PHYSICO-CHEMICAL PROPERTIES AND SELECTED NUTRITIONAL COMPONENTS OF WILD MEDLAR (*VANGUERIA INFAUSTA*) FRUIT HARVESTED AT TWO HARVESTING TIMES

by

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DECLARATION

I, Matholo Joyce Mothapo, hereby declare that this mini-dissertation submitted to the University of Limpopo, for the degree of Masters of Science in Agriculture (Plant Production) has not previously been submitted by me for a degree at this or any university; that it is my work in design and in execution, and that all material contained herein has been dully acknowledged.

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Student: Ms MJ Mothapo Date

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Co-supervisor: Mr ND Mamphiswana Date

DEDICATION

I would like to dedicate this study to my kids (Masobe and Lethabo Mothapo).

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ABSTRACT

Wild medlar (*Vangueria infausta* subsp. infausta) is a popular indigenous fruit available and consumed by rural communities in Limpopo Province, South Africa. Inadequate post-harvest practices in indigenous fruit plants including *V. infausta* fruit forms major constrains in expanding their production. There is scanty information documented on neither objective nor subjective harvesting indices of indigenous fruit plants consumed by locals in sub-Saharan Africa. Thus, the objective of this study was to determine the effect of harvesting time on physico-chemical properties and selected nutritional composition of *V. infausta* fruit. Fruits were harvested twice, where two harvesting times were regarded as treatments and each tree as replication. The reduction for fruit weight, sugar content and sugar/acid ratio was highly significant ($P \leq 0.05$), whereas for average fruit diameter, seed weight, acid ratio and pH content this may imply that the listed parameters are treatment which was non-significant ($P \leq 0.05$). The treatment reduced P, K, Mn and Fe by 33%, 18%, 3% and 7%, respectively. On the other hand, treatments had no effect on N and Ca. The reduction of phosphorus was highly significant ($P \leq 0.05$), whereas for N, K, Ca, Mn and Fe treatment impact was non-significant ($P \leq 0.05$). Similarly, the treatment consistently reduced moisture content and increased dry matter and crude protein of *V. infausta* by 76%, 300% and 7%, respectively. The reduction of moisture content, increase in dry matter was highly significant ($P \leq 0.05$), whereas crude protein treatment impact was non-significant ($P \leq 0.05$). The data indicated that the best time to harvest *V. infausta* fruit was during January when fruits were cosmetically appealing and not wrinkled. This study demonstrated that there was less variation in some measured objective harvesting indices of *V. infausta* fruit harvested at two harvesting time. More work would be required to do physico-chemical properties and selected mineral elements analysis from wide growth habitat for conclusive recommendations.

Keywords: Harvesting time, indigenous fruits, harvesting indices, *Vangueria infausta* fruit, selected nutritional composition

CHAPTER 1
GENERAL INTRODUCTION

1.1 Background

The late 1980s witnessed a resurgence of interest and research on indigenous plants including *Vangueria infausta* fruit (Figure 1.1). *Vangueria infausta* is a deciduous tree of Burch. subsp. infausta, family: Rubiaceae (Venter and Venter, 1996). It is a popular indigenous fruit available and consumed by rural communities in southern Africa. The trees bear fruits in January to May when exotic fruits such as citrus are scarce. The fruit tree serves as a source of food and medicine in livelihood of rural communities (Hines and Eckman, 1993).

This General Introduction focuses on the (1) background, which includes the description of the problem, its impact, causes and those affected by the problem and the proposed solutions, (2) problem statement, (3) motivation for the study, (4) the objectives, (5) the hypotheses and (6) the format of the mini-dissertation.

Figure 1.1 *Vangueria infausta* tree grown at the experimental farm (Syferkuil).

1.1.1 Description of the research problem

Currently, in many African countries wild growing fruit trees are still being harvested when they are over-ripe on the tree or fallen to the ground (Kadzere *et al*., 2002). The time of harvesting on fruit crops could be critical. One of the most common mistakes growers make is to harvest fruit crops too early. This is when they are under-ripe and have not yet fully developed rippen (Reid, 1992). On the other hand, harvesting of fully ripe fruit would leave only a limited consumption period. Producers of exotic commercial fruits harvest their crops according to the particular known objective harvesting indices, which indicate the optimum harvesting time (Kader, 2002). In these fruit crops harvesting is done before fruits are fully ripe, and it is timed such that the fruits reach full ripeness when presented to final consumers. However, for indigenous fruits such as *V. infausta*, there is still a need to understand their time of harvesting and ripening patterns.

1.1.2 Impact of the research problem

Despite the poor state of commercial harvesting information and post-harvesting development of various indigenous African fruits, their trading and marketing are important activities in African countries (Ramadhani, 2002; Akinnifesi *et al*., 2007). They are still sold in both urban and rural markets, showing that African consumers like the fruits and are willing to pay for them. They are also eaten mostly as a snack that is often eaten fresh in the market. The major challenge is that farmers are unable to supply indigenous fruit with specific characteristics such as size, taste and out-of-season production (Ndoye *et al*., 2004). Additionally, few indigenous fruits are processed locally (other than drying) and many have a very short shelf-life. Indigenous fruits including *V. infausta* play an important role as food substitute in times of drought and famine. It constitutes a cheap, yet rich source of essential nutrients (Schomburg *et al*., 2002). Scarcity of these indigenous fruits would lead to poor health due to deficiency of vital essential nutrients and vitamins in the dietary system.

