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On-Farm Management, Processing and Post-Harvest Handling of the Indigenous Enset (*Ensete ventricosum (Welw) Cheesman*) in Gedeo Zone, Southern Ethiopia

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Abstract

Enset is a perennial, drought-tolerant, banana-like plant that used for food, fodder, fiber production, fuel, traditional medicine, and for other different cultural practices. The enset production system of Gedeo expresses complex interrelationships between humans and biological diversity. Majority of research studies focused on higher altitudes, where enset production was established successfully for long time. However, enset can grow in wide range of environment including lower altitudes, where the potential use of the crop might be further exploited. Hence, the objective of this research was to provide information on on-farm management and processing of enset across the different agroecology of Gedeo Zone, Southern Ethiopia. From the three agroecological representative woredas, a total of seven sample kebeles were selected. Detailed information from volunteer key informants on the crop agroecological preferences, crop calendar, propagation techniques, planting methods, soil management, disease and pest management, harvesting, processing, and storage methods were collected. This information was organized and developed into a structured questionnaire. A total of 230 randomly selected farmer households were included in the data. In the study area enset crop-management and processing activities performed using traditional methods. Some alternative techniques and approaches, such as the seed propagation method overlooked.

Keywords: *Ensete ventricosum*, Food security, Traditional medicine, Underutilized crop

Introduction

Enset is a perennial, monocarpic, herbaceous, drought-tolerant, banana-like plant. It is a multipurpose crop used for food, fodder, fiber production, fuel, traditional medicine, and for other different cultural practices (Negash and Niehof, 2004; Tsehaye and Kebebew, 2006). Its multi-annual production time and flexibility on harvesting make the crop a reliable food source where the failure of annual crops is encountered (Tsegaye and Struik, 2001). Also, it improves the local climate and soil conditions (Tsegaye and Struik, 2001).

Enset has only domesticated in Ethiopia. Enset produced in Southern Nation and Nationality Peoples (SNNP), Oromia, and Gambella Regional States of Ethiopia (Tsegaye, 2002). The Gedeo enset system is unique in its design as well as in its functioning (Kippie, 2002). In Gedeo, enset-based agricultural systems date back from the Neolithic (Kippe, 2002). The crop has existed for several hundred years as a sustainable form of agriculture in the country in general and in the Southern region in particularly (Addis *et al.*, 2008). The diversity of the systems and the ability of enset to produce a relatively large amount of food per unit area and time could be the main factors that contributed to this stability (Tsegaye and Struick, 2001).

Majority of the research studies focused on higher altitudes, where enset production was established successfully for long time. However, enset can grow in wide range of environment include at lower altitudes (Addis *et al.*, 2008), where the potential use of the crop might be further exploited. Hence, the objective of this research was to provide information on on-farm management and processing of enset across the different agroecology in Gedeo Zone, Southern Ethiopia.

Materials and Methods

The study area

Gedeo zone has a total area of 1347 square kilometers in which the share of midlands and highlands, 67.53%, and 32.41%, respectively. The mean annual temperature ranges between 12.6-22.5°C and the mean annual rainfall ranges between 1001-1800 mm. It is sub-divided into six woredas (Figure 1).

