

Biopesticidal Effect of *Acokanthera schimperi* and *Nicotiana tabacum* on Maize Storage Insect, *Sitophilus zeamais*Gobu Gosa^{1,2}, Yitbarek W/Hawariat², Gezahegn Degefe*,³ , Chirotaw Ayele⁴¹ Department of Biology, Bule Hora University, Bule Hora, Ethiopia;² Department of Zoology, Addis Ababa University, Addis Ababa, Ethiopia;³ Department of Biology, Debre Berhan University, Debre Berhan, Ethiopia;⁴ Department of Biology, Dilla University, Dilla, Ethiopia;

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Article DOI:10.20372/ejed.v07i1.01**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)

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

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. Kırıcı *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	<i>Nicotiana tabacum</i>	Shrub	Cultivated	Leaf	Maize weevil
2	Qaraaruu	<i>Acokanthera schimperi</i>	Tree	Wild	Leaf	(<i>S.zeamais</i>)

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	<i>N. tabacum</i>	Powder	8	30	12	18.3	59
2	<i>A. schimperi</i>	Powder	8	30	24	6.0	18
3	Standard check /AIP	Powder	0.9	30	0	30.0	100
4	Control	-	-	30	29	0.7	0

* $\alpha=0.05$, $df=11$, $F=124.27$, $P\text{-value}=0.00$; AIP - 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 ± 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

* Nt₁- *N. tabacum* dose1, Nt₂- *N. tabacum* dose2, Nt₃- *N. tabacum* dose3; As₁- *A. schimperi* dose1, As₂- *A. schimperi* dose2, As₃- *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.

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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 research investigates the transparency of urban land management in Ethiopia, focusing on the towns of Sebeta, Gelan, and Sendafa-Bake within the Oromia Region. To fulfill this objective, a convergent research design was adopted, framed within a mixed-methods research approach. Data was gathered through both qualitative and quantitative means from primary and secondary sources. Various techniques, including interview schedules, interviews, focus group discussions, and document analysis, were employed to gather information. The study utilized both probabilistic and non-probabilistic sampling methods to select participants. Statistical and contextual analysis techniques were applied to present and interpret the data. The results of the study reveal that the land management system in the examined area is deficient in a robust transparency framework. In addition, more than 60% of the respondents stated that the level of transparency in the official activities of land management offices was limited. According to the study's recommendations, regional and local governments should make sure that the land management system adheres to transparent, uniform, and unambiguous service delivery standards in order to offer citizen's fair, impartial, and nondiscriminatory services. This helps to ensure that an efficient and effective land and land-related services system is consolidated in the study area.

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

1 Introduction

1.1 Background and Purpose

Land in Sub-Saharan Africa is increasingly recognized as an important national policy issue (Adugna & Workalemahu, 2023 and Hafte & Pregala, 2021). Nevertheless, land administration in the area is hindered by a deficiency in transparency due to convoluted regulatory frameworks and intricate administrative procedures. Degu (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." Employees at land administration offices are susceptible to corruption. The works of Zevenbergen *et al.* (2024) also recognize that inefficiency in land administration is a prevalent, persistent, and serious issue that

is becoming increasingly acknowledged as a critical characteristic of the Region. Consequently, the ambiguity surrounding land policies and laws, inadequately managed urban land administration and development processes, along with the ensuing land disputes, have consistently been among the primary issues that underscore the necessity for transparent land management in the region. This highlights the imperative to promote 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). As a result, cities and towns have alarmingly expanded into

neighboring 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 democratic 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).

According to the FDRE-Ministry of Urban Development, Housing, and Construction (2014), urban land depends on the establishment of a modern and effective system that enables the achievement of development, growth, and open governance of urban areas. The land management policy and law at the federal and regional levels, as well as the urban land lease-holding proclamations and other regulations and directives, are the legal frameworks that impact land management in the country. 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. According to these research, bribery, land grabbing, and other forms of corruption are among the many misconducts that surround the urban land administration system. In this regard, the

government has also stated that land management frameworks are top-down and inflexible, restricting what landholders may and cannot do. As a result, the land use system's flexibility—which is crucial for socioeconomic development—is reduced, which has negative effects on inclusive and transparent 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 have also sought to comprehend the land administration system from various viewpoints. The investigation carried out by Transparency International (2014) has underscored the widespread corruption within the country's land administration system, whereas Alemie's (2015) research emphasized the significance of cadaster in urban land management frameworks. Furthermore, Takele, Kwame & Melese (2014) noted in their study that methods to enhance effective management in urban land administration in the country are exemplified by a case study of Hawassa City. Olira (2022) evaluated the practices of urban land administration in Shashemene City, while Hafte (2021) examined the urban land governance of Mekelle City.

Nevertheless, the majority of current research focuses on urban land management in large urban areas, specifically 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. Furthermore, no empirical research has been done in the subject region to look at the transparency of urban land management. Given this, the current study set out to investigate the institutional transparency of the nation's land management system. This study

looked at how openly tiny, previously rapidly growing urban communities in Ethiopia's Oromia Region managed their urban land. 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 research therefore examined the level of transparency within the urban land management system of Sebeta, Gelan, and Sendafa-Bake in the Oromia Region of Ethiopia. It sought to evaluate the decision-making process, the availability of official information, the public's oversight of official actions, and various other aspects of transparency in the land management systems of the towns under study.

1.2 Institutional Transparency in Land Management

One key element that public service providers guarantee to the public is transparency in official activities. It promotes public trust in both the caliber of services being rendered and the officials who carry out their official responsibilities. 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 signifies that the policies, laws, regulations, charters, codes, and rules governing land must be accessible to the public (Transparency International, 2021). Additionally, it encompasses the statutory instruments related to land, ensuring they are understandable, which includes promoting legal literacy (Erkkila, 2020). Moreover, institutional transparency in land management pertains to the organizational structures, levels of decision-making processes, and procedures. It is essential to provide informational leaflets, checklists, guides, and forms that outline the necessary steps, the time required to complete processes, and the means to access information regarding land, including appeal routes. Furthermore, the facilities and offices should be open to the public (Zimmermann, 2008).

Urbanization and use of land for various services imply an "increased need for well-designed land policies 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 regard, the idea of transparency implies that government agencies must make judgments and take acts in an open manner in accordance with legal norms and regulations. It shows that citizens impacted by government choices and activities have unrestricted and open access to pertinent and accurate official information. This also indicates that sufficient information is supplied and that it is presented in formats and media that are easily comprehensible. Land management organizations must create innovative methods to document and preserve land information, which guarantees enhanced service delivery within a reasonable timeframe. Land allocation and dispute resolution procedures should be simple and uncomplicated. 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). Therefore, transparency in the land management institutions is crucial for "sustainable development in terms of equitability, stakeholder participation, and benefits, and consistency in law and policy implementation" (Burns & Dalrymple, 2008, p. 2). Thus, it has been proven that the management of other public sectors cannot be separated from the management of transparent land administration.

