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TRENDS AND CONSTRAINTS IN THE UTILIZATION OF AFRICAN NIGHTSHADE (*Solanum nigrum* complex) IN TANZANIA: A CASE STUDY OF KILIMANJARO AND MOROGORO REGIONS

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ABSTRACT

African nightshade (ANS, *Solanum nigrum* complex) is among the most widely distributed and consumed indigenous vegetables in Tanzania. Several challenges hamper the utilization of ANS. This study sought to assess trends and constraints to ANS utilization in Kilimanjaro and Morogoro regions, Tanzania. Quantitative and qualitative methods were employed to collect information on ANS production, processing, and postharvest handling. Semi-structured questionnaires were used to collect quantitative data, whereas focus group discussion (FGDs) was used to collect qualitative data. A total of 627 farmers participated to fill questionnaire, and about eight FGDs with 6 - 10 participants conducted in Kilimanjaro and Morogoro. The results showed that 72.1% of farmers grow different ANS species, with *Solanum scabrum* vastly cultivated. Also, 79.4% of ANS farmers use irrigation, handheld hoe (97.6%), pesticides (70.7%), and fertilizer (64.8%) to produce ANS. African nightshade is mainly used as food (96.1%), animal feed (41.3%), and medicine (38%). On average, only 5% of ANS sales contributed to family income. Findings show that the main constraints to ANS utilization were pests and diseases (92.9%), lack of knowledge (58%), fertilizer shortages (51%), shortages of pesticides (50%), inadequate means of transport (50.4%), lack of extension services (48%), improper postharvest handling (41.4%) and inadequate storage facilities (34%). Postharvest losses accounted for 78.4% loss of ANS. Mitigation measures were; harvesting in small quantities (54.5%) and instant selling (61.9%) of fresh ANS. Drying (5.3%) and fermentation (1.1%) were the minimal value addition methods for ANS preservation. Moreover, boiling (63.0%) and frying (45.4%) were the typical methods of cooking ANS. More emphasis should be placed on good agricultural practices, providing knowledge to farmers, and supporting access to agricultural inputs such as pesticides, fertilizers, and quality seeds. Furthermore, knowledge of the processing and preservation of ANS is necessary for farmers to improve utilization, reduce losses, and ensure ANS availability. Also, research should focus on breeding local cultivar, which is resistant to pests and diseases.

Key words: African nightshades, *Solanum nigrum* complex, cultivation, postharvest handling, utilization, processing, preservation

INTRODUCTION

African nightshades (*Solanum nigrum* complex) are known by various names such as common nightshade, nightshade, garden nightshade, and S*olanum nigrum* complex [1]. In East Africa, five common ANS species include *Solanum americanum*, *S. scabrum, S. villosum*, and *S. tarderemotum,* referred to as *S. eldorettii, S. florulentum,* and *S. nigrum* [1].

African nightshade is a good source of essential minerals and vitamins [2] and bioactive compounds such as zeaxanthin, lutein, flavonoids, polyphenol, and chlorophylls, vital for preventing cancer, inflammatory, microbial, and cardiovascular diseases [2,3]. African nightshades are used as food, medicine, and income for households [4,5]. The most common traditional processing and preservation technologies of ANS include cooling, blanching, fermentation, and osmotic dehydration [3,6]. Because some techniques preserve vegetables for only a short period, a combination of different preservation techniques can improve storability [3].

African nightshades grow well at medium and high altitudes at an optimum temperature of around 15 °C and 35 °C. Also, ANS requires rainy seasons with annual precipitation of around 500 - 1200 mm [1,7]. African nightshades are mainly produced during the rainy season [8]. African nightshades are grown in most zones of Tanzania including northern (Arusha and Kilimanjaro), central (Dodoma), eastern (Morogoro and Tanga), and southern (Iringa and Mbeya) [8,9]. African nightshades farming employs many smallholder farmers with socio-economic benefits. The estimated average yield of ANS in Tanzania is 1.5-3.83 t/ha, whereby the Arumeru district in the Arusha region produces 71.8% [8,10]. Nonetheless, Edmonds [7] and Abukutsa [11] reported the highest yield between 12-40 t/ha.

Even with the known nutritional value of ANS, health, and economical benefits, their utilization and production for food have been limited than optimal. The vegetable is highly neglected and underutilized and has a limited value chain due to few studies on its utilization and added value [3]. Postharvest losses and poor postharvest handling of ANS are the main problems hindering ANS utilization in sub-Saharan Africa (SSA) [6, 21]. The production and use of ANS leaves have been seasonal due to issues including limited post-harvest technologies. Leafy vegetable growers do not have appropriate storage and post-harvest technologies that increase their availability in and out of season [3, 6, 21]. In addition, during peak season, there is a high postharvest loss of ANS leaves [3]. For ensuring the availability of ANS, local communities in Tanzania use indigenous knowledge for value addition techniques; however, documented studies do not yet report on such practices their scope, and limitations. This study aims to use this information by ensuring the commonly used traditional techniques are improved and replicated in the study areas to ensure the availability of ANS and contributing to alleviating food and nutrition security in SSA.

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MATERIALS AND METHODS

Study area

Morogoro and Kilimanjaro regions are located in eastern and northern Tanzania (Fig. 1), covering the key common ANS growing areas [3,8].

