Assessing harvesting and postharvest handling practices of *Strychnos cocculoides* fruit in the Kavango West Region of Namibia

by
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Thesis presented in fulfilment of the requirements for the degree of Master of Science in Forestry and Natural Resource Sciences in the Faculty of AgriSciences at Stellenbosch University

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2016

Declaration

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December 2016

Abstract

Traditional harvesting methods used by rural people to harvest indigenous fruit remain a challenge in rural communities. Such methods lead to post harvest losses of fruit. This study was conducted in Ncuncuni Constituency of Kavango West Region; Namibia. It focused mainly on two villages namely, Kaguni and Mile 20. The study sought to assess harvesting and postharvest handling practices of *Strychnos cocculoides*. Specifically the study identified existing harvesting and postharvest handling practices. It assessed the level of postharvest losses of *S. cocculoides* fruit at different handling practices and maturity stages. It further assessed fruit quality in terms of Total Soluble Solids (TSS), taste, size, and weight.

Data was collected between September and October 2015 by means of semi structured and a consumer preferences questionnaire. Focus group discussion and direct observations were also employed during data collection. A total of 160 harvesters and 150 consumers from both study sites were interviewed. The findings indicated the fruit are harvested between June and December mainly by women and children. The fruit were harvested in crop fields and communal forests mainly for consumption and income generation. Fruit were harvested fully mature, half mature and just mature. Climbing the tree and using the stick method to dislodge the fruit to the ground was the two methods used for harvesting. From the field, the fruit were transported to homesteads and markets with a vehicle, donkey/oxen cart, head load or public trucks. The fruit were stored in traditional huts, loose on the ground or in gunny bags in the shade of trees. The fruit were sold next to the main road in both study sites as well as in urban areas within Namibia.

The maturity stages at which the fruit were harvested had no significant effect on fruit weight, size and TSS as well as taste in terms of consumer preferences. Poor harvesting and post-harvest handling practices were observed in both study sites. Fruit damage due to cracks bruises, rotting during harvesting, transportation, storage and marketing was the main challenges caused by poor harvesting and handling practices. Fruit were reported to be deteriorating resulting in short shelf life. The poor harvesting handling practices can have a negative impact on the income generated from the sale of the harvested fruit.

Opsomming

Die oes van inheemse vrugte deur landelike gemeenskappe word gekenmerk as ‘n uitdaging weens tradisionele oesmetodes omdat dit groot vrugte verliese tot gevolg het. Die studie was uitgevoer in die Ncuncuni kiesafdeling van die Kavango Wes streek; Namibië. Dit het hoofsaaklik gefokus op die Kaguni en Mile 20 gemeenskappe. Die studie het gepoog om die oes en na-oes hantering van *Strychnos cocculoides* te assesseer deur die huidige hanterings praktyke te evalueer. Daarom is die vlak van na-oes verliese van *S. cocculoides* tydens verskillende hanteringspraktyke en rypheidsgrade geassesseer. Kwaliteit van vrugte is ook geassesseer deur middel van Totale Oplosbare Suikers (TOS), smaak, grootte en gewig.

Data is tussen September en Oktober 2015 ingesamel met behulp van semi-gestruktureerde en verbruikers voorkeur vraelyste. Fokusgroepe en direkte waarnemings was ook gebruik om data in te samel. Altesaam 160 stropers en 150 verbruikers, van beide studie gebiede, was ondervra. Resultate het aangedui dat vrugte hoofsaaklik van Junie to Desember ge-oes word deur vroue en kinders. Vrugte word in die gewas velde en openbare woude hoofsaaklik vir huisgebruik en inkomste generering geoes. Verder is vrugte geoes as ten volle ryp, half ryp en slegs ryp. Boomklim en die stokmetode (vrugte word losgedraai deur middel van ‘n stok) is hoofsaaklik gebruik om vrugte te oes. Vrugte is vervoer vanaf, byvoorbeeld woude, na hutte en markte met ‘n voertuig, donkie-/oskar, op die kop of publieke vervoer (trokke). Die vrugte is gestoor in tradisionele hutte, in hope op die grond, in streepsakke of in die skadu van bome. Verder is vrugte hoofsaaklik verkoop langs hoofpaaie of in stedelike gebiede in Namibië.

Die rypheidsgrade waarby vrugte geoes was het geen betekenisvolle effek op die gewig, grootte, TOS en smaak gehad in terme van verbruikers voorkeure. Swak oes en na-oes hanterings praktyke was in beide studie gebiede waargeneem. Daarom was vrugte skade (krake, kneusplekke, interne verval), opberging en vervoer as die hoof uitdagings geïdentifiseer. As gevolg van vrugte wat vinnig versleg het geoeste vrugte ‘n kort rakleeftyd gehad. Daarom kan die swak oes en hanterings praktyke ‘n negatiewe invloed hê op die inkomste generering en verkope van vrugte.

Acknowledgements

I would like to thank God Almighty for His grace, protection and guidance that enabled me to complete this study.

I would like to extend my heartfelt appreciation to the Ministry of Agriculture, Water and Forestry (MAWF) for the funding and granting me the opportunity to undertake this study.

My deepest gratitude goes to my supervisor Hannél Ham for her valuable mentorship, guidance and advice she tirelessly rendered to me throughout the period of my study. I also wish to express my sincere thanks to all the academic staff members at the Department of Forestry especially Cori Ham for assisting me in so many ways.

I extend my appreciation to the farmers in the study sites, particularly people of Kaguni and Mile 20, Ncuncuni constituency, Kavango West Region who took great interest in the study, shared their knowledge and patiently answered many questions. Without them, this study would not have been possible.

I am taking this opportunity to thank all the colleagues in the Directorate of Forestry (DoF), particular in Hamoye Forestry Research Station for assisting me in different ways. Words may not express my immeasurable gratitude to my two colleagues Mr. Benjamin Peter Chomo and Mrs Leopoldine Alfons who participated fully in the study and assist me in data collection. I wish you all a prosperous future. To all fellow students and friends you are warmly thanked for your encouragement and support towards the completion of this study.

I am indebted to my son Michael and my niece Nancy for their patience and understanding during my long absence from home. Without their patience, inspiration and understanding, the study would have been difficult. May the Almighty God bless you in abundance.

I gratefully acknowledge all members of my family for moral support, encouragement and prayers.

Dedication

This thesis is dedicated to my son Michael and my niece Nancy for their understanding and patience during this study.

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List of Abbreviations and Acronyms

ANOVA	Analysis of Variance
DoF	Directorate of Forestry
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
ICRAF	World Agroforestry Centre
IF	Indigenous Fruit
IFT	Indigenous Fruit tree
NTFP	Non-Timber Forest Product
NWFP	Non-Wood Forest Product
MAWF	Ministry of Agriculture, Water and Forestry
NPC	National Planning Commission
N$	Namibian dollars (1 US Dollar = 14 N$ November 2016)
SADC	Southern African Development Community
SPSS	Statistical Package for the Social Sciences
TSS	Total Soluble Solids

List of units

g	Grams
cm	Centimetre

1 Introduction

1.1 Background to the study

Indigenous forests are very important to the livelihood of rural people residing around it. In the Southern Africa Development Community (SADC), fruits from indigenous forests are considered important (Akinnifesi, *et al.,* 2006) as it serves as a food source and potential cash income (Campbell *et al*., 2002; Ramadhani, 2002). During periods of drought, when other food sources are limited, indigenous fruits (IF's) substitute the diet of rural communities and contributes on average 42% to the households food security (Akinnifesi, *et al*., 2006; Campell, *et al.,* 1997). A study done in rural areas of Malawi, Mozambique and Zambia, shows that 65–80% of rural households lack access to food source for approximately 3 to 4 months a year. Therefore, they depend on indigenous fruit during that period of food scarcity (Akinnifesi, *et al*., 2004). Indigenous fruit serves as an important source of nutrients and essential vitamins that can limit malnutrition and related diseases affecting children (Mithöfer *et al.,* 2003). Baobab for example, has vitamin C levels of up to six times higher than an orange and calcium levels higher than cow's milk (Ondachi, 2001). Another important indigenous species is *Azanza garkeana* (tree hibiscus, African chewing gum) which is known for essential source of minerals such as Calcium (Ca), Magnesium (Mg), Potassium (P), and Sodium (Na) (Morejemane & Tshwenyane, 2004).

During a survey on useful indigenous fruits conducted in Zimbabwe, Zambia, Malawi and Tanzania*, Strychnos cocculoides* (monkey orange), *Uapaka kirkiana* (wild loquat) *and Parinari curatifolia* (mobola plum) were indicated as the three most important fruit tree species preferred by rural communities in the SADC countries (ICRAF, 2002). These indigenous fruit are important in terms of trading and has become cash crop commodities in many rural communities (Akinnifesi, *et al*., 2006). The economic potential of the indigenous fruit, has led to the development of market-driven domestication concepts that will improve fruit quality and production for the benefit of rural communities of Southern Africa (Simons, 1996). Domestication programmes also aim to encourage farmers to plant fruit trees with improved fruit quality that can enhance household's cash income (ICRAF, 1996).

In Namibia, *S. cocculoides* is one of the most important socio-economic and popular species in the Northeast (Kavango) region (Saka *et al.,* 2007; Mendelsohn & Obeid, 2005). The country (Namibia) has a significant number of indigenous Non Wood Forest Products (NWFP) that benefits rural populations (Hailwa, 1998). Non-wood forest products play an important role in the local economy of the Namibian people. To most rural people in Namibia indigenous fruit contribute significantly to their livelihood (Hailwa, 1998). Rural communities utilise indigenous fruit as an alternative cash income to improve their livelihood and fulfil basic household needs (Elago & Tjaveondja, 2015). A number of non-wood products such as nuts, fruits, oil, hot liqueurs and traditional wine are being traded in the informal markets within Namibia.

1.2 Problem statement

Research on harvesting and postharvest practices of indigenous fruit trees in Sub-Saharan Africa, have not been properly documented (Akinnifesi, *et al.,* 2006). Traditional harvesting methods in rural areas, such as shaking the branches, climbing the tree or using objects to dislodge the fruits to the ground; might minimise fruit quality (bruising of fruit) and result in higher fruit loss. Furthermore, these harvesting methods can cause tree damages, which can introduce pathogens and reduce the number of branches bearing fruit (Kadzere, *et al.,* 2002). Due to competition amongst members of the community, fruit are also harvested immature and buried in the ground for several weeks to ripe, increasing postharvest fruit loss (Masarirambi *et al.,* 2010). There is a need to understand current harvesting practices and how they influence postharvest loss. This will assist in the development of appropriate techniques that could minimize fruit loss.

Currently there is a need to assess the existing harvesting and postharvest handling practices of *S. cocculoides* fruit in the Kavango region of Namibia. Although the harvesting of the fruit is an established practice, there is limited information on harvesting and postharvest handling practices. A study on these can help to define better practices and thereby improve fruit quality.

1.3 Significance of study

Results from this study will assist the Directorate of Forestry to improve the current harvesting and postharvest handling practices for *S. cocculoides* and other indigenous fruits. The Directorate can develop and publish such harvesting and postharvest guidelines to improve the quality and prolong shelf life by reducing harvesting and postharvest fruit losses. Ultimately, this study will assist by adding value to indigenous fruit products and improving the livelihood of the rural communities.

1.4 The scope of the study

This study was limited to two sites (Kaguni and Mile 20) in the Ncuncuni constituency, Kavango West region of Namibia. The two study sites were selected based on the abundance of *S. cocculoides* trees and the socio–economic importance of it to the two rural communities. The majority of the households in the study sites are engaged in harvesting of indigenous fruit mainly for cash income.

1.4.1 Research objectives

The overall objective of the study was to assess harvesting and postharvest handling practices of *S. cocculoides* in relation to the quality of the fruit (harvesting to point of sale).

1.4.2 Specific objectives

The specific objectives of the study were:

- Identify existing harvesting and postharvest handling practices of *S. cocculoides* fruit.
- Assess the level of postharvest losses of *S. cocculoides* fruit at different harvesting and postharvest handling practices.
- Assess consumer preferences (fruit quality) by evaluating Total Soluble Solids (TSS), taste, size, and weight when harvested at different maturity stages (fully mature, half-mature and just mature).

The above objectives will be addressed by means of harvesters & consumer's questionnaires, focus group discussions and direct observations.

1.4.3 Thesis structure

The thesis consists of six chapters:

Chapter 1: Presents the problem statement; rational of study, overall objective, specific objectives, brief methodology and significance of the study.

Chapter 2: Literature review on the overall objective including other species

Chapter 3: Introduce the methodology, research design, sampling, data collection and analysis

Chapter 4: Presents the results obtained

Chapter 5: Discussion of the results obtained

Chapter 6: Presents the conclusion and recommendations for future studies

2 Background and literature review

2.1 Description of *Strychnos cocculoides* (monkey orange)

2.1.1 Botanical characteristics

Strychnos cocculoides is a semi-deciduous tree (Figure 2.1) that can grow 2 to 8m high, with spread branches and a compact rounded canopy (Orwa *et al*., 2009). It belongs to the Loganiaceae family and grows on deep and loamy sand (Storrs, 1995). The bark is often thin, grey-brown and corky. The spines are straight at the ends of branches and curved in pairs at nodes. The leaves are shiny, bright green and ovate to almost circular (Mendelsohn & Obeid, 2005).

Figure 2.1: *S. cocculoides* tree with fruit of various maturities

The genus *Strychnos* is widespread in the tropical parts of Africa, South America and India, but *S. cocculoides* is restricted to central and southern Africa (ICUC, 2004). In Southern Africa, *S. cocculoides* grows naturally in the miombo *Brachystegia* woodlands and mixed forests. In the miombo woodlands, *S. cocculoides* generally associated with species such *as*

Terminalia spp., *Adansonia digitata*, *Combretum* spp., *Albizia versicolor, Burkea africana Millettia stuhlmannii*, *and Uapaca* spp. etc. (Nyoka & Muskoyonyi, 2002).

However, in Namibia its distribution is within the dry woodlands of the north Eastern part of the country (Mannhener & Curtis, 2005). *Strychnos* also grows in South Africa, Zimbabwe, Zambia, Botswana, Malawi, Angola, Tanzania and Uganda (Orwa *et al*., 2009). It prefers an average climate with temperatures between 14 and 28 °C and annual rainfall between 600 and 1200mm (Orwa *et al.*, 2009). In general *S. cocculoides* adapt to a harsh environment and can survive severe drought (SCUC, 2006). The thick bark makes it possible to survive wild fire and be able to coppice afterwards.

2.1.2 Tree uses

Strychnos cocculoides fruit is rich in sugar, vitamin C, oil and proteins (Kwesiga *et al.* 2000). Mature fruit is eaten fresh or used to prepare a distilled alcoholic drink called Kashipembe (Mendelsohn & Obeid, 2005). The wood is hard and poles are suitable for construction. In Namibia, however the wood of *S. cocculoides* is not valued and not commonly used. In other countries, tool handles and building materials can be made from the wood (ICUC, 2004). The seeds contain strychnine chemical, which is toxic (ICUC, 2004).

The fruit of *S. cocculoides* is also used for medicinal purposes. Immature fruit can be crushed and mixed with water to treat snakebites, ear pain, and swellings. Immature (green) fruit are used to induce vomiting. The pulp of mature fruit mixed with table sugar is used to treat coughing. In Zambia, powder is extracted from unripe fruit and added to milk for cleansing purposes (Mwamba, 2005). A dye can also be extracted from the fruit for insect protection trays and container colouring.

The roots are chewed to treat diseases such as gonorrhoea and eczema, while leaves can help treat sores. Leaves can be soaked in water and the liquid is used as a spray for vegetables to prevent insects such as aphids and scales (ICUC, 2004). Farmers in semi-arid areas use the tree for shade.

2.1.3 Biological characteristic

Strychnos cocculoides generally flowers during the rainy season, and take 8 to 9 months from flower (fertilisation) to ripening of the fruit (Mkonda, *et al.,* 2004). In Namibia, the fruit-ripening period is between August to December. Fruits are circular, 1.6 to 10cm in diameter, dark green (immature) to orange or yellowish (mature), with a hard pericarp (shell). Seed are tenaciously entrenched in a juicy pulp (Mkonda, *et al.,* 2004).

Propagation of *Strychnos* species is known to be difficult due to erratic germination and prolonged after-ripening effects. However, *S. cocculoides* can be regenerated naturally by seed, or root suckers (Mkonda, *et al.,* 2004). Seed storage is semi-orthodox, with a shelf life of two months at room temperature. The length of seed storage has shown to affect the germination percentage, but can also vary between provenances (Mkonda, *et al.,* 2004). Previous studies indicated a germination percentage between 60 and 80% (Taylor, *et al.,* 1996; Mkonda, *et al.,* 2004). Results varied between provenances, ranging between a germination of 60% at 9 months to 10% at 15 months after sowing (Mkonda, *et al.,* 2004). Provenance trials established (Zambia) from these seedlings, started to produce fruits after 5 years with a total number of fruit ranging between 258 to 946 per tree. In Malawi, trees regenerated from seeds yielded fruits after 4 or 5 years, while 3 years in Botswana (Taylor, *et al.,* 1996). In addition *Strychnos* trees raised from seeds tend to have a deeper tap roots than those raises from propagative propagules (SCUC, 2006).

