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Determinants of postharvest losses along the baobab value chain in Malawi

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Introduction: Wild fruits like Baobab are gaining status as a valuable food resource worldwide. As with other crops, the reduction of post-harvest losses is critical to enhancing sustainable utilisation of wild food resources. However, little information is documented on the magnitude and determinants of post-harvest losses (PHLs) amongst Non-Timber Forest Products (NTFPs), and baobab in particular.

Methods: This study used cross-sectional data collected from six districts to analyse PHLs along the baobab value chain in Malawi. A multistage sampling technique was used to sample 405 collectors, 96 traders, and 316 processors. Two-limit Tobit models were used to ascertain correlates of PHLs at each value chain level. The study quantified the value of PHLs and assessed the effect of socioeconomic factors on PHLs amongst baobab actors.

Results: We found that actors in the baobab value chain lose 7.78% of the total value of products held through PHLs. The results also showed that different sets of socioeconomic factors variably influenced PHLs amongst different value chain actors in the baobab value chain. For instance, gender was found to only correlate with PHLs amongst collectors. Whilst marital status was positively correlated with PHLs amongst collectors, and had a negative relationship amongst processors. PHLs at traders' level are influenced by the number of people employed by an actor, the ability of customers to specify product attributes, and a proportional reduction in sales volume due to COVID-19. The study recommends the provision of training in PHLs management, and the formulating and enforcing of Baobab product handling standards.

KEYWORDS

baobab (*Adansonia digitata* L.), post-harvest losses (PHL), Malawi, value chain, non-timber forest product (NTFP)

1. Introduction

Reducing postharvest losses (PHLs) is fundamental to enhancing sustainable utilisation of global food resources (Chadare, 2010). According to the World Bank (2011), managing PHLs is viewed as a viable alternative for increasing world food reserves. The world needs to increase food production by 60% by 2050, but efforts to increase food production are constrained by climate change, soil degradation, reduction of arable land, and dwindling fresh water reserves (Segrè et al., 2014). Management of PHLs is a better response to this need as it involves exerting limited pressure on existing production factors. According to Ayandiji et al. (2011), reducing

PHLs by 50% can increase food availability by 20% without increasing the area of cultivated land. As such, reduction of PHLs has a direct impact on household income and nutrition as it increases the amount of food that can be sold or consumed (Sheahan and Barrett, 2017). Despite efforts to reduce PHLs, they remain a major problem in many countries, especially in developing countries, where 15–50% of total food production is lost through PHLs (Affognon et al., 2015).

Research highlights that besides increasing food availability, reducing PHLs has other benefits including stabilising food prices, improving food safety, improving efficiency in resource allocation, and promoting value chain upgrading (Hodges et al., 2011; Shee et al., 2019; World Bank, 2020). Attempts have therefore been made to generate loss estimates of different food products, map hotspots of losses along value chains, standardise methodologies for estimating PHLs, evaluate the impact of innovations implemented to mitigate PHLs, and to suggest cost-effective alternatives to current PHL mitigation measures (Ayandiji et al., 2011; Sheahan and Barrett, 2017). However, there is still no consensus on the proper methodologies to follow when collecting, analysing, and reporting data on PHLs (Affognon et al., 2015; Sheahan and Barrett, 2017). Moreover, existing studies have concentrated on PHLs of staple food crops like maize, cassava, rice, and wheat, although researchers acknowledge that PHLs of other commodity Value chains need to be studied (World Bank, 2011; Affognon et al., 2015; Sheahan and Barrett, 2017). Hence, there is a dearth of knowledge on PHLs in other Value chains, which has resulted in food and economic losses and limited value chain upgrading (Chadare, 2010; Hodges, 2013).

One of the overlooked commodity value chains is the Baobab value chain. Baobab,[1] like other non-timber forest products (NTFPs), are regaining global popularity and acceptance as a super food due to their high nutrient and vitamin content. This global recognition is driven by changes in consumer preferences, whereby a majority of consumers now prefer natural food items. This preference has led to an increase in the volume of Baobab products traded on domestic and international markets (Amosi, 2018; Darr et al., 2020). In Africa, the expansion of domestic trade in Baobab products is also credited to the consumers awareness of its health benefits and the desire to support local products (Kruger and Mohamadi, 2021). Further, an increasing number of urban consumers in Africa appreciate the health and cultural benefits in wild food products like Baobab. Given the significance of Baobab in the food system and livelihoods (Buchmann et al., 2010; Sanchez, 2011), Baobab products lost through PHLs have substantial impact on the income and nutrition of actors throughout the whole baobab value chain. For example, in Southern Africa, a total of 238 t of baobab powder was sold in the local market, and 438 t were exported (Kruger and Mohamadi, 2021). In Malawi, the per capital revenue obtained from baobab enterprises in 2011, ranged between \$2.5 to \$715 (Munthali, 2012). Other studies such as (Jäckering et al., 2019) and (Welford et al., 2015) have also shown the relationship between baobab collection and improved incomes, in Kenya and Malawi, respectively.

