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RESEARCH

South African indigenous fruits – Underutilized resource for boosting daily antioxidant intake among local indigent populations?

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Consuming more than seven portions of fruit and vegetables daily substantially lowers the risk of mortality from any cause, yet many South Africans living below the poverty line have a very low or even zero intake of fruit and vegetables. Advice on the importance of consuming a healthy, and at the same time affordable diet needs to be provided by suggesting alternatives among indigenous plants that are nutritionally superior to "exotic" fruits. But to what extent could antioxidant intake be boosted through the ingestion of selected indigenous fruits? Ten indigenous South African fruits were evaluated for their antioxidant activity and compared with blueberry and cranberry. An Antioxidant Potency Composite Index was drawn up based on the results of three equally weighted assays, namely Total Phenolic Content (FCR), Trolox Equivalent Antioxidant Capacity (TEAC) and Total Antioxidant Capacity (H-ORAC$_{FL+}$L-ORAC$_{FL}$). The antioxidant potency rankings obtained were as follows: wild plum > wild olive > colpoon > blueberry > christmas berry > crossberry > waterberry > cranberry > tortoise berry > bietou > num-num > sour fig. Blueberry and cranberry ranked 5th and 9th, respectively. It was shown that by introducing servings of as little as 25 g of wild plum, waterberry, num num or sour fig into the diet, the daily antioxidant intake can be boosted to within an acceptable range to support health. All of these freely available fruits are known and have been traditionally used by rural communities in South Africa.

Keywords: antioxidant capacity (AOC), antioxidant potency composite index, oxygen radical antioxidant capacity (ORAC), total phenolic content (TPC), trolox equivalent antioxidant capacity (TEAC)

Introduction

The dietary pattern of indigenous peoples of South Africa changed for the worse as a result of colonisation. Nutritionally superior indigenous crops have gradually been displaced by cash crops that do not serve poor rural communities well, placing rural children at a higher risk of malnutrition.[1,2]

In determining rural household dietary diversity, a study carried out in two districts of the Eastern Cape showed that sugar, tea, coffee, grains and potatoes were among the food groups most frequently consumed, while only 5% and 3% of households reported consuming vegetables and fruits, respectively.[3] To counteract the effects of eating refined grains, a plant-centred diet has been strongly encouraged,[4] as the post-prandial surge associated with such a high glycaemic index meal has negative health implications. However, the inflammatory responses triggered following digestion can be offset by the inclusion of high antioxidant fruits along with the meal.[5]

SA's long-standing problem has been one of chronic rather than acute malnutrition.[6] An estimated 21.5% of the population of South Africa falls below the poverty line,[7] and the resultant increase in food insecurity leads to a decrease in the variety of foods consumed,[8] particularly fruit and vegetables. This in turn links with chronic disease, high levels of acute lower respiratory infection and acute or chronic diarrhoea, affecting children in the long term through poor development, stunting, as well as decreased academic ability.[9,10]

The clear association between fruit and vegetable intake and household income is shown in the more limited choice of nutrient dense fruit by lower socioeconomic groups, with apples, bananas and oranges the preferred choice.[11] A nutrient dense diversified diet may cost 69% more on average, so where households are reliant on grants and pensions, meeting this extra cost becomes prohibitive.[12]

Availability issues due to absence of supermarkets in rural areas further limits healthy food choices, with fruit and vegetable intake among one adult rural group calculated at 133 g per day[13]; however, even among the urban population, 25% of urban black adults consumed zero fruits and vegetables[14] in a 24 h recall study. Similarly, only 16% of children sampled in a National Food Consumption Survey[10] had consumed fruits or vegetables in the same period. Although locally-grown wild fruits, loquats and guavas were consumed, the number of respondents consuming such fruit was below 0.5%.

While some Greek island communities consume up to 1.2 kg of fruit and vegetables per day, the World Health Organisation (WHO) has advised that a minimal quantity of 600 g of fruit and vegetables should be consumed per day to achieve optimal health benefits.[15] However, South African adults consume 115 g of vegetables and 91 g of fruit per day on average, with combined fruit and vegetable intake of rural adults reaching only 141 g per day.[16] One South African study found that children aged between 1 and 5 years consumed, on average, 52 g of vegetables and 48 g of fruit per day,[17] which is one third the recommended amount.

