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The Potential of Solid Organic Wastes as Fish Feed Ingredients in Selected Areas of Southwest Ethiopian Towns

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Declaration

I, Zerihun Taye Gebre, declare that this MSc research project entitled “The Potential of Solid Organic Wastes as Fish Feed Ingredients in Selected Areas of Southwest Ethiopian Towns is my own work and has been carried out under the supervision of Dr. Mulugeta Wakjira and Dr. Tokuma Negisho. To the best of my knowledge I confirm that this work has not been submitted for any other degree or qualification at this or any other university.

Zerihun Taye, Sign: ___________ Date: ________________________.

Acknowledgement

My heartfelt appreciation goes to my advisors, Dr. Mulugeta Wakjira (main advisor) and Dr. Tokuma Negisho (co-advisor), for their unwavering support, encouragement, and dedication to helping me succeed in this research project. I acknowledge Jimma University for funding the research cost. The Biology department also deserves recognition for providing the resources and facilities that made this investigation possible.

Table of Contents

List of Tables

List of Figures

Acronyms/Abbreviations

AOAC - Association of Official Analytical Chemists

CP – Crude Protein

DM - Dry Matter

EPA - Environmental Protection Association

ETB - Ethiopian Birr

FAO - Food and Agriculture Organization

Kg – kilogram

MoA – Ministry of Agriculture

NFE - Nitrogen-Free Extract

NRC - National Research Council

SPSS - Statistical Package for Social Sciences

Abstract

Limited availability and high costs of high-quality, sustainable fish feed impede aquaculture development in Ethiopia. This study explores the potential of utilizing readily available solid organic wastes as alternative fish feed ingredients. The research focused on selected areas within southwest Ethiopia: Jimma, Bonga, and Buno Bedele towns. A questionnaire assessed the availability, accessibility, and annual quantity of solid waste generated by various entities. Proximate analysis evaluated the nutritional value of collected wastes, including cattle blood, *tella atela*, brewery waste (spent grain), cabbage leftovers, poultry manure, various vegetable peels (beetroot, potato, onion, head cabbage), rumen liquor, coffee and tea brewing residues, cow dung, and coffee husk. Selection criteria for potential fish feed ingredients prioritized availability (abundance of the material), accessibility (ease and cost of acquisition), and quantity (consistent, reliable supply to meet production needs). The study revealed that most surveyed solid organic wastes satisfied these criteria. The majorities were readily available, freely accessible, and generated in significant quantities (100 – 100,000 kg/year) throughout the year. Notably, most wastes were not commercially sold, making them readily affordable for entities that did sell them. Key stakeholders expressed positive sentiment regarding the utilization of these wastes as fish feed, but a knowledge gap was identified that requires further information dissemination. The nutrient composition analysis (per 1 gram of dry matter) identified cattle blood (78.33% crude protein) as a promising protein source. Additionally, *tella atela* (20.0% crude protein & 45.10%), brewery waste (spent grain) (26.51% crude protein & 52.8% carbohydrate), cabbage leftovers (25.82% crude protein & 40.34% carbohydrate), and poultry manure (23.5% crude protein & 38.8% carbohydrate) demonstrated potential as combined protein and energy sources. Beetroot peel (59.11% carbohydrate), potato peel (59.0% carbohydrate), head cabbage leftover (54.0% carbohydrate), rumen liquor (51.4% carbohydrate), tea brewing residue (51.12% carbohydrate), cow dung (36.80% carbohydrate), and onion peel (48.33% carbohydrate) were identified as potential sources of dietary energy for fish. This study successfully identified several promising solid organic wastes as substitutes for conventional fish feed ingredients. Furthermore, the research demonstrates the viability of these wastes as locally-sourced, sustainable sources of protein and energy for fish feed formulations.

Keywords/phrases: Access, Availability, Organic waste; Fish feed; Aquaculture development, Quantity, Southwest Ethiopia.

1. Introduction

1.1. Background of the Study

"Aquaculture, or fish farming, is increasingly vital in addressing global food security and supporting economic development. In many developing regions, including Southwest Ethiopia, the aquaculture industry holds significant potential to enhance nutrition and livelihoods. However, the sustainability of this sector is often compromised by the high cost and limited availability of conventional fish feed ingredients (FAO, 2018). This challenge necessitates the exploration of alternative feed sources to ensure the industry's growth and sustainability. Solid organic wastes, encompassing agricultural residues, food processing by-products, and livestock manure, represent a promising solution. These materials are abundantly available locally and offer several advantages when utilized as fish feed ingredients (Demeke *et al*., 2019).

First, they can mitigate the issues of feed ingredient availability and cost by reducing dependency on imported or expensive feeds (Alemayehu et al., 2020). Second, repurposing organic wastes into valuable feed resources supports waste management and environmental sustainability, preventing these materials from becoming pollutants (Gebremariam et al., 2021). Third, integrating these waste materials into fish feed aligns with the principles of the circular economy, promoting resource efficiency and minimizing waste generation (Moges et al., 2020).

Despite these potential benefits, several challenges must be addressed to successfully integrate solid organic wastes into fish feed formulations in Ethiopia. These include ensuring the safety and nutritional adequacy of the waste-derived feeds, developing effective processing techniques, and achieving the proper nutrient balance in fish diets (Mohammed et al., 2022). Additionally, there is a need for comprehensive research to evaluate the suitability and economic viability of these alternative feed ingredients.

Therefore, this study aimed to assess the potential of solid organic wastes as sustainable fish feed ingredients in selected towns of Southwest Ethiopia. By evaluating the nutritional profiles, availability, and economic aspects of these wastes, this research seeks to contribute to the development of cost-effective and environmentally friendly fish feed solutions, supporting the sustainable growth of aquaculture in the region.

1.2. Statement of the Problems

Ethiopia's aquaculture sector has faced significant challenges in meeting the growing demand for fish products due to the limited availability and high cost of conventional fish feed ingredients

(FAO, 2018). To overcome these challenges, trying to utilize solid organic wastes as fish feed ingredients has been proposed as a potential solution. The use of solid organic wastes as fish feed ingredients and for the production of formulated fish feeds has the potential to address fish feed challenges facing Ethiopia. However, there is limited research on the potential of solid organic wastes as a source of fish feed in Ethiopia.

The utilization of these solid organic wastes in Ethiopia is hindered by critical problems that need to be addressed (Demeke *et al*., 2019). There is a lack of knowledge and research regarding the suitability (nutritional quality) and appropriate processing techniques for utilizing solid organic wastes as fish feed ingredients. The limited scientific understanding hampers the development of effective strategies for their safe and efficient utilization (Gebremariam *et al*., 2021).

Therefore, this study is intended to evaluate the potential of solid organic wastes, both in quantity and quality, as fish feed ingredients for aquaculture development in the southwestern part of Ethiopia. Specifically, the study aimed to evaluate the status of solid organic waste generation and current use, to evaluate the availability of solid organic waste for fish feed production, the willingness of entities to allow others outside the entities to utilize and/or manage their waste (accessibility), the amount of waste generated, whether any cost of purchase is involved, and whether the waste is currently being used for other purposes (competing use).

Moreover, it aimed, to evaluate the views of key stakeholders (aquaculture farmers agricultural office personnel working on the development aquaculture) regarding the uses and availability of solid organic wastes for fish feed production, and finally to determine nutritional quality of solid organic wastes as a potential source of fish feed. The ultimate goal of this study is to contribute to the development of sustainable fish feed production options that can support the growth of the aquaculture industry in Ethiopia.

1.3. Research questions

1. What is the current situation regarding the generation and use of solid organic wastes?
2. How readily available (accessible and affordable) is solid organic waste as a potential ingredient for fish feed?
3. What are the views of key stakeholders on use of solid organic wastes as fish feed?
4. What is the nutritional quality of solid organic waste?

1.4. Objectives of the study

1.4.1. General objective

- ✓ The general objective of this study was to assess and evaluate the potential of solid organic wastes as fish feed source

1.4.2. Specific objectives

The study attempted to address the following specific objectives:

- ✓ To evaluate the current situation regarding the generation and use of solid organic wastes.
- ✓ To evaluate the availability (accessibility, affordability) of solid organic wastes as fish feed.
- ✓ To evaluate the views of key stakeholders on use of solid organic wastes as fish feed.
- ✓ To conduct nutritional profiling of the available solid organic wastes to assess their suitability as fish feed ingredients

1.5. Significance of the study

By addressing these objectives, this study aims to contribute to the development of sustainable fish feed production options that can support the growth of the aquaculture industry in Ethiopia. The findings will provide valuable insights into the feasibility of using solid organic wastes as fish feed, promoting environmental sustainability, and reducing reliance on costly imported feed ingredients. Ultimately, this research will help enhance food security and support economic development in the region.