1.1.3 Possible causes of the research problem

The focus of several studies conducted on *V. infausta* plant has been on their basic propagation, medicinal and pharmacological properties (Venter and Venter, 1996; Steenkamp and Gouws, 2003; Putuka *et al*., 2006). Less attention has been given to key production factors such as harvesting time and method, post-harvest handling, marketing, processing and value adding (Kadzere *et al*., 2002). Harvesting crops at proper maturity allows handlers to begin their work with best possible quality produce. Produce harvested too early might lack flavour and not fully ripe, while produce harvested too late might be fibrous and generally lack quality (Dhatt *et al.,* 2007).

1.1.4 Proposed solutions

Harvesting indices are important for deciding when a given commodity should be harvested. This provides some marketing flexibility and ensures the attainment of acceptable fruit quality to the consumer (Kadzere *et al.,* 2006). Harvesting time plays an important role in post-harvest shelf-life and nutritional quality of any fruit (Reid, 1992). However, this vital index is not documented for several indigenous fruit crops including *V. infausta* fruit.

1.2 Problem statement

Several studies conducted in southern Africa have shown that indigenous fruits and medicinal plants play a crucial role in the livelihoods of rural communities (Legwaila *et al*., 2011; Amarteifio and Mosase, 2006). However, at different harvesting time physico-chemical composition and selected nutritional components of indigenous fruits such as *V. infausta*, predominantly consumed in by rural communities of Limpopo Province, are not known. Therefore, the study was conducted to evaluate the effect of harvesting time on physico-chemical composition and selected nutritional components of *V. infausta* fruit.

1.3 Motivation of the study

Vangueria infausta is a popular indigenous fruit available and consumed by rural communities in Limpopo Province around January to May. Information about essential mineral elements and other dietary compounds of *V. infausta* fruit grown wild in Botswana has been documented (Amarteifio and Mosase, 2006), however; influence of harvesting at different times on its fruit quality, chemical composition and nutrition is unknown. Therefore, evaluating harvesting at different times of *V. infausta* fruits would assist in guiding when to harvest the fruit. It would also, help to develop objective maturity indices that could function as harvesting indices and quality standards for this indigenous fruit.

1.4 Aim and objectives

1.4.1 Aim

The aim of the study was to determine influence of harvesting at different times on physico-chemical properties and selected nutritional components of *V. infausta* fruit.

1.4.2 Objectives

1. To determine whether harvesting at different times of *V. infausta* fruit would influence its physico-chemical properties.

2. To determine whether harvesting at different times of *V. infausta* fruit would influence its selected nutritional components.

1.5 Hypotheses

1. Different harvesting time would not influence physico-chemical properties of *V. infausta* fruit.

2. Different harvesting time would not influence selected nutritional components of *V. infausta* fruit.

1.6 Format of the mini-dissertation

Subsequent to this General Introduction, literature on the research problem was reviewed (Chapter 2). The subsequent chapter addressed the above hypotheses in Chapters 3, followed by Chapter 4, which provided a summary of the study, the significance of the findings, the recommended future research and conclusion.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Harvesting time plays an important role in post-harvest shelf-life and nutritional quality of any fruit. However, this vital index is not documented for several indigenous fruit crops. Studies have been successfully conducted on several exotic fruit crops to investigate the effect of harvesting time on quality and nutritional variables (Remorini *et al*., 2008; Moneruzzaman *et al*., 2009). The ensuing literature review would be focused on what has already been written on the research problem, existing gaps on the research problem and explanation of how the existing gaps would be closed.

2.2 Work done on the research problem

2.2.1 *Vangueria infausta* fruit tree

The wide range of indigenous fruit trees available in many areas could enable farmers to meet their varied household needs for food, nutrition and medicine. *Vangueria infausta* fruit (Figure 2.1) is a good sources of K and Mg compared to some of existing domesticated exotic fruits (Amarteifio and Mosase, 2006). Also, its Ca and P contents compare favourably with those of well-established exotic fruits. The consumption of these fruits might help to overcome micro-nutrient deficiencies that are prevalent in rural areas.

In Malawi, fruit flesh of *V. infausta* exhibited 26.5% dry matter, 5.7% crude protein, 78.1% total carbohydrate, 10.2% fibre and 2.6% fat (Saka and Msonthi, 1994). Vitamin C concentration ranged from 4.7 mg /100 g in Malawi to 16.8 mg /100 g in Botswana (Leakey, 1999). These variations could have been attributed to geographical differences in soil types and climate. The fruits are still much sought-after as food source by poor local communities in areas where they occur naturally, especially during times of famine (Du Preez, 2003).

Figure 2.1 Ripe and unripe *Vangueria infausta* fruit.

Other studies conducted on *V. infausta* were focused on propagation. As a result, *V. infausta* has been a subject of numerous propagation trials since early 1990s (Prins and Maghembe, 1994; Van Wyk and Gericke, 2003). Although not easy to be germinated from seeds, some measure of success might be achieved when the date of sowing is taken into consideration. Vegetative propagation has also been attempted and a success rate of 100% has been achieved (Akinnifesi *et al*., 2006)

2.2.2 Fruit crops maturity indices

In commercial fruit production, decisions on when to harvest are based on objective maturity indices that have been developed for specific commodities using physical, chronological, physiological and chemical characteristics (Reid, 1992; Kader, 2002). For example, fruit colour changes; shape, size, surface characteristics, abscission, and texture are all physical indicators (Kader, 1999). While numbers of days from flowering, accumulated heat units during the growing period of the fruits are chronological indicators (Kader, 1994). The accumulation of carotenoids and increased total soluble solids and decreased titratable acidity are all chemical indicators (Kader, 2002). The physiological indicators such as accumulation of ethylene and increased respiration rates can be used for harvesting time in climacteric fruits (Kadzere *et al*., 2006).