1 Baobab is multipurpose non timber forest product with products having numerous food uses and medicinal properties (Sidibe and Williams, 2002). The fruit pulp, the leaves and seeds are utilized as foods and also commercialized by rural populations in Africa (Chadare et al., 2009).

Reducing PHLs has received policy prioritisation in Malawi. However, dealing with the PHLs of NTFPs like Baobab has been overlooked in these policies (Amosi, 2018). Policies such as the Malawi National Food Security Policy of 2006, the National Agricultural Policy of 2011, the National Forest Policy of 2016, and the Malawi Nation Export Strategy II (NES II) of 2022, which specifically affect PHLs management in Malawi, have rarely focused on NTFPs. The lack of visibility of PHLs of NTFPs in the national policies has been credited to the unavailability of clear and empirical information on the value, distribution, and determinants of the losses (North et al., 2014; Amosi, 2018). This information is crucial in order to identify solutions and guide priorities of action (Kikulwe et al., 2018). Unlike other fruits, Baobab has unique product attributes, handling methodologies, and climatic conditions under which crops grow (Kitinoja and Kader, 2015), hence the methodologies used to estimate PHLs in other fruit Value chains cannot work in the baobab value chain (Amosi, 2018). In addition, some interventions for mitigating PHLs implemented in other value chains, like the use of warehouse receipt systems, pesticides, and hermetic storage bags are not applicable in the Baobab value chain (Affognon et al., 2015; Sheahan and Barrett, 2017; Amosi, 2018).

Previous studies on PHLs have majorly focused on major crops such as pineapples (Tröger et al., 2020), tomatoes (Abera et al., 2020), maize (Abass et al., 2014), sweet potatoes (Shee et al., 2019), and fruits and vegetables (Porat et al., 2018). Further, recent reviews and metanalysis that study PHLs mainly consider studies on food grains, root crops, and vegetables and fruits (Affognon et al., 2015; Stathers et al., 2020; Debebe, 2022). To the best of our knowledge we only found one study Sanon et al. (2018) that has focused on descriptively analysing PHLs in NTFPs. Other studies (e.g., Adepoju and Salau, 2007; Meinhold and Darr, 2019), mention PHLs in NTFPs, but do not undertake any detailed analysis. In this paper, we seek to contribute to this gap in the literature by analysing the value of PHLs at various stages of the Baobab value chain and to assess the extent to which socioeconomic factors influence PHLs along the Baobab value chain in Malawi studies on socioeconomic factors influencing PHLs (Shee et al., 2019; Abera et al., 2020; Bendinelli et al., 2020; Debebe, 2022) do not look into losses in NTFPs, but rather focus on staples and cash crops. However, we also expect heterogenous patterns on the effect of socioeconomic factors relative to specific value chains. Even within the same value chain, PHLs may vary based on the geographical regions (FAO, 2011). Baobab is a unique case because it is a priority NTFP that is commercialized domestically and internationally.

The subsequent sections of this paper are structured as follows; section two provides the context of the baobab value chain; section three presents an overview of data and methods, describing the study area, data sources, sampling procedure, and data analysis. Section four presents and discusses the results and the last section concludes.

2. Baobab value chain in Malawi

In Malawi, most baobab trees grow naturally and are communally owned. However, individuals may claim ownership of baobab trees if they naturally grow on their private land. The communal ownership and non-uniform distribution of baobab trees pose challenges for the collectors to effectively manage baobab trees. Crucial pre-harvest practises that are common in other value chain like protecting trees from diseases, preventing animal foraging, and ensuring harvesting of mature fruit are not followed in the baobab value chain (Amosi, 2018). Baobab fruits are mainly harvested between April and June, however some collectors would start in February and extend to October (Meinhold and Darr, 2022). The main actors in the baobab value chain include collectors, traders, processors, retailers, and consumers (Amosi, 2018; Jäckering et al., 2019). Collectors are responsible for harvesting and pre-processing of the baobab fruit. Fruits are mainly harvested by picking them from the ground or using long sticks with hooks to pluck them from the trees (Olumeh and Mithöfer, 2023). The main products that are sold by collectors are baobab fruit and pulp. Pulp is a cream-coloured powder that is embedded on the baobab seed, and it is extracted by opening the shell of the fruit using a machete or a hard object (Kaimba et al., 2020). Collectors either work individually or they are found in clubs. Collectors who are the members of baobab clubs or cooperatives may only collect fruits from designated forest and they follow strict guidelines to ensure that products are of high quality (Meinhold and Darr, 2022). The other category of the collectors does not belong to any grouping and they indiscriminately collect fruits. Actors at all baobab value chain levels store baobab products. However, there is no agreed proper storage material for baobab products especially for fruits and pulp. Some collectors store fruits in granaries and pulp in grain sacks that are coated with plastic, whilst others put the fruits in the yard, and part of livestock sheds. Collectors who store pulp in sacks with plastic lining argue that the plastic help to maintain the cream colour on pulp favoured by processing companies. Baobab traders mostly procure baobab from collectors. They market both whole fruit and pulp on seed. However, these traders are not specialised in baobab only, but baobab and its related products form part of the trader's portfolio (Meinhold and Darr, 2022). Majority of baobab purchases by traders were made between the month of April and June.