However, due to a number of obstacles in their attempts to meet public demands, nations that are developing, like Ethiopia, have a poor track record of guaranteeing a genuine and efficient urban land administration system. Even though the majority of people in most of these nations rely on land for their fundamental livelihood, their land administration systems are susceptible to a variety of issues, from straightforward administrative bottlenecks to official corruption. This raises doubts about the countries' land administration rules and procedures' transparency. Both national and municipal governments are under pressure to address the collective and individual demands and interests of citizens due to administrative, economic, political, institutional, and

technical issues. However, current debates in the literature on public administration indicate that the application of transparent management principles in the formulation and implementation of public policies, particularly in urban land management, successfully resolves problems, ensures the effective delivery of land and land-related services, and satisfies the basic needs of the people in these countries. Consequently, the study has investigated the degree of transparency in urban land management within the context of theoretical frameworks of transparency.

2 Research Methods and Materials

2.1 Research Approach and Design

A thorough analysis of the institutional transparency in land management necessitates the use of both quantitative and qualitative methodologies (Burns & Dalrymple, 2008). In this context, the study employed both quantitative and qualitative research methods. Exploring the views of respondents and analyzing documents to describe the extent of transparency in the land management process required both approaches. Both objective examination of numerical data and interpretive comprehension of respondents' responses were carried out in order to accomplish the study's goals. The study utilized a convergent research design. In this framework, the researcher used a snapshot method to collect data at a particular point during the research process, and both quantitative and qualitative data were collected in a cross-sectional fashion. Additionally, both quantitative and qualitative data were analyzed and interpreted simultaneously.

2.2 Data Sources and Type

Both primary and secondary data sources were used in the study. Focus group participants, key informants, and sample households provided primary data. This primary data was further substantiated by reviewing unpublished documents and statistical information collected from various regional and local government offices. A variety of materials were reviewed in the process of using secondary sources, including published articles, research studies, earlier investigations, books, official reports from federal and regional offices, town administration documents, government policies, legal documents, publications

from the Central Statistical Agency, and other pertinent sources. Additionally, data that was both qualitative and quantitative was gathered and examined. While key informant interviews, focus groups, and document analysis were used to obtain qualitative data, interview schedules were used to collect quantitative data.

2.3 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:

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

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).

This was used to determine the sample size, and 382 household respondents from the three towns were selected as a representative sample of the entire population. Nevertheless, 357 interview schedules were accurately recorded and examined by data collectors, while the remaining 29 were rejected because respondents' answers were not correctly filled out, and some of the questionnaires were incomplete or imprecise. As a result, 357 respondents provided quantitative data, yielding a response rate

of around 93.5%. Using SPSS (Statistical Package for Social Sciences version 25), the quantitative data was edited, coded, classed, entered, and analyzed. The results were presented 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. Text analysis of documents and content analysis of interviews were used to assess qualitative data. In terms of research ethics, the study has made an effort to uphold participant rights, informed consent, confidentiality, and anonymity.

3 Results

In the realm of urban land management, it is essential to focus on creating and reinforcing a transparent system, given that this sector is particularly vulnerable to corruption and various types of maladministration. Consequently, the subsequent section outlines the findings and discussions derived from data gathered from multiple sources concerning the degree of transparency in urban land service delivery within the towns of Sebeta, Gelan, and Sendafa-Bake in the Oromia Region, near Addis Ababa, Ethiopia.

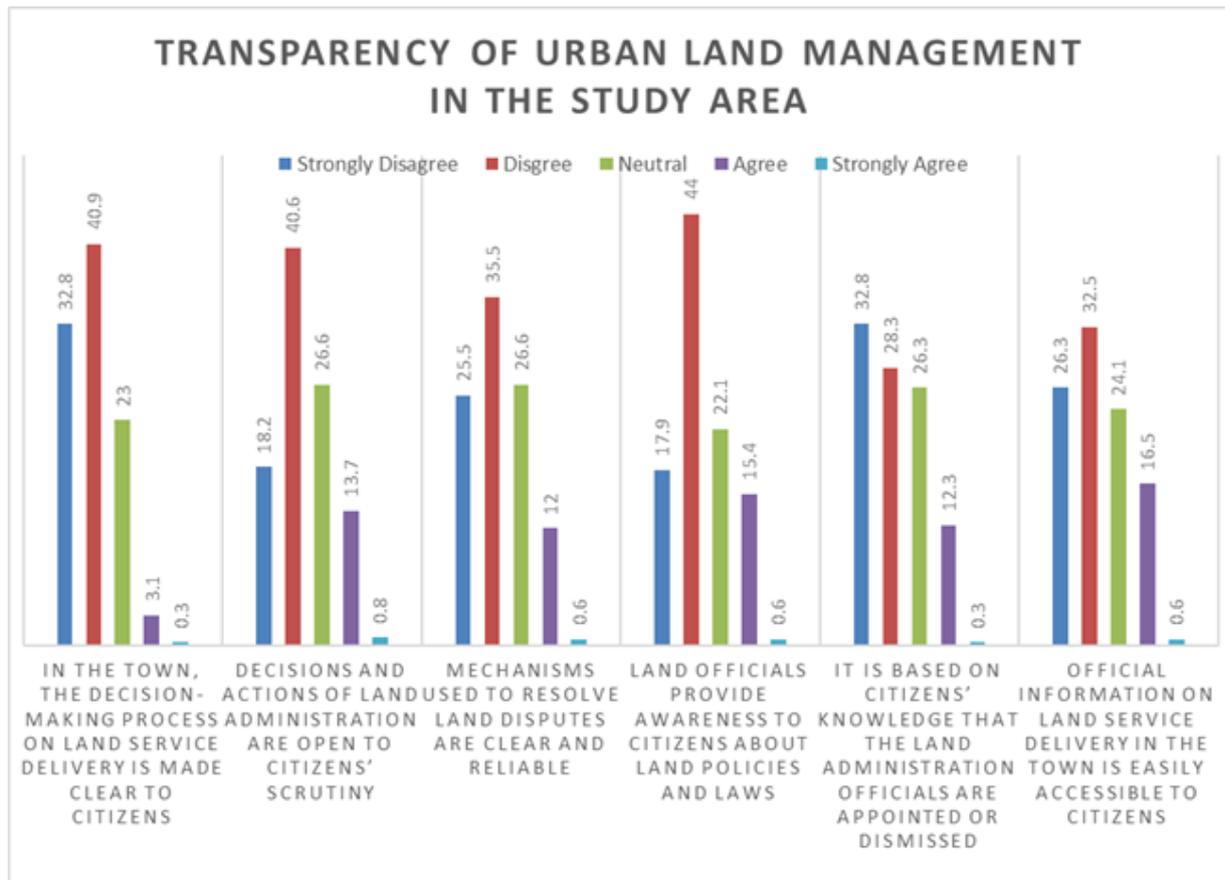
The graph below shows that the majority of respondents, 73.1% (40.9% disagree and 32.2% strongly disagree, respectively), believe that the decision-making process for land service delivery in the study towns was unclear to the public, while about 23% have a neutral opinion. However, only 14.5% of respondents thought that individuals could understand the decision-making process. In a similar vein, the majority of household heads who took part in the study (58.8%) stated that land administration decisions and actions were not subject to public scrutiny,

but approximately 14% of them had a complaint against the majority. The remaining 36.6% of respondents were undecided about the issue.

