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Biopesticidal Effect of *Acokanthera schimperi* and *Nicotiana tabacum* on Maize Storage Insect, *Sitophilus zeamais*

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Abstract

Maize serves as a primary staple food for approximately one-third of the sub-Saharan population. Despite being the third most widely produced grain globally, various factors impede its production. Insects, particularly maize weevils (Sitophilus zeamais), play a crucial role in hindering maize production, especially during storage. This study investigates the efficacy of two medicinal plants, Acokanthera schimperi and Nicotiana tabacum, in managing the maize weevil, a significant pest affecting stored grain. Adult maize weevils (S. zeamais) were collected and reared in the entomological laboratory at Addis Ababa University. The medicinal plants, Acokanthera schimperi and Nicotiana tabacum, were processed into powder and applied to the laboratory-reared S. zeamais in varying amounts. Statistical analysis, using SPSS version 16's ANOVA, was conducted to assess mean differences among replicates and dose rates. The plant toxicity test employed the "corrected mortality (%)" formula. Results indicated that Nicotiana tabacum demonstrated effectiveness against the maize weevil, with approximately 59% mortality recorded among adult weevils during the experimentation. This highlights the potential for sustainable utilization of plant resources for affordable pest management, while simultaneously mitigating the environmental detriments associated with conventional methods.

Keywords/Phrases: Adult mortality, Maize weevil, Medicinal plants, Pest Management, Storage pests

1 Introduction

Corn (*Zea mays*) is a cereal grass closely related to rice, wheat, oats, and barley. It ranks second in global grain production, following wheat (Piperno, 2011). In sub-Saharan Africa (SSA), approximately one-third of caloric intake comes directly from maize (Tadele *et al.*, 2011), which is used for animal feed, biofuel, and as a raw material in various industries. Originally cultivated as a subsistence crop, maize has evolved into a valuable cash crop relied upon by many sectors (Iken & Amusa, 2004).

In Ethiopia, maize (*Z. mays* L.) is a critical cereal crop for food, fodder, and income (Benti & Ransom, 1993; Seyoum *et al.*, 2013). In the Oromia Region, maize cultivation covered 1.11 million hectares in the 2010/11 season, yielding 28.81 million quintals at a productivity rate of 25.97 quintals per hectare (Musa, 2013).

However, several factors hinder maize production, with insect pests being a major obstacle to optimal utilization of cereal crops in SSA. Stored grain damage is particularly severe, with annual losses in Ethiopia ranging from 20% to 30%. Key pests include the maize weevil (*S. zeamais*), grain moth (*Sitotroga cerealella*), rice weevil (*Sitophilus oryzae*), and red flour beetle (*Tribolium confusum*).

These pests can cause losses of 20–40% during cultivation and 30–90% during postharvest and storage (Wakitole & Amsalu, 2012).

Losses primarily result from insect feeding and reproduction, leading to contamination from excreta, discarded skins, and dead insects. Additionally, insect activity can increase temperature and moisture levels in the grain, creating warm, humid conditions that enhance respiration and fungal growth, further accelerating deterioration (Tefera *et al.*, 2010).

In many parts of SSA, these losses jeopardize household food security and reduce market profits, prompting farmers to seek ways to protect their grain during storage (Stathers *et al.*, 2008). The region's warm tropical climate and inadequate storage methods often exacerbate pest growth, leading to significant losses (Bekele *et al.*, 1997). In some cases, farmers are forced to sell their maize at low prices immediately after harvest due to anticipated storage losses, only to buy food later at higher prices. Furthermore, farmers in developing nations, constrained by the lack of modern storage facilities, often resort to traditional granaries that are ineffective against storage pests (Charles *et al.*, 2016; Midega *et al.*, 2015).

Maize weevils (*S. zeamais*), prevalent in both tropical and temperate regions, are the primary insect pest affecting stored maize grains (Alemnew, 2017; Charles *et al.*, 2016). Substantial infestations of adult maize weevils and their larvae lead to significant postharvest losses (Markham *et al.*, 1995; Shetie and Abrham, 2023). Despite numerous efforts directed at alleviating the impact of field pests (Charles *et al.*, 2016), the persistent issue of post-harvest losses caused by insects remains a significant challenge (Tefera *et al.*, 2010).

Controlling insect pests in stored grains largely relies on synthetic insecticides, favored for their quick action and ease of use globally. However, the frequent application of these chemicals leads to environmental pollution, pest resistance, and harm to non-target organisms. Additionally, it raises application costs and creates supply challenges in developing countries due to limited foreign exchange (Mishra *et al.*, 2012). Consequently, there is a growing need to explore alternative, environmentally friendly, and cost-effective pest management systems (Suleiman

& Rugumamu, 2017).

Botanical pesticides are experiencing a resurgence in popularity, with certain plant-derived products being utilized worldwide as eco-friendly pest control agents. This revival is evident as some plant-based products gain acceptance as sustainable alternatives. Pyrethroids and neem products have long been recognized as effective botanical pesticides, while essential oils extracted from various plants have recently emerged as potent antimicrobials against storage pests. Their perceived safety and broad consumer acceptance have contributed to their adoption in pest management strategies (Dubey *et al.*, 2008).

The production and application of plant products are gaining traction due to their eco-friendly nature, adaptability, cost-effectiveness, and ability to extend seed storage life (Kumar *et al.*, 2015). Plant-based pesticides, which are easy to produce and implement, hold promise for natural crop protection, particularly benefiting small-scale farmers (Shetie & Abrham, 2023).

The primary aim of this study was to evaluate the efficacy of *Acokanthera schimperi* and *Nicotiana tabacum* in controlling *Sitophilus zeamais* infestations in stored maize within the Wodera district of the Oromia region, Ethiopia. These plants were selected for their traditional medicinal use in various parts of Ethiopia and their antimicrobial properties (Mamo *et al.*, 2021).

2 Materials and Methods

2.1 Insect rearing (IR)

Maize used for rearing was sourced from the local market in Debre Berhan and disinfected in a refrigerator at temperatures ranging from -20°C to 0°C for 48 hours. The maize grains, heavily infested with Sitophilus zeamais, were collected from voluntary farmers in the Wadera district of the Guji zone, Oromia region, Ethiopia, and stored at temperatures between 30°C and 33°C with a relative humidity of 70-75%.

Unsexed adults of *S. zeamais* were carefully collected from the infested maize samples and introduced into thoroughly washed and dried rearing containers with disinfected, uninfested maize grains.

The insect rearing was conducted at the entomological laboratory of Addis Ababa University's Department of Zoological Sciences. Adults of *S. zeamais* of known ages were multiplied in sufficient numbers to conduct the experiment, following the rearing procedures outlined by Mesele *et al.* (2013).

After a seven-day rearing period, the adult insects were removed, and new medium was added to stimulate the growth of the newly emerged generation (F1 progeny). The one-month-old offspring, excluding the parental generation, were ultimately used in the subsequent toxicity experiment.

2.2 Preparation of botanicals

In assessing the effectiveness of botanicals for managing insect pests in stored maize, medicinal plants were used as treatments, specifically tree and shrub species. The selected species included *Acokanthera schimperi* (arrow-poison tree) and Nicotiana tabacum (cultivated tobacco). Nicotiana tabacum was sourced from a home garden, while *Acokanthera schimperi* was collected from its natural habitat. The leaves of both plants were carefully washed and shade-dried in the laboratory to prepare them for grinding. After drying, the plant parts were finely ground using a grinder.

Thirty unsexed adults of *S. zeamais* were introduced into each treatment jar, while control jars contained 20g of disinfected maize seeds, with three replicates for each treatment. The prepared plant powders were applied separately through topical application at rates of 4g, 8g, and 12g for each replicate, following a completely randomized experimental design (CRED). Aluminum Phosphide (Tanphos 56%) served as the standard check, with 0.9g of powder applied in three replicates.

After 24 hours, the mortality of *Sitophilus zeamais* was recorded for both treatments and their respective controls at three time intervals (24, 48, and 72 hours). Insects showing no movement were considered deceased, while live ones were returned to their respective jars.

2.3 Toxicity test

In analyzing the insecticidal impact of the botanicals on maize weevils (*Sitophilus zeamais*), the percentage of insect mortality was determined using the following equation (Waktole, 2014)

Corrected Mortality (%) =
$$\left(1 - \frac{n \ in \ Co \ before \ treatment \ \ n \ in \ T \ after \ treatment}{n \ in \ Co \ after \ treatment \ \ n \ in \ T \ before \ treatment}\right) \times 100$$

Where: Co - Control, T - Treated, and n - insect population.

The efficacy of botanicals in inducing maize weevil mortality was assessed using a one-way analysis of variance (ANOVA) at a significance level of 5% ($P < 0.05$) with SPSS version 16. Significant differences among treatment means were evaluated using the Least Significant Difference (LSD) for post hoc multiple comparisons. Additionally, the corrected mortality percentage was calculated to determine insect mortality in the control group. This analysis aimed to further evaluate the effectiveness of the botanicals in reducing maize weevil mortality.

3 Results and Discussion

3.1 Description of plant material

Two botanicals, *Acokanthera schimperi* and *Nicotiana tabacum*, were employed for their bio-insecticidal activities against the target insect (Table 1). *Acokanthera schimperi* is native to Ethiopia and has traditionally been used in Ethiopian medicine for its antimicrobial properties (Mamo *et al.*, 2021).

Nicotiana tabacum, commonly known as tobacco, is native to the Americas and primarily cultivated for its leaves, which are processed into tobacco products. Beyond its traditional uses, tobacco has been studied for its chemical constituents and potential applications. Kırcı *et al.* (2022) isolated new sesquiterpenoids and diterpenoids from the flowers of *N. tabacum* and assessed their antifungal activity, underscoring ongoing research into its chemical properties and potential uses.

Table 1. Plants tested for their insecticidal effects on adult maize weevil (*Sitophilus zeamais*)

No.	Local name	Scientific name	Habit	Location	Part used	Insect treated
1	Tamboo	*Nicotiana tabacum*	Shrub	Cultivated	Leaf	Maize weevil
2	Qaraaruu	*Acokanthera schimperi*	Tree	Wild	Leaf	(*S.zeamais*)

3.2 Toxicity Effects of plants on Adult *S. zeamais*

The study findings indicate that locally available plants with bio-insecticidal properties can effectively reduce *S. zeamais* infestation. These plants demonstrate high efficacy in disrupting the insect's life functions, along with benefits such as easy accessibility, affordability, low cost, and minimal time requirements for farmers (Table 2). *Nicotiana tabacum* achieved a 59% mortality rate among adult maize weevils, while *Acokanthera schimperi* resulted in an 18% mortality rate. In contrast, Aluminum Phosphide, serving as the standard check, achieved a 100% mortality rate.

Table 2. The botanical efficacy tests resulted in the mortality of *S. zeamais*

No.	Treatment	Form	Av. dose (g/seeds)	IBT	IAT	MDI	Mortality (%)
1	*N. tabacum*	Powder	8	30	12	18.3	59
2	*A. schimperi*	Powder	8	30	24	6.0	18
3	Standard check /AlP	Powder	0.9	30	0	30.0	100
4	Control	-	-	30	29	0.7	0

* α= 0.05, df= 11, F= 124.27, P-value= 0.00; AlP - Aluminum Phosphide, Av- average, IBT- insects before treatment, IAT- insects after treatment, MDI- Mean of dead insects.

Several researchers have evaluated the impact of various plant-derived extracts on the repellency and mortality of storage insect pests. Shite and Abrham (2023) reported that leaf tinctures of *Brucea antidysenterica* and *Carica papaya* effectively manage *S. zeamais*. Tawose and Bagbe (2021) documented that extracts from four indigenous plants in Nigeria—*Andrographis paniculata*, *Chromolaena odorata*, *Mucuna pruriens*, and *Datura stramonium*—induced mortality in *S. zeamais* after a 22-day exposure period. Sori (2014) found that plant powders from *Chenopodium* sp., *Nicotiana* sp., and *Maesa lanceolata* had high efficacy in controlling maize weevils, causing adult mortality rates of 22.22% to 66.67% and reducing the emergence of new progeny from 80.00% to 23.00% in Jimma Zone, Ethiopia.

A study in Jimma highlighted the effectiveness of tobacco (*N. tabacum*) leaf powder in reducing pest infestation on stored maize, resulting in a 50% mortality rate. Actellic dust, a standard insecticide, demonstrated approximately 70% mortality of adult *S. zeamais*, similar to Aluminum Phosphide (Wakitole, 2014). In Nigeria, the potential of *N. tabacum* leaf powder as a plant-derived insecticide against maize weevils has been recognized. Its local availability and bio-pesticidal potential position it as a promising candidate for enhancing traditional post-harvest protection practices (Idoko and Adebayo, 2011). Additionally, a study in the Amhara region of Ethiopia identified *A. schimperi* as a botanical with insecticidal properties, presenting a viable alternative to conventional insecticides with high efficacy against *S. zeamais* (Pol, 2002).

3.3 Adult Insect Mortality at Different Dosage Rates

Statistical analysis revealed a significant difference in average insect mortality between the two botanicals. However, the variations in averages across dosage rates within each botanical were deemed insignificant (see Table 3). This finding may be attributed to the 72-hour treatment period, during which maize weevils, known for their robust exoskeletons, might have exhibited resilience to the insecticidal properties of the botanicals. Additionally, the innate behavior of these insects, such as evading or moving away from the powder towards the top of the treatment jars, could have reduced

Table 3. Mean of insect mortality across different doses of botanicals

No.	Dosage ranges	Insect experimented	Mean of death/g of dose (mean $\pm$ SE)
1	Nt_1	30	17.00 ± 1.53
2	Nt_2	30	18.33 ± 2.03
3	Nt_3	30	19.67 ± 5.13
4	As_1	30	3.33 ± 0.88
5	As_2	30	6.33 ± 1.45
6	As_3	30	8.33 ± 1.45

* Nt_1- *N. tabacum* dose1, Nt_2- *N. tabacum* dose2, Nt_3- *N. tabacum* dose3; As_1- *A. schimperi* dose1, As_2- *A. schimperi* dose2, As_3- *A. schimperi* dose3, Df-degree of freedom, LS- Level of significance, SE- Standard error. Df = 8, LS = 0.05, F =2.10, P-value = 0.42

their contact with the botanical substance, resulting in a gradual and less pronounced impact.

In a related study, Edelduok *et al.* (2012) also reported a lack of significance across various doses of melon cotyledon (*Citrullus vulgaris*) powder treatment, with the LSD test indicating no substantial difference (P > 0.05). The study concluded that the robust exoskeleton of the weevils could hinder the effective penetration of the testa powder. Furthermore, the ground testa powder settled at the bottom of the container, potentially prompting insects to move towards the top of the grains, thereby reducing their contact with the plant material.

Limitation of the study

In this study, *Acokanthera schimperi* and *Nicotiana tabacum* are known to contain toxic compounds effective against storage grain insects. However, the safety of these extracts for humans, animals, and the environment is not addressed in this research.

4   Conclusion and Recommendations

The use of ecologically safe, locally available plant-based insect pest management strategies in maize production is crucial for ensuring socio-economic stability and food security in Ethiopia and across sub-Saharan Africa. Laboratory tests showed that *Nicotiana tabacum* (tobacco) emerged as a promising bio-insecticide, effectively causing high mortality in *Sitophilus zeamais* within three days of exposure. The application of *N. tabacum* demonstrated significant potential in reducing damage and controlling *S. zeamais* infestations in stored maize.

Replacing synthetic insecticides with locally sourced plant-based bio-insecticides offers substantial benefits, including reduced environmental pollution, minimized harm to non-target organisms, and prevention of grain contamination. To maximize these advantages, it is essential to train farmers and agricultural extension agents on the effective use of botanical insecticides, a practice that should be widely adopted throughout the country.

References

Alemnew, Y. (2017).- Studies on the management of maize weevil (*Sitophilus zeamais*) using botanicals on maize grain in storage.- MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Bekele, A.J., Obeng, O. D., & Hassanali, A. (1997). Evaluation of *Ocimum kenyense* (Ayobangira) as a source of repellents toxicants and protectants in storage against three major stored product insect pests. *Journal of Applied Entomology*, 121, 169-173.

Benti, T., & Ransom, J. K. (1993). Proceedings of the first National Maize Workshop of Ethiopia. *Institute of Agricultural Research and International Maize and Wheat Improvement Center*. Addis Ababa, Ethiopia.

Charles, A. M., Alice, W., Pittchar, J. O., & Zeyaur, K. R. (2016). Managing pests of maize: Farmers' perceptions, knowledge, and practices in western Kenya. *Crop Protection*, 90, 142-149.

Dubey, N. K., Bhawana, S. Z & Ashok, K. (2008). Current Status of Plant Products as Botanical Pesticides in storage pest management. *Journal of Biopesticides*, 1, 182 - 186

Edelduok, E., Akpabio, E., Eyo, J., & Ekpe, E. (2012). Bio-insecticidal potentials of testa powder of melon, *Citrullus vulgaris* Schrad for reducing infestation of maize grains by the maize weevil, *Sitophilus zeamais* Motsch. *Journal of Biology, Agriculture, and Health Care*, 2, 13-17.

Idoko, J.E., & Adebayo, R. A. (2011). Efficacy of Single and Combined Leaf Powder of *Nicotiana Tabacum* L. [Solanales: Solanaceae] with Reduced Rates of Pirimiphos-Methyl in Management of *Sitophilus Zeamais* Motschulsky [Coleoptera: Curculionidae]. *Journal of Agricultural Science*, 3: 276-280.

Iken, J.E., & Amusa, N. A., (2004). Maize research and production in Nigeria.- *African Journal of Biotechnology*, 3, 302-307.

Kırcı, N., Yılmaz, A. F., & Doğan, M. (2022). Isolation and antifungal activity of new sesquiterpenoids and diterpenoids from Nicotiana tabacum flowers. *Records of Natural Products*, 16, 293-299.

Kumar N., Ajeet K., Mishra S., (2015). - Indigenous Technology to Protect the Storage Life of Seed, *International Journal of Innovative Science, Engineering and Technology*.- 2: 607-612.

Mamo, H., Fekadu, M., & Tsegaye, A. (2021). Evaluation of the antimicrobial activity of leaf extracts of *Acokanthera schimperi*. *Journal of Experimental Pharmacology*, 13, 15-23.

Markham, R., Bosque-Perez, N.A., Borgemeister, C., & Meikle, W. (1995). Developing pest management strategies for *Sitophilus zeamais* and *Prostephanus truncatus* in the tropics.- *FAO Plant Protection Bulletin*, 42, 97-116.

Mesele, G., Emana, G., Abdurazak, Y., & Tesfaye T. (2013). Management of *Sitophilus zeamais* Motshulsky (Coleoptera: Curculionidae) and *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) using locally available agricultural wastes in Southern Ethiopia. *Journal of Agricultural and Crop Research*, 1: 10-16.

Midega, C.A.O., Bruce, T.J., Pickett, J.A., & Khan, Z.R. (2015). Ecological management of cereal stemborers in African smallholder agriculture through behavioural manipulation. *Ecol Entomo*, 40: 70-81.

Mishra, B. B., Tripathi, S. P., & Tripathi, C. P. (2012). Repellent effect of leaves essential oils from *Eucalyptus globulus* (Mirtaceae) and *Ocimum basilicum* (Lamiaceae) against two major stored grain insect pests of coleopterans. *Nature and Science*, 10, 50-54.