2. Review of Related Literature

2.1. Aquaculture Development

Aquaculture is one of the oldest food production activities in the history of mankind (FAO, 2002) and it is the fastest growing food producing sector in the world today (FAO, 2006). Aquaculture has emerged as a vital sector to meet the rising global demand for fish and seafood. The aquaculture industry is the fastest-growing food-producing sector, excelling in capture fisheries since the mid-1990s (FAO, 2020).

Global aquaculture production has grown at 10 to 11 percent a year over the past decade and is projected to continue increasing (FAO, 2010). Aquaculture can serve as one of the best alternatives for the over-exploited natural aquatic resources, therefore aquaculture can help to reduce pressure and maintain the ecological balance of the natural ecosystems. It is probably one of the most promising answers to a world population growth in providing additional food and employment.

FAO (2006) reported that out of the total tonnes of fish consumed in the world every year, almost half is produced in a controlled environment, whereas the remaining half is harvested from the wild. Ethiopia possesses vast freshwater resources and a growing domestic fish market, offering significant potential for aquaculture sector development (Alemneh *et al*., 2020).

Aquaculture in Ethiopia remains more potential than in actual practice, despite the fact that the country's environmental and socio-economic conditions support its development (FAO, 2005). The consumption and demand for fish as a cheap source of protein is on the increase in Ethiopia. But the fish supply in most cases comes from the major lakes and rivers in the country. While capture fisheries based on species that are presently exploited seem to have reached their natural limits (FAO, 1996, Ministry of Agriculture annual report, 2008). Aquaculture activities in Ethiopia have been limited to introduction of both exotic and indigenous freshwater fish to several man-made and natural water bodies since the 1970s by different actors (Shibru 1973; Shibru & Fisseha 1981).

The aquaculture development in Ethiopia is faced with a number of challenges which include among others; lack of inexpensive and efficient locally available fish feeds, lack of locally selected and certified fish seeds, over-reliance on capture fisheries, lack of licensed fish seed multiplication centers and lack of institutional capacity in the area of training, research and technology transfer. To transform the rate of aquaculture development in Ethiopia, the country will need a multi-sectorial approach and well-coordinated collaborative efforts from all different stakeholders.

Aquaculture has a great potential in the struggle for improvement of the nutritional situation of the human population and in the alleviation of poverty of rural people especially in developing countries (Tacon, 2001). The experience of different countries in the world shows, aquaculture if developed in a sustainable way is the best alternative to tackle this kind of problems (Watanabe, 2002; Yang et al., 2006). Small-scale aquaculture, with minimal investment and high labor absorption, aligns well with Ethiopia's rural development strategies (Gebremariam *et al*., 2019). The Ethiopian government acknowledges aquaculture's role in sustaining food security and economic growth, implementing initiatives to support the sector (MoA, 2016).

2.2. Fish Feed

As aquaculture production becomes more and more intensive, fish feeds will be a significant factor in increasing the productivity and profitability of the sector (Jamu & Ayinla, 2003). Because feed management determines the viability of aquaculture as it accounts for at least 40 - 60 per cent of the cost of fish production (Shang 1992; Craig & Helfrich 2002; Jamu and Ayinla 2003). Fish feed plays a very important role in the growth, health, and overall production efficiency of farmed fish (FAO, 2009). Adequate nutrition is essential to meet the dietary requirements of fish species and optimize their performance. The sustainability of aquaculture operations heavily depends on the availability and affordability of suitable fish feed ingredients. At present, the high cost and low quality of fish feeds are major factors limiting the development of aquaculture in Africa and are likely to remain so in the near future (Jamu & Ayinla 2003).

As the cost of conventional feed ingredients continues to rise, there is a growing interest in exploring alternative and locally available sources of fish feed ingredients. The cost and availability of fish feed are major challenges faced by fish farmers, necessitating the exploration of alternative feed ingredients (Hussain *et al*., 2018).

2.2.1. Solid Organic Waste

Solid organic waste is a major by-product of human activity, encompassing food scraps, agricultural residues, livestock manure, and other biodegradable materials. Utilizing organic waste for fish feed reduces pressure on wild fish populations. Diverting organic waste from landfills also benefits the environment by minimizing methane emissions and promoting resource recovery (EPA, 2022).

Certain types of organic waste can be processed to enhance their nutritional value for fish. Fermentation, for instance, increases protein content and digestibility, making the waste more readily utilized by fish (Makkar et al., 2015). Utilizing organic waste for fish feed production can also help address waste management challenges and divert organic waste from landfills to turning those into valuable fish feed ingredients (Tadesse *et al*., 2021).

2.2.2. Availability of solid organic waste

The availability of solid organic wastes for fish feed production in Ethiopia is essential for assessing the potential of utilizing waste materials as alternative feed sources in aquaculture. Solid organic wastes like food scraps, vegetable trimmings, and agricultural residues can be processed into organic material suitable for fish feed production (FAO, 2017).

The important criteria for selecting fish feed ingredients are availability (the existence and overall abundance of a potential ingredient), accessibility (the ease and cost of obtaining the ingredient), and quantity (the consistent and reliable supply of the ingredient to meet production needs) (FAO, 1980).

2.2.3. Nutritional quality of solid organic wastes

Solid Organic wastes often contain a range of nutrients, including proteins, carbohydrates, lipids, vitamins and minerals. Livestock manure, for instance, is rich in proteins, lipids, carbohydrates, vitamins, and minerals, making it a potential source of nutrients for fish feed formulations (Ferede *et al*., 2017).

The nutritional composition of poultry byproduct meal is a common organic waste and it to be a valuable source of protein and essential amino acids for fish feed (Mollah *et al*., 2020). However, the specific nutrient content can be influenced by factors such as: source of wastes, processing methods, and storage conditions. For instance, agricultural wastes like rice husk, corn stover, and wheat straw have higher carbohydrate content, while food processing wastes like fruit peels, vegetable scraps, and brewery wastes are richer in protein and vitamins (Zhou *et al*., 2017). Pretreatment methods like grinding, fermentation, and enzymatic hydrolysis can significantly improve the digestibility and nutrient bioavailability of the waste (El-Sayed et al., 2018). Proper storage is crucial to minimize nutrient loss and prevent contamination (Abdel-Raouf et al., 2012).

2.2.4. Challenges of using solid organic wastes as fish feed ingredient

There are several obstacles using solid organic wastes as components in fish feed. Solid organic waste composition (protein, fat, carbohydrate) can vary greatly depending on source. This variability makes it difficult to formulate consistent and balanced fish feed (National Research Council, 2011). Some solid organic waste components can act as anti-nutrients; reducing fish feed digestibility and nutrient availability (Makrides *et al*., 2019).

Solid organic wastes can be contaminated with heavy metals, pathogens, and other harmful substances (Van der Waal et al., 2017). Data on nutrient composition and potential contaminants specific to local waste streams is limited (Alemneh *et al*., 2020).

2.2.5. Opportunities of using solid organic waste as fish feed ingredient

Despite the challenges, the use of solid organic wastes in fish feed production offers several opportunities. Solid organic waste diversion from landfills reduces greenhouse gas emissions and pollution, promoting a circular bio-economy (Gunders, 2019). Solid organic waste can be a cheaper alternative to traditional fishmeal, lowering production costs and improving farm profitability (Mti *et al.*, 2018).

Solid organic waste reintroduction into the food chain returns nutrients back into the productive system, promoting resource efficiency (Van der Spiegel *et al*., 2013). The economic feasibility of using agro-industrial byproducts in fish feed reduced feed costs while maintaining fish growth performance which indicates that utilizing solid organic wastes as feed ingredients can enhance the economic sustainability of aquaculture (Devi *et al*., 2017). Solid organic waste based feeds can reduce dependence on imported fishmeal, promoting local feed production and economic development (Alemneh *et al*., 2020).

3. Methodology

3.1. Study Area

The study was conducted at selected areas of southwest Ethiopia, viz. Jimma, Bonga, and Buno Bedele towns (Figure 1). Jimma town sits at an elevation of 1,780 measures above sea level, at geographical coordinates are 7 ° 40 ′ 0 ″ N 36 ° 50 ′ 0 ″ E, and lies 350 kilometers southwest of the capital Addis Ababa. Bonga town is around 440 kilometers southwest of Addis Ababa, has an elevation of 1,714 meters above sea level, and its latitude and longitude are 7 ° 16 ′ N 36 ° 14 ′E. Buno Bedele town lies 530 kilometers southwest of Addis Ababa, at latitude and longitude are 8 ° 27 ′ N 36 ° 21 ′ E, sits at a higher elevation than Jimma and Bonga ranging from 2,012 to 2,162 meters above sea level (websites of each zone, 2023).