Although 12% of respondents agreed with the statement that the procedures utilized to settle land disputes in the research area were transparent and trustworthy, two-thirds of respondents disagreed. According to 61.9% of respondents (44% disagree and 17.89% strongly disagree), land administrators were not dedicated to being informed citizens of the land laws and regulations in the research area. Conversely, about 16% of respondents believed that authorities in charge of Urban Land Management and Development tried to educate the public about the institutional frameworks and policies established by local and regional governments.

Furthermore, over 61% of the respondents said that the public knew very little about how land administration officials were selected or fired, while roughly 26% of them had no view. The remaining 12% of interviewees said that the public knew how officials were nominated or fired. Furthermore, the claim that town residents had easy access to official information on land service delivery was rejected by over 58% of the participants. However, about 17% of them stated that locals had easy access to official information regarding land management in the research area. Of them, 24.1% had no opinion about the question.

The qualitative information obtained from respondents through key informant interviews and focus group discussions (FGDs) revealed that the degree of transparent urban land services was restricted, which is consistent with the quantitative data. In this context, one of the key informants interviewed in August 2021 attested to the town's lack of transparency in its land management procedures. He stated that the town's citizens were not given enough information about the decisions and activities of the local administration. The key source said that people seldom receive timely, reliable, and correct information about urban land management. Similarly, a key informant from Gelan town expressed the opinions expressed by other key informants (conducted in August, 2021).



Graph 1. Transparency of Urban Land Management in Sebta, Gelan, and Sendafa-Bake towns of Oromia Region (Source: Field Survey, December, 2021)

As he indicated, it was challenging to assess how transparent the town’s land management system was. The informant claimed that certain officials were not cooperative enough to offer sufficient and trustworthy information regarding the land management and development process. Furthermore, the public was largely unaware of the process used to appoint and remove the head and vice head of the Land Management and Development Bureau. Furthermore, complex adjudication procedures were involved in the resolution of land and land-related disputes. He went on to say that service seekers have to make several trips to offices in order to obtain pertinent information.

Key informants from Sendafa-Bake and Gelan Towns reached the same conclusion as FGD participants in Sebta Town. Participants in the FGD stated that the town’s Land Management and Development Bureau’s decisions and actions lacked sufficient transparency. They contended that in order to obtain proper land information and services,

service seekers were expected to bribe information brokers who acted as a middleman between officials and service seekers. Official information, which was at the very least meant to be included for public knowledge, is manipulated by land brokers.

According to one of the primary informants: accurate and trustworthy information is essential for service seekers. Official information, however, is difficult to get and manipulated. "Middlemen" interact with some officials and use official data to their own benefit. Even though it is exhausting, service seekers must visit offices frequently to obtain information and services. In order to obtain reliable information and services quickly, service seekers occasionally have to engage with brokers. This hindered the transparency of land service delivery. According to a FGD participant in Sendafa-Bake Town in December 2021, the municipal land management office has failed to create an open system to address the interests of the locals.

Participants in the FGD also confirmed to the fact that municipal elected officials hardly ever examined the land management bureau's functions. Participants acknowledged, however, that attempts had recently been made to obtain land-related information on official boards in order 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. In a comparable direction, nearly every key informant interviewee at the Federal and Regional Governments acknowledged that the study towns' urban land management policies were conspicuously opaque.

4 Discussion and Interpretation

In summary, the quantitative and qualitative study presented above makes it evident that the land management methods in the towns of Sebeta, Gelan, and Sendafa-Bake need to be improved further because they do not have a sufficient system of transparency. Official information about land-related decisions and actions was not widely available to the public. In such a scenario, the municipalities' land management operations assigned individuals limited tasks as though they had no involvement 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. Furthermore, it indicates that in order to encourage officials to provide correct and timely information and services, citizens should have attended offices on a regular basis. Furthermore, the land administration system's extensive land brokering practices have restricted residents' ability to closely examine the choices and actions of local governments. 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 by Adugna and Workalemahu (2023) revealed that a lack of transparency poses significant challenges to the implementation of effective governance in urban land use planning within Ethiopia. In a similar vein, Degu (2024) identified transparency as a key factor influencing urban land governance. Furthermore, the empirical findings presented by Hafte and Pregala (2022) corroborate this notion. They discovered that the absence of accountability, insufficient transparency, minimal public engagement, widespread corruption, and breaches of the rule of law are critical factors affecting customer satisfaction levels in Mekelle City, located in the 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, Mohammed Hussein, (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 MoUDHC publication that local governments have failed to ensure transparency in land service delivery (MoUDHC, 2014). More importantly, a study by Deininger, Hilhorst, and Songw (2014) found that the lack of a transparent service delivery method makes land management techniques

in the majority of developing nations vulnerable to corruption. 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 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. According to the researcher, it is crucial to provide land services in a transparent manner so that citizens can understand the decision-making process. 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. Additionally, openness guarantees that individuals have easy access to information and that the procedures used to resolve land disputes are dependable and transparent. The validity of the land service delivery system is greatly enhanced by this. From a management standpoint, ineffective service delivery, corruption, poor administration, citizen discontent, and other types of government bottlenecks are made worse by opaque land

management methods. As a result, public legitimacy declines and the study area's municipal land management methods fall into the category of inadequate management systems. However, it is a well-known truth that providing land services necessitates that processes for allocating land and resolving disputes adhere to the due process outlined in government legislation. Therefore, maintaining transparency makes institutions and their service delivery process accessible to all pertinent parties and permits the free flow of official information that guarantees citizens exercise their fundamental rights.

5 Conclusions

Access to urban land is a crucial requirement for ensuring sufficient housing for everyone and fostering the growth of sustainable human settlements that impact urban regions. Nevertheless, the management of urban land continues to be a highly intricate and controversial matter in Ethiopia, encompassing various processes, elements, and stakeholders. The inability to implement suitable land management practices across all tiers of government is a significant source of academic concern. In this context, the study has evaluated the transparency of urban land management in Ethiopia, concentrating on the cases of Sebeta, Gelan, and Sendafa Bake in the Oromia Region. As a result, the study found that there is insufficient transparency in the land management procedures used in the study cities. Official information on decisions and actions taken by Land Management and Development offices was not widely available to the public. Additionally, rampant land corruption and brokerages hampered the extent to which official functions were carried out in a transparent manner. Additionally, there was insufficient institutionalization of citizens' participation in examining the choices and actions of municipal land management and development initiatives.