2.2 Socio-economic contribution of *Strychnos cocculoides* fruit

Non Timber Forest Product's (NTFP) are an important source for rural communities as cash income and supplement dietary requirements especially during times of droughts (26 to 50% of households) and low supply of agriculture crops (Ramadhani, 2002; Akinnifesi, *et al.,* 2008a, 2007, 2004; Shackleton *et al.,* 2000). Harvesting and marketing of indigenous fruit is an established source of household's income that enables families to live above the poverty line throughout the year (Mkonda *et al.,* 2003). In Zimbabwe, indigenous fruit was reported to have reduced poverty by about 33% in household that were living below the poverty line (Mithöfer *et al.*, 2006).

Therefore, harvesting of these NTFP's is increasing annually (Ramadhani, 2002; Akinnifesi, *et al.,* 2004). Fruit from *S. cocculoides* is rich in vitamins and minerals required for the human diet (Kwesiga, *et al.,* 2000). The pulp alone consists of approximately 30% fat, 45% crude fibre, citric acid, carbohydrate levels and vitamin C (Mwamba, 2005). Therefore, marketing and consumption of these indigenous fruit can significantly contribute to the livelihoods and cash income. There are also many opportunities for commercialisation of most indigenous fruit trees from Africa (Ramadhani, 2002). In Namibia, women in the North central region have recognised the opportunity to earn cash income by selling *Sclerocarya birrea* (Marula) products (du Plessis, *et al.,* 2002). With the traditional knowledge of harvesting and processing, rural Namibian women managed to produce Marula products that are sold on international markets (du Plessis, *et al.,* 2002). For example, Amarula cream processed from Marula is one such product that has made it onto international markets (Ham *et al.,* 2008).

In many tropical countries, NTFP's (especially fruit) can increase income revenues and employment opportunities of rural communities (Agustino, *et al.,* 2011; Akinnifesi, *et al.* 2006; Leakey *et al.,* 2005; Ruiz-Perez *et al.,* 2004). Furthermore, it was reported in South Africa that 94% of rural households in four villages have been making use of Marula fruits as a source of income (Shackleton, 2004). In Southern Africa Countries (especially Namibia), *S. cocculoides* fruit are utilised for its socio–economic value (fresh fruit, liquor produce, fruit juice etc.) contribute to rural household income (Elago & Tjaveondja, 2015; Akinnifesi, *et al.,* 2008b). Other socio-economically important fruits that are widely traded include: *Uapaca kirkiana, Parinari curatifolia,* and *Ziziphus mauritiana* (Akinnifesi, *et al.,* 2006; Ham & Akinnifesi, 2006). Income generated from the sale of these indigenous fruits is sufficient to purchase households basic utilities and render service such as school fees, hospital bills etc. (Elago & Tjaveondja, 2015, Ramadhani 2002).

For many rural households in Namibia, harvesting and selling of fruit (when in season) is a full time job. These products (juice and jam) are also exported to South Africa (Mendelsohn & Obeid, 2005). In the Kavango region, a traditional alcoholic drink (Kashipembe) is extracted from *S. cocculoides* fruit. In other countries such as Malawi, Zambia and Zaire, *S.*

cocculoides fruit is processed into juice and jam (Mwamba, 2005). A separate study in Malawi reported a higher level of zinc and copper in *Strychnos* juice than that of *U. kirkiana* (Saka *et al.,* 2002). As the fruit are abundant in Kavango region of Namibia, a small enterprise was set up in Namibia to commercialise this product (Schreckenberg, 2003).

However, in most Southern African countries, indigenous fruits are sold either at local markets or next to the road by rural communities (Ramadhani, 2002). Although there is limited formal markets for NTFP's in Namibia (du Plessis, *et al.,* 2002), the current local markets can be upgraded and utilised to sell *S. cocculoides* fruit commercially. For example, in Malawi 20% of *S. cocculoides* fruit harvested are sold to the consumer, and 80% are sold to traders (Mwamba, 2005). A previous study by Ham (2005), reported that communities in South Africa harvested Marula fruit of about 2 000 tons and earned US$180,000 annually. In the past, indigenous fruits from Zimbabwe were exported to Botswana and sold at US$0.45 per fruit (Taylor, *et al.* 1996). However, in many Southern African countries, there is lack or define mechanism for setting up indigenous market price (Ramadhani, 2002).

NTFP's can contribute to economic growth (local and international trade) and poverty reduction in rural communities (Chikamai &Tchatat, 2004). Previous studies indicated that the trade in medicinal and other Non-Wood Forest Products (NWFP) in the North Eastern Region of Himalayas are among the biggest sources of seasonal employment for only three to four months of the year (Chikamai & Tchatat, 2004). Furthermore, the chewing stick (*Garcinia* spp.) is also a major income source in Ghana (Blay, 2004). In addition, Namibia has established a national indigenous fruit task-team that supports the development of products from natural indigenous resources that will contribute to employment creation in the country (Schreckenberg, 2003). In the Zambezi region of Namibia, especially during the non-agricultural season, forest wild products offer up to 50% of household food. Furthermore, skilled carvers in Namibia can earn a cash income ranging from N$ 112.74 to N$ 1, 160.25 from Kiaat (*Pterocarpus angolensis*) planks obtained from a single tree (Moses, 2013).

Previous studies in Zimbabwe indicated that an average income of 35% is generated from NTFPs, while it can increase to 40% for poorer households (Schreckenberg, 2003). Other important species that can contribute positively to local food sources and need to be

considered are: *Tamarindus indica, Uapaca kirkiana, Vitex spp., Adansonia digitata, Allanblackia spp., Parinari spp.*, and *Thespesia garckeana* (Akinnifesi, *et al.,* 2006, Ham & Akinnifesi, 2006).

2.3 Harvesting

Harvesting refers to the deliberate action of separating the fruit from the tree, depending on the ripening season and is generally done by women (Schreckenberg, 2004; Ruiz –Pérez *et al.,* 1997). Apart from harvesting, women and children are also the main beneficiaries of indigenous fruits in most rural communities such as in Malawi, Zambia and Zimbabwe (Mithöfer, 2005; Ramadhani, 2002). Human populations have been harvesting indigenous fruits over thousands of years for household consumption and trade (income generation). Fruit harvesters will walk long distances to harvest these indigenous fruits. In Zambia some fruit harvesters could walk a distance of 15km from the fruit source to the market (Mkonda *et al.,* 2003).

Previous studies indicated that the trade of indigenous fruits in Zimbabwe alone could reduce poverty by 33% (Mithöfer, *et al.,* 2006). However, optimum harvesting procedures for many indigenous species are still poorly understood. This is mainly because harvesters are unskilled and inexperienced in said harvesting, handlings methods and protocols (Agustino *et al.*, 2011). Currently, most farmers use traditional harvesting methods, resulting in post-harvest fruit losses due to excessive bruises and damages (internal rotting) to the fruit (Kadzere, *et al.,* 2004a; Iranbakhsh *et al.*, 2009). Methods of harvesting include shaking of branches, climbing trees, or using objects to dislodge the fruit (Kadzere, *et al.,* 2004b; Kadzere, *et al.,* 2002). Shaking the tree to dislodge fruit increases the number of immature (green) fruit. Most of indigenous fruit trees in rural farmland have big wounds and scars due to inappropriate harvesting methods (Kadzere, *et al.,* 2006).

In other countries such as Tanzania, farmers only harvest fruits that have fallen to the ground after abscission, however such practice limit consumption period and increases fruit damage during transportation and storage (Ham *et al.,* 2008). Another method of harvesting is

selective harvesting practices used by the Soligas people in South India. Fruits are only harvested from trees with large quantities of fruit to ensure high economic return per unit to increase the number of fruits harvested (Sinha & Bawa 2002).

Although harvesting and marketing of indigenous fruits improve the livelihood of rural populations, the practice tend to have long term effects on the ecosystem as a result of inappropriate harvesting and postharvest handling techniques (Mithöfer, 2005; Kadzere, *et al.,* 2006). Moreover, the increased demand of indigenous fruits due to population increases, also contributes to the inappropriate harvesting techniques (Ruiz-Perez *et al*., 2004). The increase of populations leads to increases in competition of recourses in communal forests which is viewed as public goods (Ramadhani, 2002). However, with unclear on non-existing regulations on fruit harvesting, the uses of resources changed from common property to open access (Ramadhani, 2002).

Indigenous fruits are reported to be disappearing in Malawi due to a lack of stewardship. *Strychnos cocculoides* and *U. kirkiana* is also reported to be scarcer in some parts of Southern Africa because of the increase of the population and popularity (Akinnifesi, *et al*., 2006). It was further reported that cutting down of mature indigenous fruit trees in communal lands for new crop fields is a common problem in Malawi (Akinnifesi, *et al*., 2008b). Optimum harvesting and handling protocols could increase fruit availability throughout the year (Mwamba, 2005). In the meantime, the absence of appropriate handling and storage techniques causes a significant decrease on food security and availability of fruits to rural communities (FAO, 1995).

2.4 Harvest maturity

Harvest maturity is the point at which the fruit have reached a minimum level of development to withstand transportation, but will still ripen normally to produce fruits of good eating quality (Burdon, 1997). Maturation also refers to the stages between the last growth of the fruit and beginning of the fruit ripening stage (Kadzere *et al.,* 2007). This includes the development stage at which the minimum fruit quality is acceptable to the consumer for both

harvesting and postharvest handling practices (Reid, 1992). Indicators such as, fruit colour, TSS, size and weight can assist to determine the maturity of the fruit. For example, Mandarin fruit (*Citrus reticulate*) is considered to be mature enough to be harvested when the skin colour is approximately 75% or more a yellow-orange colour (Tiwari, 2006). In addition, the maturity stage at which the fruit is harvested is a very important factor that might determine fruit quality at the point of sale (Kadzere *et al.,* 2007). The quality and the postharvest shelf life of the fruit can be influenced by the stage of maturity at harvest (Anjum *et al.,* 2006; Jha *et al.,* 2007).

Fruit colour of *S. cocculoides* can, however, vary between green (immature), yellow (half-mature), and orange (just mature) when harvested from the ground or tree. Time of harvesting (fully mature, half-mature and just mature) mainly depends on the demand for the fruit (Dhatt & Mahajan, 2007, Kadzere, *et al.,* 2004b), and type of consumption (fresh, processed etc.) (ICUC, 2004). Maturity at harvest plays an important role for postharvest shelf life of the fruit and eating quality (Dhatt & Mahajan, 2007). There is a lack of understanding of the general ripening patterns and maturity indexes of indigenous fruits as fruits harvested immature tend to have an inferior quality when ripe and thus vulnerable to mechanical damages (such as shrivelling) (Kadzere *et al*., 2002). Fruits that are harvested too early or too late are, however, susceptible to physiological disorders and have a shorter storage life than fruit harvested at the proper maturity (Pareek *et al*. 2009). The storage durability of fruits is also closely linked with the stage of maturity at which the fruit was harvested (Jha *et al.,* 2007).

In general, *S. cocculoides* fruit is harvested between June to December, depending on the site (Mwamba, 2005). Fruit can still be harvested after physiological maturity and separation from the stalk. Physiological maturity is the stage when a fruit is capable of further development or ripening when harvest, but still ready for consumption or processing (Dhatt & Mahajan 2007). In general rural farmers had knowledge of the ripening period of indigenous fruits. Fruit harvesters in Zimbabwe indicate skin softness, colour changes and time of the year as some of the indicators used to determine fruit ripening (Akinnifesi *et al.*, 2004). Fruit ripening can overlap for many species, opening an avenue for having fresh fruits throughout the year (Akinnifesi *et al.*, 2004).

2.5 Postharvest fruit loss

Postharvest refers to the period after harvesting, between production and final consumption (including poor quality fruit, fresh consumption, processed etc.) (Salunkhe, 1984; Kader, 1983; Dietz, 1999). Postharvest loss is measured as qualitative and quantitative fruit damages that occur between harvesting and the consumer or end user (Hodges, *et al.,* 2011). It can be caused by external and internal factors, such as poor harvesting protocols, postharvest management (Prusky, 2011), and includes deterioration due to cracking, mechanical injury during transportation and storage (Kadzere, *et al.,* 2001; Chandrasekharan, 1993).

Harvesting and postharvest management determines the quality of the final product (fruit) (Simson & Straus, 2010). However, in many rural communities, harvesting and postharvest handling techniques are poorly developed, hence greatly affecting cash income for rural communities (Ham *et al.,* 2008). Rural farmers' employ poor traditional methods to harvest fruit such as using sticks, heavy objects or either shaking branches to dislodge fruit to the ground (Kadzere *et al.,* 2006). Therefore, fruits are harvested immature and buried until matured, a practice that could lead to further fruit deterioration, reduce fruit quality as well as market value (Wilson, 2002). Lack of sufficient and adequate storage facilities and method of transportation contribute significantly to postharvest losses (Soe *et al.,* 2006). Harvesters of indigenous fruit in most rural communities experience challenges of irregular transport to markets (Kadzere *et al*., 2002).

During the entire supply chain, fruit losses can be as high as 40 to 60% of the fruit harvested (Wilson, 2002). Most fruit harvesters in Zimbabwe experienced a fruit loss of 50 to 70% during marketing (Ramadhani, 2002). Insufficient market infrastructure, for example, for indigenous fruits is another contributing factor to postharvest loss. Most farmers sell fruit outside the formal market due to limited space (Ramadhani, 2002). Some wholesalers (for example in Zimbabwe) store fruits in heaps with no protection from harsh weather, hence reducing fruit quality (Ramadhani, 2002). However, in Zambia, fruit is stored in bags or containers (Ham *et al.,* 2008). Fruit collectors experience economic losses as a result of poor

handling practices during harvesting and transportation, and this can account for 83% of total fruit loss. Other factors such as rotting of fruit and poor sorting and packaging also contribute to economic fruit loss (Ham *et al.,* 2008). It is recommended to separate unripe and damage fruits to prevent spoilage and increase cash returns. *Strychnos cocculoides* fruits can be packed in gunny bags or boxes and stored under dry condition at room temperature (25°C) for 2 to 3 weeks. When fruit are not stored under the shade, about 25 to 50 % of fruit can be lost (SCUC, 2006).

Due to the absence of rules and regulations (official protocols) in rural communities, poor harvesting and postharvest practices have contributed negatively to the quality of the fruits (Kalaba *et al.,* 2009). This situation can be addressed by improving the handling practices, processing fruit into value added products and improving the supply chain from harvesting to consumers (Kitinoja & Kader 2015; El-ramady *et al.*, 2015; FAO, 2009). Some indigenous fruits such as *Ziziphus mauritiana* and *Parinari curatellifolia* can be sun dried or fermented before stored in order to prolong the shelf life during the off season (Kadzere *et al.,* 2001). The supply chain of the fruits or products can change from the time of harvest, to the time of consumption (Blowfield, 2001). For example, fruit colour can change from green to orange.

2.6 Aspects of fruit quality

2.6.1 Weight and diameter (fruit size)

Weight and fruit size can be used as a possible index of fruit maturation. However, it can also be influenced by other factors such as climatic conditions, sites (soils) and cultural practices (Mitchell & Mayer, 1984). For example, depending on the soil type, *S. cocculoides* fruit size can vary between 6 and 12cm (Mwamba, 2005). However, fruit weight can also be affected by the time of harvest, for instance fruit of *U. kirkiana* harvested late in the season tend to lose weight in storage compared to fruit harvested two weeks earlier (Kadzere *et al.,* 2006).

Generally, fruit weight and size varies among provenances (Mkonda *et al.,* 2004). A provenance study on variation in fruit weight and diameter (size) of *S. cocculoides* was

conducted in Zimbabwe, Tanzanian and Zambian. Among those provenances, Zimbabwe reported the highest weight (177 to 383g), followed by Zambia (158 to 296g). The lowest weight was reported in Tanzania (145 to 183g). Diameter was reported higher (6.7 to 9.0cm) in Zimbabwe, Zambia (6.9 to 8.5cm) while Tanzanian fruit attained the lowest diameter (6.7cm) (Mkonda, *et al.,* 2004). Furthermore, Botswana also reported the highest diameter (10 to 15cm) among the countries (Taylor, *et al.,* 1996). In general, the yield mainly depends on the tree genotype, but with favourable conditions, a tree may produce 300 to 700 fruit per season (Mwamba, 2005).

2.6.2 Total Soluble Solids (TSS)

TSS is a refractometer index that indicates the proportion (percentage) of dissolved solids in a solution. It is the sum of sugars (sucrose, fructose and glucose), acids and other minor components in the fruit pulp (Kadere, 2008). As the fruit develops, the sugar and these components increase. The content of TSS is influenced by the maturity stage and ripening conditions of the fruit as the starch is broken down into different sugars as the fruit ripens (Hossain *et al.,* 2012). Furthermore, the level of TSS is affected by humid conditions therefore, for a fruit to be sweet, sufficient sunlight is required (Leakey & Newton, 1994). However, not all fruit maturity stages are influencing the TSS, for example *Passiflora edulis* (passion fruit) can be harvested at different physiological maturity stage ($\frac{1}{3}$ to $\frac{2}{3}$ yellow peel or fruit) without influencing TSS (10.2 to 16.8%) (Antônio *et al.* 2015). In contrast, *Uapaka kirkiana* fruit in Malawi differ significantly in fruit maturity and between trees in terms of TSS (Saka *et al*. 2007). Previous studies in Malawi reported a TSS of 14.3% for juice processed from a mixture of sour, mild sweet and sweet fruit of *S. cocculoides* (Saka *et al*. 2007).