Another WHO funded study found that approximately 91–94 g of fruit is consumed (average per capita per day) by children aged between 1 and 5 years in South Africa. The diversity is limited to apple (26.1 g), banana (17 g), pear (10 g), orange (8.3 g) and grape (7.3 g).[10,18]

A measure of whether fruit and vegetable intake is adequate can be ascertained from the total antioxidant capacity consumed per day, as determined by the Oxygen Radical Antioxidant Capacity (ORAC) assay. From the South African ORAC database,[19] the calculated average Total Antioxidant Capacity (TAC) consumed per capita (from the above five fruits consumed by children) is 1 600 µmol Trolox Equivalents (TE) per day. This compares with the average intake of ORAC in the United States, calculated as 1 500 µmol TE/day. A high intake is considered to be 6 000 µmol TE/day and above.[20]

A study carried out by Cao *et al*. on participants consuming five fruits and vegetables per day determined their daily plasma ORAC to be around 1 670 µmol TE. Increasing the intake of fruits to ten a day increased the daily plasma ORAC to 3 300–3 500 µmol TE.[21] However, the choice of seven fruits with low ORAC values would yield only 1 300 µmol TE, whereas the choice of seven fruits with high ORAC values could yield up to 6 000 µmol TE, with a cup of blueberries alone supplying 3 200 µmol TE.

A robust inverse association for consumption of more than seven portions of fruit and vegetables daily and all-cause, cancer and cardiovascular disease mortality reduction has been shown from the 2014 Health Survey for England study.[22] Another study showed that increased consumption of fruit in childhood limits the incidence of cancer in adulthood.[23,24] In addition, a strong case for the existence of a direct relationship between the level of consumption of antioxidants and the prevention of adverse health outcomes has been made in a recent review article by Prior.[5] This is substantiated by the results released from recent clinical trials.[25]

In view of the above, the question arises: What national interventions have been put in place to encourage higher household consumption of fruits and vegetables, particularly among children?

The growing of home gardens has been promoted in an attempt to overcome the twin hurdles of affordability and accessibility, and thereby increase household consumption of fruits and vegetables.[26] At the same time the planting of endemic crops (generally better adapted to the harsh conditions of the South African climate, therefore requiring less input agriculturally), has been encouraged. As these crops are already known by the community, their acceptance is a given with the added bonus of their higher nutrient content.[27]

In reviewing the outcomes of a Medical Research Council (MRC) intervention study involving home gardens, it was noted that this nutrition education program had empowered communities with the knowledge of what constitutes adequate vitamin A intake for healthy children, as well as how to produce vitamin A dense foods, such as orange-fleshed sweet potatoes and paw paws, in home gardens.[28]. As a result, children in these households had significantly increased energy and micronutrient intakes; however, as was pointed out, a wider range of nutrients is required for good health.[29]

In 2007, the HealthKick programme, a nutrition education intervention, was initiated at several schools in the Western Cape.[30] It involves both teachers and parents in planting a school vegetable garden, while teaching the children how to grow vegetables. By 2008, more than 6 500 schools across South Africa had set up food gardens.

Since 1975, by means of Arbour Day/Week, indigenous trees nominated for planting, especially in previously disadvantaged communities, have included wild olive (*Olea europaea* subsp. *Africana*), wild plum (*Harpephyllum caffrum*), waterberry (*Syzygium cordatum*) and crossberry (*Grewia occidentalis*).[31] These are among the species bearing native fruits known and traditionally consumed by rural children in South Africa.

This exploratory study considers the extent to which local indigenous fruits could provide a source of phenolics and antioxidants, which can positively contribute to the nutritional status of South African children, despite their otherwise impoverished diet.

When food is scarce, wild resources take on an important role in the diet of people in rural areas. Of the 10 South African rural villages sampled, it was reported that families collected up to 104.2 kg ± 15.6 kg of wild fruits per year.[32]

Eighty lesser-known fruits commonly utilised in the rurals include the following varieties, six of which were used in this study: *Carissa macrocarpa* (num num), *Carpobrotus edulis* (sour fig), *Dovyalis caffra* (kei-apple), *Grewia flava* (velvet raisin bush), *Harpephyllum caffrum* (wild plum), *Nylandtia spinosa* (tortoise berry), *Olea africana* (wild olive), and *Syzygium cordatum* (waterberry).[33]

A study of indigenous edible plant use by contemporary Khoi-San, revealed that of the 58 indigenous edible plant species collected, over 40% were collected for their fruits, among them *Osyris compressa* (colpoon), *Carissa bispinosa* (num num), *Carpobrotus edulis* (sour fig) *and Muraltia spinosa* (tortoise berry), *Chrysanthemoides monilifera* (bietou), *Grewia occidentalis (crossberry)*, *Olea europaea* (wild olive) and *Chironia baccifera* (Christmas berry).[34]

