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Current status of utilization and potential of *Dovyalis caffra* fruit: Major focus on Kenya - A review

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ABSTRACT

Dovyalis caffra is an indigenous African tree originating from South Africa. It is resilient, with capability to remain green and productive in adverse conditions such as drought, frost and saline environments. Its ripe fruit is edible and very nutritious. It has a characteristic deep yellow colour, astringent/sour taste and strong odour. The fruit can be used in making jams, jellies, juices and wine amongst other products. Despite having great nutritional and health potential, the fruit remains considerably unexploited in Africa and beyond. In Kenya, *Dovyalis caffra* is considered a wild fruit tree, with its cultivation only limited to establishing hedges. Utilization for food purposes in the country is non-existent. This review aims at (1) an in-depth scrutiny of available literature and depiction of the nature, composition, utilization and potential of *Dovyalis caffra* fruit; and (2) to critically analyse challenges in the Kenyan perspective as well as potential interventions. The extreme underutilization of *Dovyalis caffra* in Kenya may be attributed to various challenges such as; the lack of awareness of the fruits food potential, limited research and scientific information, absence of standardised agronomic and agro-processing procedures, sourness of fruit and weak value chain amongst others. In addressing such challenges, several recommendations have been proposed. Such recommendations when implemented would allow for progressive adoption of *Dovyalis caffra* by the Kenyan population and hence the fruit's unexploited benefits in food and health.

Introduction

Growing research indicates that the consumption of fruits and vegetables reduces the risk of major diseases and possibly delays the onset of age-related disorders [67]. Fruits and vegetables are generally considered the main dietary sources of vitamins such as vitamin C, B6 and carotenoids. They are also a significant source of minerals [54]. They are relatively low in calories and are cholesterol-free. Other dietary constituents found in fruits and vegetables include water, fibre, proteins,

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fats and digestible carbohydrates [67]. The inclusion of underutilized fruits and vegetables in diet contributes greatly to diversification, sustainability and affordability of nutritious food [18].

Indigenous fruit trees play significant roles in enhancing food security, environmental sustainability and socio-economic status of diverse populations across the globe [17, 33, 47]. Such fruits have been historically shown to play key roles in averting hunger and nutritional deficiency, as well as income generation for households in rural areas of arid and semi-arid regions [10]. In Africa, indigenous fruits have for long been largely underutilized due to various reasons; the main one being the early introduction, domestication and promotion of Asian fruits (e.g., papaya, mango, banana and citrus) and American fruits (e.g., passion fruit, pineapple, avocado and guava) which resulted in widespread neglect of indigenous species [45]. Consequently, the production and utilization of these exotic species continue to dominate the African continent to date, whilst the indigenous fruits remain majorly unexploited [45].

Dovyalis caffra fruit is a good example of a highly underutilized local species in the African region [49, 57], and in particular Kenya. In fact, during the peak ripening seasons, heaps of un-harvested *Dovyalis caffra* fruits left to fall off and rot on the ground make up a common scenery across diverse regions of Kenya where the plant is found growing. This peculiar underutilization persists irrespective of the fruits reported potential as a good source of vitamins and minerals [69], amino acids [66], sugars [16], polyphenols and carotenoids [42] amongst other nutritional and health promoting compounds. Apparently, compositional data of *Dovyalis caffra* fruits grown in Kenya is very scarce. Apart from a recent study on basic composition of *Dovyalis caffra* fruits in Narok county [54], comprehensive scientific data of this fruit is nonexistent in the country. Such absence of scientific information partially contributes to the overall lack of interest in the fruit and hence the current Kenyan situation.

In view of all the above circumstances, this review aimed at documenting qualitative exploration of published literature based on key aspects of *Dovyalis caffra* ranging from general growth features, composition as well as potential utilization. Exposition on potential challenges associated with the current Kenyan situation as well as appropriate mitigation factors have also been presented. The review is expected to serve as a strong foundation and reliable starting point for future research and adoption of *Dovyalis caffra* for food purposes in Kenya.

Methodology

Literature search was performed on the “Web of Science” database which returned 51 results in its core collection when searched for “Dovyalis” in all fields, with the first published manuscript dating from 1973 and the last one in 2021. Further analysis showed that these manuscripts concerned various sub-species of Dovyalis with 28 publications relating to *Dovyalis Caffra*, 10 on *Dovyalis abyssinica*, 7 on *Dovyalis hebecarpa* and 1 each for the various Romana, Revoluta and Keniensis; while the rest concerned other clones and hybrid plants. Of all 28 publications relating to *Dovyalis caffra*, 25 are presently cited, 3 being not relevant to the present review as they pertain respectively to an ecotoxicological study of soil contamination, a study on cross pollination and a study on pharmacokinetic interactions. To enhance literature from the 25 main references, an additional 50 references which may not necessarily be related to *Dovyalis caffra* have been cited as supportive materials in the study.

General description of *Dovyalis caffra* fruit

Origin and distribution

Dovyalis caffra also called *Kayaba* (in Kikuyu language of Kenya), *Aberia caffra* or more commonly Kei-apple [65] is a fruit tree that is native to the South African countries namely; Malawi, South Africa, Zimbabwe and Mozambique [8, 28]. It belongs to the family Salicaceae [23, 63]. The fruit’s overall distribution (Fig. 1) is believed to have originated from the South African’s ‘Kei’ river from where its common name derives, moving northwards along the eastern side of the continent to East Africa and beyond [53]. Other countries where the fruit is also distributed include; Djibouti, Algeria, Egypt, Israel, Italy, France, Jamaica, Portugal, Spain, Australia, USA and England [40, 53]. In Kenya, the fruit tree is generally found growing randomly in the wild and more recently as a live fence across the country [54]. Formal cultivation for food purposes has however not yet been reported anywhere in the country.

Botanical description

Dovyalis caffra is a dioecious shrub or small evergreen tree that grows to a height of 3 – 5 m with an ability to reach up to 8 - 9 m if left unpruned. Young branchlets (Fig. 2-A) of the tree are covered with a smooth grey bark which slowly turns flaky as the plant ages [50]. Such branchlets also exhibit plenty of long (40–70 mm) thorny spines which are noticeably fewer in the main stem as illustrated in Fig. 2-B.

The crown of the tree is highly branched with simple leaves popping out in tight clusters on dwarf lateral branches and alternate on young shoots. Each leaf is obovate 2 - 5.5 cm by 0.5–3 cm with a rounded apex and tapering base on 5 mm-long petiole (Jøker & Omondi, 2000).