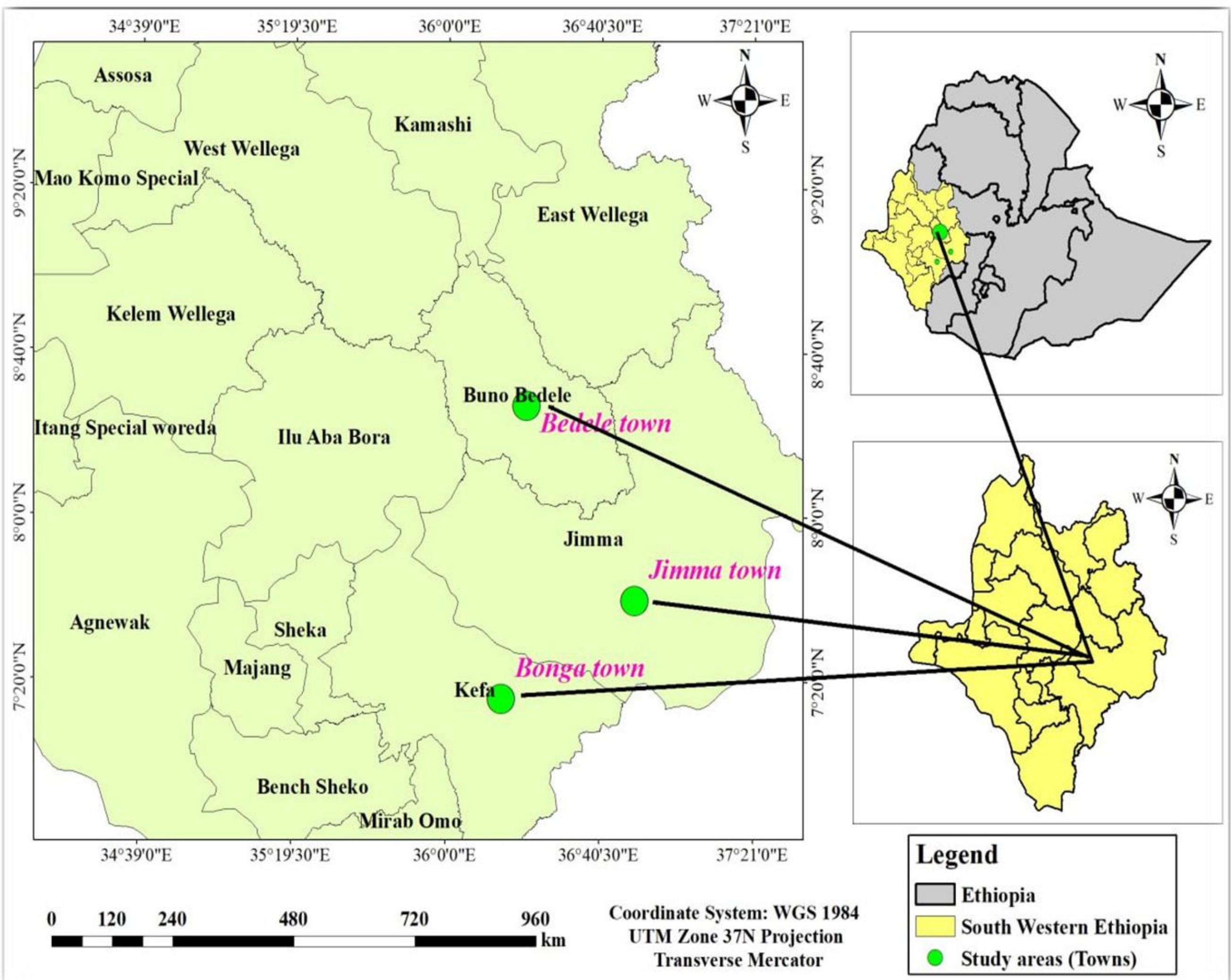

Figure 1. Map of study areas: selected town in southwest Ethiopia

3.2. Study design

The study employed a questionnaires survey approach to generate pertinent data and a nutrient proximate composition analysis to determine nutritional quality of solid organic wastes. A questionnaire was designed to survey the entities that generate solid organic wastes in their production process: to assess status solid organic waste generation and current use, to assess the availability of the solid organic waste, and to evaluate the views of key stakeholders on use solid organic wastes as fish feed. In addition to collecting data in the entities, each representative of samples was collected from each selected entity production process for nutritional quality of the wastes and analyzed in the laboratory.

3.3. Data and Sample collection process

The questionnaire (Appendix 1) comprised two main sections. Section one was designed to investigate: the status of waste generation and current use, the availability of solid organic wastes for fish feed production in the study area. Whereas, section two was designed to evaluate the views of key stakeholders regarding solid organic wastes, specially uses and potential availability information of solid organic wastes generated in their localities.

The questionnaire was developed in English and then translated into Afaan Oromo, Kafinoonoo, and Amharic to ensure valid response to each question. It consisted of close-ended questions that required respondents to choose from a distinct set of pre-defined responses, such as 'yes/no' or multiple-choice questions.

Both qualitative and quantitative data were collected from each respondent. These respondents were 2 abattoirs, restaurants, poultry, *talla* houses, coffee and tea house, and coffee processing firm (from Jimma and Bonga), dairy farm (from Jimma, Bonga and Bedele), and Brewery (from Bedele).The questionnaire were distributed physically to the 88 randomly selected entities, with a request for voluntary responses by employees the availability of wastes, overall responsibility and knowledge of entity waste production.

Totally 88 questionnaire distributed were completed and returned. Additionally the questionnaire were distributed physically to the 4 selected key stakeholders (2 local aquaculture farmers cooperatives and 2 zonal agricultural office personnel working on aquaculture development) with a request for voluntary responses of their understanding regarding solid organic waste uses and its availability as fish feed ingredient. Four (4) questionnaires distributed were completed and returned. The time taken to return completed questionnaires by the entities and the key stakeholders varied from 1 to 120 days, depending on the time available for respondents at different entities and at different office of stakeholders to complete the questionnaire. These data and sample collection was as partially shown on Figure 2.

Figure 2. The processes of data and sample collection:

(**a**) During data collection from zonal agricultural office, (**b**) collected samples, (**c**) during data collection from aquaculture farmer (Merewa, Jimma), (**d**) damped coffee husk at entity site, (**e**) during data collection from aquaculture farmers (Sheta, Bonga), (**f**) damped abattoir wastes at entity site, & (**g**) during data & sample collections from entities.

3.4. Sample preparation for nutrient proximate composition analysis

The samples were collected for determining the potential suitability (nutritional quality) of solid organic wastes for fish feed production by conducting laboratory analysis to determine the nutritional composition of different solid organic wastes. Each solid organic wastes sample was collected from each entity of selected areas. A total of 14 solid organic waste samples (potato peel, boiled coffee and tea leaf residue, cattle blood, rumen liquor, poultry manure, kitchen wastes (round cabbage leftover, cabbage leftover, cow dung, onion peel, beet root/keysir/ peel, coffee husk, tella atela/residue/, and brewery waste were collected, dried, ground, and finally packed for the nutrient composition analysis as shown in Figure 3.

Figure 3. Sample preparations for nutrient proximate analysis:

(a) Stored waste on entity site, (**b**) collected samples, (**c**) wet weight measuring, (**d**) oven drying of sample, (**e**) grinding of sample, (**f**) measuring dry weight of sample, & (**g**) prepared & packed samples for lab analysis.

3.5. The process of nutrient composition analysis of samples

The proximate analysis of chemical composition of collected samples of solid organic wastes was determined using validated logical styles following the procedures of the Association of Analytical Communities International (AOAC, 1995). Consequently, the proximate analysis of nutrient composition similar such as, crude protein, crude fat, crude fiber, ash and digestible carbohydrates of solid organic wastes as well as total nitrogen were anatomized in duplicate at the laboratory of animal nutrition, College of Agriculture and Veterinary Medicine, Jimma University as shown on Figure 4. Ash content was measured by placing a sample of given weight in a furnace of 650 °C for 4 hours, after which the samples were cooled in a desiccators and counted and the remaining weight was considered the ash. Crude protein was estimated by measuring the total nitrogen content of the component using the Kjeldahl system and calculating the crude protein position by multiplying the nitrogen content with specific conversion factors to give crude protein. Crude fat was determined by subjugating the samples to a nonstop mix with petroleum ether system using soxhlet outfit as described by AOAC (1995). Crude fiber was determined as that bit remaining after digestion with standard results of Sulfuric acid and sodium hydroxide under precisely controlled conditions. Estimate of carbohydrate (NITROGEN-FREE Excerpt (NFE)) was made by calculating the difference as 100- crude protein-crude fat- crude fiber- ash- moisture.

