Physico-Chemical Properties and Selected Nutritional Components of Wild Medlar (*Vangueria infausta*) Fruit Harvested at Two Harvesting Times

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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. 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 and pH content treatment impact 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 for moisture content and increase in dry matter was highly significant ($P \leq 0.05$), whereas for crude protein treatment impact as 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.

Key words: Harvesting Time · Indigenous Fruits · Harvesting Indices · *Vangueria Infausta* Fruit · Selected Nutritional Composition

INTRODUCTION

In fruit crops, maturity stages correspond with a number of co-ordinated biochemical and physiological processes. These changes in fruit would occur such that levels of each coincide with a single harvest time [1]. This information has been documented for most if not all exotic commercial fruit crops. However, this important objective harvesting indices information is scanty for almost all consumed indigenous fruit plants by local communities. Despite its nutritional and medicinal importance [2], no objective maturity indices have been developed for *V. infausta* fruit trees in South Africa.

Vangueria infausta is a deciduous tree of Burch. subsp. *infausta*, family: *Rubiaceae* and the species regenerates naturally by suckers, coppice and rarely, by seed [3]. It is a popular indigenous fruit available and consumed by rural communities in Limpopo Province, South 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 in Southern Africa [4]. *Vangueria*

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infausta tree has been investigated in several researches. However, most of these researches have been concentrated on medicinal and pharmacological properties of the tree [5, 6] and specific purpose they play in traditional healthcare system [7].

The principles dictating at which phase of development a fruit should be harvested are important to its consequent storage, shelf life and quality [8]. The time of harvest affects total antioxidant capacity particularly during maturity stage as large number of biochemical, physiological and physical changes occurs [9]. Harvesting crops at proper maturity allows handlers to begin their work with best possible quality produce. Produce harvested too early might lack flavour and might not ripe properly, while produce harvested too late might be fibrous and generally lack quality [10]. Determining objective harvesting indices involves establishing consistent physical and chemical changes which occur in the fruit crop commodity throughout its development and which correlate well with maturity [11]. Thus, focus of this study was to evaluate effect of harvesting time on physico-chemical properties and selected nutritional components of *V. infausta* fruit.

MATERIALS AND METHODS

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. The experiment was performed in complete randomised manner. 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 the department of Plant Production, Soil Science and Agricultural Engineering laboratory of University of Limpopo (23° 88'06' S; 29° 73'39' E).

Average fruit weight 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 was measured using ten fruits 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 of the fruits was measured using a digital calibre (Model: 16 ER, United State of America).

The total soluble solid (TSS) were analysed by hand held refractometer (Master-T, Model: 0229305, Japan) and results were reported as °Brix at 20°C. The titratable acidity (TA) was estimated [12]. 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 [13]. The pH of *V. infausta* juice was measured using a bench top pH meter (Orion-420 A, Hong Kong).

Determination of Crude Protein: Chemical analyses of fruits were carried out in duplicates to determine the crude protein contents using Kjeldahl method [14, 15]. 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 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.

Nitrogen Determination: 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 [16]. The total nitrogen concentration of the sample was expressed as a percentage.

Determination of Phosphorus: Sample of 0.5 g was weighed into a 100 ml digestion tube using digital electronic grain scale (Model: CQT1751GR, England). Then 1 measuring spoon of catalyst powder was added to each tube. After, 10 ml of H_2SO_4 and a few drops of H_2O_2 were added to each tube while shaking and placed in digestion tube at 35°C. The digestion was carried out until the liquid in the tubes was transparent green colour (about 3 hours). Another few drops of H_2O_2 were added about 10 minutes before 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.

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 were 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.

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, England). 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°C for 1 hour. Digestion temperature was then increased to 150°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 shake well before analysis on the Atomic absorption spectroscopy (AAS).

Moisture Content and Dry Matter: To determine moisture and dry matter content (%) fruits were heated in an oven (65°C, 48 h) until a constant weight was obtained and the weight loss was used to calculate the moisture and dry matter content in fruit.