It is generally found that the texture of fruit become crispy when harvested during the late part of the season (Kader, 1999). Again, fruits showed an increase in weight with each successive harvest until the fruit reaches physiological maturing stage. The highest fresh fruit weight was observed during late harvesting time in marula (*Sclerocarya birrea*), while the lowest was observed during late harvesting time (Masarirambi and Nxumalo, 2012). It was observed that the mid-term harvesting gave maximum average jackfruit weight (*Artocarpus heterophyllus*) (7.32 kg), while it was minimum (5.74 kg) in the late harvesting (Karim *et al*., 2008). Beever and Hopkirk (1990) reported that kiwifruit (*Actinidia deliciosa*) of early seasons were larger (7.1 kg) while those in the late season were small (4.6 kg).

Generally, harvesting time have low influence on seed weight (Munthali *et al*., 2012). On the other hand, late harvest time of squash (*Cucurbita moschata*) resulted in highest seeds weight, total seeds yield and weight of 1 000 seeds (Al-Hubaity and Saleh, 2012). At physiological maturity, seeds are said to be completely developed due to maximum accumulation of food reserves, amino acid, phosphorous active substances, dry matter, sugar, water soluble proteins, acids and necotonic acid levels in the seeds (Dhanelappagol *et al.,* 1994). The highest seed weight of jackfruit (0.76 kg) was obtained from early harvesting time and the lowest (0.59 kg) from late harvesting time (Karim *et al*., 2008). The interaction effects of harvesting time and selection in respect of seed weight ranged from 0.49 kg to 0.94 kg.

Attainment of a specific size is one possible index of maturation, but it cannot be used alone since fruit size for any variety can be influenced by harvesting time, climatic conditions, and cultural practices (Kader, 2002). From different harvests, there was an increase in each successive harvest from marula fruits diameter, but there was variation at Malindza (Masarirambi and Nxumalo, 2012). Iqbal *et al.* (2012)

reported an increase in fruit size of madarin (*Citrus reticulata*) during early harvesting time and tend to decline later in the season.

Brix % generally increases with maturity and ripening. The maximum percent of total sugar was found in jackfruits bulb of early harvested fruit (18.18) while it was minimum (13.93) in late ones (Karim *et al*., 2008). Kadzere *et al.* (2006) reported that Brix % in *Uapaca kirkiana* fruits were more variable within trees with fruit that were greener at harvest, compared with those that were harvested with more brown fruit. The interaction effects of harvesting times in respect of total sugar content ranged from 13.64% to 18.35% in jackfruits (*Artocarpus heterophyllus*) (Karim *et al*., 2008).

Acidity % normally increases during fruit ripening, especially during physiological maturity stage. The ratio of sugar/ acid content has been found to be more closely related to quality than acid content or sugar alone (Crisosto, 1994). The decrease in free acids, as well triggers a rise in the pH level of the grape harvested late (Robinson, 2006). Padda *et al.* (2011) reported decrease in titratable acidity in mango fruit (*Mangifera indica*) during ripening period. Moing *et al*. (2001) observed an increase in acid content and pH during late harvesting time in strawberry (*Fragaria ananassa*) fruit. Saka and Msonthi (1994) also reported high pH values in marula (*S. birrea*) and baobab (*Adansonia digitata*) fruits during late harvesting time.

2.2.3 Mineral composition

The quantity of mineral elements (N, P, K, Ca, Mn and Fe) accumulated in most fruit crops increased from early harvesting stage to late harvesting stage (Arif *et al*., 2010). However, initial nutrient concentrations in apple (*Malus domestica*) decreased quickly, undergoing slow and continuous decreases. And then remaining almost constant until the end of fruit maturation (Nachtigall and Dechen, 2006). According to Mengel and Kirkby (2001), quantities of nutrients accumulated in apple increased gradually with fruit growth. Potassium was the most accumulated nutrient in fruits, followed by N and P, regardless of the cultivar. Saka and Msonthi (1994) reported lower Ca values during late harvesting time in marula fruit. The K content of indigenous fruits was high in comparisons with other exotic fruits such as oranges (*Citrus sinensis*), banana (*Musa acuminate*) and grapes (*Vitis vinifera*) during harvesting time (Holland *et al.,* 1997). Amarteifio and Mosase (2006) recorded low levels of Fe, Zn and Mg in indigenous fruits such as marula (*Sclerocarya birrea*), baobab (*Adansonia digitata*) and spiny monkey orange (*Strychnos spinosa*).

2.3 Existing gaps and explanation on how the gaps would be closed.

Several studies have been conducted on various exotic fruit crops to evaluate the effect of harvesting time on quality variables (Remorini *et al*., 2008; Karim *et al*., 2008). For instance, when fruits are harvested too late or too early in the season, overall nutritional content may be compromised. The amount of time between harvesting and delivery to a market also can damage the nutritional value of the fruit. Allowing crops to ripen on the stem is crucial to harvesting success. Remorini *et al.* (2008) also reviewed the effect of harvesting time on the nutritional quality of peel and flesh of peach fruits. Harvesting crops at the right time, when fruits are ripe, is important, since green fruits have lower nutritional value than ripe ones (Kordylas, 1990).

Some crops can be harvested several times throughout the season, while others are harvested only once. Determining harvesting time of different varieties is therefore, important for proper management, maturity standards, packaging and storage shelf-life (Kader, 1992). However, information on neither subjective nor objective harvesting indices of most indigenous fruit crops has not been investigated. Thus, the present study was done to evaluate effect of harvesting at different harvesting time on physico-chemical properties and selected nutritional composition of *V. infausta* fruit.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Research design and sampling

Seven *V. infausta* wild trees were selected randomly in two summer seasons at University of Limpopo Experimental farm (Syferkuil), Limpopo Province, South Africa (23˚ 53’10” S; 29˚ 44’15” E). Fruits were harvested two times, where two harvesting times were regarded as treatments and each tree as replication (Figure 3.1). The experiment was laid out in randomise complete block design. At harvesting 1, fruits were harvested according to the local communities’ harvesting time (January-February). While for harvesting 2, fruits were harvested one month from local communities’ harvesting time. Blocking was done against the slope and the fruits were analysed immediately after harvest in Plant Production department, Soil Science and Agricultural Engineering laboratories at the University of Limpopo (23˚ 88”06” S; 29˚ 73”39” E).

