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FDRE TECHNICAL & VOCATIONAL TRAINING INSTITUTE

FACULTY OF AGRICULTURE AND AGRO PROCESSING TECHNOLOGY

DEPARTMENT OF FRUIT AND VEGETABLE PROCESSING TECHNOLOGY

ASSESSMENT OF HARVEST AND POST HARVEST MANAGEMENT PRACTICES AND THEIR IMPACT IN BLACK PEPPER (*Piper nigrum L.*) QUALITY IN SHEKO WOREDA, SOUTH WESTERN ETHIOPIA

MSc. THESIS

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JUNE 2026

ADISS ABABA, ETHIOPIA

FACULTY OF AGRICULTURE AND AGRO PROCESSING TECHNOLOGY DEPARTMENT OF FRUIT AND VEGETABLE PROCESSING TECHNOLOGY

ASSESSMENT OF HARVEST AND POSTHARVEST MANAGEMENT PRACTICES AND THEIR ROLES IN BLACK PEPPER (*Piper nigrum* L.) QUALITYIN SHEKO WOREDA, SOUTH WEST ETHIOPIA

A THESIS SUBMITTED TO THE DEPARTMENT OF FRUIT AND VEGETABLE PROCESSING TECHNOLOGY, FACULTY OF AGRO PROCESSING TECHNOLOGY, FDRE TECHNICAL AND VOCATIONAL TRAINING INSTITUTE IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN COFFEE, TEA AND SPICE PRODUCTION TECHNOLOGY

BY:

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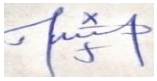
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DECLARATION

I, Aragaw Simegn Yihunie, hereby declare that this thesis entitled “assessment of harvest and post-harvest management practices and their impact in black pepper (*piper nigrum L.*) quality in sheko woreda, has been Carried out by me under the guidance and supervision of dr. Girma. The thesis is my original work and has not been presented for a degree in Any other university, and all sources of material used for this thesis is duly acknowledged.

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THESIS APPROVAL SHEET

As thesis research advisors we hereby certify that we have read and evaluated the thesis prepared under our direction by Aragaw simegn, entitled ‘assessment of harvest and post-harvest management practices and their impact in black pepper (*piper nigrum L.*) quality in sheko woreda ' and recommend that it be accepted as fulfilling the thesis requirement. I recommend the thesis to be submitted for oral defense. Approved by:

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As members of the examining board of the final M.Sc. open defense, we certify that we have read and evaluated the thesis prepared by Aragaw simegn entitled ‘assessment of harvest and post-harvest management practices and their impact in black pepper (*piper nigrum L.*) quality in sheko woreda and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in coffee, tea and spice production technology

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy to the Council of Graduate Studies (CGS) through the candidate’s School Graduate Committee.

DEDICATION

I dedicate this thesis to my family for nursing me with affections and love and their dedicated partnership for success in my life

STATEMENT OF THE AUTHOR

I, the undersigned, declare that this thesis is my work and is not submitted to any institution elsewhere for the award of any academic degree, diploma or certificate and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Technical University, faculty of agriculture and agro processing technology and is deposited at the University Library to be made available to borrowers under the rules of the library. Brief quotations from this thesis are allowable without special permission provided that an accurate acknowledgment of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the Dean or Coordinator of the School of Graduate Studies or Head of the Department of fruit and vegetable production technology when the proposed use of material is in the interest of scholarship. In all other cases, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

The author was born in 1996 from his father Simegn Yihunie and Mother Yalganesh Animut in west Gojam zone and brought up there. He attended elementary school at Aklat elementary school which is now junior High school. He completed 7th & 8th grade at Aklat Junior High School. He attended Feres bet secondary high school and completed grade 9-12 there. He took Ethiopian school leaving certificate examination and joined Debre birhan university and graduated with bachelor degree in the field of plant Science in regular program in 2016. After his graduation, he was employed Mizan ATVET College as instructor (2018-2024). The author joined the School of Graduate Studies of Technical University in February 2016 to pursue his MSc degree in Coffee, tea and spice production technology in regular program.

ACKNOWLEDGEMENTS

First and foremost, I give honor to the Almighty St. Mary and God for every protection they did to me in performing my day-to-day activities. Next, I would like to express my thanks and deepest gratitude to my advisor, Dr. Girma Hailemecheal, for his heartfelt and constructive advice and suggestions throughout the proposal and preparation of the thesis. He has worked hard to keep me on the right track and to ensure my timely completion of the study.

Furthermore, I would like to thank Technical University, faculty of agro processing for giving me the opportunity to study my MSc thesis and also the financial support to complete the study. I would likely thank Minister of skill and labor for sponsoring me to get chance MSc program.

I would like to extend my sincere thanks also to Dr. Mulualem Azen department head of fruit and vegetable processing technology and Mr. Habtamu the staff of faculty of agro processing, for their material and moral support that helped me in conducting the thesis research.

I am also very grateful to the staff members of Sheko Woreda agricultural office and kebele agricultural offices and farmers for allowing me to access information for data collection. Finally, I am glad to thank my friends and family whom they supported me in collecting data.

LIST OF ABBREVIATION AND ACRYONOMS

BCESC	Bebeka Coffee State Share Company
BPQHPHMP	Black Pepper Quality Harvest and Post-harvest management practice
CSA	Central Statistical Agency
DA	Developmental Agents
EIAR	Ethiopia Institute of Agriculture Research
FAO	Food and Agriculture Organization
FGD	Focus Group Discussions
PHM	Post-Harvest Management
MOA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
NGO	Non-Governmental Organization
SPSS	Statistical Package for the Social Sciences
SNNPR	South Nation Nationalities and Peoples Region
TNSRC	Tepi National Spices Research Center
USD	United States Dollars

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ABSTRACT

Black pepper is a vital cash crop in Southwestern Ethiopia, playing a significant role in the region's economy and the livelihoods of household farmers. Despite a long history of black pepper production in southwestern Ethiopia, its production declined due to improper harvesting and post-harvest handling practices. Assessing harvesting and post-harvesting technologies is a significant issue. The purpose of this study was aimed to assess harvesting and post-harvest management factors and their impact in determining the quality of black pepper produced by smallholder farmers in sheko woreda, South west Ethiopia. . A total of 168 black pepper farmers and traders were interviewed using a semi-structured questionnaire to assess harvesting and post harvesting practices. The gathered data were analyzed using the Statistical Package for Social Sciences (SPSS) Version 22. The results revealed that 62.3% of farmers used hand picking to harvest black pepper and 70.1% of farmers harvested pepper when at least one berry on a spike turned red. Regarding post-harvest handling, 100% of farmers reported drying their black peppers under the sun on mats, the most common practice for removing moisture. For packaging, nearly all respondents 88.1% packed their dried pepper in jute bags, which is standard practice in the region. For storage 85.7% more than half of the respondents lacked adequate storage. To improve the quality, efficiency, and sustainability of black pepper production, the introduction of appropriate harvest and post-harvest technologies can significantly benefit black pepper producer in bench sheko zone at sheko woreda.

Keywords: piper nigrum, harvesting, postharvest management, Sheko woreda.

1. INTRODUCTION

1.1. Back ground of the Study

Ethiopia's diverse climate and soil types provide ideal conditions for the growth of various indigenous and exotic spices, herbs, medicinal plants, and essential oil-bearing plants. Among these, black pepper (*Piper nigrum L.)* a perennial woody climber from the Piperaceae family, stands out as one of the most important spices (Kumar *et al*.,2021). Locally recognized as 'kundo berbere', it was introduced from India and serves both household consumption and commercial, high-value export market. Black Pepper (*Piper nigrum L*.) is among the earliest known, cultivated and used spices in the world. It was famously known as the black gold or king of spices because it is the most important, most popular and most widely used spice in the world (Nair, 2020; Spence, 2024). The spice is primarily traded in two forms: black pepper, made by drying ripe or unripe berries dried under the sun, and white pepper, produced by soaking, treating, and removing the outer skin of the berries before drying (Singh *et al*., 2021).

The crop originated in the Western Ghats of the Indian Peninsula and is now cultivated in the tropical regions of the world (Hao *et al*., 2012). The major producers of black pepper are India, Vietnam, Malaysia, Indonesia, China, and Brazil, followed by Sri Lanka and West Indies but on a smaller scale. Black pepper, commonly known as "King of spices", is one of the exotic spices crops that originated from India and distributed to other countries (Girma *et al*., 2008) which was introduced to Ethiopia in 1979. Currently some large-scale commercial farms in Sheka and Bench sheko zones have started producing black pepper for both domestic and export markets. For instance, in 2012, Bebeka Coffee Estate Share Company around 45,000 kg of dry black pepper was exported from (BCESC, 2012). The demand for black pepper and its product is increasing year by year in the world market, but production is limited to few countries. Recently, black pepper has performed well in the south west of Ethiopia, particularly, at Tepi, Gemadro and Bebeka large scale farms (Girma *et al.*, 2008).

Despite the favorable climatic conditions, variety of black pepper types for quality improvement and long history of its production in bench sheko Zone especially in Tepi and Bebeka, black pepper quality is declining from time to time due to several improper pre-and post-harvest management practices. This is still practiced by the majority of black pepper farmers/traders, from which the larger portion of the produce is obtained. These quality problems are mainly associated with poor agronomic practices like uncontrolled shade level, lack of weeding; poor harvesting practices, such as stripping and improper post-harvest processing and handling practices such as drying on bare ground, improper storage and transportation (Desse, 2008). In addition to this, natural impediment such as prolonged rainy weather, particularly during harvesting and drying season can also contribute to reduced black pepper quality (Desse, 2008)

Sheko District, situated within the Bench Sheko Zone of southwestern Ethiopia, has significant potential for black pepper production due to its humid tropical climate and increasing farmer participation in spice cultivation. Unfortunately, the effect of the harvesting and postharvest handling practices used by farmers in Sheko district on quality and storability of black pepper are less understood. Improper drying may lead to development of non-uniform color, loss of pungency and aroma, and encourage growth of mold on stored black pepper. Microbial fermentation and or mold development on black pepper can be reduced through adoption of proper harvest and drying practices (Mkojera, 2019). It is hypothesized that smallholder farmers in sheko district use poor harvest and post-harvest handling practices, resulting in poor black pepper quality (Hordofa & Tolossa, 2020).

This study aimed at generating key information on black pepper harvest and post-harvest handling practices applied by smallholder farmers at Bajeka, Shimi and Gizmeret kebeles in Sheko district. The findings from the study helps in devising proper and economically viable harvest and postharvest handling techniques for maintaining black pepper quality. Ultimately, improving these practices will contribute to reducing quality losses, enhancing market competitiveness, and increasing the income of smallholder black pepper producers in southwestern Ethiopia.

1.1. Statement of Problem

Black pepper (*Piper nigrum L.*) has an immense potential in developing Ethiopian economy, creation of employment opportunities, distribution of income, foreign exchange earnings and also important source of income for smallholder farmers in Bench Sheko Zone, where favorable agro-ecological conditions support its cultivation (Tadesse &Tesfaye, 2020). Ethiopia has considerable potential for spice production due to its diverse agro-ecology, available cultivable land, relatively low labor costs, proximity to the potential export market and favorable policy environment.; however, production volume and product quality remain below international standards, limiting the country's competitiveness in the global spice market (Gebreselassie & Tadesse, 2021).