The aim of this study was to assess, by comparative means, the potential health benefits that might accrue from the consumption of the following indigenous fruits: *Syzygium cordatum* (waterberry), *Osyris compressa* (colpoon), *Harpephyllum caffrum* (wild plum), *Nylandtia spinosa* (tortoise berry), *Carissa macrocarpa* (num num), *Chironia baccifera* (christmas berry), *Chrysanthemoides monilifera* (bietou), *Grewia occidentalis* (crossberry), *Carpobrotus edulis* (sour fig), and *Olea europaea* subsp. *Africana* (wild olive). The Afrikaans and Zulu names of these species are shown in Figure 1. For control purposes, two Northern Hemisphere berry species *Vaccinium corymbosum* (blueberry) and *Vaccinium macrocarpon* (cranberry) were included in the evaluation, as these have been extensively studied[35] and recommended for their healthy properties.

The following phenolic/antioxidant determinations were carried out on these species: Total Phenolic Content (FCR method), Trolox Equivalent Antioxidant Capacity (TEAC), H-ORAC and L-ORAC, combined to give Total Antioxidant Capacity (TAC). The results were compared with the northern hemisphere "gold standards" of blueberry and cranberry; and a composite index Antioxidant Potency Composite Index (APCI) was drawn up to rank all the fruits in terms of their antioxidant potential.

Choosing from a plethora of antioxidant capacity assays

Our antioxidant defence system is a multi-pronged network involving prevention, interception and repair.[39] Therefore, it becomes apparent that any assessment of antioxidant capacity would present a challenge due to the complexity of these biological systems. Adding to the complexity, it is possible for

Figure 1: The indigenous fruits with names given in the order Latin, Afrikaans, Zulu, and the family[36–38].

individual antioxidants to act by multiple mechanisms within a single system, including free radical chain breaking, oxygen scavenging, singlet oxygen quenching, metal chelation and inhibition of oxidative enzymes.[40]

Therefore, it is evident that natural antioxidants, being multifunctional, cannot be evaluated by means of one-dimensional methods only. As it is impossible for any single assay to accurately reflect all of the radical sources, as well as all of the antioxidants in a complex system, a valid evaluation demands the use of several assay methods which allows for the inclusion of different mechanisms of inhibition.[41,42]

In June 2004, at the First International Congress on Antioxidant Methods, Prior proposed[43] that three methods be standardised for the measurement of Antioxidant Capacity (AOC) in natural products: Total Phenolic Content by the FCR method; TEAC; and $ORAC_{FL}$. Jimenez-Alvarez[44] selected the following assays: $ORAC_{FL}$ (hydrophilic and lipophilic); FRAP; and ICA (Iron Chelating Activity), as both iron and copper have been shown to be catalysts of lipid oxidation in foods.[45] By this means, it was believed that all the relevant antioxidant mechanisms were being targeted, namely radical scavenging, reducing capacity, and metal chelating properties.

Some researchers have combined the results from multiple assays to arrive at a ranking that more accurately represents a sample's overall antioxidant potency.[46] In this case, three test results were combined into a single Antioxidant Potency Composite Index (APCI) by the following procedure: All three assays were equally weighted (TPC (FCR), TEAC and TAC). An index value of 100 was assigned to the best score for each test.

The index score of the samples in each assay was calculated as follows:

$$\text{Antioxidant Index score} = \left[\left(\frac{\text{Sample score}}{\text{Best score}}\right) \times 100\right]$$

An average of all three assays for each sample was calculated giving an overall mean index value for APCI. A simple rank order is reported.

Materials & methods

Plant materials

The species studied are found on the campus of the Cape Peninsula University of Technology and at Kirstenbosch National Botanical gardens. Samples of approximately 200 g were collected for each fruit which were harvested when ripe (fully coloured and sweet). All samples were verified by Dr N. Louw in conjunction with SANBI. *Syzygium cordatum* (waterberry), *Osyris compressa* (colpoon), *Harpephyllum caffrum* (wild plum), *Nylandtia spinosa* (tortoise berry), *Carissa macrocarpa* (num num), *Chironia baccifera* (Christmas berry), *Chrysanthemoides monilifera* (bietou), *Grewia occidentalis* (crossberry), *Carpobrotus edulis* (sour fig) and *Olea europaea* subsp. *Africana* (wild olive) were collected and rinsed with deionised water, air dried, packed into Ziploc bags and purged with nitrogen before freezing at −18°C. *Vaccinium corymbosum* (blueberry) and *Vaccinium macrocarpon* (cranberry) were purchased in frozen form from a local supermarket.

