers attach to each species could reflect the variation in supplementation priorities among animal species. During focus group discussions, participant farmers disclosed that bulls and dairy cattle received more *hora* mineral water than other large ruminants. This could be due to farmers' perceptions that *hora* mineral water increases milk yield and improves fertility (sexual desire). This result was supported by the finding of Edae et al. [8] who reported that *hora* increases milk yields, heifers' oestrous manifestation and bulls' libido.

3.4. Season, form and frequency of supplementing hora to animals

Table 4 shows season, forms and frequency of *hora* mineral supplementation in the study area. A majority of the respondents in the studied district provided *hora* mineral water to their animals during the dry season only. During the rainy season, *hora* mineral water gets polluted by floods and decreases in quality. In accordance with this result, Edae et al. [8] reported that supplementation of *hora* mineral water takes place regularly during the spring season. Before the rainy season, farmers believed that supplementing *hora* mineral water cleans the gut of animals and helps them to efficiently consume the lush grass during the upcoming rainy season. On the other hand, farmers supplement their animals with *hora* minerals after the rainy season as well. They perceived that consumption of fresh grass during the summer season causes infestation of animals with different gastrointestinal parasites. Thus, *hora* mineral supplementation of animals following the summer season helps to protect livestock from infestation with various parasites. Our results corroborate the findings of Zeleke et al. [10] who reported that minerals found in soil and water have the ability to treat diseases associated with lush grass consumption.

About 37.2 % of respondents reported that they did not adhere to a specific season of supplementing *hora* if access to *hora* was

Table 2
Source of minerals supplement for livestock in the study districts.

Variables	Districts					
	Bedele (N = 97)	Dabo (N = 96)	Gechi (N = 96)	Boracha (N = 96)	Total (N = 385)	p-value
Sources of minerals fed to livestock (% of responses)						
Table salt	32.0	26.0	27.1	21.9	26.8	0.48
Mineral water (*hora*)	33.0	43.8	49.0	47.9	43.4	
Surrounding soil only	7.2	9.4	6.3	8.3	7.8	
Both *hora* and soil	27.8	20.8	17.7	21.9	22.1	

p-values are chi-square probabilities.

Table 3
Practice, experience and priority of *hora* supplementation as reported by respondents in the study districts.

Variables	Districts					
	Bedele (N = 97)	Dabo (N = 96)	Gechi (N = 96)	Boracha (N = 96)	Total (N = 385)	p-value
Practices of *hora* supplementation (%)						
Yes	68.0	74.0	72.9	78.1	73.2	0.46
No	32.0	26.0	27.1	21.9	26.8	
Experience of feeding *hora* (years)						
<10 years	1.0	1.0	2.1	4.2	2.1	0.42
10–20 years	8.2	17.7	10.4	12.5	12.2	
Since starting to rear animals	58.8	55.2	60.4	61.5	59.0	
Not supplement at all	32.0	26.0	27.1	21.9	26.8	
Distance from *hora* point (km) (Mean ± SE)	7.7 ± 0.4^{c}	6.1 ± 0.4^{ab}	6.9 ± 0.3^{bc}	5.2 ± 0.2^{a}	6.5 ± 0.2	0.00
Hora supplementation priority **(Index(rank))**						
Small ruminant	0.22 (3)	0.20 (4)	0.18 (4)	0.21 (4)	0.20 (4)	
Large ruminant	0.33 (1)	0.33 (1)	0.37 (1)	0.26 (2)	0.32 (1)	
Equine	0.19 (4)	0.23 (3)	0.25 (2)	0.23 (3)	0.23 (3)	
All	0.26 (2)	0.24 (2)	0.20 (3)	0.35 (1)	0.27 (2)	

SE: Standard error; p-values are chi-square probabilities; Means within in rows with different superscripts differ significantly ($p < 0.05$). Index = ∑ [(4 x number of responses for a first place ranking + 3 x number of responses for a second place ranking + 2 x number of responses for a third place ranking + 1 x number of responses for a fourth place ranking)] divided by (4 x total responses for first rank + 3 x total responses for second rank + 2 x total responses for third rank + 1 x total responses for fourth rank).