Baobab processing is mostly done informally, where processing is done in a microenterprise managed by an individual. Ice lollies were the most commonly processed baobab product. Other processed products include; juice, jam, baobab powder, coffee, and cosmetic products (Darr et al., 2020). More recently, formalised baobab processing has also emerged in Malawi (Meinhold and Darr, 2022). A baobab collector association is involved in manufacturing of baobab juice which is sold domestically. On average, 60 t of baobab pulp is processed annually into powder and then stored to be used as the main raw material for juice processing. Unlike other value chains in Malawi, trade in baobab products is only regulated for formal processors (Meinhold and Darr, 2022). The Malawi Bureau of Standards (MBS) are responsible for checking the processing facilities and the manufactured products, to ensure food safety and hygiene. Also, majority of the products processed by the formal enterprises are sold in supermarkets, hence, the MBS certification is a requirement.

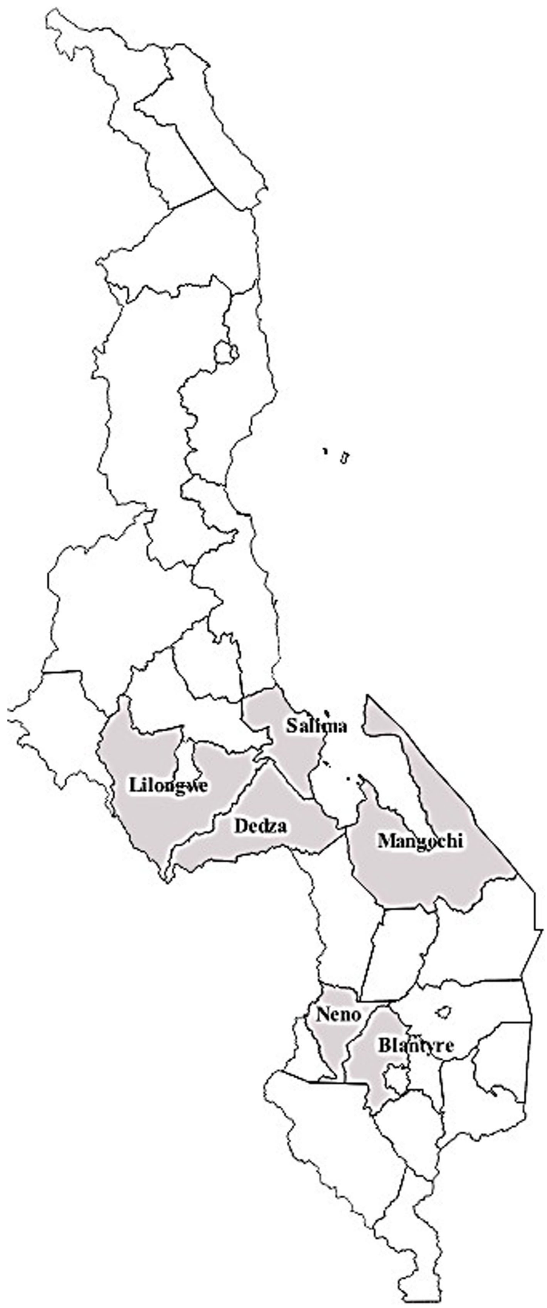

FIGURE 1
A map showing the the target study sites in Malawi.

3. Data and methods

3.1. Description of study area

Data for this study was collected in six districts in Malawi, as indicated in Figure 1. Generally, Baobab fruits are collected in areas surrounding the southern part of Lake Malawi. Some Baobab collectors in the region are organised into clubs, cooperatives, and associations through which they collectively sell Baobab products. The Baobab collectors mainly sell Baobab products to traders from Malawi's cities (Amosi, 2018). The traders sell either to consumers or household processors in the cities. The Baobab processing companies in Malawi buy Baobab products directly from collectors through contractual agreements. For this study, data on Baobab collectors was collected in Salima, Dedza, Mangochi, and Neno districts. The districts were purposively selected because of their abundance of Baobab trees, and Baobab harvesting is one of the main income-generating activities. The climatic conditions in the study areas do not favour arable crop production due to the high temperature and erratic rainfall (Munthali, 2012). Data on traders and processors was collected in Lilongwe and Blantyre. The districts were purposively selected for this study because of their active trade in Baobab products throughout the year (Munthali, 2012).

3.2. Data sources and instruments

Data was collected using a cross-sectional household survey approach. Semi-structured questionnaires were used to collect primary data at each value chain level. Face-to-face interviews were conducted at places chosen by respondents. These include homes, offices, market places, and the warehouses of Baobab cooperatives. Key informant interviews (KII) were also conducted to supplement data collected from personal interviews. Officials from Baobab processing companies and representatives of Baobab cooperatives were interviewed as key informants.

3.3. Sampling procedure

Given the variation of target respondents for this study, different sampling techniques were used for specific target groups. For collectors, we employed a multistage sampling procedure: First, we purposively selected the southern and the central regions in because of their dominance in Baobab collection in Malawi. Second, four districts with high proportions of Baobab collectors within the sampled regions were selected: Mangochi and Neno districts in the southern region and Salima and Dedza districts in the central region. Third, four villages were randomly selected from the sampled districts. Using a list of Baobab collectors – which was generated with the help of extension officers and Baobab project officers – we randomly sampled about 25 respondents in each village. Data was collected from a total of 405 collectors.