Being dioecious [27], the male and female flowers of *Dovyalis caffra* develop on different trees. These flowers are small and creamish-green in colour and occur in clusters at the leaf axils. The male ones are approximately 3 mm long and are

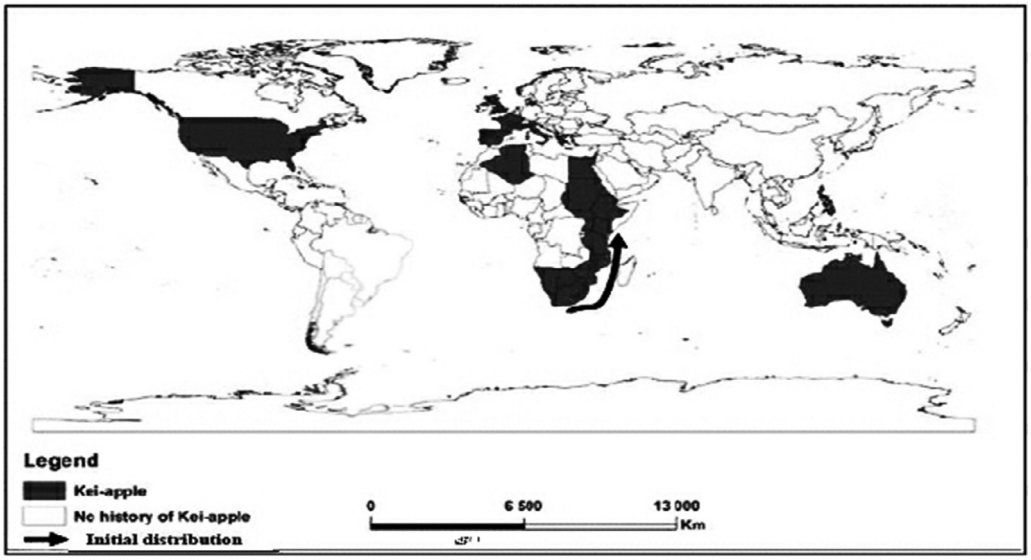

Fig. 1. Global Occurence and dispersion of *Dovyalis caffra.* Modified from Orwa et al., [52].

Fig. 2. [A] = *Dovyalis caffra* branchlet with grey bark, thorny spines and clustered leaves, [B] = Main stems of *Dovyalis caffra* shrub with sparsely spaced thorny spines, [C] = Bright yellow coloured ripe *Dovyalis caffra* fruits, [D] = A hedge made from *Dovyalis caffra* shrubs. (NB: Use colour printing for Fig. 2).

organized in dense clusters of five to ten flowers while the female ones are generally longer (4–10 mm) and occur either in solitary or in less dense clusters of up to 3 flowers [53].

Dovyalis caffra tree bears fleshy berries, with a nearly spherical shape and a diameter of up to 6 cm [51]. The skin of unripe fruits appear green in colour but changes to yellow-orange when fully ripe [45]. Fig. 2-C illustrates the bright yellow appearance of ripe *Dovyalis caffra* fruits. The pulp of the fruit encloses about 5–15 seeds arranged in circles [5]. Such seeds are characterized by hard and hairy coatings [25].

With regard to root style, *Dovyalis caffra* shrubs are shown to exhibit shallow and spreading rooting systems [52].

Biology and ecology

Dovyalis caffra mainly occur and thrive in open bushes and wooded grasslands. The tree is largely resistant to drought and frost conditions [5] and can tolerate sea breezes and salt sprays. For optimal performance, the plant requires deep, well-drained, loamy or sandy soil. Propagation is mainly by seeds although vegetative cuttings are also viable under the right conditions [26,43].

The *Dovyalis caffra* tree starts flowering after attaining a minimum of 3 years after planting [31]. The flowers are pollinated by insects such as bees or other agents such as wind. The fruit generally takes about 4 months to mature [52]. Varying flowering and fruiting periods have been previously reported for this fruit. For instance, Morton & Dowling, [40] reported plant blooming in spring with fruit ripening from August to October in the United States of America while Orwa et al., [53] reported November to January in the South African region. Such variation in flowering periods may depend on cultural practices that affect tree adaptation to local ecological factors as well as the local climatic conditions, such as the chilling requirements of fruit trees before they can bloom [5].

Nutritional composition of *Dovyalis caffra* fruit

Proximate composition

Table 1, illustrates typical nutritional composition data of *Dovyalis caffra* fruit juxtaposed against that of *Citrus sinensis* a.k.a orange for comparison purposes. Orange was considered a good bench-mark fruit because of its popularity, richness in nutrients, organoleptic desirability and extensive commercialization [71]. Proximate composition shows notable similarity between the two fruits particularly in regard to high moisture content and low levels of protein, fat, ash and fiber. The carbohydrate content of *Dovyalis caffra* fruit (4.7%) is however less than half of the amount in orange (12%). Contrary to the range of values indicated in the table, higher amounts of carbohydrates (up to 13%) were reported in *Dovyalis caffra* fruits from a different Southern African region [16]. The carbohydrate (sugar) content of a fruit is known to play a key role in determining its suitability for inclusion as a food ingredient. A study on sugar content (glucose and fructose) of nine *Dovyalis caffra* fruit accessions in South Africa reported the highest total sugar content (50 mg/g FW) in accession FH240, making it the most suitable for fresh consumption and for new product development. Analytically 29.5% of the total sugar was shown to be glucose and 70.5% was fructose [42]. In a study conducted in Egypt, the proximate composition of dried *Dovyalis caffra* fruits was reported to be as follows: carbohydrate (54.05%), crude fibre (16.3%), protein (4%), ash (7.45#x0025;), moisture (15.5%) and fat (3%) [66]. A study conducted in Kenya comparing *Dovyalis caffra* samples of 3 different maturity stages (young, middle aged and old), the carbohydrate content was reported to increase with age of fruit [54]. In the same study, the protein and lipid content was reported to decrease with advancing fruit age with specific values ranging from (2.3% - 2.7%) and (10.7% - 17.9%) DW respectively. It is worth noting that there is a strikingly large discrepancy between the lipid values reported by Osano, [54]. for *Dovyalis caffra* fruits from Kenya and those of Taher et al. [66], for Egyptian samples. This may be mainly attributed to differences in geographical location of these plants. The difference in the method of analysis may also be a potential contributor to the compositional differences i.e., the former used Bligh and Dyer method and Taher et al. [66] used the soxhlet method. In a general perspective, *Dovyalis caffra* fruit is potentially endowed to significantly contribute in the recommended dietary allowance (RDA) for water and carbohydrates but with minimum impact in RDA of protein and fat. This is also true for the orange fruit.

Amino acid composition

Table 1, shows a select list of some essential amino acids obtained from a South African study that was able to profile seventeen amino acids from *Dovyalis caffra* fruits [61]. Though slightly lower than the amounts in orange fruit, all the essential amino acids in *Dovyalis caffra* fruits were in quantities that exceed their respective RDA per day. This clearly demonstrates potential of *Dovyalis caffra* fruit in promoting good health through the various physiological and biochemical processes associated with essential amino acids. A detailed analysis conducted in Egypt reported fifteen amino acids in *Dovyalis caffra* fruit with glutamic acid being the most abundant. In a descending order of abundance the other fourteen amino acids identified were; aspartic acid > leucine > serine > alanine > phenylalanine > glycine > arginine > lysine > threonine > methionine + valine > isoleucine > histidine and proline [1]. In a similar South African study, nine accessions of *Dovyalis caffra* fruits were reported to contain varying proportions of twenty different amino acids. These are; [Histidine (His), Serine (Ser), Arginine (Arg), Glycine (Gly), Aspartate (Asp), Glutamate (Glu), Threonine (Thr), Alanine (Ala), Proline

Table 1
Nutritional composition of *Dovyalis caffra* and orange fruit.