One of the major challenges affecting black pepper quality is injudicious harvest and inappropriate postharvest handling practices such as harvesting pre-mature berries especially when pepper demand is high, delayed harvesting, inadequate drying, poor handling, and inappropriate storage conditions often lead to damage of the physical appearance, contamination, mold development, loss of aroma, and reduced market value. Due to traditionally and unimproved cultivation, inappropriate harvesting and ineffective postharvest handling practices of the country could not boost production and quality and hence could not be competitor with major spices producer and exporter (Hordofa & Tolossa,2020). Studies have shown that inappropriate harvesting and poor postharvest management significantly contribute to quality losses in black pepper production.

However, the specific effects of existing harvesting and postharvest handling practices on black pepper quality in the study area are still limited and not well documented. Most previous studies in Ethiopia have focused primarily on production aspects of spices, with relatively little attention given to harvest and postharvest management factors and its impact on quality (Hordofa & Tolossa, 2020). As a result, there is a need for systematic assessment of the harvesting and postharvest handling practices adopted by smallholder farmers and their contribution to quality losses in order to identify appropriate practices that can minimize such losses.

1.3. Objective of the study

1.3.1. General objective of the study

- ✓ Assess harvest and post-harvest practices and evaluate their impact in determining the quality of black pepper (*Piper nigrum L.*) in the major black pepper growing areas of Sheko Woreda, Southwestern Ethiopia.

1.3.2. Specific objectives of the study

- ✓ To identify the current harvest and postharvest management practices used by black pepper producers in Sheko woreda.
- ✓ To identify the major harvesting and post-harvest factors affecting the physical quality of black pepper in Sheko Woreda.

1.4. Research questions

- ✓ What was the harvesting and postharvest handling practices used by smallholder black pepper farmers in Sheko woreda?
- ✓ How does the harvesting and post-harvest management factors affect black pepper quality?

1.5. Significance of the Study

The study enables to provide information on constraint black pepper production, marketing channel and opportunities for improving harvesting and post-harvest management practices in the study area. This study result would be used for farmer, trader and governments, who want to introduce intervention in black pepper harvesting and post harvesting management practices and marketing. In addition to this, the study generated important information for research and development organizations, extension service providers, to formulate black pepper harvesting and post management practices improvement programs and guidelines for interventions that

would improve efficiency black pepper quality and marketing system. This study could be used as source of material for further studies.

1.6. Scope of the Study

The area coverage of this study was in Sheko woreda, Bench sheko zone focusing on black pepper crop which account major proportion of the production and passed through a number of marketing stages. The study emphasized on different harvesting and post harvesting management practices and their roles on black pepper quality and marketing information. The collected data entered in to a software called SPSS 22 to find the frequency of distribution, percentage and chi square result.

1.7. Limitation of the Study

Being the first study in the woreda lack details, investigations which could have reinforced in understanding of the whole system particularly in relation to harvesting and post-harvest management studies. The time limit and budget constraint exclude consideration of other neighboring woreda as well could give more weight to the limitation. The other limitation was geographical location of the kebele that most of them were far from the main road and researcher was take a long time to found the respondent and some of farmer were busy in their farm. Moreover, few producers and trader were unwilling to provide information without a benefit or payment and have no willingness to participate in this study.

1.8. Organization of the thesis.

The thesis had five chapters. The first chapter of the thesis were discussed back ground of the study, Statement of the Problem, Objective, Significance, Scope and limitation and Organization of the thesis. The Second chapter were discussed about review of related literature. The third chapter deals methodology of the study. The fourth chapter deals result and discussion and the last chapter deals about conclusion and recommendation.

2. LITERATURE REVIEW

2.1. Overview of Black Pepper (*Piper nigrum* L.)

2.1.1. Origin and History of Black Pepper

Black Pepper (*Piper nigrum L.*) "Kundo Berbere" is one of the oldest and the world's most important spices. Black pepper (*Piper nigrum L.*) is a tropical plant widely recognized for its fruit, which is commonly used as a spice across the globe. Black pepper is known as the 'king of spices' by virtue of its massive trade share in the global market (Wikipedia, 2024). Black pepper, with the scientific name Piper nigrum L. is an annual vine that belongs to the family Piperaceae and is cultivated for its peppercorns. Its dried fruits, known as "King" of spices are widely used globally as a well-known spice with a long history due to their pungent aroma, serving as a natural food enhancer to elevate the flavor of dishes. The genus Piper comprises around 1200 species, approximately 60% of which occur in Central and Northern South America. The Malabar Coast of South West India is the traditional home of black pepper, grown from almost sea level to approximately 1500 m. Black pepper was the first oriental spice to be introduced into the western world (Sarma *et al*., 2014). The crop was introduced to Ethiopia very recently; however, its use as a spice had been very well known for so long before its introduction. It is common to use pepper as a condiment in most of Ethiopian dishes (CSA, 2020).

2.1.2. Botanical Description and Characteristics

The black pepper plant is a woody climbing vine that can stretch 10 meters or more in height or length. Once established, it develops numerous lateral branches from the central stem, eventually forming a thick, bushy column. The plants form adventitious roots, which are tiny roots that attach themselves to surrounding supports (Hussain et al*.,* 2017).

The stem of black pepper stems may grow up to 10 m long and It is like a long and cylindrical vine. Young stems are green, while old stems are woody with a diameter of 4-6 cm in diameter. Primary stems, runner shoots, and fruit producing stems are the three types of stems found on

pepper plants. 20–30 fruiting spikes can be supported by a single stem (Thapa A. *et al*.,2017). Peppercorns, which are botanical drupes often measuring around 5-6 mm, are arguably the most traded spice in the world, growing on a climbing vine (*Piper nigrum*). When immature, these tiny fruits are green, but as they ripen on the vine, they develop a distinct, bright red color. Orthotropic branches have short, thick internodes with several adventitious roots at the nodes helping the plant to climb over the supports. Plagiotropic branches have no aerial roots but produce a spike from the terminal bud as they grow (Parthasarathy *et al*., 2007).

2.2. Black pepper varieties in Ethiopia

In Ethiopia, black pepper has been used as a condiment in traditional dishes even before its formal introduction into the country's agro-ecology (CSA, 2020). The Jimma and Tepi spice research teams evaluated the adaptability of over 13 introduced black pepper cultivars in various locations in southwestern Ethiopia, including Jimma, Tepi, Bebeka, Wonago, and Metu. Among these, two cultivars—4/80 (Gacheb) and 3/80 (Tato) were registered by Jimma Agricultural Research Centre (JARC) of EIAR and it performed exceptionally well in Tepi and Bebeka, demonstrating superior growth, yield, spike length, and quality (MoA, 2018).

Table 1: Registered black pepper varieties in Ethiopia

No	Released year	Released organization	Productivity in dry k/ha	0il content % (percent yield)		
				Oleoresin (%w/w)	Essential oil(%v/w)	Piperine Content
1.Tato	2007	TNSRC	30.49	10.0	2.29	6.00
2.Gacheb	2007	TNSRC	21.67	9.1	3.20	5.65

Source: MoARD (2007) Variety record book

2.3. Black pepper Production in Ethiopia

Ethiopia’s varied agro-ecology supports pepper cultivation in hot, humid lowlands, particularly in the western and southwestern areas, which offer ideal climate and soil conditions (Teka Tefera *et al*.,2025). Large areas of SWEPP, west Oromia, Benishangul Gumuz, and South Ethiopia are highly suitable for black pepper production. The area of highly and moderately suitable land for black pepper in the country covers 16.24 million ha, representing 14.32% of the

total area of the country. Oromia, BSG, SWEPP, Gambela, Southern Ethiopia, and Amhara regions possess the largest combined area of highly and moderately suitable land, with 6.06 (18.76%), 3.68 (73.04%), 2.01 (51.25%), 1.78 (%), 1.58 (28.05%) and 1.00 (6.45%) million ha, respectively. The Oromia region has extensive areas of highly suitable lands with about 1.37 (4.24%) million ha. That is followed by SWEPP, BSG, SNNP, Gambela, and Amhara regions with 1.15 (29.5%), 0.81 (16.05%), 0.63 (9.95%), 0.32 (10.19%), 0.09 (0.056%) million ha, respectively (ATA 2022).

Based the combined area of highly and moderately suitable classes, Oromia ranks first with 6.06 million ha. That is followed by BSG, SWEPP, SNNP, Gambela, and Amhara with 3.68, 2.01, 1.78, 1.58, and 1.00 million ha, respectively. However, to assess the extent of suitability accurately, the total area of each region needs to be known. For example, BSG and Gambela region take first and second place with 73.04% and 50.32% proportions for combined highly and moderately suitable areas of black pepper relative to their respective total area. However, relative to the country's total area, their contribution is only 3.25 and 1.39% highly and moderately suitable areas (MOA 2021).

2.4. Ecological requirement

According to Shango (2021), pepper reaches fully maturity about 180 to 230 days (6 – 8 months) after flowering, depending on the variety planted and the environmental circumstances at that time. The ecological requirement of these spices: black pepper, cardamom, ginger, turmeric and vanilla had been conducted. And almost all of these spices were thus found well adapted to the hot-humid and lowland agro ecologies of Southwestern Ethiopia (Girma *et al*., 2008). On the average, these high value spices plants were observed to perform best in areas with altitudes ranging between 500 and 1500 m, annual rainfall of 1200 to 7000 mm, and mean temperatures of 20 to 35°C (Purseglove *et al*., 1981).

Fertile or alluvial soils rich in humus were also identified to be highly suitable for the production of the lowland spices (Purseglove *et al*., 1981). Likewise, cardamom requires humus-rich forest covered soils that could sustain prolific and luxurious growth of crop plants. Forest coffee chocolate, red colored soil rich in humus has been proved to be very suitable for the successful production of these spices (Girma *et al*., 2008). Under small-scale production,

cardamom, black pepper, ginger, and turmeric were found to be intercropped successfully with other horticultural crops like inset, banana, and coffee (Girma *et al*., 2008). These technologies well adapted to most parts of Southwestern Ethiopia, where the farming system is commonly characterized by the growth of one or more of these complementary species.

2.5. Importance of black pepper

Black pepper is one of the most versatile spices used in virtually in all kinds of savory cooking. In order to keep their fragrance and flavor intact, they are generally ground just before preparing dishes and added at the last minutes in the recipes (since prolonged cooking results in evaporation of essential oils). Ground pepper can be added to almost any cooked dish, as well as certain fresh recipes. It has a pungent, sharp taste that freshens most recipes. Additionally, though, black pepper can improve digestion and reduce gas. Ground pepper only stays fresh for about three months, but peppercorns will last indefinitely. To make the most of your harvest, store peppercorns in an airtight container in a cool, dark location. Grind them immediately before use for best flavor. Add pepper to soups, meat dishes, or salad dressings. In India and Pakistan, black peppercorn powder is mixed with salt, and the mixture is a common item found on the serving table in restaurants. The mixture is used as sprinkle over vegetable/fruit salads, chats, lemonades, in soups, etc. Lassi (churned yogurt) is often flavored with this spice-salt mixture in the Punjab province (Hai and Long 2015).

2.6. Challenges in the spices production and marketing in Ethiopia

Though spices have various utilizations, the emphasis given by research and extension activities are very unsatisfactory. Hence, there is lack of awareness on spice production, processing, storage and marketing among producers. Farmers used their traditional farming practices and usually harvest very low yield. Similarly, the marketing system is not managed through organized efforts. Price of spices is not determined by the demand, supply and price information but by individual decision. Individual decision-making process of the marketing of spice leads to inefficient and ineffective service of the market. Therefore, farmers are not getting expected benefits from this sector. Hence, a radical change should be undertaken in the system to exploit the benefit from these marginalized crop (Tiru *et al*., 2017).