Figure 3.1 Sample of experimental treatments and their replications.

3.2 Data collection

Average fruit weight (Figure 3.2) was measured using twenty fruits per sample. Fruits were weighed separately in grams, using digital electronic grain scale (Model: CQT1751GR, England). While average seed weight (Figure 3.3) was measured and seeds were separated from pulp and washed thoroughly with tap water to remove the pulp. Average seed weight was then measured separately in grams, using the same digital electronic grain scale. Average diameter (Figure 3.4) of the fruits was measured using a digital calibre (Model: 16 ER).

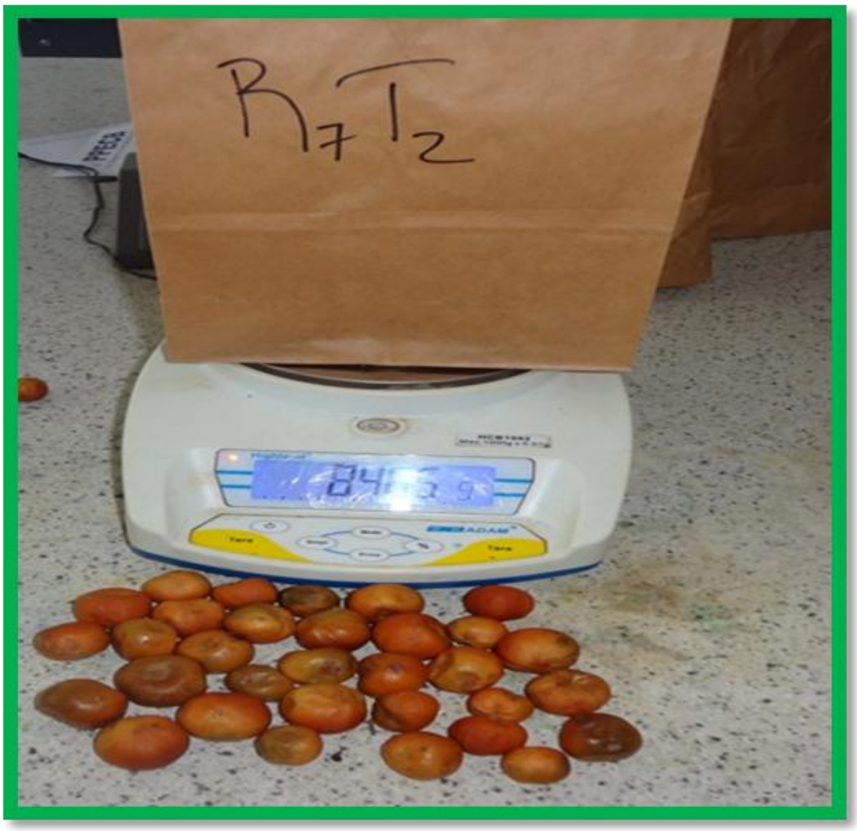

Figure 3.2 Sample of *Vangueria infausta* fruit ready to be weighed.

Figure 3.3 Sample of *Vangueria infausta* seeds ready to be weighed.

Figure 3.4 Measuring diameter of *Vangueria infausta* fruit.

The total soluble solid (TSS) were analysed (Figure 3.5) by hand held refractometer (Master-T, Model: 0229305) and results were reported as ºBrix at 20ºC. The titratable acidity (TA) was estimated by method suggested by Khan *et al.* (2010). The pulp material was added to boiling water, cooled, filtered and transferred in volumetric flask. The volume was made up and aliquot was titrated with 0.1 M NaOH using 1% phenolphthalein solutions as an indicator. Sugar\acid ratio was calculated from sugar and acid values using (sugar acid ratio = °Brix value\ citric acid) formula (AOAC, 2005). The pH of *V. infausta* juice was measured using a bench top pH meter (Orion-420 A).

3.2.1 Determination of nitrogen

A 0.25 g ground sample was encapsulated in N-free tin foil (LECO Corporation) and combusted in the furnace of a protein/ nitrogen determinator (LECO FP-528) at 85 °C. Combustion products in the gas phase, including CO_2, H_2O, NO and N_2, were collected and passed to hot copper wire by a helium carrier gas to remove excess oxygen and reduce any NO to N_2 gas. CO_2 and H_2O were later removed by sodium hydroxide on a silicate carrier (Lecosorb®, LECO Corporation) and magnesium perchlorate (Anhydrone®, LECO Corporation) and the remaining combustion product, nitrogen, was measured by a thermal conductivity cell. The total nitrogen concentration of the sample was expressed as a percentage.

3.2.2 Determination of phosphorus

Sample of 0.5 g was weighed into a 100 ml digestion tube using digital electronic grain scale (Model: CQT1751GR). Then one measuring spoon of catalyst powder was added to each tube. After, 10 ml of H_2SO_4 and four drops of H_2O_2 were added to each tube while shaking and placed in digestion tube at 35 ^{o}C. The digestion was carried out until the mixture in the tubes was transparent green colour (about 3 hours). Another four drops of H_2O_2 were added about 10 minutes before they were removed from the block. The tubes stand were allowed to cool in the fume cupboard and made up to the 100 ml mark with H_2O. The tubes were swirled thoroughly before filling the auto sampler tubes for analysis on auto sampler.