Parameter		*Dovyalis caffra*	Orange fruit	Recommended dietary allowance (RDA)
Proximate composition (g/100g)	Moisture	85.9	86.4	2.1 – 2.6 L/day
	Protein	0.4	0.7	28 – 65 (g/day)
	Fat	0.4	0.2	44 – 77 (g/day)
	Ash	0.3	0.7	≤5 mg/100g
	Fibre	0.3	0.5	18 – 35 (g/day)
	Carbohydrate	4.7	12	130 (g/day)
Essential amino acids (g/100g)	Leucine	0.36	0.75	39 (mg/kg/day)
	Valine	0.31	1.36	39 (mg/kg/day)
	Lysine	0.28	3.32	30 (mg/kg/day)
	Phenylalanine	0.24	13.04	25 (mg/kg/day)
	Isoleucine	0.22	1.59	20 (mg/kg/day)
	Methionine	0.08	1.15	15 (mg/kg/day)
	Histidine	0.08	4.40	10 (mg/kg/day)
	Tyrosine	0.04	0.82	25 (mg/kg/day)
Minerals (mg/100g)	Potassium	606	118	4700 mg/day
	Phosphorus	10.5	31.7	700 mg/day
	Sodium	9.5	4.4	1500 mg/day
	Calcium	4.8	20	1000 mg/day
	Magnesium	0.4	11.4	260 mg/day
	Iron	0.14	4.1	20 mg/day
	Copper	0.06	0.06	0.9 mg/day
Vitamins (mg/100g)	Vitamin C	117	50	45 mg/day
	Niacin	0.3	0.18	16 mg/day
	Riboflavin	0.05	0.02	1.1 mg/day
	Thiamine	0.01	0.04	1.1 mg/day
Reference		(Sibiya et al., 2021; Wehmeyer, 1966)	(Correa et al., 2018; Nagy & Attaway, 1980; Trong & Bui, 2018)	(Weltgesundheitsorganisation et al., 2007; World Health Organization & Food and Agriculture Organization of the United Nations, 2004)

(Pro), Cysteine (Cys), Lysine (Lys), Tyrosine (Tyr), Valine (Val) Isoleucine (Ile), Leucine (Leu), Phenylalanine (Phe), Asparagine (Asn), Glutamine (Gln), gamma-aminobutyric acid (GABA) and *Ornithine* (Orn) (non-proteinogenic amino acid) [42]. Overall, one accession of the fruit (FH236) recorded significantly higher levels of essential amino acids such as phenylalanine (27.79 mg/L) and leucine (23.17 mg/L) and was generally declared a potential source of the same [42].

Minerals

The mineral composition of *Dovyalis caffra* fruit according to Wehmeyer, [69], is illustrated in Table 1. In his study, Wehmeyer, [69], established that *Dovyalis caffra* is a fairly good source of minerals in comparison to two other under-utilized fruits namely; marula (*Sclerocarya birrea)* and wild apricot (*Prunus armeniaca)*. For instance, the potassium levels reported for *Dovyalis caffra* were found to be as high as threefold that of wild apricot and over tenfold that of marula fruit. Such content is however significantly lower than that reported for banana fruit (1620 mg/100 g) which is considered the typical fruit source of potassium [24]. With regard to phosphorus and sodium, Wehmeyer, [69] further established *Dovyalis caffra* fruit to be considerably higher in these minerals as compared to marula and apricot fruit samples. Additionally, the fruit's copper, iron and calcium levels though numerically lower than those of marula fruit and wild apricot, the amounts recorded were shown to be fairly comparable to the two fruits. Overall, *Dovyalis caffra* was shown to be deficient in magnesium and may be therefore considered a poor source of the same [69. In a Kenyan study by Osano, [54]], yellow ripe

Dovyalis caffra fruits were reported to have copper and iron contents of (0.13 mg/100 g) and (10.559 mg/100 g) respectively; amounts that are considerably higher than those reported for the same fruit species byWehmeyer, [69]. Comparison with orange fruit (Table 1) affirms *Dovyalis caffra*'s superiority in potassium and sodium; and inferiority in the rest of the minerals. Numerically, consumption of 100 g of *Dovyalis caffra* fruit would yield 12.89% of the daily RDA for potassium.

Vitamin C

Dovyalis caffra fruit has been reported to be an excellent source of ascorbates [46,61]. Loots et al. [34] demonstrated that *Dovyalis caffra* fruit juice from South Africa has higher total ascorbates (658 mg/L) as compared to orange (411 mg/L), grape (12 mg/L) and strawberry (211 mg/L) juices while still exhibiting a comparably low dehydroascorbate (DHA) content. Moreover, the ascorbates in *Dovyalis caffra* juice showed exceptional stability with very little oxidation to DHA. This is of particular importance to both health and industry [34]. In a different report, Du Preez et al. [16] further confirmed that *Dovyalis caffra* from South Africa is a superior source of ascorbic acid in comparison to citrus and guavas. Such findings are in perfect harmony with the disparity observed in Vitamin C content of *Dovyalis caffra* and orange fruit (Table 1). The value of ascorbic acid reported for Egyptian *Dovyalis caffra* fruit (83 mg/100g) is also in fair agreement with previous reports [40]. Basically, intake of just a few *Dovyalis caffra* fruits ($\leq$100g) would be sufficient enough to meet the daily RDA for ascorbic acid.

Beta carotene

Other than ascorbic acid, β-carotene is another antioxidant vitamin (pro-vitamin A) that has been reported in *Dovyalis caffra* fruits [42]. In this study, Mpai et al., [42] reported a β-carotene range of (1.41–4.78 mg/ 100 g FW) in various accessions of *Dovyalis caffra* fruits. As compared to carrots (23.25 mg/100 g) [19], such range of β-carotene is quite low. However, even as it is, the range is still notably higher than that of several common commercial fruits. For instance, Apple cultivars Beni Shogun (0.32 mg/ 100 g) and Gala (0.11 mg/ 100 g FW) exhibited lower β-carotene content than all the *Dovyalis caffra* accessions studied. Blueberries were no different [42]. In general, and from an antioxidant perspective, it is clear that *Dovyalis caffra* fruit is a rich source of plant derived antioxidant compounds (vitamin C and β-carotene) over and above the numerous phenolic compounds - subsequently discussed (Section 3), all of which have notable health promoting properties. Whilst *Dovyalis caffra* is a highly underexploited fruit in Kenya, it is evident that it can be proposed or rather recommended as a novel source of these compounds in the country's food system.

B-complex vitamins

The B-complex vitamins of *Dovyalis caffra* fruit according to Wehmeyer, [69], are illustrated in Table 1. In his findings, Wehmeyer, [69], evidently showed that *Dovyalis caffra* fruit is comparable to marula fruits in terms of thiamin, riboflavin and niacin contents. The study however reported *Dovyalis caffra* to be an inferior source of these vitamins in comparison to the wild apricot. Further comparison of the findings by Wehmeyer, [69], with a study involving common commercial fruits indicates *Dovyalis caffra* to be superior to both bananas and guavas in terms of riboflavin and niacin but slightly inferior in thiamine concentration [29]. This scenario is also true for orange as shown in Table 1. Broadly speaking, by being fairly rich in a substantial number of vitamins and minerals, *Dovyalis caffra*, though commercially unexploited, holds great potential in contributing to the daily dietary requirements of micronutrients necessary for optimal physiological functioning of the human body. It is therefore justifiable to recommend inclusion of this fruit in the daily diet plans as an alternative source of these micronutrients. Overall, such action could lead to diet diversification and improved nutritional and health status of the consumers.