Musa, H. A. (2013). *Economic Efficiency of Smallholder Farmers in maize Production: The Case of Arsi Negele District, Oromia National Regional State, Ethiopia*. MSc thesis.

Piperno, D. R. (2011). The Origins of Plant Cultivation and Domestication in the New World Tropics: Patterns, Process, and New Developments. *Current Anthropology*. 52, 453-470.

Pol, J. L. (2002). Forest Is Not Only Wood: the Importance of Non-Wood Forest Products for the Food Security of Rural Households in Ethiopia. *Walia*, 22: 11-27.

Seyoum, A., Dorosh, P., & Gemessa, S.A. (2013). "Crop production in Ethiopia: regional patterns and trends," Food Agric. Ethiop. Prog. Policy Challenges, University of Pennsylvania Press, Philadelphia, PA, USA, pp. 53–83.

Shetie, G., & Abrham, C. (2023). Evaluating Plant Leaf Tinctures against Maize Weevils (*Sitophilus zeamais* Motsch.) in Stored Maize (*Zea mays* L.) under Laboratory Conditions. *International Journal of Agronomy*, 2023, 1-13.

Sori, W. (2014). Effect of selected botanicals and local seed storage practices on maize insect pests and health of maize seeds in Jimma zone. *Singapore J. Sci. Res*. 4(2):19-28.

Stathers, T.E., Riwa, W., Mvumi, B.M., Mosha, R., Kitandu, L., Mngara, K., Kaoneka, B., & Morris, M. (2008). Do diatomaceous earths have potential as grain protectants for small-holder farmers in sub-Saharan Africa? The case of Tanzania. *Crop Protection*, 27, 44-70.

Suleiman, M., & Rugumamu, C. P. (2017). Management of insect pests of stored sorghum using botanicals in Nigerian traditional stores. *Journal*

of Stored Products and Postharvest Research, 8, 93-102.

Tadele, T., Stephen, M., & Paddy, L. (2011). Effects of insect population density and storage time on grain damage and weight loss due to maize weevil (Sitophilus zeamais) and larger grain borer (Prostephanus truncatus). *Africa Journal of Agricultural Research*. 6, 2249-2254.

Tawosel, F.O., & Bagbe, A.S. (2021). Comparativeness of Insecticidal Action of Local Medicinal Plants against Stored Grains Pest (Weevils). *Annals of Experimental Biology*, 9, 1-6.

Tefera, T., Kanampiu, F., Groote, H.D., Hellin, J., Mugo, S., Kimenju, S., Beyene, Y., Boddupalli, P., Shiferaw, B., & Banziger, M. (2010). The metal silo: an effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop Protection*, 30, 240-245.

Waktole, S. & Amsalu, A. (2012). "Storage pests of maize and their status in Jimma Zone, Ethiopia,". *African J. Agric. Reseearch*, 7, 4056–4060.

Waktole, S. (2014). Effects of Selected Botanicals and Local Seed Storage Practices on Maize.- *Singapore Journal of Scientific Research*, 4, 19-28.

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Institutional Transparency of Urban Land Management in Ethiopia: a Case Study in Sebeta, Gelan and Sendaf-Bake Towns of the Oromia Region

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Abstract

The study examines the transparency of urban land management in Ethiopia considering the case of Sebeta, Gelan and Sendafa-Bake towns of the Oromia Region. To achieve the objective, the study employed a convergent research design within the framework of a mixed-methods research approach. Both qualitative and quantitative data were collected from primary and secondary sources. Interview schedules, interviews, focus group discussions, and document analysis techniques were used to solicit information. The study used both probabilistic and non-probabilistic sampling techniques to select sample respondents. Statistical and context analysis methods were utilized to present and analyze the data. The findings of the study indicate that the land management system in the study area lacked a rigorous transparency system. In addition, more than sixty percent of the respondents stated that the level of transparency in the official activities of land management offices was limited. The study, based on the findings, recommends that governments at regional and local levels need to ensure that the land management system follows open, consistent, and clear service provision standards to provide impartial, objective, and non-discriminatory services to citizens. This helps to ensure that an efficient and effective land and land-related service system is consolidated in the study area.

Keywords/Phrases: Transparency, Land management, Land service delivery, Towns in Oromia Region

1 Background and Purpose

Land in Sub-Saharan Africa is increasingly recognized as an important national policy issue (Adugna & Workalemahu, 2023 and Hafte & Pregala, 2021). However, land administration in the region suffers from a lack of transparency because of confusing regulatory frameworks and complex administrative processes. Nigatu (2024, p.2) stated that "Urban land management practices and processes have been vulnerable to mismanagement and corruption due to the absence of good governance." People who work in the land administration offices are exposed to the temptation of corruption. It is also acknowledged in the works of Zevenbergen *et al*., (2024) that inefficiency in land administration is a common, chronic, and severe problem that is increasingly recognized as a significant feature in the Region. Hence, lack of clarity on land policies and laws, poorly managed processes of urban land administration and development, and the resulting conflicts over land have long been among the major concerns that justify the essentiality of transparent land management in the region. This entails the need to ensure good governance in land administration (Transparency International, 2021).

Similar to most Sub-Saharan African countries, the increase in the economic weight of urbanization in Ethiopia is reflected in the increased concentration of people in urban areas (Ministry of Urban Development, Housing, and Construction, 2014). This has resulted in an alarming expansion of cities and towns into the boundaries of adjacent rural areas. Studies conducted by Giorgis & Goitom (2024); Olira (2022); Bekele (2021); Adugna, &

Workalemahu, (2023); Takele, Kwame & Melese (2014) and Alemie, Zevenbergen & Bennet (2015) stated that most of the urban centers in Ethiopia face numerous challenges in land management. In the country, urban land administration processes have been prone to unclear policy frameworks, corruption, and misappropriation due to the absence of transparent management (Fekadu, 2022). However, the Ethiopian government mentions the importance of applying the principles of transparency in urban land as stated below;

The prevalence of transparent management is a foundational institutional requisite for the development of an efficient, effective, equitable, and well-functioning land and land property market, the sustenance of a robust market economy, and for building a transparent and accountable land administration system (Federal Democratic Republic of Ethiopia (FDRE), Urban Lands Lease Holding Proclamation No. 721, 2011, p. 1).

In addition, the FDRE-Ministry of Urban Development, Housing, and Construction (2014) states that urban land is based on the establishment of a modern and effective system, which enables the realization of achieving development, growth, and transparent management of urban centers. In the country, the legal frameworks shaping land management include the land management policy and laws at federal and regional levels, including the urban land lease-holding proclamations and other regulations and directives. Besides, the Constitution provides regional States the responsibility of land administration, and the large regions have all issued several frameworks in their jurisdiction (Royal Tropical Institute, 2016). Studies conducted by Hafte & Pregala, (2021); Olira (2022); Ashenafi (2015); Alemie (2015); Takele, Kwame & Melese (2014), and Alemie, Zevenbergen & Bennet (2015), however, specified that the system of land administration in the country in general and in the four large regions (Amhara, Oromia, in the then SNNP, and Tigray Regions) in particular have substantial structural shortcomings. These studies found that the urban land administration system is bounded by various malpractices such as bribing, land grabbing, and other types of corruption. In this context, the government has also declared that land administration frameworks regulate what land-

holders can and cannot do excessively, making them top-down and rigid. As a result, flexibility in the land use system, which is desperately needed for socio-economic development, is eliminated with all the adverse implications for transparent and inclusive land use.

In the country, several researchers examined the land management system. Study reports mentioned in the above paragraph state that the theory and practice of the land administration system indicate theoretical and empirical gaps. In doing this, the study has attempted to fill the research gaps found in earlier research. Previous research studies also have tried to understand the land administration system from different perspectives. The study conducted by Transparency International (2014) has highlighted the prevalence of corruption in the land administration system of the country, while Alemie's (2015) study revealed the importance of cadaster in urban land management systems. Besides, Takele, Kwame & Melese, (2014) observed in their research that the ways of strengthening good management in urban land management in the country take a case study of Hawassa City. Olira (2022) has assessed the practices of urban land administration in Shashemene City while Hafte (2021) investigated the urban land governance of Mekelle City.

However, existing research works are limited to the study of urban land management in major urban centers particularly in Addis Ababa, Adama, Hawassa, Shashemene, Mekelle, and Bahir Dar. This implies that existing studies did not give adequate concern for the study of the institutional transparency of urban land management in the country. In this, empirical literature overlooked the institutional bottlenecks of transparency in urban land management in the study area. The issue of urban land management and the required institutional transparency thereof also needs further empirical analysis. In addition, indicators of institutional transparency need to be discussed to expose gaps in this regard. On top of this, there are no empirical studies conducted to examine the transparency of urban land management in the study area. In light of this, the current study aimed to examine the institutional transparency of the land management system in the country. This study examined the transparency of urban land man-

agement of small hitherto highly expanding urban centers found in the Oromia Region of Ethiopia. In support of this, the researcher has conducted a personal observation in the study sites and explored that there are problems (which include lack of openness in land service delivery, inadequate answerability of officials, and weak information supply to the citizens) in the process of ensuring transparent land service delivery in the urban centers of the Zone. The study hence, investigated the extent of transparency in the urban land management system of Sebeta, Gelan, and Sendafa-Bake of the Oromia Region of Ethiopia. In this, it attempted to assess the decision-making process, accessibility of official information, citizens' scrutiny of official activities, and other dimensions of transparency in the land management system of the study towns.

2   Institutional Transparency in Land Management

Transparency in official duties is an important value that public service providers ensure to the citizenry. It helps citizens to have confidence both in officials who perform their official duties and the quality of services being provided. Properly maintained, transparency in the public sector enables citizens to have relevant, timely, and credible information about the decisions and actions that public agencies take concerning the services that are delivered to citizens (Amalia, 2023). Source

Institutional transparency indicates that the policies, laws, regulations, charters, codes, and rules that govern land should be publicly available (Transparency International, 2021). It further covers the statutory instruments that govern land be comprehensible including legal literacy (Erkkila, 2020). Beyond this, institutional transparency in land management involves the organizational set-ups, tiers of decision-making processes and procedures and it is required to provide info leaflets, checklists, guides, and forms that specify the steps, time required to complete processes, and the means of access information about land including routes of appeal. The facilities and offices should also be open to the public (Zimmermann, 2008).

Urbanization and use of land for various services imply an "*increased need for well-designed land poli-*

cies to ensure the security of land-holders rights, to facilitate land access, and to maintain equitable and transparent land distribution" (World Bank, 2012, p. 1). In this context, the concept of transparency connotes that decisions and actions made by government organs need to be conducted in an open decision-making process based on legitimate rules and regulations. It indicates that pertinent and accurate official information is unreservedly and openly available to citizens affected by government decisions and actions. It also means that enough information is provided and that it is provided in easily understandable forms and media. Land management institutions need to develop new ways to record and maintain the land information that ensures improved service delivery within a reasonable time. Procedures for land allocation and conflict resolution should be clear and simple. On top of these, an effective transparency system facilitates the interaction, cooperation, and synergy between citizens and government offices, which in turn increases public trust in the government and its services (Konrad-Adenauer-Stiftung, 2011). Transparency in the land administration institutions is thus essential for "*sustainable development in terms of equitability, stakeholder participation, and benefits, and consistency in law and policy implementation*" (Burns & Dalrymple, 2008, p. 2). It is thus, affirmed that transparent management in the land administration cannot be treated separately from the management of other public sectors.

However, developing countries including Ethiopia do not have a good record in ensuring a legitimate and effective urban land administration system as they face various challenges in their effort to address the public demands. In most of these countries, although the land is a basic means of survival for the majority of the people, land administration processes in these countries are vulnerable to multifaceted problems that range from simple administrative bottlenecks to state corruption. This in turn makes the transparency of the policies and practices of land administration in the countries questionable. Administrative, economic, political, institutional, and technological challenges put pressure on governments at both national and local levels to respond to the collective and individual needs and interests of citizens. However, recent debates in public administration literature indicate that the application of transpar-

ent management principles in the process of public policy-making and implementation in general and urban land management, in particular, overcomes the problems, ensures effective delivery of land and land-related services, and addresses the core demands of the people in these countries. In the case area, accordingly, the study has examined the extent of the transparency of urban land management in light of theoretical perspectives of transparency discussed in the above.

3 Research Methods and Materials

3.1 Research Approach and Design

A systematic examination of the institutional transparency of land management requires the application of both quantitative and qualitative methods (Burns & Dalrymple, 2008). In this background, both quantitative and qualitative research approaches were used in the study. Exploring the views of respondents and analyzing documents to describe the extent of transparency in the land management process required both approaches. In achieving the objectives of the study, both objective analysis of numerical data and interpretive understanding of the qualitative responses from respondents were conducted. The research has applied a convergent research design. In this design, both quantitative and qualitative data were collected in a cross-sectional manner where the researcher, using a snapshot approach, collected data at one point in the course of the research. Besides, the analysis and interpretation of both quantitative and qualitative data were conducted at the same time.

3.2 Data Sources and Type

The data sources for the research were both primary and secondary. Primary data was collected from sample households, key informants, and focus group participants. The primary data was supported by the review of unpublished documents, and statistical data, which were gathered from different regional and local government offices. In utilizing secondary sources, published articles, research works, previous studies, books, government official reports from the federal and regional offices, official documents from town administrations, government policy, and legal documents, Central Statistical Agency publications, and other sources were reviewed. In addition to this, the collection, and analysis of both qualitative and quantitative data were made. Quantitative data were collected through interview schedules while qualitative data was gathered through key informant interviews, focus group discussions, and document analysis.

3.3 Selection of Respondents

Before the establishment of Sheger city in October 2022, the towns in the Oromia Region surrounding Addis Ababa included eight major town administrations (Gelan, Burayu, Sebeta, Sululta, Dukem, Lege-Tafo-lege Dadi, Sendafa-Bake and Holota). Currently, except Sendafa-Bake and Holota towns, the remaining six towns are included in the new establishment of Sheger City as the sub-cities of the Sheger City Administration. During the time this research is conducted, three towns namely Sebeta, Gelan, and Sendafa-Bake towns were selected using simple random sampling technique to ensure that adequate representation was ensured. In selecting the survey respondents, a systematic random sampling technique is used. It is employed to identify sample respondents from each randomly selected town. Sample respondents were selected using a sampling formula that is suggested by Krejcie & Morgan (1970, p. 610). The formula is stated as:

Sampling Formula: $S = \frac{\chi^2 NP(1-P)}{D^2(N-1)+\chi^2 P(1-P)}$

Where:

S = required sample size; χ^2 = the table value of chi-square for 1 degree of freedom at 0.05 confidence level (1.96); N = the population size; P = the population proportion (assumed to be 0.50 as this would provide the maximum sample size); and d = the degree of accuracy expressed as a proportion (0.05).

Based on this, sample size determination was conducted and a sample size of 382 household respondents was taken from the three towns as a representative sample of the total population. However, 357 interview schedules were properly recorded and analyzed by data collectors while the remaining 29 of them were discarded due to errors made in filling in the answers of respondents appropriately, and some of the questionnaires lacked completeness and pre-

cision. Hence, quantitative data was collected from 357 respondents making the response rate around 93.5%. The quantitative data was edited; coded, classified, entered, and analyzed using SPSS (Statistical Package for Social Sciences version 25), and the analysis was made to present the findings using frequency distribution, percentage, and descriptive statistics of the median. On the other hand, qualitative data was gathered from key informants. Six key informant interviews were conducted to collect data. From each town, two key informants were purposively selected based on their knowledge of the matter. Two key informant interviews were also made with experts working in regional, and federal Land Management and Development Offices. In addition, one FGD was conducted in each town. The FGD participants were drawn purposively from different segments of the population. Elders, government employees, merchants, and youth representatives were members of the FGDs. Qualitative data was analyzed using content analysis of interviews and text analysis of documents. Regarding ethical issues of the research, the study has tried to respect the rights of participants and maintained informed consent, confidentiality, and anonymity.

4   Results

In the context of urban land management, the emphasis is required on establishing and strengthening a transparent system as the sector is highly susceptible to corruption and other forms of maladministration. In light of this, the following section presents the results and discussion made based on data collected from various sources regarding the level of transparency in urban land service delivery in Sebeta, Gelan, and Sendafa-Bake towns of Oromia Region around Addis Ababa, Ethiopia.

The following graph indicates that an overwhelming of the respondents 73.1% (40.9% and 32.2% disagree and strongly disagree respectively) have an opinion that the decision-making process on land service delivery in the study towns was not clear to citizens while around 23% of them held a neutral opinion. On the other hand, very few respondents (14.5%) agreed that the process of decision-making was clear to citizens. Similarly, the majority (58.8%) of household heads who participated in the survey

declared that decisions and actions of land administration were not open to citizens' scrutiny while around 14% of them had a claim against the majority. The remaining 36.6% of the respondents had a neutral opinion on the matter.

The opinion of two-thirds of the respondents showed that they disagreed with the claim that mechanisms used to resolve land disputes in the study area were clear and reliable whereas 12% agreed with the claim. In the views of 61.9% (44% disagree and 17.89% strongly disagree) of the respondents, land administrators were not committed to being aware citizens of the land policies and laws in the study area. On the contrary, around 16% of respondents held the view that Urban Land Management and Development officials worked to let citizens understand the policies and other institutional frameworks put in place by the regional and local governments.

On top of these, more than 61% of the respondents claimed that citizens had little information on the manner land administration officials were appointed or dismissed while around 26% of them had a neutral opinion about the issue. The remaining 12% of participants stated that citizens had information on the manner officials were appointed or dismissed. Besides, more than 58% of the participants disagreed with the assertion that official information on land service delivery was easily accessible to citizens in the towns. However, around 17% them of claimed that official information about land management in the study area was easily accessible to the residents. The remaining 24.1% of them were neutral on the subject of inquiry.

