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Estimating avocado postharvest loss across its value chains and its determinants in Sidama and Gedeo areas, Southern Ethiopia

Hana Tafesse[1]*, Mulugeta Fola[1], Tsadiku Alemu[1], Teklu G/Tsadik[1], Berhanu Yacob[2] and Atnafua Bekele[3]

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A B S T R A C T

Fruit plays a vital role in enhancing nutrition security; however, it faces persistent postharvest losses due to socioeconomic, institutional, and biological factors. To reduce these losses, it is essential to identify the major causes and estimate the magnitude of loss to inform policy strategies. This study assessed the primary causes of avocado postharvest losses across the avocado value chain. A two-stage stratified sampling technique was employed to select sample respondents. Accordingly, a total of 212 producers were randomly selected from avocado-producing districts in the Sidama region and Gedeo zone. The results indicate that, on average, postharvest loss accounts for 19.02 percent of the total avocado harvest, despite avocados contributing 24.09 percent of the producers' total annual income. Across the value chain, collectors and retailers experienced losses exceeding 50 percent, whereas processors had losses below five percent. A multiple linear regression model was used to identify the determinants of postharvest avocado losses. The results show that harvesting with traditional sticks, unfavorable weather conditions, the use of soft storage materials, the presence of disease, and low frequency of extension contacts were significant factors contributing to postharvest losses. Therefore, the dissemination of improved harvesting and storage materials, combined with expanded extension support, is essential to minimizing postharvest losses in the area.

Keywords: Avocado, Gedeo, Multiple linear regression, Post-harvest Losses, Sidama

[1]*Department of Agricultural Economics, Sidama Agricultural Research Institute, Hawassa, Ethiopia*
[2]*Department of Food Science, Sidama Agricultural Research Institute, Hawassa, Ethiopia*
[3]*Department of Horticulture, Sidama Agricultural Research Institute, Hawassa, Ethiopia*

*Corresponding author's email: hanatafese2018@gmail.com (Hana Tafesse)

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Introduction

Ethiopia has a comparative advantage in horticultural crop production due to its favorable climate, high domestic demand, and relatively low labor costs. Among these crops, fruits and vegetables are abundant sources of dietary fiber, vitamins, and minerals, and they also contribute significantly to economic growth and promote food and nutrition security (Banjaw, 2017). Across Ethiopia, a total of 116,284.63 hectares are dedicated to fruit cultivation. In this area, bananas account for approximately 59.95 percent of the cultivated area, followed by avocados at 17.98 percent (CSA, 2020). Most of these crops are produced by smallholder farmers and supplied to nearby markets. Although a wide variety of horticultural crops are cultivated, not all outputs reach consumers due to environmental, technical, and economic challenges that hinder harvesting, handling, and the effective distribution of produce from growers to consumers (Gebru and Belew, 2015).

In addition, most fruits are highly susceptible to persistent postharvest losses, which exacerbate declines in output, limit food availability, and adversely affect the economy at both the household and national levels (Banjaw, 2017). Compared with other crops, the magnitude of fruit loss is particularly high due to their perishable nature, inadequate sorting to remove defects before storage, use of insufficient packaging materials, rough handling, poor cooling and temperature management, and contamination by pathogens (Kitinoja and Kader, 2002; Atanda *et al.*, 2011). As a result, an estimated 15-70% of horticultural crops incur postharvest losses (Misrak *et al.*, 2014). Practices that significantly contribute to these losses include improper harvesting and handling, inadequate storage facilities, insufficient transportation, poor packaging, and weak marketing systems (Banjaw, 2017).

However, postharvest management of most horticultural crops in Ethiopia has received inadequate attention, making it difficult to accurately account for losses during harvest and postharvest (Adugna *et al.*, 2011). Although the horticultural sector is growing, support for reducing postharvest loss and improving crop quality remains insufficient (Mohammed and Afework, 2016). To address this, since 2010, the Government of Ethiopia has been expanding mega and medium agro-industries to promote value addition through processing of agricultural outputs, aiming to boost foreign earnings and enhance economic growth under the Growth and Transformation Plan (GTP) (MoA, 2015). In southern Ethiopia, Sidama and Gedeo together account for approximately 29.6 percent of total avocado production (CSA, 2020). Among agro-industries, one mega and one medium industry were established in Sidama and Gedeo, respectively, and are currently processing avocado oil. The primary source of inputs for these industries is smallholder farmers' production. However, these industries face shortages in raw avocado supply in both quality and quantity due to production constraints, postharvest losses, and other socioeconomic and institutional factors.