Table 4
Season, form and frequency of supplementing *hora* to animals in the study districts.

Variables	Districts					p-value
	Bedele (N = 66)	Dabo (N = 71)	Gechi (N = 70)	Boracha (N = 75)	Total (N = 282)	
Season of supplementing						0.01
Wet season	6.1	8.5	7.1	6.7	7.1	
Dry season	75.8	50.7	52.9	45.3	55.7	
Season independent	18.2	40.8	40.0	48.0	37.2	
Forms of supplementing						0.46
Indoor supplementation	16.7	8.5	10.0	10.7	11.3	
Trekking to the site	83.3	91.5	90.0	89.3	88.7	
Frequency of supplementation						0.00
Daily	6.2	24.0	10.4	31.3	17.9	
Once a week	2.1	5.2	5.2	2.1	3.6	
Once a year	27.8	15.6	26.0	16.7	21.6	
Twice a year	32.0	29.2	31.3	28.1	30.1	
Never	32.0	26.0	27.1	21.9	26.8	

p-values are chi-square probabilities.

available throughout the year. Livestock farmers located near *hora* sources have an advantage in more frequent access to *hora* minerals over farmers residing at further distances. This was substantiated by the fact that the majority of respondents from the Boracha district stated that livestock had access to *hora* minerals freely throughout the year. The finding of Zeleke et al. [10] indicated that mineral soil supplementation was year round followed by dry season supplementation. Farmers in the study districts practiced two different methods of *hora* mineral supplementation: 1) trekking animals to the *hora* source or 2) indoor supplementation. In agreement with this finding, Zeleke et al. [10] reported that the majority of the farmers in Wolaita zone trekked their animals to locate soil licking areas and supplement them with soil minerals. About 8.3 % of the respondents in the study area confirmed that indoor supplementation or providing *hora* mineral water at home was used for calves, milking cows, pregnant animals, and sick animals that could not travel to the *hora* site(s). The different forms of *hora* mineral supplementation across the study district varied based on distance from the *hora* source. Similar to this, Zeleke et al. [10] found that a lower percentage of respondents supplemented mineral soil indoors due to the transport distances involved.

The frequency of supplementing *hora* mineral water differed ($p < 0.05$) significantly among districts. Across the studied districts, a majority of the respondents practiced a supplementation frequency of twice a year, followed by once a year, daily and once weekly. A majority of the farmers in Boracha and Dabo districts practiced daily supplementation with *hora* due to easy access to *horas* over short distances (Table 4). Edae et al. [8] also reported that livestock drink at *hora* sites twice annually (during the spring and winter seasons). In contrast to the present findings, Zeleke et al. [10] and Desalegn and Mohammed [28] reported that mineral soils were supplemented to sheep on a weekly basis in the Humbo district, and both mineral water and soils were supplemented to camels on a monthly basis in the Jijgjiga district, respectively. The discrepancy may result from the use of soil lick areas in addition to the local market's supply of natural mineral soils as supplements.

3.5. Farmers' perceptions on the effect of hora supplementation on animal performance

Table 5 shows farmers' perceptions on the effect of *hora* supplementation on animal performance in the study area. Traditionally, farmers knew the importance of *hora* mineral supplementation for their animals and perceived its effect through observable and measureable indicators in terms of improved productive and reproductive performance. The main effects of *hora* mineral supplementation on animal performance as perceived by farmers interviewed included improved milk yield and milk fat, weight gain, body condition, birth weight, meat quality, and regular heat/oestrus (on-set of puberty and increased conception rate), an improved libido of bulls, and a shorter fattening period. These findings are in agreement with Zeleke et al. [10] who reported that mineral soil and water supplementation enhanced milk yield and milk fat yield, improved weight gain, increased feed intake, and increased disease resistance. Farmers in all districts had a similar ($p < 0.05$) perception about the effect of *hora* mineral water supplementation on production and reproductive performance of animals.