Similar to the quantitative data, the qualitative information gathered from respondents through key informant interviews, and FGDs showed that the extent of providing transparent urban land services was limited. In this milieu, one of the key informant interviewees (conducted in August 2021) confirmed that there was low transparency in the land management practices of the town. He mentioned that decisions and actions made by municipal administration were not adequately transparent to the residents of the town. Additionally, the key informant stated that citizens rarely get timely, accurate, and credible information regarding urban land management.
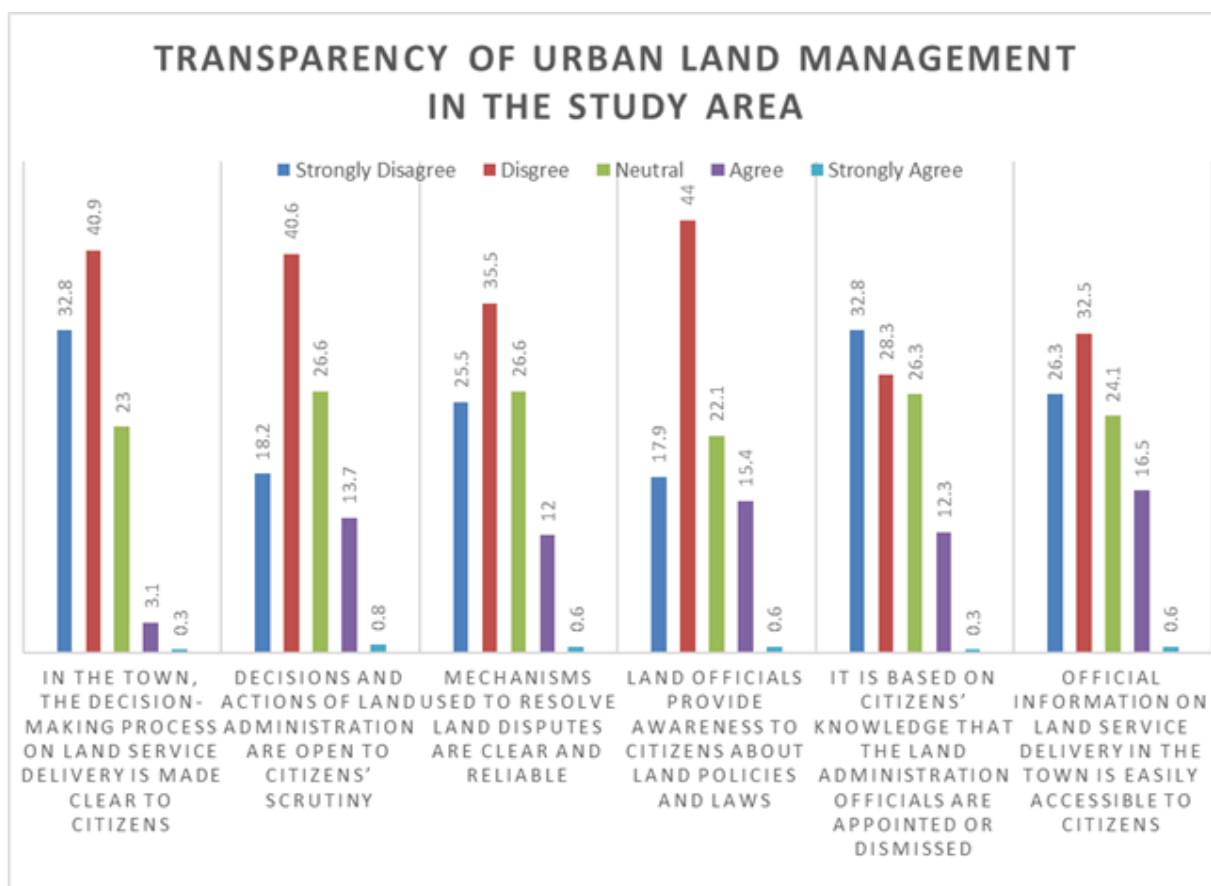
Graph 1. Transparency of Urban Land Management in Sebta, Gelan, and Sendafa-Bake towns of Oromia Region (Source: Field Survey, December, 2021)

In the same manner, a key informant from Gelan town shared the views raised by other key informants (conducted in August, 2021). As he mentioned, it was difficult to judge the strength of transparency in the land management system of the town. According to the informant, some of the officials were not cooperative enough to provide adequate and reliable information about the process of land management and development. Besides, the public had little knowledge about how appointments and dismissals of the Land Management and Development Bureau head and vice head were made. Moreover, the process of resolving land and land-related conflicts faced intricate adjudication processes. He further pointed out that to get appropriate information, service seekers were required to visit offices repeatedly.

FGD participants in Sebeta town had arrived at the same conclusion as the key informants in Sendafa-Bake and Gelan Towns. FGD participants mentioned that decisions and actions taken by the Land Management and Development Bureau of the town were not adequately transparent. They argued, there were information brokers between service seekers and officials, and service seekers were expected to bribe brokers to get accurate land information and services. Land brokers manipulate official information, which was at least supposed to be on board for public awareness. In the words of one of the key informants;

Service seekers need accurate and reliable information. However, official information is manipulated and is not easily accessed. 'Middlemen' deal with some of the officials and manipulate official information for their advantage. Service seekers need to visit offices frequently to get information and services although it is tiresome. There are times when service seekers are forced to deal with brokers to get accurate information and services as a shortcut. This made the transparency of land service delivery handicapped. The municipal land management office has failed to establish a transparent system to address residents' interests (FGD Participant in Sendafa-Bake Town, December 2021).

FGD participants also confirmed that elected representatives of the people at the municipal level rarely scrutinized the activities of the land management bureau. However, participants also admitted that there were efforts in recent times to avail land-related information on official boards to reach citizens. Participants acknowledged that in recent days, there were improvements made by the local governments to provide adequate and reliable information about land management to citizens. Similarly, almost all key informant interviewees at Federal and Regional Governments admitted that there were visible deficiencies in the transparency of urban land management practices in the study towns.

5 Discussions

In summing up, it is clear from the above quantitative and qualitative analysis that land management practices in Sebeta, Gelan, and Sendafa-Bake towns require further improvement as they lack an adequate system of transparency. Citizens had limited access to official information about decisions and actions regarding land. In this context, the roles of citizens were given meager roles by the municipals' land management activities as if they did not have a stake at all. In broader terms, land management practices need to integrate the constitutional as well as democratic rights of citizens enshrined in the institutional frameworks to check the activities and performances of the government service delivery system. Besides, the data collected from respondents revealed that citizens had limited access to the official decisions regarding land service delivery. This also contradicts the legal rights of citizens to have adequate information regarding public service delivery as stipulated in the FDRE Constitution Article 29. Additionally, it is found that citizens should have visited offices repeatedly and sometimes were required to incentivize officials to get accurate and timely information and services. On top of this, widespread land brokering activities in the land administration system had limited citizens' roles in scrutinizing the decisions and actions of municipal administrations. This paved the way for malpractices and corruption in the service delivery system. In the view of respondents, the institutional transparency in the land service delivery process was limited. It is inferred from the empirical data that there has been an insubstantial transparency

system in the land management offices. This is manifested in the situation that citizens got low access to land information, decision-making activities were not clear to citizens' and citizens did not have adequate knowledge of how land administration officials were appointed or dismissed.

Quite a lot of studies have shown similar findings. According to Dinka, Grima & Armies, (2016, p. 29), "*there is no transparency of decisions and action taken by urban land management and development officials in Shanbu town*" in the Oromia Region. The report by Transparency International (2014, p. 6) concluded that the primary "*driver of corruption in the country is the lack of transparency and access to information. Lack of transparency is seen to permeate almost all aspects of land administration in the country*".

A recent study conducted by Adugna, & Workalemahu (2023) indicated that lack of transparency is one of the Challenges to the Practice of Good Governance in Urban Land and Use Planning in Ethiopia. Similarly, Nigatu (2024) showed that one of the determinants of urban land governance is transparency. The empirical evidence displayed by Hafte & Pregala (2022) supports the same idea. They found that the absence of accountability, the lack of transparency, little public participation, the existence of rampant corruption, and the violation of the rule of law were the major determinants of customer levels of satisfaction in Mekelle City of Tigray Region.

In a study conducted by Ashenafi, (2015), it is found that land management and development activities in Addis Ababa City have failed to give adequate concern for the values of a transparent land service delivery. Similarly, MohammedHussein (2008) conducted a study in Bishoftu town and revealed that the lack of a transparent service delivery process has hampered citizens to have timely, accurate, and credible land-related information in the town. This is also attested in the Ethiopian Ministry of Urban Development, Housing, and Construction (MoUDHC) publication that local governments have failed to ensure transparency in land service delivery (MoUDHC, 2014). More to the point, a study conducted by Deininger, Hilhorst & Songw (2014) has confirmed that the land management practices in most devel-

oping countries are susceptible to corruption as the process lacks a transparent service delivery process. Moreover, Misganaw (2019, p. 1) concluded that "*the post-1991 urban land management of Ethiopia opens a loophole for corruption due to its contents lacking clarity and non-transparent implementations, which attract many in the line to exercise administrative malpractices such as partiality, favoritism, working with illegal brokers and the of course corruption*".

The literature on public sector transparency clearly indicates that land and land service delivery should meet the requirements set in urban land policies, and laws. The information about land and land related services should easily be accessible and be publicly available. In addition, the decision-making processes and procedures applicable the process of service delivery need to specify the steps, and time required to complete land service delivery and ensure that the means to access information is easily accessible to citizens.

In general, the aspects of transparency of land management considered in the study indicates that there was low level of transparency of the decision-making process on land service delivery. Citizens had limited access to land and land related official information and their level of involvement in ensuring transparency in the land management system was also inadequate. The result from the three towns showed consistency. The researcher claimed that there was no major differences of results among the three towns considered in the study. The researcher argues that transparent land service delivery is paramount in ensuring that the decision-making process on land service delivery is made clear to citizens. Decisions made by the Land Management Office are required to be open to citizens' scrutiny. This helps to maintain the integrity of the service delivery system. It also contributes to the viability and credibility of municipal land management processes in the eyes of citizens. Besides, transparency ensures that citizens can easily access information, and the mechanisms used to solve land disputes will be clear and reliable. This significantly increases the legitimacy of the land service delivery system. In considering the management perspective, lack of transparency in land management practices exacer-

bates service provision inefficiency, corruption, maladministration, citizens' dissatisfaction, and other forms of government bottlenecks. This in turn deteriorates public legitimacy and puts municipal land management practices of the study area in the realm of weak management systems. On the other hand, it is an acknowledged fact that land service delivery requires that procedures for land allocation and dispute resolution follow the due process defined by government law. Hence, ensuring transparency allows the free flow of official information that ensures citizens exercise their basic rights and makes institutions and their service delivery process open to any relevant entities.

6 Conclusions

Access to urban land is a strategic prerequisite for the provision of adequate shelter for all and the development of sustainable human settlements affecting urban areas. However, urban land management remains a highly complex and contentious issue in Ethiopia, involving a complex processes, aspects and stakeholders. The failure to adopt, appropriate land management practices at all levels of government remains a primary cause of academic concern. In this, the study has assessed the transparency of urban land management in Ethiopia focusing on the case of Sebeta, Gelan, and Sendafa Bake of Oromia Region. Accordingly, the study identified that the practices of land management in the study towns lack an adequate system of transparency. Citizens had limited access to official information regarding decisions and actions made by Land Management and Development offices. In addition, the extent to which official activities were made in a transparent process was limited due to widespread land corruption and brokerages. Citizens' engagement in scrutinizing the decisions and actions of municipal land management and development activities was also inadequately institutionalized.

Implications of the study

The study has examined a topic that is poorly investigated in the Ethiopian context. A few types of research have examined the institutional transparency of urban land management in the area where the highest rate of urbanization is exhibited both in

the region and in the country. Hence, such an intrinsic deficit in the literature on the subject of the study calls for further academic research on the topic. In addition, the study has analyzed the nature of urban land management exclusively from an institutional transparency perspective. It did not touch upon other aspects of land management and development activities. However, it is also necessary to study urban land management with rural land policies and practices.

Recommendations

Based on the findings discussed in the above sections, the study has suggested the following recommendations:

- The study found that the decision-making process on land service delivery is not from citizen to citizen. Hence, the decision by municipality as well as regional urban land management offices should be made transparently and clearly to stakeholders.
- It is also recommended that the decisions and actions of land administration offices need to be open to citizens' scrutiny so as they can act as whistleblower and participate in the information board as members. This helps to combat malpractices and corruption in the sector.
- The study found that the mechanisms used to resolve land disputes are not clear and reliable. Therefore, concerned government agencies should work diligently to ensure that land dispute settlement mechanisms are reliable and patent to citizens.
- Municipal administrations should be committed to properly aware citizens of policies and laws that govern urban land administration.
- It is also important for both the government and service takers that land and land-related information are easily accessible and citizens have the right to have information regarding the appointment and dismissal of land administrators though their participation in the governance process of local governments.

References

Adugna, F. & Workalemahu, L. D. Challenges to the Practice of Good Governance in Urban Land Use Planning: The Case of Two Selected Ethiopian Towns. *Sustainability*, Vol. 15, 7248. https://doi.org/10.3390/su15097248

Alemie B. (2015). *Urban Cadasters for Urban Land governance: A Socio-Technical Analysis*. Enschede, Netherlands.

Alemie B. K., Zevenbergen J., & Bennett R. (2015). *Assessing Land governance in Ethiopian Cities* (2002 -2011): Lessons for the Implementation of the 2011 Urban Land governance Policy, the Netherlands, FIG Working Week 2015a, Sofia, Bulgaria, 17-21

Amalia, M.M. (2023). Enhancing Accountability and Transparency in the Public Sector: A Comprehensive Review of Public Sector Accounting Practices. *Journal of Es Accounting and Finance*, Vol. 1, No. 03.

Ashenafi A. (2015). Assessment of Good Urban governance Practice in the land Administration of Addis Ababa: The Case of Yeka Sub-City. Addis Ababa, Ethiopia. MA Thesis, Addis Ababa University, Ethiopia.

Bekele S. A. (2021). Good Governance in Oromia: Challenges and Strategies (Major Cities in Arsi and East Shewa zone in focus, Ethiopia). *Journal of Entrepreneurship & Organization Management*. Volume 10, No.3.

Burns, T., & Kate Dalrymple. (2008). Conceptual Framework for governance in the land Administration. International Federation of Surveyors, Article of the Month, Sweden.

Degu N.B. (2024) Practices and determinants of urban land governance in Sheger City, Ethiopia. *Journal of urbanization, urban, land, governance, land governance.*

Deininger, K., Hilhorst T., & Songwe V. (2014). *Identifying and addressing land governance constraints to support intensification and land market operation: Evidence from 10 African countries*. World Bank, Washington, DC, United States, *Food Policy*, Vol. 48, pp. 76-87.

Dinka T., Girma D., & Ermias A. (2016). An Assessment of the Challenges and Prospects of Good

Urban governance Practice in the Land Administration System: Case of Shambu Town, Oromia Region, Ethiopia. Department of governance and Development Studies, *Journal of Good governance and Sustainable Development in Africa (JGGSDA)*, Vol. 3, No 3, Jimma University, Jimma, Ethiopia

Erkkila, T. (2020). Transparency in Public Administration. Oxford Research Encyclopedia of Politics, Oxford University Press, Oxford

FDRE. (2011). Urban Lands Lease Holding Proclamation No.721/2011. A proclamation to provide for Lease Holdings of Urban Lands,. *Federal Negarit Gazeta of the Federal Democratic Republic of Ethiopia, 18ᵗʰ year No. 4,*. Addis Abeba, 2011.

Fekadu M. Z. (2022) Assessment of Transparency Practices in Urban Land Administration: The Case of Wolkite Town Municipality, Ethiopia. *European Journal of Business and Management*, Vol.14, No.17.

Giorgis G. C. & Giotom A. B. (2023). Urban Horizontal Expansion and Its Effect on Rural Community Livelihood: The Case of Sheger City (Oromia Special Zone Surrounding Finfinne OSZSF) Towns and Addis Ababa City Administrations. *Journal of Urban Development Studies*. Vol. 3, Issue 2.

Hafte G G. & Pregala P. (2021). Urban Land Governance in Ethiopia: Empirical Evidence from Mekelle City. Stellenbosch University. *Journal of Public Administration*. Vol.56, N0. 3.

Konrad-Adenauer-Stiftung. (2011). *Concepts and principles of democratic governance and accountability*. A guide for peer educators, European Union, Uganda Office 51a Prince Charles Drive Kampala.

Krejcie, R.V. & Morgan, D.W. (1970). Determining sample size for research activities. *Journal of Educational and Psychological Measurement*, vol. 30, pp. 607-610.

Ministry of Urban Development, Housing, and Construction. (2014). *National Report on Housing and Sustainable Urban Development*. Addis Ababa, Ethiopia.

Misganaw G. Beza. (2019). Corruption in the Post-1991 Urban Land governance of Ethiopia: Tracing Major Drivers in the Law. Conference on Land Policy in Africa, CLPA- 19 Abidjan, Cote d'Ivoire, 4-8 November 2019

MohammedHussen M. (2008). Customers' satisfaction in the land delivery service by urban local governments: *a case study of Bishoftu Town Administration*. MA thesis, College of Business and Economics, Addis Ababa University, Addis Ababa, Ethiopia.

Nigatu, D. B. (2024). Practices and determinants of urban land governance in Sheger City, Ethiopia. *Frontiers in Sustainable Cities*, 6, 1387751.

Olira K. B. (2022). Urban land administration practices in emerging cities of Ethiopia: the case of Shashemene City of Oromia Regional State, Southern Ethiopia International Journal of Current Research ·

Royal Tropical Institute. (2016). *Food Security and Land governance Factsheet Ethiopia*. Land governance for Equitable and Sustainable Development, Netherlands.

Takele N., Sungena Kwame C. Serbeh-Yiadom, & Melesse Asfaw. (2014a). Strengthening Good governance in Urban Land governance in Ethiopia: A Case study of Hawassa. *Journal of Environment and Earth Science*, Vol. 4, No. 15.

Transparency International. (2014). *Ethiopia: Overview of corruption in the land administration*. Contributor, Lindner, Samira.

Transparency International. (2021). Urban & Peri-Urban Land Governance in Zimbabwe towards a Corruption-free, Transparent and Accountable System.

World Bank. (2012). *Diagnosing Corruption in Ethiopia: Perceptions, Realities, and the Way Forward for Key Sectors*. 1818 H Street NW, Washington DC, USA, Editor Janelle Plummer.

Zimmermann, W. (2008). Effective and transparent management of public land: experiences, guiding principles and tools for implementation. *International Federation of Surveyors*, 17.

Occurrence and Associated Risk Factors of Inedible Foreign Objects in Cattle Butchered at Dilla Municipal Abattoir, Southern Ethiopia

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Abstract

The research was conducted on cattle slaughtered at the Dilla Municipal Abattoir in the Gedeo Zone of Southern Ethiopia from March to July 2024. The study aimed to evaluate the prevalence and associated risk factors of indigestible waste objects in slaughtered cattle. A cross-sectional study design was employed to assess the animals through both ante-mortem inspections and post-mortem examinations. During these examinations, various foreign bodies were identified in the rumen and reticulum. Out of 384 slaughtered cattle, 172 (44.79%) tested positive for the presence of foreign bodies. The prevalence of foreign bodies showed a significant difference based on the sex of the cattle ($\chi^2 = 7.07$, $p < 0.01$) and age categories ($\chi^2 = 6.01$, $p < 0.05$). Post-mortem results revealed that the most found foreign objects included plastics (21.5%), nylon clothes (20.93%), rope (13.95%), and iron/wires (11.63%). Plastic materials were primarily located in the rumen, while non-plastic objects were mainly found in the reticulum. Rumen foreign bodies had a higher prevalence than those found in the reticulum ($\chi^2 = 7.3$, $p < 0.00$). Additionally, the prevalence of foreign bodies varied significantly across different age groups in relation to body condition ($\chi^2 = 7.95$, $p < 0.05$). These findings indicate that the ingestion of waste materials poses significant veterinary health challenges, leading to decreased production and productivity, which ultimately results in higher mortality rates in cattle managed under extensive systems. In conclusion, these results can inform the formulation of policies for solid waste management and strategies aimed at reducing environmental pollution while safeguarding animal health. Therefore, it is recommended that further surveillance and monitoring of organ condemnation at the Dilla abattoir be implemented to control the spread of zoonotic and other diseases.