Phytochemical composition and potential health benefits of *Dovyalis caffra* fruit

Phytochemical composition of Dovyalis caffra *fruit*

Phytochemicals are natural bioactive compounds produced by plants for various purposes such as protection against pathogenic attack, insect damage, chemical pollution, exposure to UV rays, submergence, drought and other environmental stresses [36]. In addition, these chemicals also largely contribute to the colour, taste and odour of plants [4]. In such context, the bright yellow colour and strong aroma of *Dovyalis caffra* fruits [46] may be indicative of its rich content in phytochemicals. In general, due to their bioactive nature, odour and colourful properties, phytochemicals, have found a wide range of industrial applications such as manufacture of pharmaceuticals, herbicides, insecticides, perfumes, and colouring agents [6, 36, 56].

Overall phytochemicals in plants occur in thousands and thousands of varying forms and structures, to the extent that it is so difficult to identify and study all of them exhaustively [32, 59]. For this reason, broad classifications of these chemicals are made based on their role in plant metabolism and hence the two main categories namely; primary and secondary metabolites. Primary metabolites comprise the common sugars, proteins, amino acids, purines and pyrimidines of nucleic acids as well as chlorophylls. Some of these metabolites have been previously analysed in *Dovyalis caffra* fruits as discussed

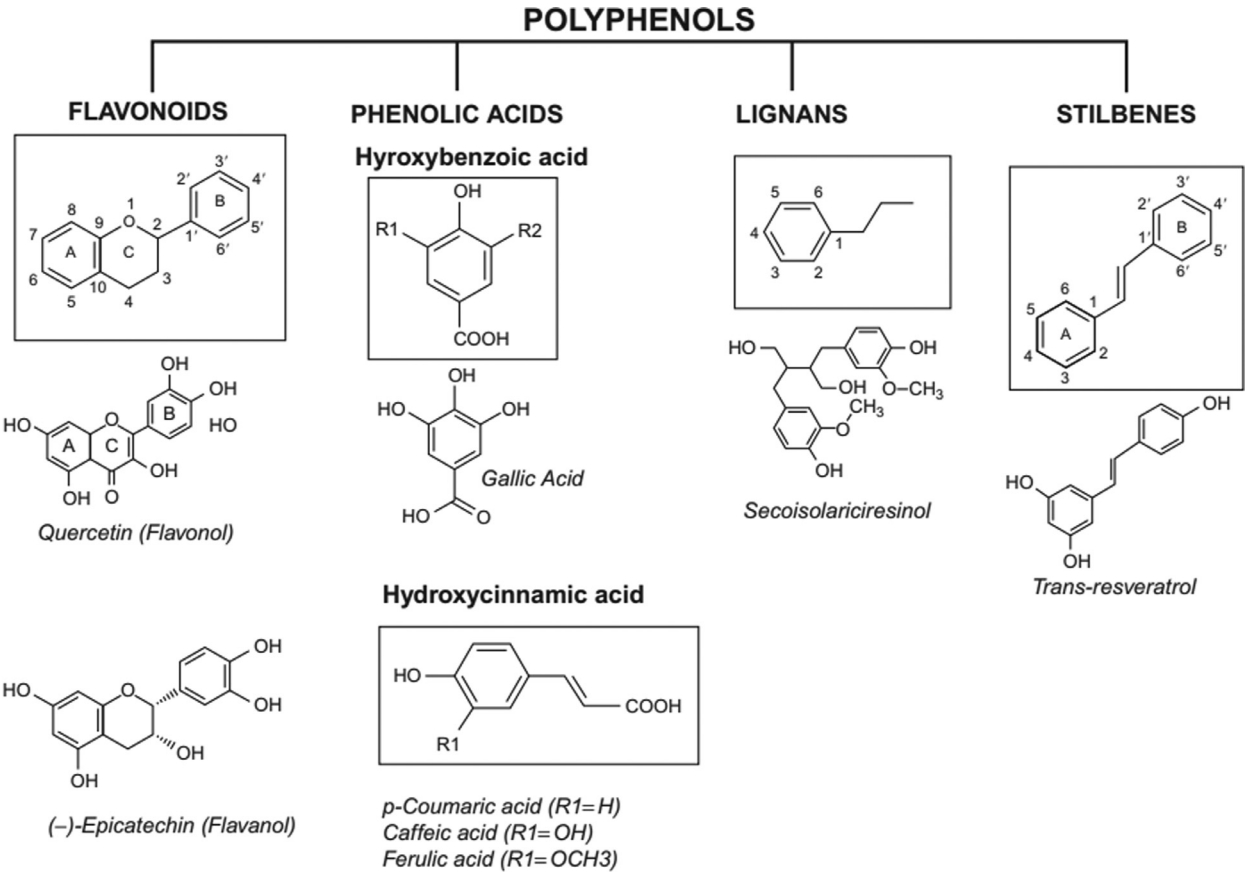

Fig. 3. Basic structure of polyphenolic compounds.
Source: [12]

Table 2
Total polyphenols and antioxidant activity of *Dovyalis caffra*, straw berry, grape and orange juices.

Fruit	Total Polyphenols (mg GAE/L)	Antioxidant Capacity – ORAC (mMTE)
Dovyalis caffra	1013±3.0	43.9 ± 1.3
Straw berry	567±10	33.0 ± 2.6
Grape	269±1.4	15.7 ± 0.7
Orange	264±0.9	21.0 ± 1.4

GAE: Gallic Acid Equivalent, ORAC: Oxygen Radical absorbance Capacity, mMTE: millimole Trolox Equivalent.
Source: Loots et al., [34].

earlier under nutritional composition. Other than primary metabolites, the rest of the plant chemicals constitute secondary metabolites e.g. phenolics, flavonoids, alkaloids, terpenes, lignans, plant steroids, saponins, curcumins and glucosides [59, 68]. amongst all the mentioned phytochemicals, phenolics form the largest and most widely distributed category in the plant kingdom [6]. The category is also the most potent in terms of bioactivity [6]. Subsequently this is the most studied group amongst the phytochemicals in plants [6, 55]. Structurally, polyphenols are characterized based on the number of phenol rings and the nature of their carbon skeleton [12]. The basic classification and structures of major polyphenols is shown in Fig. 3.

Phenolic compounds of most commercial fruits have been widely studied and documented with an overall analysis indicating that such fruits are good or excellent sources of the these compounds [44]. A few studies have also been conducted on the wild *Dovyalis caffra* fruit with reports indicating that it is also a potential source of phenolic compounds [62]. Table 2 shows a brief comparison of phenolic compounds in juices from *Dovyalis caffra* and a few selected commercial fruit samples of South Africa prepared and analysed under the same conditions [34].