For traders and processors, we employed a two-stage sampling procedure that was complemented with a snowballing technique. In the first stage, three districts were purposively selected based on the density of traders and processors: Neno, Blantyre, and Lilongwe. In the second stage, a list of traders and processors was generated with the help of Baobab collectors and project officers. Finally, the snowballing technique was used to identify the target respondents. A total of 96 traders and 316 processors from villages and townships listed in Table 1 were interviewed.

TABLE 1 Sample of actors interviewed in each study area.

District name	Value chain level		
	Collectors	Traders	Processors
Mangochi	164	–	–
Dedza	74	–	–
Salima	36	–	–
Neno	131	23	–
Lilongwe	–	25	116
Blantyre	–	48	200
Total	**405**	**96**	**316**

3.4. Data analysis

3.4.1. Estimating the value of postharvest loss at each stage of the baobab value chain

Loss estimates at each stage along the baobab value chain were expressed as a percentage of the total value of Baobab fruits or Baobab products that were harvested, bought, or processed but not used for human consumption. The loss estimates were calculated for each main activity handled by the chain actor. Loss estimates were calculated following the procedure outlined by Egyir et al. (2008). However, the procedure was slightly modified by substituting "value" for "quantity" in the loss estimation equation. This enabled aggregation of loss estimates of different Baobab products handled by the same actor because products like ice-lollies, juice, and pulp cannot be aggregated on the basis of quantity. For each type of Baobab product handled, the following steps for estimating PHLs were taken:

The first step involved determining the value of Baobab products (j) lost (vq_j) by subtracting the quantity used for human consumption (tu_j) from the initial quantity held (tq_j) at each link in the value chain and multiplying the difference by the average market price (P_j).

$$vq_j = \left(tq_j - tu_j\right)P_j \quad (1)$$

The second step involved finding the mean value of Baobab (TVQ_{ij}) held and lost (VLQ_{ij}) for each Baobab product in the sample (n) at each ith link in the chain.

$$TVQ_{ij} = \left(\frac{\sum tq_j}{n}\right)P_i \quad (2)$$

$$VLQ_{ij} = \frac{\sum vq_j}{n} \quad (3)$$

However, Equation 2 was modified when determining the quantity of Baobab products held by collectors and processors. This was done to incorporate the possibility that Baobab products could change form whilst being handled by an actor. Two unique scenarios were thus observed. The first scenario was observed at the collectors' level, where actors harvested fruits but processed some of the harvested fruits into pulp. As such, they sold pulp and fruits. Consequently, the figure that denotes initial value held needed to reflect the added value gained from processing fruits into pulp. This was achieved following the procedure outlined below:

The value of fruits used for pulp production (V_{fp}) was determined by subtracting the value of fruits that were not processed into pulp (V_{fh}) and the value of fruits that were lost at the harvesting stage (VL_{fh}) from the value of the harvested fruits (V_{hf}).

$$V_{fp} = V_{hf} - V_{fh} - VL_{fh} \quad (4)$$

After that, the value added from processing fruits into pulp (VA_p) was determined by subtracting the value of pulp held (V_{ph}) from the value of fruits used to produce pulp (V_{fp}).

$$VA_p = V_{ph} - V_{fp} \quad (5)$$

The value of Baobab products held by collectors (VH_c) was determined by adding the value added due to processing fruits into pulp (VA_p) to the value of fruits harvested (V_{hf}). As can be seen, the processed pulp has value that can be broken into two parts: one which is equal to the value of fruits used to make pulp; and another which is equal to the added value from processing. Hence, it is reasonable to increase the value of harvested fruits by adding the value gained from processing activities only.

$$VH_c = V_{hf} + VA_p \quad (6)$$

The other scenario which necessitated modification of Equation 2 was observed at the processors level. At this level, processors were all using procured Baobab products (fruits and pulp) to produce different processed products. As such, the value of raw materials was captured in the value of the processed products. However, this value does not reflect the total value held by processors, since the processors incurred losses before they could produce the processed products. Hence, the value of Baobab products held by processors (VH_p) was determined by adding the value of processed products (V_{pp}) to the value of raw materials lost (VL_{rm}) before processing.

$$VH_p = V_{pp} + VL_{rm} \quad (7)$$

The third step involved calculating a loss ratio (VL) by taking a ratio of mean value lost to initial mean value held at each link in the chain.

$$VL = \frac{VLQ_{ij}}{TVQ_{ij}} \quad (8)$$

Lastly, the average of the sum of loss ratios for all links in the value chain was expressed in percentage form as follows.

$$\%TVL = \frac{\sum \frac{VLQ_{ij}}{TVQ_{ij}}}{N} \times 100 \quad (9)$$

Where:

%TVL = percentage postharvest loss per Baobabs products along the value chain.

VLQ_{ij} = mean value of Baobab products lost at each ith stage along the value chain.

TVQ_{ij} = mean initial total value of Baobab products held at each ith stage along the value chain.