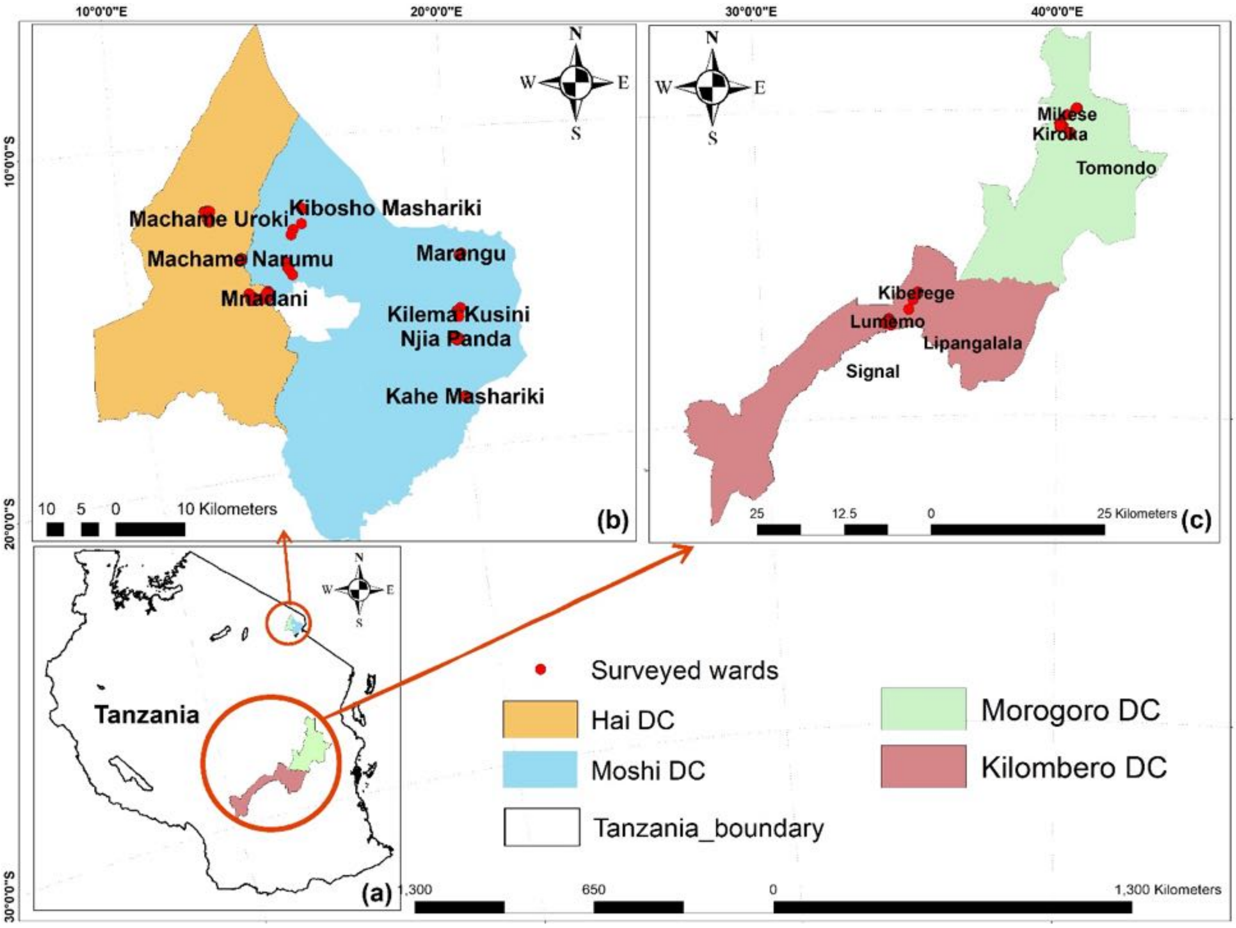

Figure 1: A map of Tanzania showing African nightshades cultivating areas in Hai, Moshi rural, Morogoro rural, and Kilombero districts

Sampling procedure

The survey was conducted in Morogoro and Kilimanjaro regions from April 2019 to August 2019, as shown in Fig. 1. The random sampling was used to select the study site (Kilimanjaro and Morogoro regions), districts of Hai and Moshi Rural in the Kilimanjaro region, and Kilombero and Morogoro Rural in the Morogoro region. In all districts, 20 villages with 627 households/respondents were interviewed for the survey. All household heads (farmers) engaging in the production of ANS were listed by the Village Executive Officers (VEOs) with the assistance of Village Agricultural or Community Development Offices (VADOs). The participants were randomly selected from the lists of all household heads (farmers) provided by VEOs VADOs. Consent to participate in the study was sought from all the participants.

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The household data on cultivation, processing, preservation, utilization, and constraints were collected using semi-structured questionnaires supplemented by the focused group discussions (FGDs). The FGDs were organized through community meetings in two selected villages in each district. About 6 - 10 people participated in FGD in the selected villages. The group includes VADOs, farmers, processors, consumers, and sellers. Both genders were considered in the selection of the participants for FGD. During FGDs, a checklist with guiding questions was used to facilitate the discussion.

Sample calculation

The sample size was determined using the formula, n = $\frac{z^2 p\, q}{r\,(e^2)}$

Whereby; n; sample size, z; statistic for a level of confidence (1.962) at 95%,
p: proportion of the farmers expected to have ANS farms (50%) =0.5,
q (1-p) = the percentage in the selected population not expected to have ANS farms
e; marginal of error (5%) = 0.048,
r; response rate (80%).

In the equation above, the sample size is approximately 522 [12].

Study designs and approach

In this study, a cross-sectional community-based survey was conducted. Qualitative data were collected by FGDs, while quantitative data were collected using a semi-structured questionnaire.

Development of questionnaire, pretesting, and administration

A semi-structured questionnaire was administered through face-to-face interviews by trained enumerators. Enumerators were selected considering their personality (friendly, polite, and open) and gender (equal men and women), nativity to the study area with the bachelor's degree. The Swahili language questionnaire was used since most Tanzania speaks Swahili, but those who did not speak Swahili language enumerators translated it into their native language. Mtshali [41] reported that some communities are sensitive to gender, whereby men prefer being interviewed by men and women prefer being interviewed by women. Therefore, the enumerators worked in pairs. Pretesting of the questionnaire was conducted on a group of non-participating individuals before being issued for data collection.

Ethical clearance

The ethical approval for the study was obtained from the National Institute for Medical Research (NIMR) (NIMR/HQ/R.8a/Vol.IX/3041). Further, permission to conduct surveys in Kilimanjaro and Morogoro regions was sought from the district and regional government authorities.

Data analysis

Statistical Package for Social Sciences (SPSS) version 25. Chi-square was used to compare group differences for categorical variables.

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RESULTS AND DISCUSSION

Socio-economic characteristics of the farmers

A large propositional of ANS farmers (70.4%) were male-headed households. The United Republic of Tanzania [13] reported that 80% of Tanzania households are male-headed. Most farmers, 73.9%, had attained primary education level, 5.7% with non-formal education, and 0.9% had college and university education (Table 1). The head of household (HH) age was between 42-and 53 years, with a household size of five individuals. Likewise, the household size for rural households reported in Tanzania is 5.3 members [13]. The most considerable portion of farmers, 80.5%, were native to the surveyed area. Further, 88.4% and 72.6% of farmers in Kilimanjaro and Morogoro were natives. It could have significance in the high production of ANS because they are native to the area. Small scale farmers (83.3%) were predominant with less than one acre of farm size. Likewise, Abukutsa [4] reported that most farmers (86%) cultivate less than one acre of ANS in Kenya. In Kilimanjaro, 90% or more of the land has been utilized [13]; this contributed to the more significant population cultivating less than one acre [13]. Furthermore, 97.6% of all participants were familiar with ANS (Table 1). The majority of farmers use indigenous knowledge in ANS cultivation such as local fertilizer and pesticides.

Crop production and animal keeping engaged 98.8% of households [13]; however, this study reported that 83.3% of farmers were involved in agricultural activities. Also, 3.6% of participants were older people above 65 years, the dependency group. Nono-Womdim *et al*. [13] reported that 4% of the farmers were above 65 in the national census of smallholder agriculture in Tanzania.

Cultivation of African nightshades

African nightshades grow naturally around farmers' households and farms (79%), especially during the rainy season $p<0.05$. Morogoro (84.9) had the highest rate of naturally growing ANS than Kilimanjaro. In Kilimanjaro, cultivated ANS is common as a result of the low availability of naturally growing ANS. African indigenous leafy vegetables can grow naturally, mainly in home gardens within the homestead [4]. Modern and local varieties of ANS were reported to grow naturally by 44.9% and 83.6%, respectively. The local varieties represent *S. villosum*, *S. nigrum,* and *S. americanum*, while the modern variety refers to *S. scabrum*. A more significant number of farmers (47%) grow modern varieties, and 34.4% grow local varieties of ANS. In both Kilimanjaro and Morogoro regions, 99.4% and 44.7% of farmers produce ANS, respectively. *Solanum scabrum* is highly grown because it is less bitter with large succulent leaves, with rapid new leaf sprouting after harvest and late flowering. It has 40 days of maturity, picking can continue for 6-8 weeks, and resistance to diseases like Fusarium wilt [3,14]. High maturity rate, less use of inputs, less infestation by the pest, and diseases are factors attracting farmers to grow ANS [15]. *Solanum scabrum* is the most grown and available species in SSA with the highest yields [3].