Implications of the study

The study has examined a topic that is poorly investigated in the Ethiopian context. The institutional transparency of urban land management in the region and nation with the highest rate of urbanization has been the subject of a few different types of research. Therefore, more scholarly research on the topic is necessary due to the inherent deficiency in

the literature. Furthermore, the study has only examined urban land management from the standpoint of institutional transparency. Other facets of land management and development operations were not discussed. However, researching rural land policy and practices in conjunction with urban land management is as essential.

Recommendations of the Study

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 investigation discovered that the procedures for settling land disputes are unclear and untrustworthy. As a result, concerned government organizations should put forth great effort to guarantee that land dispute resolution procedures are trustworthy and accessible to the general public.
- 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 through their participation in the governance process of local governments.

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

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Abstract

The purpose of the study was to assess the frequency of indigestible waste items in slaughtered cattle as well as related risk factors. From March to July 2024, the study was carried out on cattle killed at the Dilla Municipal Abattoir in the Gedeo Zone of Southern Ethiopia. The animals were evaluated using both ante-mortem and post-mortem inspections using a cross-sectional study design. Numerous foreign objects were found in the reticulum and rumen during these tests. 172 (44.79%) of the 384 killed animals had positive tests for 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%). The rumen contained the majority of plastic materials, whereas the reticulum contained the majority of non-plastic items. Foreign bodies were more common in the rumen than 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.

In order to address the health and digestive issues that cattle confront, this study concentrates on the frequency and location of indigestible foreign bodies in the fore-stomach (rumen and reticulum). In order to address foreign body ingestion in animal health and reduce environmental pollution, it will also be easier to design management protocols, preventive strategies, and policies if associated risk factors are identified. Assessing the frequency and distribution of indigestible foreign bodies and identifying associated risk factors in calves killed at the Dilla Municipal Abattoir are the goals of this study.

2 Materials and Methods

2.1 Study Area

The investigation was carried out at the Dilla Municipal Abattoir in Southern Ethiopia, which is 365 kilometers from Addis Ababa. With an average el-

evation of 1,570 meters above sea level, Dilla is located at latitude 6°24'30" N and longitude 38°18'30" E. Hawassa is about 90 kilometers away from the town. The Gedeo Zone has a mild, humid climate with mean annual temperatures between 17°C and 22.4°C and mean annual rainfall between 1,200 and 1,800 mm.

There are an estimated 102,624 people living in Dilla, with 50,286 men and 52,338 women. According to CSA (2021), there are 133,925 cattle, 197,846 sheep, and 22,621 goats in the Gedeo Zone.

2.2 Study Population

The investigation was carried out between March and July 2024 at the Dilla Municipal Abattoir on 384 butchered cattle of both sexes that appeared to be in good health. The livestock that were killed came from the midland and lowland agro-ecological zones and were housed under different management techniques. To determine the prevalence of swallowed inedible solid waste items, the animals were divided into groups according to breed, age, sex, and bodily condition.

2.3 Study Design

In order to determine whether solid waste elements were present in the rumen and reticulum of butchered cattle, a cross-sectional investigation was carried out at the Dilla Municipal Abattoir between March and July 2024. The study examined the cattle's breed, age, bodily condition, sex, and place of origin as possible risk factors. Based on dentition, age groups were categorized as young, adult, and old (Johnson *et al.*, 1997). Visual examination and lumbar vertebral palpation were used to evaluate the state of the body (Rabana *et al.*, 2022).

2.4 Sampling Technique and Sample Size Determination

The formula provided by Thrusfield (2005) was used to calculate the sample size. A required precision of 5% at a 95% confidence interval and an expected predominance of 50% were used to determine the test estimate. The following formula was used to determine the sample size:

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

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

The cattle's age, sex, breed, and physical condition were evaluated through ante-mortem examinations. There were three age categories: young (less than five years), adult (five to ten years), and old (more than ten years). According to Nicholson and Butterworth (1986) and Mangun *et al.* (2024), body condition was classified as poor, medium, or good based on the animal's appearance and physical palpation of the spinal processes and transverse processes of the lumbar vertebrae. 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 any solid waste found were recorded.

2.6 Data Analysis

The Statistical Package for Social Sciences (SPSS, Version 20) was used to evaluate the data after it was input into a Microsoft Excel worksheet. The findings were summarized using descriptive statistics like means and percentages. By dividing the total number of cattle found to have swallowed foreign bodies by the total number of cattle examined, the frequency of foreign bodies in the rumen and reticulum was computed as a percentage. The Pearson

chi-square (χ^2) test was used to investigate the relationship between possible risk variables and the occurrence of foreign bodies. A significant difference was defined as $P < 0.05$.

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). About 68.2% of the foreign bodies in the 172 positive instances were discovered in the rumen, 25.58% in the reticulum, and 6.4% in both organs. Although less than the 70.2% prevalence reported by Bitew (2025), this indicates a large presence of foreign bodies in the rumen. As the major digestive compartment, the rumen receives a significant amount of ingested feed, which raises the possibility of foreign body buildup. This could account for the greater prevalence of foreign bodies in the rumen seen in earlier research.



Figure 1. Disclosed organs from rumen, reticulum and both

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. Furthermore, the high percentage of plastic foreign bodies may be made worse by the absence of recycling businesses in the research region, which would increase the frequency of occurrences involving plastic in the rumen. Additionally, the rumen's structural nature makes it easier for certain ingested foreign bodies—especially plastic materials—to be retained (Tesfaye and Chanie, 2012).

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

Three age groups were created from the butchered cattle: ≤ 5 years (young), 5–10 years (adult), and ≥ 10 years (old). About 11 (26.8%) of the young cattle, 112 (46.7%) of the adult cattle, and 49 (47.6%) of the elderly cattle tested positive for foreign bodies among the groups under examination. The prevalence of foreign bodies varied significantly between the three age groups ($\chi^2 = 6.01$; $p = 0.05$) and exhibited an increasing trend from younger to older age groups. This result is in line with reports by Desalegn *et al.* (2018) and Amin and Fantahun (2020),

which showed that 80% of foreign bodies were discovered in the fore-stomach of older cattle, most likely as a result of the buildup of indigestible materials over time.

Of the animals that were slaughtered, 145 (52.5%) came from the midland and 27 (25%) from the highland. According to Table 2, the results showed a highly significant difference in the cattle's origin ($\chi^2 = 23.8$; $p = 0.00$). This discrepancy could be explained by differences in the individual regions' waste management and animal management systems.