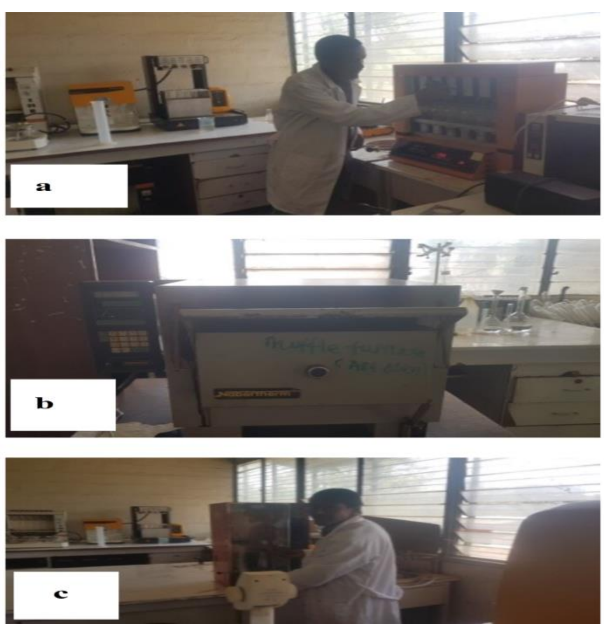

Figure 4. Proximate analysis processes**:** (**a**) During crude fat analysis, (**b**) ash analysis on muffle furnace, (**c**) during crude protein analysis

3.6. Data analysis

The responses from the questionnaire survey were quantitatively analyzed for percentages of respondents for all objectives. Then, these were graphically presented using a bar graph for easy visualization and comparisons.

Each collected samples was assessed and anatomized in terms of their physical- chemical parcels in percent. Physical- chemical parcels of solid organic waste considered were, , ash content, protein content, fat content, carbohydrate content, and fiber content.

4. Result

4.1. The current situation regarding the generation and use of solid organic wastes

4.1.1. Waste generation and Storage

A total of 88 entities (including 2 slaughterhouses, 18 tella houses, 21 restaurants, 33 coffee and tea houses, 4 dairy farms, 5 coffee processing firms, 4 poultry farms, and 1 beer factory) were surveyed (Figure 5a). All of these entities generate various forms of waste during their production processes, including brewery waste, abattoir wastes, cow dung, coffee & tea leaf brewing residues, coffee husk; tella atela, kitchen wastes, and poultry manure (Figure 5b).

Of the surveyed entities: 3 poultry farms and 8 tella houses (12.5%) generated 100 – 1000 kg of waste per year, 2 slaughterhouses, 4 dairy farms, 33 coffee and tea houses, and 21 restaurants (80.7%) generated 1000 – 5000 kg of waste per year, The beer factory (1.1% of entities) produced 5000 - 10,000 kg of waste per year, 1 coffee processing firm (1.1% of entities) produced 50,000 - 100,000 kg of waste per year, and 4 coffee processing firms (4.5% of entities) produced more than 100,000 kg of waste per year (Figure 5c). Approximately 86.4% of entities mix their wastes with other wastes, while 13.6% of entities separately store their wastes (Figure 5d).

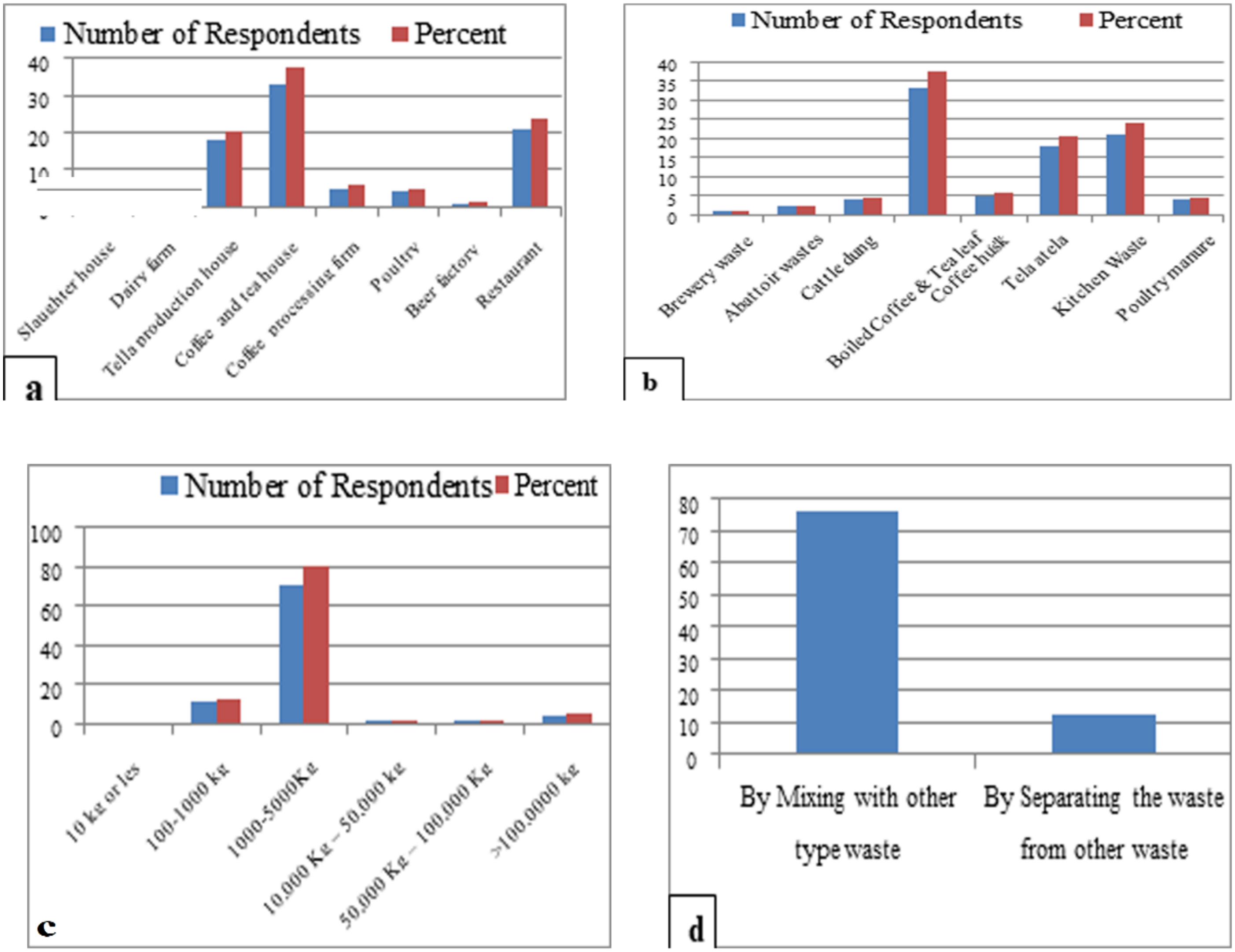

Figure 5. Graphical presentations of solid organic waste generation and storage:

(**a**) Type the surveyed entities, (**b**) type of solid organic wastes, (**c**), quantity of generating wastes per year and (**d**) waste storage methods.

4.1.2. Current use of solid organic wastes

Only 4.5% (4 out of the surveyed entities) utilize their waste for other purposes. This breaks down as follows: 2 dairy farms use their waste as fertilizer, 1 tella house uses its waste as animal feed, and 1poultry farm uses its waste as animal feed, potentially for sheep, by mixing it with other ingredients (Figure 6a). Among the entities using waste, 1 dairy farm (25%) utilizes all its waste, while the remaining 3 entities (1 dairy farm, 1 tella house, and 1 poultry farm, representing 75%) only use half of their waste (Figure 6b). Among those not currently using their waste 94% believe their waste has no value, 3.6% lack storage space for the waste, and 2.4%

have no plan for waste utilization (Figure 6c). Waste disposal practices are as follows: 63.5% of entities dump their waste at designated dumping sites, 12.9% dump their waste on-site at their own facilities, 3.5% give their waste away to others for free (Figure 6d). Only one entity, the beer factory (1.1%), has external users for its waste. The remaining 98.9% do not have external users (Figure 6e). 98.9% of entities do not track the amount of waste they generate.