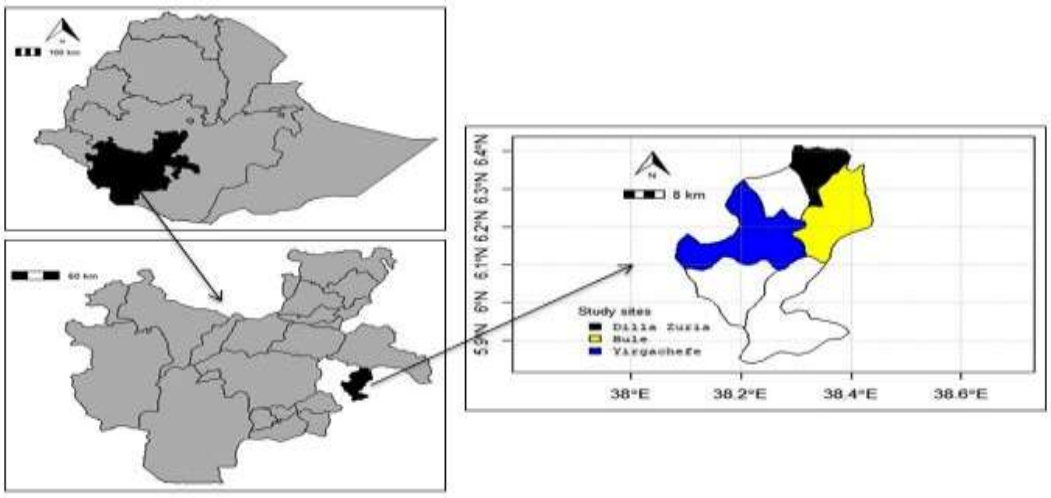

Figure 1: Location of the study site

The Survey Design and Data collection

The selection of the woredas and kebeles (the lowest administrative units) was performed based on differences in altitude. The enset farming system of Gedeo was stratified into three: lowlands (<1,500 m.a.s.l), midlands (1,500-2,500 m.a.s.l) and highlands (>2,500 m.a.s.l). Accordingly, four Woredas and seven kebeles were included in the study (Table 1). In the process of selection, agricultural experts and each woreda (kebele) Development Agents consulted (Table 1).

Table 1: Description of the samples

Woredas	kebeles	Enset land cover (ha)	Altitude (m.a.s.l)	Number of Enset producers		
				M	F	Total
Bule	Haro Welabu	261	2600-3200	370	8	378
	Sika	391	2800-3000	427	213	640
Yirgachefe	Wete	283	2100-2500	581	23	604
	Bowcha	150	1950-2120	840	18	858
Dilla Zuria	Amba	345	1750-2015	881	123	104
	Harsu	130	1950-2500	122	15	137
Dilla Zuria	Haroresa	50	980-1450	42	6	48

Source: Gedeo Zone Agriculture and Natural Resource Bureau; Dilla City Agriculture and Natural Resource Development Office

Data collection was performed with the help of key informant interviews, structured questionnaires, and focus group discussions. Key informants were selected and interviewed by consulting agriculture experts and Development Agent. Cultural attachment and indigenous knowledge of enset were the main criteria for selecting key informants. A structured questionnaire was developed based on key informants and secondary data information and pretested before the data collection started. A total of 230 randomly selected households were included, which was about 10% of the total number of enset producers (Table 2).

Table 2: Socio-economic data of the respondents

Household Characteristics	Category	Frequency (%)						
		Haro Welabu	Sika	Wete	Bowcha	Amba	Harsu	Haroresa
Gender	F	9.1	20.0	12.8	12.3	46.2	30.0	50.0
	M	90.9	80.0	87.2	87.7	53.8	70.0	50.0
Land size (ha/m^2)	<0.5	0.0	3.5	3.0	66.7	80.0	8.0	12.8
	<1	0.0	10.5	18.2	33.3	0.0	40.0	34.9
	<1.5	15.4	40.4	24.2	0.0	10.0	24.0	31.4
	<2	46.2	17.5	12.1	0.0	0.0	24.0	12.8
	<2.5	7.7	15.8	30.3	0.0	10.0	0.0	7.0
	≥2.5	30.8	12.3	9.1	0.0	0.0	4.0	1.2
Years of formal education	<6	15.4	61.4	75.8	66.7	30.0	83.3	55.8
	7-8	30.8	24.6	12.1	16.7	30.0	12.5	30.2
	9-12	30.8	14.0	12.1	0.0	30.0	4.2	14.0
	>12	23.1	0.0	0.0	16.7	10.0	0.0	0.0
Family size	<5	0.0	22.8	6.1	50.0	10.0	12.0	8.1
	5-10	38.5	70.2	51.5	33.3	50.0	76.0	82.6
	>10	61.5	7.0	42.4	16.7	40.0	12.0	9.3
Age	<30	0.0	29.8	18.2	0.0	10.0	12.0	0.0
	30-60	100.0	64.9	81.8	66.7	90.0	80.0	95.3
	61-80	0.0	5.3		16.7	0.0	8.0	4.7
	>80	0.0	0.0	0.0	16.7	0.0	0.0	0.0

Data verification and analysis

The collected data checked for completeness and reliability. Clarification on some variables performed using focus group discussions and observation. Descriptive statistical summaries such as frequencies, percentages, and averages and correlation analysis were performed in R version 3.6.2 (R Development Core Team, 2020).