N = total number of links along the chain.

3.4.2. Analysing correlates that influence postharvest losses

This study used a two-limit Tobit regression model – that is, a model censored on both sides – in order to analyse socioeconomic factors that influence PHLs of Baobab products at each level of the value chain in Malawi. The Tobit model was chosen as it is suitable for describing a relationship between a non-negative continuous variable that is cut off at a certain minimum value and a set of correlates (Gujarahti, 2009). The natural logarithm of value lost through PHLs was used as the dependent variable in the Tobit model. Data on the value of PHLs had minimum and maximum points where data values were concentrated. These points acted as censoring points for the Tobit model. The model was implicitly specified as:

$$y* = x\beta + \varepsilon \quad (10)$$

Due to presence of upper limit (ul) and lower limit (ll), the model was specified as:

$$y = \begin{cases} y^* if\ ul\langle y^* \rangle ll \\ 0\ if\ ll \le y^* \ge ul \end{cases} \quad (11)$$

The general model was explicitly specified, as shown in Equation 12. A parsimonious model for each value chain level was estimated. Consequently, some of the variables included in the general model were dropped.

$$\begin{aligned} lnPHL = a + \beta_1 Age + \beta_2 VPH + \beta_3 Edu + \beta_4 \exp + \beta_5 Storage \\ + \beta_6 PSDC + \beta_7 Labour + \partial_1 Training + \partial_2 Gender \\ + \partial_3 Region + \partial_4 CSPA + \partial_5 Married + \varepsilon_i \end{aligned} \quad (12)$$

We provide a description of variable measurements and hypothesised signs in Table 2.

TABLE 2 Description of variables.

Variables	Description	Expected sign
Male	1 = actor is male, 0 = actor is female	+
Age	Age of actor in years	–
Married	1 = actor is married, 0 = otherwise	–
Years of education	Years of formal schooling completed	–
Southern region	1 = actor lives in the southern region, 0 = otherwise	–
Years of experience	Number of years of experience	–
Log of quantity fruits harvested	Natural logarithm quantity fruits harvested	–
Storage day	Number of storage days	+
Labour	Number of labourers employed	–
Training in PHL	1 = actor received training in PHL reduction, 0 = otherwise	–
Customer specify product attributes	1 = customers specify attributes of Baobab products they want to be supplied, 0 = otherwise	+
Sales reduced COVID (%)	Percentage change in sales volume of Baobab products due to COVID-19	–

Variables that would influence the extent of PHLs amongst baobab actors are selected based on economic theory and empirical evidence on PHLs. The main variable of interest are derived from literature on determinants of PHLs (e.g., Abass et al., 2014; Shee et al., 2019; Abera et al., 2020; Tröger et al., 2020; Debebe, 2022).[2] Factors that commonly influence PHLs include household characteristics (gender, age, marital status, level of education, years of experience, access to training on PHLs) and shocks (reduction of sales due to Covid). For instance, we expect gender to have an influence on PHLs amongst baobab actors. In particular, we expect female baobab actors to exhibit less PHLs than male actors. Females are more likely to give care and management to their output than men, due to their expertise in NTFPs, they try to handle their products and reduce losses. Abera et al. (2020) made a similar observation in Ethiopia when they found that male farmers exhibited more maize losses than females. We expect older baobab actors to exhibit less PHLs than younger actors. This could be because, older actors, based on their experience, they are more likely to adopt and implement PHLs management technologies. Similar observation is made by (Tesfaye and Tirivayi, 2018) in Ethiopia. We hypothesise that educated actors are less likely to experience PHLs. Through education actors may be exposed to better product handling methods which may help to reduce post-harvest losses. A similar observation is made by Shee et al. (2019) in Uganda. We expect married actors to have less PHLs relative to their unmarried counterparts. Married actors are more likely to have access to more family labour, which offers support with better handling of products after collection (Abera et al., 2020). Number of days of storage of baobab are expected to positively influence PHLs amongst actors. During storage the produce may be lost due to storage pests or poor storage conditions. Storage pests were reported as one of the major factors that increased PHLs in Tanzania (Abass et al., 2014). Baobab actors who have access to labour are likely to experience less PHLs. Most post-harvest activities are labour intensive, hence having access to additional labour may support in undertaking the PHLs activities to reduce losses (Debebe, 2022). Shocks such as COVID-19 are expected to have a positive effect on PHLs. For instance, in Malawi, Covid was reported to have restricted movements of actors and limited transportation options (Matita and Chimombo, 2020).