From Table 2, it is evident that the total polyphenol content of *Dovyalis caffra* juice is about twice that of strawberry and about four times that of grapes and orange juice. The antioxidant activity of *Dovyalis caffra* is also shown to be substantially higher than either of the other fruits. In another study conducted in South Africa, Mpai et al., [42] similarly reported higher

polyphenolic content and antioxidant activity (FRAP assay) for various accessions of *Dovyalis caffra* fruits in comparison to blue berries. Moreover a study in Egypt also reported high total polyphenol values of 2901 mg GAE per 100g dry weight and high antioxidant activity - (DPPH assay) in *Dovyalis caffra* whole fruit extracts [66]. Overall, a positive correlation has been shown to exist between high levels of polyphenols and high antioxidant activities in *Dovyalis caffra* fruits from various regions [34, 42, 66].

With regard to detailed profiling of phenolic compounds in *Dovyalis caffra*, a few studies have been previously undertaken and have reported varying outcomes (Table 3). A general analysis by Loots et al. [34] involving fractionation of the phenolic compounds in *Dovyalis caffra* fruit juice demonstrated that phenolic acids were the most abundant fraction with a contribution of 66.3% of the total phenolic compounds, followed by procyanidin, catechin, and anthocyanin monomers at (28,8%) and then anthocyanin polymers at (3.2%) and finally flavonols at 1.7%. A more detailed qualitative and quantitative analysis by GC–MS of the fruit juice further indicated that caffeic acid (Table 3) was the most prevalent polyphenol (128.7 mg/L) accounting for 63% of the total antioxidant capacity of all the individual compounds identified. In a descending quantitative order, the other major non-flavonoid compounds identified by Loots et al., [34] were as follows; *p*-coumaric acid > *p*-hydroxyphenylacetic acid > protocatechuic acid > 3–methoxy- 4-hydroxyphenylacetic acid. Loots et al., [34] further demonstrated the individual contribution of these compounds to the overall antioxidant capacity (TEAC) to be in the following descending order; caffeic acid > p-coumaric acid > protocatechuic acid > 3–methoxy-4-hydroxyphenylacetic acid. In a more recent study, Taher et al., [66] identified and quantified by HPLC twenty three phenolic compounds in whole *Dovyalis caffra* fruit extract with the summarized profile consisting of seventeen phenolic acid derivatives, three bound flavonoids and three free flavonoids in varying concentrations (Table 3). Individually, chlorogenic acid which is an ester of caffeic acid was in this case reported to be the most abundant (2270 μg/g dry weight) phenolic compound. In another study Mpai et al. [42], reported pyrogaroll to be the most abundant phenolic compound in *Dovyalis caffra* fruit (Table 3). From a perspective of phenolic profiling, it is clear that there are notable variations in the composition of *Dovyalis caffra* fruits. Such variations may be attributed to varying extraction conditions such as solvent composition which has been shown to affect the solubility of different phenolic acids and their derivatives during analysis [66]. Other reasons for the variations in fruit composition may be differences in sample geographical origin, fruit age, seasonal variations, genetic variations, climatic conditions etc. For instance, a study conducted in Kenya reported a negative correlation between the antioxidant activity (DPPH) of *Dovyalis caffra* fruits and their maturity [54]. The study reported that the young fruit samples registered an IC_{50} concentration of 28.1385 μg/mL and the old fruit sample a value of 16.7316 μg/mL.

Potential health benefits of dovyalis caffra *fruit*

Phytochemicals in general have been suggested to be of great benefit to human health in particular due to their antioxidant properties [6]. Antioxidants such as flavonoids have been shown to have potential antimicrobial, antioxidant, anticancer, anti-inflammatory, and wound-healing properties [6, 15]. Studies have also shown epidemiological association between high dietary flavonoid content and low incidence of cardiovascular disease and certain cancers [37]. The role of vitamin C in performing vital physiological functions and prevention of disorders such as atherosclerosis, common cold, glaucoma, macular degeneration, diabetes, stroke, cataracts and heart diseases has also been reported [13].

As far as *Dovyalis caffra* is concerned however, human *in-vivo* studies have not yet been reported so far in regard to the fruit's medicinal value [5]. Animal models have however been previously used in study of the fruits pharmacological properties. In one such study Gomaa et al., [21] demonstrated that an aqueous extract of *Dovyalis caffra* fruit stimulated intestinal motility, inhibited uterine contractions in rats and prolonged the stimulation of ventricular contractions in *Bufo regularis*.

Despite the lack of direct human pharmacological data of *Dovyalis caffra*, the *in-vitro* phytochemical data from previous studies clearly projects the fruits superb bioactivity and hence potential for imparting various health benefits to humans. For instance, the 5.4 mM/L of flavonoids reported for its juice is higher than that of strawberry, oranges and grapes [34]. This translates to higher overall biological activity and subsequently the desirable health benefits associated with consumption of flavonoids. Phenolic acids in general are reported to be involved in nutrient uptake, enzymatic activity, structural components and protein synthesis [15]. Caffeic acid is known to block the biosynthesis of leukotrienes which are the constituents involved in immune regulation diseases, asthma, and allergic reactions [15]. *Dovyalis caffra* being laden with phenolic acids including caffeic acid is therefore a potential conveyer of such health benefits. Additionally, the antioxidant, antitumor and anti-carcinogenic activities of phenolic acids have also been reported [15]. In fact the acids have been demonstrated to be more effective antioxidants (*in-vitro*) than vitamin E and C on the same molar basis as a result of their ideal structural chemistry for free radical scavenging activity [15]. In a general perspective, *in-vitro* medicinal properties of *Dovyalis caffra* have also been reported in other plant parts e.g., cytotoxic activity against lung tumour cell line by methanolic extracts of the branches [41]. Additionally, besides the fruit, antimicrobial properties have also been recorded in the root and stem extracts of the plant [70].

Physicochemical characteristics of *Dovyalis caffra* fruit

The physical and chemical properties are vital quality parameters which determine a fruit's suitability for consumption or processing. For instance, the colour of a fruit greatly influences consumer perception of the raw material since it is

Table 3
Summary of polyphenolic compounds identified in *Dovyalis caffra* fruit.

Sample	Identified polyphenols	Quantity	Method of analysis	Reference
		(μg/g)		
Whole fruit extract	Rosmarinic acid	1.00	Extraction of phenolics from	Taher et al.
	p- Coumaric acid	2.00	the fruit sample was done	[66]
	Cinnamic acid	2.00	using a mixed solvent	
	Luteolin	2.00	constituting distilled water:	
	3,4,5-Trimethoxycinnamic acid	3.00	methanol [4:1v/v]. Extracts were then injected into a	
	Quercetin	3.00	reversed phase HPLC with a	
	Rutin	6.00	diode array detector (Hewlett	
	Resveratrol	6.00	Packard 1050) and a guard	
	Ferulic acid	6.00	column Alltima C18, 5 mm.	
	Hesperidin	7.00		
	Coumarin	7.00		
	Gallic acid	8.00		
	Catechol	9.00		
	p-OH benzoic acid	9.00		
	Caffeic acid	16.00		
	Ellagic acid	24.00		
	Isoferulic acid	41.00		
	Epicatechin	230.00		
	Vanillic acid	247.00		
	Catechin	292.00		
	Protocatechuic acid	292.00		
	Chlorogenic acid	2730.00		
	Pyrogallol	5070.00		
		(Mg/Kg)		
Fruit pulp			A homogenized fruit sample	Mpai et al. [42]
	3-Methoxy-4-hydroxyphenylacetic acid	1.39	(1g) was extracted in 10mL of methanol containing 1% BHT in an ultrasonic bath. The	
	Ellagic acid	4.85	extract was then centrifuged,	
	p- Coumaric acid	9.03	filtered and injected (10 μL)	
	p-Hydroxyphenylacetic acid	11.36	in a HPLC with a photodiode array ultraviolet detector and	
	Vanillic acid	15.94	a C18 column (100 $\times$ 4.6 mm;	
	Syringic acid	72.28	5 μm particle size).	
	Protocatechuic acid	227.58		
	Pyrogallol	1939.48		
		(Mg/L)		
Fruit juice	Hydro-*p*- coumaric acid	0.35	Sample juice was first	Loots et al.
	Salicylic acid	0.35	extracted and chemically	[34]
	α-Resorcylic acid	0.57	derivatized to facilitate further	
	Syringic acid	0.66	analysis. Identification and	
	Ferulic acid	0.81	quantification of individual	
	m-Coumaric acid	1.67	polyphenols was done using	
	Gallic acid	2.36	an Agilent 6890 GC ported to	
	Catechin	2.71	a 5973 mass selective detector	
	Vanillic acid	3.64	(CA).	
	m-Hydroxybenzoic acid	4.27		
	Protocatechuic acid	9.51		
	p-Hydroxyphenylacetic acid	10.62		
	p- Coumaric acid	15.70		
	Caffeic acid	128.70		