2.7. Factors Affecting Production of Spices in Ethiopia

When assessing the quality of black pepper (*Piper nigrum*), it really comes down to a perfect blend of physical appearance, chemical composition (essential oils and Piperine), and sensory characteristics like aroma and flavor. These factors are heavily dictated by both pre-harvest conditions such as the specific cultivar, maturity at harvest, and growing climate—and post-harvest techniques like drying and processing. Ultimately, high-quality black pepper is recognized by a powerful, pungent aroma and a sharp bite, paired with uniform, dark, and well-filled berries (Tadesse, 2020).

High frequency of weeding and high input requirements including seed and fertilizers, high cost of production could result in loss of market prices are below the expected level as there are irregularities. In addition, due to lack of facilities for drying, long time is required to dry by using traditional practices that lead to development of fungi during wet weather condition contributing to low market price. Inadequate fertilizer supply, inadequate planting materials, shortage of access to credit and wild animal competition were some factors affecting spices production (Fissiha, 2016).

According to Masresha (2010) lack of high yielding verities, need for improved spice agricultural research in existing and new and locally adaptable varieties that offer opportunities for increased yield, poor quality of final output ,weak role of private commercial investors in spices production, irregular supply and variable quality of spices produced from forest and agricultural landscape, lack of proper post-harvest handling practices, post-harvest wastage/spoilage and product quality deterioration, lack of use of appropriate modern technologies in farm management, drying, storage, etc. and lack of appropriate spices development strategic interventions were some of factors affecting production of spices.

2.8. Preharvest factors attributing to black pepper quality

The quality attributes of black pepper such as nutritional composition, flavor, color and pungency are as crucial as yield (Meghwal M and Goswami T. 2012). Variations in the chemical composition of essential oils in pepper have been reported and among contributing reasons include varietal differences, geographic origin, variations in fruit maturity, processing methods and procedures as well as storage (Orav A. *et al*.,2004). The yield and quality of pepper products can be affected by a number of preharvest factors including genetic makeup of the cultivars grown, climatic and edaphic conditions as well as crop management practices applied.

2.9. Harvesting factors influencing black pepper quality

The method and timing of harvest have influence on the yield, quality and safety of the product. Harvesting of immature crops will result into small size, uncharacteristic shape and flavor/aroma and therefore, a poor quality. Early harvest also effects weight and price of the spices (Petropoulos *et al*., 2017).

2.9.1. Harvesting Methods

Pepper fruits mature about 6–8 months after flowering to reach full maturity, depending on prevailing environmental conditions and variety grown (Balasubramanian *et al*.,2016**).** However, small-scale farmers normally harvest pepper even before maturity, hence compromising the final quality. Usually, harvesting is scheduled based on the kind of required pepper product. In order to achieve a product of good appearance and biochemical composition, it is very important to harvest pepper at the proper maturity stage**.** Under good management, a bush black pepper tree can yield an average of 150–300g of dry pepper per plant/year (Ravindran *et al*., 2012). In bench sheko harvesting of black pepper occurs in two seasons: minor harvesting season (June-August) and major harvesting season on December- January (Tadesse, 2020).

Black pepper (*Piper nigrum*), known locally in Ethiopia as "kundo berbere," is primarily harvested using manual hand-picking methods, especially in smallholder farming systems in regions like Bench Maji and Sheka zones. While mechanical threshing is becoming more common for separating berries post-harvest, field harvesting remains largely manual due to the

nature of the crop and the infrastructure of the farms. Black pepper (Piper nigrum) is an important cash crop in Ethiopia, and its harvesting methods can significantly influence the quality and yield of the product (Edossa *et al*., 2020).

2.9.2. Determination of Harvesting Stage at Maturity

In order to achieve a product of good appearance and biochemical composition, it is very important to harvest pepper at the proper maturity stage .The flavor, aroma, and pungency of a spice are directly linked to its secondary metabolites primarily essential oils and oleoresins and these compounds accumulate to their peak only at specific stages of development (Hailemichael *et al*., 2009). Harvest too early, and these compounds are underdeveloped. Harvest too late, and they begin to degrade, or the physical structure of the crop deteriorates. Farmers in sheko district determine the harvesting stage at maturity using commonly based on the color change of the berries and sometimes using berry size, and days after flowering. Green berries gradually turn yellow and then red when fully mature, and harvesting at the correct stage ensures optimal flavor, aroma, and piperine content (Hailemichael *et al*., 2009).

2.10. Postharvest management factors influencing the quality of black pepper

Postharvest factors influencing the quality and safety of pepper. Postharvest handling plays a great role in the pepper quality maintenance and improvement (Joy *et al*., 2002). The postharvest operations involve threshing, blanching, drying (sun/ mechanical), sorting, grading, packaging, storage and processing (Ravindran 2012). Most postharvest factors are controllable and if they get out of hand, they can provide carry-over effects to the remaining value chain of pepper.

2.10.1. Drying of the raw materials

Drying is critical stage that decides pepper quality because storage water content is determined at this stage. Since pepper is hygroscopic in nature, and its starch content may subject to mold attack and insect infestation, hence efficient and proper drying is an important process to reduce the mold growth (Balasubramanian *et al*., 2006). Once peppercorns are contaminated during drying, other handling practices may also cause additional contamination. Mkojera B. (2019) reported that small-scale pepper farmers in Morogoro district, Tanzania use color change and experience to decide level of dryness, although such methods are not sufficient indicators of

proper drying. Depending upon the climatic conditions, sun-dried pepper berries take 4–5 days for proper drying. To get a good quality product, it is essential to use proper drying surface. The common surfaces used for dying are bamboo mat, cement floor, and polyethylene fabric (Mkojera B. 2019). Open sun drying (OSD) on the ground in homestead amplify risk of microbial contamination because of dust and livestock. In Ethiopia especially in south west Ethiopia small scale farmers use open sun drying (OSD) on the ground in homestead amplify risk of microbial contamination because of dust and livestock (Hussen *et al*., 2021).

2.10.2. Sorting and grading

In addition to poor harvesting, lack of produce sorting and grading lead to failure of meeting quality standards, especially for the export markets. Grading is done to separate contaminants, undersize peppercorns as well as damaged and discolored spices. Most spices are subjected to size reduction and graded to allow different forms of spices in the market, such as raw, dried or pre-ground dried (Balasubramanian *et al.,* 2016). Other characteristics used for grading include seed maturity, shape, size and color. Sorting and grading of pepper are based on relative density, color and size. High-quality pepper is considered to be large, round, with an even black color, high pungency and complex aroma imparted by high levels of essential oils (Schulz *et al.,* 2005). Separation of pepper at small-scale level is normally done manually; it is time-consuming and may be ineffective due to human error. A pepper grading machine comprising of vibrating and rotary motion of AC motor was designed and fabricated for sorting and screening pepper based on their size and weight by involving a series of meshes (Hussain A. and Mohankuamar D. 2017).

2.10.3. Packaging

Dried spices in whole or in powdered form are usually packed into gunny packs and stored until they are delivered to the traders and the processing industry. Packaging provides ease of handling while maintain the characteristic quality of the product during postharvest distribution. It also adds an additional value to the product for marketing (Das and Sharangi, 2018). The black pepper (in whole or ground) should be packed into polypropylene packaging (bags or flasks) or glass. All packaging must be hermetically sealed to avoid loss in the mass or modifications in the moisture content. Some care should be taken when removing the air from within the packaging

before sealing. The vacuum packaging improves the conservation of the quality of the dehydrated pepper.

2.10.4. Storage

Proper storage of black pepper is essential to preserve its pungent, aroma and flavor, which is easily lost if exposed to heat, light, or moisture. To maintain high-quality black pepper, it must be stored in a cold, ventilated, cool environment, shielded from direct sunlight, and kept free from domestic animals and pests, with continuous supervision and monitoring. Besides the drying operation, storage is another critical control point because the control of storage temperature and humidity is indispensable to prevent damages of the spice material. The dehydrated pepper must be stored in fresh places that are protected from the light and moisture. The light alters the color, whereas the heat reduces the life time of the product. Susceptibility of dried spices to spoilage and toxin producing microorganism increases with water activity above safe limits, and storage temperature suitable for their growth (Duncan *et al*., 2017). Black pepper should be kept in a tightly sealed glass container in a cool, dark and dry place Whole peppercorns will keep almost indefinitely, while ground pepper will stay fresh for about three months. Pepper can also be frozen although this will make its flavor more pronounced (Hai and Long An, 2015). In many cases, small scale farmers store their produce under conditions favoring contamination by insects, rodents, and other vermin, thus increasing the risk for postharvest destruction and loss.

2.10.5. Black pepper processing

The black pepper processing includes the post-harvest operations of the spice. The main unit operations, mostly practiced, are reported in Figure 1. Black pepper is obtained from dried immature berries, harvested when one or more berries turn to orange or red color on a spike (Samuel k. 2019). During maturation of fruits, the piperine and starch contents increase, while the volatile oils and non-volatile resins decrease (Ramana k. 2000). Therefore, the fruits should be harvested at the same and carefully chosen stage of maturity, to ensure a low crop loss during processing and a uniform final product with high quality.

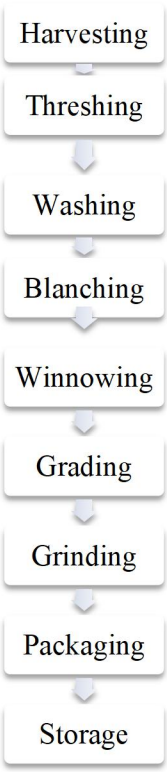


Figure 1: Flow diagram of black pepper processing

2.11. Factors Affecting black pepper harvesting and Postharvest Handlings

2.11.1. Socio-economic determinants

Sex of the Household Head (SHH): This is a dummy variable (takes a value of 1 if the household head is male and 2 if it is female). In this studies variable assumed positive relation with quality of black pepper, (Bebe *et al*., 2012) noted that majority of the female are resource constrained given that they do not own critical resources in vegetable marketing to obtain additional income. As a result, male household heads have more chance to apply proper harvesting and post harvesting technology than female household heads.

Farming experience and age of the households: A household with better experience in black pepper farming is expected to produce more amounts and better-quality black pepper than the one with only less experience. Therefore, experience in black pepper production is expected to have positive relationship with farm-level marketable supply of black pepper. Abay (2007) discussed that as farmer's experience increases, the tomato supplied to market will increase. Age

of the household, a continuous variable, is also one of the explanatory variables. As an individual stay long, he will have better knowledge and will decide to allocate more size of land, produce more and supply more. Accordingly, aged and experienced household heads are prone to use resources with an expected positive effect on market participation and marketable surplus (Bezabih and Hadera, 2007).

Education Level of the Household Head (EduHH): This is a dummy variable with a value of one if a household head had been literate and zero otherwise. Educational status of the farmer determines the speed with which the farmer to adopt agricultural technologies. Those who can read and write stand a better chance of understanding things faster. Moreover, better-educated farmers tend to be more innovative and are therefore more likely to adopt better harvesting and post harvesting management practices. The variable had positive and significant relationship to the independent variable. (Grover *et al*,.2012) found level of education affected marketed surplus of wheat and rice positively and significantly. Therefore, in this study, education level of house hold was hypothesized to affect the quality of black pepper positively and significantly.