4. Results and discussion

4.1. Socioeconomic characteristics of respondents

Table 3 presents a summary of socioeconomic characteristics of the actors involved in this study. The table shows that Baobab collection and processing is dominated by females. This observation is similar to other NTFP value chains, where they are viewed as a woman's domain (Sunderland et al., 2014). For instance, Olumeh and Mithöfer (2023) found that majority of baobab collectors in Malawi were female. Females may exhibit high participation in NTFPs value chains and baobab in particular because of limited barriers to entry, minimal use of inputs and technology, and low capital threshold (Mithöfer and Waibel, 2003; Kiptot and Franzel, 2011). At least 70% of actors at each baobab value chain level are married and more than 60% are from the southern region. The southern region of Malawi has been documented to have a higher intensity of baobab collection than other regions (Darr et al., 2020). More processors received training in PHL reduction than other value chain actors. The average number of years of experience in trading Baobab products for processors is 50% lower than other value chain actors. A plausible explanation for this observation could be that processing of baobab into various products has recently emerged due to the growing demand for natural products from wild fruits. (Meinhold and Darr, 2022). The average age for collectors is four-to-six years higher than for processors and traders. An average trader or processor has attended secondary school education. The number of members in a household of actors at each value chain level is about five members. An average trader or processor experienced a 40% decline in the sales volume of Baobab products due to COVID-19 in the 2020/2021 season. Majority of business activities in Malawi were disrupted due to the Covid restrictions on movements and gatherings. Close to 60% of business enterprises in Malawi reported a decline of business activities due to COVID (Matita and Chimombo, 2020). On average, traders store Baobab products for two months longer than collectors and one month longer than processors.

4.2. Extent of postharvest losses at each value chain level

Results in Table 4 show the proportion of PHLs incurred at each level of the Baobab value chain. Results shows that an average collector handles Baobab products worth MK 62,002 annually and loses an average of MK 1,167 of total value of Baobab products held, which represents a PHL of 1.88%. This loss is substantial in a country where an average person spends MK 598 per day (National Statistical Office (NSO), 2021). The table also shows that fruits are more susceptible to PHLs than pulp, as 3.94% of the total value of fruits held is lost, compared to 0.68% of the total value of pulp. The difference in the extent of PHLs for fruits and pulp can be credited to different upgrading strategies implemented by holders of these products. Most pulp producers are either from Dedza or Mangochi, where collectors have pursued horizontal upgrading in the form of collectors clubs. As a by-law, club members extract pulp together under the supervision of trained personnel, collectively called "the packaging department." The packaging department ensures that correct instruments and utensils are used to produce pulp of good quality. As a result, minimal PHLs are incurred. In addition, club members also pursue vertical upgrading in the form of supply contract with the Zankhalango Association. Under the terms of the contract, the Zankhalango Association provides training, equipment, and materials that help reduce PHLs. On the other hand, Baobab fruit collection and trading is largely unregulated. There is no supervision of fruit collection activities by trained personnel; neither do institutions like the Zankhalango Association provide materials to be used. As such, fruits incur more PHLs than pulp.

Results in Table 4 show that an average trader holds Baobab products worth MK 1,091,443 but incurs losses of MK 132,841, which represents annual PHLs of 12.17%. Traders incur more PHLs at grading, storage, and marketing stages. Traders claimed that a higher portion of Baobab product is lost at the grading stage because most collectors do not sell graded products. Losses for fruits are high at the marketing

2 Due to paucity in literature we rely on evidence from other value chains rather than NTFPs to discuss the selection of variables that may influence PHLs among baobab actors.

TABLE 3 Socioeconomic characteristics of respondents at each value chain level.

	Collectors (n = 405)	Standard deviation	Traders (n = 96)	Standard deviation	Processors (n = 316)	Standard deviation
Female (%)	56		38		92	
Married (%)	82		69		76	
Live in the southern region (%)	73		73		63	
Trained in PHL reduction (%)	43		48		63	
Customer specify attributes (%)	-		77		69	
Sales decline due to COVID (%)	-		48	21	41	19
Years of experience (mean)	9	5	8	6	4	3
Age (mean)	40	12	35	9	36	10
Years of education (mean)	5	2	9	2	10	3
Storage days (mean)	32	24	87	66	57	41
Labour (mean)	3	1	22	22	2	1
Household size (mean)	5	2	5	1	5	1

stage. Results from KIIs show that most PHLs at the marketing stage are in the form of rotten fruits. The rotten fruits are mostly discovered after cracking. For Baobab fruit traders, fruit cracking is only done at the marketing stage resulting in uncovering of higher PHLs at this stage. This study also found that most PHLs for Baobab products at Traders' level are incurred during storage, like in other food chains such as rice, tomato, and potatoes (Basavaraje et al., 2007;Anaba, 2018;Shee et al., 2019). This is because Baobab products are kept in storage for a long time, which exposes the products to various factors that exacerbate PHLs.

Table 4 also shows that an average processor, processes Baobab products worth MK 325,324 but loses MK 15,420 due to various PHLs, which represents a proportional loss of 4.74%. Processors lose substantial proportions of ice-lollies and coloured-pulp, losing 16.19 and 15.53% of total value held, respectively. Results from KIIs indicated that these high losses emanate from the processing methodologies that are used to make these products. Ice-lollies need to remain frozen once they are made. But due to frequent power cuts in Malawi, ice-lollies incur high PHLs because they are not kept in ideal conditions. Similarly, high PHLs are experienced when dried pulp is made wet when processors dye pulp with different colours to make coloured-pulp. Processors lack the proper equipment to facilitate drying (Amosi, 2018). As result, prolonged wetness leads to the development of microbes, which consequently promote PHLs.