Overall, the majority of respondents reported increased milk and milk fat yields following supplementation of *hora* mineral water. This might be due to the trace mineral elements in *hora* playing a vital role in maintaining mammary gland health and building immunity to fight infections such as mastitis. Previous studies have shown that supplementation of organic, inorganic and or chelated minerals have a positive effect on milk production, milk fat and fat-corrected without any negative effect on milk chemical composition [29,30]. In this study, about 55.6 % of the farmers indicated that *hora* mineral water supplementation improved body weight gain of animals. A significantly ($p < 0.05$) higher proportion of the respondents from Bedele district stated that supplementation of *hora* minerals improved live weight of animals compared with other districts. The study of Kuraz et al. [31] indicated that supplementation of sheep with mineral soil (*Bole*) improved daily weight gain. Previous studies proved that mineral supplementation improved body weight gains of beef cattle [32]. About 15.3 % of farmers indicated a positive effect of *hora* mineral water supplementation on meat quality. Untea et al. [33] reported that chromium improves broilers' meat quality, by increasing the protein concentrations and mineral composition.

About 66.5 % of the respondents noticed a positive effect of *hora* mineral water supplementation on regularity of heat (oestrus); there was no significant difference ($p > 0.05$) among districts. Farmers believed that heifers supplemented with *hora* are more likely to conceive. Most of the respondents (~79.2–86.6) reported that supplementation of *hora* mineral water increased bulls' libido. Farmers' perceptions regarding the importance of *hora* mineral water might be associated with the presence of essential minerals that are responsible for improving reproductive performance of animals. Zinc, selenium, copper and calcium phosphate are the most important minerals used to improve reproductive performance of large ruminants [11,34].

According to local farmers, the major indicators of animals that have received an adequate amount of *hora* are increased feed intake, smooth and shining hair coats, and a pleasant odour following eructation. Previous studies also indicate that mineral supplementation can improve feed intake of weanling pigs, chickens and quail [35,36]. A smooth, shiny hair coat was associated with animals receiving adequate *hora* mineral water by a majority of farmers interviewed (~73.2–95.8 %, Table 5), although responses differed significantly ($p < 0.05$) among districts. Thus, animals in the study districts supplemented most frequently with *hora* mineral water might obtain essential minerals (especially copper and molybdenum) linked with healthy coat and hair. Furthermore, farmers perceived that supplementation of *hora* mineral water will alter foul smells through cleansing the gut, and that an unhealthy gut with a

Table 5
Farmers' perceptions on effect of *hora* supplementation on animal performance and health.

Performance variables	Farmers' perceived effects	Districts					p-value
		Bedele (N = 66)	Dabo (N = 71)	Gechi (N = 70)	Boracha (N = 75)	Total (N = 282)	
Production and reproduction performance	Increased milk yield and milk fat	81.4	72.9	79.2	79.2	78.2	0.52
	Improved weight gain	69.1	52.1	55.2	45.8	55.6	0.01
	Improved meat test/quality	18.6	20.8	9.4	12.5	15.3	0.09
	Regular heat/oestrus and libido	86.6	85.4	83.3	79.2	83.6	0.53
Physiological and physical appearance	Increased appetite/fed intake	79.4	76.0	69.8	70.8	74.0	0.37
	Smooth and shining hair coat	73.2	75.0	81.3	95.8	81.3	0.00
	Avoid bad smell upon eructation	33.0	42.7	45.8	50.6	40.5	0.30
Behavioural change	Maintain normal behaviour	55.7	71.9	67.7	58.3	63.4	0.06
	Stop licking soil, stone and old clay pot	72.2	70.8	74.0	71.9	72.2	0.97
State of well being	Expel internal parasites	81.4	82.3	68.8	76	77.1	0.09
	Control external parasites	70.1	70.8	57.3	60.4	64.7	0.11
	Clear digestive tract through diarrhoea	73.2	80.2	77.1	90.6	80.3	0.01
	Avoid bloating of grazing lush grass	53.6	55.2	28.1	35.4	43.1	0.00
	Increase disease resistance	76.3	71.9	70.8	72.9	73.0	0.83

p-values are chi-square probabilities.

disturbed rumen ecosystem may result in bad odours upon eructation. According to Shannon and Hill [37], weaned nursery pigs fed high concentrations of zinc showed reduced incidence of diarrhoea and improved gut morphology. A majority of the respondents (~55.7–74 %) in the study area revealed that *hora* mineral supplementation could maintain normal behaviours of animals and prevent deviated appetite. Abnormal behaviours and ingestion of non-feed items could be associated with mineral deficiency. During focus group discussions, farmers disclosed that different abnormal behaviours such as licking soil, old pots and stones, sniffing behaviours in the direction of *hora* locations, sudden running to *hora* sources and frequent bellowing were the signs developed by animals that did not receive adequate *hora* mineral water supplementation. Thus, animals consuming *hora* mineral water could obtain essential minerals to some extent that could contribute to maintaining normal behaviours and optimum health.