Marital status: The legal and social marital status at the time of the survey is referred to as the "marital status of household" (MSHH), which is divided into four categories: married (1), single (2), divorced (3), and widowed (4). Marital status influences household labor availability, decision-making, and resource management, which may affect farming activities such as harvesting and post-harvest handling (Creswell, 2014).

Family size (FAMSZ): This variable is a continuous explanatory variable and measured in number and refers to the total number of family in the household. Households with more than four members generally have greater access to family labor, which enables timely harvesting and proper postharvest management, reducing physical and quality losses. Conversely, households with fewer than four members may face labor constraints, leading to delayed harvesting, inadequate sorting, and suboptimal storage, all of which can compromise pepper quality. Several studies indicate that family size directly influences smallholder farmers' capacity to adopt recommended agricultural practices and maintain crop quality (Belay *et al*., 2019).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted in South west Ethiopia, specifically in Bench sheko (previously known as Bench Maji) zone. The zone designated as black pepper belts of Ethiopia, where almost all of the country's black pepper production is located (Abdu *et al*., 2016; EIAR, 2016). Sheko District lies approximately 597 km southwest of Addis Ababa and 17 km from Mizan Aman, the zonal capital. It is geographically bordered by Debub Bench to the south, Guraferda to the west, the Gambella Region to the northwest, Sheka Zone to the north, and Semen Bench to the east. The district consists of 23 rural kebeles and one urban kebele, totaling 24 kebeles, the smallest administrative unit in Ethiopia. The major area of Sheko is classified under warm and humid to peri humid agro-ecological zone (Lemecha *et al*., 2006). The region lies between latitude and longitude of 6^0 50' N and 35^0 00' E coordinates, respectively, and at an altitude that ranges from 950 to1800 meters above sea level (SARDO 2010). The season of the region is divided into three: the main rainy season (June-October), dry season (November-February) and short rainy season (March-May). According to the annual report of Sheko Woreda Agriculture and Rural Development (SARDO 2010), the mean annual temperatures were 22.6 ^{0}C and the annual rainfall at Mehal Sheko town (the capital of the Sheko district) ranges from 1200 to 2200 mm.

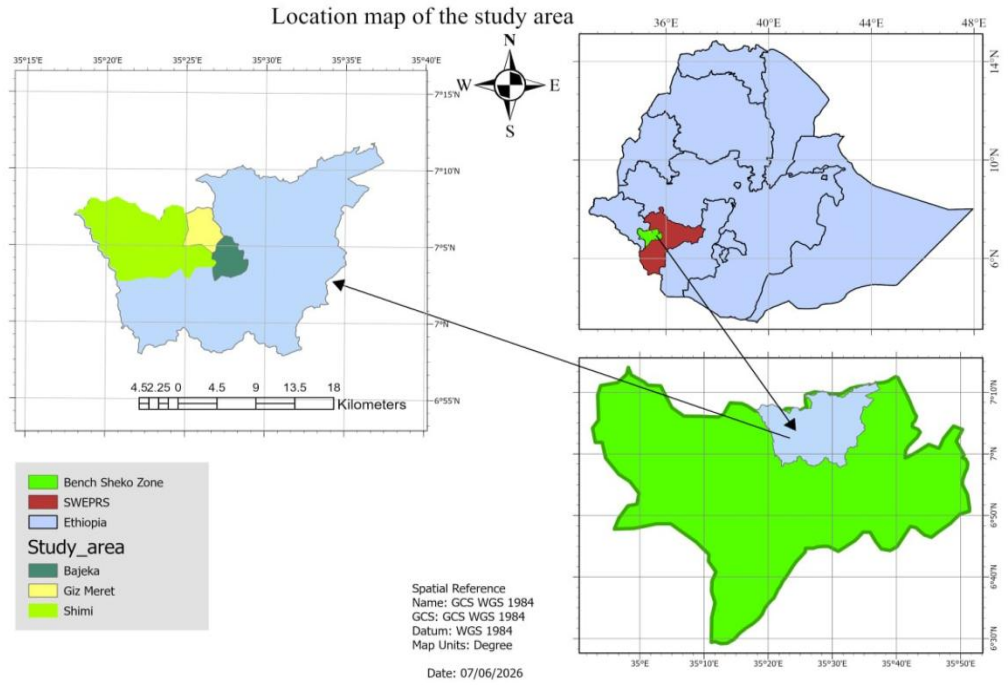


Figure 2: map of the study area

3.2. Sources and Method of Data Collection

In order to address the objective of the study both primary and secondary source of data were used with cross- sectional data. The primary source of data was collected from black pepper producers and traders (wholesaler and Retailer) involved in black pepper production and marketing using questionnaire and focus group discussion (FGD) with key informant. The questionnaire was designed both for producers and trader (retailers and wholesalers). The structure of the questionnaire was designed in both open and close ended and focus group discussions was conducted in the study area with purposively selected individual from community for the sake of this particular study which include developmental agent workers from selected kebeles, model black pepper producers based on their production capacity and traders. Secondary source of data was collected from published article and unpublished reports of different level of agricultural bureau (country, regional and zonal and woreda,), report of central statistical agency, websites and different published articles.



Figure 3: Filing of questionnaires

3.3. Sampling Technique and Sample size determination

To select sample of black pepper producer and trader multi-stage and simple random probability sampling technique were used respectively. To select sample of black pepper producer multi-stage probability sampling technique were used with three stages procedure. In the first stage, Sheko woreda were select purposively based on the amount and volume of production, accessibility and communication and 25 kebele were found. In the second stage, with the consultation of woreda agricultural experts three- major black pepper producer kebeles (Bajeka, Shimi, and Gizmeret) were purposively selected based on the volume of production and 250 black pepper producers were found. In the third stage a list of black pepper producer was prepared for each selected kebeles and sample of black pepper producer were selected by simple random sampling technique and sample size was determined and allocated to each selected kebele through proportionately. The number of selected samples from each kebele represented in table 2 were (52, 48, and 54). The following formula were used in the determination of sample size because the proportion of total population is known (Yamane Taro, 1967).

$$n = \frac{N}{1+N(e)2}$$ Where n= is the sample size needed ----------Equation (1)

N is the total number of black peppers producing farmers, **e** is the precision level. A 95% confidence level will take and e= 0.05,

Then n= (250/1+250(0.05) ^{2} =154 ----------Equation (2)

Therefore, a total of 154 black pepper producers were select for this study from three Kebeles.

Table 2: Sample of black pepper producers in three selected kebeles

Name of kebeles	Total number of households participating in black pepper production	Total number Sample producers in each kebeles
Bajeka	84	52
Shimi	78	48
Gizmeret	88	54
Total population	250	154

Source: Sheko woreda natural resource and development agricultural office (2025)

The sites for the trader (collector, retailer and wholesaler) surveys were obtained in the market. On the basis of flow of black pepper crop, two markets (sheko and Gizmeret) were selected as, the main black pepper marketing sites for this study. To select sample of trader (collector, retailer and wholesaler) simple random sampling technique was used from specified market place. The total numbers of trader (collector, retailer and wholesaler) were 15 (wholesaler was 3, Collector 8 and Retailers was 4). From the selected market site (sheko and Gizmeret) 7, 4, 3 sample of collector, retailer and wholesaler trader was selected respectively from sheko. 14 samples of traders were selected for this study from selected market site. Therefore, total of 168 samples size was used, 154 producers and 14 traders of black pepper.

Table 3: Sample of black pepper trader in Sheko and Gizmeret market

Traders	Sheko Woreda	Sample traders
Wholesaler	3	3
Collector	8	7
Retailer	4	4
Total	15	14

Source: Sheko Woreda Gibiyit and Hibret sira office and own computation (2025).

3.4. Survey Variables

3.4.1. Demographic factors

1. Sex of household head (SHH): This is a dummy independent variable, indicating the sex of the household head. Household headed by male coded 1 or 2 for female. The results of Alemayehu (2014) on banana shows that gender have significant effect on technical efficiency. The result shows that female headed households are less efficient than male headed households, which indicates sex of household head has negative contribution for technical, allocative and economic efficiency of the farmer. On the other hand, male-headed households have better access for information than female households that helps for adoption of improved agricultural technologies. Therefore, male household head is expected to be positively associated with the adoption of black pepper quality harvesting and post-harvest management practices (Shamsudeen *et al*., 2017).

2. Age of household head (AHH): It is continuous variable and hypothesized to reflect the experience of the farmer or describes how long a farmer or trader has been involved in farming or trading and is categorized as 19-33(1), 33-48(2) and >48 (3). The age of household was expected to have a positive influence on black pepper quality harvesting and post-harvest management practices. This means that older farmers are expected to have greater tacit knowledge and experience on productivity enhancing technology and cost effective than younger farmers (Kifle, 2017)

3. Family size (FS): It is continuous variable, which is measured by counting the family members of sample households. Households with fewer than four individuals were coded as 1 in this study, whereas households with more than four members were coded as 2. It is hypothesized that household heads with large family size are more likely to improve black quality due to more labor during harvesting and post-harvest management (Mohamed and Authayla, 2011).

4. Educational status of household head (EDHH): It is continuous variable which is measured by the sample household head ‘s formal years of schooling and is categorized as illiterate (1), literate (2), read and write (3), primary education (4). It is expected that education can enhances the acquisition and utilization of information on improved technology by the farmers. Therefore, it is hypothesized that farmers with more years of formal schooling are economically more efficient than their counterparts (Samuel *et al*., 2014).

5. Marital status of house hold (MSHH): The legal and social marital status at the time of the survey is referred to as the "marital status of household" (MSHH), which is divided into four categories: married (1), single (2), divorced (3), and widowed (4). Marital status influences household labor availability, decision-making, and resource management, which may affect farming activities such as harvesting and post-harvest handling (Creswell, 2014).

6. Access to market information: It is a dummy variable determine the producer had access to market information or not. The better information farmers have the more efficient utilization of inputs which in turn increases the technical efficiency of black pepper production. The general idea is that maintaining a competitive advantage requires a sound business plan which means producing optimum black pepper. Hence, it was hypothesized that farmers who have access to

better information expected to be economically more efficient and more competent in market than others (Sisay *et al*., 2015)

3.4.2. Harvesting factors

1. **Berry maturity stage during harvesting (BMSH**): Black pepper quality is significantly influenced by the physiological development stage of black pepper berries at the time of harvest. In this study, this variable was treated as an independent variable coded 1 harvested at full maturity, or 2 harvested at immature stage or 3 harvested at over mature.

2. **Method of black pepper harvesting (MBH):** Different methods of black pepper harvesting are exercised by pepper farmers. If farmers harvest their pepper by selective hand picking coded as 1, or 2 for strip harvesting and 3 for cutting entire branches of spikes. Harvesting method significantly affects yield and quality, with selective hand picking of mature spikes being the most recommended practice for producing high-quality black pepper (Hirko *et al*., 2022).

3. Determine the Right Harvesting time (DRHT): Refers to identifying the optimal stage at which *Piper nigrum* berries should be harvested to achieve maximum yield and quality. In this study, it is coded as 1=color change of berries, 2 = size and maturity, and 3 = number of days after flowering. Among Southwest Ethiopian farmers, integrating color change, berry size, physiological maturity and firmness as combined decision criteria was the most reliable and practical approach to determine the right harvesting time (DRHT). Adoption of this integrated assessment, together with selective hand picking, enhanced pepper quality, reduced post-harvest losses, and improved farmers' income and competitiveness in spice markets (Teshome B. *et al*., 2021).

