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Nutritional and economic postharvest loss analysis of African indigenous leafy vegetables along the supply chain in Kenya

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A B S T R A C T

Over the last decade, African indigenous leafy vegetables (AIVs) such as African nightshade (*Solanum scabrum* Mill.) have featured increasingly in both formal and informal markets in the peri-urban and urban centres of Africa, due to the increasing awareness of their nutritive and medicinal as well as expanding economic value. AIVs are rich in nutritional and health promoting plant compounds such as vitamins, minerals, proteins, dietary fibre and antioxidant compounds. However, the crop is highly perishable and more than half of it is lost before it reaches the consumer. In Kenya, appropriate postharvest handling and treatments, storage or refrigeration facilities are lacking. More so, the information on postharvest losses of the AIVs is limited, making the management of such losses along the supply chain very difficult. The objective of the study was to determine nutritional and economic losses of African nightshade plants along the supply chain, i.e. from producer until marketing. The study was conducted in the three main commercial AIVs producing counties in Kenya, i.e. Nakuru, Kisii and Kakamega, where three farmers from each county were randomly selected. The farmers were allowed to carry out their normal routine AIVs handling procedure right from harvesting to selling; and samples were collected at each supply chain stage (at harvest, before transport, after transport and at the market). Dry matter, selected macro-nutrients (N, P, K, Ca and Mg) and micro-nutrients (Fe and Zn), protein, carotenoids and chlorophyll content, cumulative produce and economic losses as well as the causes of losses were evaluated. The results obtained revealed significant quantitative, nutritive, and economic losses of African nightshade along the supply chain. The dry matter content was reduced by between 32.8–45.5%, depending on the county, along the supply chain. The mineral elements and protein were reduced by between 3.2–29.4%, while chlorophylls and carotenoids were reduced by between 70.9–90.9% and 70.4–91.9%, respectively. Cumulative produce loss was between 71.8–292.4% while the economic loss was between 12.6–34.4%. The findings indicate the immense losses of nutritional, quantitative and economic values of African nightshade along the supply chain. Lack of certified seed varieties, unfavourable weather, inadequate postharvest handling practices and technologies as well as insect pest and diseases are the main causes of losses during the supply chain. Therefore, maintaining quality attributes and managing postharvest losses in AIVs could be among the key issues to improving food security in developing countries.

1. Introduction

The main global challenge is how to feed over 9.1 billion people with qualitative valuable and safe food by the year 2050 (Parfitt et al., 2010). While considerable attention is geared towards increasing food production by 70% to meet this target, one important and complementary factor that is often forgotten is reducing food loss and waste (Hodges et al., 2011). More alarmingly, evidence suggests that postharvest losses tend to be highest in developing countries like Kenya who is highly dependent on a sufficient food access (Onyango et al., 2009). Under these circumstances, in a malnutrition and increasingly competitive world, reducing postharvest food losses is a major agricultural goal. In fact, investments made to manage food loss after harvest are usually less costly for the grower and the consumer and less harmful to the environment than efforts to increase production (Kitinoja and AlHassan, 2012). Even a partial reduction in postharvest losses can significantly reduce the overall cost of production and lessen dependence on marginal land and other scarce resources (Kader, 2005).

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Estimation of postharvest loss is by tracking or indirect estimates via surveys by actors in the supply chain who experienced the losses (Hodges et al., 2011). While the direct measurement by tracking approach may focus only on discarded quantitative losses, the estimate by survey approach may not give true representative values because of the possibility of either underestimating or overestimating actual losses. Currently, an up to date database on postharvest handling and loss management practices is a major problem in small-scale farming systems of developing countries like Kenya, who form the majority of producers (Gogo et al., 2016). Postharvest losses consist of quantitative, qualitative and economic losses. Qualitative losses occur as a result of either altered physical condition, perceived substandard value, deterioration in texture, wilting, flavour, change in colour, and or nutritional value, whereas quantitative losses refers to physical losses of food as unacceptable for human consumption and hence readily discarded; while economic loss is the loss in monetary value (Hodges et al., 2011; Hailu and Derbew, 2015).

It has been reported that the food insecurity situation has worsened in Sub-Saharan Africa since 1970, where the percentages of malnourished people remains high, at around 35% with absolute numbers increasing annually due to population growth (Rosegrant et al., 2005). The situation is not different in Kenya with both poverty and, in particular, food insecurity being major developmental problems. About 56% of Kenyans live below the poverty line and about 50.6% of the population lack access to adequate food; moreover, even the little they get is of poor nutritional value and quality, resulting to serious micronutrient deficiency problems (especially vitamins, Fe and Zn), the so called 'hidden hunger' (Irungu et al., 2007; McGuire, 2015). Accordingly, this translates to socioeconomic consequences which lead to the enactment of the Kenyan food security policy. The main aim of the Kenyan food security policy, as stated in vision 2030, is to ensure that an adequate supply of nutritionally balanced food is available in all parts of the country at all times (Abukutsa-Onyango, 2003; FAO, 2011). As acknowledged in this policy, indigenous foods including African indigenous leafy vegetables (AIVs) and reduction in postharvest losses would contribute immensely to the alleviation of these problems without necessarily increasing production, both as a source of income and as a nutritional food component (Habwe et al., 2008; Kitinoja et al., 2011).