In the study districts, local farmers perceived that *hora* mineral water supplementation could expel internal parasites (~68.8–82.3 %) through frequent urination and defecation. In line with this finding, Zeleke et al. [10] reported that minerals found in soil may help to offset gastrointestinal ailments of animals. To remove external parasites, farmers paint the external body of the animals with wet soil (mud) sourced in and surrounding *hora* mineral water. During data collection, we observed that farmers also painted and rubbed the skin of their animals with *hora* mineral water soils. They perceived that wet soils around *hora* mineral waters have medicinal value to remove external parasites such as ticks, lice and mites. A majority of the farmers (~73.2–90.6 %) indicated that *hora* enhances well-being (health status) of animals by clearing digestive tracts through diarrhoea. Their perception might be associated with the presence of essential minerals (such as zinc and selenium) in *hora* water that are responsible for improving an animal's immune status. Different sources of mineral supplementation could have beneficial effects on improving the immune system of the animals and thereby increase disease resistance [2,38].

3.6. Farmer perceptions on the adverse effects of hora supplementation on animal performance

The majority of the respondents (192/282 = 68.1 %) stated that supplementation of *hora* mineral water has no adverse effect on animal performance or health. However, a few farmers reported that overconsumption on an empty stomach may cause some health problems. *Hora* waters are salty in nature (might contain sodium and chloride) and overconsumption of this mineral source might thus affect health [25]. According to Wu [39], anorexia, weight loss, edema, nervousness, and paralysis have been reported in cattle associated with high intake of mineral elements such as sodium chloride. Farmers from the study districts also indicated that excessive *hora* mineral water could induce diarrhoea in animals with no previous exposure of drinking *hora* mineral water. In agreement with this study, Edae et al. [8] and Temesgen et al. [25] reported that supplementation of excess *hora* on an empty stomach, or consumption of salty soils on a daily basis could harm animal health.

Farmers reported several negative impacts associated with increased levels of hora consumption, including abortion, birth defects, delayed puberty, decreased conception, and paralysis Table 6. In line with this study, Zeleke et al. [10] reported that excess consumption of mineral soil can cause abortion in pregnant cows. The number of respondents in Boracha districts that reported supplementation of *hora* mineral water leads to abortion was lower (7 farmers) than the number of farmers in Gechi (13) and Bedele (12) district. On the other hand, the number of farmers in Boracha districts that reported supplementation of *hora* mineral water leads to birth defects was higher (n = 11) than in other districts. Few farmers reported experiencing any minor adverse effects. Most farmers indicated that these problems are associated with excessive consumption, consumption on an empty stomach or excessive intake when consuming *hora* for the first time. To minimise the adverse impacts of increased *hora* consumption, farmers developed different coping strategies such as restricting excessive consumption, gradual adaptation and providing adequate basal feeds to animals before *hora* mineral water consumption.

3.7. Status and management practice of hora

Status and management practices, or conservation of *hora* mineral waters in the study area, are presented in Table 7. About 54.6 % of the respondents felt that the status of *hora* mineral water is decreasing, while the rest reported no change over time. A higher proportion of farmers in Dabo district indicated that the status of *hora* mineral water is constant compared to farmers in other districts, likely due to better management practices compared to other districts. For example, our research team noticed that a built-in concrete wall protected one of the *hora* sources found in the Dabo district. The main factors affecting the quality of *hora* mineral waters includes flooding/sedimentation during the rainy season, lack of conservation, indifference, and the cultivation of food and cash crops like banana, coffee, sugarcane, and other spices near the *hora* mineral source. Other factors affecting the quality and quantity of *hora*

Table 6
Farmer perceptions on adverse effects of increased levels of *hora* consumption on animals in the study area.