3.2.3 Determination of potassium

Potassium (K) standards 20, 15, 10 and 5 ppm were prepared by dilution of the stock standards. De-ionised water was the blank solution. To 10 g of fruit sample 50 ml of de-ionised water was added. Solution was filtered through an ashless filter paper into a litre volumetric flask. It was ensured that the solid particles retained by the paper were washed thoroughly and washings directed into the same 1 L flask. Then diluted to the mark with de-ionised water, the flask was stopped and mixed by inversion. The flame photometer was set up as outlined in its instruction manual for sodium. Then the blank was set to zero (de-ionised water). The standards were aspirated and their stable readings were recorded. A graph of meter reading against standard concentration was plotted. The sample solution was aspirated into the flame photometer. The filter position was adjusted to select the potassium filter and stages 5 to 9 were repeated for potassium. Note that if the K concentrations in the fruit juice are outside the range of standards the sample should be diluted accordingly. The concentration of K obtained from the graph was multiplied by the dilution factor, e.g. x 100, to express the result in ppm or mg/l of K in the original fruit juice.

3.2.4 Determination of Calcium, Iron and Manganese

Sample of 0.5 g was weighed into a 100 ml digestion tube using digital electronic grain scale (Model: CQT1751GR). After, 5 ml of HNO_3 was added and allowed to stand overnight. Then, 3 ml of $HClO_4$ was added and placed on a pre-heated digestion block at 70 ^{o}C for 1 hour. Digestion temperature was then increased to 150 ^{o}C and digested until the digest is clear and/ or a white vapour was visible. The tubes were removed from the digestion block and water was added up to 25 ml mark. After cooling, the tubes were filled up to 50 cm mark and shaken well before analysis on the Atomic absorption spectroscopy (AAS).

3.2.5 Determination of crude protein

Chemical analyses of fruits were carried out in duplicates to determine the crude protein contents using Kjeldahl method (AOAC, 1990). The method consists of heating a substance with sulfuric acid, which decomposes the organic substance by oxidation to liberate the reduced nitrogen as ammonium sulfate. In this step potassium sulfate was added to increase the boiling point of the medium (from 169°C to 189°C). Chemical decomposition of the sample was completed when the initial very dark-coloured medium had become clear and colourless.

The solution was then distilled with a small quantity of sodium hydroxide, which converted the ammonium salt to ammonia. The amount of ammonia present, and thus the amount of nitrogen present in the sample, was determined by back titration. The end of the condenser was dipped into a solution of boric acid. The ammonia reacted with the acid and the remainder of the acid was then titrated with a sodium carbonate solution by way of a methyl orange pH indicator.

3.2.6 Determination of moisture content and dry matter

To determine moisture and dry matter content (%) fruit were heated in an oven (65ºC, 48 h) until a constant weight was obtained and the weight loss was used to calculate the moisture and dry matter content in fruit.

3.4 Data analysis

All data was subjected to two sample Student t - test at probability level of 5 % using Statistix 9.0 (Statistics Analytical Software, 1985-2009) software. Relative percentage impacts were computed [Impact (%) = (Harvesting 2/ Harvesting 1 – 1) × 100] in order to establish the magnitude and direction of the impacts.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Results

Relative to harvesting 1, harvesting fruits of *V. infausta* month after harvesting 1 reduced all measured physical properties (Table 4.1). The treatment reduced fruit diameter, fruit weight and seed weight of *V. infausta* by 4%, 49% and 6%, respectively. The reduction of fruit weight was highly significant ($P \leq 0.05$), whereas for fruit diameter and seed weight treatment impact was not significant ($P \leq 0.05$). Similarly, the treatment consistently reduced sugar content and sugar/ acid ratio of *V. infausta* fruit by 49% and 51% as chemical properties, respectively (Table 4.2). However, harvesting fruit after a month from harvesting 1 had no effect on acid and pH content of *V. infausta* fruit. The reduction of sugar content and sugar/acid ratio was highly significant ($P \leq 0.05$), whereas for acid and pH content treatment impact was non-significant ($P \leq 0.05$).

Harvesting fruits of *V. infausta* a month after harvesting 1 reduced some of the mineral contents (Table 4.3). The treatment reduced P, K, Mn and Fe by 33%, 18%, 3% and 7%, respectively. On the other hand, treatments had no effect on N and Ca. The reduction for phosphorus was highly significant ($P \leq 0.05$), whereas for N, K, Ca Mn and Fe treatment impact was non-significant ($P \leq 0.05$). Similarly, the treatment consistently reduced moisture content and increased dry matter and crude protein of V. infausta by 76%, 300% and 7%, respectively. The reduction for moisture content and increase in dry matter was highly significant ($P \leq 0.05$), whereas for crude protein treatment impact was non-significant ($P \leq 0.05$).

Table 4.1 Mean±SE effect of harvesting time on physical properties of *Vangueria infausta* fruit (n=7).

Treatments	Physical properties		
	Fruit diameter (mm)	Fruit weight (g)	Seed weight (g)
Harvesting 1	22.8 ±0.9	113.2±8.8	14.5±1.1
Harvesting 2	22.0 ±0.8	58.2±3.4	13.6±1.3
Impact (%)^{x,y}	-4^{ns}	-49***	-6^{ns}

^{y}Impact (%) = [harvesting 2/harvesting1) – 1] × 100. ^{x}Impact values with ^{ns} and *** indicated that treatment means were not significant at P ≤ 0.05 and highly significant at P ≤ 0.05 according to two-sample Student t-test.

Table 4.2 Mean±SE effect of harvesting time on chemical properties of *Vangueria infausta* fruit (n=7).