linked to the degree of ripeness. A study conducted in South Africa by Augustyn et al., [7] reported L*•a*•b* values of 28 *Dovyalis caffra* fruit selections to be in the range of L*: 53.83–69.81; a*: 5.25–10.67; b*: 43.19–67.50; C: 44.28–68.35; and h: 77.00–83.50, where; L* represents Lightness, a* - red-green, b* - yellow-blue, C - chroma and h - hue angle. The authors further reported significant variations in the yellow/orange colour (IY values) of the fruits and the pulps between the various selections.

In the same study, textural analysis showed *Dovyalis caffra* fruits to be harder and firmer (9.56 $\pm$ 0.71 N) than the plum fruit ($\pm$8 N). The taste of a fruit is dictated by the balance between its constituent sugars and acids. Analytically this is

Table 4
Organic acid profile of *Dovyalis caffra* fruit.

Organic acid	Amount (g/100 g DW)	Percentage (%)
Succinic acid	0.35	2.81
Malic acid	10.15	81.4
Citric acid	0.57	4.57
Oxalic acid	0.42	3.37
Lactic acid	0.34	2.73
Propionic acid	0.64	5.13

DW: Dry Weight.
Source: Taher et al. [66].

determined as the ratio between total soluble solids (TSS) and the total titratable acidity (TTA). In addition, *Dovyalis caffra*, samples obtained from the regions called Skukuza and Bundu 2 were shown to have high TSS and high TTA levels as compared to the other samples. The fruits collected from Mananga region did not have exceptionally high TSS values but their TTA values were very low resulting in a high TSS: TTA ratio. Such high TSS:TTA ratio was clear indication that the selections were more suitable for consumption as fresh fruit, since they were less sour [7]. In a study conducted in Kenya, the total soluble solids of *Dovyalis caffra* was shown to increase with increase in fruit age [54]. On average a TSS of between 11 and 13 was recorded amongst three different stages of fruit development [54]. Similar figures were reported for the same fruit species [11].

The total titratable acidity of *Dovyalis caffra* fruit is on average quite high because most of its organic acids exist in free form [66]. The fruit is in fact sometimes considered too acidic to be eaten raw [66]. In a study conducted in Egypt, Taher et al., [66] registered a TA of 3.49 g malic acid /100 g FW in *Dovyalis caffra* fruits. Similarly, Minnaar et al., [39] reported an equally high TTA acidity of 144.01 g/L in the same species of fruit (Table 4). Shows a profile of organic acids identified and quantified from a *Dovyalis caffra* fruit sample in Egypt. From the figures reported, it is evident that malic acid is the most predominant, constituting an average of approximately 81% of the total organic acids present in the fruit. The rest of the acids have been shown to occur in smaller quantities only. As far as pH is concerned, a study by [54], showed a decrease in pH with increase in fruit age. In this study, young fruits were reported to have a pH of 2.98 and old fruits a pH of 1.19.

Value addition of *dovyalis caffra* fruit

To the best of our knowledge, there are so far no official reports of any research on product development from *Dovyalis caffra* fruits in Kenya. Other regions of the world (mainly South Africa) have however carried out a number of studies in this respect. Below is a highlight of these studies.

Wine

In a study conducted in South Africa by Minnaar et al., [39], wine was developed by fermenting *Dovyalis caffra* fruit juice using a mixed culture of *Schizosaccharomyces pombe* + *Saccharomyces cerevisiae* and a single culture of *Saccharomyces cerevisiae.* The effect of these yeast cultures on the phytochemical, sensory and physicochemical properties of the wine was determined. The mixed culture produced wine with a higher percentage of alcohol and pH and corresponding lower titratable acidity, residual sugar and L-malic acid content as compared to the single culture. Low L-malic acid concentration was reported in the mixed culture due to the ability of *Saccharomyces pombe* to degrade it. Such ability has also been reported by Benito, [9]. With regard to phytochemicals, fermentation by both sets of culture resulted in an increase in total polyphenols but with variations in individual phenolic compounds. The increase in concentrations of phenolic acids in the wines was contemplated to be caused by breakdown of plant cell walls by the yeast, which releases phenolic compounds and effect of hydrolytic enzymes or acid hydrolysis. In terms of sensory evaluation, wine produced by single culture was shown to be fresher, fruitier and lower in off-odours than the mixed culture counterpart. Overall, development of *Dovyalis caffra* fruit wine is demonstrated to be feasible and of great potential for future studies towards its improvement in sensory, phytochemical and physicochemical parameters. Such findings come in handy not only to South Africa, but also to Kenya, particularly in guiding future research and exploitation of this underutilized fruit in the country. Such future studies may involve testing new yeast cultures in *Dovyalis caffra* wine making, product development using Kenyan fruit varieties and process modifications amongst others.

Vinegar

Apart from alcoholic fermentation, further acetous fermentation of *Dovyalis caffra* wine has also been recently reported in South Africa [38]. In such study, a culture of Acetic acid bacteria constituting *Acetobacter pasteurianus, Acetobacter malorum, Kozakia baliensis, Gluconobacter cerinus,* and *Gluconobacter oxydans* was demonstrated to significantly affect the quantities of various phenolic acids in vinegars produced from wines of different starter cultures. For instance, wine from *Saccharomyces cerevisiae* registered an increased level of syringic and chlorogenic acid while that of *Saccharomyces pombe* recorded an

increase in gallic, caffeic, and p-coumaric acids of the end product. Acetous fermentation however, was shown to cause a decrease in some phenolic acids such as sinapic acid and ferulic acid. Overall, such study demonstrated the need for future research on potential of vinegar production using *Dovyalis caffra* fruit as a raw material. Possible aspects to be studied may include variation of acetous fermentation culture and process optimization amongst others. Focus on Kenyan fruits in such studies is strongly recommended.