Results and Discussions

Agro-ecology

In this study, the majority of respondents preferred midland agroecology and shady areas for enset productivity (Table 3). Enset is usually productive in moist mid-altitude and highland environments (Negash and Niehof, 2004). However, the efficient use of light for optimum yield can relate to the clone type (Tsegaye and Struik, 2001).

Table 3: Respondents' perception in light and altitude preference for enset crop

Agro-Site Preference	Category	Respondent Frequency (%)						
		Haro Welabu	Sika	Wete	Bowcha	Amba	Harsu	Haroresa
Light preference	Shady	38.5	5.3	12.1	33.3	10.0	12.0	0.0
	Open	61.5	7.0	6.1	0.0	70.0	4.0	0.0
	No difference	0.0	10.5	42.4	66.7	0.0	32.0	0.0
	I do not know	0.0	77.2	39.4	0.0	20.0	52.0	100.0
Agro- ecology preference	Highlands	74.8	0.0	98.2	45.5	0.0	20.0	52.0
	Midlands	21.7	84.6	1.8	54.5	100.0	20.0	48.0
	Lowlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Highlands and midlands	3.5	15.4	0.0	0.0	0.0	60.0	0.0

Crop calendar

The propagation period differs from one area to another as it heavily depends on environmental conditions. In lowland areas, the time is determined based on moisture availability. In highland areas, it is determined based on warm temperature (Negash and Niehof, 2004; Semman *et al.*, 2017). In the study areas, the highland and low land crop calendar based on different requirement (Figure 2).

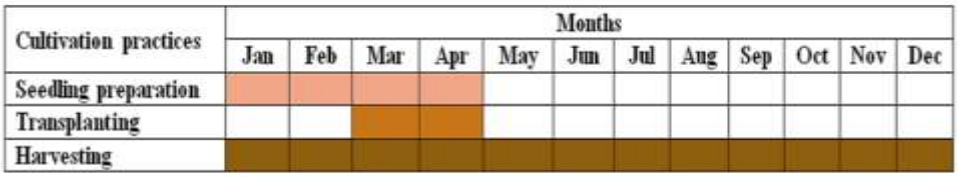

Figure 2: General enset-cultivation calendar in Gedeo as per the majority of respondents

The seed propagation

In our study, the majority of the respondents, except from Haro Welabu kebele did not have any clue about the seed propagation method (Table 4). The reason can be due to the crop harvesting time, which is before the flowering-period and setting of the seed. However, some of the respondents who know seed propagation even tried it in their field (Table 4). During group discussion, seed propagation dependency on season, lack of knowledge and awareness, and lack of available seed were mentioned as the main problem for using seed propagation method. Also, they believe that plants from seeds require a longer time than plants from corm sprouts to reach harvesting or flowering stage. Surprisingly, some of the farmers strongly believe that enset cannot set seed.

Table 4: Seed propagation method status

Agro-Site Preference	Category	Respondent Frequency (%)						
		Haro Welabu	Sika	Wete	Bowcha	Amba	Harsu	Haroresa
About enset seed propagation	Known	72.7	44.0	20.9	28.1	0.0	30.0	16.7
	Unknown	27.3	56.0	79.1	71.9	100.0	70.0	83.3
Use of seed propagation method	Yes	0.0	0.0	0.0	25.0	0.0	100.0	0.0
	No	100.0	100.0	100.0	75.0	100.0	0.0	100.0

Enset can be propagated by both seed and vegetative methods (Figure 3). Cultivated enset crops are mostly propagated by the vegetative method as the germination percentage of the intact seed is very poor (Alemu and Sandford, 1996; Karlsson *et al.*, 2013). Previous study showed that there is no general delay in the growth of seedlings compared to vegetative sprouts, even some plants showed early flowering (Karlsson *et al.*, 2013). The growth rate of enset is probably correlated to the environmental circumstances rather than to the propagation method (Pijls *et al.*, 1995; Tsegaye and Struik, 2001; Tsehaye and Kebebew, 2006).