Among the few studies on the determinants of avocado cultivation in Ethiopia, Benta *et al.* (2024) investigated the constraints of avocado production and marketing in southern Ethiopia using descriptive analysis. To the best of our knowledge, no studies have conducted a parametric analysis of the factors affecting avocado postharvest losses across its value chain in the area. Consequently, this study estimates avocado losses across the value chain and identifies their determinants using a robust multiple linear regression model. In doing so, the study contributes to identifying key intervention areas across the value chain to enhance sustainable productivity, value addition, and marketing of avocados.

Research Methodology

Method of data collection and sampling techniques

The study used primary data collected from avocado producers, traders, and processors during 2022. Before collecting household-level data, key informant interviews and focus group discussions were conducted to identify constraints in avocado production, including postharvest losses, and to understand the role of local institutions in its management. A two-stage sampling technique was then employed to select the sample respondents. In the first stage, districts with high avocado production potential were selected. In the second stage, two kebeles from each district were chosen based on their relative production potential. A total of 212 respondents were selected from both study areas, with 107 from the Sidama region and 105 from the Gedeo zone, using random sampling. The distribution of samples across the respective districts is presented in Table 1.

Table 1. Sample sizes from selected districts

Region/Zone	Sample districts	Sample size	Frequency
Sidama Region	Aleta wondo	35	16.51
	Wondo Genet	35	16.51
	Dale	37	17.45
Gedeo Zone	Yirgachefe	32	15.09
	Dilla zuria	39	18.40
	Wonago	34	16.04

Method of data analysis

The collected data were analyzed using both non-parametric (descriptive) and parametric (econometric) methods. Descriptive statistics included the mean, percentage, frequency distribution, and standard deviation. A multiple linear regression model was employed to estimate population parameters and identify the causes of postharvest avocado loss.

The MLR model was employed to identify the causes of avocado postharvest loss (PHL) because the dependent variable, the amount of postharvest loss, is continuous and measured in kilograms. Twelve explanatory variables were considered as potential factors influencing PHL. The nature of these variables varies. Sex, storing materials, weather conditions, and disease are dummy variables, while harvest, education, age, family size, extension contact, distance to the nearest market, tropical livestock unit (TLU), and annual income of the respondents are continuous or discrete variables, depending on their characteristics. To overcome the estimation failure of ordinary least squares, robust estimation was employed.

$$Y_i = f(x_i, \beta) + \epsilon_i \text{ ---------- (1)}$$

Where,

Y_i is the amount of avocado PHL in kilograms, and xi is a vector of independent variables. These are harvest, sex, storage materials, weather conditions, disease, education, age, family size, extension contact, distance to the nearest market, tropical livestock unit (TLU), and annual income of the respondents; ϵ_i is the error term.

Results and Discussion

Socioeconomic characteristics of sample households

The average postharvest loss (PHL) of avocados is 309.79 kilograms per year, with a range of 1 to 2,600 kilograms per year. The mean harvested amount of avocado fruit is 1,939.58 kilograms, with a range of 32 to 63,300 kilograms. This indicates that the area has high potential for avocado production, with postharvest loss representing a significant production constraint. Among the total sample, 83 percent of respondents were male, and 17 percent were female. The mean educational level of respondents is approximately seven grades. The average age and family size of respondents are 42.41 years and seven persons, respectively. Regarding storage practices, 34 percent of respondents used wooden hard-covered materials, while the remainder used jute sacks or baskets, indicating that only a minority of producers employ materials that protect avocados from damage.

Regarding production challenges, 87 percent of respondents reported that last year's weather conditions were unfavorable for avocado production, contributing to postharvest losses. Similarly, 45 percent of respondents reported that the disease affected avocado crops, resulting in additional postharvest losses. The average extension contact is 2.52 days per year, the average distance to the market is 3 kilometers, and the mean tropical livestock unit (TLU) is 1.44. The average annual income of respondents, derived from sources such as annual and perennial crop sales, livestock and livestock product sales, and other on-farm and off-farm activities, is 24,310 Birr.

Table 2. Socioeconomic and institutional variables of sample respondents.