Ready to drink fruit juice

In South Africa, a study to develop a functional beverage with demonstrable nutritional benefits and sensory acceptability using *Dovyalis caffra* fruit juice was conducted by Gore, [22]. As part of product development, different fruit flavors (Apple, vanilla and mint + vanilla) were independently incorporated to the drink in order to masque the strong characteristic taste and aroma associated with *Dovyalis caffra* fruits. The effect of different flavors on consumer acceptability of developed beverages was determined. Overall, the apple flavoured beverage was shown to be the most preferable, with significantly higher scores in taste, overall acceptability, consumption intent, purchase intent and preference as compared to the rest. No notable difference was reported in all attributes between vanilla and vanilla + mint flavoured beverages. With regard to phytochemical analysis, the total polyphenols of all sample beverages was shown to be lower than expected, an outcome attributable to phenolic degradation during processing. This general observation notwithstanding, vanilla flavoured beverage recorded a higher figure of total phenolics as compared to the rest. This was contemplated to be caused by the vanillic acid molecule itself since it also has a phenolic structure. In this same study, comparison of *Dovyalis caffra* beverage with commercial cranberry juice showed superiority of the latter in terms of total polyphenols and ascorbic acid concentrations. Gore, [22] attributed the inferior levels of vitamin C to degradation during pasteurization and oxidation during pulping of the *Dovyalis caffra* fruits. In summary, development of a functional beverage from *Dovyalis caffra* fruits is established to be a feasible task with potential of future advancement in new product formulations and modifications. In a Kenyan perspective, it would be prudent to use new local fruit flavors in conducting similar research and also to engage in developing processing procedures that are less detrimental to nutrients and phenolic acids in *Dovyalis caffra* fruit drinks.

Nectar

A nectar drink from ripe *Dovyalis caffra* fruits was developed and characterized in a study conducted in South Africa by Du Preez et al., [16]. In the study, *Dovyalis caffra* nectar was formulated by mixing 30% of fruit pulp with water, sugar and citric acid up to an end point of 14° Brix. Sensory evaluation by the affective tasting method indicated a gross acceptance of the product by all the panellists. The study however identified a little concern with the high acidity of *Dovyalis caffra* fruit and its influence on the nectar's taste. Consequently, further research in product formulation was recommended. Overall, the study was able to demonstrate the feasibility and potential of nectar development by using *Dovyalis caffra* fruit as a raw material. By embracing similar studies in relation to the *Dovyalis caffra* fruits in Kenya, significant growth would occur in the beverage industry. This would be inform of new beverage in the market, new flavour ingredient, new source of phytochemicals etc. Further product diversification may be achieved by blending *Dovyalis caffra* pulp with other fruits pulps during formulation.

Dried fruit rolls

In South Africa, Du Preez et al. [16] was able to develop and characterize various formulations of dried (60 °C for 15 h) fruit rolls from *Dovyalis caffra* fruit pulp and sugar. Different sugar levels (0 – 26%) resulted in fruit rolls of varying taste scores, with 20% formulation exhibiting the highest value of 3 on a five point hedonic scale. There was however no difference in the colour and texture scores of all formulations with each of them recording a value of 4. This study clearly demonstrated the potential of *Dovyalis caffra* in making dried fruit rolls with excellent organoleptic properties. Further research should however be done on possible ways of improving the taste of such products. With focus on Kenya and in consideration that drying can also be done by other means such as solar energy, adoption of a drying technique for local *Dovyalis caffra* fruits would have a great impact on people living in rural areas, particularly due to the simplicity and economical nature of the method. Drying in general would help address the problem of seasonality and short shelf life of the fruits.

Preserves: jams, jellies and marmalades

Domestic production of preserves from *Dovyalis caffra* fruits is widely mentioned in a South African context even though details of such processing are not elaborated [7,52,58]. These fruits are considered ideal for preserve development due to their high acidity and pectin levels which enhance their gel making properties [45]. These fruits produce amber-coloured jams, jellies and marmalades [45]. The demonstrated potential of *Dovyalis caffra* fruits ought to be explored in preserve development utilizing Kenyan fruits. A scientific approach should be used in product formulation and optimization in order to generate a standardized processing procedure for *Dovyalis caffra* preserves in the country. For improved quality and diversity of preserves, blending of *Dovyalis caffra* with other local Kenyan fruits should be done during product formulation.

Pickles

Just like in preserves, and as reported by Augustyn et al., [7], pickles of *Dovyalis caffra* fruits are widely made domestically in South Africa. For instance, unripe fruits of *Dovyalis caffra* without vinegar are served as instant pickles in South Africa [45]. In general, process improvement and standardization for *Dovyalis caffra* pickles should be conducted scientifically. Application of pickling technique to Kenyan *Dovyalis caffra* fruits is highly recommended particularly due to its simplicity and suitability for small scale manufacturers.

Other value added forms of Dovyalis caffra *fruit*

Ripe *Dovyalis caffra* fruit has been reported to make salads and desserts with just a brief preparation. In such cases, the ripe fruit is first peeled, cut in halves, deseeded, sprinkled with sugar and allowed to stand for some time before consumption [15].

Elsewhere, *Dovyalis caffra* fruit juice is added to boiled millet or sorghum grains to make special porridge mainly associated with the *Bapedi* people of South Africa [5].

The fruit may also be briefly cooked into a sauce for use in meat and fish flavouring [45]. Still under cooking, brief simmering of syrup soaked *Dovyalis caffra* fruits is reported to produce tasty fillings of potential use in pies, puddings and cakes [45].

Non-food uses of *Dovyalis caffra* fruit tree

Home uses

In Kenya, *Dovyalis caffra* trees are mainly cultivated for fencing purposes. When planted close together, the trees form an impenetrable hedge barrier around homesteads and farms that keeps off unwanted animals and intruders. The thorny branches and stems makes *Dovyalis caffra* an ideal choice for such role [64]. Being an evergreen shrub, *Dovyalis caffra* exhibits great potential for ornamental purposes and hence is also used in beautification of urban landscapes [30].

In the rural areas, *Dovyalis caffra* tree offers a good source of wood for use in furniture and building structures in the farm as well as for fuel [49]. Its wood is characteristically white, dense and heavy [52].

Other benefits of the tree are provision of shade during hot sunny days as well as acting as a wind barrier during harsh weather [5].

Agriculture and environment

Dovyalis caffra fruit has been reported to be a potential source of a natural bio-herbicide [49]. When the fruit is soaked in water and allowed to ferment, it is said to produce a liquid with herbicidal properties [5].

Due to the plant's drought resistance, *Dovyalis caffra* tree presents great potential for an all-seasoned source of fodder for livestock [52], particularly in the arid and semi-arid regions.

In apiculture, *Dovyalis caffra* trees are useful in provision of shade/shelter to the bees/bee hives and in improving honey production by acting as potential nectar sources during their flowering seasons [52].

With regular pruning recommended for *Dovyalis caffra* trees [52], the resultant 'waste' branches and leaves can be incorporated into compost making and mulching, leading to improved soil nourishment and conservation [49]. Mulching in general also enhances water conservation and weed management [60].

Cultivation of *Dovyalis caffra* trees in the arid and semi-arid regions enhances greater biodiversity of wildlife e.g. by creating home for birds which would have otherwise migrated to other areas. This further translates to increased biomass and soil fertility from the birds droppings [49].