Figure 3: Reproduction parts of typical enset plant: (A) Fruit arrangement, (B) Collected fruits, (C) Seeds extracted from ripe fruits (D) Botanical seeds

The vegetative propagation

Enset is commonly and traditionally propagated by vegetative techniques in almost all enset producing areas (Karlsson *et al.*, 2012; Pijls *et al.*, 1995). All farmers in the study areas use vegetative propagation methods. They cut the mother plant above the junction of the pseudostem and the corm to prepare it for propagation. Then they scrape out and remove the central part of the corm to induce sucker production (Figure 4). Differently, in Sheka and Wolaita zone, most farmers uproot the mother plant, expose it to sunlight for three days to one week, and then they replant the corms. According to these farmers, using this method, a large number and quick emergence of seedlings can be achieved (Figure 4; Tesegaye , 2002).

Figure 4: Asexual propagation: (A) Enset plant pseudostem prepared for harvesting and sexual propagation (B) Cutting at the bottom to use the underground part for propagation and the upper part for *kocho* harvesting (C) The underground part divided into four parts and small portion of the middle part removed to initiate sprouting

In Gedeo, number of seedlings that emerged per plant is very irregular. They obtained in a range of 200 to 300 suckers from a single mother plant (Figure 5). The highest number of seedlings signified from midland areas. The number of suckers per mother plant depends on soil condition, types of clones, size and age of the mother plant, amount of rainfall, land preparation, and time of planting (Shumblo *et al*., 2012). Sucker regeneration capacity, growth parameters, and yield potential of enset depend on the corm size. The larger the corm size, the higher the number of suckers grown (Buke, 2016). Further researches are required to clarify and scale up the best practices.

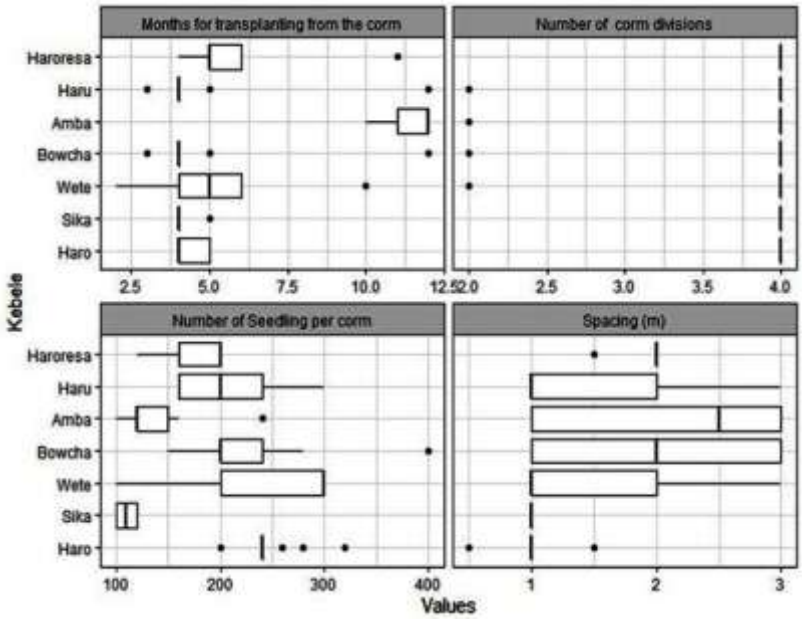

Figure 5: Propagation and plating techniques

Planting method

In the study area, the majority of respondents applied a minimum of one-meter and a maximum of two-meter space among seedlings in the main field (Figure 5). Plant spacing affects growth, development, and production of enset. Narrow plant spacing affects harvestable pseudostem and yield (Shumblo *et al.*, 2012). On the other hand, wider spacing beside yield increment reduces the duration of maturity (Shumblo *et al.*, 2012). Thus, further research works to determine the optimum spacing is recommended.

Soil management

In the midlands of Gedeo, the abundantly available coffee residue is infrequently used, but other plant residues are frequently applied (Figure 6). Both manure and compost are frequently applied. This might be due to where enset commonly grown. It grows at homesteads where animal manure and homestead wastes are accessible (Egizabiher *et al.*, 2020). But, coffee wastes mainly exist in coffee processing plants. Hence, further study on coffee waste management for enset production is recommended.