Keywords/Phrases: foreign body, Indigestible product, plastic, prevalence, reticulum, rumen

1   Introduction

The occurrence of inedible foreign objects in cattle, especially those intended for butchering, is an increasing concern worldwide (Thomas *et al.*, 2017). This issue encompasses various aspects of animal health, food safety, and economic implications within the livestock industry. In many developing nations, including Ethiopia, domestic animals are frequently exposed to indigestible foreign objects from multiple sources due to environmental contamination with undesirable solid materials (Abebe and Nuru, 2011). The widespread presence of these ma-terials contributes to environmental pollution, and the ingestion of foreign objects poses a significant challenge to animal development in tropical regions (Gurara *et al.*, 2020). Ruminants are the most affected livestock in this regard.

The anatomy of ruminants' digestive systems leads to indiscriminate feeding habits, resulting in the ingestion of solid waste. Furthermore, the expansion of industrialization and agricultural mechanization has increased environmental pollution due to improper waste disposal, further elevating the risk of animals ingesting solid waste objects (Desiye and

Mersha, 2012; Jaja *et al*., 2023). In developing countries, the ingestion of foreign bodies is particularly common, often exacerbated by substandard animal management practices. Nutritional deficiencies and feed shortages can also increase the likelihood of foreign body ingestion by animals (Duresa *et al*., 2022).

The presence of foreign bodies in the forestomach of ruminants can trigger acute reticulo-peritoneal inflammation, leading to conditions such as peritonitis, pleuritis, and pericarditis. This results in significant production losses and, in severe cases, animal mortality (Ramprabhu *et al*., 2002; Mekuanint *et al*., 2017). Additionally, foreign bodies can impair the assimilation and absorption of volatile fatty acids, reducing body weight gain and hindering animal fattening.

Overall, this issue has substantial economic implications due to the marked decrease in milk and meat production, increased treatment costs, and higher mortality rates (Sileshi *et al*., 2013). While there have been efforts in Ethiopia to study the prevalence of various infectious diseases, the problem of ingested foreign bodies has not received adequate attention as a distinct health concern. Moreover, in the study area, information about the prevalence and impact of indigestible foreign bodies in cattle is notably limited.

Thus, this study focuses on the prevalence and location of indigestible foreign bodies in the forestomach (rumen and reticulum) to address the health and digestive challenges faced by cattle. Additionally, identifying associated risk factors will aid in developing management protocols, preventive strategies, and policies for addressing foreign body ingestion in animal health and mitigating environmental pollution. The objectives of this study are to assess the prevalence and distribution of indigestible foreign bodies and to identify related risk factors in cattle butchered at the Dilla Municipal Abattoir.

2 Materials and Methods

2.1 Study Area

The study was conducted at the Dilla Municipal Abattoir, located 365 km from Addis Ababa in Southern Ethiopia. Dilla is situated at a latitude of $6^{o}24'30"$N and a longitude of $38^{o}18'30"$E, with an average elevation of 1,570 meters above sea level. The town is approximately 90 km from Hawassa. The Gedeo Zone is characterized by a warm and humid climate, with a mean annual temperature ranging between 17°C and 22.4^{o}C, and mean annual rainfall between 1,200 and 1,800 mm.

The population of Dilla is estimated to be 102,624, comprising 50,286 males and 52,338 females. The Gedeo Zone has an assessed livestock population of 133,925 cattle, 197,846 sheep, and 22,621 goats (CSA, 2021).

2.2 Study Population

The study was conducted on 384 apparently healthy butchered cattle of both sexes at the Dilla Municipal Abattoir from March to July 2024. The slaughtered cattle originated from two agro-ecological zones (midland and lowland) and were kept under various management systems. The animals were categorized based on age, sex, body condition, and breed to assess the occurrence of ingested inedible solid waste materials.

2.3 Study Design

A cross-sectional study was conducted at the Dilla Municipal Abattoir from March to July 2024 to examine the presence of solid waste materials in the rumen and reticulum of butchered cattle. The study considered breed, age, body condition, sex, and origin of the cattle as potential risk factors. Age groups were classified as young, adult, and old based on dentition (Johnson *et al*., 1997). Body condition was assessed through visual inspection and palpation of the lumbar vertebrae (Rabana *et al*., 2022).

2.4 Sampling Technique and Sample Size Determination

The sample size was determined using the equation given by Thrusfield (2005). The test estimate was decided based on an anticipated predominance of 50% and a desired precision of 5% at a 95% confidence interval. The sample size was calculated utilizing the following formula:

$$N = \frac{(1.96)^2 P_{exp}(1 - P_{exp})}{d^2}$$

Where, N = required sample size; P_{exp} = expected prevalence; d^2 = desired absolute precision.

Therefore, the minimum sample size of the present study was 384.

2.5 Method of Data Collection

Ante mortem examination

Ante-mortem examinations were conducted to assess the age, sex, breed, and body condition of the cattle. Age was categorized as young (<5 years), adult (5-10 years), and old (>10 years). Body condition was recorded as poor, medium, or good based on the animal's appearance and manual palpation of the spinal processes and transverse processes of the lumbar vertebrae, as described by Nicholson and Butterworth (1986) and Mangun *et al.* (2024). Breeds were classified as either local or crossbred, depending on the species of animal brought to the abattoir. The age of the animal was determined based on dentition, as outlined by Kelly (1975) and Mohammed *et al.* (2014).

Postmortem examination

Postmortem examinations were performed on both the rumen and reticulum to determine the presence or absence of ingested solid materials. After butchering, the stomach was carefully removed from the abdominal cavity and examined for foreign materials through palpation and visualization. Any foreign objects discovered during the examination were washed with clean water to facilitate observation and identification. The location and type of solid waste found were recorded.

2.6 Data Analysis

The data collected was entered into a Microsoft Excel worksheet and analyzed using the Statistical Package for Social Sciences (SPSS, Version 20). Descriptive statistics, such as means and percentages, were used to summarize the results. The prevalence of foreign bodies in the rumen and reticulum was calculated as a percentage by dividing the total number of cattle positives for ingested foreign bodies by the total number of cattle inspected. The Pearson chi-square (χ^2) test was employed to examine the association between the prevalence of foreign bodies and potential risk factors. Significant differences were considered at P $\leq$ 0.05.

2.7 Ethical clearance

The study was approved in accordance with ethical principles regarding animal handling. It was conducted with safety and humanity to protect animal welfare and uphold research ethics. All relevant slaughterhouse rules and protocols were followed during the study. Before data collection, the Dilla Municipal Abattoir was fully informed of all aspects of the study in written form.

3 Results and Discussions

3.1 Solid indigestible materials in rumen and reticulum

A total of 384 butchered cattle at the Dilla Municipal Abattoir revealed a prevalence of 44.79%. This finding aligns with studies by Negash *et al.* (2015) in Haramaya and Shiferaw *et al.* (2014) in the Amhara region, which reported prevalence rates of 43.4% and 41.8%, respectively. Conversely, Ismael *et al.* (2007) identified a significantly higher prevalence of 77.41% among adult dairy cattle in Jordan. In contrast, Bassa and Tesfaye (2017) found a much lower prevalence of 17.16% at the Wolaita Sodo Municipal Abattoir in Ethiopia.

The higher prevalence rates observed in some studies may be attributed to various factors, including feed shortages and the lack of supplementary feeding during the extended dry season, which often leads livestock to consume inappropriate materials (Tesfaye and Chanie, 2012). Among the 172 positive cases identified, approximately 68.2% of foreign bodies were located in the rumen, while 25.58% were found in the reticulum, and 6.4% were present in both organs. This suggests a significant presence of foreign bodies in the rumen, although lower than the 70.2% prevalence reported by Bitew (2025). The higher prevalence of foreign bodies in the rumen in previous studies may be explained by the fact that a substantial portion of ingested feed is directed to this organ, which, being the primary digestive compartment, increases the likelihood of foreign body accumulation.

The foreign bodies detected included plastics, nylon

clothes, iron/wire, sacks, hair, leather, and combinations such as plastic plus cloth and plastic plus wire plus nails. These materials were frequently encountered among the positive cases in the study. This prevalence may arise from the widespread use of plastic for shopping, waste storage, and food packaging, which is often improperly disposed of in the environment, leading to consumption by free-grazing animals. Additionally, the high proportion of plastic foreign bodies may be exacerbated by the lack of recycling industries in the study area, contributing to the prevalence of plastic-related incidents in the rumen. The anatomical structure of the rumen also facilitates the retention of various ingested foreign bodies, particularly plastic materials (Tesfaye and Chanie, 2012).

Figure 1. Disclosed organs from rumen, reticulum and both

3.2 Occurrence of Foreign Body Based on Sex and Breed

In this study, among the 384 examined cattle, 162 (47.09%) were male and 25% were female. Of these, 311 were local breeds and 73 were crossbreds. Notably, the prevalence of foreign bodies in the rumen and reticulum differed significantly between the two sexes and breeds (P < 0.05). Specifically, 47.6% of local breed cattle tested positive for foreign bodies, while only 32.9% of crossbred cattle showed similar results. Interestingly, female cattle exhibited a lower prevalence of foreign body ingestion compared to their male counterparts. This finding may be related to the practice of limiting the slaughter of female animals to those that are anestrus. This contrasts with a study by Bihon *et al.* (2020), which reported a higher prevalence of foreign bodies (17.22%) in female cattle compared to males at the Wolaita Sodo Municipal Abattoir in Ethiopia.

The higher occurrence of foreign bodies in local breeds (47.6%) compared to crossbreds (32.9%) could be attributed to the feeding practices associated with local breeds, which often involve more extensive grazing and greater exposure to environmental debris, thereby increasing the likelihood of foreign body ingestion. Overall, these findings provide valuable insights into the prevalence of foreign bodies in cattle based on breed and sex, highlighting the need for further research to explore the underlying factors influencing these differences.

Table 1. prevalence of foreign bodies based on sex and breed in the study area

Risk factors		Examined animals	positive animals	Prevalence	χ^2	P-value
Sex	Male	344	162	47.09	7.07	0.01
	Female	40	10	25		
	Total	384	172	44.79		
Breed	Local	311	148	47.6	3.86	0.05
	Cross	73	24	32.9		
	Total	384	172	44.79		

3.3 Prevalence of Foreign Body based on Age and Origin

The butchered cattle were categorized into three age groups: ≤5 years (young), 5-10 years (adult), and ≥10 years (old). Among the examined groups, approximately 11 (26.8%) of the young, 112 (46.7%) of the adult, and 49 (47.6%) of the old cattle tested positive for foreign bodies. The occurrence of foreign bodies among the three age groups showed significant variation (χ^2 = 6.01; p = 0.05) and revealed an increasing trend from younger to older age categories. This finding is consistent with reports by Amin and Fantehun (2020) and Desalegn *et al.* (2018), which indicated that 80% of foreign bodies were found in the fore-stomach of older cattle, likely due to the accumulation of indigestible materials over time.

Based on the origin of the slaughtered animals, 145 (52.5%) were from the midland and 27 (25%) were from the highland. The results indicated a highly significant difference in the origin of the cattle (χ^2 = 23.8; p = 0.00), as shown in Table 2. This distinction may be attributed to variations in animal management systems and waste management practices in the respective areas.

Table 2. The prevalence of foreign bodies in relation to age and origin

Risk factors	Variable	No. of animals examined	Animals with foreign bodies	Prevalence	χ^2	p-value
Age	≤5years	41	11	26.8	6.01	0.05
	5-10years	240	112	46.7		
	≥10years	103	49	47.6		
	Total	384	172	44.79		
Origin	Midland	276	145	52.5	23.8	0.00
	Highland	108	27	25		
	Total	384	172	44.79		

3.4 Predominance of Foreign Body based on Body Condition Score

The study indicated that the prevalence of foreign bodies was 41% in cattle with good body condition, 46% in those with medium body condition, and 55.2% in those with poor body condition. The variance among the different body conditions was statistically significant (χ^2 = 7.95; p = 0.02), as shown in Table 3. This finding aligns with the study by Desiye and Mersha (2012), which reported a higher prevalence of foreign bodies in poorly conditioned animals (72.72%) compared to those with medium (35.95%) and good (7.33%) body condition. The presence of foreign bodies may contribute to poor body condition in animals, leading to reduced weight gain due to interference with the absorption of volatile fatty acids (VFA) (Ismael *et al.*, 2007; Rahel, 2011).

Table 3. Prevalence of foreign bodies in cattle based on body condition

Risk factor	Variable	Examined animal	Positive	Prevalence	χ^2	P-value
Body condition	Good	200	82	41	7.95	0.02
	Medium	126	58	46		
	Poor	58	32	55.2		
	Total	384	172	44.79		

3.5 Prevalence of Foreign Bodies within the organ

The study identified 117 foreign bodies (68.02%) in the rumen, 44 (25.58%) in the reticulum, and 11 (6.4%) in both the rumen and reticulum. The results showed a highly significant difference among the stomach compartments (p = 0.000), as indicated in Table 4. The findings revealed a higher occurrence of foreign bodies in the rumen compared to the reticulum, which is consistent with previous research by Tesfaye and Chanie (2012), who reported 67.3% in the rumen and 32.7% in the reticulum. This discrepancy may be attributed to the larger volume of the rumen, which accommodates a greater variety and quantity of foreign materials. In contrast, metals and sharp objects tend to concentrate more in the reticulum (Kalu *et al.*, 2018).

Table 4. Frequency of rumen and reticulum foreign body slaughtered cattle in related to organ

Type of Foreign body	Location site of foreign body %			Total (N=172)
	Rumen (n=117)	Reticulum (n=44)	Rumen & Reticulum (n=11)	
Plastic	27(23.10)	8(18.60)	1(9.10)	37(21.50)
Nylon cloth materials	28(23.90)	8(18.60)	0(0.00)	36(20.93)
Rope materials	23(19.70)	1(2.30)	0(0.00)	24(13.95)
Leather materials	4(3.40)	4(9.30)	4(36.40)	12(6.97)
Iron /wire	6(51.13)	14(32.60)	0(0.00)	20(11.63)
Hair	8(6.80)	7(16.30)	0(0.00)	15(8.72)
Sack	13(11.10)	2(4.70)	0(0.00)	15(8.72)
Plastic +cloth	8(6.80)	0(0.00)	0(0.00)	8(4.65)
Plastic +wire + nail	0(0.00)	0(0.00)	6(54.50)	6(3.48)
Total	117(68.02)	44(25.58)	11(6.4)	172(100)
	χ^2 =7.13		P-value= 0.00	

4 Conclusion and Recommendations

The findings of this study underscore the pressing issue of inedible foreign objects in cattle slaughtered at the Dilla Municipal Abattoir in Southern Ethiopia. Inappropriate disposal of foreign materials in grazing areas poses significant risks to the health and well-being of cattle. The study highlights that cattle consuming foreign objects experience increased mortality rates and diminished productivity, exacerbating the challenges faced by livestock management in developing nations like Ethiopia.

A notable prevalence of such foreign materials was observed in the rumen and reticulum of affected cattle, particularly among those in poor body condition and older age groups. As Ethiopia moves toward greater industrialization and mechanization, it is imperative for the government to collaborate with veterinary professionals to raise awareness about the challenges and potential strategies related to the presence of foreign objects in cattle diets.

Based on these conclusions, we recommend that the government implement policies to mitigate environmental pollution and promote bioremediation to lower the risk of foreign body ingestion in livestock. Additionally, educational programs for farmers and

the public should emphasize the hazards posed by foreign objects in cattle diets and the importance of proper waste disposal. A robust monitoring system is needed to regularly evaluate cattle health and detect foreign objects in slaughtered animals. Implementing effective diagnostic methods for the timely identification of at-risk cattle will facilitate prompt treatment for affected animals.

Acknowledgements

References

Abebe, F. and Nuru, M. (2011): Prevalence of indigestible foreign body in small ruminants slaughtered at Luna export Abattoir, East Shoa. *Ethio. Jour. Anim. Vet. Sci.* 10(12):1598-1602.

Bassa, K. and Tesfaye, W., 2017. Study on rumen and reticulum foreign bodies in cattle slauthered at Wolaita Sodo municipal Abattoir, Ethiopia. Int. J. Adv. Multidiscip. Res., 4, 1, 11-19. University of Georgia, Athens, Pp:1-4.

Bihon, A., Bayeleyegn, T., Assefa, A., & Muktar, Y. (2020). Fore-Stomach Foreign Bodies: prevalence, associated risk factors and types affecting cattle slaughtered at Gondar ELFORA abattoir, northwest Ethiopia. *Ethiopian Veterinary Journal*, 24(2):112-122.

Bitew, Z. (2025). Investigation of Adult Paramphistomum and Indigestible Foreign Bodies in the Fore Stomach of Cattle Slaughtered in Gondar Elfora Abattoir, Ethiopia.

Central Statistical Agency (CSA), (2021). Federal Democratic Republic of Ethiopia, Agricultural Sample Survey 2019/20[2012EC.] Volume II Report on Livestock and Livestock Characteristics (Private Peasant Holdings) Statistical bullet in 587, Addis Ababa, Ethiopia

Desiye, T., and Mersha, C. (2012): Study on Rumen and Reticulum Foreign Bodies in Cattle Slaughtered at Jimma Municipal Abattoir, Southwest Ethiopia. *American-Eurasian Journal of Scientific Research*, 7(4):160-167.

Duresa, L. A., Kitessa, J. D., & Feyissa, C. T. (2022). Prevalence of indigestible foreign bodies and its associated potential risk factors in rumen and reticulum of domestic ruminants at Bishoftu Elfora Export Abattoir. *Veterinary Medicine and Science*, 8(6):2623-2630.

Gurara, S. T., Getahun, T. K., & Duguma, M. (2020). Study on Assessment of Foreign Body in Rumen and Reticulum of Cattle Come from Different Market Slaughtered at Holeta Municipal Abattoir. *Journal of Biology, Agriculture and Healthcare*, 10, 24.

Jaja, I. F., Slayi, M., Zhou, L., & Oguttu, J. W. (2023). Solid waste negligence as an emerging environmental threat to ruminant health in resource-limited countries: a narrative review. *Recent Trends in Solid Waste Management*, 231-243.

Johnson, T., Hunt, R. & Kink, N. (1997). *Veterinary* 6th edition USA. Lipponcont, Williams and Wilkins, Pp. 664-667.

Kalu, E., Kelechi, E. J., Okwara, N., & Egwuogu, C. F. (2018). Indigestible foreign bodies in slaughtered cattle (occurrence and seasonality) in an abattoir in south-eastern Nigeria. *Animal Health and Production*, 759.

Kelly, W.R. (1975). Age determination by Teeth, In: Veterinary Clinical Diagnosis, 2nd Edn, Bailliere, Tindall, London. Pp. 12-15.

Mangun, M., Duma, Y., Malewa, A. D., Indriani, I., Tanari, M., & Damry, D. (2024). Body weight, body condition score, and morphometrics of donggala cattle in Sigi Regency, Central Sulawesi, Indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 1341, No. 1, p. 012017). IOP Publishing.

Mekuanint S., Alemneh T. and Asredie T. (2017): Indigestible rumen foreign bodies-causes rumen impaction in cattle, sheep and goats slaughtered at Addis Ababa Abattoir Enterprise, Ethiopia. *Journal of Veterinary Science and Medicine*. 5(1):5.

Mohammed, T., Kebede, K., Mekasha, Y., & Abera, B. (2014). On-farm phenotypic characterization of native sheep types in North Wollo zone, Northern Ethiopia. *International Journal of Genetics*, 4(2):16-25.