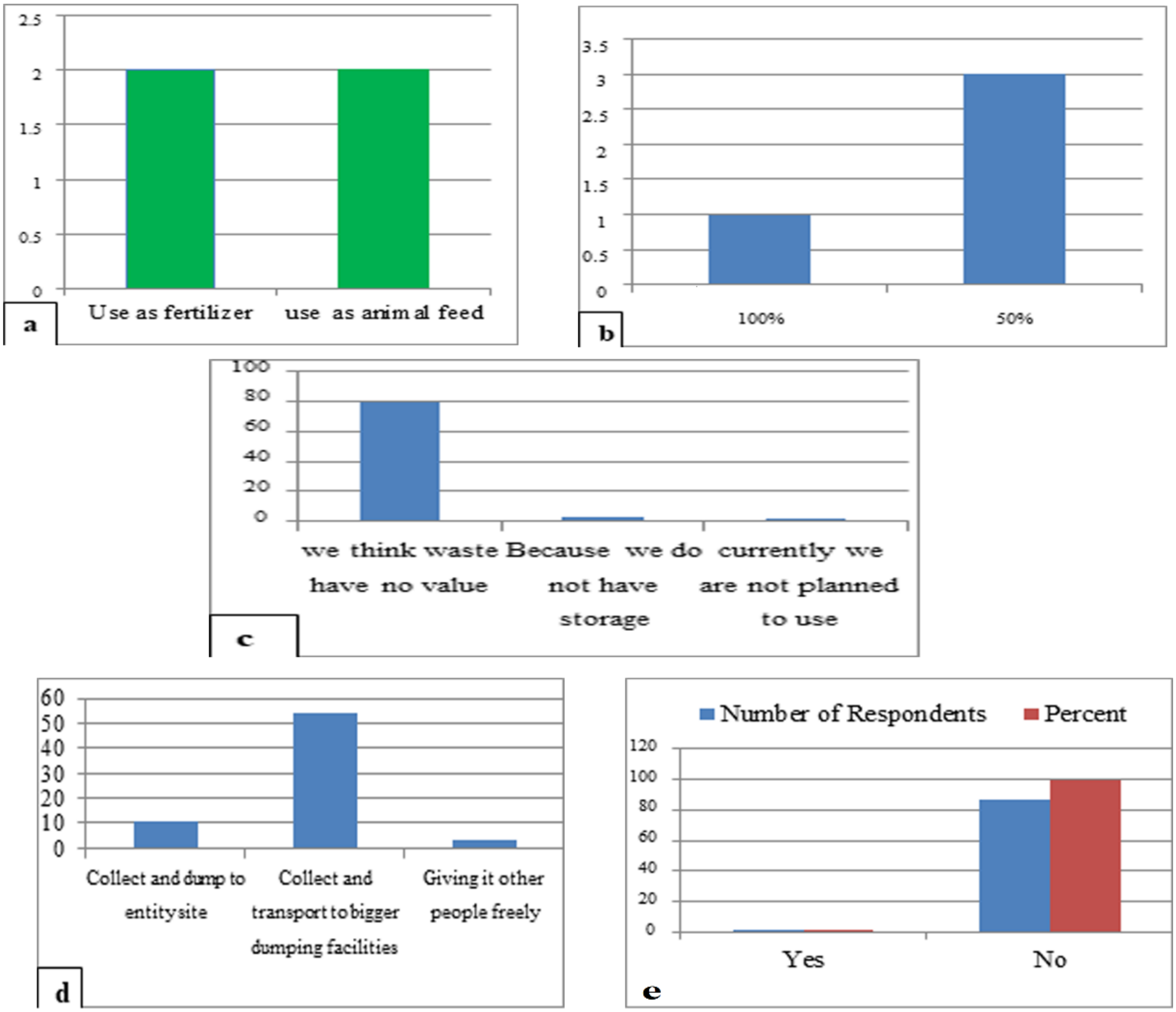

Figure 6. Graphical presentations for current use of the waste:

(**a**) method of using waste, (**b**) proportion of waste used, (**c**) reason why not use wastes, (**d**) final destination of waste & (**e**) created external user of wastes,

4.2. Availability of solid organic wastes

The survey identified entities that fully utilize their waste. One dairy farm and one poultry farm (2.3%) reported not allowing any external users for their waste because they utilize it entirely within their own operations (Figure 7a). In contrast, 97% of the surveyed entities allowed other users to collect their waste. While most surveyed entities did not sell their waste, 18 tella houses (21%) reported occasionally selling it to interested parties (Figure 7b). Among these waste-selling entities, the breakdown of prices was as follows: 5.7% sold their waste for 2 ETB/kg, 6.8% sold their waste for 3 ETB/kg, 6.8% sold their waste for 4 ETB/kg, and 6.8% sold their waste for more than 5 ETB/kg. The survey also investigated waste generation rates across different entities (Figure 7c). Here's the breakdown: Three poultry farms and eight tella houses (12.5%) generated between 100 and 1,000 kg of waste per year, Two abattoirs, four dairy farms, 33 coffee and tea houses, and 21 restaurants (80.7%) generated between 1,000 and 5,000 kg of waste per year, One beer factory (1.1%) generated between 5,000 and 10,000 kg of waste per year, One coffee processing firm (1.1%) generated between 50,000 and 100,000 kg of waste per year, and Four coffee processing firms (4.5%) generated more than 100,000 kg of waste per year. The survey found that 98.9% of the entities did not face competition from other users for their waste (Figure 7d).

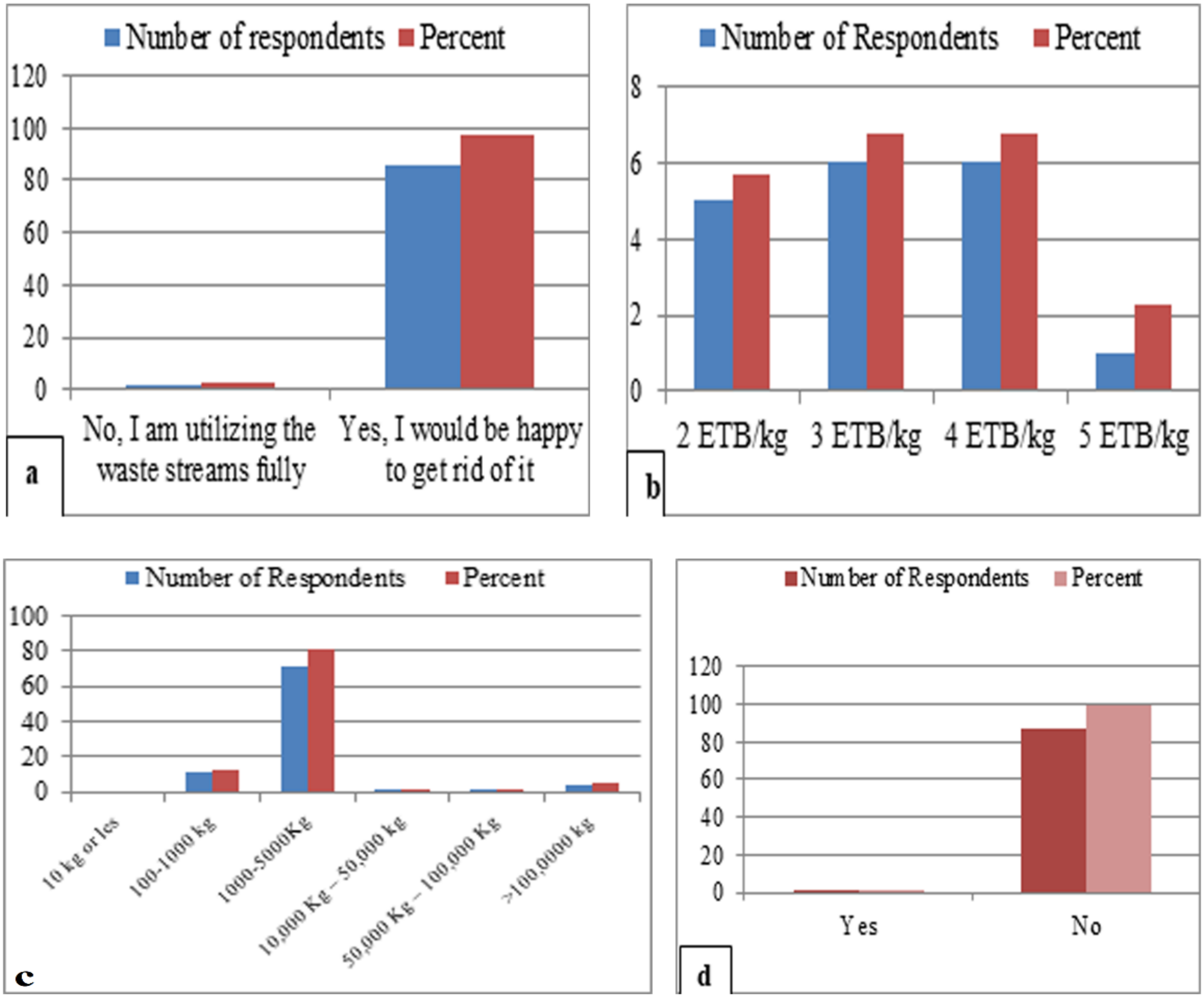

Figure 7. Graphical presentations of the availability of solid organic wastes: (**a**) Accessibility of wastes, (**b**) price of purchase for wastes, (**c**) quantity of waste wastes generated per year, & (**d**) competing users of wastes.

4.3. Views of key stakeholders on using solid organic waste as fish feed

All stakeholders surveyed (two fish farmer cooperatives and two agricultural office personnel) indicated that all the solid organic wastes identified in this study were available within their communities (Figure 8a). Furthermore, all stakeholders believed that these locally available wastes could be used as fish feed.

Cattle dung was considered suitable by two agricultural office personnel and one fish farmer cooperative (75%). However, all stakeholders agreed that poultry manure was a more suitable option for fish feed (Figure 8b).