Resembling ANS, a traditional vegetable *Justicia heterocarpa*, (*Mwidu* or *Lichuru*), was found to be highly consumed in Morogoro. *Justicia heterocarpa* is almost similar in taste to ANS besides not being sold in the local markets. The consumers in

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Kilombero district highly prefer *J. heterocarpa.* Also, *Mwidu* grows even better and more than ANS around the family compounds and farms with no input requirement. *Justicia heterocarpa* has been reported to possess several therapeutic properties and is also used to treat various diseases such as fever, headache, Malaria, cancer, diabetes, mental disorder, sedatives, hallucinogens, epilepsy, gastrointestinal diseases, rheumatic, HIV, and inflammation [16–18]. *Justicia heterocarpa* is rich in vitamins, minerals (iron, zinc, calcium, and magnesium), polyphenols and flavonoids, and free fatty acids [16–18]. Various species of *Justicia* are consumed as food in Tanzania, including *Justicia pinguior* [19].

African nightshades cultivation utilizes agriculture inputs, irrigation, and cropping systems, mainly mono- and intercropping (Table 2). Generally, pesticides and fertilizers applications were common in Kilimanjaro. Inorganic pesticides and organic fertilizers application were higher at 77.5% and 45.5%, respectively (Table 2), with inadequate awareness of the benefits of organic pesticides. Studies reported ashes and animal manure as pests and diseases control [4,5]. Irrigation was common in both regions, whereas rivers and ponds were the primary water sources. Likewise, irrigation of ANS was more common during the dry season, with primary water resources from rivers and ponds [20]. In Kilimanjaro, irrigation was facilitated by an extensive network of open, unlined canals, which obtain water from rivers, most of them built centuries ago.

On the other hand, the Kilombero river and water channels in the Kiroka ward facilitated the irrigation of ANS in Morogoro. Both monocropping and intercropping practices were reported, with monocropping being dominant (66%) Table 2. The dominance of monocropping in most ANS farmers in Kenya was reported [21]. Intercropping of ANS during the rainy season was in practice to utilize the land for various crops [4,11]. Furthermore, no mechanization in ANS farming. African nightshades production in most Kenyan societies is still small, with 80% farming less than 0.25 acres using handheld tools such as hand hoe [4].

Furthermore, seasonal production of up to 500 kg was reported by 79 - 85.4% (Fig. 2), indicating the highest amount produced. In contrast, very few farmers could produce more than 500 kg.

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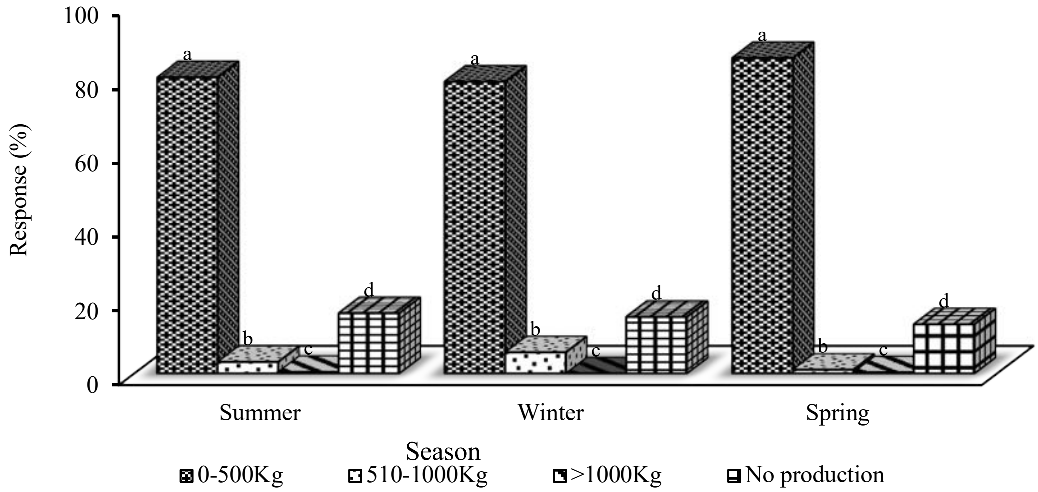

Figure 2: African nightshades yield (kg) during different seasons in Morogoro and Kilimanjaro regions

From the study, several challenges were observed to contribute to the low productivity. Lack of knowledge, pests and diseases (92.9%), lack of extension services, small farm sizes, lack of quality/certified seeds, and shortage of quality fertilizer and pesticides, drought are the primary factors for low productivity (Fig. 3). The typical insect pests of ANS include; aphids, spider mites, red and black ants, cutworms, caterpillars (larvae), grasshoppers, whiteflies, and beetles, sp.), Nematodes [3]. Also, fungi, bacteria, and viruses are the major causes of ANS diseases. According to Dinssa *et al.* [22], low-yielding cultivars, non-application of fertilizer, and poor management result in low ANS production in SSA.

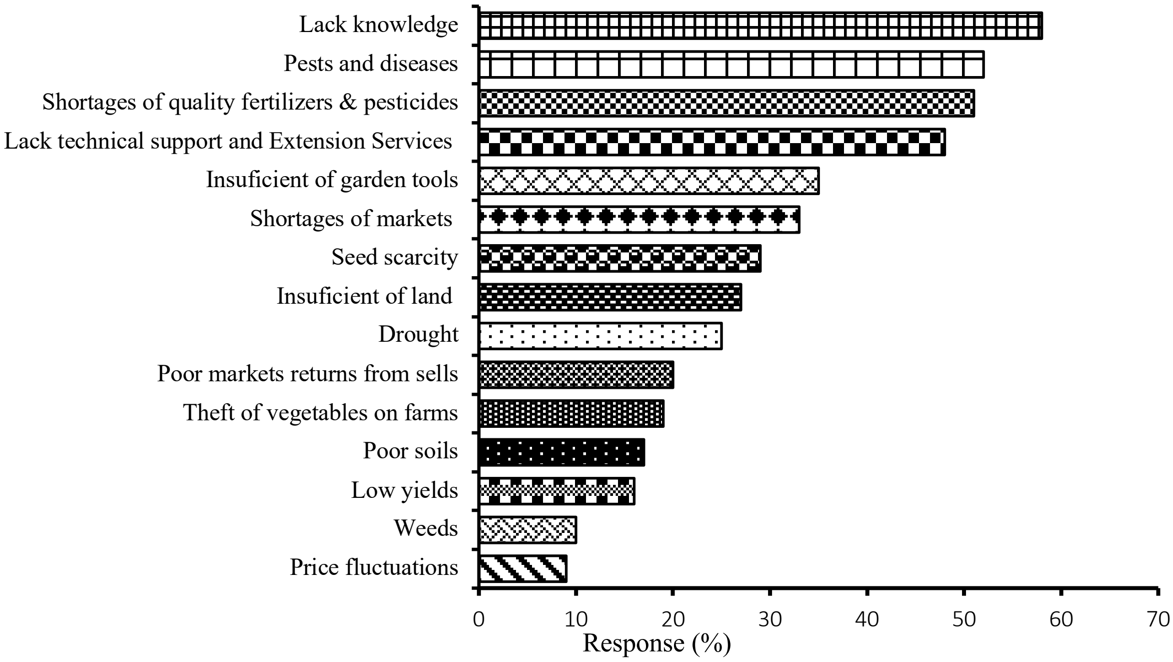

Figure 3: The overall challenges hindering cultivation and increasing post-harvest losses of African nightshades in Tanzania (n=442)

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African nightshades were shown to generate between 5 – 50% of the farmers' income (**Table 3**). Only 4.4% of farmers were earning between 51 - 100% of their income. Long-term benefits from ANS production were reported by 67.2% of the farmers. The annual net value of 5,612,042.25/= TZS on selling ANS, higher than Chinese cabbage and spinach, has been reported [10]. Therefore, ANS cultivation can be a good source of income generation for the farmers contributing to improved livelihoods.