Negash, S., Sibhat, B. and Shiferaw, D., (2015). A postmortem study on indigestible foreign bodies in the rumen and reticulum of ruminants, eastern Ethiopia, *Onderstepoort J. Vet. Res.*, 82(1):881-886.

Nicholson MJ and Butterworth MH (1986). A guide to condition scoring of zebu cattle. International Livestock Center for Africa, Addis Ababa, Ethiopia. pp, 1-29.

Rabana, L.J., Bukola, Y.Z., Mustapha, M. and Adamu, L. (2022) Indigestible foreign materials impaction of small ruminants in Gombe State, Nigeria. *Iran. J. Vet.*, 16(1):1–14.

Rahel, M. (2011): Study on fore stomach foreign body in cattle Slaughtered Hawassa Municipal Abattoir, Ethiopia, DVM thesis Gondar University, Faculty of Veterinary Medicine, Gondar, Ethiopia, Pp. 3-9.

Sileshi N, Ramaswamy V, Chandrashekhar U and Raja N (2013): Studies on foreign body ingestion and their related Complications in ruminants associated with inappropriate Solid Waste Disposal in Gondar Town, North West Ethiopia. *International Journal of Animal and Veterinary Advances*, 5(1):67–72.

Tesfaye, D. and Chanie M., (2012). Study on Rumen and Reticulum Foreign Bodies in Cattle Slaughtered at Jimma Municipal Abattoir, Southwest Ethiopia. *American- Eurasian J. Sci. Res.*, 7(4):160-167.

Thomas, A. M., White, G. R., Plant, E., & Zhou, P. (2017). Challenges and practices in Halal meat preparation: a case study investigation of a UK slaughterhouse. *Total Quality Management & Business Excellence*, 28(1-2):12-31.

Thrusfield, M. (2005): Veterinary epidemiology. 3rd ed. *Burgh, U.K: Black well science LTD*, Pp: 182-189.

Backyard Sheep Fattening: Constraints, and Economic Implications in Bule District, Gedeo Zone, Ethiopia

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Abstract

The study was conducted in the Bule district of the Gedeo Zone to assess backyard sheep fattening practices, limitations, opportunities, and economic viability. Six out of 18 Kebeles were purposively selected based on sheep resources, farmer experience, and accessibility. A total of 126 households were randomly chosen for the survey. Sheep fattening was prevalent in the area, with 94.4% of households utilizing tethering and free-grazing systems. Traditional fattening methods were dominant, with an average of 1.97 ± 0.08 sheep fattened over periods of 2 to 6 months, and 1.59 ± 0.059 rounds per year. Rams were the preferred type for fattening (72.2%), followed by both rams and ewes (17.5%), and ewes alone (10.3%). The Easter season (27.78%) was the most common time for fattening, and 40.48% of fatteners engaged in this practice primarily for income generation. Separate housing for sheep was common, although often poorly managed; 35.7% of households housed sheep separately within other livestock shelters. Key challenges included feed shortages, diseases, rising veterinary drug prices, decreasing grazing land, low sheep productivity, and issues with predators and theft. Conversely, opportunities included favorable agro-ecological conditions, abundant fresh grass, experienced farmers, a large sheep population, increasing market demand, rising sheep prices, higher literacy rates, and larger household sizes, all of which could enhance fattening practices. Despite these opportunities, sheep fattening remained unprofitable under current management systems. To improve profitability, the study recommends targeted training, ongoing support, collaboration among stakeholders, improved forage development, and consistent monitoring and evaluation.

Keywords/Phrases: Backyard, Bule, Easter, Fattening, Profitability, Ram

1 Introduction

Ethiopia has one of the largest livestock populations in Africa, with approximately 70.3 million cattle, 42.9 million sheep, 52.5 million goats, 8.2 million camels, 2 million horses, 9 million donkeys, 0.38 million mules, and 49 million chickens (CSA, 2021). For many rural communities, livelihoods are deeply intertwined with livestock production, complementing traditional agricultural practices (Estefanos *et al*., 2014). Sheep, in particular, play a vital role in Ethiopian livestock, being extensively reared across the country (Tadesse *et al*., 2015; Abera and Elias,

2019). As a result, sheep fattening has emerged as a crucial economic activity that enhances food security and supports vulnerable groups, including women and disadvantaged members of society (Teketel *et al*., 2021).

Despite the significance of sheep in the local economy, productivity faces numerous challenges (Tariku & Etefa, 2022). While previous studies have attempted to address these issues, most have focused on specific feeding systems within controlled environments (Skunmun *et al*., 2012; Wude, 2017; Gebrekidan, 2018; Sime, 2019; Kokeb *et al*., 2021;

Alemu, 2023). This focus highlights a critical gap in research regarding farmers using diverse feeding systems that utilize local feed resources.

Bule District in the Gedeo Zone is recognized as a potential hub for sheep production, benefiting from a favorable climate and a rich tradition of backyard sheep fattening. The district features a robust livestock market and hosts a diverse sheep population, including various breeds from the Oromia and Sidama regions. However, modern sheep fattening practices remain largely absent, and economic growth among sheep fatteners has been sluggish. There is a notable lack of cooperative associations, investors, or initiatives aimed at developing sheep fattening into a viable business. Many farmers treat sheep fattening as a traditional activity rather than a reliable income source, leading to inconsistent practices and a reliance on basic grazing without additional management strategies.

Furthermore, a comprehensive investigation of backyard sheep fattening, including constraints, opportunities, and profitability in this area, has not yet been conducted. Current evidence suggests that in-adequate research and limited technological skills in fattening practices prevent households from capitalizing on potential economic benefits throughout the sheep value chain (Wamatu et al., 2022). Therefore, this study aims to assess backyard sheep fattening practices, identify existing limitations, explore potential opportunities, and evaluate the economic profitability of sheep fattening in Bule District.

2 Materials and methods

2.1 Description of the study area

The study area is situated in the Gedeo Zone of the South Ethiopia Regional State, approximately 386 km from Addis Ababa. It spans 27,300 hectares and has an altitude range of 2,001 to 3,000 meters above sea level. The average annual rainfall in the region is estimated at 1,600 mm, with temperatures ranging from 12.6^{o}C to 20°C. The predominant farming system is a mixed crop-livestock production system. Major crops include barley, beans, peas, maize, and wheat, along with perennial plants such as enset and coffee. The area borders the Oromiya region to the south, east, and west, and the Sidama Zone to the north (Bule Woreda BOPE, 2022, unpublished).
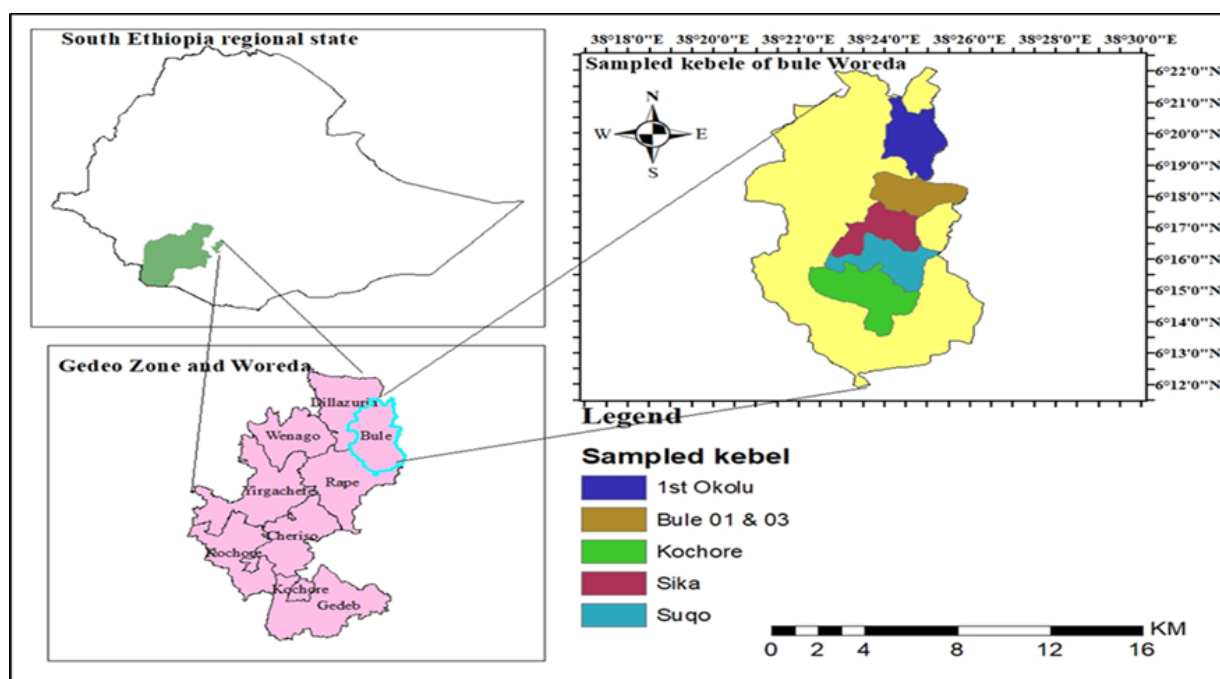

Figure 1. Study area map

2.2 Sampling method and sample size determination

The study employed a multistage sampling method. Initially, six out of 18 kebeles (Bule 01, Bule 03, Sika, Kochor, Suqo, and Igna Okolu) were purposively selected based on sheep resources, farmer experience in sheep production, and accessibility. These selected kebeles represent 33.3% of the district's total kebeles.

To begin the selection process, all household heads involved in sheep production were listed to create the sampling frame. Representative households were then randomly selected using simple or systematic random sampling methods, ensuring representation of key criteria relevant to sheep fattening practices.

The study targeted sheep-fattening farmers in the selected kebeles, identified from a population of 328 households according to district livestock data. A sample size of 126 households was determined using Yamane's formula (1973) with a standard error of 0.07 and a 95% confidence level. This resulted in the allocation of 21 households from each of the six kebeles, which were randomly selected for interviews and data collection.

2.3 Method of data collection

Data were collected by using semi-structured questionnaire, field observation, key informant interview and focus group discussions.

2.3.1. Questionnaire survey

Data was collected using pre-tested, semi-structured questionnaires administered by trained enumerators to 126 randomly selected households. The survey gathered information on fattening practices (cycle, season, sources, and feed conservation) as well as household demographics (age, sex, family size, education, marital status, landholding, and income sources), fattening constraints, and economic profitability.

2.3.2. Field observation

During the administration of the questionnaire, the husbandry methods for fattened sheep—including management, feeding, and housing conditions—were observed. Additionally, preferred mor-

phological characteristics of the fattening sheep, such as coat color, body length and height, horn shape, tail type, health status, and age determined by dentition, were important components considered during field observations (Kostera, 2007; Ciesielska & Jemielniak, 2018).

2.3.3. Key informant interview

Key informant interviews will be conducted with individuals who possess in-depth knowledge and experience related to backyard sheep fattening. This may include agricultural extension workers, livestock experts, community leaders, cooperative heads, and experienced sheep farmers. The aim is to gather qualitative insights on local practices, challenges, and support systems associated with sheep fattening.

2.3.4. Focus group discussions

Six focus groups were conducted across the selected kebeles, comprising diverse participants, including women and elders. Discussions explored feeding systems, fattening challenges, animal husbandry practices, and potential opportunities for sheep fattening in the region. The insights gathered provided valuable qualitative data to complement the quantitative findings of the study.

2.4 Partial budget analysis

Sheep fattening costs and returns have been estimated using budgeting procedures. Specifically, the budgeting method will make use of gross margin analysis, which is exactly how model's net income was calculated (Rahman & Lawal, 2003).

$$Gross\ margin = Gross\ income - Total\ variable\ cost$$
$$(1)$$

$$Net\ farm\ income = Gross\ margin - Total\ fixed\ cost$$
$$(2)$$

2.5 Statistical data analysis

Survey data were analyzed using SPSS version 20. Descriptive statistics (mean, percentage, standard deviation) were used to summarize the findings. According to a formula of index employed by Musa

et al., 2006), indexes were obtained to provide a ranking of the specifically favorable fattening season, mostly preferred type of ram and ewe, fattening sheep selection criteria. Therefore, the index was calculated as,

Index = Sum of $[(r_n*C_1+r_{n-1}*C_2 \ldots r_1*C_n)]$ raised for an individual season, preference, and criteria divided by the sum of $[(r_n*C_1+ r_{n-1}*C_2 \ldots r_1)])$ for the overall season, preference and criteria.

Where,
r_n = Value for the least ranked level (for example if the least rank is 5th rank, then r_{n-5}, $r_{n-1} = 4$, and... $r_1 = 1$); C_n = Counts of the least ranked level (in the above example, the count of the 5th rank = C_n, and the counts of the 1st rank = C_1.

3 Results and Discussions

3.1 Demographic characteristics of households

In the study area, respondents had an average family size exceeding the national rural average of 4.9 members per household (Ayele & Gebretsadik, 2024). This increase can be attributed to cultural influences that view family members as valuable resources for labor in agricultural activities and social status, as well as the prevalence of polygamous marriages, often pursued to acquire additional farmland (see Table 1).

The average age of sheep fatteners in the study area was 41.38 years, ranging from 19 to 83 years old. This finding aligns with Zemene & Tolemariam's (2016) report of 41.9 years for households in the Jimma Zone. However, it is lower than the average ages reported by Teklay (2008) and Endale (2015),

who found averages of 48.1 and 49.14 years, respectively. The age range is comparable to Yeshitila's (2008) study in Alaba, which reported an average of 42.82 years. This age distribution suggests that an active and potentially interested population is engaged in sheep fattening and broader agricultural activities within the study area.

Households in the study area had an average total landholding of 0.76 hectares, significantly less than the 1.93 hectares reported in the South Gondar Zone (Tilahun, 2021). Fortunately, literacy rates are promising, with 76.3% of sheep fatteners having at least some formal education, which could facilitate the adoption of improved farming techniques.

Group discussions revealed a local tradition that dictates livestock ownership in the area belongs to the husband, even if the wife has her own fattening sheep. This finding is consistent with Gebru *et al.* (2017), who reported that, similar to other African nations, household resource leaders are primarily men.

3.2 Occupation of the households

In the study area, pure agriculture dominated household occupations, accounting for 87.3% of fatteners. This was followed by agriculture combined with small trade (6.3%), agriculture with labor work (2.4%), and agriculture combined with civil service (4%). The dominance of pure farming, which typically involves mixed crop cultivation and livestock rearing, can likely be attributed to favorable agro-ecological conditions that support both agricultural and livestock activities. This observation aligns with findings from West Hararghe, Oromia, where mixed crop-livestock farming serves as the primary livelihood and income source (Abdi *et al.*, 2013).

Table 1. Fatteners socio-economic data in study area

Variables		Kebeles						Total N=126	p-value
		Bule 01 n=21	Bule 03 n=21	Sika n=21	Suqo n=21	Kochore n=21	1gna okolu n=21		
FS	Mean ±SE	$5.62 \pm .71^{b}$	$5.10 \pm .46c$	$5.43 \pm .50b$	$5.14\pm.46c$	$7.14\pm.43a$	$7.43\pm.62a$	$5.98\pm.23$	0.004
	Mi	1	3	2	2	4	3	1	
	Ma	14	10	12	10	10	13	14	
Age	Mean ±SE	36.24 ± 2.81^{c}	37.33 ± 1.6^{c}	$45.90 \pm 3.26a$	$40.05 \pm 1.64b$	$42.00\pm1.8b$	$46.76\pm2.6a$	41.38 ± 1.01	0.007
	Mi	19	24	26	25	28	29	19	
	Ma	72	46	83	56	56	81	83	
TLH(ha)	Mean ±SE	$0.70 \pm .071^{b}$	$.69 \pm .058^{c}$	$0.67 \pm .053c$	$0.851 \pm .087a$	$0.76\pm.098b$	$0.90\pm.06a$	$0.76\pm.035$	0.094
	Mi	0.23	0.25	0.25	0.25	0.25	0.35	.023	
	Ma	1.65	1	1.03	1.70	1.25	1.67	1.70	
MS	Married%	14.3	16.7	14.3	15.9	15.9	15.9	92.9	0.610
	Single%	0.8	0.0	1.6	0.0	0.0	0.0	2.4	
	Widowed%	1.8	0.0	0.8	0.8	0.8	0.8	4.8	

		Sex of Respondents (%)				
			Male (n=108)	Female (n=18)	Total	χ^2	p-value
Education level of HHs		Illiterate	25.9	77.8	33.3	18.051	0.001
		1-4	34.3	5.6	30.2		
		5-8	29.6	11.1	27.0		
		9-10	5.6	0.0	4.8		
		Diploma	2.8	5.6	3.2		
		Degree	1.9	0.0	1.6		
Occupation of fattener/sources of income			Frequency (N=126)	%		
		Agriculture (crop and livestock production)	110	87.3		
		Agriculture and petty-trade	8	6.3		
		Agriculture and labour work	3	2.4		
		Agriculture and civil servant	5	4.0		

SE=standard error Ma = maximum; Mi = minimum; FS = family size; TLH = total land hold; MS = marital status; HH = households; N = number of respondents.
The above table adopted from Tsegaye and Wondewsen (2024) which was published on Online Journal of Animal and Feed Research

3.3 Number, Duration and fattening cycle

On average, fatteners in the study area completed 1.50±0.050 sheep fattening cycles per year, ranging from 1 to 3 rounds, with no significant differences across kebeles. The findings of the current study differ from those of Shewangzaw *et al.* (2018) in the Amhara region, where the average number of fattened sheep per fattening period was higher at 2.86. However, these findings are consistent with those of Assefa & Ayza (2020) in the Hadiya Zone of Southern Ethiopia, where farmers typically practice fattening 2 to 3 times a year.

In contrast, Nurlign (2020) reported predominantly 2 cycles, while Getachew *et al.* (2017) noted only one cycle in the Fogera District. Samuel (2016) found similar results of 1.625±0.05 rounds per year in the Amhara region. The study suggests that improving feed and nutritional status, as well as management practices, may be key to increasing both the number of fattened sheep per cycle and the total number of fattening cycles per year. The variation in the number of fattening cycles across study kebeles may be attributed to differences in resources, agro-ecological conditions, and seasonal variations in fattening (see Table 2).

Table 2. Number, duration and cycle of fattening sheep in study area

Variables		Kebeles						Overall N=126	p-value
		Bule 01	Bule03	sika	suqo	kochore	1gna okolu		
NFS	Mean±SE	1.6±.14^c	1.4±.13^c	2.05±.18^a	2.2±.22^a	2.1±.24^a	2.1±.22^a	1.9±.08^b	0.02
	Mi	1	1	1	1	1	1	1	
	Ma	3	3	4	4	5	4	5	
FD	Means	4.1±.96^a	4±.13^a	3.9±.19^b	3.8±.19^b	3.6±.16^c	3.6±.16	3.8±.07^c	0.2
	Mi	2	3	2	2	2	2	2	
	Ma	6	5	5	5	5	5	6	
FC	Mean±SE	1.8±.159^a	1.3±.126^c	1.4±.11^c	1.7±.15^a	1.5±.14^b	1.5±.14^b	1.5±.05	0.09
	Mi	1	1	1	1	1	1	1	
	Ma	3	3	2	3	3	3	3	

NFS = Number of fattening sheep FD = Fattening duration; FC = Fattening cycle; N = total sampled respondents; Mi = Minimum; Ma Maximum; SE = standard error

3.4 Fatteners ranking criteria for selection of sheep fattening

In the study area, sheep fatteners employed specific selection criteria, prioritizing conformation (height, length, and appearance) through visual assessment (see Table 3). This criterion was ranked as the most important factor (Index = 0.22), followed closely by physical characteristics such as color, horn shape, and tail type (Index = 0.21). Age and health status were equally important, ranking third (Index = 0.17), while adaptability and price were considered less crucial.