2.6.3 Consumer preference (fruit taste)

Fruit taste is an important aspect of market preference and can be divided into: sweet, sour or bitter (Dinehart *et al.,* 2006; Ramadhani, 2002). Bitterness is an undesirable taste found in some of the fruits while sourness is an indication of immature fruit (Dinehart *et al.,* 2006; Harker *et al.,* 2003). The balance between taste and flavour is important, but influenced by the consumers individual preferences (Dinehart *et al.,* 2006). Immature fruit generally are

rejected by the consumer due to irregular ripening and lack of full flavour and aroma development (Engineering *et al.*, 2014). Sweet *Strychnos* fruit produce an acceptable juice and jam suitable for commercialisation (Saka *et al*., 2007).

3 Materials and methods

3.1 Description of the study area

This study was conducted in the Kavango West Region, Ncuncuni Constituency, Namibia (Figure 3.1). Kavango splits into two regions; Kavango East and Kavango West. The region consists of eight constituencies, namely: Kapako, Mankumpi, Mpungu, Musese, Ncuncuni, Ncamangoro, Nkurenkuru, and Tondoro. The Kaguni village (approximately 26 km) and Mile 20 (approximately 32 km) are situated south of Rundu, along the Rundu-Grootfontein main road. In total, the area is 48,742 km^2 with 4.6 people per km^2. The total population size is approximately 222 500 people, with an annual population growth rate of 3.7% (NPC, 2012).

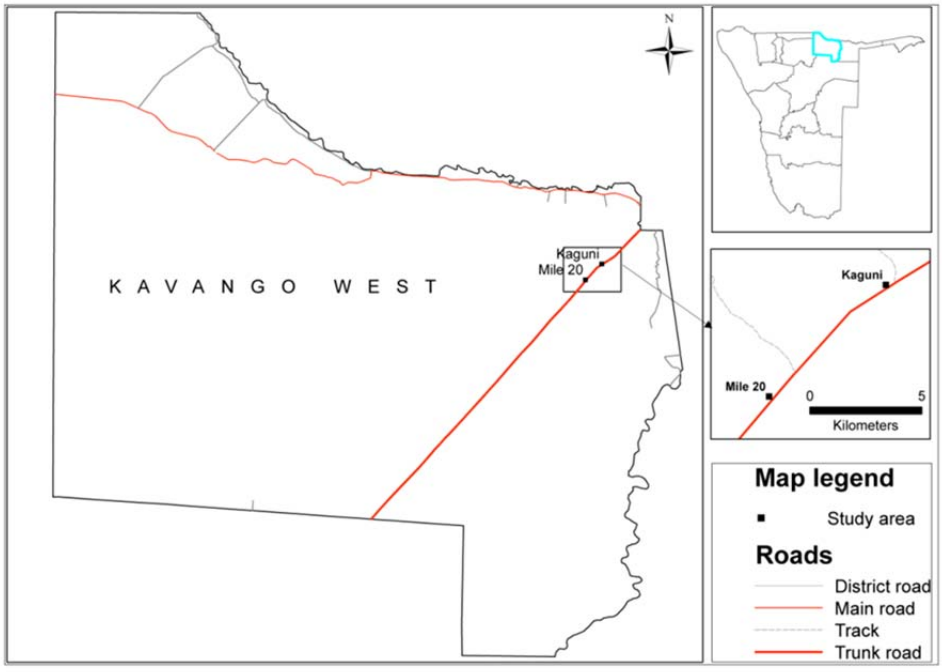

Figure 3.1: Map of the Kavango West region indicating the two study sites indicated of Kaguni and Mile 20 (NRSC, 2015).

The Kavango region has an average annual rainfall of 550mm (September to May), which increases slightly from southwest to northeast (Erkilla & Siikonen, 1992). Eighty percent of the precipitation occurs between December and March, when the maximum rainfall in 24 hours can be between 100 and 120mm (Erkilla & Siikonen, 1992). Animal husbandry, horticulture and fishing play an increasing role in the economic lives of the Kavango people (Mendelsohn & Obeid, 2005). The most important crops are pearl millet (*Pennisetum glaucum)*, sorghum and maize, while ground nuts, beans, pumpkins, and tobacco are cultivated on a smaller scale (Mendelsohn & Obeid, 2005).

3.2 Research design

The study used both qualitative and quantitative methods in a triangulation approach. Triangulation can verify and validate data collected with conventional data collection methods (Sabina & Khan, 2012). This multiple approach of data collection applies when examining a social phenomenon in a holistic way (Cresswell, 2003).

Qualitative data was collected in the form of interviews, Focus Group Discussions (FGD) and direct observations. The quantitative approach was in the form of questionnaires, content analyses and literature review of previous surveys conducted. The obtained data were used to interpret and develop a description of the two communities (research unit), the meaning of the study (needs analysis) and future outlook (Cresswell, 2003). The qualitative and quantitative approaches in this study was used to gather information about the harvesting and postharvest handling practices and the consumer fruit preferences by making use of questionnaires.

3.3 Sampling method

The total sample size of harvesters was estimated based on the number of households in the two communities. Kaguni consisted of 312 households and Mile 20 had 220 households (MRLGRD, 2014). In total 160 harvesters from Kaguni (94) and Mile 20 (66) were interviewed, representing a 30% sample size of households per community. In general, a sample size between 5 and 10% is recommended for household's surveys (Boyd *et al.*, 1981). The decision to increase the sample size was to minimize sampling biasness. The harvesters were selected randomly at the point of sale, further decreasing biasness of data.

The fruit were divided into three physiological harvesting maturity stages: fully mature (orange/yellow) half mature (green/orange) and just mature (green) (Dhatt & Mahajan, 2007). Although the fruit were harvested at different maturity stages, they were all displayed at the point of sale when fully matured. At each stage, the weight (digital scale), diameter (digital calliper), TSS (hand held refractometer) and taste of the fruit were assessed.

Consumers at the point of sale (road site) tasted the fruit from each physiological harvesting maturity stage. Taste were scored from 1 to 3; where 3 represents like, 2 represents neither like nor dislike (neutral), and 1 represents dislike. After fruit tasting, TSS (% Brix), weight (g) and diameter (cm) were immediately measured and recorded.

3.3.1 Data collection

Data for harvesting and postharvest handling practices of the fruit was assessed through a flexible semi-structured questionnaire (Appendix A) as a face-to-face interview offers the possibility of modifying responses and investigating underlying responses (Robinson, 2002). Post-harvest fruit loss percentage was estimated as follows:

$$Loss\ \% = \frac{No.of\ bags\ discarded}{No.of\ bags\ harvested} \times 100$$

The impact of harvesting and postharvest losses was also calculated in terms of the number of bags harvested and the cost thereof. Fruit are harvested and stored in gunny bags (50kg), consisting of approximately 110 fruits (per bag) at the market price of N$3 per fruit (Elago & Tjaveondja, 2015).

Data of consumer's preferences were collected by means of consumer preference questionnaires (Appendix B). The two different questionnaires were administered to local harvesters selling fruit and consumers purchasing fruit at the main road at both study sites. Harvesters and consumers were randomly selected and the consumers were interviewed as they purchased the fruit at the point of sale. In addition, the study employed FGD's with the harvesters from both study sites. Direct observations were done in order to have a clear understanding of the harvesting and postharvest practices and fruit consumer preferences.

3.3.2 Focus Group Discussion

The FGD's were held in order to have a good perspective and understanding of the community knowledge based on issues of harvesting and postharvest handling practices. This gave the researcher the opportunity to obtain information that could not be obtained from individual interviews. Furthermore, this approach also assists in observing a large amount of interaction on a topic in a limited period of time (Babbie & Mouton, 2011). FGD's can also act as a source of data verification to strengthen, qualify and amend unclear areas in the other forms of data collection techniques employed during a study. It also stimulates contribution of interested issues and topics, which could be useful to the interviewer (Babbie & Mouton, 2011).

3.3.3 Direct observation

Direct observations were done at harvester's homesteads and in the fields where fruit were harvested. Direct observations require the researcher to be in the field, or to be present in the natural settings where the study takes place. This enables the researcher to understand the participants' lives and their perceptions concerning the subject under study (Maykut & Morehouse, 1994). These methods enable the researcher to interact with the participants and

become part of the community. However, this technique does not rely on what the community says but draws on the direct evidence of an eyewitness observing events first hand (Denscombe, 1998).

3.3.4 Pre-testing questionnaire

There is always a possibility of error no matter how careful a researcher may design the questionnaire (Babbie & Mouton, 2011). To avoid such error, a pre-test was conducted on a limited number of community members from the same population for which the eventual study was intended (Weman & Kruger, 1999). Therefore, a preliminary semi-structured questionnaire was administered prior to the actual day of the commencement of the data collection. The questionnaire was adjusted in areas where proved to be complicated, irrelevant, and incomplete.

3.4 Data analyses

Data analysis was based on the specific objectives of the research. Microsoft Excel computer package was used to encode data collected. The Statistical Package for the Social Sciences Computer (SPSS) version 23 (2015) was used to analyse data. Data was pre-tested with Cronbach's Alpha to measure the internal consistency and reliability of the questionnaires. A value of 0.74 (74%) was obtained and data deemed reliable. Analyse of Variance (ANOVA), Chi-square for Pearson correlation coefficient, linear contrasts ($p = 0.05$) were performed to determine statistical differences at 5%.

4 Results

4.1 Socio-demographic description

In total, 160 harvesters from both study sites participated in the study. There were more female than male respondents in both study areas. In Kaguni, 78% of the respondents were female, and 91% in Mile 20. The majority of the respondents were between 45 to 54 years of age. In Kaguni 31% and Mile 20, 33% of the respondents fell into this age class.

4.2 Harvesting handling practices of the fruit

4.2.1 Harvesting area and distance travelled to the field

Fruit were harvested mainly from the farmers' own crop field or nearby forests within the two study sites. The majority of the harvesters in Kaguni (91%) and Mile 20 (96%), harvested fruit from the crop fields, while 9% in Kaguni and 4 % in Mile 20 harvested fruit from the nearby communal forest. There was no significant difference ($p = 0.16$) between the two study sites in terms of harvesting places.

At Kaguni: the majority of the harvesters (47%) travelled between 2 and 4 km to harvest the fruit, 28% travelled between 4 and 6km, while 25% travelled a distance of more than 6km. In Mile 20: 70% travelled between 2 and 4km, 20% travelled between 4 and 6km, while 10% travelled more than 6km. The results indicated no significant difference ($p = 0.007$) in distance travelled between the two study sites.

4.2.2 Person harvesting and time of harvesting fruit

The majority of the harvesters were women and children in both study sites. In Kaguni 93% were women and children; 7% men, women and children; while in Mile 20, 98% were

women and children; with 2% represented by men, women and children. There was no significant difference ($p = 0.90$) in terms of people harvesting in both study sites.

In terms of harvesting time, the majority of harvesters harvested fruit only in the morning (95% in Kaguni and 79% in Mile 20), while the remaining harvesters harvested in the morning and evening. There was a significant difference ($p = 0.002$) between the two study sites in terms of time of harvesting.

4.2.3 Frequency of harvesting

Fruit are harvested during the season either daily, weekly or monthly. Figure 4.1 indicates that 71% of the harvesters in Kaguni and 82% of Mile 20 harvested weekly. Approximately 24% in Kaguni and 15% in Mile 20 harvested daily. Few respondents, 4% in Kaguni and 3% in Mile 20 harvested fruit per month, while only 1% in Kaguni harvested per season. There was no significant difference ($p = 0.406$) in terms of frequency of harvesting.

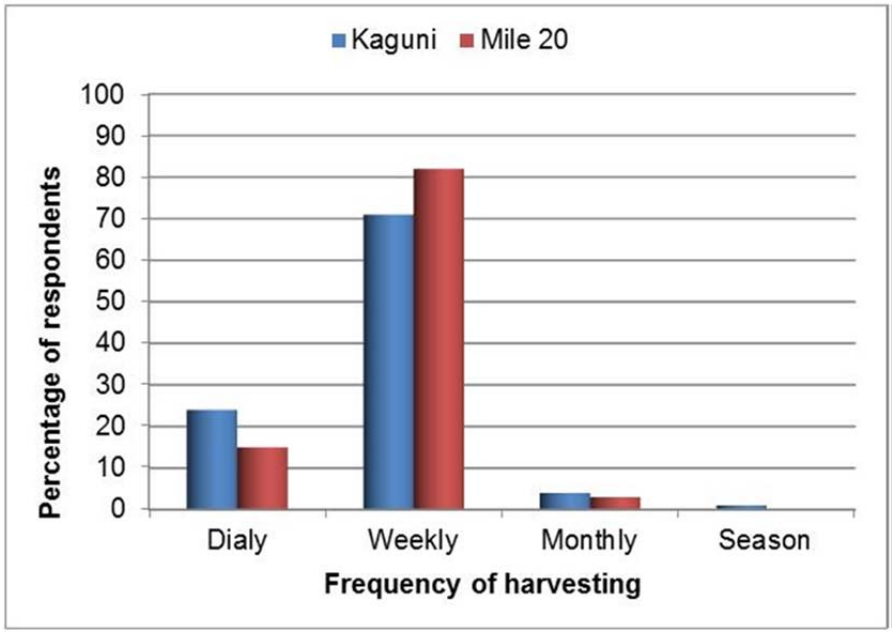

Figure 4.1: Frequency of fruit harvesting (Kaguni: $n = 94$, Mile 20: $n = 66$)

4.2.4 Harvesting purpose

Fruit were harvested for private (household) consumption and selling (generate income) from August to December. The majority of the respondents in Kaguni (88%) and in Mile 20 (86%), harvested fruit for both private consumption and sale, while only 12% (Kaguni) and 14% (Mile 20) harvested for private consumption only (Table 4.1). There was no significant different between the two study sites in terms of purpose of harvesting fruit ($p = 0.716$).

Table 4.1: Purpose of harvesting fruit as a percentage per community (Kaguni: $n = 94$, Mile 20: $n = 66$)

Harvesting purpose	Community (%)	
	Kaguni	Mile 20
Consumption	12	14
Consumption and sale	88	86

4.3 Method of harvesting and handling practices

4.3.1 Harvesting method

Tree climbing and the stick method were the most common methods used for harvesting of fruit in both study sites. However, a majority of harvesters in Kaguni (49%) and Mile 20 (53%) used a combination of tree climbing and the stick method for harvesting of fruit. Approximately 37% in Kaguni and 36% in Mile 20 used stick only, while tree climbing was only used by 14% in Kaguni and 11% in Mile 20 (Figure 4.2). There was a highly significant differences ($p = 0.001$) in harvesting methods between the two study sites. Figure 4.3 shows stick (twist down the fruit) used as a method of harvesting.

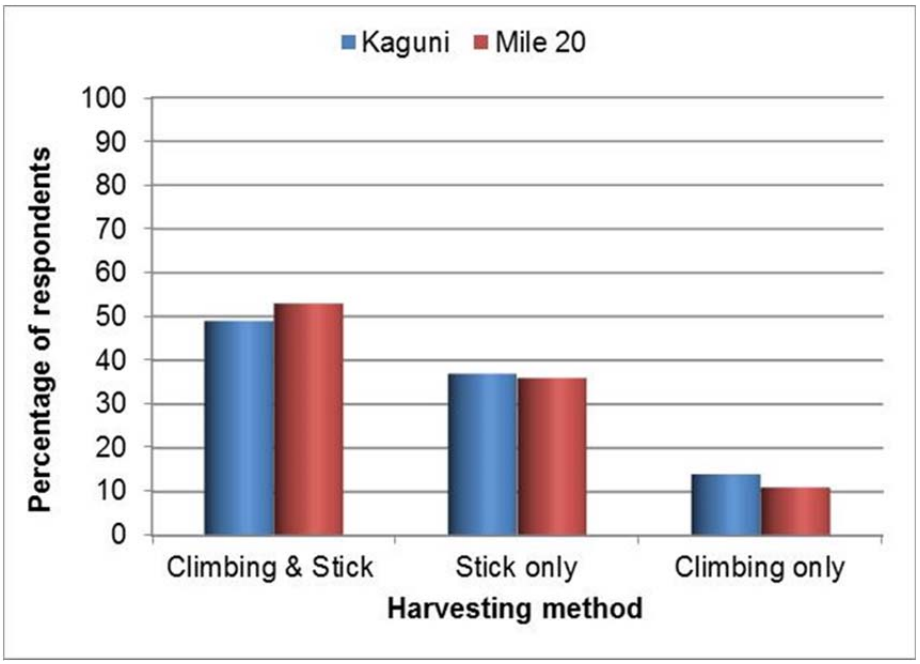

Figure 4.2: Different harvesting methods employed (Kaguni: $n = 94$, Mile 20: $n = 66$)

Figure 4.3: Harvesting method by means of stick (twist down the fruit)

4.3.2 Fruit at harvesting maturity stage

Most harvesters state that they harvested a combination of fully mature (orange), half mature (yellow/green) and just mature (green) fruit. The majority of harvesters in Kaguni (70%) and Mile 20 (45%) harvested a combination of just mature and half-mature fruit (Figure 4.4). However, 7% and 30% harvested a combination of fully and half mature fruit in Kaguni and

Mile 20 respectively. No respondents harvested only fully mature fruit in Kaguni, while half-mature fruit alone were harvested in Mile 20 (2%) and Kaguni (23%). There was a highly significant different (p = 0.001) in maturity of fruit harvested between the two study sites. Figure 4.5 shows a combination of fruit harvested at different harvesting stages (fully ripe, half-mature and just mature).