4. Harvesting materials (HM): Refers to the type of materials commonly used for collecting of black pepper and it was coded as 1for basket made of bamboo, 2 for local wooden container and 3 for plastic sacks.

5. **Who Harvested Black Pepper (WHBP):** Referred to the type of labor involved in harvesting black pepper (*Piper nigrum* L.). The variable in this study is coded as follows: 1 for family labor, 2 for hired local labor, 3 for migrant labor, and 4 for contractors. Black pepper harvesting labor choices had an impact on berry quality, post-harvest losses, and harvest efficiency. Farmers

used one or a combination of these labor types depending on farm size, labor availability, cost, and skill levels (Teshome B. *et al*., 2021).

6. Constraints during harvesting of black pepper (CBPH): refer to factors that limit efficient harvesting of *Piper nigrum*, affecting yield and quality. In this study, constraints were coded as 1 for labor availability, 2 for labor cost, and 3 for logistics and transportation. These constraints can significantly reduce harvest efficiency and post-harvest quality.

3.4.3. Post-harvest factors

1. Drying method: Refers to the technique used to reduce moisture in black pepper (*Piper nigrum*) after harvest and was coded as 1 for sun drying and 2 for mechanical drying. Proper drying method is critical for preserving pepper quality, aroma, and shelf life.

2. **Drying material of black pepper (DMC)**: refers to the surface or equipment used to dry black pepper (*Piper nigrum*). Black pepper drying is always a delicate operation which should be carried out carefully. It is expected that using cemented floor and raised bed with mesh wire, wooden and bamboo bed can enable farmers/traders drying their black pepper better than farmers/traders drying on the ground. If the farmer/traders use cemented and mesh wire for drying it was coded as 1, wooden bed and bamboo coded as 2 and, on the ground, coded as 3.



Figure 4: Drying of black pepper on cemented floor

3. Moisture determination method: the way in which farmers determine the moisture content of black pepper and was coded as 1 for crushing with teeth,2 for by its sound and 3 for without considering moisture content.

4. **Type of black pepper packing materials used (TCP):** indicating type of packing materials that farmers use for marketing and storage. coded as 1 for jute bags, 2 for plastic bags, and 3 for traditional. Apart from drying methods, black pepper quality is influenced by packing materials, because different packaging materials can have adverse effects on pepper quality. Therefore, Appropriate packaging helps maintain pepper quality by reducing contamination and spoilage, and is expected to correlate positively with quality (Ermias *et al*., 2021).

5. Storage availability (SA): indicates the access of storage house or room to keep the black pepper either short or long periods of time and coded as 1 for yes and 2for no. Adequate storage reduces quality deterioration and prevents mold development, thereby maintaining pepper quality (Alemu *et al*., 2020).

6. Storage period: refers to the duration black pepper (*Piper nigrum*) is kept in storage and was coded as 1 for less than 4 months and 2 for greater than 4 months. Longer storage under proper conditions can help maintain quality and reduce post-harvest losses (Workineh, M., 2020).

7.Transporting: the way in which the producer moves the produce from production site to storage area or market place either separately or mixed with other product and it was coded by 1 if its transport separately and 2 if its transport with other products.

8. **Marketing information**. Access to reliable marketing information plays an important role in influencing farmers' decisions regarding the choice of market outlet, the timing of sales, the price at which black pepper is sold, and the selection of potential buyers, thereby improving market participation and bargaining power (Barrett,2008)

3.5. Statistical Analysis

3.5.1. Analysis of field survey

The data collected from the field through structured questionnaires were analyzed by employing the statistical procedures of SPSS version 22. Using descriptive statistics, the frequency and percentage values of variables were also computed to observe their distribution. Pearson chi-square was also analyzed to study the relationship between the dependent and independent variables. The statistical significance of relationships among variables was determined using the Chi-square test at $p \leq 0.05$.

Table 4: Definition of explanatory variables to explain adoption of BPQHPHMP by farmers

Variables code	Definition Category
SHH	Sex of house hold 1= if male headed households or 2= if female headed house hold
AHH	Age of house hold 1= if 18-33 or 2= if 33-48 and 3= >48
FS	Family size 1= if >4 or 2= if <4
EDHH	Educational status of households 1= if illiterate, 2= if literate,3=R&W ,4=primary
MS	Marital status 1=if married 2= if single 3= if divorced 4=if windowed
WHC	Who harvest the crop 1=if Family labor, 2= if Haired local Labor, 3=migrant labor,4= contract
HS	Harvesting stage 1=if pre-mature, 2= if over mature or 3=mature
DRHT	Determine right harvesting time 1=for color change, 2=for size &maturity or 3= NDAF
HM	Harvesting Method 1= Hand picking,2=Strip harvesting,3= cutting spike with knife
CDBPHS	Constraints during black pepper harvesting season 1=if Labor availability, 2=if Labor Cost and 3=Logistics and transportation
DM	Drying Method used 1=sun drying 2=mechanical drying
DMU	Drying materials used 1= if cemented floor 2=if wooden bed or 3= on ground
MDM	Moisture determination method 1= crushing with teeth,2=by its sound and 3=WCMC
AS	Availability of Adequate storage 1= if yes or 2= if No
TS	Time of black pepper storage 1= if <4 months or 2= if>4 months
HCP	How long control the produce 1=until price high ,2=Until price agreement done 3= both
TU	Transportation used 1=if vehicle,2=pack animals,3=human head
TS	Transportation system 1=if separately ,2= if with other product
TWDS	To whom do you sell 1= Collector 2=dc 3=local market
CCQS	Customer complaining about quality of spice 1=if yes or 2=no
WPS	Where is the place to sell 1=if farm gate 2= local market 3=town 4=road side
DPP	Determine the price of the product 1= if farmer 2=if government 3= brokers

4. RESULTS AND DISCUSSION

This study was undertaken under field condition. It is mainly concerned with the description and interpretation of information obtained from farmers and traders. The field survey data were collected from respondents using structured questionnaire. The first section of the study offerings demographic and socio-economic characteristics of sampled producer and trader and actor participated with their marketing channel. The second section presents harvesting and post harvesting activities of black pepper. The third section marketing information about black pepper.

4.1. Socio-Demographic Characteristics of Black pepper Households

In this study, some demographic parameters were collected to know their pattern of distribution in the study areas.

4.1.1. Sex of household head (SHH)

As indicated in Table 5, from a total of 154 respondents the majority 146 (94.8%) of household black pepper farmers were males, whereas, the remaining 8 (5.2%) were females. As shown in Table 5, the sex distribution of the respondent farmers was predominantly male. Furthermore, the results showed that both men and women participate in black pepper harvesting and post harvesting practice, however Hence, the majorities of the respondents were male in the selected kebeles. This result confirmed the prior expectation that male-headed households have more access to improved agricultural technologies, updated information, credit and extension services than female-headed household.

This result is consistent with other findings; Doss and Morris (2000) showed that females have less access to an improved agricultural technologies and extension services, which contribute to lower adoption rates. Therefore, it is said to be on improving and maintaining black pepper quality male-headed household can have better than female-headed. This implies that the participation of women in harvesting and post harvesting management of black pepper was very low; this might be related with the culture and belief of the society. In the study area, men were found to be often responsible for farm work and the women have the major responsibility in the reproductive roles, marketing of smaller quantities of farm products and purchase of food and non-food items for consumption.

Therefore, it is hypothesized that male status of household head is positively related with adoption of black pepper quality harvesting and post harvest management practices. Chi-square test was computed ($\chi^2 = 1.251$, $p = 0.263$) indicated that there is no statistically significant association between the sex variables and exercising practices of black pepper quality improving factors at less than 5% probability level (Table 5).

Table 5: Demographic profile of sample /responding farmers based on sex

Sex	Frequency	Percentage	Chi square(X^2)	P- value
Male	146	94.8%	1.251	0.263
Female	8	5.2%		
Total	154	100%		

Source: Computed from survey data result,2025

4.1.2. Age of the house hold (AHH)

The survey on this major demographic factor, measured in years, provided a clue on working ages of households. The average age of the sample households was 38 years indicating that most household heads were within the economically productive age group. The age distribution of the respondents indicated that 46 (29.9%) of the farmers were young producers aged between 18 and 33 years, while the majority 86 (55.8%**)** fell within the middle-age group of 33–48 years. In contrast, 22(14.3**%)** of the respondents were above 48 years of age. This pattern suggests that black pepper production in the study area were predominantly undertaken by farmers who are within the economically productive and active working age groups, which is often associated with greater labor capacity, farming experience, and ability to adopt improved agricultural practices (Abafita *et al*., 2016). The study of Senkondo *et al*. (2004), in Tanzania revealed that experiences in farming were positive and significant in explaining adoption of RWH technology.

Across all three survey areas, in Shimi, Gizmeret, and Bajeka, more numbers of farmers were categorized under age of greater than 33 and less than 48. This implied that a considerable proportion of household heads were relatively older and likely possessed greater farming experience. Such experience is expected to contribute positively to efficient resource utilization,

improved harvesting and post-harvest management practices, and enhanced market participation. Chi-square test was computed (χ^2 = 0.96, p = 0.953) indicated that there is no statistically significant association between the age variables and exercising practices of black pepper quality improving factors at less than 5% probability level (Table 6).

Table 6: Age of respondents

Age	Frequency	Percentage	Chi square (X^2)	P-value
>48	22	14.3	0.96	0.953
33-48	86	55.8		
18-33	46	29.9		
Total	154	100		

Source: Computed from survey data result,2025

4.1.3. Marital status of the respondent (MSR)

As presented in Table 7, the marital status of the respondents was predominantly married. The majority of the respondents,124 (80.5%)**,** were married, while 16 (10.4%) were single and 10(6.5%) were divorced. The remaining 4(2.6%) respondents were widowed. This distribution indicates that most black pepper producers in the study area are married household heads. This implies that the workload of single individual will reduce by making labor division if they are married and simultaneously it also increases the productivity of an individual. Married household heads had better access to family labor**,** which facilitated timely harvesting, proper sorting, careful drying, and appropriate packaging of black pepper. On the other hand, household head who were window, divorced, or single had to deal with labor shortages, especially during harvest season. Due to these restrictions, black pepper quality deteriorated as a result of delayed harvesting, poor post-harvest handling, and reliance on inappropriate drying and storage techniques. The availability of labor within the household reduced delays in post-harvest operations, thereby minimizing quality losses such as mold development, contamination, and uneven drying (Alidu *et al*.,2016).

Chi-square test was computed ($\chi^2 = 2.764$, $p = 0.429$) indicated that there were no statistically significant association between the martial status and exercising practices of black pepper quality improving factors at less than 5% probability level (Table 7). Adugna (2009) gave a picture of almost the same harmony of respondents' marital status in Tigray. However, it was much lower than what Alemnew (2010) reported that 97.5% of red pepper producers in West Gojjam Zone are married.

Table 7: Marital status of responding/sample farmers

Marital status	Frequency	Percent	Chi square ($X^{2)}$	P-value
Married	124	80.5%	2.764	0.429
Single	16	10.4%		
Divorced	10	6.5%		
Windowed	4	2.6%		
Total	154	100%		

Source: Computed from survey data result,2025

4.1.4 Educational status of household head (EDHH)

The study has revealed the educational profile of sample respondents as shown in the Table 8, that the majority of farmers 84(54.5%) were Can read & write, followed by and illiterate farmers which accounts to 50(32.5%), while the remaining educational levels is primary education was small in comparison with others 20(13.0%). Therefore, the majority of the farmer respondents were can read and write and in primary education.