Data Analysis: All data was subjected to two sample Student t - test at probability level of 5 % using Statistix 9.0 [17] software. Relative percentage impacts were computed [Impact (%) = (Harvesting 2/ Harvesting 1 – 1) × 100] in order to establish the magnitude and direction of the treatment impacts.

RESULTS

Relative to harvesting 1, harvesting fruits of *V. infausta* month after harvesting 1 reduced all measured physical properties (Table 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 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 fruit of *V. infausta* a month after harvesting 1 reduced some of the mineral contents (Table 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 (Table 4). 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 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 2: Mean±SE effect of harvesting time on chemical properties of *Vangueria infausta* fruit (n=7).

Treatments	Chemical properties			
	Acid content (%)	Sugar content (°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 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: 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.

DISCUSSION

In attempt to document objective harvesting indices for *V. infausta* fruit trees, effect of two harvesting time on its fruit physico-chemical properties was studied. Generally, qualities of many fruit depend strongly on harvesting time, which is usually determined on the bases of chemical and physical parameters [18]. Inadequate harvesting time influences quality and storability of various fruit crops [19]. When harvested at different times, fruits of *V. infausta* showed a decrease in fruit weight from harvesting time (H1) to second harvesting time (H2). The current results differ with results of Beever and Hopkirk [20], Al-Maaitah *et al.* [21] and Masarirambi and Nxumalo [22], 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 late lost weight as compared to those harvested early [23]. The observed weight reduction in this study on *V. infausta* fruit harvested in H2 could be attributed to wrinkling and loss of moisture by fruits at this stage.

The total soluble solid (TSS) is an important quality factor attribute for many fresh fruits during ripening [24]. 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 is inconsistency with the results of several investigators [22, 25-26], 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* agree with published data reported by Moing and Tosun [27] and Ustun and Tekguler [28] on strawberry and blackberry (*Rubus ursinus*) fruits, respectively. This indicated that acidity of *V. infausta* fruit remains 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 number of cell formed during cell division in phase I [29]. Therefore, 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 [29]. In this study fruit diameter for both treatments was the same. The results are contradicting with findings of Bowman [30] and Iqbal *et al.* [31], 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 same environmental conditions. The

seed weight of *V. infausta* was not influenced by harvesting time. Munthali *et al.* [32] 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 [33]. In this study, minerals elements (K, N, Ca, Mn and Fe) of *V. infausta* fruit from two harvesting times were not significantly different. These observations are inconsistency with findings of Nachtigall and Dechen [34] who reported that nutrient concentrations (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and B) of 'Gala', 'Golden Delicious' and 'Fuji' are 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 early (H1), which had lowest phosphorus, when compared to those harvested late (H2). This was also obtained by Nachtigall and Dechen [34] who reported that phosphorus quantities accumulated in apple fruits of the three cultivars increase gradually with fruit growth.

Results from this study showed an increase in dry matter of *V. infausta* fruit from harvesting time (H1) to second harvesting time (H2). These observations are similar to findings of Karima *et al.* [35], 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 is 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 was minimum during late harvesting time. The results from this study are similar to findings of Karima *et al.* [35] who reported moisture content of jackfruit bulb as 73.1 during late harvesting time and 81.08 during early harvesting time.

The actual protein content depends among other composition of the substrate, size of the fruits and harvesting time [36]. However, crude protein of *V. infausta* fruit from this study was not significantly different with respects to both harvesting times.

The results are inconsistency with findings of Anegbeh *et al.* [37] and Kinkéla *et al.* [38] who reported the values of crude protein (13.06 - 14.52%) in African pear (*Dacryodes edulis*) and jackfruits (*Artocarpus heterophyllus*) fruits, at different harvesting time. Furthermore, the values of *V. infausta* fruit crude protein in our study are closer to that reported by Amarteifio and Mosase [2]. 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 [8]. In conclusion, the study demonstrated that there is less variation in physico-chemical properties and selected nutritional components of *V. infausta* fruit harvested at two harvesting time. Perhaps more work would be required to do physico-chemical properties and selected nutritional components from wide growth habitat for conclusive recommendations.

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