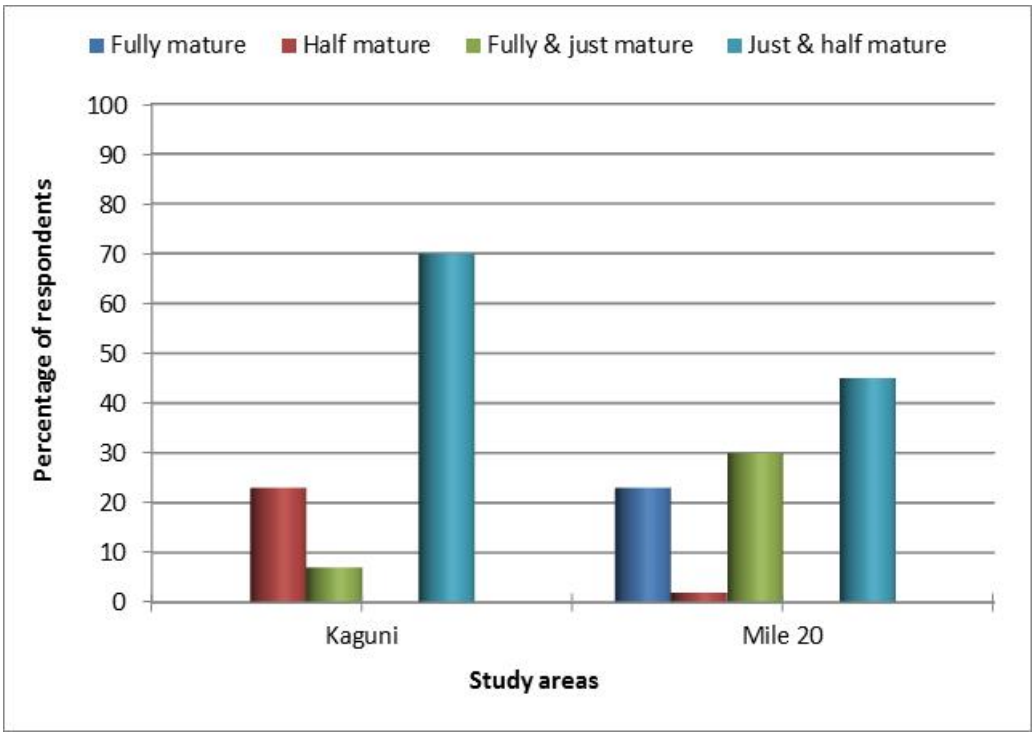

Figure 4.4: Fruit harvested at different maturity stages (Kaguni: n = 94, Mile 20: n = 66)

Figure 4.5: Combination of fruit at different harvesting maturity stages (fully mature: orange, half-mature: yellow and just mature: green)

4.3.3 Transportation of fruit from the field

After harvesting, the fruit were transported from the field to homesteads by motor vehicle, donkey/oxen cart or head load (bags with fruit carried on the head) (Figure 4.6). In Kaguni (79%) and Mile 20 (36%) harvesters used an oxen/donkey cart, while a motor vehicle was used only at Mile 20 (64%). Fruits were only transported on the head at Kaguni (21%) (Table 4.2). There was a significant difference ($p = 0.001$) in transportation of fruit between the two study sites.

Table 4.2: Mode of fruit transportation after harvesting as a percentage per community (Kaguni: $n = 94$, Mile 20: $n = 66$)

	Community (%)	
Mode of Transport	**Kaguni**	**Mile 20**
Vehicle	0	64
Oxen/donkey cart	79	36
Head load	21	0

Figure 4.6: Oxen cart and head load as a mode of transportation

4.3.4 Storage of fruit

Fruit were stored loose in a traditional hut, under the tree or in gunny bags to mature (Figure 4.7). In general, fruit were stored between 2 and 4 weeks before they were considered matured (yellow/orange) enough for sale or fresh consumption.

Figure 4.7: Fruit stored in gunny bags (50kg) and in traditional huts (pile of fruit)

4.3.5 Market place of fruit

The fruit are sold in different parts of the country, namely town/urban, main road and the Rundu open market (Table 4.3). Kaguni (57%) and Mile 20 (41%) sold the fruit in different towns/urban areas within the country (Namibia). These included Grootfontein, Tsumeb, Oshakati and Windhoek. About 25% of the harvesters in Kaguni and 45% in Mile 20 sold at the main road in both study sites. However, 6% of the harvesters in Kaguni sold the fruit at the Rundu open market. Some of the harvesters in Kaguni (12%) and Mile 20 (14%) did not sell fruit, but use it for private consumption.

Table 4.3: Marketing place of fruit harvested as a percentage per community (Kaguni: *n* = 94, Mile 20: *n* = 66)

Market place	Community (%)	
	Kaguni	Mile 20
Town/urban	57	41
Main road	25	45
Rundu open market	6	0
Do not sell	12	14

4.3.6 Transportation of fruit to market

The majority of the harvesters used public trucks or any type of vehicle to transport fruit to the market (Urban area, Rundu) and alongside the road. In Kaguni (89%) and Mile 20 (35%) harvesters transported fruit to the market by means of trucks. However, 35% of harvesters in Mile 20 used any type of vehicle. Harvesters who sold fruit at the main road, transported fruit by head load (Figure 4.8).

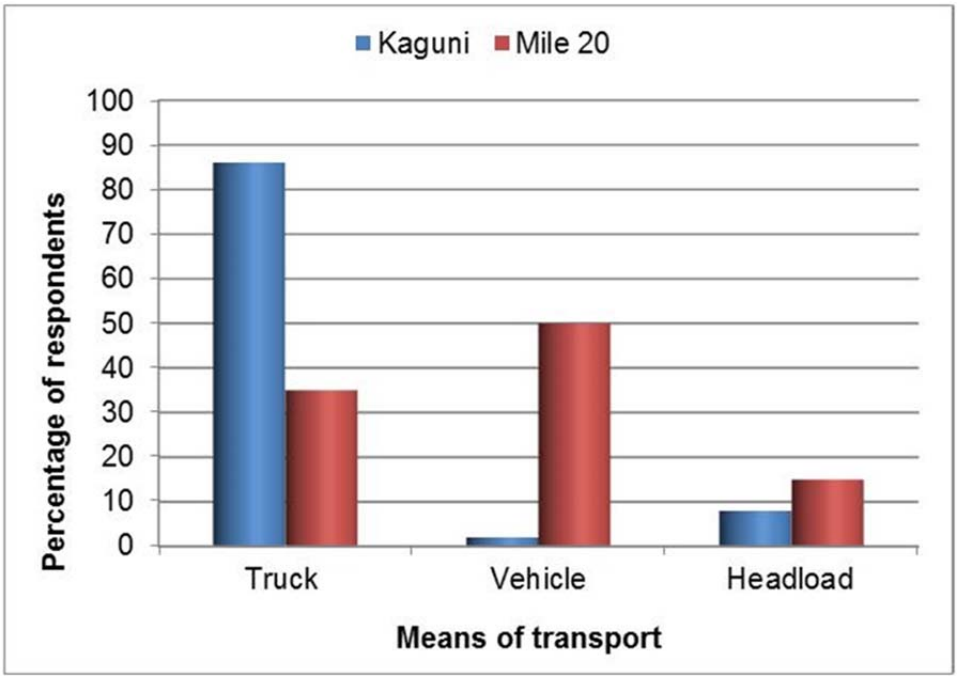

Figure 4.8: Means of transport to the market from community (Kaguni: *n* = 94, Mile 20: *n* = 66)

4.4 Postharvest fruits loss

Fruit losses were experienced at both study sites and occurred at various stages such as harvesting, transportation, storage and marketing. Mechanical loss (physical injuries) was reported to be higher in Kaguni (32%) than Mile 20 (29%) during the transportation of fruit from the field to the market. This was followed by rotting in Kaguni (26%) and Mile 20 (31%) during storage of fruit. Physiological (sun exposure) damages only occurred at the market stage with 24% in Kaguni and 20% for Mile 20. There was no significant difference ($p = 0.706$) in terms of post-harvest loss between the study sites (Figure 4.9).

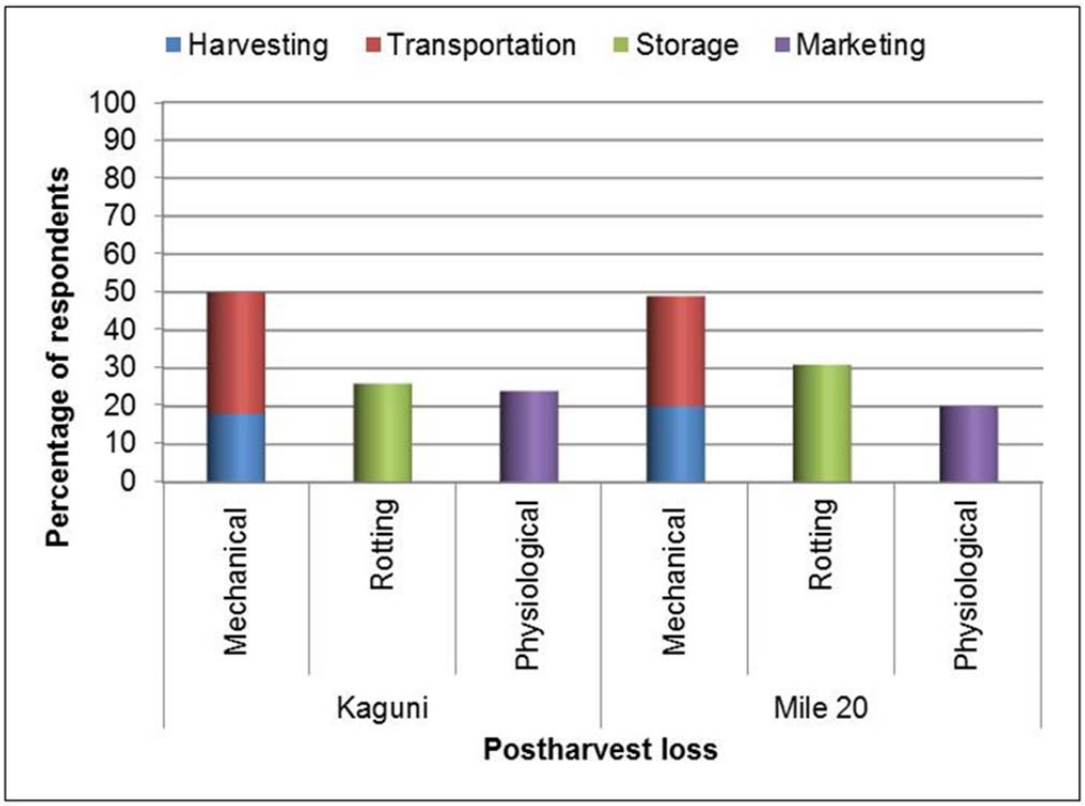

Figure 4.9: Different post-harvest fruit losses (Kaguni: $n = 94$, Mile 20: $n = 66$)

Postharvest loss and income were estimated based on the number of bags harvested and discarded, as well as fruit sold. On average, a gunny bag weighs 50 kg and has approximately 110 fruit valued at N$3.00 each (Table 4.4). The majority from Kaguni (86%) and Mile 20 (76%) harvested about 50 to 100 gunny bags (50kg each) during this study. They experienced

a loss of about 10 to 30 gunny bags (20 to 30%). The harvest was expected to generate an amount (fruit x N$ 3) of N$ 16 500 to N$ 33 000 after fruit sale. However, due to fruit losses, only N$ 3 300 to N$ 9 900 was generated. About 15% of respondents in Mile 20, harvested 45 gunny bags with a loss of 5 to 10 bags (11% to 22%) which could have generated an income of N$ 14 850 after sales. However, due to fruit loss only N$ 1 650 to 3 300 was generated. About 10% in Kaguni, 5% in Mile 20 harvested 105 to 155 gunny bags with an estimated loss of 25 to 50 gunny bags (23 to 32%). The expected income can be estimated at N$ 34 650 to 51 150, but due to fruit losses only N$ 8 250 to 16 500 was generated. A few harvesters at Kaguni (4%), and Mile 20 (2%) harvested 205 gunny bags. Respondents reported an estimated loss of 70 to 100 gunny bags (34 to 49%) with an expected income of N$ 67 650. However due to losses, only N$ 23 100 to 33 000 was generated. Figure 4.10 shows spoiled fruit during the harvesting and storage.

Table 4.4: Estimate income and loss per household (Kaguni: $n = 94$, Mile 20: $n = 66$)

Village (%)		**Bags (50kg)**		**Fruit per bag (x110)**		*** Annual income per bag (N$)**	
Kaguni	**Mile 20**	**Harvested**	**Loss**	**Harvested**	**Loss**	**Harvested**	**Loss**
0	15	45	5 - 10	4 950	550 – 1 100	14 850	1 650 – 3 300
86	76	50 - 100	10 - 30	5 500 – 11 000	1 100 – 3 300	16 500 - 33 000	3 300 - 9 900
10	5	105 - 155	25 - 50	11 550 – 17 050	2 750 – 5 500	34 650 – 51 150	8 250 – 16 500
4	2	205	70 - 100	22 550	7 700 – 11 000	67 650	23 100 – 33 000

*50kg bag with 110 fruit, valued at N$ 3.00 per fruit

Figure 4.10: Spoiled fruit due to poor harvesting and post harvesting handling practices

4.5 Consumer preferences

A sample of 150 fruit per study site was used for consumer preferences tasting during interviews. Weight, diameter, TSS and taste of the fruit from the three fruit maturity stages (fully mature, half-mature and just mature) were measured at the point of sale. The majority of consumers that participated were female in Kaguni (58%) and Mile 20 (72%). The age class distribution was 25 to 34 years in Kaguni (46%) and 45 to 54 years in Mile 20 (30%).

4.6 Fruit quality parameters

4.6.1 Weight of fruit at harvesting maturity stages

Fruit weight from both study sites ranged from 100 to 801g per fruit. In Kaguni, a high percentage of fruit were harvested fully mature (40%) with a weight between 401 and 500g per fruit. Approximately 10% of the fruit were half-mature with a weight of more than more than 801g. There was a significant difference (p = 0.001) for weight of fruit harvested at different maturity stages in Kaguni.

For Mile 20, the highest percentage of fruit was harvested just matured (38%) with the weight ranging between 401 and 500g per fruit. This is followed by 28% harvested when fully mature, 28% half mature and 28% just mature with a weight ranging between 501 and 600g per fruit. There was no significant difference (p = 0.145) for fruit weight harvested at different maturity stages in Mile 20. The comparison between the two study sites, also had no significant difference (p = 0.640) for weight of fruit harvested at different maturity stages (Figure 4.11).

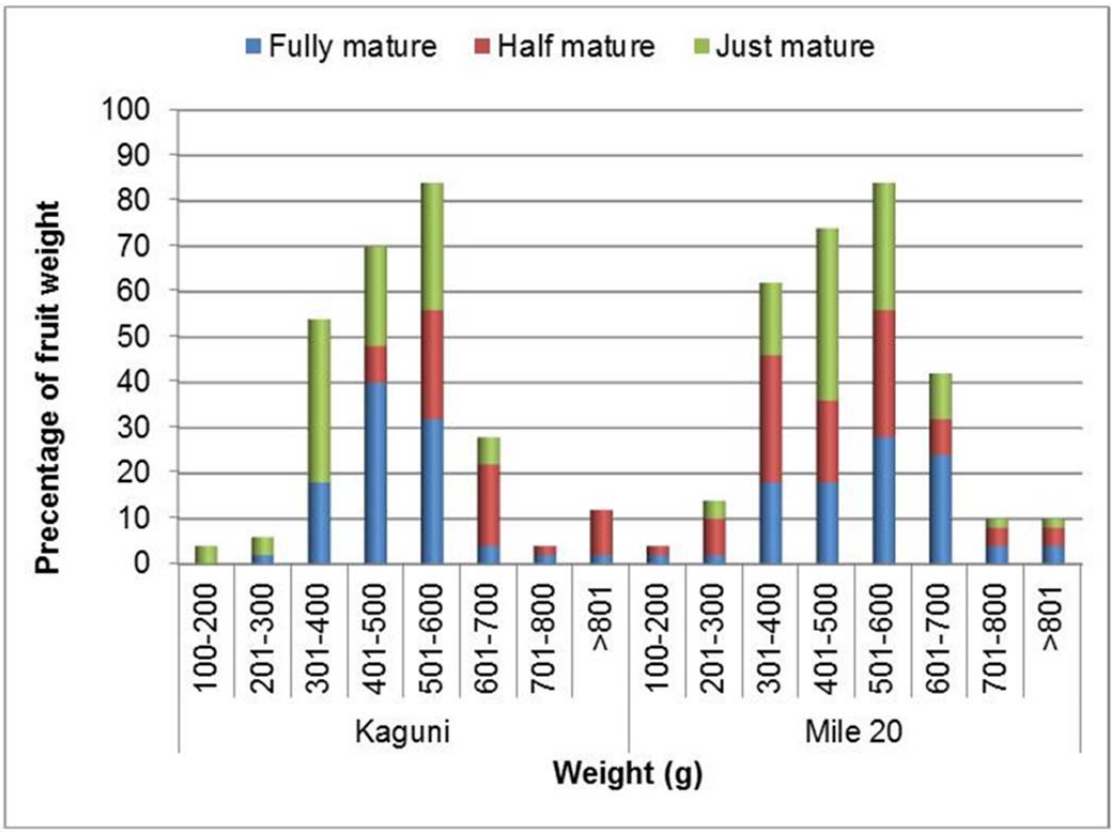

Figure 4.11: Weight (g) at harvesting maturity stage

4.6.2 Fruit diameter harvested at different maturity stages

Diameter of fruit ranged from 7 to 7.9cm to more than 11cm per fruit. In Kaguni, most fully mature fruit (66%) had a diameter of 9 to 9.9cm, followed by harvested just mature (50%) and half mature fruit (48%). There was no significant difference ($p = 0.117$) for fruit diameter harvested at different maturity stages in Kaguni.