Results suggest that majority of the farmers in the study area had low level of education which could lead to low adoption of improved harvesting and postharvest handling practices of black pepper. Farmers with low level of education struggle to understand written information and combine technical skills with implicit local understanding of post-harvest management practices. A study conducted by (Abate *et al*., 2019) reported that increase in education level improve ability of farmers to utilize existing technologies. The long-term involvement of farmers in black pepper cultivation suggests that they possess substantial experience in pepper production, which

may contribute to the adoption of effective harvesting and postharvest handling practices in the study area (FAO, 2011). As the educational entitlement increased there is proper harvesting and post harvesting management and marketing of black pepper in the study area also increased and also improved the ability to acquire new idea in relation to market information and improved production of the households. Educated households use proper harvesting and post harvesting management practices to get good production and supply more products to the market with the right price, at the right time and to the right place. It is expected that those farmers with higher formal education be disposed to decide to participate in quality maintenance practices. Thus, educational status is hypothesized to influence the adoption decision of farming households positively.

Chi-square test was computed (χ^2 = 62.648 p = 0.000) indicated that there were statistically significant association between the educational level and exercising practices of black pepper quality improving factors at less than 5% probability level (Table 8). Level of education can have a significant effect on black pepper quality because illiterate farmers are not well adopting improved technology. Similarly, the finding of several studies revealed that the level of education is a strong and important determinant of farmers' adoption of improved agricultural technologies (Zemedu, 2004). Besides, as reported by (Deressa *et al*., 2009), years of schooling positively influenced farmers' adoption decisions on improved agricultural techniques. Therefore, education is crucial for the farmers to understand and interpret the information coming from any direction to them (Jima *et al*.,2017).

Table 8: Educational level of sample farmers

Educational level	Frequency	Percentage	Chi square ($X^{2)}$	P-value
Illiterate	76	49.3%	20.463	0.003
Can read & write	58	37.7%		
Primary	20	13.0%		
Secondary	0	0%		
Total	154	100%		

Source: Computed from survey data result,2025

4.1.5 Family size of respondent (FS)

The survey result shown that the majority of the sampled households heads had a family size greater than four members. Out of the total 154 respondents, 100 households (64.9%) reported having more than four family members, while 54 households (35.1%) had less than four family members. Household members serve as family labor against short fall of hired labor (Otekunrin *et al*., 2021). The majority of post-harvest tasks such as timely harvesting, drying, winnowing, packaging is labor-intensive and require a large number of people. It has been reported that a 1% rise in adult family size in households would result in a 0.77% decrease in the probability of crop post-harvest losses (Bachewe *et al*., 2020; Stathers *et al*., 2020). The existence of high family size will have a positive impact on the harvesting and post harvesting management and marketing of black pepper and it reduces the labor cost.

Chi-square test was computed (χ^2 = 0729, p = 0.393) indicated that there were no statistically significant association between the family size and exercising practices of black pepper quality improving factors at less than 5% probability level (Table 9). Birhanu (2011) the existence of high family size will have a positive impact on the harvesting and post harvesting management and marketing of black pepper and it reduces the labor cost. In addition, Bezabih and Hadera (2007) have witnessed different labor sources are employed in horticultural production of eastern Ethiopia where family labor takes the majority share of labor. It is hypothesized that household heads with large family size are more likely to improve black pepper quality due to more labor during harvesting and post-harvest management. In this study, it is hypothesized that family size is to be positively related with black pepper quality harvesting and post-harvest management factors.

Table 9: Family size of the sampled farmers

Family size	Frequency	Percentage	Chi square ($X^{2)}$	P-value
>4	100	64.9%		
<4	54	35.1%	0.729	0.393
Total	154	100%		

Source: Computed from survey data result,2025

4.2. Demographic response of black pepper traders

In the field survey study, similar to study made for farmers assessments were made for black pepper traders considering demographic factors maintaining or deteriorating black pepper quality in the study areas. In terms of demographic factors out of a total of 14 sampled black pepper traders the majority of them (85.71%) (12) were male, while the remaining 14.29% (2) were female. This implies that women's participation in black pepper trading was minimal. Many evidences showed that female households have less access to improved technologies, credit and extension service (Ellis and Mudhara, 1995). Therefore, male status of household head is positively correlated with adoption of black pepper quality & post-harvest management practices.

On the other hand, the survey result showed that proportionally 28.6%, 21.4%, 50% and sampled black pepper traders were in the age group of greater than 48, 19-33, and 33-48 years old, respectively. Since substantial numbers of traders were in the age groups between 33 and 48 years, this is probably due to their wealth accumulation through long years of trading and this implies that all respondents were able to use resource wisely. Furthermore, the study also indicated that majority of sampled black pepper traders had (78.58 %) greater than four family members while the rest had (21.42%) less than four (Table 10). Regarding marital status of the traders, the majorities 11 (78.57%) of the traders were married, 2(14.29) were single and the rest 1 (7.14%) of sample respondents were divorced. It implies that when traders get married their labor cost for sales will increase. And the educational level of traders result shows that 3 (21.43%) were can read and write, 7 (50%) were primary school and the left 4(28.57%) were secondary school, this means as the level of education increases, traders and farmers are more capable of acquiring and utilizing new knowledge related to market information, improved handling practices, and emerging technologies, which enhances their capacity to maintain and improve the quality and market value of black pepper (Barrett, 2008).

All demographic factors considered for the sampled traders were not significantly associated with black pepper quality at the 5% probability level; however, educational level showed a statistically significant association with the quality of black pepper based on the chi-square test. suggesting that traders with higher levels of education are better equipped to implement strategies that preserve or enhance product quality. This result is in line with research by Abafita

et al., (2016) and Gebre *et al.*, (2018), which found that farmers and traders with greater levels of education have better knowledge of quality preservation methods and postharvest management.

Table 10: Frequency, proportional distribution and association (chi-square) of black pepper quality with demographic factors among sampled traders HHs

Demographic Characteristics	Description	Frequency	Percentage	Chi square ($X^{2)}$	P-value
Sex	Male	12	85.71%	0.933	0.334
	Female	2	14.29%		
	Total	14	100%		
Age	19-33	3	21.4%	2.10	0.350
	33-48	7	50%		
	>48	4	28.6		
	Total	14	100		
Family size	>4	11	78.58	1.527	0.217
	<4	3	21.42		
	Total	14	100%		
Marital status	Married	11	78.57%	0.859	0.651
	Single	2	14.29%		
	Divorced	1	7.14%		
	Total	14	100%		
Educational level	Illiterate	0	0%	10.733	0.013
	Can read and write	3	21.43%		
	Primary	7	50%		
	Secondary	4	28.57%		
	College diploma	0	0%		
	Total	14	100%		

Source: Computed from survey data result, 2025

4.3. Harvest and post-harvest related factors

4.3.1 Harvesting factors

Harvesting practices are among the major factors influencing the quality of black pepper. Inadequate harvesting methods have been identified as a key cause of the widespread failure to maintain the inherent quality of spices and coffee produced in Ethiopia (Alemayehu, 2014). Similarly, harvesting methods have been reported to have a highly significant influence on the raw quality attributes of spice crops (Ameyu *et al*., 2017). In addition to the harvesting system, the maturity stage at harvest also plays a crucial role in determining black pepper quality. Studies have shown that harvesting at the appropriate maturity stage significantly improves both the physical and organoleptic quality of the product. For instance, harvesting well-matured red cherries has been found to produce superior physical and sensory quality compared with immature fruits (Bertrand *et al*., 2006).

Concerning harvesting method, surveyed farmers exercised commonly three methods of harvesting (Table11), selective hand picking (62.3%), strip harvesting (31.8%) and cutting entire branches of spikes (5.8%). During the black pepper harvesting, most practices were focused on quantity and speed, not quality. Around 38% of respondents in the area were harvested only once, and all ripe and unripe berry are striped together. Striping is much faster than picking only mature spikes, by doing so farmers are harming their black pepper quality, besides decreasing the potential buds which will result in a good yield in the coming season. Collected black pepper through hand picking or selective harvesting regarded as the best technique for preserving quality, as it minimizes physical damage and allows selective harvesting of mature spikes (Shango *et al*., 2021). Harvesting involved ascending tall pepper plants using bamboo poles or ladders, since these plants can grow over 40 meters high. The harvesting practices could lead to poor spike selection during picking. Farmers could adopt to harvest all spikes to avoid the risks of repeated climbing. Swarnapriya (2020) reported that harvesting of pepper berries from tall trees requires experienced and skilled laborers. It also takes time to climbing and do the selective harvesting.

Over half of the farmers (92, 59.7%) picked black pepper when it was fully mature, which is ideal for obtaining greater color, aroma, and pungency and so improves overall quality. However, a significant percentage were collected in the immature stage (13.6%) or over-mature stage (26.7%), which can lower quality due to uneven drying, poor color development, decreased essential oil content, and increased shattering (Balasubramanian *et al*., 2016). These results suggest that picking black peppers at the right maturity stage is essential to preserving their good quality.

From the survey, it was revealed that around 92.2% (Table 11) of the respondents used appropriate harvesting materials, that is, local containers (bamboo and wooden made) which were reported to have no contact with other chemicals. However, 7.8% of respondents used plastic sacks. They need to avoid using plastic/polyethylene sacks for harvesting since it has an opportunity to contaminate black pepper quality especially when the container is used for transporting grains and/or chemical fertilizers. Generally, in the research area, harvesting material was not the main problem of black pepper quality.

Most of surveyed Farmers (42.9%)**,** determined the appropriate time of harvesting based on berry color change, whereas (29.9%) and 27.2% of farmers were based berry size and maturity and days after flowering respectly**.** Color change was the most commonly used maturity indicator because commercial harvest maturity of black pepper is generally identified when one or two berries on a spike change from green to yellow or red, as this stage offers the best balance of aroma, pungency, and postharvest performance (Ganapathi *et al*., 2018). However, discussions with farmers revealed variations in practice, with some harvesting at the green-to-yellow stage while others waited until berries turned red. The use of berry size or days after flowering as maturity indicators may be less precise, as berry size varies among cultivars and it influences on enviroromental and management factors. Consequently, such practices may increase the likelihood of harvesting immature or over-mature berries, which can negatively affect pepper quality in terms of pungency, color, and storability (Shango *et al*., 2021).

As shown in table 11 in south west Ethiopia especially sheko district producers used family labor, haired, migrant labor and contractors as main labor force for harvesting black pepper majority of respondents (73, 47.4%), in sheko district used family labor force for harvesting black pepper who are more familiar with the crop and handling practices that helps maintain of black pepper quality, whereas (69, 44.8%) of black pepper were harvested by haired local labor. Small proportion of harvesting was done by migrant labor (7, 4.5%) and contractors (5, 3.2%), who may have limited experience and could increase the risk of mechanical damage, mixing of immature or over-mature berries, and overall quality loss. This indicates that the type of labor used during harvesting can significantly influence the physical integrity and market quality of black pepper (Shango *et al*., 2021).

The main challenges faced by farmers in sheko district during harvesting were labor availability (69 respondents, 44.8%) and labor cost (60 respondents, 39.0%), followed by logistics and transportation (25 respondents, 16.2.0%). Most of the respondents informed that labor availability and labor cost were the main challenges faced during harvesting. Limited labor access or high labor costs can delay harvesting, resulting in berries being picked at over-mature stages, which negatively affects color, aroma, and overall quality of black pepper due to deterioration in essential oil and oleoresin content (Tadesse, 2020).