Based on the seasons, ANS productivity was the highest during the dry season and the least during autumn (**Table 4**). Heavy rainfall and lack of a modern cultivation system and greenhouse were the contributors to reducing ANS yields [8,15]. Heavy rains and flooding of the Kilombero river significantly reduced the yield of ANS. Apart from growing ANS, other leafy vegetables such as *Mchunga* (*Launea cornuta*), *Mlenda mgunda* (*Corchorus olitorius*), *Mchicha pori* (*Amaranthus spp.*)*, Mnafu pori or Bwasi* (*Solanum incanum*), *Mlenda mwage* (*Sesbania* spp.), *Mgange*, *Mlenda mwidu* (*Corchorus* spp.) *Matembele pori* (*Ipomoea* spp*.), Kisamvu* (*Manihot grazioli*), Pumpkin leaves (*Cucurbita pepo* (L.), *Mashona nguo* (*Bidens pilosa*), *Kunde pori* (*Vigna vexillata*), and African eggplants (*Solanum macrocarpon.*) were grown in high quantity. Additionally, cowpea leaves (*Vigna unguiculata*), sweet potatoes leave (*Ipomoea batatas* (L.), beans leave (*Phaseolus vulgaris*), and cassava leaves (*Kisamvu-muhogo* (*Manihot esculenta*) and *Kisamvu-mpira* (*Manihot glaziovii*) **Table 4**. These vegetables are abundant during rainy seasons to reduce the demand for ANS, and some can be obtained for free such as *Mwidu* (*Justicia hetorocarpa*). On the other hand, exotic vegetables such as spinach (*Spinacia oleracea*), Chinese cabbage-*Michihili* (*Brassica rapa spp.*), and cabbages (*Brassica oleracea* var. capitate) were also grown. The availability of other leafy vegetables reduces the consumption of ANS. African nightshades had stiff competition with cabbage, spinach, kale, and lettuce [4].

From the study, it was found that little value addition is done to ANS. Freshly harvested ANS was directly sold to consumers with no value addition. Nonetheless, ANS contributed to the income generation of farmers; besides, it was not sustainable. Therefore, value addition can optimize profits generated from ANS if well considered. Products such as dried and fermented (pickles) ANS could add more value, contributing to farmers' household income. Notably, fresh ANS is highly perishable; therefore, farmers encounter substantial losses.

Utilization and value chain of African nightshades

Large propositional of farmers, 96.1% consume ANS in Kilimanjaro and Morogoro regions. African nightshades are grown for food and income generation (Fig. 4), similar to Kenya [15]. Many household members consumed ANS, and the least consumers were children below five years. Most farmers consume ANS since it is nutritious and make them strong [11]. Generally, ANS can be consumed alone (84.1%) and sometimes blended with other vegetables (48.6%) during cooking. Further, amaranth (73.8%), spinach (59.3%), pumpkin leaves (20.3%), and cowpeas leave (12.5%) are vegetables blended with ANS, whereas potato leaves (9.2%) and bean leaves (7.5%) are the least. Other foods reported to be mixed with ANS include meat (92.4%), internal organs such as intestines (30.6%), fish (31.2%), and eggs (1.4%); moreover, they were

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pre-cooked in advance. Incorporating ANS into meat, other vegetables, and legumes improves taste, appetite, and nutritional quality. Mixing cowpea leaves into ANS increased carotenoids and vitamin C [23]. Singly prepared ANS and combined with other vegetables did not influence sensory acceptability, although a mixture of ANS and cowpea increased carotenoids and vitamin C [23,24]. Overcooking ANS with meat or fish facilitates the degradation of essential micronutrients such as vitamin B, C, β-carotene, and iron [25]. Various reasons such as improving taste (82.4%), improving appetite (57.2%), and reducing bitterness (38.8%) necessitate blending of ANS with other foods.

Interestingly, ANS can be accompanied by several staples, including *ugali* (96.9%), rice (60.4%), *Makande* (17.6%), and cooked green banana (12.1%). Cooked nightshades leafy were reported to be served with *fufu* or *ugali* [26]. In East Africa, ANS can be blended with amaranth, spinach, kale, and cabbages and accompanied by staples such as stiff porridge (*ugali*), rice, yams, banana, and cassava [1,4].

Local varieties of ANS, especially the bitter ones, were mainly preferred (75%) instead of exotic types (24.9%). Consumption of ANS is expected to increase in the next five years, reported by 69.4% of farmers. Due to the absence of diverse varieties of processed ANS products, about 46.3% of farmers would consume fermented ANS. Almost 53.1% of participants consume ANS for its nutrients; however, other reasons include bitter taste (33.6%) and improving appetite (30.8%). It was also observed that ANS is consumed based on gender, whereby men prefer bitter dark variety. African nightshades were reported to be used mainly as food in both Morogoro and Kilimanjaro regions. Nevertheless, in Kilimanjaro, ANS is more utilized for commercial purposes. The presence of national and international research institutions, including the Asian Research and Development Centre (AVRDC), Seeds of Expertise for the Vegetable Sector in Africa (SEVIA), and the International Institute of Tropical Agriculture (IITA), might have contributed to promoting high production and utilization of AIVs around northern zone regions such as Kilimanjaro, Arusha, and Tanga.

On the other hand, ANS is also used as medicine (38%) and animal feeds (41.3%) (Fig. 4). African nightshades have been exploited for food, drugs, animal feed, and spirituality, but the vegetable has been less exploited for economic benefits in SSA countries [4,5]. As a source of medicine, ANS is used to cure and bring relief to various diseases such as malaria and stomach complications. Some consume ANS to recover the lost or poor appetite due to illness [5,25]. Further, it was reported to clean blood, cure stomach complications, low blood pressure, improve CD4 for immune-compromised people, fatigue, boils, and improve men's libido [5,25]. Besides, it cures hemorrhage, wounds, itching in pubic parts, wounds in the anus, hernia, malaria, pressure, pneumonia, diabetes, eyes, headache, and skin disease [3,5,7,11,20]. Also, the roots and fruits of ANS are used for food therapeutical purposes [3,5].

The marketing channels for fresh, cooked, and processed ANS is via open markets (54.1%), homes (32%) and hotels (23.8%), supermarkets (19.6%), kiosks (15.0%), and farms or gardens (13.6%). About 70.2% of ANS is sold as wholesales, 14.2% retailers or local markets (52.4%), whereas only a tiny fraction is processed (1.3%). A study in

Kenya reported large quantities of ANS being sold to wholesalers, besides in supermarkets, it fetches a higher price than in other places [27].

Postharvest handling of African nightshades
Harvesting Techniques
Factors to consider during harvesting ANS mainly includes; the right maturity, harvesting time, and immediate storage conditions; practically, ANS can be harvested either in the morning or evening, but morning time was preferable (67.7%) ($p < 0.001$). In Morogoro, 85.1% of farmers harvest in the morning, whereas 75% in Kilimanjaro harvest in the evening. Harvesting in the late evening or morning after dew evaporation from the leaves and before the sun becomes too hot is highly recommended [11].

Harvesting of ANS begins after 3-4 weeks, mentioned by 46.2%. However, the early harvest starts at 1-2 weeks after planting, reported by 38.5%, and the late harvest takes place at 5-6 weeks; the harvesting time had a significant difference ($p < 0.001$). Moreover, the first harvest usually takes place 4-5 weeks after sowing [4]. African nightshades re-harvesting is done every week after the first harvest, reported by 67.8% of farmers, with very few farmers harvesting after every two weeks ($p < 0.001$). The harvest termination was reported to occur after three months since planting from the nursery mentioned by 22.9% of farmers, while other farmers terminated harvest in two, four, five, and six months respectively ($p = 0.001$). A study [4] reported that harvesting could go up to 5 months, including two months of seed maturity. Furthermore, the harvest duration of ANS depends on a sufficient supply of nutrients and seasons [4,28].