Variables	Mean	St.Dev	Min	Max
PHL in kilograms	309.79	480.15	1	2600
Harvested amount in kilograms	1939.58	4850.07	32	63300
Sex	0.83	0.37	0	1
Education in grades completed	6.53	3.60	0	15
Age	42.41	14.54	14	85
Family size	6.58	2.53	0	12
Storing materials	0.34	0.48	0	1
Weather condition	0.87	0.34	0	1
Disease	0.45	0.49	0	1
Extension contacts	2.52	2.73	0	20
Market distance	3.003	3.12	0.1	15
TLU	1.44	1.48	0	6.88
Income in 1000's Birr	24.31	40.93	0	355.6

Economic role of avocado fruit and its post-harvest losses

According to the data, the average avocado production in the study area is estimated at 1,939 kilograms per year. By region, production in the Gedeo zone is higher than in the Sidama region, with averages of 2,042 and 1,839 kilograms, respectively. This difference may be attributed to the agricultural system in the Gedeo zone, which is predominantly agroforestry, with avocado as a major intercropped fruit. The harvested amount is further classified into sale, consumption, and postharvest loss. On average, postharvest loss accounts for approximately 19.03 percent of total avocado production. Despite this loss, avocados contribute significantly to farmers' annual income. The average annual income of avocado-producing farmers in the area is about 29.13 thousand Birr, with avocados contributing, on average, 24.09 percent of this income. This indicates that roughly one-fourth of farmers' income depends on avocados, highlighting the fruit's importance as both a source of income and a food. Across the study areas, the income share from avocados ranges from 22.66 to 25.51 percent.

Table 3. Avocado production, PHL, and income share of avocado production.

Roles	Sidama Region		Gedeo Zone		Total	
	Mean	St.Err	Mean	St.Err	Mean	St.Err
Avocado produced in kilograms	1839	295	2042	603	1939	333
Avocado PHL share in percent	19.03	1.52	19.01	1.17	19.02	0.96
Annual income in 1000 Birr	32.44	42.18	25.76	44.31	29.13	30.59
Avocado income shares in percent	25.51	2.31	22.66	2.52	24.09	1.71

All of the factors described above have either a positive or negative relationship with the amount of postharvest loss (PHL). Therefore, conducting a multiple linear regression model is necessary to quantify the relationship and determine the magnitude of their effects on avocado postharvest loss.

Table 4. Avocado amount collected and loss across its value chains.

Roles	Retailers		Collector		Processors	
	Mean	St.Err	Mean	St.Err	Mean	St.Err
Avocado collected in kg	5328.94	1837.79	9100	7100	2790	1710
Avocado loss shares in percent	55.39	11.89	60.5	20.5	4.8	3.8

Retailers: These are village-level buyers who purchase avocados primarily from producers. Due to the use of inappropriate harvesting materials at the farm level, the farm experiences significant avocado losses. The average loss at the retail stage is 55.39 percent, indicating that over half of the total amount purchased was lost.

Collectors: These are local assemblers who collect avocados from producers and retailers, then sell them to traders in other areas, such as Addis Ababa, Adama, and Jijiga, as shown in Figure 1. The average loss at the collector stage is 60.5 percent of the total collection.

Processors: These are small-scale processors who mainly produce juice. The average loss at this stage is about 4.8 percent, which is lower than the losses experienced by collectors and retailers. This relatively small loss occurs because processors purchase already ripe, high-quality fruit and process it daily. There is also a considerable amount of loss after collectors gather avocados from the locality. Before transporting them to the central market in Addis Ababa, collectors sort out damaged avocados, and these discarded fruits represent a loss for the collectors.

Fig. 1. Collector sorting damaged avocado at Aleta Wondo, Sidama.

Multiple linear regression model results

Twelve variables were used to identify the causes of postharvest avocado losses. Among them, five variables were found to significantly affect postharvest avocado losses. These are the amounts of avocados harvested, handling and storage materials, weather conditions, diseases, and the frequency of extension contacts. Among these variables, storage or handling materials and the frequency of extension contact have negative and significant effects, while the remaining variables have positive and significant effects. These results are consistent with prior expectations. Regarding model fitness, the R^2 is 78.39 percent, indicating that 78.39 percent of the variation in postharvest loss is explained by the explanatory variables included in the model.

Table 5. Multiple linear regression model result.

Variables	Coefficients	Standard Error
Harvest	17.41***	3.22
Sex of the respondent	-10.01	31.38
Educational status of the respondent	-0.52	2.85
Age of the respondent	0.059	0.63
Family size of the respondent	3.55	3.75
Storing materials for avocado	-56.68***	16.39
Weather conditions	48.63**	23.07
Disease of the avocado	73.59***	28.15
Extension contact frequency	-6.19*	3.26
Market distance	5.58	4.99
Tropical livestock unit	2.56	7.18
Income of respondent per year	-0.0004	0.0003
Constant	-26.63	42.98
R^2	*78.39*	
Observations	*212*	