Importantly, all stakeholders indicated there were no existing regulations prohibiting the use of solid organic wastes as fish feed (Figure 8c). The study also found that these wastes were readily available for interested users and not typically sold within the community (Figure 8c).

The primary challenge identified by all stakeholders in utilizing these wastes was ensuring their safety and quality for fish consumption (Figure 8d). Additionally, all stakeholders expressed concerns about the nutritional value of the solid organic wastes as fish feed (Figure 8e).

On a positive note, half of the surveyed stakeholders believed that using waste as fish feed could contribute to reducing waste generation. Additionally, all stakeholders agreed that this practice aligns with the principles of a circular economy, which emphasizes reusing waste for valuable purposes (Figure 8e).

Regarding ongoing support for this practice, only one fish farmer cooperative (25%) indicated the presence of non-governmental projects exploring sustainable fish feed production that support the use of waste (Figure 8f & g). The remaining 75% reported no such ongoing projects.

Encouragingly, all surveyed stakeholders expressed a willingness to participate in research projects investigating the feasibility and effectiveness of using solid organic waste as fish feed. They also indicated a readiness to provide technical support for such projects (Figure 8h). Interestingly, the survey results revealed that while 50% of stakeholders were aware of research on using waste as fish feed, the other 50% were not (Figure 8h).

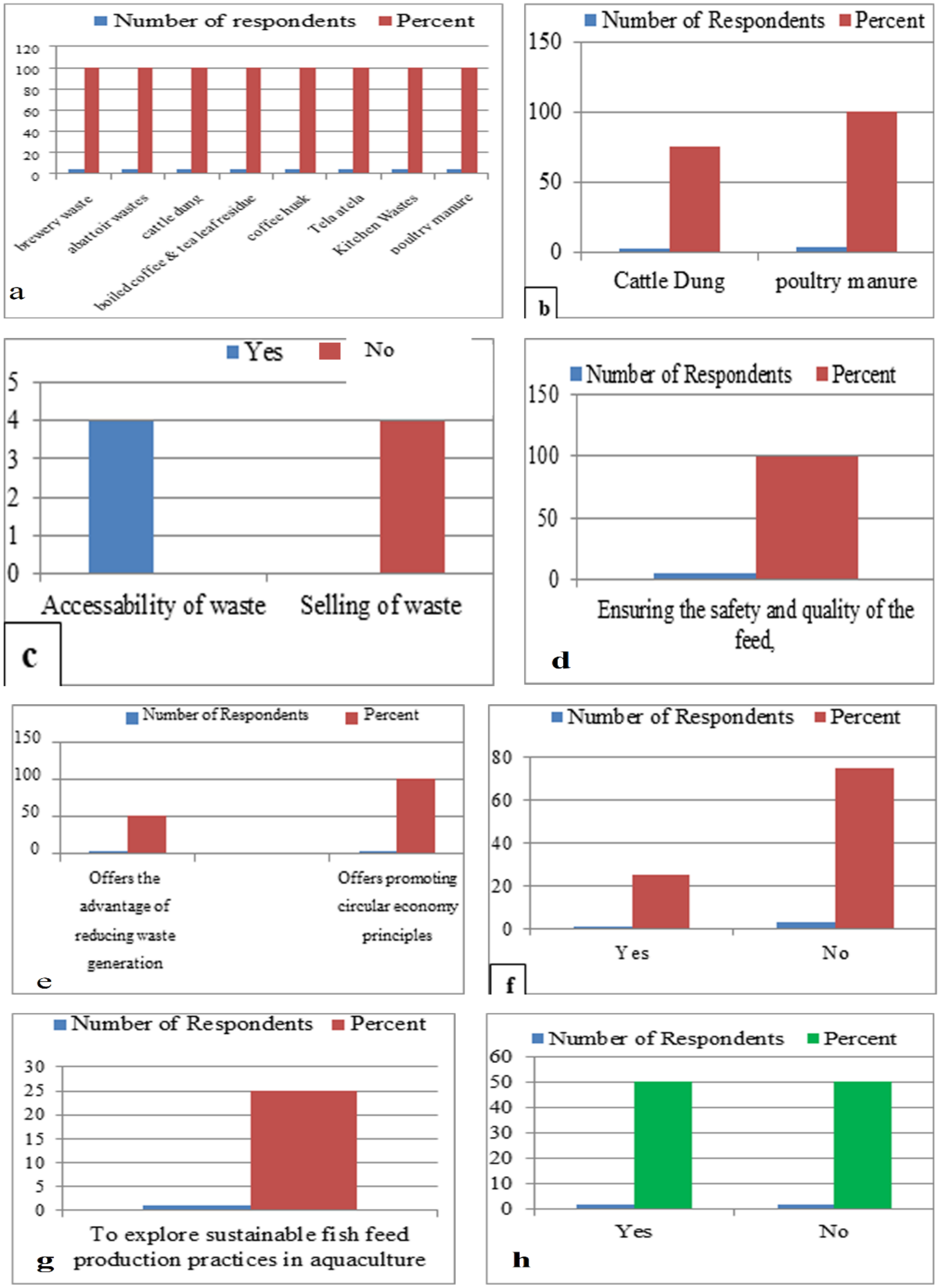

Figure 8. Graphical presentations for the views of key stakeholders on using solid organic waste as fish feed**:**

(**a**) Type of solid organic wastes, (**b**) type of waste could be suitable for fish feed, (**c**) accessibility & selling of the wastes, (**d**) challenges to use the wastes as fish feed, (**e**) opinions on the using of wastes as fish feed, (**f**) ongoing projects support the using of wastes, (**g**) aim of this project, & (**h**) awareness of studies conducted about wastes as fish feed.

4.4. Nutrient composition of solid organic wastes

The nutrient proximate compositions of 14 samples of solid organic wastes was analyzed per 1 gram of dry matter of each sample described and presented in percent as shown in Table 1 and. Figure 8.

Table 1.Nutritional quality analysis of solid organic wastes per 1 gram of dry matter

Serial No	Name wastes	%Fat/DM	%Protein/DM	%Ash/DM	%Carbohydrate/DM	%Fiber/DM
1	Beet root peel	2	14.3	13.7	59.11	11.10
2	*Tella atela*	2	20.0	17.0	45.1	16.10
3	Potato peel	2	16.31	10.0	59.0	13.11
4	Cabbage leftover	1	25.82	14.51	40.34	18.40
5	Onion peel	1	13.04	19.0	48.33	19.1
6	Tea brewing residue	1	18.02	8.0	51.12	22.0
7	Cow dung	2	17.0	21.21	36.80	23.10
8	Head cabbage leftover	2	17.10	13.0	54.0	14.2
9	Coffee brewing residue	3	14.22	9.32	41.35	32.14
10	Cattle blood	3	78.33	6.81	7.74	4.13
11	Coffee husk	2	1.49	13.97	45.3	37.3
12	Rumen liquor	3	18.81	16.7	51.4	10.15
13	Poultry manure	4	23.5	25.64	38.8	8.13
14	Brewery waste	7	26.51	6.6	52.8	7.2