Treatments	Chemical properties			
	Acid content (%)	Sugar content (^{o}Brix)	Sugar/acid (ratio)	pH
Harvesting 1	0.2±0.02	7.7±0.4	38.4±2.4	3.2±0.03
Harvesting 2	0.2±9.9	3.9±0.7	19.0±1.2	3.2±0.02
Impact (%)^{x,y}	0^{ns}	-49***	-51***	0^{ns}

^{y}Impact (%) = [harvesting 2/harvesting1) – 1] × 100. ^{x}Impact values with ^{ns} and *** indicated that treatment means were not significant at P ≤ 0.05 and highly significant at P ≤ 0.05 according to two-sample Student t-test.

Table 4.3 Mean±SE effect of harvesting time on mineral contents of *Vangueria infausta* fruit (n=7).

Treatments	Minerals (mg/ 100g)					
	N	P	K	Ca	Mn	Fe
Harvesting 1	0.9±0.03	0.3±3.5	2.2±0.2	0.2±0.02	47.4±8.9	20.1±4.1
Harvesting 2	0.9±0.03	0.2±5.1	1.8±0.3	0.2±0.02	46.0± 8.9	21.6±3.5
Impact (%)^{x,y}	0^{ns}	-33^{***}	-18^{ns}	0^{ns}	-3^{ns}	-7^{ns}

^{y}Impact (%) = [harvesting 2/harvesting1) – 1] × 100. ^{x}Impact values with ^{ns} and *** indicated that treatment means were not significant at P ≤ 0.05 and highly significant at P ≤ 0.05 according to two-sample Student t-test.

Table 4.4 Mean±SE effect of harvesting time on selected proximate chemical components of *Vangueria infausta* fruit (n=7).

Treatments	Composition (%)		
	Dry matter	Moisture	Crude protein
Harvesting 1	19.3±4.0	80.7±13.0	5.4±0.2
Harvesting 2	80.9±8.9	19.1±5.0	5.8±0.2
Impact (%)^{x,y}	300^{***}	-76^{***}	7^{ns}

^{y}Impact (%) = [harvesting 2/harvesting1) – 1] × 100. ^{x}Impact values with ^{ns} and *** indicated that treatment means were not significant at P ≤ 0.05 and highly significant at P ≤ 0.05 according to two-sample Student t-test.

4.2 Discussion

In an attempt to document objective harvesting indices for *V. infausta* fruit trees, the effect of two harvesting time on its fruit physico-chemical properties was studied. When harvested at different times, fruit of *V. infausta* showed a decrease in fruit weight from harvesting time 1 to second harvesting time. The current results differed with results of Beever and Hopkirk (1990); Al-Maaitah *et al.* (2009); Masarirambi and Nxumalo (2012), who observed increased fruit weight with each harvesting time in marula (*Sclerocarya birrea*), olives (*Olea europaea*) and kiwifruit (*Actinidia deliciosa*), respectively. Additionally, fruits of marula that were harvested in December lost weight (18%) as compared to those in November (9%) (Akinnifesi *et al*., 2006). The observed weight reduction in this study on *V. infausta* fruit harvested in harvesting 2 could be attributed to wrinkling and loss of moisture by fruits at this stage. The prolonged hanging of physiological mature fruit results in fruit that are fully hydrated and lost weight (Elmsly *et al*., 2007).

The total soluble solid (TSS) is an important quality factor attribute for many fresh fruits during ripening (Lu, 2003). In this study, the TSS content of *V. infausta* fruit from two harvesting times varied significantly with fruits harvested early had the highest TSS, when compared to those harvested late. This observation was not in agreement with the results from Chapman and Horvat (1990); Anwar *et al*. (1999); Moing *et al.* (2001); Masarirambi and Nxumalo (2012), for peaches (*Prunus persica*), sweet oranges (*Citrus sinensis*), strawberries (*Fragaria ananassa*) and marula (*Sclerocarya birrea*) fruits, respectively. On these studies, fruit moisture, soluble solids and sugar concentrations increased continuously during fruit development. However, in this study *V. infausta* fruit harvested late were dryer and resulted in decreased total soluble solids. Decreased TSS of *V. infausta* fruit harvested late might be associated with prolonged hanging of fruits on trees, which in many fruit crops lead to fruit quality deterioration. Development of titratable acid content and pH of *V. infausta* fruit agree with published data reported by Moing *et al.* (2001); Tosun *et al.* (2008) on strawberry and blackberry (*Rubus ursinus*) fruits. This indicated that acidity of *V. infausta* fruit remained constant with each harvesting time. At the beginning of harvesting time sugar/acid ratio was high due to high sugar content and high acid content. However, during late harvesting time sugar/acid ratio was low because of low sugar content.

Generally, in phase III of stages in fruit development, most fruits attain their final shape and size, which is determined by a number of cells, formed during cell division in phase I (Srivastava, 2002). Hence, the final fruit diameter in most fruits is determined at phase III due to accumulation of food reserves after rapid cell growth in phase II (Srivastava, 2002). In this study fruit diameter for both treatments was the same. The results contradicted the findings of Bowman (1994); Iqbal *et al*. (2012), who reported increase in sweet oranges (*Citrus sinensis*) and mandarin (*Citrus reticulate*) fruit size from early harvesting time and tend to decline during later harvesting time. Perhaps the similarity in fruit diameter in two harvesting time might be attributed to the fact that both stages of harvesting were within phase III and phase IV of fruit development where there is usually no further fruit growth. Since the fruits evaluated in this were from trees of the same genotype and grown under the same environmental conditions. The seed weight of *V. infausta* was not influenced by harvesting time. Munthali *et al.* (2012) indicated that seed weight is less influenced by genetic constitution than its fruit weight, which is probably due to the fact that the ovules develop within the fruits where the environment is relatively more constant than that in which the fruits themselves develop.