4.3. Correlates of postharvest loss at each baobab value chain level

We assessed correlates of PHLs at the collectors, traders, and processor levels of the baobab value chain using two-limit Tobit models. The results of the estimated models are presented in Table 5. The results indicate heterogenous effects of socioeconomic factors on PHLs amongst actors in the baobab value chain, indicating that policy interventions for reducing PHLs in the Baobab value chain should be context specific.

Male Baobab collectors are less likely to incur PHLs (Table 5). This finding is different from the findings of Shee et al. (2019) and Kambewa et al. (2009), who reported that women incur less PHLs than men. Men and women may incur different PHLs because of differences in accessing training on PHL reduction. In this study, access to training in PHLs differed significantly by gender (Chi2(1) =4.75, $p = 0.029$). Men had an advantage over women in accessing PHL reduction training. Considering that women dominate Baobab collection, increasing women's access to PHL reduction training can help to reduce PHLs amongst collectors. Further, male collectors may be more likely to adopt strategies and technology meant for reduction of PHLs than female collectors. Gender has been found to be highly correlated with adoption of technology amongst smallholders (Owusu et al., 2017), with females exhibiting lower adoption rates.

Marital status was negatively correlated with PHLs amongst processors. A plausible explanation for these results could be due to access to additional household labour amongst married actors (Abera et al., 2020). Majority of PHL management activities during processing are labour intensive and access to family labour amongst married actors may help in ensuring adequate time of product handling which minimises losses.

Surprisingly, years of education was found to be positively associated with PHLs in Baobab products. More educated baobab collectors were more likely to incur PHLs. A possible explanation for this observation could be that educated Baobab actors are also actively engaged in other income generating activities, and therefore are likely not to spend more investments in management of baobab losses. Similar findings were also observed in Ethiopia where literate tomato farmers reported higher PHLs than illiterate farmers (Abera et al., 2020).

Collectors and processors who lived in the southern region of Malawi are more likely to incur PHLs than those who live in the central region. This observation may be attributed to differences in the harvesting season. Most Baobab fruits in the southern region (especially in Neno district) are harvested during the rainy season when there is insufficient sunlight to dry Baobab fruits. Weather changes are noted to exacerbate PHLs, especially when the harvested crop needs to dry, incidences of rainfall may hamper the drying process leading to losses (Abass et al., 2014).

The quantity of Baobab fruits harvested was positively correlated with the PHLs incurred by collectors. These results indicate that collectors who hold more fruits are more likely to incur PHLs. A probable explanation for our results could be that collectors who have large quantities are more likely to have pressure in undertaking good

TABLE 4 Extent of postharvest losses at each value chain level.

Loss stage	Collectors			Traders			Processors					
	Fruits (n = 405)	Pulp (n = 309)	Overall (405)	Fruits (n = 55)	Pulp (n = 62)	Overall (96)	Fruits (n = 2)	Pulp (n = 316)	Juice (n = 307)	Ice-lollies (n = 30)	Coloured-pulp (n = 21)	Overall (316)
Harvesting	0.01%	–	–	–	–	–	–	–	–	–	–	–
Assembling	0.03%	–	–	1.56%	1.16%	–	–	–	–	–	–	–
Grading and sorting	0.03%	–	–	4.50%	1.05%	–	–	–	–	–	–	–
Temporal processing (drying, etc)	0.10%	–	–	1.79%	1.26%	–	–	–	–	–	–	–
Loss during storage	3.04%	0.66%	-	4.53%	4.62%	-	4.65%	4.84%	–	–	–	–
Loss during processing	–	–	–	–	–	–	–	–	1.72%	8.84%	10.96%	–
Loss during marketing	0.36%	0.02%	–	3.64%	2.24%				1.37%	7.35%	4.57%	–
Percentage of total value lost	3.94%	0.68%	1.88%	16.02%	10.34%	12.17%	4.65%	4.84%	3.08%	16.19%	15.53%	4.74%
Mean annual value held (MK)	39,088	51,537	62,002	545,089	1,290,600	1,091,443	68,500	104,358	325,772	19,783	26,972	325,324
Mean value lost (MK)	1,598	267	1,167	87,327	120,303	132,841	3,185	5,051	10,182	3,314	3,825	15,420
Mean quantity lost	453Kg (216Kg)	370Kg (197Kg)		326Kg (235Kg)	272Kg (244)		15Kg (21Kg)	17Kg (17Kg)	40 L (33 L)	10 L (11 L)	7Kg (10)	

standard deviations are in parenthesis.

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TABLE 5 Correlates of postharvest losses amongst Baobab collectors, traders, and processors.