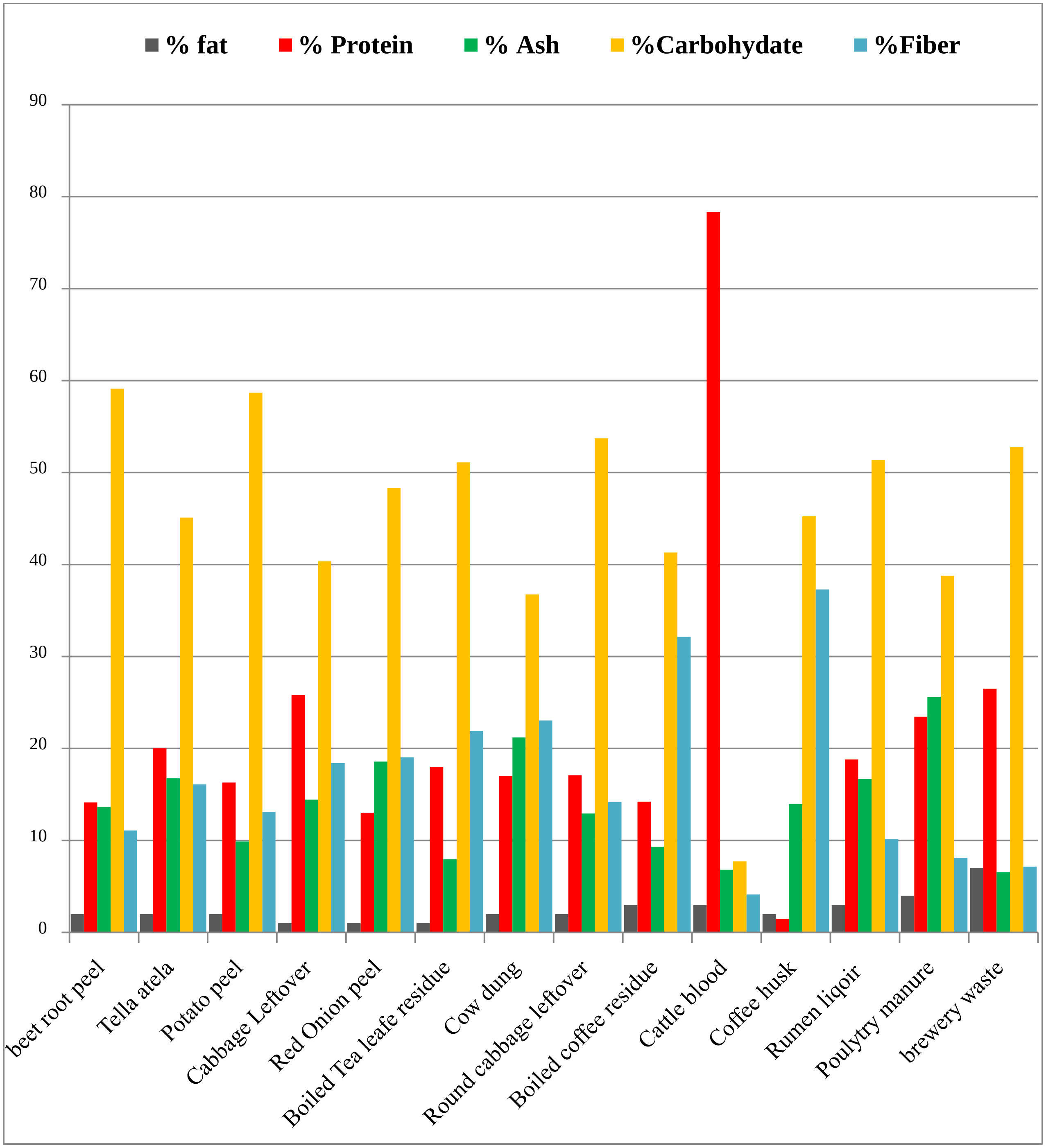

Figure 9. Graphical presentations for nutritional quality of solid organic wastes

5. Discussions

5.1. The current situation regarding the generation and use of solid organic wastes

5.1.1. Solid organic waste generation and Storage

All 88 entities surveyed generate various forms of solid organic waste during their year-round production processes. The quantities vary considerably, ranging from approximately 100 to 100,000 kg/year. Notably, 86.4% of these entities mix their waste with other types of waste, while only 13.6% store their waste separately. This finding suggests that the identified solid organic wastes, potentially a valuable resource for fish feed production, are generated throughout the year in varying amounts. However, the practice of mixing these wastes with others during storage raises concerns about their suitability and potential toxicity for fish feed. Unfortunately, no specific data exists on the exact quantities of solid organic waste generated and stored.

5.1.2. Current use of the solid organic wastes

While most entities don't utilize their waste for other purposes, a small portion does find uses as fertilizer or animal feed. Among these waste users, some employ their entire waste stream, but most only utilize half. Several factors hinder waste utilization. The majority of entities perceive their waste as valueless. Additionally, 3.6% lack storage space, and 2.4% lack a plan for utilizing their waste. Dumping remains the predominant method of waste disposal. Most entities use landfills, while 12.9% dispose of waste on-site, and 3.5% give it away free of charge. Only 1.1% of surveyed entities, specifically the beer factory, had external users for their waste. The remaining 98.9% lacked such connections. Most entities didn't view their waste as suitable for fish feed and didn't track the amount of waste generated.

5.2. Availability of solid organic wastes

All surveyed entities generated varying amounts of solid organic waste throughout the year, ranging from approximately 1,000 kg/year to 100,000 kg/year. Most entities were willing to have their waste managed by external stakeholders interested in doing so. Additionally, most entities did not sell their waste and faced no competition for its use. This suggests a consistent generation of solid organic waste in various quantities across most surveyed entities. This waste could potentially be used for fish feed production as it is readily available, typically free of charge, and faces no competing users. The data indicates that solid organic waste in the study areas has the potential to be a readily available, continuous, and affordable source of material for fish feed production. No previous data available on the availability of solid organic wastes.

5.3. Views of key stakeholders on use of solid organic wastes as fish feed

The survey of key stakeholders revealed that all identified solid organic wastes were available within their communities. All stakeholders believed these local wastes could be used as fish feed. Notably, while 75% considered cattle dung suitable, all stakeholders viewed poultry manure as a more appropriate option. Interestingly, all stakeholders reported no existing regulations prohibiting the use of solid organic wastes for fish feed. Additionally, the study found that these wastes were readily available for interested users, as the community did not sell their waste. However, challenges were identified regarding the use of solid organic wastes as fish feed. All stakeholders agreed that ensuring the safety and quality of these wastes presented the main hurdle. The survey results suggest that stakeholders have valuable insights. All identified solid organic wastes were readily available, could be used as fish feed, and there were no regulations against their use. Additionally, the wastes were freely accessible. Ensuring the safety and quality of the wastes was identified as the primary challenge. Half of the stakeholders believed utilizing waste as fish feed could reduce waste generation. All agreed that it aligned with the principles of a circular economy by reusing waste for valuable purposes. This suggests potential environmental benefits and support for waste-to-feed initiatives. While data on stakeholder views regarding existing research on waste-to-fish-feed applications was unavailable, all stakeholders expressed willingness to participate in such research projects and offer technical support. Interestingly, only half of the stakeholders were aware of previous research on this topic.

5.4. Nutrient composition analysis of solid organic wastes

This study investigated potential replacements for conventional fish feed based on the nutritional content of various solid organic wastes. Cattle Blood: Identified as the most promising protein source due to its very high crude protein content (Table 1, Figure 9). Studies show complete replacement of fish meal with blood meal in catfish juveniles with no negative effects (Barnes et al., 2012; Dedeke et al., 2013). Tella Atela: This waste contains high crude protein, and high carbohydrate content (Table 1, Figure 9). Can serve as dietary source of protein and energy, While research exists on its use in feeding dairy cows, small ruminants, and poultry (Mekasha et al 2003; Demeke 2007), no data is available on its application in fish feed. Brewery Waste: With high protein, and high carbohydrate content (Table 1, Figure 9), brewery waste can serve as a source of protein and energy. Studies in various fish species demonstrate successful utilization of brewery byproducts as replacements for fish meal (Hoffman et al., 2001; Schneider et al., 2004;

Desale et al 2008). Cabbage Leftover: These leftovers exhibit high protein and high carbohydrate content (Table 1, Figure 9), making them suitable for both protein and energy provision. Their incorporation into tilapia feed has been shown to improve growth performance and feed utilization (Monia et al., 2017). Poultry Manure: Containing high protein, and high carbohydrate content (Table 1, Figure 9), poultry manure can serve as a source of both protein and energy. Its inclusion in African catfish feed enhances growth performance and feed efficiency (Sogbesan et al., 2015). Beetroot Peel: While low in protein and fat, but boasts high carbohydrate content (Table 1, Figure 9). Can be a good energy source, no data exists on its use in fish feed. Potato Peel: Moderate in protein, and high in carbohydrates content (Table 1, Figure 9), potato peels can be a good energy source. Their use in Nile tilapia diets has resulted in positive growth performance and feed efficiency (Nour et al., 2019). Head cabbage leftover: Low in protein, but high in carbohydrates (Table 1, Figure 9), head cabbage leftover may serve as an energy source. However, data on their use in animal or fish feed is lacking. Rumen liquor: This byproduct has moderate protein, but high carbohydrates content (Table 1, Figure 9), may serve as an energy source. While not studied in fish feed, rumen liquor offers potential due to its high volatile fatty acid, microbial protein, and vitamin content, which can improve digestion and overall health (Becker et al., 2018). Brewing tea residue: Similar to rumen liquor, brewing tea residue has moderate protein, but high carbohydrates content (Table 1, Figure 9), may serve as an energy source. Data on its use in fish feed is unavailable. Cow dung: has moderate protein, but contains high carbohydrates content (Table 1, Figure 9), cow dung may be an energy source, but research on its application in animal or fish feed is missing. Onion peel: Low in protein, but contain high carbohydrates content (Table 1, Figure 9), onion peel may serve as an energy source. However, data on its use in animal or fish feed is absent. Coffee brewing residue: While containing high carbohydrate for potential energy provision, boiled coffee residue also has high fiber content, which might limit its inclusion in feed (Table 1, Figure 9). No data exists on its use in fish feed. Due to its very low protein content, along with moderate carbohydrates and very high fiber content (Table 1, Figure 9), coffee husk has limited nutritional value and may not be suitable for inclusion in fish feed. Data on its use in fish feed is scarce.