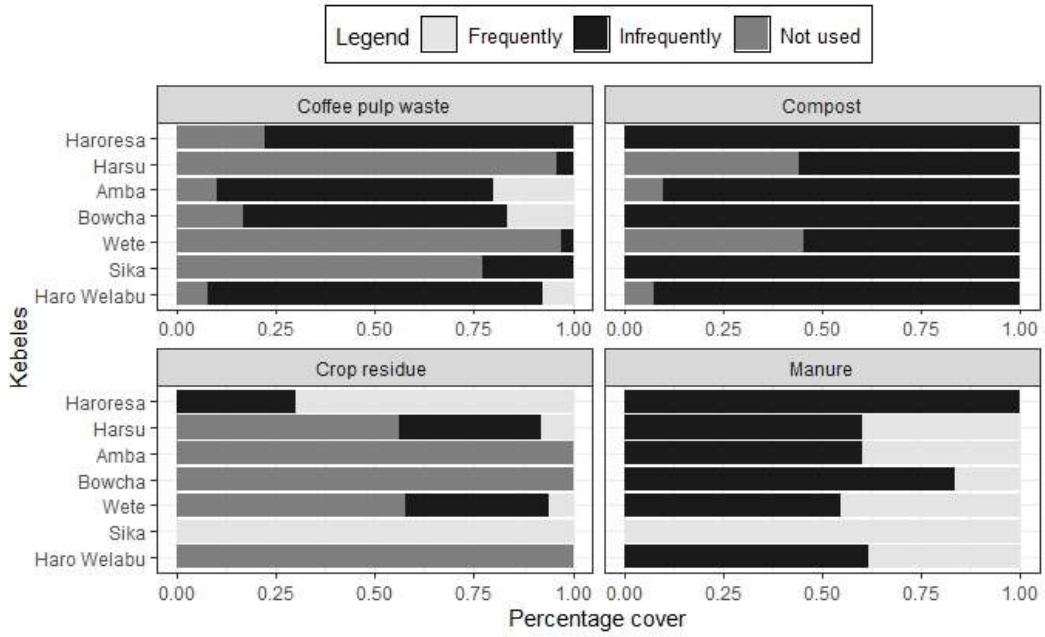

Figure 6: Organic fertilizer usage

Disease and pest management

Our study showed that Enset root mealy bug damage was medium-scale in highlands, but high in midland and lowland areas. On the other hand, the damage

porcupine was high in highland areas while the damage of the mole rat was high both in highlands and midland areas (Figure 7). The absence of effective control measures for the diseases, pests, and mole rats affects enset productivity and results in the loss of some important landraces. Bacterial wilt of enset was the most important disease affecting production and productivity in the study area and almost all enset producing areas (Figure 7; Nakato *et al.*, 2018). Enset root mealybug is also one of the major concerns of the farmers in Gedeo and other areas (Figure 7; Addis *et al.*, 2008).