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	≤ 5 years	41	11	26.8	6.01 0.05	
	5-10years	240	112	46.7		
	≥ 10 years	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

According to the study, foreign bodies were found in 41% of cattle in good body condition, 46% of cattle in medium body condition, and 55.2% of cattle in poor body condition. Table 3 demonstrates that the variance between the various bodily conditions was statistically significant ($\chi^2 = 7.95$; $p = 0.02$). This result is consistent with a study by Desiye and Mersha (2012) that found that animals in poor condition had

a greater prevalence of foreign bodies (72.72%) than animals in medium condition (35.95%) and good condition (7.33%). Because foreign materials interfere with the absorption of volatile fatty acids (VFA), they may cause animals to be in poor physical condition and gain less weight (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 44 (25.58%) foreign bodies in the reticulum, 117 (68.02%) in the rumen, and 11 (6.4%) in both the reticulum and the rumen. As seen in Table 4, the results demonstrated a highly significant difference across the stomach compartments ($p = 0.000$). In line with earlier research by Tesfaye and Chanie (2012), who reported 67.3% in the rumen and 32.7% in the reticulum, the results showed that foreign bodies were more common in the rumen than in the reticulum. This disparity could be explained by the rumen's bigger volume, which can hold a wider range and amount of foreign substances. On the other hand, the reticulum tends to concentrate more on metals and sharp items (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)
		$\chi^2 = 7.13$	P-value= 0.00	

4 Conclusion and Recommendations

The study's conclusions highlight the urgent problem of inedible foreign items in cattle killed at Southern Ethiopia's Dilla Municipal Abattoir. The health and welfare of cattle are seriously endangered when foreign items are improperly disposed of in grazing areas. 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.

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

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Abstract

The research was carried out in the Bule district of the Gedeo Zone to evaluate the practices, challenges, opportunities, and economic feasibility of backyard sheep fattening. Six out of the 18 Kebeles were intentionally selected based on the availability of sheep resources, the experience of farmers, and ease of access. A total of 126 households were randomly selected for the survey. Sheep fattening was widespread in the region, with 94.4% of households employing tethering and free-grazing methods. Traditional fattening techniques were predominant, with an average of 1.97 ± 0.08 sheep being fattened over durations ranging from 2 to 6 months, and 1.59 ± 0.059 cycles per year. Rams were the preferred choice for fattening (72.2%), followed by a combination of 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 boasts one of the most substantial livestock populations in Africa, comprising around 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 exten-

sively 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 envi-

ronments (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 research area is located in the Gedeo Zone of the South Ethiopia Regional State, roughly 386 km away from Addis Ababa. It covers an area of 27,300 hectares and has an elevation range between 2,001 and 3,000 meters above sea level. The average annual precipitation in this region is approximately 1,600 mm, with temperatures varying from 12.6°C to 20°C. The main agricultural system practiced here 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).

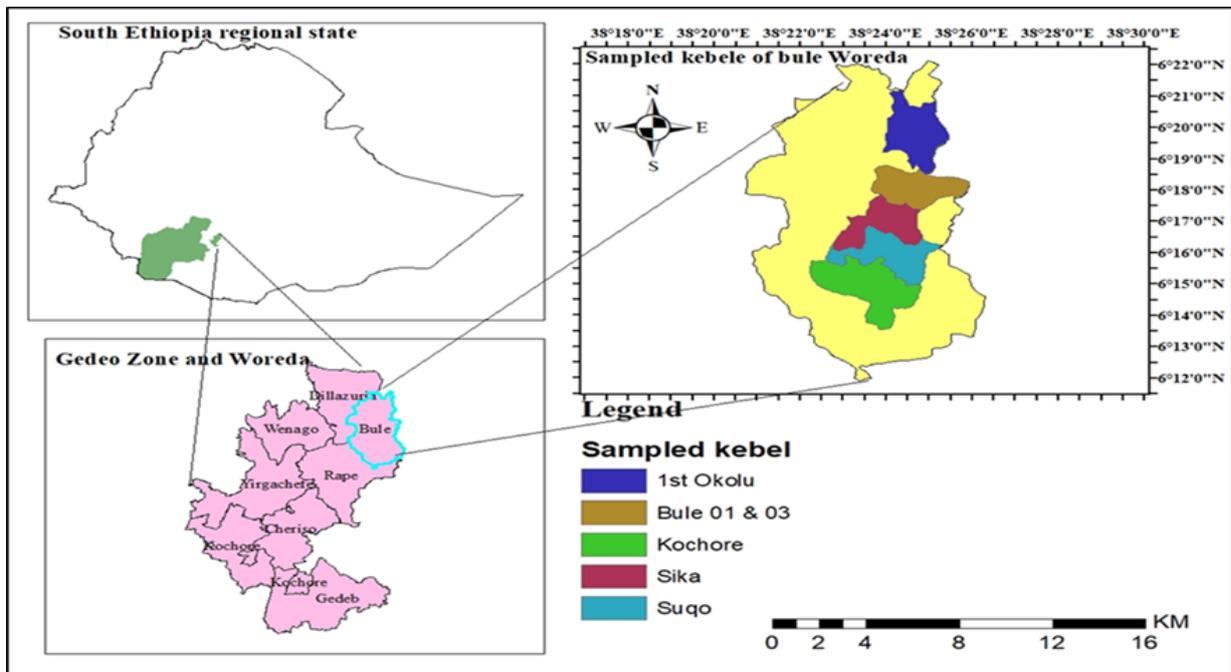


Figure 1. Study area map

2.2 Sampling method and sample size determination

The research utilized a multistage sampling technique. Initially, six kebeles (Bule 01, Bule 03, Sika, Kochor, Suqo, and Igna Okolu) out of a total of 18 were purposefully chosen based on the availability of sheep resources, the experience of farmers in sheep production, and their accessibility. These kebeles account for 33.3% of the total kebeles in the district.

To initiate the selection process, a comprehensive list of all household heads engaged in sheep production was compiled to establish the sampling frame. Representative households were subsequently chosen at random through either simple or systematic random sampling methods, ensuring that key criteria pertinent to sheep fattening practices were adequately represented.

The study focused on sheep-fattening farmers within the selected kebeles, identified from a total population of 328 households as per district livestock records. A sample size of 126 households was calculated using Yamane's formula (1973), applying a standard error of 0.07 and a confidence level of 95%. This led to the selection of 21 households from each of the six kebeles, which were randomly chosen for interviews and data collection.

2.3 Method of data collection

Data were gathered through the use of a semi-structured questionnaire, field observations, key informant interviews, and focus group discussions.