Districts	Adverse effect	Types of adverse effect (number of respondents)				
	No. of. resp. "yes"	Abortion	Birth defect	Delayed puberty	Decreased conception rate	Paralysis
Bedele	22	12	5	2	1	2
Dabo	17	10	4	1	0	2
Gechi	24	13	4	3	2	2
Boracha	27	7	11	4	0	5
Overall	90	42	24	10	3	11

Table 7
Status and management practices of *hora* in the study area.

Variables	Districts					p-value
	Bedele (N = 66)	Dabo (N = 71)	Gechi (N = 70)	Boracha (N = 75)	Total (N = 282)	
Current status of *hora*						
Constant	43.9	49.3	42.9	45.3	45.4	0.88
Decreasing	56.1	50.7	57.1	54.7	54.6	
Management practice of *hora*						
Construction of fence	12.1	12.7	12.9	22.7	15.2	0.00
Using external watering trough	7.6	4.2	10.0	10.7	8.2	
Digging drainage channel to prevent flood contamination	4.5	7.0	8.6	2.7	5.7	
Removing excess mud and sediments from the sources	7.6	2.8	5.7	2.7	4.6	
Have no management	63.6	47.9	62.9	57.3	57.8	
Others	4.5	25.4	0.0	4.0	8.5	

p-values are chi-square probabilities.

mineral water include inappropriate use, cattle and wild animals entering and contaminating it with urine and dung, and road crossing the side of the *hora* point. Climate change and extended dry seasons are also reducing the quantity of *hora* according to information obtained during data collection. Thus, fencing, digging drainage ditches to divert surface runoff entering the *hora* source, using *hora* feeding troughs and regular cleaning of the mud are suggested as protection measures to maintain the quality and quantity for sustainable utilisation and improved performance of livestock.

A majority of respondents (~47–63.6 %) in the current study area indicated that *hora* mineral waters have no conservation practices, and most reported no organised management, possibly due to a lack of awareness regarding the potential use of *hora* in animal feeds. About 42.2 % of the respondents in the current study used different management practices such as constructing fences to prevent livestock contamination when directly drinking, using external watering troughs to avoid animal contamination, digging drainage channels surrounding *horas* to prevent erosion and flood contamination, cleaning the sources to remove excess mud or sediments, and other mechanisms such as a building concrete wall enclosures around the *horas.*

3.8. Constraints of using hora mineral water

Fig. 2 shows the major constraints facing local community use of *hora* water as a livestock mineral supplement. Based on survey responses, distance from the *horas* (33.0 %), accessibility of modern veterinary services (27.0 %), and lack of awareness (26.6 %) were identified as the major barriers to *hora* utilisation. According to the farmers, access to veterinary services has reduced the use of *hora* mineral water as a preventative measure against diseases, but not impacted its importance as a source of mineral supplementation. Anciently, before the emergence of biomedicine, local farmers used this mineral source as ethno-veterinary medicine for animal health [8]. Thus, the expansion of veterinary services and availability of synthetic veterinary medicine affects the attitude of local farms to use *hora* mineral waters. Furthermore, about 13.5 % of the respondents from the study district listed other constraints (such as reducing the quantity of *hora* resources, negative attitudes and lack of awareness of the *hora* locations) as factors affecting *hora* mineral water utilisation.

An obvious limitation of the current investigation is the lack of chemical analysis of *hora* mineral spring waters and nearby soils. Nonetheless, farmers clearly feel that *horas* provide important livestock management resources in this region. This survey provides the foundation for a validation study.