Harvesting of ANS can be done by cutting the tender leaves, either by hand pinching 50.3% or cutting with a knife (46%). Very few farmers, 18.4%, were harvesting ANS by uprooting the whole shoot. This practice was commonly done when ANS reached maturity. Pinching is the common method for harvesting ANS involves removing terminal buds that encourage the branching of plants. Pinching delayed flowering and increased the leaves of amaranths and cowpeas, eventually increasing the yields and influencing the' plant's nutritional composition [4,29]. Cutting lateral and main stems 5 - 10 cm from the tip improved the ANS yield, thus stimulating side shoots [1].

Handling of African nightshades
The handling of ANS is done immediately after harvesting. Washing was done by 79.9% of farmers to remove physical contaminants such as sands and debris. Only 26.7% of farmers were using portable water. The water sources were boreholes (49.1%), rivers (44.9%), and dams (15.9%). Vegetable washing after harvest was a common practice of most farmers; cleaning, sorting, grading, trimming, and packaging are necessary practices to remove any dirt or residue particles, agents of microbial contamination [28]. The use of non-potable water for washing fresh ANS after harvesting was common. This practice increases the chance of microbial contamination and accelerates the deterioration rate of vegetables. Likewise, [20] observed that 52% of growers did not wash the harvested nightshades.

On the other hand, various methods were utilized to cool fresh ANS, including sprinkling with water (57.3%) and placing it under the shade (34.5%). Other practices

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include dipping in water (8.7%) and placing outside for an overnight (9.4%). Moreover, setting ANS outside overnight was commonly done immediately after harvesting or when it remained unsold. Additionally, the use of refrigeration and traditional cooling chambers (zero-energy cooling chambers) were reported by 27.2%, and 35.5%, respectively. Notably, 19.1% of farmers did nothing to cool the ANS. Since ANS is highly perishable, the chance of spoilage increases rapidly with storage time, incredibly when poorly handled [27]. Therefore, cooling is essential to remove field heat within a short period. According to Gogo et al. [30], covering ANS with banana leaves with water sprinkling can keep the ANS fresh. The standard methods include placing the vegetables under shade, sprinkling with water, and dipping in water [30]. Besides, a zero-energy cooling chamber can preserve the nightshades for 3–7 days or more [30]. Therefore, postharvest handling of ANS can extend shelf life, ensure a constant supply, reduce losses, and lead to nutritious and safe food for the consumers.

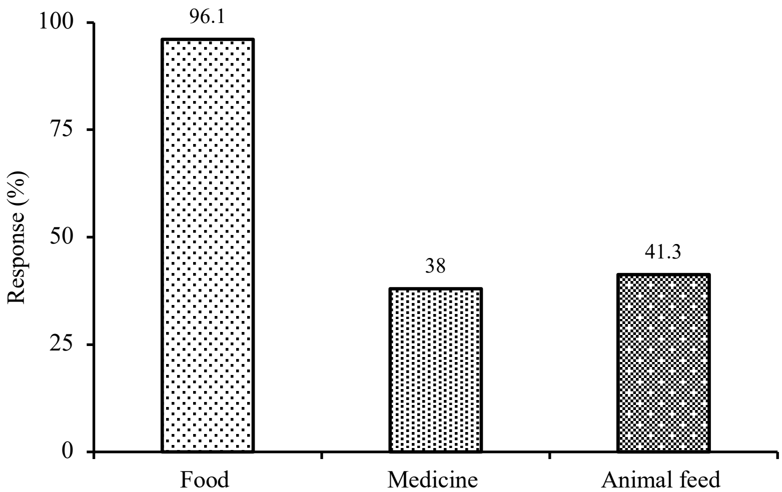

Figure 4. Utilization of African nightshades (n=560)

Transportation of African nightshades

Transportation of ANS was done from the farms to the marketplace. Common means of transportation were carrying on the head (50.4%), use of motorcycles (44.9%), bicycles (32.3%), carts (10%), and trucks (16.0%). Different carrying containers were used although, bamboo woven containers (*Matenga*) were highly preferred 34% ($p < 0.05$). Other containers include polyethylene bags, plastic sacks or nylon, sisal sacks, and wooden crates (Fig. 5).

Matenga is woven bamboo crates perforated and prevents mechanical damage; thus, it can keep ANS fresh for some time. Using plastic gunny bags to transport fresh can increase damage since fresh vegetables are fragile and brittle. Mechanical damage to vegetables causes leafy tearing and crushing, midrib breakage, head cracking, or bruising. It increases the oxidation of phenolic compounds and increases susceptibility to decay. Also, damaged leaves allow water loss by 3-4 times of undamaged vegetables [31]. Using non-perforated polythene or nylon-reinforced increases wilting, and metabolic activities and favors microbial spoilage [20,30,32]. Proper handling of vegetables during transportation can minimize postharvest losses. Therefore, vegetables

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should be kept at the optimum temperature and humidity to reduce respiration and transpiration [3].

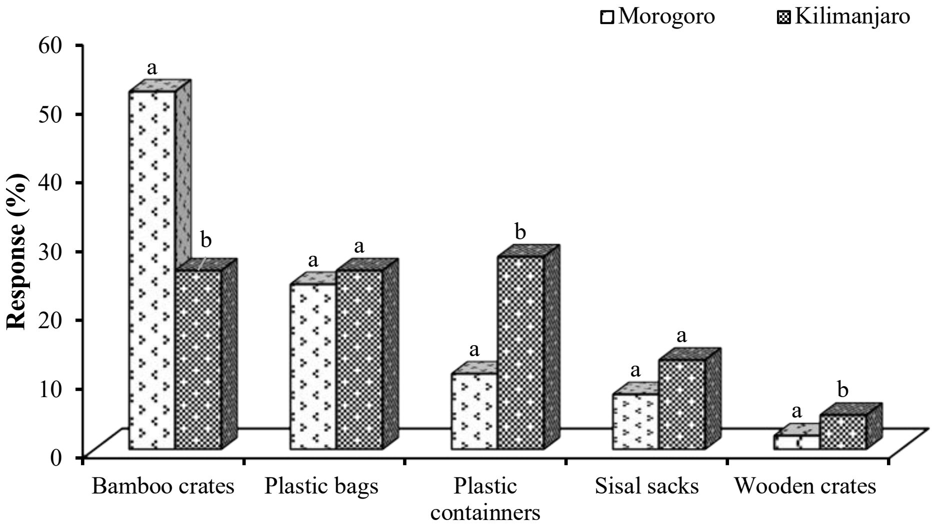

Figure 5: Containers used for handling fresh African nightshades. Different letters for an attribute indicate a significant difference at $p < 0.05$

Processing and preservation of African nightshades

Approximately 60.9% of farmers process (frying and boiling) ANS, though only 26.2% used portable water in cooking and other processing activities. The common sources of water for cooking ANS were government tap water 34.6%, river water 30.1% ($p = 0.772$), pond water 29.3% ($p = 0.68$), rainwater 26.4% ($p = 0.001$) and well water 17.0% ($p = 0.001$). The source of energy for cooking ANS were, firewood 88.0% ($p = 0.001$), charcoal 64.9% ($p = 0.001$), maize cobs 12.8% ($p = 0.76$), kerosene 3.4% ($p = 0.36$) and gas 1.6% ($p = 0.001$). Frying (45.4%) and boiling (63.0%) Table 5, were the main processing and preservation methods for ANS, with minimal drying and fermentation. Firewood was the essential heating energy used in processing; however, it may accelerate environmental degradation [33]. Cooking with firewood produces various airborne toxins, resulting in poorer respiratory health [34] and imparts undesirable sensory properties to the food.