6. Conclusions and Recommendations

6.1. Conclusions

From the present findings, the following major points can be drawn:-

- ✓ The present study provides the status of current generation and use of existing types of entities' solid organic wastes have the potential to be resourceful feedstock in fish feed production in the surveyed areas.
- ✓ This study found that all surveyed entities in southwest Ethiopian towns consistently generate all the wastes presented in the study throughout the year. However, most of them neither reuse the waste nor sell it, and there were no external competing users for their waste. Based on these availability criteria, we can conclude that all the solid organic wastes in the surveyed areas were readily available for fish feed production as an ingredient.
- ✓ This survey highlights stakeholder interest in exploring the use of solid organic waste for fish feed. Their insights suggest readily available resources, potential environmental benefits, and a knowledge gap regarding existing research. Stakeholder willingness to participate in future research projects provides a valuable opportunity to explore the feasibility and effectiveness of this approach.
- ✓ This study identified several promising solid organic wastes as potential replacements for conventional fish feed ingredients. In addition, the present study found that these solid organic wastes can be used as dietary sources of both protein and energy for fish feed that relies heavily on local resources.

6.2. Recommendations

Based on the findings of the present study, the following recommendations are suggested:

- ✓ More surveys, are recommended to initiate and try to use solid organic wastes as fish feed for the development of the aquaculture industry in Ethiopia.
- ✓ Further research is recommended to investigate the feasibility and optimal inclusion levels of these waste products in practical fish feed formulations. This will help to address the pressing issue of a shortage of fish feed and will contribute to the advancement of aquaculture development in the current study areas as well as in other regions of the country.
- ✓ The potential of these solid organic wastes as dietary sources of protein and energy for fish feed is primarily assessed based on their protein and carbohydrate content. However, further research is needed to determine the feasibility of removing anti-nutritional components and to evaluate the amino acid profile and digestibility of these wastes.

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Appendix 1

Questionnaire

Section one (1): Questions for local entity

1. What type of products does the Entity produce?
a. Production of Tella
b. Production of food
c. Processing of coffee and Tea
d. Dairy product
e. Coffee bean
f. Meat
g. Chicken and egg
h. Beer
i. Others
2. What is the nature of the main raw materials for your products?
a. Unprocessed raw material (not grounded or primary commodity)
b. Processed raw material (grounded and partially processed/secondary commodity)
c. Mixture of unprocessed and processed raw material
d. None of both.
3. Does your process generate any waste? (Waste is anything not part of the actual main product)
a) Yes
b) No
4. If yes, which type of waste do you have?
a. brewery waste
b. abattoir waste (cattle blood and rumen liquor)
c. cow dung
d. boiled coffee & tea leaf residue
e. coffee husk
f. Tella atela
g. Kitchen wastes
h. Poultry manure

i. Others
5. How do you store the waste?
a. By Mixing with other type wastes
b. By Separating the waste from other wastes
c. Others
6. What are the total quantities of waste you produce per year in kilogram (Kg)?
a. 10 Kg or Les
b. 10 Kg -100 Kg
c. 100 Kg – 1000 Kg
d. 1000 Kg - 5000 kg
e. 5000 Kg - 10,000 kg
f. 10,000 Kg – 50,000 kg
g. 50,000 Kg – 100,000 Kg
h. > 100,000 Kg
7. Do you produce constant amount of waste throughout the year?
a. Yes
b. No
8. If not, what factors affect the amount of waste produced?
a. Type and nature of raw materials
b. Technological reasons
c. Product demand and supply
d. Labor skills
9. Do you use the waste for other purpose?
a. Yes
b. No
10. If yes, how do you use the waste?
a. Reuse in the production process
b. Produce heat or other valuable resources
c. Use as fertilizer
d. use as animal feed
e. Others

11. If yes, what proportion of the waste do you use?

a. 100 %

b. 75%

c. 50%

d. 25%

e. Less than 25 %

12. If no, why do you not use the waste?

a. Because it is contaminated

b. We think the waste have no value

c. Because we do not have space for storage

d. It is costly to use

e. currently we are not planned to use the wastes for other purpose

13. If not use, what happens to the waste then?

a. Collect and dump at the Entity site

b. Collect and transport to bigger dumping facilities

c. Incinerate the waste (open air burning)

d. Giving it to other people freely

e. Selling it to other people

14. Would you allow to anyone else out of your Entity to utilize and/or manage your waste freely?

a. No, I am utilizing the waste streams fully

b. No, unless I am paid for it

c. No, we would like to/are planning to use it

d. Yes, I would be happy to get rid of it

e. Yes, it would reduce the costs

15. Are there any other users of waste generated by your Entity?

a. Yes

b. No

16. If yes, who are the users and for what purpose they use the waste?

17. Do you sell the solid organic wastes for others out of your Entity?

a. Yes

b. No

18. If yes, what is the cost of solid organic wastes per kilogram (Kg)?

a. 2 ETB/kg

b. 3 ETB/kg

c. 4 ETB/kg

d. 5 ETB/kg

e. > 5 ETB/kg

19. Have you ever considered using solid organic wastes as fish feed ingredients?

a. Yes

b. No

20. If yes, which types of solid organic wastes do you think could be suitable for fish feed?

a. Brewery waste

b. Cattle blood

c. Rumen liquor

d. Cow dung

e. Boiled coffee residue

f. Boiled tea leaf residue

g. Coffee husk

h. Poultry manure

i. Tella atela

j. Kitchen wastes

k. Others

21. Do you monitor and document the produced waste?

a. Yes

b. No

22. If yes, what method do you use to measure and monitor the waste?

a. Daily recording

b. Estimates and assumptions

c. Through utilization

23. If no, why don’t you monitor and record?

a. We do not have the equipment required for monitoring

b. It takes too much time and/or resources

c. We do not see the need

Section two (2): Questions for major stakeholders (fish farmers in the localities and Zonal Agriculture Office personnel working on aquaculture development).

24. What types of solid organic wastes are generated in your area/community? (Tick all options that apply) brewery waste

a. abattoir wastes

b. cattle dung

c. boiled coffee residue

d. boiled tea leaf residue

e. coffee husk

f. Tella atela

g. Kitchen wastes

h. Others

25. Are these solid wastes currently being disposed of or managed in any way?

a. disposed

b. managed

26. If managed, what waste management methods currently your community practicing? damping,

a. recycling,
b. composting,
c. waste-to-energy facilities,
d. other

27. Have you ever considered using solid wastes as fish feed ingredients?

a. Yes

b. No

28. If yes, which types of solid organic wastes do you think could be suitable for fish feed?

a. brewery waste
b. abattoir wastes

c. cattle dung

d. boiled coffee residue & tea leaf residue

e. coffee husk

f. Tella atela

g. Poultry manure
h. Kitchen wastes
29. Do you think those solid organic wastes are freely accessible to use as a fish feed ingredients from the sources?
a. Yes
b. No
30. If no, why? The entity uses their own waste
a. It needs cost
b. Competition with other user
c. Other reasons
31. Does the Entity sell their waste?
a. Yes
b. No
32. If yes, what is the price of per kilogram?
a. 2 ETB/kg
b. 3 ETB/kg
c. 4 ETB/kg
d. 5 ETB/kg
e. > 5 ETB/kg
f. Others
33. Are there any other users compete for the waste?
a. Yes
b. No
34. If yes, who are the competent users and for what purpose they use?
35. What are the main barriers or challenges in utilizing solid wastes as fish feed ingredients?
a. Ensuring the safety and quality of the feed
b. Addressing potential contaminants or toxins present in the waste
c. Finding appropriate processing methods,
d. Others
36. Are there any regulations or restrictions that prevent the use of solid wastes as fish feed ingredients?

a. Yes
b. No

37. If yes, what are the regulations or restrictions?
38. Are there any ongoing initiatives or projects in your area/community that promote the use of solid wastes as fish feed ingredients?

a. Yes
b. No

39. If yes, what type of projects is there?

a. Governmental
b. Non- governmental

40. What is the aim of these projects?

a. To explore innovative waste management strategies
b. To explore sustainable fish feed production practices in aquaculture.
c. Others

41. Are you aware of any research or studies conducted on the use of solid wastes as fish feed ingredients?

a. Yes
b. No

42. If yes, what is the focus of these research studies is?

a. On evaluating the nutritional value
b. On safety considerations using waste
c. On environmental impacts associated with using of different types of wastes as fish feed
d. On the effect of solid organic wastes using as fish feed

43. What is your opinion on the potential benefits and risks associated with using solid wastes as fish feed ingredients? Offers the advantage of reducing waste generation

a. Offers promoting circular economy principles,
b. It poses risks ensuring feed safety and quality
c. Addressing environmental impacts
d. Complying with regulatory standards

44. Would you be willing to participate in a research project or pilot study to explore the feasibility and effectiveness of using solid wastes as fish feed ingredients?

a. Yes
b. No

45. If yes, what would your willing is? To participate in financial?

a. To participate in technical?
b. To participate in instrumental?
c. Others