These findings align with previous research (ESG-PIP, 2012; Assefa & Ayza, 2020; Diriba *et al.*, 2021; Getahun, 2022), which emphasizes factors like body condition, frame, age, and health. Fatteners primarily relied on visual cues, such as body frame, hair appearance, and the presence of diarrhea, to assess sheep suitability. While most respondents (65.1%) considered age important, they relied on visual estimation rather than dentition; however, a significant portion (34.9%) deemed age less critical for fattening purposes.

Table 3. Fattening Sheep Selection Criteria

No	Selection Criteria	Frequency of rank given fatteners						Total	Index	Rank
		1st	2nd	3rd	4th	5th	6th			
1	Body conformation (height, length and appearance)	55	9	34	16	13	3	130	0.22	1
2	Physical characteristics	11	64	23	18	5	2	123	0.21	2
3	Age	46	11	3	1	26	42	129	0.17	3
4	Health	9	23	32	32	27	6	129	0.17	3
5	Price	4	2	13	11	33	61	124	0.09	6
6	Adaptability	1	17	21	48	22	12	121	0.14	5
	Mostly preferred physical characteristics									
1	Color	22	39	21	20	-	-	102	0.27	2
2	Horn	15	24	37	33	-	-	109	0.24	3
3	Tail	5	16	33	39	-	-	93	0.17	4
4	Body length and height	58	21	9	8	-	-	96	0.32	1

		Respondent %						Total	χ^2	p-value
	Consideration of age of fattening sheep	Bule 01	Bule03	Sika	Suqo	Kochore	1gna okolu		22.071	0.001
	Yes (%)	6.3	10.3	14.3	15.9	10.3	7.9	65.1		
	No (%)	10.3	6.3	2.4	0.8	6.3	8.7	34.9		

Index = [(6 × number of responses for 1st rank + 5 × number of responses for 2nd rank + 4 × number of responses for 3rd rank + 3 × number of responses for 4th rank +2 × number of responses for 5th rank+1 × number of responses for 6th rank)] divided by (6 × total responses for 1st rank + 5 × total responses for 2nd rank + 4 × total responses for 3rd rank + 3× total responses for 4th rank + 2×total responses for 5th rank+1 × number of responses for 6th rank).

3.5 Preferences of fatteners for sheep fattening

The study revealed that the majority (72.2%) of respondents preferred fattening rams due to market demand, feed efficiency, potential profit, and superior weight gain, consistent with findings in the Genji district (Diriba *et al.*, 2021). Mature rams were ranked highest (index value 0.37) because of their rapid growth, high market demand, and favorable pricing, followed by young rams (0.31) and old rams (0.30). Fatteners prioritized mature rams for their quicker attainment of market weight (47.9%), strong market demand (39.6%), and higher selling prices (12.5%), as indicated in Table 4.

In the study area, barren ewes were preferred for fattening due to their marketability, associated with good body condition and non-reproductive use (Index = 0.40). Old ewes were also favored for their low purchase price and suitability for culling (50%) and high demand from local butchers (37.5%). Gimmer ewes were preferred due to market demand and usage by local butchers (Mamo, 2020; Getahun, 2022). This aligns with findings in other regions, where unproductive female sheep or aged animals are commonly fattened due to market factors (Diriba *et al.*, 2021; Samuel, 2016) (see Table 5).

Table 4. Condition of castration practices, preferred fattening sheep type

Variable		Frequency (n)	Percent (%)
Castration practices	Yes	0	0.0
	No	126	100.0
Type of sheep for fattening	Ram	91	72.2
	Ewe	13	10.3
	Both	22	17.5
Total		126	100.0

Table 5. Community preference of fatten sheep in the study area

Mostly preferred type of ram	1st ranked F	2nd ranked F	3rd ranked F	Total	Index	Rank
old ram	23	50	40	113	0.30	3
matured ram	48	47	18	113	0.37	1
young ram	42	16	55	113	0.31	2
Mostly preferred type of Ewe						
Old ewe	8	14	13	35	0.29	2
Barren/infertile ewe	21	13	1	35	0.40	1
Gimmer ewe	6	8	21	35	0.25	3

Index = [(3× number of responses for 1st rank + 2 × number of responses for 2nd rank + 1 × number of responses for 3rd rank)] divided by (3 × total responses for 1st rank + 2 × total responses for 2nd rank + 1 × total responses for 3rd rank); F=frequency.

3.6 Sheep fattening occasions

Sheep fattening in the study area is a seasonal practice, with 27.78% of farmers targeting the Easter season (see Figure 2). This finding aligns with research by Wude (2017) in the Debre-Berhan area and Assefa & Ayza (2020), who also noted peak fattening periods around Easter, Christmas, and the Ethiopian New Year.
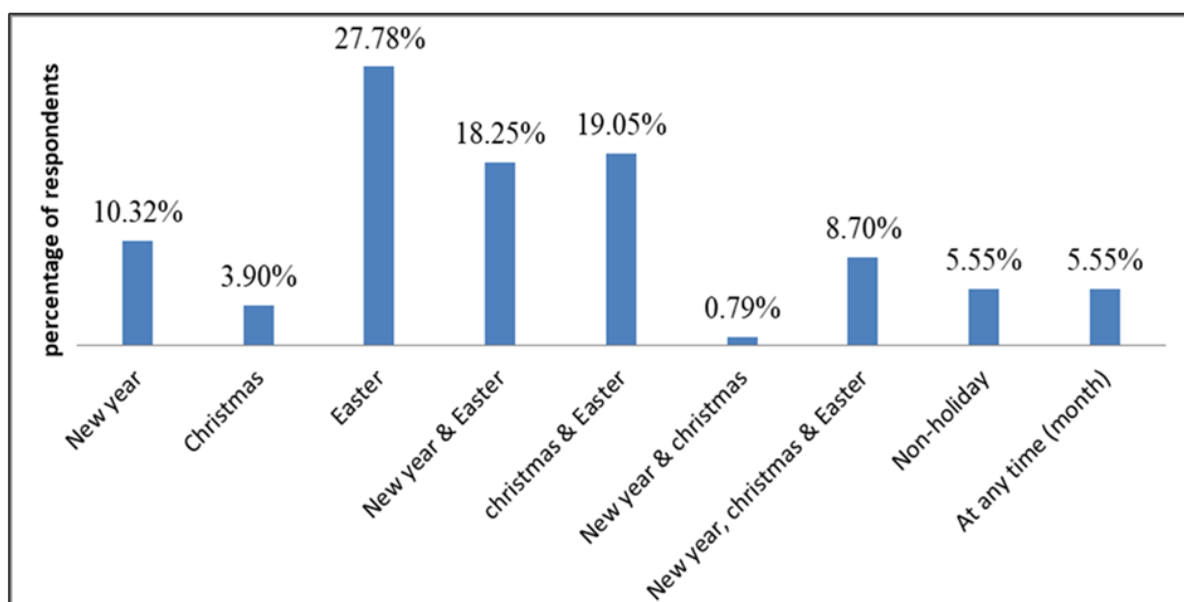

Figure 2. Seasons of sheep fattening in study area

3.7 Reasons for fattening sheep

Sheep fattening in the study area is primarily driven by income generation (40.48%), with additional motivations including saving, purchasing more sheep, and fulfilling socio-cultural functions. This finding aligns with the research of Fikru & Gebeyew (2015) in the Degehabur Zone and Samuel (2016) in the Amhara Region, both of which also reported income generation as the main purpose of sheep fattening (see Figure 3).
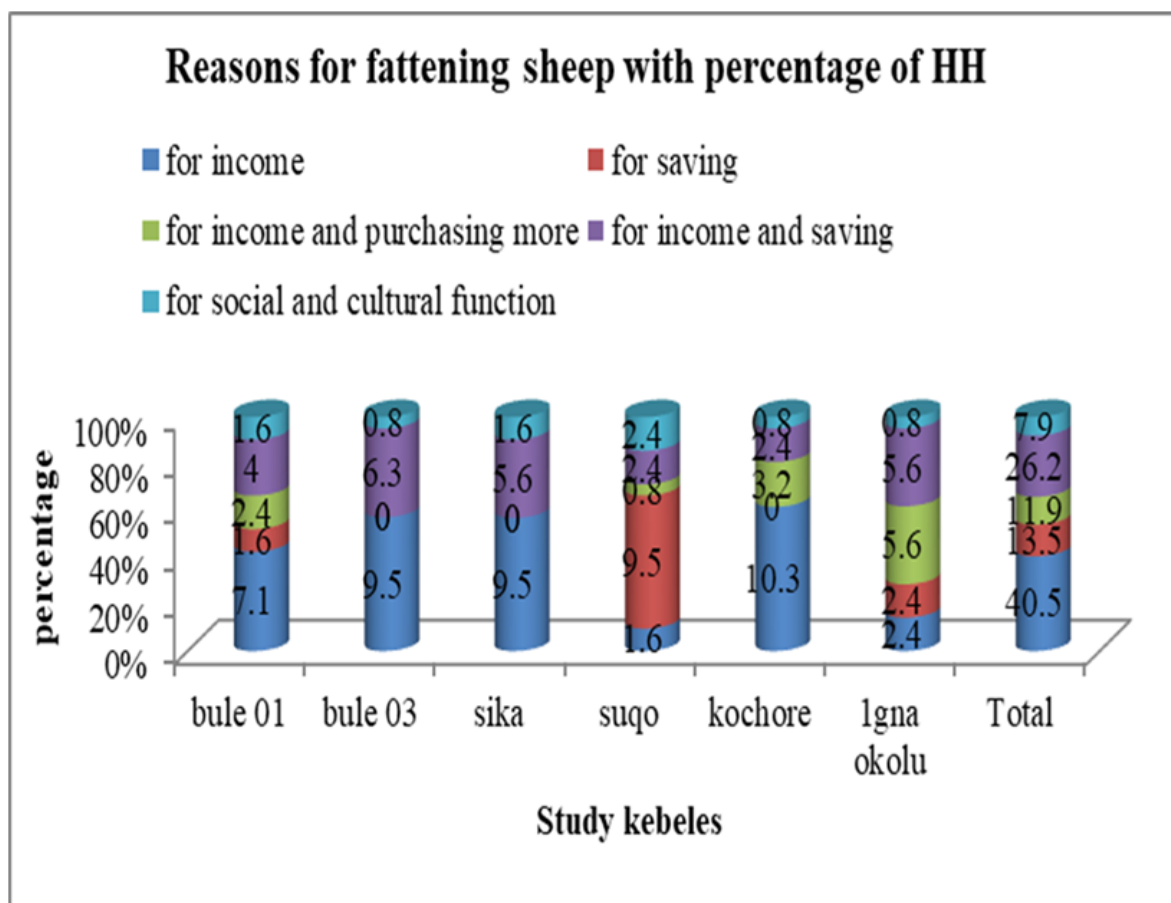
Figure 3. Main purpose of involving in sheep fattening activities

3.8 Fattening sheep, feeding system and supplementary feed types

The commonly provided feed and feeding systems for fattening sheep in the study area are presented in Table 6. The predominant feeding systems include tethering with stall feeding (68.3%), semi-grazing with stall feeding (20.6%), and free grazing with a cut-and-carry system (11.1%). This result aligns with Getachew *et al.* (2017), who reported that stall feeding (56.1%), free grazing (18.1%), mixed systems (11.1%), and tethering (7.4%) were common among respondents in the upper land of Fogera District. The current findings also agree with Esatu *et al.* (2019), who noted that tethering, cutting, and carrying were practiced feeding systems for sheep in Arba Minch Zuria District.

Table 6. Provided feed and feeding/fattening system in study area

Description		Sheep fattening/Feeding system (%)			Total	χ^2	p-value
		FGCC	TSFS	SGSFS			
Feed for sheep during stall-feeding	B.L & HL	2.4	20.6	6.3	29.4		
	GFG	4.8	23.8	6.3	34.9	7.779	0.4
	CF	4.0	10.3	2.4	16.7		
	Enset	0.0	10.3	3.2	13.5		
	CRB	0.0	3.2	2.4	5.6		
Total		11.1	68.3	20.6	100.0		

B.L & HL = Bamboo leaf & home leftover; GFG = Green fresh grass; CF = Cultivated forage; CRB = crop residues with bole; FGCC = Free grazing with cut and carry system; TSFS = Tethering with stall feeding system; SGSFS = semi-grazing with stall feeding system.

Backyard sheep fatteners in the Bule district commonly tether sheep on nearby pastures, supplementing their diet with fresh grass, bamboo leaves, and enset. Tethering with stall feeding is practiced, with fresh grass (23.8%), bamboo leaves (20.6%), and cultivated forage (10.3%) being the primary feeds. This observation aligns with findings from Salo *et al*. (2017) in Anelemo Woreda, where farmers also tether animals and provide pasture grown between enset.

Tethering is a common sheep fattening practice in the study area, promoting weight gain through grazing, reducing aggression, and preventing breeding (Getachew *et al*., 2017). This method optimizes feed utilization, reduces labor, and minimizes unnecessary movement, ultimately leading to faster attainment of market weight. Households utilized three main feeding systems: semi-grazing with stall feeding, tethering with stall feeding, and free grazing with cut-and-carry. Semi-grazing with stall feeding involves allowing sheep to graze freely before confining them to a fenced pasture for stall feeding (Esatu *et al*., 2019). Free grazing with cut-and-carry was also common, where sheep grazed freely for 11 hours a day and were provided with additional supplements (Abebe *et al*., 2021).

The study found no significant difference (p > 0.05) in the types of feed provided to fattening sheep across different feeding systems in the study area. Fresh green grass (34.9%) was the primary feed, supplemented with bamboo leaves and home leftovers, with variations based on kebele and availability. The similarity in feed types across systems and the unknown daily amounts given may explain this finding, with basal feed resources used as supplements during grazing. This aligns with Machen (2019), who also reported variations in supplementary feed types across locations due to factors such as land availability (see Table 6).

3.9 Utilization and type of available supplementary feed

As indicated in Figure 4, supplementary feeds for sheep fattening in the Bule district primarily included salt, kitchen leftovers (such as cereal screenings and coffee residues), and enset (18.3%). Combinations of salt, bole, and home leftovers (15.1%) as well as enset with salt (11.1%) were also common. Coffee residues served as a readily available daily supplement due to household production. This study aligns with Nurlign (2020), who reported the use of food leftovers and cereal screenings in Ethiopian sheep fattening.

Within the study area, some farmers utilized crop residues treated with salt or bole soaking, and 9.5% believed that using crop residues could help mitigate feed shortages. Abshir (2018) similarly emphasized the importance of crop residues in addressing acute feed resource shortages. According to Tolera *et al*. (2012), crop residues account for approximately 50% of the total feed supplied in Ethiopia. Nonetheless, the use of these techniques by fatteners in the current area remains minimal due to factors like low palatability, labor intensity, and time constraints. Respondents indicated that chopping crop residues requires additional labor and time, further complicating their use.

Moreover, Alemu *et al*. (1991) highlighted that the feeding value of crop residues is limited by poor voluntary intake, low digestibility, and deficiencies in nitrogen, energy, minerals, and vitamins. Fatteners noted that population growth and intensified crop cultivation have resulted in insufficient grazing land, compelling them to restrict livestock access to pastures until grass is established for grazing during designated seasons.

To improve the intake and nutritional status of available feeds, fatteners could enhance utilization efficiency by employing techniques such as chopping, salting, and mixing bole (mineral soil) into feed materials. Among these practices, salting was noted as particularly common; it often followed the chopping of feed into manageable sizes to enhance intake. Sampled households affirmed that employing these techniques significantly alleviated some consequences arising from feed shortages. Supporting evidence from the central highlands of Ethiopia suggests that feed processing methods like chopping, wetting, grinding, boiling, and roasting could significantly contribute to resolving feed-related issues (Ahmed *et al*., 2010).
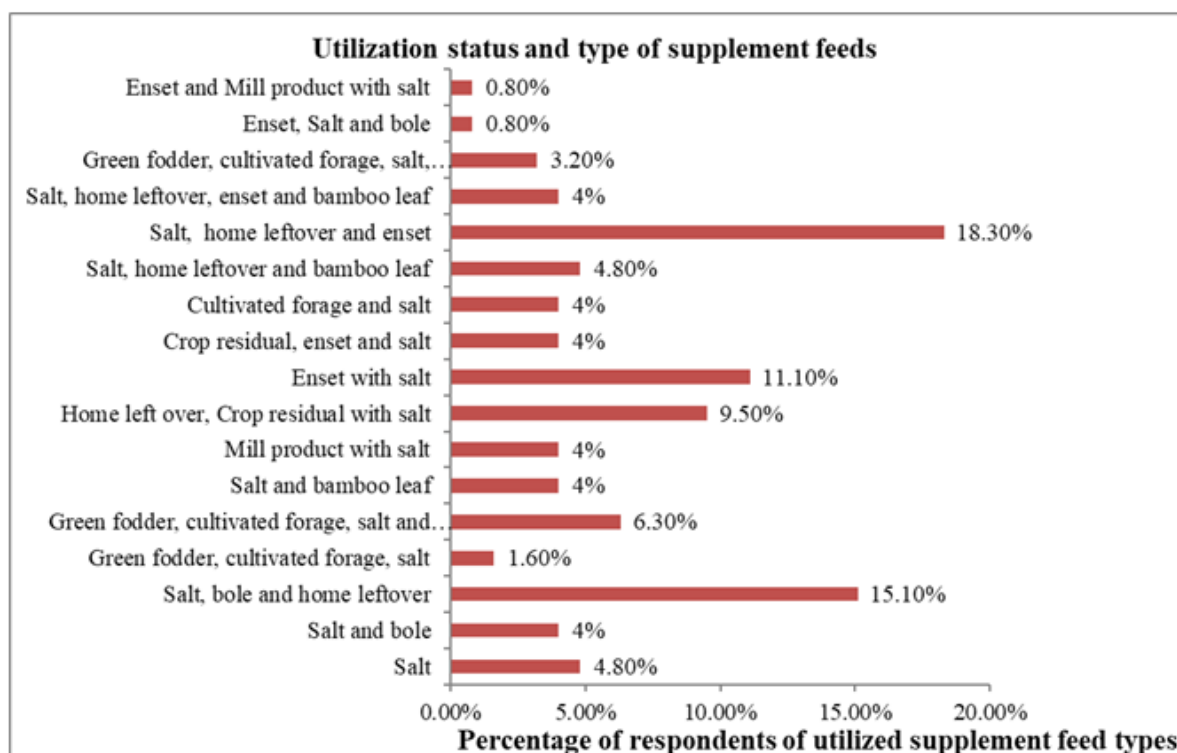
Figure 4. Percentage HHs supplementary feeds used

3.10 Economic analysis of sheep fattening

Budgeting analysis of sheep fattening in the Bule district revealed that while farmers achieved a gross margin of 517.3 ETB per sheep after 2 to 6 months of fattening, the practice was ultimately unprofitable. Costs were categorized into fixed expenses (such as equipment depreciation and land rent) and variable costs (including feed and healthcare), with sheep procurement accounting for 61% of total expenses. Feed represented the largest cost component, averaging 694.7 ETB, while variable feeding costs constituted 86.4% of total feed expenditure.