Different preparation methods for ANS were reported, whereas boiling, stir-frying with cooking oil, onion, and tomatoes, and stir-frying with cooking oil and onion were most preferred. In contrast, fermentation and blanching were the least preferred (Table 5). African nightshades can be cooked in different ways, such as boiling or frying with onions and tomatoes or adding milk and cream to improve the taste [5]. On the other hand, ANS by-products were reported to be used as animal feeds 38.3% ($p = 0.03$), manure 35.2% ($p = 0.001$), disposal as waste 34.1% ($p = 0.001$), medicinal 10.0% ($p = 0.001$) and sources of biogas 1.8% ($p = 0.001$). The utilization of ANS by-products reduces environmental degradation and reduction of greenhouse gas (GHG) emissions, consequently preventing global warming.

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From the study, several factors were reported to hinder the processing and preservation of ANS. Lack of knowledge of processing (62.0%), lack of cold storage facilities or refrigeration (29.0%), and high cost of electricity (28.6%) are the main factors. Furthermore, electricity shortages and frequent shutdowns (22.4%), unavailability of enough raw materials (21.6%), and lack of sustainable markets (16.3) % were also reported. This further suggests that 41.4% of farmers stored ANS at ambient temperature, and 27.2% used refrigeration.

Constraints to the utilization of African nightshades

Higher PHL losses of African nightshades

African nightshades undergo loss through improper postharvest handling. Farmers were experiencing losses of fresh ANS by 53.6% as a result of poor post-harvest handling. Poor handling results in a qualitative and quantitative loss of vegetables, including flavor, texture, and nutritional quality [3,35]. Lack of knowledge on proper postharvest handling methods, shortage of market, poor market return from sales, and price fluctuation were the causes of ANS losses along the value chain (Fig. 3). Notably, the majority of the farmers experienced < 10% of fresh ANS losses during transportation and storage. On the other hand, very few farmers experienced losses between 20 - 30% (Table 6). Therefore, postharvest losses of ANS can occur at any point along the value chain. About 20 - 50% of all vegetables produced in SSA undergo loss [36,37]; similarly, 50% of postharvest losses of AIVs were reported in Kenya [30]. The losses of vegetables can occur during harvesting, storage, packaging, and transportation[38]; besides, factors affecting postharvest losses vary from place to place [1].

Microorganisms are the primary causative agent of postharvest loss of fresh vegetables if they are not well handled [31]. Therefore, ANS needs quick handling after harvesting, such as cooling, to preserve its quality [3]. The vegetables should be stored at 5-10 °C for a long storability [4,30]. Besides, modern cooling techniques, such as refrigeration, are less feasible in rural and peri-urban areas where horticultural farming is mainly practiced [39]. Alternatively, a zero-energy cooling chamber should be considered in rural areas [39]. The rapidly growing population and demand for nutritious foods increase the demand for AIVs in SSA; hence, vegetable loss should be reduced [24].

From the study, different methods of handling ANS, such as selling immediately after harvest (61.9%), harvesting in small quantities (54.5%), market searching before harvesting (47.7%), and storage in a cold environment (22.2%), were employed to minimize spoilage of fresh ANS. Other methods include the use of proper packaging (15.6%), minimizing mechanical damage (14.9%), and drying (5.3%). Farmers were reportedly selling ANS immediately after harvest as the main alternative way to control postharvest loss. Once farmers fail to sell their day produce, they encounter loss due to limited shelf life and lack of postharvest handling techniques [40]. Most sellers strive to finish all fresh ANS supplied on the delivery day; whatever remains is thrown as waste [27]. The chance of deterioration increases within 24 hours if ANS is not sold immediately after harvest. Some farmers/sellers sprinkle water and leave the vegetables in the open space overnight; however, microbial contamination still hinders their effort [30]. In Tanzania's public markets, sellers had no access to refrigeration, accelerating

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postharvest losses and reducing ANS utilization [20]. Postharvest handling of vegetables has led to safe and nutritious food for consumers [3,40]. Therefore, proper postharvest handling of fresh vegetables should be applied to minimize losses.

CONCLUSION

African nightshades are important AIVs in Tanzania due to their nutritional value and contribution to livelihoods. Small farm sizes were common for both local and modern varieties. African nightshades production is hampered by insect pests and diseases with intensive inorganic pesticides and fertilizers application. ANS contributed between 5-50% of the household income. African nightshade is highly utilized as food and consumed with very minimal value addition. Frying and boiling were the main preparation methods for ANS served with many staple foods. Poor post-harvest handling and preservation of ANS were the primary causes of losses. Minimal losses of ANS occurred during transportation and storage. Various postharvest handling methods, mainly washing and cooling with water, were employed for shelf life extension. However, lack of processing knowledge, inadequate storage facilities, and unreliable energy sources were the constraints for ANS utilization. Training on production, pre-harvest, and post-harvest handling and preservation techniques such as fermentation and drying can improve ANS accessibility and utilization.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Table 1: Socio-economic characteristics of the African nightshades' farmers

Variable		Districts					Chi-Square (χ^2)
Parameter		**Morogoro Rural**	**Kilombero DC**	**Moshi Rural**	**Hai DC**	**Mean (SD)**	**Level of Significance**
Gender (%)	Male	81.6	49.3	72.7	78.0	70.4 (14.5)	χ2=46.89, df=1, p=0.001
	Female	18.4	50.7	27.3	22.0	29.6 (14.5)	
Education level (%)	None	11.8	5.9	2.7	2.3	5.7 (4 .4)	χ2 = 0.81; df = 1; p = 0.3
	Primary	84.2	77.6	73.2	60.7	73.9 (9 .9)	
	Secondary	2.6	15.1	10.3	15.3	8.7 (5.9)	
	College & University	0.5	0.5	1.1	2.1	1.1 (0.9)	
Place of Birth in (%)	Native	68.9	76.3	89.8	86.9	80.5 (9 .7)	χ2=0.4, df=1, p=0.41
	Migrant	31.1	23.7	10.2	13.1	19.5 (9.7)	
Age	16-41	19.4	18.4	26	16.2	20 (4.3)	χ2=210.158, df=1, p=0.01
	42-53	35.5	38.2	34.7	35.9	36.1 (1.5)	
	54-65	17.2	19.1	9.3	28.3	18.5 (7.8)	
	66-77	7.1	3.3	4.0	2.4	4.2 (2.0)	
	78+	0.0	2.6	0.0	1.2	1.0 (1.3)	
Household size (%)	1–5	63.2	58	60	54.9	59 (3.5)	χ2=322.689, df=2, p=0.04
	6–10	32.2	40.1	40	45.1	39.4 (5.3)	
	>10	4.6	1.3	0.0	0.0	1.5 (2.2)	
	Mean (SD)	5±2.7	5±2.1	5±1.8	5±1.8	5 (2.1)	
Farm Size	<1 acre	65	55	68	70	64.5	χ2 = 3.83; df = 1; p = 0.17
	1-5 acres	30	34	29	26	29.8	
	Above 5 acres	5.0	11	3.0	4.0	5.8	
Occupation (%)	Farmer	86.9	93.2	81.2	72	83.3 (9)	χ2=0.9, df=1, p=0.29
	Farmers& business	7.5	4.1	0.2	17.8	9.9 (5.8)	
	Farmer & teacher	0.9	1.4	5.7	3.3	2.8 (2.2)	
	Farmers & doctor	0.6	1.4	-	1.9	1.3 (0.7)	
	Farmer & other	4.1	0.0	2.8	5.1	3.0 (2.2)	
Knowledge of ANS (%)	Yes	96.0	94.1	100	100	97.6 (3)	χ2=0.23, df=1, p=0.62