Variables	Collectors		Traders		Processors	
	Coef	Std. error	Coef	Std. error	Coef	Std. error
Male	−0.79**	(0.37)			−0.20	(0.20)
Age	0.00	(0.01)			0.00	(0.01)
Married	0.56	(0.37)			−0.29**	(0.13)
Years of education	0.06*	(0.03)	0.04	(0.04)	−0.01	(0.02)
Southern region	1.23***	(0.23)			0.45***	(0.11)
Years of experience	−0.02	(0.02)			0.01	(0.02)
Log of quantity fruits harvested	0.31***	(0.10)				
Storage day	0.01**	(0.00)	0.00***	(0.00)	0.00***	(0.00)
Labour			0.02***	(0.01)	0.06*	(0.03)
Training in PHL			0.47**	(0.23)	−0.49***	(0.12)
Customer specific attributes			0.84***	(0.27)	−0.11	(0.12)
Sales reduced COVID (%)			0.01***	(0.01)		
Constant	0.96	(1.12)	8.33***	(0.61)	9.40***	(0.35)
var(e.lnPHLprocessors)	2.97***	(0.31)	1.10***	(0.17)	0.82***	(0.09)
Log likelihood	−298.71		−138.96		−379.99	
Pseudo R2	0.06		0.12		0.08	
Observations	403		95		315	

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

handling practises and finding adequate storage facilities, which may lead to PHLs. In Uganda, pineapple value chain actors reported economic losses as a result of poor handling practises (bruised, squeezed, injured) that led to the loss of quality (Tröger et al., 2020).

The positive coefficient of storage indicates that Baobab products are more likely to incur PHLs when they spend more days in storage. The results are coherent with the findings of Kitnoja et al. (2015), who found that, an extended storage period creates a conducive environment for loss agents to cause damage. Results from the KIIs showed that Baobab products like juice are made without adding preservatives. As such, the products become prone to microbial attacks when storage time increases resulting in increased likelihood to incur PHLs.

Access to training in PHLs was found to have mixed effects amongst Baobab traders and processors. Whilst Baobab traders who had access to PHLs training were less likely to experience PHLs, processors with access to similar training were more likely to incur PHLs. A probable explanation for this observation could be based on the quality of training received by the traders and processors. It may be that they are only trained in managing PHLs in the raw products (Baobab whole fruit and pulp), which are mostly traded by traders, as opposed to the Baobab-processed products that are mostly handled by processors. The results on traders are similar to the results of Shee et al. (2019) whilst studying PHLs along the maize value chain in Uganda.

The reduction of sales due to Covid-19 was positively correlated with PHLs amongst traders. Reduction of sales volume may lead to an increased likelihood of PHLs when Baobab products are improperly stored for a long time. The control and management measures to Covid-19 put in place a lot of movement restrictions that had an effect to both demand and supply markets, thus compelling traders to store baobab products for longer durations. Our results corroborate with the findings of Underhill et al. (2023) who found that approximately 70% of market vendors of fruits and vegetables in Tonga, Fiji, and Samoa reported that on farm crop losses had increased due to COVID-19.

5. Conclusion and recommendations

Wild fruits are gaining status as a valuable food resource worldwide. As with other crops, the reduction of postharvest losses is critical to enhancing sustainable utilisation of wild food resource and strengthening value chains for local development. Baobab, like other wild fruits are regaining global popularity and acceptance as a super food due to their high nutrient and vitamin content. However, little information is documented on the magnitude and correlates of postharvest losses (PHLs) along the Baobab value chain in Malawi. Using a cross sectional data set from baobab collectors, traders, and processors in Malawi we employ the loss estimation procedure outlined by Egyir et al. (2008) and tobit models to assess the magnitude of PHLs and the effect of socioeconomic characteristics on PHLs, respectively.

The results show that 7.78% of the total value of Baobab products held by actors along the Baobab value chain in Malawi is lost through different forms of PHLs. A large proportion of the losses are incurred at storage and marketing stages. The results also indicate that PHLs at different value chain levels are influenced by different sets of socioeconomic factors. Collectors who are male, more educated, and more experienced are less likely to incur PHLs. The likelihood of incurring PHLs at the traders' level increases with a greater COVID-related sales reduction, if customers specify product attributes, and if more labourers are recruited. Processors are less likely to incur PHLs if the processor is female, married, and has received training in PHL reduction.

Our findings have key policy implications, for instance we recommend that development practitioners and relevant government institutions should provide training in the proper handling of Baobab products to all actors along the Baobab value chain to reduce PHLs. The training content should emphasise the better management of Baobab products at storage and marketing stages. In addition, the government, through the Malawi Bureau of Standards (MBS), should implement and enforce product-handling standards to ensure the production of quality products that are capable of withstanding PHLs. National policy strategies need to guarantee inclusion of sustainable NTFPs storage infrastructure. This will have a positive effect on reducing losses during storage of baobab products.

Because of complexity in estimating value lost due to quality deterioration, we could not include it in our assessment of PHLs. Failure to include PHLs attributable to quality loss means that our estimate for PHLs is only composed on the losses that are quantifiable. Also, data on quantity lost is based on self-recall data and could be affected by strategic bias of the respondent. Rather than using actors' self-reported estimates, future research should use direct measurement methods and include qualitative PHLs.

Data availability statement

The datasets presented in this article are not readily available because the data used for this manuscript is still being used in development of other research articles. Requests to access the datasets should be directed to FC; cossamfoster98@gmail.com.

Author contributions

FC, JD, BK, and DM contributed to the conception and design of the study. FC and DO organised for data collection and performed statistical analyses. FC wrote the first draft of the manuscript. DO and DM wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1119107/full#supplementary-material

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