2.3.1. Questionnaire survey

Data was gathered through pre-tested, semi-structured questionnaires that were administered by trained enumerators to a total of 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 morphological 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).

$$\text{Gross margin} = \text{Gross income} - \text{Total variable cost} \quad (1)$$

$$\text{Net farm income} = \text{Gross margin} - \text{Total fixed cost} \quad (2)$$

2.5 Statistical data analysis

The survey data were examined utilizing SPSS version 20. Descriptive statistics, including mean, per-

centage, and standard deviation, were employed to encapsulate the results. 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 $[(r_n * C_1 + r_{n-1} * C_2 \dots r_1 * C_n)]$ raised for an individual season, preference, and criteria divided by the sum of $[(r_n * C_1 + r_{n-1} * C_2 \dots r_1)]$ 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	Igna okolu n=21			
FS	Mean ±SE	5.62 ± .71 ^b	5.10 ± .46 ^c	5.43 ± .50 ^b	5.14±.46 ^c	7.14±.43 ^a	7.43±.62 ^a	5.98±.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 ± 3.26 ^a	40.05 ± 1.64 ^b	42.00±1.8 ^b	46.76±2.6 ^a	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 ± .071 ^b	.69 ± .058 ^c	0.67 ± .053 ^c	0.851 ± .087 ^a	0.76±.098 ^b	0.90±.06 ^a	0.76±.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	kocho	lgna 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
		1 st	2 nd	3 rd	4 th	5 th	6 th			
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	1 st ranked F	2 nd ranked F	3 rd 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 = $[(3 \times \text{number of responses for } 1^{\text{st}} \text{ rank} + 2 \times \text{number of responses for } 2^{\text{nd}} \text{ rank} + 1 \times \text{number of responses for } 3^{\text{rd}} \text{ rank})]$ divided by $(3 \times \text{total responses for } 1^{\text{st}} \text{ rank} + 2 \times \text{total responses for } 2^{\text{nd}} \text{ rank} + 1 \times \text{total responses for } 3^{\text{rd}} \text{ rank})$; 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 Fig. 1). 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.

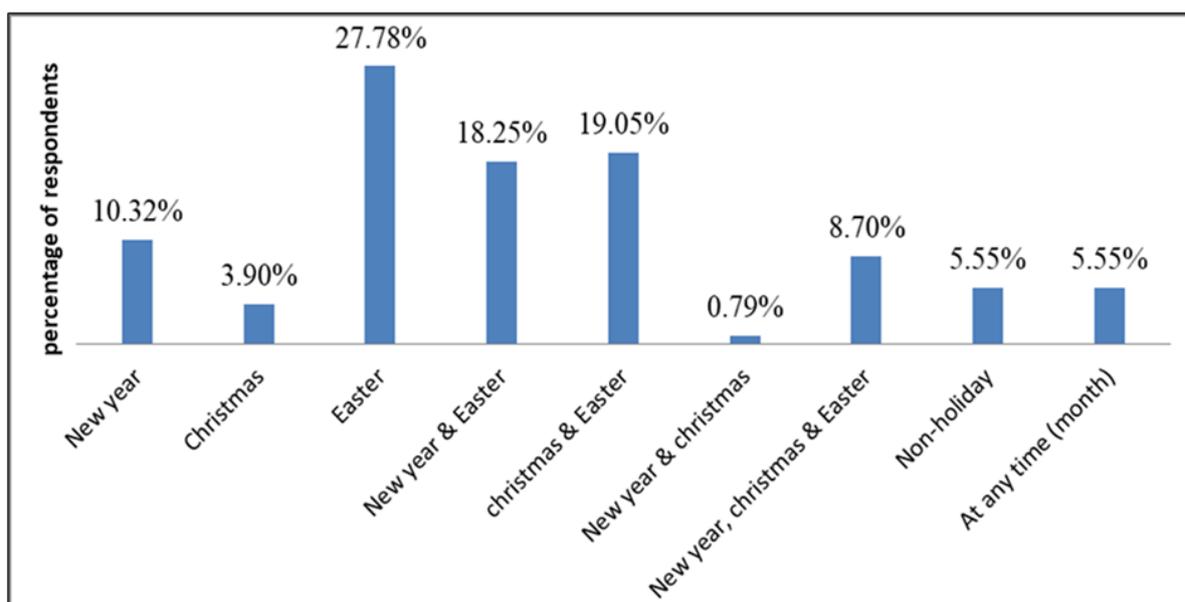


Figure 2. Seasons of sheep fattening in study area

3.7 Reasons for fattening sheep

The primary motivation for sheep fattening in the study area is income generation, accounting for 40.48%. Other reasons include saving, acquiring additional sheep, and meeting socio-cultural needs. This observation is consistent with the studies con-

ducted by Fikru & Gebeyew (2015) in the Degehabur Zone and Samuel (2016) in the Amhara Region, both of which identified income generation as the principal aim of sheep fattening (refer to Fig. 2).

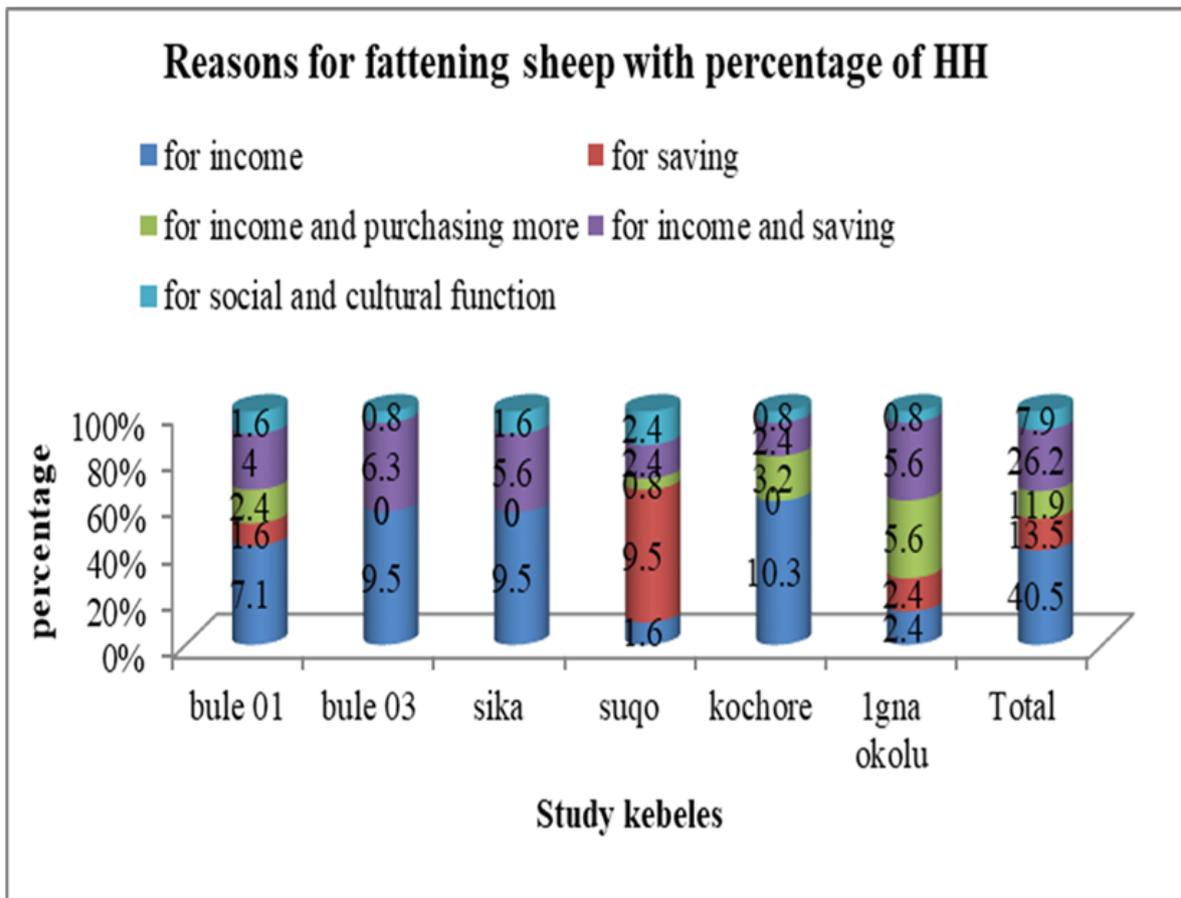


Figure 3. Main purpose of involving in sheep fattening activities

3.8 Fattening sheep, feeding system and supplementary feed types

The feeding systems and feed types typically utilized for fattening sheep in the study region are detailed in Table 6. The main feeding systems observed are tethering combined with stall feeding (68.3%), semi-grazing alongside stall feeding (20.6%), and free grazing utilizing a cut-and-carry method (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	7.779	0.4
	GFG	4.8	23.8	6.3	34.9		
	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 7).