The quantity of mineral elements (N, P, K, Ca, Mn and Fe) accumulated in most fruit crops increased from early harvesting stage to late harvesting stage (Arif *et al*., 2010). In this study, mineral elements (K, N, Ca, Mn and Fe) of *V. infausta* fruit from two harvesting times were not significantly different. These observations were not in agreement with the findings of Nachtigall and Dechen (2006) who reported that nutrient concentrations (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and B) of ‘Gala’, ‘Golden Delicious’ and ‘Fuji’ were relatively high in the initial fruit development, decreasing systematically with growth in apple fruit, respectively. Similar mineral contents were observed in this study since; fruits were collected from trees which are grown within the same soil type and environmental conditions. Furthermore, *V. infausta* fruit from two harvesting times varied significantly with fruits harvested first, which had lowest phosphorus, when compared to those harvested second. This was also obtained by Nachtigall and Dechen (2006) who reported that phosphorus quantities accumulated in apple fruits of the three cultivars increased gradually with fruit growth.

Results from this study showed an increase in dry matter of *V. infausta* fruit from first harvesting time to second harvesting time. These observations were similar to findings of Karima *et al*. (2008), who reported maximum (22.03%) dry matter during late harvesting time and minimum (19.10%) during early harvesting time in jackfruits (*Artocarpus heterophyllus*), respectively. It was found that the moisture content of *V. infausta* fruit was significantly affected by harvesting times. The percentage of moisture content decreased since harvesting was delayed. Moisture content of *V. infausta* fruit harvested early had the maximum percentage of moisture content while it was minimum during late harvesting time. The results from this study were similar to findings of Karim *et al.* (2008) who reported moisture content of jackfruit bulb as 73.1 units during late harvesting time and 81.08 units during early harvesting time.

The actual protein content depends on, among other composition of the substrate, the size of the fruits and harvesting time (Nwosuagwu *et al*., 2009). However, crude protein of *V. infausta* fruit from this study was not significantly different with respects to both harvesting times. The results were not in agreement with the findings of Anegbeh *et al.* (2005); Kinkela *et al.* (2006) who reported the values of crude protein (13.06 - 14.52%) in African pear (*Dacryodes edulis*) and jackfruits (*Artocarpus heterophyllus*) fruits, at different harvesting times. Furthermore, the values of *V. infausta* fruit crude protein in our study were closer to that reported by Amartefio and Mosase (2006). The variations in the present study and those reported by previous studies might be attributed to differences in the methods of analysis employed and genetic make-up of the fruit (Kader, 1992).

CHAPTER 5
SUMMARY, CONCLUSION AND FUTURE RESEARCH

Worldwide producers of commercial fruit crops harvest their crops according to specified objective harvesting indices, which indicate optimum harvesting time (Carmichael, 2011). Several studies conducted in southern Africa have shown that indigenous fruits such as *V. infausta* fruit play an important role in the livelihoods of rural communities (Hines and Eckman, 1993). However, those studies were concentrated mainly on medicinal and nutritional properties (Amarteifio and Mosase, 2006; Palgrave, 2002). Information on neither objective nor subjective harvesting indices for almost all indigenous fruits consumed by locals in sub-Saharan Africa is not documented. Hence, the study was conducted to determine effect of different harvesting times on physico-chemical properties and selected nutritional components of *V. infausta* fruit.

The data indicated that the best time to harvest *V. infausta* fruit was during January when fruits were cosmetically appealing and not wrinkled. Furthermore, the study demonstrated less variation in seed weight, fruit diameter, acid content, crude protein, N, K, Ca, Fe, and Mn of *V. infausta* fruit harvested at two harvesting times. *Vangueria infausta* fruits were collected from a limited number of trees in this study. Thus, further studies are required with broader fruits collection from various growing sites to understand and draw a better conclusion of physico-chemical properties and selected nutritional components of *V. infausta* fruits.

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APPENDICES

Appendix 1 Two-Sample Student t-test result for acid content.

Trt	N	Mean	SD	SE
1	7	0.2140	0.0582	0.0220
2	7	0.2066	0.0261	9.86
Difference		7.43	0.0451	0.0241

Appendix 2 Two-Sample Student t-test result for average fruit diameter.

Trt	N	Mean	SD	SE
1	7	22.814	2.4350	0.0220
2	7	22.046	1.9504	0.7372
Difference		0.7686	2.2060	1.1792

Appendix 3 Two-Sample Student t-test result for fruit weight.

Trt	N	Mean	SD	SE
1	7	113.2	23.170	8.7573
2	7	58.243	9.0287	3.4125
Difference		54.974	17.583	9.3987

Appendix 4 Two-Sample Student t-test result for pH.

Trt	N	Mean	SD	SE
1	7	3.1843	0.0834	0.0315
2	7	3.1643	0.0658	0.0249
Difference		0.0200	0.0751	0.0402

Appendix 5 Two-Sample Student t-test result for sugar content.

Trt	N	Mean	SD	SE
1	7	7.7143	1.1127	0.4206
2	7	3.8571	0.6901	0.2608
Difference		3.8571	0.9258	0.4949

Appendix 6 Two-Sample Student t-test result for seed weight.

Trt	N	Mean	SD	SE
1	7	14.463	2.9002	1.0962
2	7	13.586	3.3520	1.2669
Difference		0.8771	3.1342	1.6753

Appendix 7 Two-Sample Student t-test result for nitrogen.

Trt	N	Mean	SD	SE
1	7	0.8714	0.0687	0.0260
2	7	0.9329	0.0690	0.0261
Difference		0.0614	0.0688	0.0368

Appendix 8 Two-Sample Student t-test result for potassium.

Trt	N	Mean	SD	SE
1	7	2.1600	0.4221	0.1595
2	7	1.7896	0.6789	0.2566
Difference		0.3704	0.5652	0.3021

Appendix 9 Two-Sample Student t-test results for phosphorus.