The average cost of purchasing sheep was 2,554.07 ETB, with a selling price of 4,122.23 ETB. The resulting benefit-cost ratio of 0.98 indicates that for every 1 ETB invested, the return was only 0.98 ETB, confirming economic unprofitability under current management practices, as a profitable business typically has a benefit-cost ratio greater than one (Sarma *et al.*, 2014).

This loss is exacerbated by a lack of awareness among farmers regarding the tracking of variable costs, leading them to primarily focus on the purchase-sale price differential while neglecting other significant input costs. To improve profitability, it is crucial for fatteners to meticulously record all costs associated with sheep fattening, enabling a more comprehensive understanding of the true economic benefits and potential for optimization.

4 Conclusion and recommendation

4.1 Conclusion

The study identifies challenges in backyard sheep fattening, including inadequate housing, poor feed management, and disease outbreaks. Opportunities exist to improve productivity but require coordinated efforts.

4.2 Recommendations

- Enhance farmer's capacity through training related to proper management practices, including record-keeping and disease control.

- Improve feed access- Develop strategies to improve feed quality and availability, including supplementary feeding and nutrient-rich basal feeds.

- Support from authorities- Provide government

support through subsidies, grants, or low-interest loans, and expand training in modern techniques and disease control.

- Encourage best practices - Foster collaboration among stakeholders to implement best practices and raise awareness among farmers about efficient management.
- Promote long-term profitability- Encourage better practices through education and demonstration of long-term profitability.

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Data availability

Data will be made available on request.

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 manuscript.

References

Abdi, E., Kamal, K., Yassin, E. and Muleta, D. (2013). Cattle production in west hararge and opportunity and constraints assessments in Darulabou, Gemechis and Chiro districts Oromiya Regional State Ethiopia. *International Journal of Livestock Production Research*, 1(1): 1- 15.

Abebe, Y., Tefere, M., Shiferaw Dagnew, Y. G., Selassie, E. E., Smaling, E. M., & Teshome, A. (2021). Challenges of Shifting from Free Grazing to Adoption of Cut-and-Carry Feeding System in North-Western Ethiopian Highlands. ESAP P, 255.

Abera Anja and Elias Hesebo (2019). Sheep Fattening Practices and Constraints in East Badewacho Woreda, Hadiya Zone Southern Ethiopia. *Global Veterinaria*, 21 (3): 109-115.

Alemu Gashe Desta (2023). Nutritional Content Analysis of Crop Residues in Three Agroecologies in East Gojjam Zone. *Research Article. The Scientific World Journal*. Volume 2023, Article ID 1974081, 8 pages. https://doi.org/10.1155/2023/1974081.

Assefa, A., & Ayza, A. (2020). Assessment of sheep fattening and marketing systems in Duna Woreda, Hadiya zone, Southern Ethiopia. *J Dairy Vet Anim Res*, 9(4), 130-135.

Ayele, T., & Gebretsadik, T. (2024). Gender analysis in selected agricultural practices in Gedeo and Halaba zones in Southern Ethiopia. *International Journal of Agricultural Research, Innovation and Technology (IJARIT)*, 14(1), 1-9.

Ciesielska, M., & Jemielniak, D. (Eds.). (2018). *Qualitative methodologies in organization studies* (p. 33). Cham, Switzerland: Palgrave Macmillan.

CSA (2021). Crop yield for major grain crops, private smallholder farms, main season. Addis Ababa, Ethiopia.

Diriba, T., Zemene, W., Solomon, D., and Monenus, E., (2021). Assessment of sheep fattening practices under smallholder farmers in Genji district of West Wollega, Western Oromia, Ethiopia. *International Journal of Veterinary Sciences and Animal Husbandry*; 6(4): 18-25.

Disassa H, Teklu T, Adem H. (2013). A study on ovine pneumonic pasteurellosis: isolation and identification of Pasteurellae and their antibiogram susceptibility pattern in Haramaya District, Eastern Hararghe, Ethiopia. BMC Vet Res. 9:1–8. https://doi.org/10.1186/1746-6148-9-239.

Endale, Y., (2015). Assessment of Feed Resources and Determination of Mineral Status of Livestock Feed in Meta Robi District, West Shewa Zone, Oromia Regional State, Ethiopia. Msc. Thesis Submitted to the School of Graduate Studies of Ambo University, Ethiopia.

Esatu, B., Yisehak, K., Chencha, C., (2019). Feed resources availability, feeding system and feed balance of sheep in Arba Minch Zuria District of Gamo Zone, Southern Ethiopia. *Research Article. OMO Int. J. Sci.* Vol:2 Issue :2 :59-75; (ISSN: 2520 – 4882).

ESGPIP (Ethiopia sheep and goat productivity improvement program) (2012). Short Term Intensive Fattening of Sheep and Goats for Rapid Improvement in Weight and Condition and also Producer Incomes, Technical Bulletin No.11.p2-6.

Estefanos T., Tesfaye A, Feyisa H, Gashaye W, Tatek W, Tesfaye K, Osho T. (2014). Traditional cattle production in the highlands of Hararge: Case study for East and West Zones of the high lands of Hararghe, Eastern Ethiopia. *Basic Res.J. Agricult. Sci. Rev.*, 3(12): 122-130.

Fikru, S., & Gebeyew, K. (2015). Sheep and goat production systems in Degehabur Zone, Eastern Ethiopia: Challenge and opportunities. *J Adv Dairy Res*, 3(134), 2.

Gebrekidan, T. (2018).sheep and goat husbandry practices in eastern tigray, and effects of substitution of mulberry (*Morus alba*) leaf meal for concentrate mix on growth and carcass traits of Tigray highland lambs in barley straw based feeding. PhD Dissertation. Addis Ababa University, Addis Ababa, Ethiopia.

Gebru, H., Mohammed, A., Dechassa, N., & Belew, D. (2017). Assessment of production practices of smallholder potato (Solanum tuberosum L.) farmers in Wolaita zone, southern Ethiopia. *Agriculture & Food Security*, 6(1), 1-11.

Getachew, M., Firew, T., and Yeshambel, M. (2017). Sheep fattening practices in Fogera District, Amhara National Regional State, Ethiopia. *Journal of Biology, Agri. and Health care*; 7(15):33-39.16.

Getahun, B. (2022). Sheep fattening and marketing systems in Angollelana Tera district, North Shewa Zone, Ethiopia. Msc thesis. Debre Berhan University, Debre Berhan, Ethiopia.

Kokeb, M., Mekonnen, Y., & Tefera, M. (2021). Feed intake, digestibility and growth performance of Dorper-Menz cross bred sheep fed local brewery by-product (atella) and concentrate mixture at different levels of combination. *African Journal of Biological Sciences*; 3(4):33–41.

Kostera, M. (2007). *Organizational Ethnography: Methods and Inspirations*. London: Sage.

Machen, R. (2019). Supplementation of grazing sheep. Texas A&M Agrilife Ext., TX, USA. Available at:(accessed 2 July 2020).

Mamo, B., (2020). Assessment of Sheep Fattening Practices around Chalia District West Shoa Zone. *J. Ethol & Animal Sci*, 3(1): 000116.

Musa, L. M. A., K. J. Peters and M. K. A. Ahmed, (2006). On farm characterization of Butana and Kenana cattle breed production systems in Sudan. *Livest. Res. for Rural Develop.* 18 (12).

Nurlign, M. (2020). Sheep Fattening, Marketing Systems and Constraints of Ethiopia: A Review. *World Appl. Sci. J.*, 38 (5): 416-421.

Rahman, S. A., & Lawal, A. B. (2003). Economic analysis of maize-based cropping systems in Giwa Local Government Area of Kaduna State, Nigeria. *An International Journal of Agricultural Sciences, Science, Environment and Technology*, 3(2), 139-148.

Salo, S., Tadesse, G., & Haylemeskel, D. (2017). Survey on constraints of improved forage adoption in Anelemo Woreda, Hadiya Zone, Ethiopia. *Agri Cultural Research and Technology: Open Access Journal*, 12(2).

Samuel, M. (2016). Characterization of sheep fattening at small holder level in different Agro-Ecological Zones of Ethiopia–Amhara Region. M.Sc. Thesis. Bahir Dar University, Bahir Dar, Ethiopia.

Sarma P. K., S. K. Raha and H. Jørgensen (2014). An economic analysis of beef cattle fattening in selected areas of Pabna and Sirajgonj Districts. *J. Bangladesh Agril. Univ.* 12(1): 127–134.

Shewangzaw M. A., Teshager, A. A., Endeshaw, A. G., Birhan Atinaw, M., & Tesfa Sendeku, A. (2018). Small ruminant fattening practices in Amhara region, Ethiopia. *Agriculture & Food Security*, 7: 64.

Sime, T. E. (2019). Assessment of production status and evaluation of biomass yield, chemical composition and supplementary value of mulberry (*Morus alba*) on growth performance and carcass characteristics of yearling arsi-bale sheep (Doctoral dissertation).

Skunmun, P., Boonyanuwat, P.K., Koonavoot, R.S. and Suwanasopee, T. (2012). Improving Smallholder and Industrial Livestock Production for Enhancing Food Security, Environmental and human welfare. Proceedings of the 15th AAAP Animal Science Congress held at Thammasat University, Pathum Thani, 26-30, November 2012, AVAT. Pp. 267.

Tadesse, E., Negesse, T., Abebe, G. (2015). Sheep production and marketing system in southern Ethiopia: the case of Awassa zuria district. *Trop. Anim. Health Prot.* 47(7):1417-1425.

Tariku, B., & Etefa, M. (2022). Study on Improved Sheep Fattening Production, Value Addition and Marketing in Bekiyo Bekit Kebele, Adiyo District, Kaffa Zone, Southwest Ethiopia. *Journal of Applied Agricultural Economics and Policy Analysis*, 5(1), 9-18.

Teketel, M., Temesgen, D., Hamza, D., & Fesseha, H. (2021). Determinants of smallholder farmers' participation in improved sheep production: The case of Doyogena District, Kembata Tembaro Zone, Southern Ethiopia. *Advances in Agriculture*, 2021, 1-17.

Teklay, A. (2008). Assessment of the Feeding Systems and Feed Resources of Dairy Cattle in Lemu-Bilbilo Wereda Dairy Products-Processing Cooperatives, Arsi Zone of Oromia Regional State, Ethiopia. Addis Ababa University, Addis, Ethiopia.

Tilahun, D. (2021). Assessment of available livestock feed resources in South Gondar Zone, Amhara National Regional State, Ethiopia. *American Journal of Agriculture and Forestry*, 9, 269-275.

Wamatu, J., Ekule, M., & Mebratie, A. (2022). Assessment of knowledge, attitude and practice of smallholder farmers on market-oriented sheep fattening in North Shewa, Ethiopia.

Wude T. (2017). Sheep production systems in urban and peri-urban areas of debre-berhan and dessie, ethiopia, and performance of lambs fed different combinations of wheat bran and lentil screening. PhD Dissertation. Addis Ababa University, Addis Ababa, Ethiopia.

Yamane, Taro. (1973). *Statistics and Introductory analysis*, 3rd Ed., New York: Harper and Row.

Yeshitila, A. (2008). Assessment of Livestock Feed Resources Utilization In Alaba *Woreda*, Southern Ethiopia. Msc Thesis. Haramya University, Haramya, Ethiopia.

Zemene, W., Tilahun, S., & Tolemariam, T. (2016). Assessment of the prevailing cattle fattening practices in Jimma Zone, South-Western Ethiopia. *Global Veterinaria*, 17(2), 105-113.

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In vitro antibacterial activity of Tamarind (*Tamarindus Indica*) seed extracts against *Staphylococcus aureus* and *Klebsiella pneumoniae*

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Abstract

Despite the discovery of antibiotics, infectious diseases remain a serious concern due to the rise of antibiotic resistance. This situation necessitates the urgent search for alternative antimicrobial agents from various sources. Plants are a priority because of their bioactive components, which have potential in combating multi-drug resistant microorganisms. In Ethiopia, communities have traditionally used the seeds of Tamarind (Tamarindus indica) for wound healing, snake bites, abdominal pain, inflammation, helminth infections, antimicrobial effects, and diabetes management. However, scientific studies on this plant remain limited. This study aimed to investigate the antibacterial effects of Tamarindus indica seed extracts collected from Itang Woreda, Gambella, Ethiopia, against Staphylococcus aureus and Klebsiella pneumoniae. The maceration technique was used for extraction, employing acetone and ethanol as solvents. The antibacterial activity of each extract was evaluated at concentrations of 100, 200, and 300 mg/mL using the disk diffusion method. Pathogenic strains of Staphylococcus aureus (ATCC 25923) and Klebsiella pneumoniae (ATCC 700603) were obtained from the Ethiopian Biodiversity Institute and cultured on selective media. The findings indicated that neither the acetone nor ethanol extracts were effective against S. aureus or K. pneumoniae at any tested concentration. No significant differences were observed between the extracts and the negative control (P > 0.05). However, results were significantly different from the positive control (P < 0.05). These results suggest that Tamarindus indica seed extracts do not exhibit antibacterial activity against the tested bacteria. Further research on other pathogenic bacteria and fungi is recommended for more comprehensive conclusions.

Keywords/Phrases: Antibacterial activity, Disk diffusion, Maceration, Pathogenic bacteria, *T. indica*

1   Introduction

Infectious diseases have long posed a significant threat to humanity, and the discovery of antibiotics was initially considered a major victory against them. However, the increasing incidence of multi-drug resistance among pathogenic bacteria has intensified the struggle, seemingly favoring the bacteria (Aminov, 2010; Rios *et al*., 2016; Reygaert, 2018; Kim and Song, 2019; Talebi *et al*., 2019).

Attempts to combat infectious diseases through advancements in medicine have targeted not only bacteria but also fungi, viruses, and parasites. Unfortunately, these efforts often appear futile due to the widespread resistance to chemical antibiotics, which has reached alarming levels and poses a significant threat to global health (Reygaert, 2018; Stokes *et al*., 2020).

Despite significant efforts to manage infectious diseases with antibiotics, the rise of antimicrobial resistance, along with the high costs and widespread side effects of conventional drugs, highlights the ur-

gent need for new antimicrobial agents. This necessity drives scientists to explore alternative sources, particularly plants, which are prioritized for their bioactive components that may effectively combat multi-drug resistant microorganisms (Rahman *et al*., 2018; Stokes *et al*., 2020). Literature reviews indicate that plants possess bioactive compounds that support their use in traditional medicine and can serve as sources for pharmaceutical products.

Historical records show that the use of medicinal plants to alleviate human suffering dates back thousands of years, originating with early human civilization (Muluken *et al*., 2017; Helen *et al*., 2019). Phytochemicals produced during the secondary metabolism of plants—such as tannins, alkaloids, phenolic compounds, and flavonoids—are scientifically recognized for their therapeutic effectiveness (Belayhun *et al*., 2024; Njeru *et al*., 2013; Pagare *et al*., 2015). These compounds are valuable in traditional medicine for treating chronic and common microbial infections (Yuan *et al*., 2016; Salmerón-Manzano *et al*., 2020).

Ethiopia boasts a rich traditional healthcare system based on plants, with roots extending back several millennia. This long history has made it a vital part of Ethiopian culture as a source of therapeutics (Kebede *et al*., 2007; Netsanet *et al*., 2020). However, knowledge about medicinal plants varies among Ethiopian communities; a plant valued in one area may be underutilized in another due to a lack of documentation regarding its therapeutic properties (Behailu *et al*., 2021). While studies have acknowledged this diverse traditional knowledge, there has yet to be a systematic investigation into the antimicrobial effects of each species to enhance indigenous practices.

Prior research (Kuru, 2014; Menezes *et al*., 2016; Gomathinayagam *et al*., 2017; Pramila and Jirekar, 2021) has identified various bioactive phytoconstituents in *Tamarindus indica*, associated with numerous health benefits in traditional medicine, including wound healing, snake bites, abdominal pain, inflammation, helminth infections, antimicrobial properties, and antidiabetic effects. This background serves as the basis for the current study, which evaluates the antibacterial effects of crude seed extracts of *Tamarindus indica* against *S. aureus* and *K. pneu-*

moniae.

Tamarindus indica L., belonging to the Fabaceae (Leguminosae) family and the Caesalpinioideae subfamily, is commonly known as tamarind. It is believed to be native to tropical Africa, particularly Sudan and surrounding regions, including Ethiopia, but has been widely naturalized and cultivated across tropical and subtropical areas of the world (Orwa *et al*., 2009). While not originally native to Ethiopia, tamarind has been cultivated extensively, particularly in lowland and arid regions such as Afar, Somali, Eastern Hararge, South Omo Zone, Benshangul-Gumuz, Gambella, and the Rift Valley (Abdulrazak and Tadesse, 2016).

Though tamarind (*Tamarindus indica*) is primarily valued for the nutritional aspects of its fruit pulp, its seeds are traditionally used to treat various diseases, often discarded as waste. In a previous study, we explored the antibacterial activities of tamarind fruit pulp extracts, yielding encouraging results (Gatluak *et al*., 2024). Despite the traditional use of tamarind seeds for medicinal purposes across various Ethiopian communities, the potential of these extracts as antimicrobial agents against drug-resistant bacteria has not been thoroughly investigated. This study aims to examine the antibacterial activity of tamarind seed extracts, traditionally considered waste, to provide scientific evidence supporting their use as alternatives for treating antibiotic-resistant pathogens.

2 Material and methods

2.1 Seed sample collection

Dry pods of *Tamarindus indica* were collected from Itang Special Woreda, located 35 km from Gambella city and approximately 801 km from Addis Ababa, Ethiopia, in January 2022. The samples were then transported to the microbiology laboratory at Dilla University, Ethiopia. This Woreda is situated between latitudes 8^o4N to 8^o5N and longitudes 34^o30E to 33^o55E, classified as lowland with an altitude ranging from 350 to 480 meters above sea level. The climate is hot and humid, with annual temperatures ranging from a minimum of 18.09^oC to a maximum of 39.34^oC, and an average annual rainfall of 1500 to 2000 mm during the rainy season.

Upon arrival at the microbiology laboratory, the collected *Tamarindus indica* pods were cut with scissors, wrapped in newspaper, and placed in a sealable plastic bag. They were then taken to the Department of Biology at Dilla University, where a botanist identified the samples, which were kept under voucher number GG-002. The pulp was manually peeled off using a stainless-steel knife, and the seeds were allowed to dry at room temperature in the laboratory for about two weeks, with careful monitoring to prevent contamination.

After complete drying, the seeds were ground using a general-purpose grinder to an appropriate size for extraction, utilizing a 0.5 mm mesh (Geremew *et al.*, 2018). The resulting powder was labeled and stored in a tightly sealed glass bottle at -20ºC until use.