3.9 Utilization and type of available supplementary feed

As indicated in Figure 3, 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.

Sheep fatteners in the study area faced significant constraints due to feed shortages. According to household respondents, the primary consequences included weight loss in fattening sheep (47.6%), a reduction in the annual fattening cycle (42.9%), and increased mortality rates among sheep due to harsh conditions (9.5%) (see Table 10). To mitigate these challenges, farmers proposed several measures: purchasing forage or renting grazing land (42.9%), utilizing available crop residues (9.5%), and excluding pasture areas from livestock access (47.6%).

These findings align with results reported by Guyo (2016), who observed that in Bonke Woreda of Gamo Gofa Zone, 62.5% of households in highland areas used farm residues, while 37.5% of mid-altitude producers relied on purchased feed to combat feed shortages. However, the proportions of crop residue users and feed purchasers in the current study were notably lower.

Farmers adopted various strategies before and during feed shortages, including purchasing materials like enset and its residues and renting grazing pastures specifically for fattening animals. This proactive approach indicates that some farmers possess the knowledge and skills needed to anticipate feed shortages and implement preventive measures. Furthermore, extending improved forage cultivation could become viable if supported by training and attention from stakeholders.

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. Respon-

dents 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 avail-

able 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).

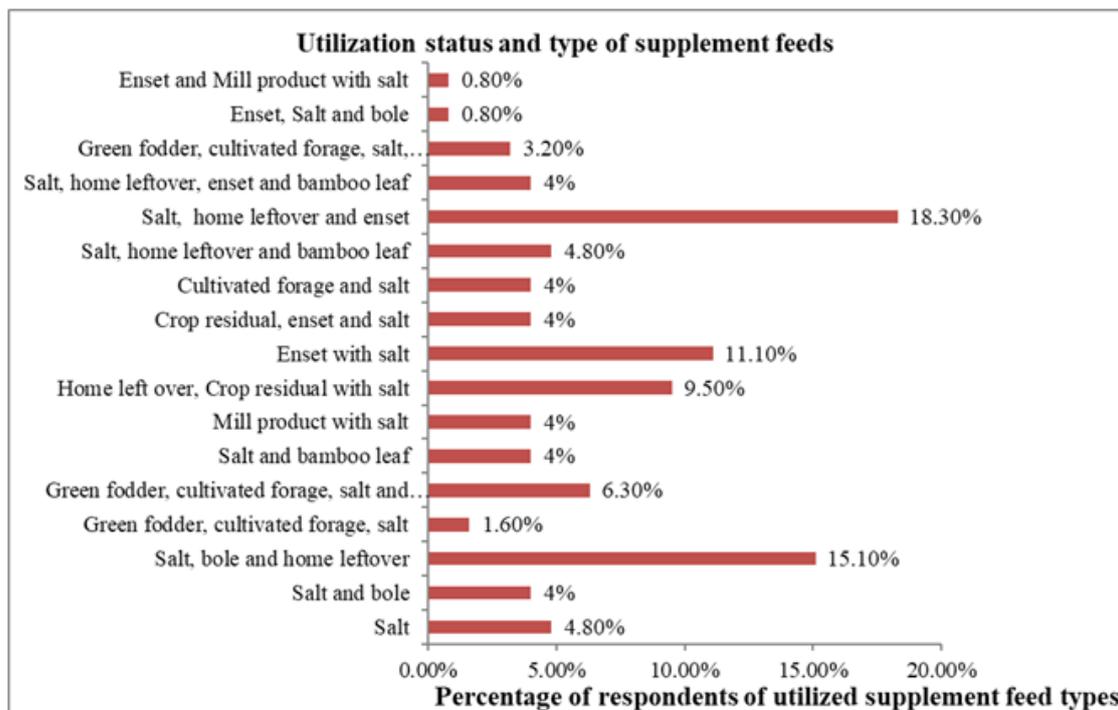


Figure 4. Percentage HHs supplementary feeds used

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.

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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. Tamarind (*Tamarindus indica*) seeds have long been used by Ethiopian communities to treat wounds, snake bites, abdominal pain, inflammation, helminth infections, antibacterial effects, and diabetes. Scientific research on this plant is very scarce, nevertheless. The purpose of this study was to examine the antibacterial properties of *Tamarindus indica* seed extracts obtained from Itang Woreda, Gambella, Ethiopia, against *Klebsiella pneumoniae* and *Staphylococcus aureus*. Acetone and ethanol were employed as solvents in the maceration method of extraction. The disk diffusion method was used to assess each extract's antibacterial activity at doses of 100, 200, and 300 mg/mL. 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. The extracts and the negative control did not differ significantly ($P > 0.05$). The outcomes, however, differed considerably from the positive control ($P < 0.05$). These findings imply that the examined bacteria are not susceptible to the antibacterial action of *Tamarindus indica* seed extracts. For more thorough findings, greater investigation into other harmful bacteria and fungi is advised.

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 ad-

vancements 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). Tannins, alkaloids, phenolic compounds, and flavonoids are examples of phytochemicals that are formed during the secondary metabolism of plants and are known to have medicinal properties (Belayhun *et al.*, 2024; Njeru *et al.*, 2013; Pagare *et al.*, 2015). Traditional medicine uses these substances to treat common and chronic 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.

According to earlier studies (Kuru, 2014; Menezes *et al.*, 2016; Gomathinayagam *et al.*, 2017; Pramila and Jirekar, 2021), *Tamarindus indica* contains a variety of bioactive phytoconstituents that are linked to a number of health benefits in traditional medicine, such as wound healing, snake bites, abdominal pain, inflammation, helminth infections, antimicrobial qualities, and antidiabetic effects. The current work, which assesses the antibacterial properties of *Tamarindus indica* crude seed extracts against *S. aureus* and *K. pneumoniae*, is based on this background.