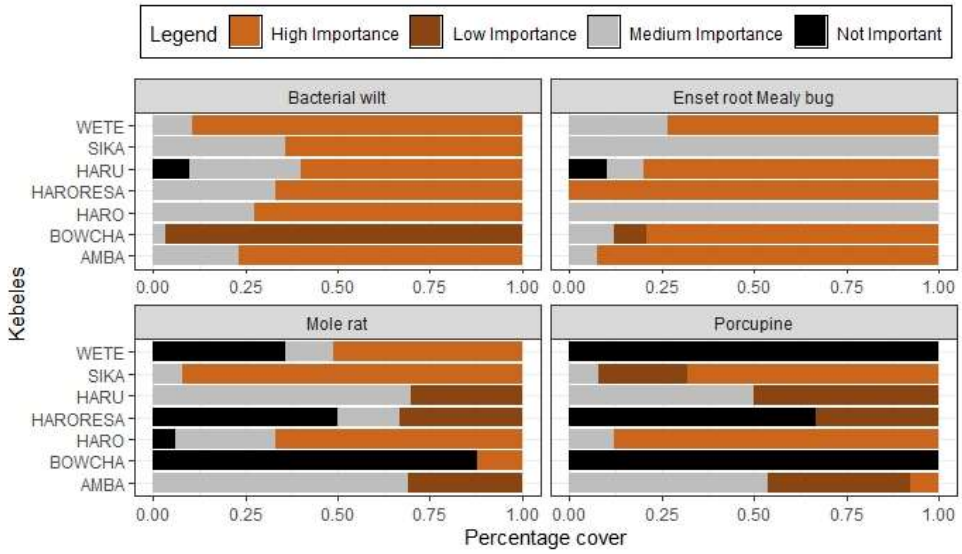

Figure 7: Importance of damage by pests of enset at Gedeo zone

Harvesting

The harvesting process of enset was similar to other enset cultivating areas and performed by womens (Figure 8; Tsegaye and Struik, 2001; Yeshitila, 2014). In our study, besides these three major food products (kocho, bulla, and amicho), a new type of traditional food was identified, called *Gumme*. It is taken out systematically from the center of the corm during the harvesting processes and consumed raw by youth and children at the field (Figure 8).

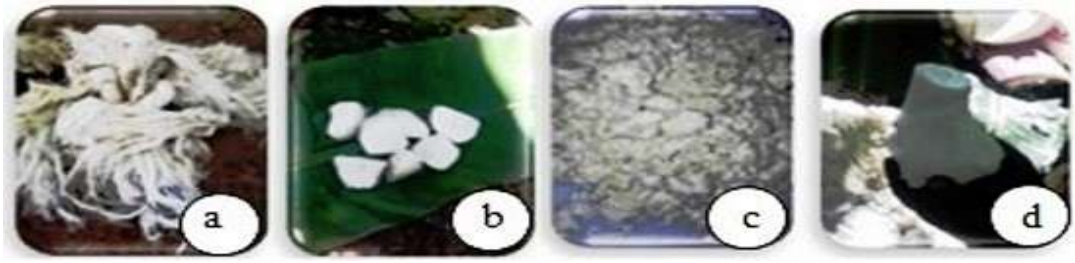

Figure 8: Enset products: (a) Fiber, (b) Amicho, (c) Kocho, (d) 'Gumme'

In the study area, the data showed that the average *kocho* yield per plant was 72 kg, which is much more above the recorded average. The crop yield was very high in the midlands, followed by highlands (Figure 9). The main product of the enset crop is a starch extracted from the underneath corm and the leaf sheaths (pseudostem), locally known as *kocho* (Figure 8). Tsegaye (2002) showed that the *kocho* yield of enset per unit space and time was much higher than any other crop cultivated in Ethiopia. It fills the food gap during seasonal shortages in a year for human beings and also livestock as well (Yeshitila, 2014).