In Mile 20, most fruit (56%) had a diameter of 9 to 9.9cm when harvested just mature, followed by half mature (52%), and fully mature (46%). There was no significant difference ($p = 0.066$) for fruit diameter harvested at different maturity stages in Mile 20. Furthermore, there was no significant difference ($p = 0.664$) for diameter of fruit harvested at different maturity stages between the two study sites (Figure 4.12).

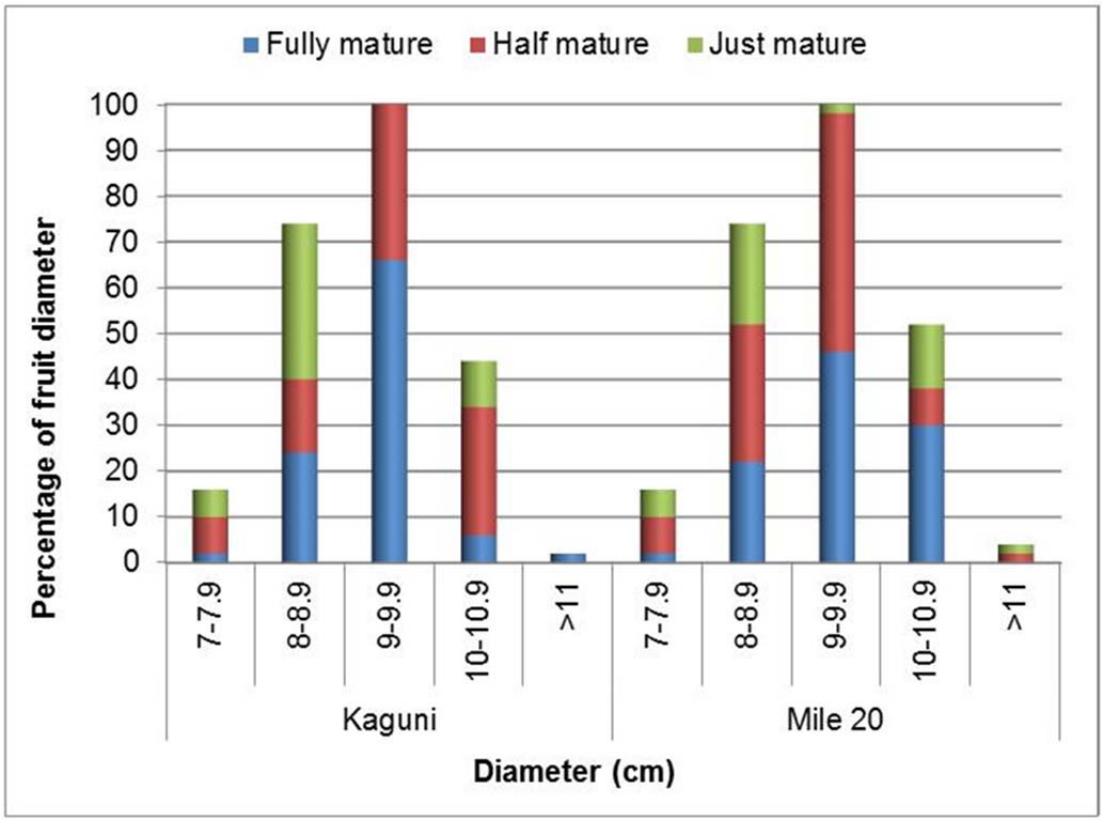

Figure 4.12: Fruit diameter at different harvesting maturity stages

4.6.3 Fruit diameter and weight

The weight of most fruit in both Kaguni (24%) and Mile 20 (24%) ranged between 501 and 600g with a diameter of 9 to 9.9cm. There was no significance difference (p = 1.000) for fruit weight and diameter in both study sites (Figure 4.13).

4.6.4 Fruit TSS at different harvesting maturity stages

The TSS ranged between 14 and 25°Brix % in both study sites. Most fruit had a TSS between 17 and 22°Brix % (Figure 4.14). There was no significant difference (p = 0.758) for fruit TSS at different harvesting maturity stages for both study sites.

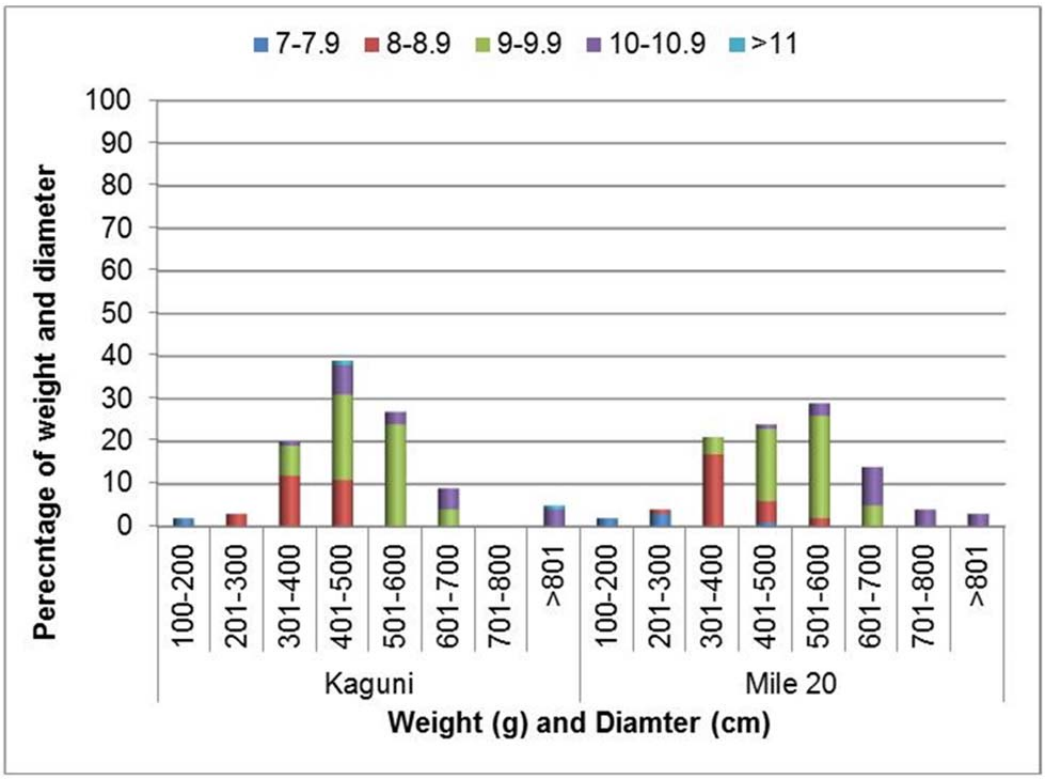

Figure 4.13: Fruit weight (g) and diameter (cm) at both study sites

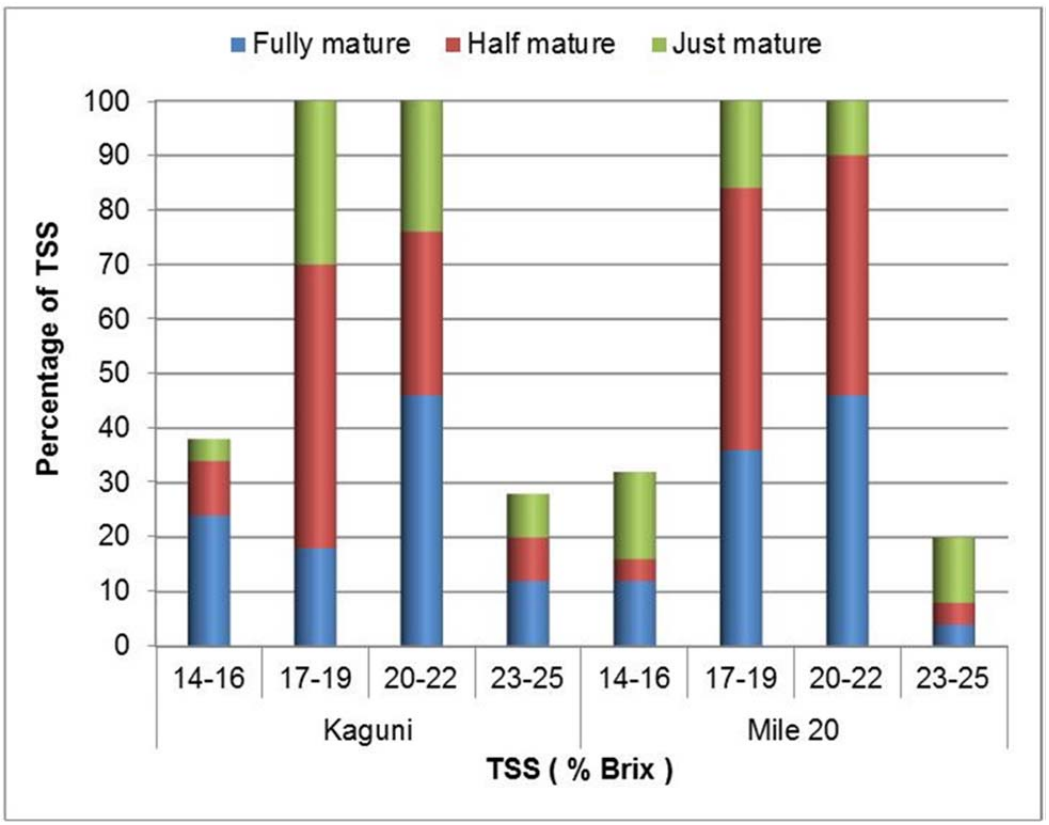

Figure 4.14: Fruit TSS at different harvesting maturity stages

4.6.5 Consumer preferences of fruit harvested at different maturity stages

Although fruit were harvested at three different maturity stages, most consumers liked the fruit because it was sweet (Figure 4.15). However, the consumers (32%) disliked some fruit harvested at just mature stage from Mile 20 as it tasted sour. There was a significant difference ($p = 0.012$) in fruit taste for both study sites (Figure 4.15).

In Kaguni (37%) and Mile 20 (39), most fruit had a TSS of between 17 and 22°Brix %. These fruit were sweet and preferred by the consumers. A highly significant difference ($p = 0.001$) between the two study sites for TSS and taste were observed (Figure 4.16).

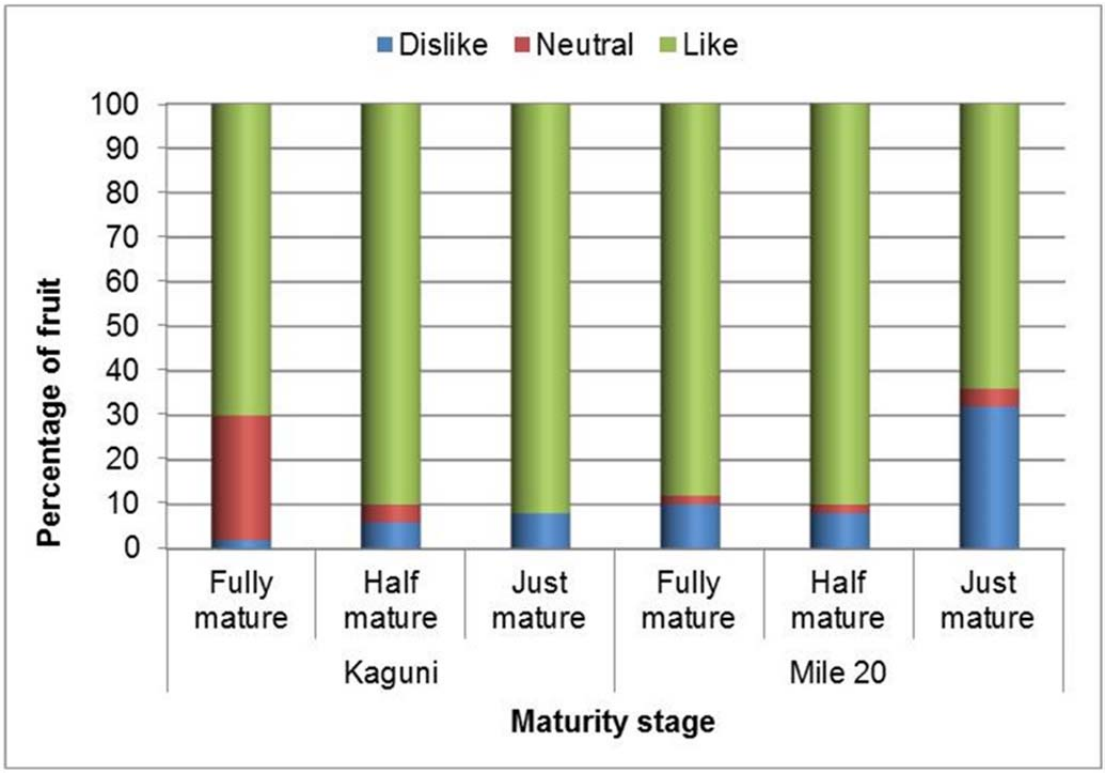

Figure 4.15: Consumer preferences in terms of fruit taste harvested at different maturity stages

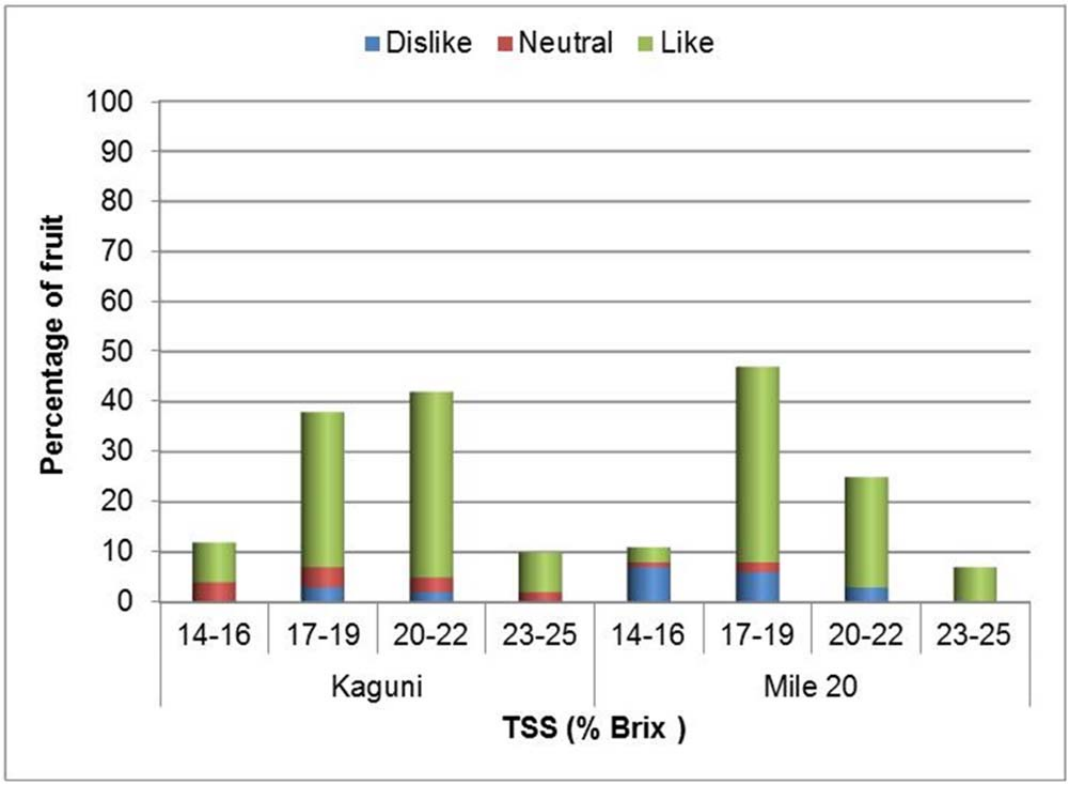

Figure 4.16: TSS of fruit harvested at different maturity stage

5 Discussion

5.1 Harvesting and postharvest handling practices of *S. cocculoides* fruit

Time of fruit harvesting can be determined by many factors, such as experience of the rural community, natural abscission, fruit colour, and other morphological characteristics (Kadzere *et al.,* 2006). During this study, *S. cocculoides* fruit were harvested between August and December. However, as the harvesters (rural community) have indigenous knowledge on when is the best time to harvest the fruit, it can be harvested as early as June in some years. In general, fruits are harvested from crop fields and communal forests with the majority of the harvesters (mainly women and children) travelling a distance of 2 to 4km. The decision to sell the fruit (when and where), is also made by the women.

These findings agree with the report by Ruiz –Pérez *et al.* (1997) who stated that women are the primary fruit collectors and decision makers in terms of selling indigenous fruits in rural areas. Similarly, Mithöfer (2005) and Ramadhani (2002) stated that women and children are the main harvesters and beneficiaries of indigenous fruits especially in countries such as Malawi, Zambia and Zimbabwe. Children can assist parents in selling the fruit, especially at the main road close to rural communities. Men are mostly involved in wood carving activities and regard the harvesting and selling of indigenous fruit activities as the duties of women and children. This is similar to the findings by Neumann & Hirsch (2000) who reported that women are more involved in the activities of harvesting NTFP's, since harvesting can be easily combined with other female responsibilities.