Tamarind is the common name for *Tamarindus indica* L., a member of the Caesalpinioideae subfamily and the Fabaceae (Leguminosae) family. 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). Although many Ethiopian communities have long used tamarind seeds for medical purposes, little research has been done on the extracts' potential as antibacterial agents against drug-resistant bacteria. The purpose of this study is to investigate the antibacterial activity of tamarind seed extracts, which are typically regarded as trash, in order to offer scientific proof that they can be used as alternatives to treat infections that are resistant to antibiotics.

2 Material and methods

2.1 Seed sample collection

In January 2022, dry *Tamarindus indica* pods were gathered from Itang Special Woreda, which is around 801 kilometers from Addis Ababa, Ethiopia, and 35 kilometers from Gambella city. The samples were then transported to the microbiology laboratory at Dilla University, Ethiopia. This Woreda is situated between latitudes 8°4N to 8°5N and longitudes 34°30E to 33°55E, 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°C to a maximum of 39.34°C, 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.

Following full drying, the seeds were ground with a 0.5 mm mesh in a general-purpose grinder to the proper size for extraction (Geremew *et al.*, 2018). Before being used, the resultant powder was labeled and kept at -20°C in a firmly sealed glass bottle.

2.2 Crude extraction and yield

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

In summary, 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 filtered using double-layer filter paper (Fisher brand) to produce filtrates and residues, which were then macerated in ethanol for an additional 24 hours.

The filtrates were evaporated using a rotary evaporator (Merk, UK) at 45°C 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°C. The yield percentage was calculated using the formula provided by Mariah *et al.* (2021), as shown in Eq. 1.

$$\text{Extract yield}(\%) = \left(\frac{\text{Dry weight of extract}}{\text{Dry weight of plant seed powder}} \right) \times 100$$

2.3 Test bacteria

For this investigation, two bacterial strains from the American Type Culture Collection (ATCC) were utilized: *Staphylococcus aureus* (ATCC 25923), a Gram-positive strain, and *Klebsiella pneumoniae* (ATCC 700603), a Gram-negative strain. These strains were chosen because of their toxicity and correlation with recurrent and severe human illnesses.

The Ethiopian Biodiversity Institute in Addis Ababa, Ethiopia, graciously supplied the bacterial samples.

2.4 Preparation of test solutions

In accordance with Mesay *et al.* (2020), the crude seed extracts were diluted to create three distinct concentrations in different flasks. In particular, 100, 200, or 300 mg of each extract were transferred into sterile test tubes with 1 mL of 3% Tween 20 to create working stock solutions of 100, 200, and 300 mg/mL. Concentrations of 100, 200, and 300 mg/mL were the outcomes. Until more research was conducted, the stock solutions were kept at -20°C.

2.5 Antibacterial activity

The antibacterial activity of the extracts was assessed using the disk diffusion method, in accordance with the protocols outlined by Gatluak *et al.* (2024) and Workineh *et al.* (2024). In short, paper disks about 6 mm in diameter were punched out of a sheet of absorbent filter paper and autoclaved for an hour at 121°C to sterilize them.

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°C for 24 hours. After that, a few colonies of each strain were moved to nutritional broth using a sterile inoculating loop, and the turbidity was adjusted to meet the McFarland 0.5 turbidity criterion.

Sterile cotton swabs were used to streak the two bacterial strains on two sets of Mueller-Hinton agar plates. Acetone extracts were tested in one group and ethanol extracts in another. Each plate's surface was split into five portions, each of which could hold five paper disks: one for the positive control, one for the negative control, and three disks with extracts at various concentrations. The positive control was tetracycline, a broad-spectrum antibiotic that works against both aerobic and anaerobic Gram-positive and Gram-negative infections.

In distinct quadrants of each plate, 50 µL of the crude extract at the designated concentrations were placed onto each disk. In the other two quadrants, one disk was submerged in 1 mL of 3% Tween 20 (negative control) and another disk held 30 µL of a

2.5 mg/mL Tetracycline solution (positive control). Following a 24-hour incubation period at 37°C, the zone of inhibition was measured using a ruler and reported in millimeters. The average zone of inhibition (ZOI) for each plant extract was used to express the outcomes of the test, which was carried out in triplicate.

2.6 Data analysis

The zone of inhibition (ZOI) for each control and crude extract against each bacterium was measured in millimeters for all data derived from the experimental results. The mean \pm standard error of the mean (SEM) from the triplicate tests was used to compute the average results. One-way analysis of variance (ANOVA) with Tukey's Honest Significant Difference (HSD) test and 95% confidence intervals (CI) was used to compare the outcomes. Statistical significance was defined as a P-value of less than 0.05.

2.7 Ethical Consideration

After obtaining a letter from the Department of Biology, the Dilla University ethical committee granted ethical approval.

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.

The crude extracts from *T. indica* seeds exhibited surprising antibacterial efficacy against *Klebsiella pneumoniae* and *Staphylococcus aureus*. The growth of both tested pathogenic bacteria was not inhibited by any of the three concentrations (100, 200, and 300 mg/mL) of either acetone or ethanol extracts (Table 1).

Based on these findings, the crude extracts and the negative control did not differ statistically significantly ($P > 0.05$). But compared to the positive control, the outcomes differed significantly ($P < 0.05$) (Table 2). The lack of difference between the crude extracts and the negative control (3% Tween 20) and the substantial difference between the crude extracts and the medication (positive control) indicate that the extracts have no antibacterial activity against the test bacteria.

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*. In contrast, Das *et al.* (2014) found that the methanolic extract of *T. indica* seeds exhibited varying degrees of antimicrobial activity 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.

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	
		<i>Staphylococcus aureus</i>	<i>Klebsiella pneumoniae</i>
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)	<i>S. aureus</i>		<i>K. pneumoniae</i>	
		Mean \pm SEM	P-value	Mean \pm SEM	P-value
Tween 20	1 mL	0.00 \pm 0.00 ^b	< 0.05	0.00 \pm 0.00 ^b	< 0.05
Tetracycline	2.5	15.67 \pm 0.67 ^a	> 0.05	16.33 \pm 0.33 ^a	> 0.05
	100	0.00 \pm 0.00 ^b	< 0.05	0.00 \pm 0.00 ^b	< 0.05
Acetone	200	0.00 \pm 0.00 ^b	< 0.05	0.00 \pm 0.00 ^b	< 0.05
	300	0.00 \pm 0.00 ^b	< 0.05	0.00 \pm 0.00 ^b	< 0.05
Tetracycline	2.5	15.33 \pm 0.33 ^a		16.33 \pm 0.33 ^a	
	100	0.00 \pm 0.00 ^b	< 0.05	0.00 \pm 0.00 ^b	< 0.05
Ethanol	200	0.00 \pm 0.00 ^b	< 0.05	0.00 \pm 0.00 ^b	< 0.05
	300	0.00 \pm 0.00 ^b	< 0.05	0.00 \pm 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.

3 Conclusion

The results of this investigation show that there was no antibacterial activity in the *Tamarindus indica* seed extract. 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.

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Conflict of Interest

The authors affirm that they have no conflicting interests with regard to this work.

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