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Table 2: Different practices conducted during the production of African nightshades

Items	(%)	(n)	Chi-Square ($\chi 2$)
Agricultural inputs			
Pesticide	70.7	299	$\chi 2 = 115$; df = 1; p = 0.001
Inorganic pesticide	77.5	121	$\chi 2 = 34.83$; df = 1; p = 0.001
Organic pesticides	45.5	121	$\chi 2 = 5.11$; df = 1; p = 0.024
Fertilizer	64.8	330	$\chi 2 = 165.53$; df = 1; p = 0.001
Inorganic fertilizer	49.8	330	$\chi 2 = 7.5$; df = 1; p = 0.006
Organic fertilizer	70.6	330	$\chi 2 = 36.3$; df = 1; p = 0.001
Handheld tools	98.3	300	$\chi 2 = 4.77$; df = 1; p = 0.029
Oxen-drawn ploughs	4.8	300	$\chi 2 = 7.3$; df = 1; p = 0.007
Irrigation	79.4	504	$\chi 2 = 7.69$; df = 1; p =0.01
Sources of water (n=479)			
Rivers	49.9		$\chi 2 = 7.19$; df = 2; p = 0.028
Ponds	35.5		$\chi 2 = 21.58$; df = 1; p = 0.001
Wells	31.7		$\chi 2 = 8.22$; df = 1; p = 0.004
Tap water	5.0		$\chi 2 = 5.73$; df = 1; p = 0.017
Springwater	5.7		$\chi 2 = 5.99$; df = 1; p = 0.014
Cropping system (n=379)			
Monocropping	66.3		$\chi 2 = 0.01$; df = 1; p = 0.97
Intercropping	39.8		$\chi 2 = 2.27$; df = 1; p = 0.132

Table 3: Contribution of African nightshades to the household income of the farmers (n=158)

Income (%)	Morogoro	Kilimanjaro	Average	Chi-Square (χ^2)
<5	46.80	39.20	43	$\chi 2 = 17.55$; df = 10; p = 0.063)
5-50	49.3	56	52.7	
51-100	3.9	4.8	4.4	

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Table 4: Production of other leafy vegetabales and African nightshades in Morogoro and Kilimanjaro regions

Items (%)	Morogoro	Kilimanjaro	Chi-Square (χ2)
Other leafy vegetables (n=466)			
Spinach	59.3	71.6	χ2 = 5.73; df = 1; p = 0.017
Chinese cabbage	43.4	35.5	χ2 = 2.17; df = 1; p = 0.14
Cabbage	16.8	50.7	χ2 = 38.67; df = 1; p = 0.001
Cowpeas leaves	30.1	13.5	χ2 = 15.16; df = 1; p = 0.001
Sweet potatoes leaves	31.0	5.1	χ2 = 51.15; df = 1; p = 0.001
Beans leaves	20.4	14.9	χ2 = 1.79; df = 1; p = 0.18
Cassava leaves	29.2	5.4	χ2 = 43.92; df = 1; p = 0.001
ANS production seasons (n=420)			
Spring	44.1	37.7	χ2 = 1.65; df = 1; p = 0.199
Autumn	24.3	29.9	χ2 = 1.50; df = 1; p = 0.221
Winter	44.1	33.0	χ2 = 5.09; df = 1; p = 0.02
Summer	58.1	66.4	χ2 = 2.83; df = 1; p = 0.93
Reason to grow ANS (n=409)			
High maturity rate	30.9	44.9	χ2 = 5.64; df = 1; p = 0.02
Less input needed	42.3	28.4	χ2 = 6.23; df = 1; p = 0.01
Less infestation pest and diseases	44.5	18.9	χ2 = 22.73; df = 1; p = 0.01
High yield	21.9	63.2	χ2 = 14.44; df = 1; p = 0.01
High profit	19	20.6	χ2 = 0.13; df = 1; p = 0.72
Consumer's preference	29.2	16.1	χ2 = 7.18; df = 1; p = 0.007
Bitter test	19.7	38.1	χ2 = 11.79; df = 1; p = 0.01
Resistant to draught	20.4	19.6	χ2 = 0.03; df = 1; p = 0.863

Table 5: Different processing and preservation techniques of African nightshades

Practice (n=469)	Morogoro (%)	Kilimanjaro (%)	Chi-Square (χ^2)
Boiling	70.9	55.1	χ2 = 61.3; df = 1; p = 0.001
Stir-frying	53.4	37.4	χ2 = 2.8; df = 1; p = 0.09
Sun drying	12.3	2.7	χ2 = 12.5; df = 1; p = 0.001
Solar drying	-	2.7	χ2 = 5.3; df = 1; p = 0.02
Blanching	0.5	0.5	χ2 = 0.01; df = 1; p = 0.97
Fermentation	-	1.1	χ2 = 2.1; df = 1; p = 0.15

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Table 6: The quantities of African nightshades lost during transportation and storage (n=344)

Point in the value chain	Quantity (%)	Morogoro	Kilimanjaro	Average	Chi-Square (χ^2)
Transportation	<10	83.00	66.30	69.40	$\chi2 = 7.86$; df = 5; p = 0.16
	20	10.60	22.00	19.80	
	30	4.30	6.30	6.00	
Storage	<10	87.1	58.5	63.9	$\chi2 = 12.55$; df = 6; p = 0.051
	20	6.5	23.7	20.5	
	30	-	12.6	10.2	

REFERENCES

1. **Yang RY and C Ojiewo** African nightshades and African eggplants: Taxonomy, crop management, utilization, and phytonutrients. *ACS Symp. Ser.* 2013; **1127:** 137–165.

2. **Yuan B, Byrnes D, Giurleo D, Villani T, Simon JE and Q Wu** Rapid screening of toxic glycoalkaloids and micronutrients in edible nightshades (Solanum spp.). *J. Food Drug Anal.* 2018; **26:** 751–760.

3. **Sangija F, Haikael M and A Matemu** African nightshades (*Solanum nigrum* complex): The potential contribution to human nutrition and livelihoods in sub-Saharan Africa. *Compr Rev Food Sci. Food Saf.* 2021, 1–35.

4. **Abukutsa OM** The diversity of cultivated African leafy vegetables in three communities in Western Kenya. *African J. Food Agric. Nutr. Dev.* 2007; **7:** 1–15.

5. **Ontita E, Onyango C, Onwonga R and D Nyamongo** Indigenous knowledge on the uses of African nightshades *(Solanum nigram* L.) Species among Three Kenyan communities. *Asian J. Agric. Extension, Econ. Sociol.* **2016**; **14:** 1–8.

6. **Wafula EN** Effects of postharvest-processing technologies on the safety and quality of African indigenous leafy vegetables, University of Hamburg, 2017, Vol. 102.

7. **Edmonds JM and JA Chweya** *Black nightshades. Solanum nigrum L. and related species. Promoting the conservation and use of underutilized and neglected crops*; Gatersleben/International Plant Genetic Resources Institute: Rome, Italy, 1997; ISBN 9290433213.

8. **Weinberger K and J Msuya** *Indigenous Vegetables in Tanzania. Significance and Prospects*; Kalb, T., Ed.; AVRDC—The World Vegetable Center, Technical Bulletin No. 31, AVRDC Publication 04-600: Shanhua, Taiwan, 2004; Vol. 31; ISBN 9290581360.