Fruits are mainly harvested in the morning due to the high humidity, cool temperatures and low evaporation (Genova *et al.,* 2006). However, harvesters with motor vehicles for transport prefer to harvest in the morning and evening. During this study, it was evident that harvesters prefer to harvest fruit weekly. The most preferred methods of fruit harvesting were climbing of tree and using a stick. The combination of these two methods is known to be non-destructive, fast and easy, although children can be harmed when climbing the trees. Other known methods (shaking branches, throwing heavy objects into the tree, picking from the

tree or from the ground) were not employed in the two study sites as with previous studies (Kadzere, *et al.,* 2004a). Although women and children mainly did the harvesting, only children will climb the tree when harvesting fruit. Therefore, households that have children mostly use climbing and stick or stick only, while households with no children use stick only as a method of harvesting.

Observations of the trees indicated that climbing might have a long-term effect on the tree, leaving damaged stems and branches. Furthermore, fruit that fell from the tree because of climbing or stick method, obtained cracks and bruises. The damage of the fruits also depends on the height of the tree as well as the ground surface. According to Kadzere, *et al.,* (2004a), fruits can obtain cracks and bruises as they fell to the ground with force.

Fruits are harvested during three physiological maturity stages: fully mature, (orange) half-mature (yellow/green), just mature (green). Harvesting of just mature fruit is more common in the study sites due to competition, as individuals aim to increase their harvest to maximise income from the sale of fruits. Just ripe or unripe fruits are harvested and kept in gunny bags or loose under a tree to mature. Similar findings have been reported in Zimbabwe by Kadzere, *et al.,* (2004b), indicating that due to competition of resources, unripe fruits are harvested and left to mature at homesteads. The number of fruit harvested can increase the household cash income from the sale of the indigenous fruits. Although the fruits are harvested from the farmers own crop fields, it is not fenced, thus anyone can enter the fields and harvest the fruits. Harvesters indicated that when two or more fruits are mature on a tree, they harvest all the fruits from that specific tree to have the competitive edge. Ramadhani (2002) indicated that similar harvesting practices were experienced in Zimbabwe. The increased in demand for indigenous fruits has led to resources competition. There are no property rights in the free access open areas and this might cause exploitation of resource, a situation that has been termed as tragedy of the common by Hardin (1968).

In southern Africa, indigenous fruit markets are generally informal and small (Akinnifesi *et al.,* 2006). In this study, fruits were sold in both rural and urban markets. According to Ramadhani (2002), the selling of indigenous fruits in rural and urban markets is an indication of appreciation of fruits by the consumers and their willingness to pay. Harvesters of Kaguni

sold fruits alongside the road (exposed to the sun); therefore, just mature and half mature fruits were more popular to harvest as they mature slower without being spoiled. However, harvesters in Mile 20 preferred to harvest mature fruit as fruits are sold either in the shade of a big tree or on an informal market. The informal market is open daily, thus mature fruits do not need to be kept fresh for long periods of time (short shelf life). When fruits are transported to other urban areas in Namibia, just mature and half-mature fruits are preferred, as they are not damaged during transportation. The findings agrees with Akinnifesi *et al.* (2008b) who indicated that fully matured fruits may result in bigger fruit losses compared to those harvested when partially ripe or unripe especially during long distance transportation.

After harvesting, fruits are transported to homesteads with oxen/donkey cart, motor vehicle or in bags on the head. From the homestead to the main road or informal market, fruits are transported by head. When transporting fruits to other towns outside the Kavango region, motor vehicles or trucks are used. Although fruits are harvested in the early morning (lower temperatures), transporting of fruits occurs throughout the day (higher temperatures). These findings are in line with Ramadhani (2002), who indicated that fruit harvesters in Zimbabwe use ox-carts, pick-up trucks, head load and buses as a means to transport fruits to the market.

It is however, recommended that fruit should be transported during the cooler parts of the day. As transportation can contribute to the quality of the fruit, it is important to keep temperatures low and prevent mechanical losses due to the shaking of fruit (Kwesiga *et al.,* 2000; Akinnifesi *et al.,* 2004). Also, harvesting early in the morning has become common practice due to the growing need to generate alternative sources of income (better fruit quality and thus higher income generated) as well as acquiring food for households (Kwesiga *et al.,* 2000). Akinnifesi *et al*. (2004) also indicated that due to increased competition to harvest fruit as soon as possible from the tree, rural people tend to practice earlier fruit harvesting by forcefully dislodging unripe fruit.

5.1.1 Sorting, storage, grading and packaging of fruit

Fruit of *S. cocculoides* can be stored for up to two weeks in the shade (Ruffo *et al.,* 2002). During this study, fruits were stored for up to four weeks depending on the maturity stages

during harvest. Fruits (mixed maturities) were stored in tradition huts, under trees or in gunny bags (50kg with an average of 110 fruits) with limited protection from sun and wind (Elago & Tjaveondja, 2015). Stored fruits were also a mixture of damaged and undamaged fruit. Furthermore, shelf life of fruit depends on the maturity of the fruits during harvest (Anjum *et al.,* 2006; Jha *et al.,* 2007). FGD's during this study stated that if care is taken with the storage of fruit, it might be stored for more than four weeks. Factors to consider should include maturity of fruit, health of fruit (presence of cracks etc.) and the storage place. Fruits can then be graded and priced accordingly. During this study, fruits were placed or packaged in one basket regardless of the size and maturity with varying prices.

The findings are in line with Ramadhani, (2002), who indicated that in Zimbabwe pre-sale activities, grading and packaging of *S. cocculoides* fruit is not well documented or executed. In contrast, Akinnifesi *et al.* (2008a) reported that some farmers in Zimbabwe sell *Uapaca kirkiana* fruit according to the size and price. From the findings, it shows that not much was done in terms of value addition and the harvesters lacked knowledge of proper sorting, storage, grading and packaging in both study sites.

5.2 Postharvest losses at different handling stages

Postharvest losses are measurable in terms of fruit damages (qualitative and quantitative) that occur between harvesting and the point of sale (Hodges *et al.,* 2011). Fruit damages can reduce the quality (appearance) and shelf life (storage after purchasing) of the fruits as it gets spoiled in a shorter period (Kadzere, *et al.,* 2001; Chandrasekharan, 1993). The impact on fruit damages was also observed at the point of sale, as customers are reluctant to purchase fruits with extensive cracks and bruises. These losses can occur during harvesting, transportation, storage and marketing. Therefore, harvesters need training in fruit harvesting and handling methods. Harvesters in the two study sites requested the Directorate of Forestry (DoF) to offer training on harvesting and postharvest technique in conjunction with community forestry activities.

During the harvesting stages, mechanical injuries (cracks, bruises etc.) were experienced by harvesters at both study sites. Severe cracks and bruises were observed when fruits were dislodged from the trees (stick and climbing methods) and free fall to the ground. Furthermore, as fruits were accumulating in heaps on the ground, injuries and fruit losses accumulated as well. These injuries occurred independently from the maturity stages of the fruits. Although harvesters can obtain cash income from the sale of *S. cocculoides*, it is not optimised due to poor harvesting and handling practices (Ham *et al.,* 2008). As the fruits are harvested from natural forests for free (no input costs necessary), harvesters are more careless with the harvesting and handling processes of the fruits. A study done by Kalaba (2007) indicated that the absence of rules and regulations concerning harvesting of indigenous fruits were a major constraint to sustainable use of resources.

During the transportation stage (from field to homesteads, road, markets etc.), mechanical damages (cracks and bruises) were evident during on- and offloading of fruits. This might be due to careless handling, as fruits were thrown into the motor vehicle, poorly packed and rubbing against one another. Moreover, according to Akinnifesi *et al.* (2008a), the method of bulk storage has a negative effect on the quality of the fruit, as the bottom fruits are squashed by the weight of the fruit on top causing fruit damages.

Harvesters indicated that lack of reliable transport (frequency and quality) from Kavango region to urban areas might be a significant challenge that needs to be addressed. Most of these harvesters do not own motor vehicles, hampering transportation of fruits to other regions or markets. Therefore, unreliable public transport (when available) is used to transport fruits to other regions. This contributes to injuries, number of spoiled and mature fruits as they are packed into gunny bags, stacked on top of each other (poorly arranged) with no space between bags for air movement (like ethylene). To minimise fruit losses, transportation between harvesting sites and markets, need to be addressed. Similar findings was reported by Karaan *et al,* (2006), who indicated that fruit collectors in Zimbabwe packed fruits in large bags and make use of public transport or hike truck, a method that reduces quality and shelf life of the fruits.

It was evident in the study that, as fruits are stored in gunny bags, loose in tradition huts (in a large heap on the ground) or under trees with no protection against natural elements, rotting of fruits were a severe problem. Fruit are not sorted or handled properly, thus contributing to rotting and injuries of good fruit and limiting shelf life and thus loss in potential income. Training on harvesting times, sorting of fruit (according to size, maturity, injuries etc.), handling practices and optimum storage can increase the cash income for harvesters. With little effort, they can increase the cash income and have a more sustainable source of income. Akinnifesi *et al.* (2008b) indicated that there is a need to develop appropriate techniques for harvesting and postharvest in order to maximize profits for fruit products. According to SCUC (2006), it is recommended to separate unripe and damaged fruits to prevent spoilage and increase cash income for fruit collectors. These findings are supported by Ham *et al.* (2008), who indicated that in many rural communities, harvesting and postharvest handling techniques are poorly developed and reduce fruit quality and shelf life, hence affecting market value.

Physiological damage or fruit losses can also be due to higher temperature (insufficient air movement between fruits), sun and wind exposure during the market stage at the road, community or urban markets. Ramadhani (2002) indicated that fruit collectors in Zimbabwe sell the fruit along the roadside, highways or in the street. In addition, harvesters indicated that the majority of them do not have authority to sell *S. cocculoides* fruit in most open markets within Namibia. Currently DoF does not issue market permits for indigenous fruits. The harvesters reported that, market permits for open markets are regulated by the town councillors in each specific town. Consequently, the harvesters sell the fruit in an open area outside the open markets that is exposed to the sun and causing fruit losses. It is significant for DoF to assist and facilitate fruit marketing permits for rural communities. According to Mkonda *et al.* (2003), the pre-sale cost and the market fees vary depending on the market site and marketing level.

Harvesting and postharvest losses have a direct and negative impact on the income of farmers. During this study, the impact was observed along the supply chain from harvest through to the point of sale (consumers). Although farmers only sell a small portion of their harvest, those sales account for a relatively small portion of their annual income due to the

losses. During the study, the total harvest per household was determined based on the number of gunny bags harvested. The fruit were sold at a cost of N$ 3.00 per fruit. On average a household harvested 50 to 100 bags (50kg each), however due to poor handling practices along the supply chain, 10 to 30 bags are discarded. In terms of income, the impact is an estimated loss of N$3 300 to 9 900, of which N$ 16 500 to 33 000 could have been generated in the absence of these postharvest losses.

Ramadhani (2002) reported that a 5 litre tin of *U. kirkiana* in Zimbabwe was sold at US$ 0.30 while *S. cocculoides* were sold for US$ 0.06-0.15 per fruit. These prices varied to the location where the fruit was sold. For instance *U. kirkiana* was sold between Z$ 1.73/kg in Murehwa to Z$ 1.78 in Gokwe and Z$ 3.34/kg in Mbare (Ramadhani, 2002). Moombe (2009) reported that farmers in Chipata district of Zambia sold *U. kirkiana* fruit at K 314.00/kg at the harvesting stage and for K 2 509.00/kg at the retailer in Lusaka (the capital). Therefore, the number of fruit harvested can increase the household cash income if proper handling methods are applied.

Ramadhani (2002) reported that indigenous fruits are generally processed for home consumption and sale at rural markets. However, during this study not much is done when it comes to processing of fruit for value addition. Value addition by processing the fruit into jam, juice etc. can also increase community income (Tieguhong & Ndoye 2004).

5.3 Aspect of fruit quality (weight, size, TSS and taste) at different maturity stage

The weight of *S. cocculoides* fruit can vary from 40 to 100g per fruit and the diameter from 1.6 to 10cm (Mkonda, *et al.,* 2004; Mwamba, 2005). The number of fruits on a tree can also vary from 300 to 700 per tree when grown in favourable conditions (Mkonda, *et al.,* 2004; Mwamba, 2005). For this study, the average fruit weight in both study sites ranged between 501 to 600g per fruit with a diameter of 9 to 10cm. These values are higher than those reported by Mkonda *et al.* (2004) for the provenance trails in Zimbabwe, Zambia and

Tanzania. The fruit maturity stages had no effect on the weight and size (diameter) of the fruit in both study sites.

TSS of fruit ranged from 17 to 22% on average with no significant difference in terms of the harvest maturity stages. In terms of fruit taste, the consumers liked most of the fruits harvested at different maturity stages (fully mature, half mature, and just mature). However, a significant difference with 32% of fruits harvested at just mature stage from Mile 20 was observed due to sourness. The consumers indicated that the fruits were sour and they thus disliked the fruits. It was discovered during the FGD's that, although harvesters do pre-testing of fruits from trees as criteria to determine the superior fruits in terms of taste, not all harvesters practises this method. High competition and the pressure to obtain quick household cash income might have led to some farmers harvesting immature fruits (not fully developed) from any available tree.

Léchaudel and Joas (2006) indicated that fruit harvested at an immature stage may not achieve normal ripening characteristics causing sourness and are mostly rejected by the consumer due to irregular ripening and lack of full flavour and aroma development. In addition, previous studies (see Dinehart *et al.,* 2006; Harker *et al.,* 2003; Engineering *et al*., 2014), reported that sourness could be due to fruit harvested immature due to competition and pressure to obtain quick cash income.

6 Conclusion and recommendation

6.1 Conclusion

The aim of this study was to assess harvesting and postharvest handling practices of *S. cocculoides* fruit in relation to the quality of the fruit, from harvesting up to the point of sale in the Kavango region. The study assessed existing harvesting and postharvest handling practices of the fruit, including the level of postharvest losses of the fruit at different harvesting and postharvest handling practices. This was done in terms of TSS, taste, size, and weight when harvested at different maturity stages.

Fruit are harvested from crop fields and communal forests mainly for home consumption and cash income. Women and children are the main harvesters from August to December by means of climbing the tree and using the stick method. Fruit are harvested fully mature, half-mature or just mature. However, due to competition, unripe fruit (just mature or green) is commonly harvested in the Kavango region. The harvesters used donkey/oxen carts, head load, vehicle and public trucks as a means of transporting the fruit from the field or outside the Kavango region to relevant markets for sale.

Postharvest losses are experienced due to poor harvesting and postharvest handling practices. Competition for resources during the entire supply chain also plays an important role. Community farmers lack knowledge of proper harvesting and postharvest handling practices despite their numerous years of harvesting experiences. Postharvest losses had a negative impact on income generated by the communities in both study sites. Lack of transportation and insufficient access to formal markets also had a contributing factor to fruit losses.

Physiological maturity stages at which the fruit were harvested had no effect on the weight, diameter, TSS and taste when fruit are fully developed. However, the study concluded that the TSS for quality fruit of *S. cocculoides* in the Kavango region ranged between 17 to 22%.

Community farmers lacked knowledge of proper harvesting and postharvest handling practices despite their numerous years of harvesting experience.

6.2 Recommendation

The following recommendations are made for future studies:

- There is an urgent need to improve on the existing harvesting methods by recommending appropriate harvesting tools and methods. The method of climbing the tree and stick need to be improved because of the negative impact it might have. Stepladders and other methods need to be investigated.
- The Directorate of Forestry (DoF), should offer training on appropriate harvesting and postharvest management that leads to better handling practices of indigenous fruits. This include transportation (method and frequency), storage (method), sorting (colour, maturity etc.), grading (colour, maturity etc.), packaging (prevent cracking) and market access (permits). DoF needs to investigate, propose and establish policies that implement and monitor postharvest management standards for fruit markets.
- The DoF can also establish a formal market for all indigenous fruits in the region that is more accessible to customers, buyers and sellers that represent the supply chain in order to improve community income and livelihoods.
- Programs can also be developed to reduce postharvest losses by promoting commercialization. This can be done by economic value adding to indigenous fruit. Development centres equipped with sorting, grading, packaging, storage and processing equipment can be set up in rural communities to provide support with development of products such as juice, jam, wine, medicine, cosmetic and other products.
- An extension approach to disseminate information on indigenous fruit to the community through pamphlets, brochures; farmers open days and radio talks are also needed. Working directly with farmers and other stakeholders can establish a postharvest management information networking system.
- DoF can also assess available indigenous knowledge on the uses of the forest products, like medicinal properties, by collaboration with academic institutions.

- Furthermore, effective harvesting methods and protocols need to be put in place to protect the natural resources from overexploitation.
- Extraction of chemicals such as strychnine and brucine from *Strychnos* species for pharmaceutical and industrial uses needs to be investigated.

7 References

Agustino, S., Mataya, B., Senelwa, K., & Achigan-Dako, G.E. 2011. Non-wood forest products and services for socio-economic development. A Compendium for Technical and Professional Forestry Education. The African Forest Forum, Nairobi, Kenya, 219.

Akinnifesi, F., Kwesiga, F.R., Mhango J., Mkonda, A., Chilanga, T. & Swai, R. 2004. Domestication priority miombo indigenous fruits trees as a promising livelihood option for smallholder farmers in Southern Africa. Acta Horticulture, Issue 632: 15-30.