4. Conclusion

Natural mineral water (*hora*) and accompanying soils are the prominent sources of mineral supplements for animals in Buno Bedele zone, Southwestern Ethiopia. Farmers in the study area trek their livestock to the *hora* points twice a year (in the spring and the winter) to supplement with *hora* minerals. Local farmers perceive that *hora* supplementation has a beneficial effect on production, reproduction and well-being of animals. Increased milk yield, improved weight gain, regular heat/oestrus cycling and improved bull sexual desire are among the major production performances observed in animals supplemented with *hora* water. Farmers also thought that animals consuming adequate mineral water are less susceptible to disease and parasites. Some problems associated with *hora* supplementation mentioned during interviews included abortion, birth defects, delayed puberty, decreased conception and paralysis. Currently, natural and man-caused factors are affecting the status of *hora* mineral waters in Ethiopia. The majority of *hora* mineral springs found in the study district have no formal associated conservation or management practices. The main barriers to local farmers using *hora* mineral water include lack of awareness, distance, and access to veterinary services. Based on the results of this study, the importance of *hora* mineral water in animal nutrition and health needs further investigation. The positive perceptions concerning the supplementation value of *hora* mineral water would appear to alleviate mineral deficiency affecting grazing animals. Controlled experimental studies are needed to prove the importance of *hora* mineral water and soils on animal health and production as well as to

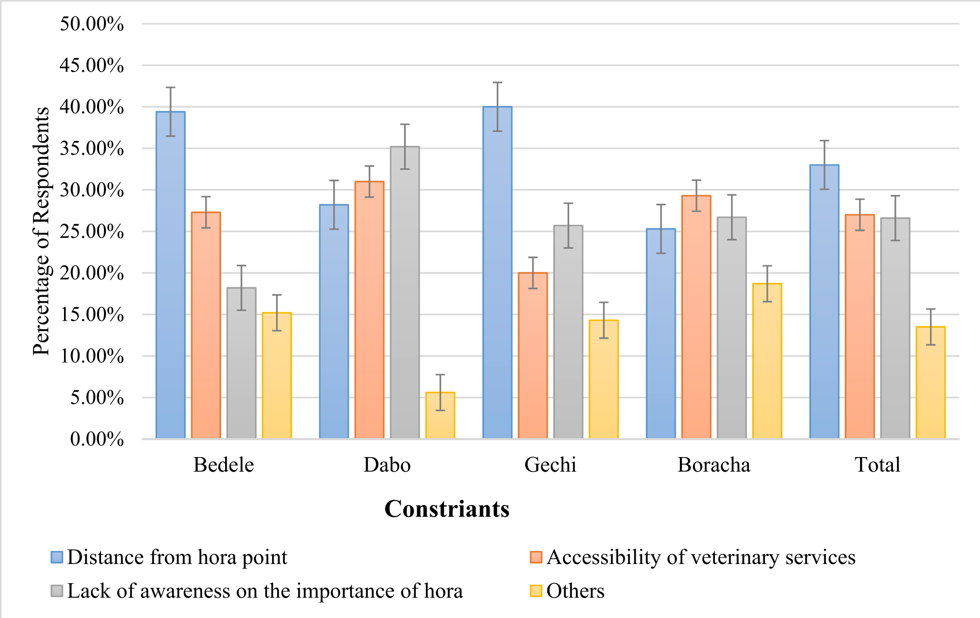

Fig. 2. Constraints of using *Hora* mineral water in the Buno Bedele zone, southwestern Ethiopia.

protect against possible detrimental effects. Furthermore, laboratory mineral analysis is required to quantify nutrient concentrations; livestock mineral status and mineral content of both *hora* waters and soils, with respect to animal requirements, need to be evaluated for better understanding of nutritional relationships. Strong collaboration of responsible stakeholders is crucial for further conservation, potential commercialisation and promotion of *hora* mineral water for further uses.

Ethical approval

The data collection instrument (participant survey questionnaire) was reviewed for ethical clearance and approved (RGS/588/2022) by the Jimma University, College of Agriculture and Veterinary Medicine. Furthermore, informed consent was obtained from all surveyed participant households of this research. Participants in this study had the option to stop at any moment, and all information was kept strictly confidential.

Data availability statement

Data will be available upon request.

CRediT authorship contribution statement

Ashenafi Miresa Kenea: Writing – review & editing, Writing – original draft. **Taye Tolemariam Ejeta:** Writing – review & editing. **Belay Duguma Iticha:** Writing – review & editing. **Ellen S. Dierenfeld:** Writing – review & editing. **Geert Paul Jules Janssens:** Writing – review & editing. **Solomon Demeke Cherkos:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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