2.2   Crude extraction and yield

The maceration technique was adopted for extraction due to its high efficiency. Crude extracts were obtained using two analytical-grade solvents with increasing polarity: acetone from Loba Chemie Pvt. Ltd and ethanol from Alpha Chemika, India. The extraction protocols were based on Jundi *et al.* (2021) with minor modifications.

Briefly, 100 grams of *Tamarindus indica* seed powder were macerated in acetone for 24 hours at a ratio of 1:5 (w/v). The mixture was then filtered using double-layer filter paper (Fisher brand), yielding filtrates and residues. The residue was subsequently macerated in ethanol for another 24 hours using the same ratio as with acetone.

The filtrates were evaporated using a rotary evaporator (Merk, UK) at 45^oC to obtain the crude extracts. The resulting mass was weighed in grams using an electronic balance and stored in small bottles in a refrigerator at -20^oC. The yield percentage was calculated using the formula provided by Mariah *et al.* (2021), as shown in Eq. 1.

$$Extract\ yield(\%) = \left(\frac{Dry\ weight\ of\ extract}{Dry\ weight\ of\ plant\ seed\ powder} \right) x100$$

2.3   Test bacteria

Two bacterial strains from the American Type Culture Collection (ATCC) were used for this study: one Gram-negative strain, *Klebsiella pneumoniae*

(ATCC 700603), and one Gram-positive strain, *Staphylococcus aureus* (ATCC 25923). These strains were selected due to their pathogenicity and their association with frequent and serious infections in humans. The bacterial samples were kindly provided by the Ethiopian Biodiversity Institute in Addis Ababa, Ethiopia.

2.4   Preparation of test solutions

The crude seed extracts were diluted to prepare three different concentrations in separate flasks, following the methods of Mesay *et al.* (2020). Specifically, working stock solutions of 100, 200, and 300 mg/mL were prepared by transferring 100, 200, or 300 mg of each extract into sterile test tubes, each containing 1 mL of 3% Tween 20. The resulting concentrations were 100, 200, and 300 mg/mL, respectively. The stock solutions were stored at -20^oC until further investigation.

2.5   Antibacterial activity

The disk diffusion method was employed to evaluate the antibacterial activity of the extracts, following the procedures described by Gatluak *et al.* (2024) and Workineh *et al.* (2024). Briefly, paper disks with an approximate diameter of 6 mm were punched from a sheet of absorbent filter paper and sterilized in an autoclave at 121^oC for 1 hour.

Each bacterial strain was grown on its selective medium: *Klebsiella pneumoniae* on MacConkey agar and *Staphylococcus aureus* on mannitol-salt agar and incubated at 37^oC for 24 hours. A few colonies of each strain were then transferred with a sterile inoculating loop to nutrient broth, adjusting the turbidity to match the McFarland 0.5 turbidity standard.

Two groups of plates containing Mueller-Hinton agar were prepared, with the two bacterial strains streaked using sterile cotton swabs. One group was used to test acetone extracts, while the other was for ethanol extracts. The surface of each plate was divided into five sections, each accommodating five paper disks: three disks containing extracts at different concentrations, one for the positive control, and one for negative control. Tetracycline, a broad-spectrum antibiotic effective against both aerobic and anaerobic

Gram-positive and Gram-negative pathogens, was used as the positive control (Nguyen *et al*., 2014; Pancu *et al*., 2021).

Each disk was loaded with 50 μL of the crude extract at the specified concentrations in separate quadrants of each plate. In the other two quadrants, one disk contained 30 μL of a 2.5 mg/mL Tetracycline solution (positive control), and another disk was immersed in 1 mL of 3% Tween 20 (negative control). All plates were incubated at 37°C for 24 hours, after which the zone of inhibition was measured in millimeters using a ruler and recorded. The test was conducted in triplicate, and the results were expressed as the average zone of inhibition (ZOI) for each plant extract.

2.6 Data analysis

All data obtained from the experimental results were recorded by measuring the zone of inhibition (ZOI) in millimeters for each control and crude extract against each bacterium. The average values were calculated as the mean $\pm$ standard error of the mean (SEM) from the triplicate tests. The results were compared using one-way analysis of variance (ANOVA) with Tukey's Honest Significant Difference (HSD) test, with 95% confidence intervals (CI). A P-value of less than 0.05 was considered statistically significant.

2.7 Ethical Consideration

Ethical clearance was obtained from the ethical committee of Dilla University after securing a letter from the Department of Biology.

2.8 Results and Discussions

The study results indicated that the extraction of *Tamarindus indica* seed powder yielded two different crude extracts: the acetone extract and the ethanol extract, with respective crude masses and percent yields of 5.0 g (5%) and 7.1 g (8%). These results show variation in the crude mass obtained from the extraction, with ethanol yielding a higher crude mass than acetone. This finding aligns with the work of Mesay *et al*. (2020), which reported higher yields from ethanol compared to acetone and chloroform. Similarly, Mariah *et al*. (2021) found that among various solvents, hexane yielded the least due to its lower polarity.

The variation in solvent polarity appears to be a significant factor influencing the extraction efficiency. Since ethanol has higher polarity than acetone, it is expected to extract more soluble compounds, resulting in a higher yield. However, given the limited sample size (using only two solvents), caution is warranted, as these findings may not be generalizable across a broader range of organic and inorganic solvents used in extraction processes.

In terms of antibacterial activity, the crude extracts from the seeds of *T. indica* showed unexpected results against *Staphylococcus aureus* and *Klebsiella pneumoniae*. None of the three concentrations (100, 200, and 300 mg/mL) of either acetone or ethanol extracts demonstrated inhibitory effects on the growth of both tested pathogenic bacteria (Table 1).

According to this data, this study found no statistically significant difference between the crude extracts and the negative control (P > 0.05). However, the results were significantly different from the positive control (P < 0.05) (Table 2). The significant difference between the crude extracts and the drug (positive control), along with the lack of difference between the crude extracts and the negative control (3% Tween 20), suggests that the extracts have no antibacterial activity against the test bacteria.

Table 1. Qualitative growth inhibitory level of *T. indica* seed extracts on the tested pathogenic bacteria compared to the Tetracycline antibiotic (positive control) and Tween 20 (negative control)

Solvent	Extract concentration (mg/mL)	Test bacteria	
		Staphylococcus aureus	*Klebseilla pneumoniae*
Tween 20	1 mL	-	-
Tetracycline	2.5	++++	++++
Acetone	100	-	-
	200	-	-
	300	-	-
Ethanol	100	-	-
	200	-	-
	300	-	-

Note: - = No effect, ++++ = Strong effect

Table 2. Quantitative growth inhibitory activity (mm) of *T. indica* seed extracts against pathogenic bacteria compared to both positive (Tetracycline antibiotic) and negative (Tween 20) controls

Solvent	Extract concentration (mg/mL)	*S. aureus*		*K. pneumoniae*	
		Mean $\pm$ SEM	P-value	Mean $\pm$ SEM	P-value
Tween 20	1 mL	0.00 ± 0.00^b	< 0.05	0.00 ± 0.00^b	< 0.05
Tetracycline	2.5	15.67 ± 0.67^a	> 0.05	16.33 ± 0.33^a	> 0.05
	100	0.00 ± 0.00^b	< 0.05	0.00 ± 0.00^b	< 0.05
Acetone	200	0.00 ± 0.00^b	< 0.05	0.00 ± 0.00^b	< 0.05
	300	0.00 ± 0.00^b	< 0.05	0.00 ± 0.00^b	< 0.05
Tetracycline	2.5	15.33 ± 0.33^a		16.33 ± 0.33^a	
	100	0.00 ± 0.00^b	< 0.05	0.00 ± 0.00^b	< 0.05
Ethanol	200	0.00 ± 0.00^b	< 0.05	0.00 ± 0.00^b	< 0.05
	300	0.00 ± 0.00^b	< 0.05	0.00 ± 0.00^b	< 0.05

a; b = showing significant differences of the extracts with the positive control,
the mean values with different superscripts in the same column are significantly different.

In accordance with the present results, these findings mirror those of Sutrisno *et al.* (2019), which demonstrated that the hexane crude oil extract from *Tamarindus indica* seeds showed no inhibition against *Staphylococcus aureus* and Escherichia coli. Conversely, the outcomes presented here contrast with the findings of Das *et al.* (2014), who reported varying degrees of antimicrobial activity from the methanolic extract of *T. indica* seeds against Salmonella paratyphi A, Salmonella typhi, E. coli, *S. aureus*, methicillin-resistant *S. aureus*, Vibrio cholerae, S. paratyphi B, Pseudomonas aeruginosa, Bacillus subtilis, Proteus alcalifaciens, Proteus mirabilis, C. fulvum, Neurospora crassa, and Aspergillus niger.

Furthermore, the levels of activity observed in this investigation were significantly lower than those reported by Sujith *et al.* (2015), who noted good activity against some Gram-positive bacteria with the seed coat extract, although not against Gram-negative bacteria.

The reasons for these contradictory results are unclear, but they may relate to the nature of the solvents used, as different solvents can produce varying phytochemicals (secondary metabolites) from the same plant sample (Tiwari and Rana, 2015; De Castro *et al.*, 1998; Twaij and Hasan, 2022). Additionally, the specific bacterial strains tested (*S. aureus* and *K. pneumoniae*) and possible interference from the extraction solvents cannot be ruled out.

3 Conclusion

The findings of this study indicate that the *Tamarindus indica* seed extract did not exhibit antibacterial activity. Therefore, these results do not support strong recommendations for its use by indigenous communities for treating various diseases, as the implications of both the solvent used and the specific bacterial strains should be considered. Further research involving other pathogenic bacteria and fungi is necessary to draw more convincing conclusions.

Conflict of Interest

The authors declare that there is no competing interest in relation to this work.

References

Abdulrazak Mohammed, and Tadesse Abdisa (2016). Review on indigenous multipurpose agroforestry tree species in Ethiopia: Management, challenges and their future prospects. *International J. of Multidisciplinary and Current Research*, 4, 571–577.

Aminov, R. (2010). A brief history of the antibiotic era: lessons learned and challenges for the future. *Front Microbiol*. http://doi.org/10.3389/fmicb.2010.00134.

Behailu Assefa, Moa Megersa, & Tilahun Tolossa Jima. (2021). Ethnobotanical study of medicinal plants used to treat human diseases in Gura Damole District, Bale Zone, Southeast Ethiopia. *Asian J. of Ethnobiology*, 4(1): 42–52.

Belayhun Mandefro, Workineh Mengesha Fereja, Dawit Fremichael, Saeid Tiku Mereta, Argaw Ambelu (2024). Analysis of Achyranthes aspera leaf extract and acute toxicity study on fingerlings of Nile tilapia, Oreochromis niloticus. *J. of Biochemistry and Biophysics Reports*. 37. http://doi.org/10.1016/j.bbrep.2023.101624.

Brown, S.P., Grillo, M.A., Podowski, J.C., Heath, K.D. (2020). Soil origin and plant genotype structure distinct microbiome compartments in the model legume. *Medicago truncatula. Microbiome*. 8(1):1-17.

Das, S., Pramanik, G., & Mandal, S. C. (2014). Antimicrobial properties of methanol extract of *Tamarindus indica* seeds: An ethnomedicinal plant. *J. of Ethnopharmacology*, 1(2): 60–62.

De Castro, F., Azevedo, H., & Dodd, I. C. (1998). The influence of environmental conditions on tree physiology and growth. *J. of Experimental Botany*, 49: 123–132.

El-Shemy, H., Aboul-Soud, M., Nassr-Allah, A., Aboul-Enein, K., Kabash, A., Yagi, A. (2010). Antitumor properties and modulation of antioxidant enzymes' activity by *Aloe vera* leaf active principles isolated via supercritical carbon dioxide extraction. *Current medicinal chemistry*. 17(2):129–138.

Gatluak Goanar, Geremew Tafesse, & Workineh Mengesha Fereja (2024). *In vitro* antibacterial activity of fruit pulp extracts of *Tamarindus indica* against *Staphylococcus aureus* and *Klebsiella pneumoniae*. BMC Complement Med Ther 24, 127. https://doi.org/10.1186/s12906-024-04404-6.

Geremew Tafesse, Yalemtsehay Mekonnen, Eyasu Makonnen, Runner R. T. Majinda, Gomotsang Bojase-Moleta, Samuel O. Yeboah (2018). Antibacterial activity of crude extracts and pure compounds isolated from *Vernonia galamensis* leaves. *African J. of Pharmacy and Pharmacology*, 12(11): 136–141.

Gomathinayagam, S., Tewari, B. B., & Rekha, G. (2017). Heavy metal and phytochemical studies of crude leaf extract of tamarind (*Tamarindus indica*). *Advances in Life Sciences*, 7(1): 1–4.

Helen Bitew, Haftom Gebregergs, Kald Beshir Tuem, Mariamawit Yonathan Yeshak (2019). Ethiopian medicinal plants traditionally used for wound treatment: A systematic review. *Ethiopian J. of Health Development*, 33(2): 102–127.

Jundi Ismael, Engida Dessalegn, & Workineh Mengesha Fereja (2021). *In Vitro* antioxidant and antibacterial activity of leaf extracts of *Measa lanceolata*. *International J. of Food Properties*, 24(1), 702–712.

Kebede Deribe Kassaye, Alemayehu Amberbir, Bekalu Getachew, Yunis Mussema (2007). A historical overview of traditional medicine practices and policy in Ethiopia. *Ethiopian J. of Health Development*, 20(2): 127–134.

Kim, H., & Song, J. (2019). Computational prediction method of antibiotics resistance by PK/PD algorithms using bioinformatics software. *Advances in Biotechnology*, 14(2): 41–52.

Kuru, P. (2014). *Tamarindus indica* and its health-related effects. *Asian Pacific J. of Tropical Biomedicine*, 4(9): 676–681.

Mariah, N. M., Mourine, K., & Christine, B. (2021). Qualitative and quantitative phytochemical profiling of crude fractions of *Pechuel-Loeschea leubnitziae* leaves. *J. of Medicinal Plants Research*, 15(2): 64–72.

Menezes, A. P. P., Trevisan, S. C. C., Barbalho, M., & Guiguer, E. L. (2016). *Tamarindus indica* L. A plant with multiple medicinal purposes. *J. of Pharmacognosy and Phytochemistry*, 5(3): 50–54.

Mesay Bahiru, Geremew Tafesse, Nitin M. Chauhan, & Ermias Assefa (2020). Antimicrobial activity of crude extract from *Millettia ferruginea* leaves and barks against selected bacterial pathogens and Candida albicans. *J. of Microbiology and Antimicrobials*, 12(2): 81–87.

Muluken Wubetu, Tefera Abula, & Getye Dejen. (2017). Ethnopharmacologic survey of medicinal plants used to treat human diseases by traditional medical practitioners in Dega Damot district, Amhara, Northwestern Ethiopia. *BMC Research Notes*, 10(1): 157–170.

Netsanet Gonfa, Dereje Tulu, Kitessa Hundera, & Dasalegn Raga (2020). Ethnobotanical study of medicinal plants, its utilization, and conservation by indigenous people of Gera district, Ethiopia. *Cogent Food & Agriculture*, 6(1): 1–25.

Njeru, S. N., Matasyoh, J., Mwaniki, C. G., Mwendia, C. M., & Kobia, K. (2013). A Review of some phytochemicals commonly found in medicinal plants. *International J. of Medicinal Plants*, 105: 135–140.

Nguyen, V.; Lilly, B.; Castro, C. (2014). The exoskeletal structure and tensile loading behavior of an ant neck joint. *J. of Biomechanics*, 47:497-504.

Orwa, C.; Mutua, A.; Kindt, R.; Jamnadass, R.; Anthony, S., (2009). Agroforestree Database: a tree reference and selection guide version 4.0. World Agroforestry Centre, Kenya. http://worldagroforestry.org/output/agroforestree-database.

Pagare, S., Bhatia, M., Tripathi, N., Pagare, S., & Bansal, Y. K. (2015). Secondary metabolites of plants and their role: Overview. *Current Trends in Biotechnology and Pharmacy*, 9(3): 293–304.

Pancu DF, Scurtu A, Macasoi IG, Marti D, Mioc M, Soica C, Coricovac D, Horhat D, Poenaru M, Dehelean C. (2021). Antibiotics: Conventional Therapy and Natural Compounds with Antibacterial Activity-A Pharmaco-Toxicological Screening. *Antibiotics (Basel)*, 10(4):401. http://doi.org/10.3390/antibiotics10040401.

Pramila, G., & Jirekar, D. (2021). *Tamarindus indica*: An important medicinal plants. *International J. of Innovative Research in Technology*, 8(4): 321–325.

Rahman, M. M., Shahriar, M. R., Meghla, N. S., Ishika, T., Roy, P. C., & Kamruzzaman, M. (2018). Antimicrobial activity of some medicinal plant extracts against Gram positive and Gram negative bacteria in Bangladesh. *Asian J. of Medical and Biological Research*, 3(4): 405–411.

Reygaert, W. C. (2018). An overview of the antimicrobial resistance mechanisms of bacteria. *AIMS Microbiology*, 4(3): 482–501.

Rios, A. C., Moutinho, C. G., Pinto, F. C., Del Fiol, F. S., Jozala, A., Chaud, M. V., Vila, M. M. D. C., Teixeira, J. A., & Balcão, V. M. (2016). Alternatives to overcoming bacterial resistances: State-of-the-art. *Microbiological Research*, 191: 51–80.

Salmerón-Manzano, E., Garrido-Cardenas, J. A., & Manzano-Agugliaro, F. (2020). Worldwide research trends on medicinal plants. *International J. of Environmental Research and Public Health*, 17(10): 3376–3396.

Stokes, J. M., Yang, K., Swanson, K., Jin, W., *et al.* (2020). A deep learning approach to antibiotic discovery. *Cell*, 180(4): 688–702.

Sujith, S., Sreedevi, R., Suja, R. S., & Juliet, S. (2015). Evaluation of *Tamarindus indica* seed coat for its antimicrobial activity and acute oral toxicity. *International J. of Applied and Pure Science and Agriculture*, 1(3): 13–18.

Sutrisno, S., Retnosari, R., & Marfu'ah, S. (2019). Study of antibacterial activity of *Tamarindus indica* L. seed oil and its fatty acids. *IOP Conference Series: Earth and Environmental Science*, 299(1): 1–6.

Talebi, A. B. A., Rizvanov, A. A., Haertlé, T., & Blatt, N. L. (2019). World Health Organization Report: Current crisis of antibiotic resistance. *BioNanoScience*, 9(4): 778–788.

Tiwari, R., & Rana, C. S. (2015). Plant secondary metabolites: A review. *International J. of Engineering Research and General Science*, 3(5): 661–670.

Twaij, B. M., & Hasan, Md. N. (2022). Bioactive secondary metabolites from plant sources: types, synthesis, and their therapeutic uses. *International J. of Plant Biology*, 13(1): 4–14.

Workineh Mengesha Fereja, Wakuma Debessa Geleta, Engida Desalegn, *et al*. (2024). *In vitro* antioxidant and antibacterial activities of *Ajuga integrifolia* leaf extracts obtained with different solvents. *BMC Complement Med Ther* 24, 368. https://doi.org/10.1186/s12906-024-04668-y

Yuan, H., Ma, Q., Ye, L., & Piao, G. (2016). The Traditional Medicine and Modern Medicine from Natural Products. *Molecules*, 21(5): 559–577.