Akinnifesi, F., Kwesiga, F.R., Mhango J., Chilanga, T., Mkonda, A., Kadu, C.A.C., Kadzere, I., Milthofer, D., Saka, J.D.K., Sileshi, G., Ramadhani, T. & Dhiliwayo, P. 2006. Towards the development of miombo fruits trees as commercial tree crops in Southern Africa. Forest, Tress and Livelihoods, (16):103-121.

Akinnifesi, F.K., Mhango, J., Sileshi, G. and Chilanga, T. 2007. Early growth and survival of three miombo indigenous fruit tree species under fertilizer, manure and dry-season irrigation in southern Malawi. *Forest Ecology and Management*.

Akinnifesi, F., Ajayi, O.C., Sileshi, G., Matakala, P., Kwesiga, F.R., Ham, C., Kwesiga, F.R., Kadzere, I., Mhango J., Mng'omba, S.A., Chilanga, T., Mkonda, A. 2008a. Creating Opportunities for Domesticating and Commercializing Miombo Indigenous Fruit Trees in Southern Africa: In *Indigenous Fruit Trees in the Tropics Domestication, Utilization and Commercialization*, edited by Akinnifesi, F., Leakey, R., Ajaya, O., Sileshi, G., Tchoundjeu, Z., Matakala P. and Kwesiga, F. CABI Publishing

Akinnifesi, F., Leakey. R.R.B., Ajayi O.C., Sileshi. G., Tchoundjeu, Z., Matakala, P. & Kwesiga, F.R. (Eds.). 2008b. Indigenous Fruits Trees in the Tropics: Domestication, Utilization and Commercialization. London: CAB International.

Antônio, M., Plácido, G. R., Caliari, M., Sousa, B. de., Marins, R., Cagnin, C. & César, R. 2015. Physical and chemical characteristics and instrumental color parameters of passion fruit (*Passiflora edulis* Sims), *10*(10), 1119–1126.

Anjum, N., Masud, T., & Latif, A. 2006. Effect of various coating materials on keeping quality of mangoes (*Mangifera indica*) stored at low temperature. Am. J. Food Technology, 1(1): 52-58.

Babbie, E. & Mouton, J. 2011. The practice of Social Research. Cape Town: Oxford University Press, 2nd edition.

Blay, D. 2004. Dental hygiene and livelihoods: a case of chewing sticks in Ghana. In Sunderland, T and Ndoye, O (eds). Forest Products, Livelihoods and Conservation. Case Studies of Non-Timber Forest Products Systems. Vol 2 Africa.

Blowfield, M. 2001. Value Chains. Issue Paper 2. London: Resource Centre for the Social Dimensions of Business Practice. [Online]. Available at: www.resource-centre.org [10/12/2015].

Boyd, H. K.R., Westfall, E. & Stasch, S.F. 1981. Marketing Research Text and Cases, Richard D Publisher.

Burdon, J. 1997. Postharvest handling of Tropical and Subtropical fruits. In: S. Mitra (ed). Post-harvest physiology and storage of Tropical and Subtropical fruit. CAB International, Issue Chap.1: 1-19.

Campell, B.M., Jefrey. S., Kozanayi, M., Kuckert, M. Mutamba, M. & Zindi, C. 2002. *Households Livelihoods in the semi-Arid Regions:* Options and constraints. Centre for International Forestry Research. Bongor, Indonesia.

Campell, B., Lukert, M. & Scoones, I. 1997. Local level valuation of Savannah resources: A case study from Zimbabwe. Economic Botany 51:57-77.

Chandrasekharan, C. 1993. Issues involved in the sustainable development of Non-Wood Forest Products. Proceedings for the Expert consultation on NWFPs for English speaking African Countries, Arusha, Tanzania.

Chikamai, B & Tchatat, M. 2004. Forest Management For Non-Wood Products and Services in Africa. A Report prepared for the Project: Lessons Learnt on Sustainable Forest Management in Africa. AFORNET, Nairobi.

Cresswell, J. W. 2003. Research Design. Sage Publications Ltd: California.

Denscombe, M. 1998. The Good Research Guide for Small Scale Research Projects. Buckingham, Philadelphia: Open University Press.

Dhatt, A.S. & Mahajan, B.V.C. 2007. Horticulture post-harvest technology harvesting, handling and storage of horticultural crops. Punjab Horticultural Postharvest Technology Centre, Punjab Agricultural University Campus, Ludhiana.

Dietz, H. 1999. Opportunities and potential for processing of horticultural products by small entrepreneurs. Project 95.2254.1-001.00. Promotion of Horticulture, March/April, 34

Dinehart, M. E., Hayes, J. E., Bartoshuk, L. M. & Lanier, S. L. 2006. Bitter taste markers explain variability in vegetable sweetness, bitterness and intake. Physiol. & Behav. 87:304–313.

du Plessis, P., Lombard, C. & den Adel, S. 2002. *Marula in Namibia: Commercial Chain Analysis. North Central Namibia,* Namibia: CRIAA SA-DC.

Elago, S.N. & Tjaveondja, L. 2015. Socio-economic importance of two indigenous fruit trees: *Strychnos cocculoides* and *Schinziophyton rautanenii* to the people of Rundu Rural West Constituency in Namibia. European Journal of Physical and Agricultural Sciences, 3(2):16–27.

El-ramady, H.R., Domokos-Szabolcsy, É., Abdalla, N. A., Taha, H.S. & Fári, M. 2015. Postharvest Management of Fruits and Vegetables Storage. Lichtfouse. E (ed.) Switzerland: Springer International Publishing.

Engineering, A. P., Harvest, P. & Centre, T. 2014. Maturity Measurement of Mango and Banana as Related to Ripening, 7(9), pp.1–4.

Erkilla, A. & Siikonen, H. 1992. Silvica Calerica 20 Forestry in Namibia 1850-1990. Survey of research needs in Northern and Southern Namibia. Directorate of Forestry, Research Division., Finland: University of Joensuu, Faculty of Forestry.

FAO, 1995. Report of the International Expert Consultation on Non Wood Forest Products. Non-wood forest products – 3. FAO, Rome.

FAO, 2009. Course on agribusiness management for producers' associations. Module 4 – Post-harvest and marketing. Santacoloma P, Roettger A, Tartanac F (eds.) Training materials for agricultural management, marketing and finance, Vol 8. Food and Agriculture Organization of the United Nations, Rome.

Genova, C., Weinberger, T., Chanthasombath, B., Inthalungdsee, K., Sanatem & Somsak, K. 2006. Post-harvest loss in the supply chain for vegetables-The case of tomato, yardlong bean, cucumber and chilli in Lao. PDRC. AVRDC-The World Vegetable Centre, Shanhua, Taiwan. ROC. AVRDC Publication No. 06-684, Working Paper No. 17: 49 [Online] Available: www.avrdc.org/pdf/ [29/08/2016].

Hailwa, J. 1998. Non-wood forest products of Namibia. Data Collected and Analysis for Sustainable Forest Management in ACP Countries-Linking National and International Efforts. EC-FAO Partnership Programme (1998-2000). Tropical Forestry Budget line B7-6201/97-15/VIII/FOR Project GCP/INT/697/EC. Directorate of Forestry, Ministry of Environment and Tourism, December 1998, Windhoek, Namibia.

Ham, C., Akinnifesi, F., Franzel, S., Jordaan, D., Hansmann, C., Ajayi, O.C. & De Kock, C. 2008. Opportunities for commercialisation and enterprise development of indigenous fruits in southern Africa. In *Indigenous Fruit Trees in the Tropics Domestication,*

Utilization and Commercialization, edited by Akinnifesi, F., Leakey, R., Ajaya, O., Sileshi, G., Tchoundjeu, Z., Matakala P. and Kwesiga, F. CABI Publishing.

Ham, C. & Akinnifesi, F.K. 2006. Priority fruit species and products for tree domestication and commercialization in Zimbabwe, Zambia, Malawi and Tanzania. IK Notes No. 94. The World Bank, Washington, DC, 5 pp

Ham, C. 2005. Plant for food and drink. In: Mander, M. and Mckensie, M. (eds) *Southern African Trade Directory of Indigenous Natural Products. Commercial Products from the Wild Group*. Department of Forest and Wood Science, Stellenbosch University, Stellenbosch, South Africa, pp. 17–22.

Hodges, R.J., J.C. Buzby, & Bennelt. B. 2011. "Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use." Journal of Agricultural Science, 149:37-45.

Harker, F. R., Gunson, F. A. & Jaeger, S. R. 2003. The case for fruit quality an interpretative review of consumer attitudes, and preferences for apples. Postharvest Biol. Technol, 28:333–347.

Hardin, G. 1968. The tragedy of common. Science 162:1243-1248.

Hossain, A., Rahman, M. & Shabuz, Z. R. 2012. Quality of Industrially Processed Fruit Juices : An Assessment Using Multivariate Framework, 60(2): 169–173.

IBM Corp, 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

ICRAF, 2002. Domestication and Marketing of Indigenous Fruit Trees of the Miombo for Improved Household Nutrition and Incomes in Southern Africa. Proposal to the German Federal Ministry of Economic Cooperation and Development (BMZ). International Centre for Research in Agroforestry. Nairobi, Kenya

ICRAF, 1996. ICRAF Annual Report. International Centre for Research in Agroforestry, Nairobi, Kenya.

ICUC, (C.f.U.C.). 2004. Fruits for the Future: Monkey Orange.[Online] Available at: www.icuciwmi.org/files/Resources/Factsheets/strychnos%20facts.pdf [04/05/2015].

Iranbakhsh, A., Ebadi, M. & Zare, Z. 2009. The contribution of indigenous fruit trees in sustaining rural livelihoods and conservation of natural resources, 1(1):1–6.

Jha, S.N., Chopra, S. & Kingsly, A.R.P. 2007. Modelling of color values for non-destructive evaluation of maturity of mango. J. Food Eng, 78(1): 22-26.

Kader, A. 1983. Influence of harvesting methods on quality of deciduous tree fruits. HortScience, Issue 18: 409-411.

Kadere, A. 2008. Flavor quality of fruits and vegetables. J.Sci. Food Agric, Issue 88: 1863-1868.

Kadzere, I., Hove, L., Gatsi, T., Masarirambi, M.T., Tapfumaneyi, L., Maforimbo, E. & Magumise, I. 2004a. Domestication of indigenous fruits: post-harvest fruit handling practices and traditional processing of indigenous fruits in Zimbabwe. In: Rao, M.R. and Kwesiga, F.R. (eds.) Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihood in Southern Africa: Putting Research into Practice. World Agroforestry Centre (ICRAF), Nairobi, 353–363.

Kadzere, I., hove, L., Gatsi T., Masarirambi, M.T., Tapfumaneyi, L., Maforimbo, E. & Magumise, I. 2004b. Current status of post-harvest handling and traditional processing of indigenous fruits in Zimbabwe. In: Rao M.R. and Kwesiga F.R. (eds.) Agroforestry impacts on livelihoods in Southern Africa: Putting research into practice. Proceedings of the regional agroforestry conference held on 20-24 May, 2002. Warm baths, South Africa. World Agroforestry Centre (ICRAF), Nairobi, Kenya, 353-363.

Kadzere, I., Watkins, C.B., Merwin, I.A., Akinnifesi, F.K., Saka, J.D.K. & Mhango, J. 2006. Harvesting and post-harvest handling practices and characteristics of Uapaca kirkiana (Muell. Arg.) fruits: A survey of roadside markets in Malawi, Agroforestry System, 68:133-142.

Kadzere, I., Watkins, C.B., Merwin, I. A. & Saka, J.D.K. 2007. Harvest date affects colour and soluble solids concentrations (SSC) of Uapaca kirkiana (Muell. Arg.) fruits from natural woodlands. Agroforestry Systems, 69 (2):167–173.

Kadzere, I., Hove, L., Gatsi, T., Masarirambi, M.T., Tapfumaneyi, L., Maforimbo, E. & Magumise, I. 2002. Current status of postharvest handling and traditional processing of indigenous fruits in Zimbabwe. In: Rao, M.R. and Kwesiga, F.R. (eds.) *Proceedings of the Regional Agroforestry Conference on 'Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research into Practice'*. World Agroforestry Centre (ICRAF), Nairobi, Kenya.

Kadzere, I., Hove, L., Gatsi, T., Masarirambi, M.T., Tapfumaneyi, L., Maforimbo, E., Magumise, I., Sadi, J. & Makaya, P.R. 2001. Current practices on post-harvest handling and traditional processing of indigenous fruits in Zimbabwe. Final Technical Report to Department of Agricultural Research and Technical Services. Department of Agricultural Research and Technical Services Zimbabwe, 66 pp

Kalaba, F.K. 2007. The role of indigenous fruit trees in the rural livelihoods: A case of the, Mwekera area, Copperbelt province, Zambia Master degree thesis. Stellenbosch University.

Kalaba, F.K., Chirwa P.W. & Prozesky, H. 2009. The contribution of indigenous fruit trees in sustaining rural livelihoods and conservation of natural resources. Journal of Horticulture and Forestry, (1) 1: 001-006.

Karaan, M., Ham, C., Akinnifesi, F., Moombe, K., Jordaan, D., Franzel, S. & Aithal, A. 2006. Baseline Marketing Surveys and Supply Chain Studies for Indigenous Fruit Markets in Tanzania, Zimbabwe and Zambia. World Agroforestry Centre and CPWild Research Alliance.

Kitinoya, L. & Kader, A. A. 2015. Measuring postharvest losses in fruits and vegetables in developing countries. White paper No. 15-02 La Pine, Oregon USA: The Postharvest Education Foundation. 26pp.

Kwesiga, F., Akinnifesi, F.K., Ramadhani, T., Kadzere, I. & Saka, J. 2000. Domestication of indigenous fruit trees of the miombo in Southern Africa. In: Shumba, E.M., Lusepani E. and Hangula R. (eds.) Proceeding of a SADC Tree Seed Centre Network Technical Meeting. Windhoek, Namibia, Co-sponsored by CIDA and FAO.

Leakey, R. R. B. & Newton, A.C, 1994. Domestication of Cinderella Species Aas The Start Of a Woody-Plant Revolution. In: Tropical Trees: The Potential For Domestication And Rebuilding Of Forest Resources. (ed.) R.R.B Leakey and A.C Newton. HMSO, London.

Leakey, R.R.B., Tchoundjeu, Z., Schreckenberg, K., Shackleton, S.E. & Shackleton, C.M. 2005. Agroforestry Tree Products (AFTPs): Targeting poverty reduction and enhanced livelihoods. International Journal for Agricultural Sustainability, 3: 1-23.

Léchaudel M. & Joas J. 2006. Quality and maturation of mango fruits of cv. 'Cogshall' in relation to harvest date and carbon supply. Australian Journal of Agricultural Research, 57: 419–426.

Maykut, P. & Morehouse, R. 1994. Beginning Qualitative Research: A Philosophic and Practical Guide. UK. The Falmer Press.

Mannhener, C. & Curtis, B. 2005. Tree Atlas of Namibia. Windhoek, Namibia: National Botanical Research Institute.

Masarirambi, M.T., Mavuso V., Songwe V. D., Nkambule T. P. & Mhazo, N. 2010. Indigenous post-harvest handling and processing of traditional vegetables in Swaziland: A review. African Journal of Agricultural Research, 5(24): 3333–3341.

Mendelsohn, J. & Obeid, S. 2005. Forest and Wood of Namibia. Hong Kong: Sing Cheong Printing.

Ministry of Regional and Local Government, Housing and Rural Development (MRLGRD) 2014. Ncuncuni Regional councillor office, Namibia

Mitchell, F. & Mayer, G. 1984. Red color separation of plum maturity. In: Final Report, California Tree Fruit Agreement.

Mithöfer, D., Saka J.D.K., Sileshi G., Ramadhani T., & Dhliwayo P. 2003. Towards the development of Miombo fruit trees as commercial tree crops in southern Africa. Forests, Trees and Livelihoods, 16:103-121.

Mithöfer, D., Waibel, H. & Akinnifesi, F. 2006. The role of food from natural resources in reducing vulnerability to poverty: a case study from Zimbabwe. Paper presented to the 26th Conference of the International Association of Agricultural Economists (IAAE), 12-18 August 2006. Queensland, Australia,

Mithöfer, D. 2005. Economics of Indigenous Fruit Tree Crops in Zimbabwe. PhD Thesis, Department of Economics and Business Administration, University of Hannover, Germany

Mkonda, A., Akinnifesi, F.K., Swai, R., Kadzere, I., Kwesiga, F.R., Maghembe, J.A., Saka, J., Lungu, S. & Mhango, J. 2004. Towards domestication of 'wild orange' *Strychnos cocculoides* in southern Africa: a synthesis of research and development efforts. In *Indigenous Fruit Trees in the Tropics Domestication, Utilization and Commercialization*, edited by Akinnifesi, F., Leakey, R., Ajaya, O., Sileshi, G., Tchoundjeu, Z., Matakala P. and Kwesiga, F. CABI Publishing.

Mkonda, A. Ramadhani, T., Mafongoya, P.L., & Jere, .I. 2003. Marketing potential of indigenous fruits of miombo woodlands of Southern Africa: a case of *Uapaca kirkiana* fruits in Eastern Zambia. ICRAF.

Moombe, K.B. 2009. Analysis of the market structures and systems for indigenous fruit trees : the case of *Uapaca kirkiana* in Zambia. Master degree thesis. Stellenbosch University.