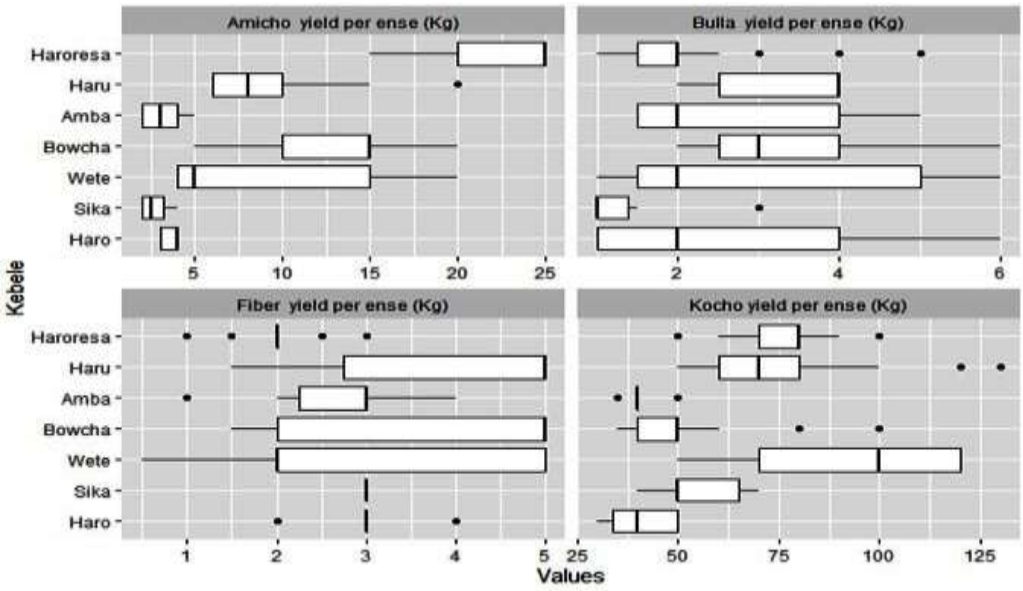

Figure 9: Yield of enset products

Bulla is the water-insoluble starchy product. It obtained when leaf sheaths and corms pulverized, the liquid squeezed out, and allowed concentrating into a white powder (Yemataw *et al.*, 2016). The regional recorded average of kilograms bulla yield was 10.4 (Tsegaye and Struik, 2002), and the study area average was 2.7 kg (Figure 9). The other product, amicho, is the fleshy inner part of the enset corm (Negash and Niehof, 2004). The average yield in the study area is 13.8 kg (figure 9).

The study area average fiber yield was 2.9 kg per enset plant (Figure 9). The fiber, after sun-drying, is either sold in a market or is put to domestic use (Olango *et al.*, 2014). After using the pseudostem for food products, the remaining fiber is used for making strong ropes, mats, twine, sacks, for wrapping enset products and for squeezing out excess moisture from *kocho* (Negash and Niehof, 2004; Olango *et al.*,2014).

Processing and Storage

In the study area, a starter solution, called *Gamama*, is prepared from amicho (40%), fermented *kocho* (38%), or both (22%) beforehand (Table 4). In Gedeo, the average was 17 days, and the maximum was one month recorded from Sika and Haroresa woredas (Table 4). The fermentation period in Haro Welabu, Bowcha, and Amba was less than ten days (Table 4). The starter used to rapidly initiate the fermentation process (Tsegaye and Struik, 2001). The quality and adequacy of the previously prepared starter and the environment determine the rate of the fermentation process (Tsegaye and Struik, 2001). The length of the fermentation period varies from a few weeks to several months (Olango *et al.*, 2014; Tsegaye and Struik, 2001).

Table 4: *Bulla* preservation methods, *kocho* quality parameters and *kocho* fermentation at Gedeo

Variable description	Category	Respondent Frequency (%)						
		Haro Welabu	Sika	Wete	Bowcha	Amba	Harsu	Haroresa
Bulla preservation methods	Drying	74.3	0.0	63.2	84.8	0.0	0.0	84.0
	Soaking in water	16.1	100.0	10.5	9.1	100.0	70.0	8.0
	Both	7.4	0.0	26.3	3.0	0.0	0.0	4.0
Kocho Quality preferred parameters	Color	43.0	76.9	64.9	81.8	16.7	50.0	76.0
	Texture	43.0	76.9	64.9	81.8	16.7	50.0	76.0
	Smell	93.9	100.0	100.0	87.9	83.3	50.0	84.0
	Food test	46.5	76.9	64.9	93.9	16.7	50.0	92.0
Fermentation in days	<10	100.0	0.0	51.5	100.0	100.0	48.0	0.0
	10-20	0.0	29.8	48.5	0.0	0.0	52.0	46.5
	20-30	0.0	70.2	0.0	0.0	0.0	0.0	53.5

Farmers use indigenous knowledge to store and maintain the quality of enset products. Different types of parameters determined the quality of enset products. The quality of *kocho* is determined using color, texture, smell, and test. In Gedeo, however, the majority of the farmers considered the smell as a significant criterion for *kocho* quality (table 4). The smell developed during fermentation. *Kocho* and bulla were mainly preserved and stored by drying. In Gedeo, like other enset producers, *kocho* can also be stored in the pit for long periods without spoiling (Table 4; Tesfaye and Kebede, 2006). Most farmers at Sika, Amba, and Harsu woredas stored and preserved *bulla* by soaking in water (Table 4).

Conclusion

This study provided an overview of the Gedeo enset production and processing culture across different agroecological zones. Enset crop-management and processing activities performed using traditional methods. Some alternative techniques and approaches, such as the seed propagation method overlooked. The information from this study would help for further research and scientific interventions on the Gedeo enset system.

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