Trt	N	Mean	SD	SE
1	7	0.3044	9.13E-03	3.45E-03
2	7	0.2253	0.0134	5.06E-03
Difference		0.0209	0.0115	6.12E-03

Appendix 10 Two-Sample Student t-test result for calcium.

Trt	**N**	**Mean**	**SD**	**SE**
1	7	0.2114	0.0511	0.0193
2	7	0.1867	0.0911	0.0344
Difference		0.0247	0.0738	0.0395

Appendix 3.11 Two-Sample Student t-test results for iron.

Trt	**N**	**Mean**	**SD**	**SE**
1	7	20.143	10.854	4.1024
2	7	21.571	9.2170	3.4837
Difference		1.4286	10.069	5.3820

Appendix 3.12 Two-Sample Student t-test result for manganese.

Trt	**N**	**Mean**	**SD**	**SE**
1	7	47.429	23.628	8.9306
2	7	46.000	23.685	8.9523
Difference		1.4286	23.657	12.645

Appendix 13 Two-Sample Student t-test result for dry matter.

Trt	N	Mean	SD	SE
1	7	19.2901	12.58	4.0220
2	7	80.9012	22.0261	11.8621
Difference		61	8.0451	2.0241

Appendix 14 Two-Sample Student t-test result for moisture content.

Trt	N	Mean	SD	SE
1	7	80.7103	24.0582	13.0220
2	7	19.1001	13.0261	5.0269
Difference		62	9.0451	2.0241

Appendix 15 Two-Sample Student t-test result for crude protein.

Trt	N	Mean	SD	SE
1	7	5.4457	0.4307	0.1628
2	7	5.8314	0.4327	0.1636
Difference		0.3857	0.4317	0.2308

Appendix 16 Abstract submitted and presented as the oral at the 11th African Crop Science Society Conference, Entebbe-Uganda 14-17 October 2013.

Mothapo M.J., Mafeo, T.P. and N.D. Mamphiswana. 2013. *Physico-chemical properties of wild medlar (Vangueria infausta) fruit harvested at two harvesting time.* African Crop Science Society Conference, Entebbe- Uganda 11: 168.

Physico-chemical properties of wild medlar (*Vangueria infausta*) fruit harvested at two harvesting times

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Abstract

Inadequate postharvest practices in indigenous fruit plants such as wild medlar (*Vangueria infausta*) fruit forms major constrains in expanding production and commercialisation of these fruit trees. There is scanty information documented on harvesting indices of indigenous fruit plants consumed by locals in sub-Saharan Africa. Thus, objective of this study was to determine effect of harvesting *V. infausta* fruit at two harvesting times. Fruits were harvested two times, where two harvesting times were regarded as treatments and each tree as replication. The reduction for fruit weight, sugar content and sugar/acid ratio was highly significant ($P \leq 0.05$), whereas for average fruit diameter, seed weight, acid and pH content treatment impact was non-significant ($P \leq 0.05$). The data indicated that best time to harvest *V. infausta* fruit was during January when fruits were cosmetically appealing and not wrinkled. Our study demonstrated that there was less variation in some measured objective harvesting indices of *V. infausta* fruit harvested at two harvesting time.

More work would be required to do physico-chemical properties analysis from wide growth habitat for conclusive recommendations.

Keywords: Harvesting time, indigenous fruits, objective harvesting indices, subjective harvesting indices

Appendix 17 Abstract submitted and presented as the oral at the 3rd Faculty of Science and Agriculture Research Day, 3-4 October 2013.

Mothapo M.J., Mafeo, T.P. and N.D. Mamphiswana. 2013. *Different harvesting time on selected mineral elements and proximate chemical components of wild medlar (Vangueria infausta) fruit*. Faculty of Science and Agriculture Research Day, Polokwane-South Africa 3: 26.

Different harvesting time on selected mineral elements and proximate chemical components of wild medlar (*Vangueria infausta*) fruit

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Abstract

There is scanty information documented on selected mineral elements and proximate chemical components of indigenous fruit plants such as *V. infausta* fruit consumed by locals in sub-Saharan Africa. *Vangueria infausta* tree has been investigated in several researches. However, most of these researches have been concentrated on medicinal and pharmacological properties of the tree (Palgrave, 2002; Steenkamp and Gouws, 2003) and specific purpose they play in traditional healthcare system (Samie *et al*., 2005). Thus, objective of this study was to determine effect of harvesting at different times on selected mineral elements and proximate chemical components of *V. infausta* fruitSeven *V. infausta* wild trees were selected randomly in two summer seasons at University of Limpopo Experimental farm (Syferkuil). Fruits were harvested two times, where two harvesting times were regarded as treatments and each tree as replication. The experiment was performed in complete randomised manner. After harvesting the fruits mineral elements and proximate chemical components were analysed. The treatment reduced P, K and Mn by 33%, 18% and 3%, respectively. On the other hand treatments had no effect on N and Ca. The reduction for phosphorus was highly significant ($P \leq 0.05$), whereas for

N, K, Ca and Mn treatment impact was non-significant (P ≤ 0.05). Similarly, the treatment consistently reduced moisture content and increased dry matter and crude protein of *V. infausta* by 76%, 319% and 7%, respectively. The reduction for moisture content and increase in dry matter was highly significant (P ≤ 0.05), whereas for crude protein treatment impact as non-significant (P ≤ 0.05). The study demonstrated that there was less variation in selected mineral elements and proximate chemical components of *V. infausta* fruit harvested at two harvesting time. Perhaps more work would be required to do mineral elements and proximate chemical analysis from wide growth habitat for conclusive recommendations.

Keywords: Indigenous fruits, harvesting time, selected mineral elements, proximate chemical components, *Vangueria infausta*