Moses, M. 2013. *Assessment of trade-offs between timber and carbon values of*. Master degree thesis. Stellenbosch University.

Morejemane, W., & Tshwenyane, S. O. 2004. *Azanza garkeana:* A valuable edible indigenous fruit tree of Botswana. Asia Network for Scientific Information. *Pakistan Journal of Nutrition 3 (5): 26-27, 2004.*

Mwamba, C. 2005. Monkey orange. Strychnos cocculoides. Southampton Centre for Underutilised Crops, Southampton, UK.

National Remote Sensing Centre (NRSC). (2015). Ministry of Agriculture, Water & Forestry, Directorate of Forestry. Namibia.

National Planning Commission (NPC). 2012. *National Population Census 2011 Report*, Namibia.

Neumann, R.P. & Hirsch, E. 2000. Commercialisation of non-timber forest products: review and analysis of research. CIFOR, Bogor.

Nyoka, B.I. & Muskoyonyi, C. 2002. *State of forest and tree genetic resources in Zimbabwe*. Forest Genetic Resources Working Paper No. 35, 23 pp.

Pareek, S. Kitinoja, L., Kaushik, R.A., & Paliwal. R. 2009. Postharvest physiology and storage of ber. *Stewart Postharvest Review*, 5(5), pp.1–10.

Prusky, D. 2011. Reduction of the incidence of postharvest quality losses and future prospects. Food Security, Issue 3: 463-474.

Ondachi, P. 2001. Nutritional composition of some indigenous fruits in dry land. In Proceedings of the Regional Social Forestry Extension Seminar for Semi-arid and Arid areas.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Anthony, S. 2009. Agroforestree Database: a tree reference and selection guide version 4.0 [online]. Available at: www.worldagroforestry.org./sites/treedbs/treedatabases.asp.[29/08/2016].

Ramadhani, T. 2002. Marketing of indigenous fruits in Zimbabwe. PhD Thesis. University of Hannover. Country.

Reid, M. 1992. Maturation and maturity indices. In: LaRue, J.H.; Johnson, R.S. (eds.) Peaches and Nectarines: Growing and handling for Fresh Market. University of California Department of Agriculture and Natural Resources Publication No.3331, Issue 3331: 21-28.

Robinson, C. 2002. Real World Research. Victoria: Blackwell.

Ruffo, C.K., Birnie, A. & Tengas, B. 2002. Edible Wild Plants of Tanzania. Relma Technical Handbook no 27: 766.

Ruiz –Pérez, M., Broekhoven, A.J., Aluma, J.R.W., Iddi, S., Lowroe, J.D., Mutemwa, S.M & Odera, J.A. 1997. Research on non-timber forest products in selected in southern and east Africa: themes, research issues, priorities and constraints, CIFOR Working Paper No. 15. Bongor, Indonesia.

Ruiz-Perez, M., Belcher, B., Achdiawan, R., Alexiades, M., Aubertin, C., Caballero, J., Campbell, B., Clement, C., Cunningham, T., Martinez, A., Jong, W. de, Kusters, K., Kutty, M.G., Lopez, C., Fu, M., Alfaro, M.A., Nair, T.K., Ndoye, O., Ocampo, R., Rai, N., Ricker, M., Schreckenberg, K., Shakleton, S., Shanley, P., Sun, T. & Young, Y.C. 2004. Markets drive the specialization strategies of forest peoples. Ecology and Society, 9:1-9.

Sabina, Y. & Khan, F.R. 2012. Triangulation Research Method as the Tool of Social Science Research. Bup Journal, 1(1), pp. 2219-4851.

Salunkhe, D. 1984. Postharvest biotechnology of fruit. CRC Press, Boca Raton, FL, (1):168

Saka, J.D.K., Rapp, I., Ndolo, V., Mhango, J. & Akinnifesi, F. K. 2007. Physicochemical and organoleptic characteristics of *Uapaca kirkiana, Strychnos cocculoides*, *Adansonia digitata* and Mangiferia indica fruit products. . International Journal of Food Science & Technology, 42(7): 836–841. [online] Available at: http://www.blackwell-synergy.com/loi/ifs.

Saka, J.D.K., Mwendo-Phiri, E. & Akinnifesi, F. K. 2002. Community processing and nutritive value of some miombo indigenous fruits in central and southern Malawi. In: Kwesiga, F., Ayuk, E. and Agumya, A. (eds.) Proceedings of 14th Southern African Regional Review and Planning Workshop, 3–7 September 2001. ICRAF, Harare, Zimbabwe, pp. 164–169.

SCUC. 2006. Monkey Orange, *Strychnos cocculoides*, Field Manual for Extension Workers and Farmers, SCUC, Southampton, UK.

Schreckenberg, K. 2003. 'Appropriate Ownership Models for Natural Product-based Small and Medium Enterprises in Namibia'. Consultancy Report for the Ministry of Trade and Industry, Windhoek, Namibia.

Schreckenberg, K. 2004. The contribution of shea butter (Vitellaria paradoxa C.F. Gaerther to local livelihoods in Benin. In: Sunderland T. and Ndoye O. (eds). Forest products, livelihoods and conservation. Case studies of non-timber forest product systems. Vol. 2- Africa. CFOR, Indonesia.

Shackleton, C.M. 2004. Use and selection of *Sclerocarya birrea* (Marula) in the Bushbuckridge lowveld, South Africa. In: Rao, M.R. and Kwesiga, F.R. (eds.) *Proceedings of Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research into Practice*. World Agroforestry Centre, Nairobi, Kenya, pp. 77–92.

Shackleton S., Shackleton, C. & Cousins, B. 2000. Re-Valuing the Communal Lands of Southern Africa: New Understandings of Rural Livelihoods. Natural Resource Perspectives Number, 62: 1–4.

Sinha, A & Bawa, K. S. 2002. Harvesting techniques, hemi parasites and fruit production in two non-timber forest tree species in south India. Forest Ecology and Management, 168: 289–300.

Simson, S.P. & Straus, M.C. 2010. *Post-Harvest Technology of Horticultural Crops.* Narayan Niwas, Delhi: Oxford Book Company.

Simons, A.J. 1996. ICRAF's strategy for domestication of indigenous tree species. In: Leakey, R.R.B., Temu, A.B., Melnyk, M. & Vantomme, P. (eds.) *Domestication and Commercialisation of Non-Timber Forest Products in Agroforestry Systems*. FAO Non-Wood Forest Products No. 9. FAO, Rome, pp. 8–22.

Soe T.T., Shiwachi H., Koshio K., Iwahori S. & Takahashi H., 2006. Post-harvest storage of Irwin mango under various conditions. J. ISSAAS, 12, 11–20.

Storrs, A. 1995. Know your Trees: Some common Trees Found in Zambia. Regional Conservation Unit.

Taylor, F., Mateke, S. & Butterworth, K. 1996. A holistic approach to the domestication and commercialization of non-timber forest products. In: Leakey, R.R.B, Temu, A.B., Melnyk M. and Vantomme, P. (eds) Domestication and Commercialization of Non-timber Forest Products in Agroforestry Systems. Non-Wood Forest Products, 9: 8-22.

Tiwari, S. 2006. Mandarin: Post Harvest Management Guide Extension Bulletin, Published under the Technology, Mission on Integrate Development of Horticulture and Forestry, Pasighat.

Tieguhong, J. C. & Ndoye, O. 2004. Development of trade and marketing of Nonwood forest products for poverty alleviation in Africa. CIFOR, Yaounde, Cameroon, 48.

Weman, J. & Kruger, S. 1999. Research methodology for the business and administrative sciences. Cape Town: Oxford.

Wilson, W. R. S. 2002. Status report on the postharvest handling, processing and marketing of underutilized fruit crops in Sri Lanka. In: Haq, N. and Hughes, A. (eds) *Fruits for the Future in Asia: Proceedings of the Consultation Meeting on the Processing and Marketing of Underutilised Tropical Fruits in Asia*. International Centre for Underutilised Crops (ICUC), Southampton, UK, pp. 199–204. In *Indigenous Fruit Trees in the Tropics Domestication, Utilization and Commercialization*, edited by

Akinnifesi, F., Leakey, R., Ajaya, O., Sileshi, G., Tchoundjeu, Z., Matakala P. and Kwesiga, F. CABI Publishing.

8 Appendices

8.1 APPENDIX A: Semi structure Questionnaire

HARVESTING AND POST HARVEST HANDLING PRACTICES QUESTIONNAIRE

Questionnaire number:.....☐☐.....Study sites : Mile 20 ☐ Kaguni ☐

Interviewer's name: .....Date: ...../...../2015

The information that you will provide will only be used for the said exercise.

SECTION A:

==========

Q1. Gender (sex) of respondent: 1. [ ] Female 2. [ ] Male.

Q2. Age category of respondents

a) 13-17	
b) 18 – 23	
c) 24 – 28	
d) 29 – 34	
e) 35 – 40	
f) 41 – 45	

g) 46 – 51	
h) Above 52	

Q3. Number of residents or household members

	1-5	6-10	11-15	
01. Adult Male				
02. Adult Female				
03. School going children				
04. Pre-school going children				

SECTION B:

==========

Q4. Do you have *Strychnos cocculoides* fruits trees in your crop field or homestead?

1. Yes [ ]

2. No [ ]

Q5. Do you harvest *Strychnos cocculoides* fruits?

1. Yes [ ]

2. No [ ]

Q6. Where do you harvest the fruits?

a) In the crop field	
b) Community forest	
c) Nearby forest	
d). Other places (specify)	

Q7. Why do you harvest fruit from those areas?

Nearest homestead	
No collection restriction	
Plenty of fruits	
Sweet fruits	
Other (specify)	

Q8. How often do you harvest the fruits? (*Indicate quantity/time unit*)

Parameter	
1 Daily	
2 Weekly	
3 Monthly	
4 Per season	

Q9. Do you harvest *Strychnos cocculoides* fruits for consumption, sale or both?

1 Consumption	
2 Sale	
3 Both consumption and sale	

Q10. Where do you sell the fruits?

1 Main road only	
2 Main road & urban	
3 Rundu open market	
4 Urban only	
5 Other places (specify)	

Q11. Who are your customers?

1Local people	
2 Communal agents	
3 Urban/towns dwellers & tourist	

Q12. Do you know of any rules and regulations in place for harvesting *Strychnos cocculoides* fruits or for other indigenous fruits in this community?

1. Yes [ ]

2. No [ ]

Q13. If yes, explain?

……..……

……..……

Q14. Which month do you normally harvest *Strychnos cocculoides* fruits?

Month	
August	
September	
October	
November	

Q15. Is there any selection of the specific type of trees to harvest from?

1. Yes [ ]

2. No [ ]

If yes, what are the criteria used to select the trees? Please give reason

Criteria	**Reason**

Q16. What fruit characteristic do you consider when harvesting?

……

……

Q17. Apart from you, who else is involved in the harvesting of the fruits in your household?

a) Husband	
b) Wife	
c) Children	
d) Hired labor	
e) Others (specify)	

Q18. What harvesting method or techniques do you use to harvest the fruits?

a) Picking the fruit from the tree	
b) Picking the fruit from the ground	
c) Shaking the tree	
d) Knocking off the fruit from the tree using sticks	
e) Climbing the tree	
f) Cutting down the tree	
g) Using heavy objects	

h) Other (specify)	

Q19. At which stage do you harvest fruits?

a) Fully mature (orange)	
b) Half mature (yellow/green)	
c) Just mature) (green	

Give reason

……

……

Q. 20. How do you know that the fruit is ripe and ready to be harvested?

……

……

Q21. Do you harvest unripe fruits with the aim to bury them in the ground for ripening?

1. Yes [ ]

2. No [ ]

Q22. If yes, give reason

……

……

Q23. For how long can the fruits be buried under the soil before ripe?

Period	
1-2 Weeks	
3-4 weeks	
1 month	

Q24. What is the distance from where you harvest the fruits to your homestead?

……

……

Q25. Do you transport fruits immediately after harvesting?

1. Yes

2. No.

Give reason

Q26. Which mode of transport do you use to transport fruits to your homestead?

……..……

……..……

Q27. At what time of the day do you normally harvest the fruits and why?

Time	**Reason (s)**
a) Morning	
b) Afternoon	
c) Evening	
d) Any time of the day	

Q28. Do you experience loss after harvest?

1. Yes

2. No.

Q29. Mention the cause of fruit loss and estimate the loss you experience

Type of losses	**Estimate loss**
a) Rotting	
b) Physiological	
c) Mechanical damage (physical injury)	
d) Other (specify)	

Q30. At what handling stage do you experience fruit loss?

Handling stage	

a) Harvesting	
b) Transportation	
c) Marketing	
d) Other (specify)	

Q31. Which mode of transport do you use to transport fruits to the market (point of sale)?……

……

Q32. Based on your experience, is there quality difference between the fruits harvested ripe and the ones that are harvested unripe and buried in the ground to ripe? Explain?

……..……

……..

Q33. Are the fruits sorted after harvesting and before selling?

1. Yes [ ]
2. No [ ]

Q34. If yes, explain how?

……..……

……

Q35. If not, give reason why?

……

……

Q36. Do you store the fruits sometimes after harvesting for ripening?

1. Yes [ ]
2. No [ ]

Q37. If yes, how, where and how long do you store the fruits?

Storage place How (e.g. bags, loose etc.) How long (days, weeks etc.)

Q38. What are the effects of storage?

……

……

Q39. For how long can the fruits be stored after harvesting without being spoiled?

Period		
a) 1-4 weeks		
b) 1-3 months		
c) 4-6 months		

Q40. What normally tends to spoil the fruits?

……

……

Q41. How do you package your fruits for sale?

Packaging material	
Baskets	
Bags	
Other (specify)	

Q42. Could you suggest ways in which the quality of the fruits can be improved for both home consumption and for sale?

……

……

Q43. How many years of experience do you have in harvesting and selling the fruits?

Years	
1-5	
6-10	
11-15	
16-20	
21-25	

Q44. How long (duration) does it take for you to sell out the fruits?

Harvesting stage	**Duration**
Fully mature	Days
Half mature	Weeks
Just mature	Months

Q45. Have you undergone any training on forestry activities?

1. Yes [ ]

2. No [ ]

If yes, explain?

……..……

……

Q46. Do you have other comment or suggesting concerning harvesting and selling of *Strychnos cocculoides* fruits?

……

……..

THANK YOU FOR YOUR TIME

8.2 Appendix B: Consumer preference questionnaire

CONSUMER PREFERENCE QUESTIONNAIRE

Questionnaire number:.....☐☐.....Study sites: Mile 20 ☐ Kaguni ☐

Interviewer's name: .....Date: ...../...../2015

INSTRUCTION: PLEASE TICK [√] OR WRITE IN THE APPROPRIATE SPACE(S) PROVIDED.

The information that you will provide will only be used for the said exercise and will remain CONFIDENTIAL

SECTION A: Demographic information

==========

Q2. Gender (sex) of respondent: 1. [ ] Female 2. [ ] Male.

Q3. Respondent category

1. Farmer [ ] 2. Farmers group/association [ ]

3. Visitor [ ] 4. Tourist [ ] 5. Other (specify)……..

Q4. Age category

a) 13-17	
b) 18 – 23	
c) 24 – 28	

d) 29 – 34	
e) 35 – 40	
f) 41 – 45	
g) 46 – 51	
h) Above 52	

SECTION B: **Consumer preference**

Fruits are divided into three categories:

Category 1: Fruits harvested fully mature (orange)

Category 2: Fruits harvested half mature (yellow/orange)

Category 3: Fruits harvested just mature (green)

Q1. **CATEGORY 1**: Fully mature (orange)

Weight (g)	**Size (cm)**	**TSS (% Brix)**	**Appearance**	**Taste**

Fruit characteristics: Appearance and Taste: (3 score)

Appearance

1. Dislike [ ]
2. Neither like nor dislike [ ]
3. Like [ ]

Taste

1. Dislike [ ]
2. Neither like nor dislike [ ]
3. Like [ ]

Q2. **CATEGORY 2:** Half mature (yellow/orange)

Weight (g)	Size (cm)	TSS (% Brix)	Appearance	Taste

Fruit characteristics: Appearance and Taste: 5- point hedonic scale

Appearance

1. Dislike [ ]
2. Neither like nor dislike [ ]
3. Like [ ]

Taste

1. Dislike [ ]
2. Neither like nor dislike [ ]
3. Like [ ]

Q3. **CATEGORY 3:** Just mature (green)

Weight (g)	Size (cm)	TSS (% Brix)	Appearance	Taste

Fruit characteristics: Appearance and Taste: (3-score)

Appearance

1. Dislike [ ]
2. Neither like nor dislike [ ]
3. Like [ ]

Taste

1. Dislike [ ]
2. Neither like nor dislike [ ]
3. Like [ ]

Q10. What color of the fruit do you prefer when buying the fruit?

……

……

Q11. What characteristic do you consider important when buying and /or consuming the fruit?

Characteristic	**Consideration strength**		
	Strongly considered	**Considered**	**Not considered**
Price			
Appearance (damage, color)			
Selling site			
Source			
Taste (sweetness)			
Cleanliness of fruits			
Neatness of the selling			
Fruit maturity			
Fruit size			
Weight			

Q12. What problems do you experience as a consumer of *Strychnos cocculoides* fruits?

……

Q13. Is there any improvement you would like the sellers or harvesters to consider?

……

THANK YOU FOR YOUR TIME