Table 11:Harvesting related factors of Black pepper in the study area

Variables		frequency	Percentage
Method Harvesting	Hand picking	96	62.3%
	Strip harvesting	49	31.8%
	Cutting entire branches of spikes	9	5.9%
	Total	154	100%
Harvesting stage	Fully maturity stage	92	59.7%
	Immature stage	21	13.6%
	Over mature stage	41	26.7%
	Total	154	100%
Harvesting materials	Basket made of bamboo	92	59.7%
	Local wooden containers	50	32.5%
	Plastic sacks	12	7.8%
	Total	154	100%
Who harvest	Family labor	73	47.4%
	Haired local labor	69	44.8%
	Migrant labor	7	4.5%
	Contractors	5	3.2%
	Total	154	100%
Determine right HT	Color of pepper change	108	70.1%
	Size &Maturity	36	23.4%
	Number of days after flowering	10	6.5%
	Total	154	100%
Constraint during harvesting	Labor availability	69	44.8%
	Labor cost	60	39.0%
	Logistics and transportation	25	16.2%
	Total	154	100%

Source: Computed from survey data result,2025

4.3.2 Drying of Black Pepper

As table 12 showed that all respondents (100%) used sun drying as their only drying technique, whereas none (0%) reported using mechanical drying. This reflects the sampled producers' complete dependence on traditional sun-drying methods. Open sun drying method results in poor quality produce since the food material is easily polluted by dirt, dust, damage from animals, birds, or insects and their droppings. Similarly, direct exposure of pepper to sun radiation degrades some produce quality and render it susceptible to fungi, bacteria, and other microorganism attack (Lingayat *et al*., 2020).

The results indicated that the majority of sampled farmers (63%) dried black pepper on the ground level with mud and cow dung, while 27.3% dried it on wooden beds and only 9.7% used cemented floors. This suggests that ground level with mud and cow dung are the dominant drying method in the study area. As the result confirmed, use of raised wire mesh beds and cemented ground for black pepper drying is very small in the study area. The finding showed that use of inappropriate drying methods can be considered as one of the main problems contributing to low black pepper quality in the study area. The appropriate drying method for black pepper is on raised wire mesh beds, cemented ground and if not, better to use mats made of bamboo. This result is in line with Getachew *et al*. (2015), who reported drying coffee on mesh wire and bamboo mats with thin layer thicknesses earned better raw quality attributes. Given the potential problems associated with drying on this surface, and its negative image, the practice of direct drying of black pepper on ground leveled with mud and cow dung should be strongly discouraged.

Black pepper producing farmers and traders in the studied woreda have no black pepper moisture testers; hence, both farmers and traders use their sense organs to determine moisture contents of the black pepper (Table 12). The result in Table 12 shows that half of the respondents (52%) determine moisture content by its sound, 31.8% test by crashing with their teeth and around 13.1% farmers store their black pepper without considering moister content, at the end which resulted in mold development. Drying is considered an important step in quality black production, since moisture levels higher than 12% can promote microbial growth and mycotoxin formation (Getachew *et al*., 2015).

Table 12: drying of black pepper in the study area

Variables		Frequency	Percentage
Drying method	Sun drying	154	100%
	Mechanical drying	0	0%
	Total	154	100%
Drying Surface of Black pepper	On cemented	15	9.7%
	Ground	97	63.0%
	Wooden beds	42	27.3
	Total	154	100%
Moisture determination method	Crushing with teeth	49	31.8%
	By its sound	80	52.0%
	Without considering moisture content	25	16.2%
	Total	154	100%

Source: Computed from survey data result,2025

4.3.3 Packaging and Storage of black pepper

According to Table 13, the majority of farmers 128 (79.67%) used sacks to package black pepper, followed by 18 (17.03%) who utilized locally produced, traditional materials, and the remaining 8 (3.29%) who used plastic bags. The use of hermetic bags to store pepper was not common among pepper farmers in the study area although could potentially reduce moisture loss or gain and hence lower mold growth on produce (Afifah *et al*., 2018).

Focus group discussions revealed that farmers are unaware of the safe moisture limit for storing black peppers. Farmers in the study area kept packaged pepper on the floor in rooms with inadequate ventilation, according to field observations. These storage conditions encourage rodent, insect, and decay microbial contamination, which raises postharvest losses. Several researchers in underdeveloped nations have observed similar storage outcomes for various crops (Díaz-Valderrama *et al*., 2020). According to Mkojera (2019), for example, pepper was kept on the floor in living and bedrooms, which encouraged contamination.

Only 46 respondents (29.9%) had access to suitable storage facilities, according to the data, whereas 108 respondents (70.1%) did not. This implies that poor storage facilities constitute a significant barrier for black pepper growers in the study area, potentially exposing produce to contamination, moisture absorption, and pest infestation. Therefore, the preservation of black pepper quality and market value may be adversely affected by the scarcity of suitable storage facilities (Habetewold, 2013).

Most farmers (79.2%) of black pepper farmers in Sheko district store their produce for less than four months, while only 20.3% store it more than four months. long time storage under high relative humidity and warm conditions increases moisture content and consequently reduce quality. If longer storage is sought, it is better to store black pepper at a temperature below 20°C and 65% relative humidity to maintain and preserve quality. The predominance of short storage periods likely helps maintain pepper quality by reducing risks of moisture absorption, mold growth, and quality deterioration associated with prolonged storage (Hirko *et al*., 2022).

Table 13:Packing and storage of black pepper in study area.

Variables		Frequency	Percentage
Packing bag	jute bags	128	88.1%
	Plastic bags	8	5.2%
	Traditional	18	11.7%
	Total	154	100%
Adequate Storage facilities	Yes	22	14.3%
	No	132	85.7 %
	Total	154	100%
Storage period	Less than 4 months	122	79.2%
	Greater than 4 months	32	20.3%
	Total	154	100%

Source: Computed from survey data result,2025

4.3.4 Transporting of Black Pepper

According to the findings, the majority of Sheko black pepper growers (76.6%) transported their produce together with other goods, whereas only 23.4% transported it alone. This suggests that mixed transportation methods may raise the risk of contamination, moisture exposure, and mechanical damage, which could have a detrimental effect on the quality of black pepper during handling and transit (Tadesse & Taye, 2021).

The findings revealed that pack animals (51.3%) were the most common way to transport pepper folowed by human carriage (30.5%) and local carts (18.2%). This suggests that depending too m uch on traditiona transportation methods may expose the produce to vibration, compression, moi sture, and ier handling, which can result in physical damage, contamination, and lower market qu ality in addition to limiting the amount supplied to the market (Bekele *et al*., 2025).

The majority of producers utilized sacks (47.4%) and containers (46.8%) for loading and unloading, while piling (5.8%) was used by a smaller percentage. Pepper quality can be deteriorated by improper sacks and piling techniques, which can lead to spills, crushing, and increased exposure to moisture and dirt (Bekele *et al*., 2025).

Inadequate postharvest handling and transportation practices significantly reduce black pepper weight and quality through breakage, spillage, and contamination, according to the results, which revealed that a very high proportion of respondents (92.2%) reported losses during loading and unloading. This is consistent with evidence that poor handling techniques are a major cause of postharvest crop loss and quality deterioration in Ethiopia (Yeshiwas & Tadele, 2021).

Table 14:Transporting of black pepper in study area

Variables		Frequency	Percentage
Transportation system	With other products	118	76.6%
	Separately	36	23.4
	Total	154	100
Means Transportation	local carts	28	18.2%
	Pack animals	79	51.3%
	Human	47	30.5%
	Total	154	100
Method the produce loading& unloading	Sacks	73	47.4%
	Container	72	46.8%
	Pile	9	5.8%
	Total	154	100
Loss during loading & Unloading	Yes	142	92.2%
	No	12	7.8%
	Total	154	100%

Source: Computed from survey data result,2025

Table 15 :Association (chi-square) of black pepper quality with harvest and post-harvest factors among sampled black pepper producing farmers HH

Independent variables		X^2	df	P-value
Bean maturity stage at harvest				
full maturity stage				
Immature		0.680	2	0.712
over mature				
Drying materials used				
on cemented		51.84	2	0.000
Raised mesh wire				
On ground				
Type of packing materials used				
jute bag		55.32	2	0.000
Plastic bag				
Traditional				
Storage availability	Yes	35.56	1	0.001
	No			
Method of black pepper harvesting				
hand picking				
strip harvesting		0.336	2	2.179
Harvesting cutting the entire branches of spike				
Storage period	<4 month	137.33	1	0.000
	>4 month			
Transportation system	Separately	143.42	1	0.000
	With other products			

The majority of the harvest and postharvest variables were found to be significantly correlated with the quality of black pepper among the Bench-Sheko studied farmers (Table 15). In particular, at the 5% probability level in this study, drying materials (χ^2 = 51.84), packing material type (χ^2 = 55.32), storage availability (χ^2 = 35.56), storage duration (χ^2 = 137.33), and transportation system (χ^2 = 143.42) demonstrated statistically significant associations with black pepper quality. However, at the 5% probability level, there was no statistically significant correlation found between black pepper quality and harvesting method (χ^2 = 2.179) or bean maturity stage at harvest (χ^2 = 0.680). This outcome may be explained by the fact that most farmers selectively hand-pick their black peppers when they are fully grown.

4.4. Black pepper Market Chain Actors and Their Impacts

From farm gate to final consumers, the black pepper market chain in the study area involves a number of players, including producers, rural collectors, wholesalers, and retailers who help the product move through the Bench Sheko District marketing channel (Hordofa & Tolossa, 2020). Thus, the following clearly describes the overall flow of the black pepper market chain in the research area: Producers (farmers) → Input providers → Collectors/assemblers → Brokers → Wholesalers → Processors → Retailers → Customers. This sequence of actors reflects the typical spice marketing system in Ethiopia, where agricultural products pass through several intermediaries before reaching the final consumer (Tadesse & Tesfaye, 2017).

4.4.1. Marketing assessment

The findings showed that the majority of respondents (87.7%) reported receiving customer complaints about spice quality, implies that quality problems are common among farmers in the study area. while only (19, 12.3%) respondents reported that they had not received any complaints about black pepper quality. These complaints are likely associated with inadequate harvesting and post-harvest practices such as improper harvesting time, poor drying, and inadequate storage, which can negatively affect spice quality (Abebe *et al*., 2018).

Most farmers marketed their products in town markets (50.0%) while others sold their produce in farm-gate sales (16.9%) and local markets (33.1%). This suggests that reliance on far-off markets may raise the risk of quality degradation during handling and transit. In order to meet

customer demands and secure better prices, farmers that sell in local and town markets typically use superior post-harvest handling techniques such washing, drying, and sorting. This has an impact on quality management methods. Regarding produce control, 73.4% of farmers store their products while they wait for higher pricing. This can have a detrimental effect on the quality of black peppers because of changes in moisture, the growth of mold, pest infestation, and the loss of volatile oils during extended storage (Hailu *et al*., 2019).