For many years, the use and hence the commercialisation of AIVs have remained low despite their nutritive value and potential economic use. Their commercialisation has only begun to gain prominence recently in the Kenyan markets and especially in the urban and peri-urban centres (Chelang'a et al., 2013; Brückner and Caglar, 2016). However, available AIVs cannot meet the consumption demand being attributed to their seasonality and heavy postharvest losses (Gogo et al., 2016). Hence, promoted marketing, consumption and most importantly improved postharvest handling of AIVs that are well adapted to the agro-ecological conditions would go a long way in ensuring food security (Shiundu and Oniang'o, 2007). Minimizing postharvest losses of horticultural perishables is a very effective way of reducing the area needed for production and increasing food availability (Kader, 2005). AIVs domesticated in Africa, including African nightshade (*Solanum scabrum* Mill.) have been known to be rich in micronutrients such as iron and carotenoids (vitamin A) (Mampholo et al., 2016), possess antibiotic, probiotic and prebiotic properties (Kinyuru et al., 2012; Chege et al., 2014), and contain antioxidants and phytochemicals that contribute to protect people against carcinogenic diseases, high blood pressure and diabetes (Kimiywe et al., 2007). However, after harvest, AIVs are prone to deterioration due to their high perishability nature and high surface area to volume ratio. Faster rate of physical and biochemical changes resulting in loss of weight, colour, texture and nutritional value have been reported to be the most critical bottleneck that hampers this lucrative industry (Gogo et al., 2016). Therefore, reducing such losses after harvest is important for sustainable agricultural development and increasing food availability (Karki et al., 2016; Mampholo et al., 2016). Onyango and Imungi, (2007) reported a loss of 3.1%, 3.5%, 4.2% and 5.5% for spider plant (*Cleome gynandra* L.), African nightshade, cowpea (Vigna unguiculata (L.) Walp) and vegetable amaranth (*Amaranthus* spp.), respectively as a result of excessive wilting alone, in Nairobi (Kenya) groceries. In a study done in Kenya on potato value chain, losses were reported to be 12.0% during harvest, 0.8% during storage, 8.8% during handling and transportation, 15.6% during sorting, 12.0% during processing and 25.0% as a result of quality loss (Kaguongo et al., 2014). Based on these results, it was concluded that there is a pressing need for more quantitative evidence of the actual level and nature of postharvest loss on such commodities (Onyango and Imungi, 2007). The present study sought to evaluate quantitative and qualitative postharvest losses, i.e. cumulative produce loss, nutritive loss (selected mineral elements and protein), carotenoids and chlorophyll losses as well as economic loss of African nightshade plants along the supply chain.

2. Material and methods

2.1. Study site and plant material

The study was conducted in the three main commercial AIVs producing counties in Kenya (Nakuru, Kisii and Kakamega) between March and April 2016. The sites were selected due to their distinct characteristics in the distribution of African nightshade plants to the peri-urban and urban centres of Kenyan cities. African nightshade plant was chosen based on the initial survey that revealed the vegetable to be the most commonly produced and traded in all the studied counties (Gogo et al., 2016). With the support of agricultural extension officers and farmers, African nightshade used for the study was of the same variety (*Solanum scabrum* Mill. cv. Olevolosi) and same harvesting stage (42 d from sowing). Moreover, this was the most preferred variety by the consumers in peri-urban and urban dwellers due to its sweet taste (and lack of bitter taste).

2.2. Characteristics of farmers and experimental design

The farmers selected from Nakuru were mainly supplying their AIVs to a major supermarket (Ukwala) in Nakuru town that had cold storage facilities for vegetables. Distance from farmer's field to the supermarket was approximately 10 km. AIVs for this market were tied in bundles, packaged in baskets and transported on a motorbike. AIVs farmers from Kisii mainly sold their produce to Nakuru county closed market under ambient conditions. Distance from farmer's field to the market was approximately 210 km. AIVs were packed in gunny bags and transported in a pick-up vehicle. AIVs farmers from Kakamega county sold their vegetables at Kakamega county open market under ambient conditions. Distance from farmer's field to the market was approximately 5 km. AIVs were tied in bundles, packaged in 10 kg polythene bags and transported on a bicycle. Three farmers from each county were randomly selected. Each of these farmers served as a replicate.

2.3. Sample collection and preparation

At each stage of the supply chain (at harvest, before transport, after transport and at the market), samples were collected for analysis (nutritive and qualitative analysis). At every stage, 0.5 kg samples were collected and immediately deep frozen in liquid nitrogen to stop further biochemical reactions, then packed and transported in ice boxes and stored in a deep freezer (−20 °C) for later compound analysis. An aliquot of 1 g fresh weigh sample from each replicate was used for the analysis of carotenoids and chlorophylls while another 50 g was used for the dry matter determination. The remaining samples were lyophilized, ground, mixed to a fine homogenized powder, and stored in a desiccator for mineral and protein analysis.