Harvest: Farmers in the study area use locally available materials to harvest avocados. These materials often result in mechanical damage to the fruit. During harvesting, most farmers use sticks that damage both immature and mature avocados. Damaged avocados tend to decay quickly or are lost within a short period after harvest. This implies that postharvest avocado loss is expected to increase with the amount harvested; that is, the higher the harvest, the greater the loss. Among the total sample, none of the farmers used improved harvesting sticks or technologies to reduce postharvest loss. Therefore, the amount of avocado harvested using locally available materials was used to evaluate the relationship between production levels and postharvest loss. The results indicate that postharvest avocado losses are strongly associated with harvested volume. According to the results presented in the table, avocado harvest is positively associated with postharvest loss. Specifically, for each additional 100 kilograms harvested, postharvest loss increases by an average of

17.41 kilograms. This finding, which highlights the contribution of improper harvesting materials to postharvest fruit losses during harvesting, is consistent with prior studies (Obse *et al.*, 2021; Yebirzaf and Esubalew, 2021; Solomon, 2019; Seble, 2016; Humbe and Reneby, 2014; Victor, 2014).

Storing materials: In the study area, farmers use two types of storage materials after harvest. These are locally prepared wooden containers (such as kircho[1]) and jute sacks or baskets. The study evaluated which materials significantly reduce postharvest losses in avocado fruit. This evaluation was based on the premise that, compared with jute sacks or baskets used to store avocados after harvest, wooden containers have a hard shell that protects the fruit from mechanical damage during transportation and storage. Based on the results presented in the table, compared with jute sack users, farmers who use wooden materials experience, on average, 56.68 kilograms less postharvest avocado loss, holding other variables constant. This finding, which shows that hard-covered wooden and plastic materials help prevent postharvest loss of avocado, is consistent with prior studies (Obse *et al.*, 2021; Yebirzaf and Esubalew, 2021; Solomon, 2019; Seble, 2016; Victor, 2014; Humbe and Reneby, 2014).

Weather conditions: Weather can have both favorable and unfavorable effects on crop production, including fruit production. Unfavorable weather conditions that contribute to postharvest loss of avocado fruits include extreme temperature, relative humidity, air velocity, and atmospheric composition. Deviations in these conditions from normal levels can increase postharvest losses. According to the results, compared with respondents who reported favorable weather conditions for avocado production, those who reported unfavorable weather conditions experienced an average reduction of 48.63 kilograms of avocado due to postharvest loss. This finding is consistent with the studies conducted by Obse *et al.* (2021) and Victor (2014).

Disease: Disease is a major cause of postharvest avocado losses, leading to fruit decay and the discarding of damaged produce. Disease is a location-specific problem, and it was included to evaluate the magnitude of its effect on postharvest loss. Based on the results, sample respondents who reported that disease is a problem for avocado production experienced, on average, 73.53 kilograms more in postharvest loss than those who reported that it is not a problem. This finding is consistent with the results reported by Solomon (2019) and Victor (2014).

Extension contacts: The provision of extension support improves agricultural production by providing information on managing avocados during both preharvest and postharvest stages and by helping identify potential markets with higher demand for avocados. Thus, it is hypothesized to reduce postharvest losses. It is measured by the number of contacts with extension personnel per year regarding avocado production and marketing. According to the results, for each additional day of extension contacts, the postharvest loss of avocado decreases by an average of 6.19 kilograms, holding other factors constant.

Conclusion and Recommendation

The results of the study reveal that postharvest loss is a major production constraint for avocado in the area. It accounts for about 19.02 percent of total harvest loss, despite avocado contributing 24.09 percent of the annual income of producer farmers. A robust multiple linear regression model was employed to identify the causes of postharvest loss. Accordingly, harvesting practices, storage materials, weather conditions, disease, and extension contact were identified as significant contributors to postharvest loss. Among these factors, disease and unfavorable weather conditions contribute to increased postharvest losses. In addition, due to the use of traditional harvesting materials, every one-hundred-kilogram increase in harvest results, on average, in a loss of 17.41 kilograms. On the other hand, increased extension contact and the use of hard-covered storage materials reduce postharvest loss.

Consequently, a greater emphasis on improving avocado production is highly needed. Due to the lack of improved harvesting tools or methods, increased harvest has led to higher losses. Therefore, the dissemination of improved harvesting materials, such as tools that collect fruits in small bags, is necessary. In addition,

[1]Kircho is a locally prepared wooden storage material made from bamboo.

introducing improved varieties with shorter tree heights and fruits that can be easily collected manually would have an advantage over the tall local varieties. Although the use of soft storage materials increases postharvest loss, the popularization of wooden storage materials and the introduction of plastic materials for improved storage and packing are important. Furthermore, to reduce disease-related losses, strengthening research and development of disease control mechanisms is essential to minimize avocado losses in the area. Finally, expanding the reach of extension services to ensure effective dissemination of information on avocado production and marketing is crucial.

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