Table 16: Market place determination and complain of customer at the study districts

Characteristics		Frequency	Percentage
Have your customers complained about the quality of your spies	Yes	135	87.7%
	No	19	12.3%
	Total	154	100%
Place to sell the produce	Far m gate	26	16.9%
	Local market	51	33.1%
	Town	77	50.0%
	Total	154	100%
How long do they have control of produce	Until price get high	113	73.4%
	Until price agreement is done	31	20.1%
	Both	10	6.5%
	Total	154	100%

Source: Computed from survey data result,2025

Response of farmers

Most black pepper producers (66.9%) sell directly to customers, which helps preserve product freshness and quality because of shorter market chains and less handling (Table 17). On the other side, 30.5% are sold to collectors and 2.6% are sold to retailers, where additional handling and storage may increase the risk of quality degradation from contamination, moisture gain, and grade mixing (Hirko *et al*., 2022).

Table 17: Farmers' response to whom do you sell

To whom do you sell	Frequency	Percentage
To collector	47	30.5%
Directly to customers	103	66.9%
Retailer	4	2.6%
Total	154	100%

Source: Computed from survey data result,2025

Price setting

The results shown that most prices were set by farmers themselves (79.2%), followed by buyers (15.6%) and the government (5.2%). Farmer price-setting or negotiation encourages producers to improve quality-related practices such as harvesting at proper maturity and applying better post-harvest handling (drying, cleaning, grading, and packaging) to obtain premium prices, whereas buyer-determined prices may reduce farmers' bargaining power and lead to the sale of lower-quality pepper (Hordofa & Tolossa, 2020). Overall, fair price determination and timely payment systems serve as important incentives for farmers to adopt improved harvesting and post-harvest practices, which in turn enhance the quality and marketability of black pepper in the study area. Evidence shows that stable pricing systems improve producers' returns and that strengthened postharvest management contributes significantly to quality improvement and reduced losses (Befikadu, 2018).

Table 18: Farmers response on price setting and terms of payment

Price setter	Frequency	Percent
Myself(farmer)	122	79.2%
Buyers	24	15.6%
Government	8	5.2%
Total	154	100%

Source: Computed from survey data result,2025

4.5. Focus group discussion result

During the focus group discussion, the researcher explained the objectives of the discussion together with guiding questions and provided a detailed explanation about the contribution of the study to improving harvesting and post-harvest management practices and enhancing the quality of black pepper in the study area (figure 5). The group discussion revealed that both harvesting and post-harvest management practices of black pepper producers were largely traditional. Participants identified the major reasons for poor black pepper quality as lack of training on improved harvesting and post-harvest handling practices, limited awareness about the importance of quality management, poor adoption of improved post-harvest technologies, inadequate extension services, and lack of attention from concerned bodies such as local administrators and agricultural offices. In addition, farmers had limited knowledge of proper maturity indices, drying, storage, grading, and packaging practices. Lack of support from NGOs in providing training and improved technologies was also mentioned as a major constraint. Participants further indicated that unfavorable weather conditions during harvesting and drying periods, along with poor market access and limited infrastructure, negatively affected the quality and market value of black pepper in the area.



Figure 5 : A picture that was taken during focal group discussion in the study Sites.

5. CONCLUSION AND RECOMENDATION

Based on the survey data results, Black pepper is a vital cash crop in Southwestern Ethiopia, playing a significant role in the region's economy and the livelihoods of household farmers. As one of the major cash crops in the Bench Sheko Zone, black pepper is produced in several woredas, including guraferda and sheko. The crop serves as a major source of income and livelihood for black pepper-producing farming households in the study area. Despite the favorable climatic conditions, availability of local black pepper landraces and limited varieties with quality potential, and a long history of black pepper production in the bench sheko Zone, the quality of black pepper produced remains low. This is mainly attributed to the continued use of traditional and poor harvest and post-harvest management practices by the majority of farmers, from whom the bulk of the production is obtained.

This study was, therefore conducted in the year 2025 under field conditions in Sheko Woreda in Bench sheko zone in Bajeka, Shimi and Gizmeret with objectives of assessing the effect of harvest and post-harvest management factors and their roles in black pepper (*Piper nigrum L.*) quality in the study areas. In the field survey, a total of 168 respondents (154 household farmers and 14 respondent traders were randomly selected following sample size determination procedures of probability proportional to size technique. In total 168 black pepper farmers and traders were purposefully selected from the bench sheko woreda and interviewed from November to December, 2025 to generate primary data.

Black pepper farming in the southwestern Ethiopia at sheko district is predominantly smallholder-based and relies heavily on manual labor. Out of 168 sample of producer and traders selected from three kebele dominantly were male headed. The results indicated that most of respondents (59.7%) harvest their black pepper at majority red ripe stage. Concerning harvesting method, 62.3% of respondents practice selective hand picking, while the rest 37.7% harvest by striping and cutting the entire spike branches. However, appropriate harvesting materials which were reported to have no contact with other chemicals were used by 92.5% of respondents. From post-harvest handling point of view, lack of storage (85.7%), lack of appropriate drying (63.0%) and method of harvesting (37.7%) were the top three factors which are significantly affecting black pepper quality in sheko district.

Despite opportunities like favorable climate and rain fall, challenges such as inadequate infrastructure, disease, pest, and lack improved varieties, plastic bags, packaging, storage more than four months, shortage of money at harvesting time and traditional way of black pepper moisture testers hinder progress. Addressing these issues, particularly by introducing advanced pre-harvest and post-harvest technologies, could significantly enhance the quality, efficiency, and sustainability of black production in the region. To enhance sustainability and productivity of black pepper production, addressing infrastructure gaps and introducing advanced harvest and post-harvest technologies such as mechanized processing and pest management were critical. These measures could significantly boost quality and efficiency, benefiting smallholder black pepper producers.

Based on the study findings, the following recommendations are recommended: To enhance black pepper production and quality, it is essential to introduce disease-resistant and high-yielding black pepper varieties developed by research institutions. Farmers training on sustainable farming, disease, pest, and advanced cultivation practices will improve productivity and quality of black pepper. Promote raised bed drying surface to eliminate soil and debris contamination and Mechanized drying technologies should be promoted to ensure efficient processing and consistent quality while reducing mold risks. Advice to use well-ventilated and moisture resistant bags to prevent mold growth. Bench sheko district agricultural Development office should give enough attention by giving sufficient training and continuous assistance for the black pepper harvesting and post harvesting management practices. Radio programs and mobile platforms can support farmers with real-time weather updates, market prices, and post-harvest best practices. Additionally, comprehensive training and extension services are necessary to ensure farmers effectively utilize these new technologies, enabling sustainable and efficient black pepper production. To boost black production and productivity, it is recommended to introduce mechanization to enhance productivity and reduce labor intensity, establish more black pepper processing plants, and provide training on proper processing techniques. These measures aim to improve black pepper quality, increase value, and enhance the livelihoods of black pepper producer households. Large scale and comprehensive research for further investigation on limiting factors that affect black pepper quality highly recommended setting appropriate solution.

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7. APPENDICES

Appendix 1: Questionnaire used to gather data

This questionnaire is prepared by Aragaw Simegn, MSc student at Technical University, to conduct a study entitled by "assessment of harvesting and post-harvest management practices and their roles in black pepper (piper nigrum) quality in the case of sheko district, South west regional state, Ethiopia. This questionnaire is filled out by respondents selected randomly from the area. Since the quality and success of this study depends on the information you supply, you are kindly requested to provide your genuine response. Therefore, you are extremely demanded to respond the questions provided below as per your willingness.

General Instructions

- Please provide appropriate response by circling on the letter that holds your answer.
- write your opinion briefly for short answer question on the space provided for open ended questions

  Thank you in Advance for your kind cooperation in filling up this questionnaire.

Study Keble name----------

Study respondent code----------

Name of interviewer----------

Date of interview----------

Part I. Demographic information

1. Name of farmer ----------

2. Sex of the household heads A. Female B. Male

3. Age of the households A. 18 years B. 19 – 33 years C. 33 – 48 years D. > 48 years

4. Marital status of respondents A. Single B. Married C. Divorced D. Widowed

5. Family size A. > 4 family members B. < 4 family members

6. Educational status of the household heads/ respondent A. Literate B. Illiterate C. Primary D. Secondary E. College or diploma

Part II. Harvesting assessment

1. How do you determine when the black pepper is ready for harvesting? (Select all that apply)

A. Visual inspection of spike maturity (e.g., color change)
B. Size and maturity
C. Specific number of days after flowering
D. Historical data/calendar
E. Other (Please specify): _____

2. At which fruit maturity stage do you harvest your black pepper for sale?

A. Full maturity stage B. over mature stage. C. Immature stage.

3. Who typically performs the black pepper harvesting on your farm? (Select all that apply)

A. Family labor
B. Hired local labor
C. Migrant labor
D. Contractors
E. Other (Please specify): _____

4. What methods are used for harvesting black pepper? (Select all that apply)

A. Manual picking of individual spikes (hand picking)
B. Cutting entire branches with spikes (cutting with knife)
C. Strip (bulk)harvesting
D. Other (Please specify): _____

5. What tools are commonly used for harvesting?

_____

6. Which materials used for harvesting black pepper?

A. Basket made of bamboo
B. Local wooden containers
C. Plastic sacks
D. Other material

7. How are the harvested spikes collected and transported from the field? (Select all that apply)

A. Baskets
B. Sacks
C. Wheelbarrows
D. Trucks/Tractors
E. Other (Please specify): _____

8. What are the biggest challenges you face during the black pepper harvesting season? (Select all that apply)

A. Labor availability
B. Labor cost
C. Weather conditions
D. Logistics and transportation
E. Other (Please specify): _____

Part III. Post harvest Assessment practice

1. What type of drying surface is used? A. concrete B. ground C. raised platforms

D. Other ……

2. During drying, do you know how to identify well dried spices? A. Yes B. No

How do you establish that the spices have been well dried?.....

A. Color change
B. Color change and pressing
C. Color change and sound
D. color change and biting with teeth

3.What methods used to determine moisture content? (Select all that apply)

A. Crushing with teeth

B. By its sound

C. With out considering the moisture content

4. Do you grade and sort spices? A. yes B. No

If yes, what aspects do you consider when grading and sorting? ……

A. size

B. maturity

C. both

5. How is foreign matter removed from the dried black pepper? (Select all that apply)

A. Manual sorting

B. Sieving

C. Air separation (winnowing)

D. Magnets (for metallic contamination)

E. Other (Please specify): _____

6. Where is the dried and processed black pepper stored before packaging or sale?

_____

7. What are the storage conditions (temperature, humidity, ventilation) for the dried black pepper?

_____

8. What type of packaging materials are used for the processed black pepper? (Select all that apply)

A. Jute sacks

B. Polypropylene bags

C. Paper bags

D. Plastic containers

E. Vacuum packaging

F. Other (Please specify): _____

9. Do you have storage house for your black pepper to store?

A. Yes B. No

10. Do you clean the storage structures obefore using them? A. Yes B. No

11. How long do you keep your black pepper in store before taking to market?

A. < 4 months B. > 4 months

12. What type of transportation means do you use? A. vehicle/Isuzu B. pack animals C. human head D. Others, Specify

13. Which system of transportation do you use A. Separately B. With other products

Part IV. Market assessment

1. To whom do you sell? A. To collectors/brokers B. directly to consumers C. To local market D. To Unions E. To Wholesalers

2. Have your customers complained about the quality of your spies? A. yes B. No

If yes explain ……

Complaints based on

A. Visible mold growth
B. Improper drying
C. General appearance*

3.Where is the place to sell? A. farm gate B. local market C. town D. roadside E. others, specify

4.Who determines price of the produce? A. Farmers themselves B. Brokers C. Wholesalers/collectors D. Government E. others, specify

5. How long do they have control of produce? A. Until price get high B. Until price agreement is done C. both “A & B” D. Others, specify