Carbon dioxide accumulation in the atmosphere is considered to be one of the main contributors to global warming [20]. Due to their climatic hardiness, *Dovyalis caffra* trees are a potential choice of sustainable carbon dioxide sinks towards reduced global warming [49].

In general, the multipurpose nature of the tree makes it a suitable choice for agroforestry, with evidence of positive impacts from systems such as eco-gardens, which optimize the use of water, nutrients, labour and solar energy, thus enhancing the overall health of an ecosystem [35].

Potential industrial uses

Based on the bright yellow colour exhibited by *Dovyalis caffra* fruits [46], extraction of colouring pigments may be potentially done from the same. Such colouring pigments may be utilized in production of industrial products such as dyes, inks and paints.

The high acidity exhibited by *Dovyalis caffra* fruits [66], may be exploited for industrial production of organic acids e.g. Malic acid, which happens to be the most abundant in these fruits. In industrial applications, Malic acid has been previously used in production of pharmaceuticals and cosmetics [14].

The strong unique odour of *Dovyalis caffra* fruits [46] may also be potentially harnessed in industrial production of air fresheners and assorted toiletries. This is also applicable in the context of food aroma and flavouring extracts.

The potential use of *Dovyalis caffra* fruit extracts in the chemical synthesis of biomediated Zinc Oxide nanoparticles and silver-gold bimetallic nanoparticles have been recently reported [2,3].

Challenges facing adoption and utilization of *dovyalis caffra* and its products in kenya

In Kenya, *Dovyalis caffra* trees are primarily conceived as fencing (Fig. 2-D), ornamental or simply wild plants. Consequently, the plants are seldom exploited for other purposes like food. Such deep rooted underutilization translates to adverse postharvest losses of *Dovyalis caffra* fruits recurring season after season. This situation is unfortunate and does call for prompt interventions to resolve it. Below is a brief analysis of several factors potentially responsible for the current state of affairs, along with proposed interventions.

General neglect and lack of interest in the fruit

As mentioned earlier, the introduction, domestication and promotion of Asian and American fruit species in Africa led to a decline in utilization of local fruits in favour of the new exotic species. As time went by, extreme loss of interest and total neglect of local indigenous fruits normalized across the continent [45]. This explains the current status of utilization of *Dovyalis caffra* fruit in Kenya.

Apart from the historical backdrop, a more modern reason or the continued neglect of *Dovyalis caffra* fruit is the lack of awareness by the general population in regard to the fruit's nutrition and health value; as a result of limited access to scientific information by the wider public. This is a very common challenge that has also been reported for most other indigenous fruits in the entire African continent [8].

To address these challenges, effort should be made in creating awareness to the general public regarding the nutritional and health potential of *Dovyalis caffra* fruits. Awareness creation may take the form of seminars, posters, magazines, electronic media etc.

Limited scientific research on the fruit

Production and trade of fruits in Africa is dominated by exotic species thus prompting scientific researchers to focus much of their efforts on them and very little, if any, on the local counterparts [48]. This leaves local fruits poorly studied and subsequently poorly utilized. Such denotes the current status of *Dovyalis caffra* fruits in Kenya.

In order to salvage the current situation, deliberate efforts must be promptly made towards detailed scientific studies of *Dovyalis caffra* in Kenya. Such would be the foundation for future exploitation of the fruit.

Absence of improved agronomic and agro processing techniques for the fruit

Apart from recent usage in hedges, the growth of *Dovyalis caffra* in Kenya remains predominantly wild, with a few scarce cases growing traditionally in rural areas. Despite the potential as a source of food, knowledge and skills of harnessing the tree agronomically seems to be widely lacking. Standardized scientific selection, breeding and propagation techniques for the fruit tree are also strikingly unavailable. Apparently, there are also no standard protocols for the fruits production, harvesting, handling and processing. With such knowledge and technical gaps, adoption of *Dovyalis caffra* for food production in Kenya remains nascent.

To address these challenges, *Dovyalis caffra* should be subjected to a focused tree improvement program that would holistically analyse, develop and improve its overall quality. Some aspects that should be addressed by such a program include but not limited to; nursery management, propagation studies, phenology, varietal selection for superior fruit quality, post-harvest technology and value addition amongst others.

Fruit sourness and thorniness of tree

Dovyalis caffra fruit exhibits considerably high acidity to the extent that it is sometimes considered too acidic to be eaten raw [66]. The sourness associated with such acidity is disliked by some people and hence total rejection of the fruit. Such rejection is not only observed in Kenya but also in Israel and Florida [45]. Processing of the fruit provides an opportunity for masking the sourness e.g., by use of aspartame, stevia, sucralose etc.

The thorny nature of *Dovyalis caffra* tree though important in live fence, is disliked by some people who may wish to grow the tree in different setups other than hedges e.g., as a source of fruits in a kitchen garden. In such case the thorns would make fruit picking and other garden maintenance activities difficult. This challenge may be addressed by selective breeding and possibly genetic modification of the species to yield spineless trees.

Weak value chain

As stated previously, *Dovyalis caffra* in Kenya is largely considered wild, with only minimal application in hedges (Fig. 2-D). Apart from the superficial trade on seedlings meant for hedges, there is currently no elaborate marketing system of economic significance for *Dovyalis caffra* tree and its fruits amongst other products. This discourages potential farmers who would have otherwise wanted to invest in cultivation of the plant for food purposes. Future domestication, value addition and suitable marketing policies will revitalize the market value chain for *Dovyalis caffra*.

Conclusion and recommendation

Dovyalis caffra fruit has great nutritional and health potential which remains largely unexploited in Kenya. Though several reasons for underutilization have been pointed out, the main challenges seem to revolve around limited research and awareness in the country. In order to facilitate and enhance acceptance of the fruit therefore, a thorough research should be conducted on agronomical aspects such as quality planting materials, reduced fruiting period, higher fruit yield, breeding and selection of thorn-less varieties and less sour fruits; and post-harvest aspects such as modernised preservation and processing techniques. Findings inform of new products and techniques from such research should be promptly disseminated to the general public for awareness creation, familiarization and adoption. Dissemination may for example be done by; demonstrations in agricultural shows, community-based programmes organized by chiefs and door to door extension services organized by the Ministry of Agriculture. In order to achieve maximum impact, these research and extension activities should take a multi-sectoral approach incorporating government research bodies e.g., Kenya Plant Health Inspectorate Service (KEPHIS), Kenya Industrial Research and Development Institute (KIRDI), Kenya Forestry Research institute (KEFRI), Kenya Agricultural and Livestock Research Organization (KALRO) and universities; and non-governmental bodies such as farmer organizations, food processors and individual investors amongst others. Finally, for improved value chain, suitable government policies should be formulated in support of continuous research, cultivation, value addition and marketing of *Dovyalis caffra* fruits and products. Ultimately, the relevant interventions will lead to accelerated adoption of the fruit and hence its numerous benefits in food, health, environment and industry amongst others.

Contribution

Daniel Mwangi Waweru – Original draft preparation, Joshua Mbaabu Arimi, Eunice Marete, Jean-Christophe Jacquier and Niamh Harbourne - Reviewing and editing.

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Declaration of Competing Interest

The authors declare no conflict of interest.

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