9. **Keller GB** African nightshades, eggplant, spiderflower et al.–production and consumption of traditional vegetables in Tanzania from the farmers point of view, Georg-August Universität Göttingen, 2004.

10. **Molina PB, D'Alessandro C, Dekeyser K and M Marson** *Sustainable food systems through diversification and indigenous vegetables. An analysis of the Arusha area*; 2020.

11. **Abukutsa-Onyango MO** African nightshade: broad leaved nightshade. *Jomo Kenyatta Univ. Agric. Technol.* 2015; 1–2.

12. **Barlett JE, JW Kotrlik and CC Higgins** Organizational Research: Determining Appropriate Sample Size in Survey Research. *Inf. Technol. Learn. Perform. J.* 2001; **19:** 43–50.

13. **United Republic of Tanzania (URT).** *National Sample Census of Agriculture Small Holder Agriculture Volume Ii: Crop Sector, National Report.*; 2012.

14. **Nono-Womdim R, Ojiewo C, Abang M and MO Oluoch (Eds)** Good Agricultural Practices for African Indigenous Vegetables. In Proceedings of the Proceedings of a Technical Consultation Workshop Held in Arusha, Tanzania; 2009.

15. **Muhanji G, Roothaert RL, Webo C and M Stanley** African indigenous vegetable enterprises and market access for small-scale farmers in East Africa African indigenous vegetable enterprises and market access for small-scale farmers in East Africa. *Int. J. Agric. Sustain.* 2011; **9:** 194–202.

16. **Al-Juaid S S and MA Abdel-Mogib** Novel Podophyllotoxin Lignan from Justicia heterocarpa. *Chem. Pharm. Bull. (Tokyo).* **52:** 507 509.

17. **Corrêa GM and AFDC Alcântara** Chemical constituents and biological activities of species of Justicia - a review. *Brazilian J. Pharmacogn.* 2012; **22:** 220–238.

18. **Mbaveng AT, Hamm R and V Kuete** Harmful and Protective Effects of Terpenoids from African Medicinal Plants. *Toxicol. Surv. African Med. Plants* 2014; 557–576,

19. **Ruffo CK, Birnie A and B Tengnäs** Edible wild plants of Tanzania. In Proceedings of the RELMA Technical Handbook Series 27; Regional Land Management Unit (RELMA), Swedish International Development Cooperation Agency (Sida): Nairobi, Kenya, 2002.

20. **Lotter DW, Marshall MI, Weller S and A Mugisha** African indigenous and traditional vegetables in Tanzania: production, postharvest management and marketing. *African Crop Sci. J.* 2014; **22:** 181–189.

21. **Onyango C, Ontita E, Onwonga R, Desterio N and J Gapusi** Status and Production Practices of Vegetable African Nightshade (*Solanum nigrum* L.) in Selected Communities of Kenya. *Am. J. Exp. Agric.* 2016; **13:** 1–12.

22. **Dinssa FF, Hanson P, Dubois T, Tenkouano A, Stoilova T, Hughes JA and JDH Keatinge** AVRDC – The world vegetable center's women-oriented improvement and development strategy for traditional African vegetables in sub-Saharan Africa. *Eur. J. Hortic. Sci.* 2016; **81:** 91–105.

23. **Oluoch MO, Habwe FO, Ngegba JB, Koskei KR and RY Yang** Food Preparation and Processing Methods on Nutrient Retention and Accessibility in Selected Indigenous Vegetables from East Africa. 2012; **15:** 233–241.

24. **Habwe FO and KM Walingo** Food Processing and Preparation Technologies for Sustainable Utilization of African Indigenous Vegetables for Nutrition Security and Wealth Creation in Kenya. *Int. Union Food Sci. Technol.* **2008**, 1–8.

25. **Shackleton CM, Pasquini MW and AW Drescher** *African indigenous vegetables in urban agriculture*; Shackleton, C.M., Pasquini, M.W., Drescher, A.W., Eds.; CPI Antony Rowe: United Kingdom, 2009; ISBN 9781849770019.

26. **Chagomoka T, Kamga RT, Tenkouano A and M Mecozzi** *Traditional Vegetables Recipes from Cameroon*; AVRDC – The World Vegetable Center: Shanhua, Tainan, 2014.

27. **Onyango CM and JK Imungi** Post-harvest handling and characteristics of fresh-cut traditional vegetables sold in Nairobi-Kenya. *African Crop Sci. Soc.* 2007; **8:** 1791–1794.

28. **Nyaura J A, Sila DN and WO Owino** Post Harvest Stability of Vegetable Amaranthus (Amaranthus Dubius) Combined Low Temperature And Modified Atmospheric Packaging. *Food Sci. Qual. Manag.* 2014; **30:** 66–73.

29. **Koile S** Influence of Fertilizer Application, Time of Pinching and Harvesting Method on Growth, Yield and Nutritional Quality of Cowpea (Vigna Unguilata L.) and Spider Plant (*Cleome gynandra* L.). **2018**.

30. **Gogo OE, Opio MA, Ulrichs C and S Huyskens-Keil** Postharvest treatments of African leafy vegetables for food security in Kenya: A review. *African J Hort Sci.* 2016; **9:** 32–40.

31. **Acedo AL** *Postharvest Technology for Leafy Vegetables*; Mecozzi, M., Ed.; AVRDC-ADB Postharvest Projects RETA 6208/6376: AVRDC Publication No. 10-733. AVRDC - The World Vegetable Center, Taiwan., 2010.

32. **Vigneaultl C, Thompson J, Wu S, Catherine KP, Hui KPC and DI LeBlanc** Transportation of fresh horticultural produce. *Res. Signpost* 2009; **2:** 1–24.

33. **Jung JH and M Uxham** Firewood usage and indoor air pollution from traditional cooking fires in Gazi Bay, Kenya. 2019; **11:** 1–12.

34. **Silwal AR and A Mckay** The Impact of Cooking with Firewood on Respiratory Health : Evidence from Indonesia The Impact of Cooking with Firewood on Respiratory Health : Evidence from Indonesi**a. 2016;** *0388*.

35. **Wakholi C, Cho BK, Mo C and MS Kim** Current State of Postharvest Fruit and Vegetable Management in East Africa. 2015; **40:** 238–249.

36. **Global Panel.** *Preventing nutrient loss and waste across the food system: Policy actions for high-quality diets. Policy Brief No. 12. London, UK: Global Panel on Agriculture and Food Systems for Nutrition*; 2018.

37. **Kitinoja L and AA Kader** *Measuring postharvest losses of fresh fruits and vegetables in developing countries*; 2015.

38. **Katinka W and LAJ Eds Acedo** *Best practices in postharvest management of leafy vegetables in Greater Mekong Subregion countries: Proceedings of a GMS workshop*; AVRDC-The World Vegetable Center, Taiwan: Hanoi, Vietnam, 2007; ISBN 9290581786.

39. **Ambuko J and F Wanjiru** Chemining'wa, G.N.; Owino, W.O.; Mwachoni, E. Preservation of Postharvest Quality of Leafy Amaranth (Amaranthus spp.) Vegetables Using Evaporative Cooling. *J. Food Qual*, 2017; 1–7.

40. **Shiundu KM and RK Oniang'o** Marketing African Leafy Vegetables: Challenges and Opportunities in the Kenyan Context. *African J. Food Agric. Nutr. Dev.* 2007; **7:** 1–16.

41. **Mthali SM** Household Livelihood Security in Rural KwaZulu-Natal, South Africa. *Wageningen University and Research*, 2002.