Extraction methods

The method of Sellapan *et al.*[47] was followed for the TPC and TEAC assays. Approximately 2 g of fruit was used. The skins were not removed; however, fruits were deseeded (except for bietou and sour fig fruits). For the ORAC assay, the extraction method of Prior *et al*. was followed.[48]

Chemicals and apparatus

The following chemicals were used: acetonitrile, gallic acid, quercetin, caffeic acid, 4-dimethylaminocinnamaldehyde (DAC), Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), potassium persulphate ($K_2S_2O_8$), 2,2-diphenyl-1-picrylhydrazyl (DPPH), 3′,6′-dihydroxy-spiro[isobenzofuran-1[3H]-xanthen]-3-one (Fluorescein), 2,2′-azobis (2-amidino-propane) dihydrochloride (AAPH), ascorbic acid and butylated hydroxytoluene was purchased from Sigma (South Africa). Folin Ciocalteu reagent and ABTS (2,2′-azinobis (3-ethylbenzothiazoline-6-sulfonate)) was purchased from Fluka Chemicals. Acetic acid (glacial), sodium carbonate, hydrochloric acid (32%), methanol, 95% ethanol, trisodium orthophosphate dodecahydrate, ammonium molybdate tetrahydrate and sulphuric acid, all of analytical reagent grade, were obtained from Merck (South Africa). Milli-Q water was used.

A Pharmacia LKB Ultrospec II E Spectrophotometer and a Sigma centrifuge 2–16 were used. ORAC absorbance was read on a fluorescent plate reader (Fluoroskan Ascent, Thermo Electron Corporation, USA).

Methods

The methods used for the three assays are as follows: Total Phenolic Content (Folin Ciocalteu reagent);[49] TEAC ($ABTS^+$) assay;[50] and, ORAC.[48]

Results & discussion

The findings obtained for the three assays for 10 indigenous fruits and 2 controls are presented in Table 1.

Table 1. Results obtained for three assays for ten indigenous fruits and two controls

	TPC (FCR)[a]	TEAC Assay[b]	H-ORAC$_{FL}$[b]	L-ORAC$_{FL}$[b]	TAC[b]
Blueberry	6 080 ± 2.35	8.3 ± 0.4	84.30 ± 5.36	34.94 ± 2.65	119.24
Cranberry	282 ± 4.69	9.5 ± 0.1	34.23 ± 1.76	30.22 ± 4.45	64.45
Waterberry	342 ± 0.75	3.2 ± 0.1	77.04 ± 1.45	48.32 ± 2.44	125.36
Colpoon	3 581 ± 5.14	8.5 ± 0.2	323.39 ± 2.23	55.60 ± 1.94	378.99
Wild plum	5 193 ± 1.12	55.6 ± 1.8	125.90 ± 4.13	27.10 ± 2.51	153.00
Tortoise berry	182 ± 1.18	12.2 ± 0.2	44.51 ± 0.42	3.46 ± 0.33	47.97
Num-num	32 ± 2.07	7.6 ± 0.1	29.93 ± 6.49	20.02 ± 6.72	49.95
Christmas berry	34 ± 2.80	8.7 ± 0.3	261.37 ±1.98	80.98 ± 7.86	342.35
Bietou	210 ± 0.48	7.6 ± 0.2	48.34 ± 8.24	0.63 ± 6.19	48.97
Cross berry	282 ± 6.71	2.6 ± 0.3	238.37 ± 5.01	12.98 ± 4.16	251.35
Sour fig	201 ± 0.75	0.6 ± 0.3	63.25 ± 5.33	0.22 ± 2.54	63.47
Wild olive	1 437 ± 0.59	34.2 ± 0.6	267.38 ± 1.34	69.14 ± 1.78	336.52

[a]Results expressed as mg of gallic acid equiv/100 g FW.
[b]Results expressed as μmol Trolox equiv/g FW.

The results for the Antioxidant Potency Composite index are presented in Chart 1.

Wild plum ranked first for the overall APCI, having obtained the highest ranking in the TEAC assay. The red fruits of wild plum are well known and commonly used for eating. Some trees bear sweet tasting fruit, while others bear fruit that is sour. While the commercial cultivation of wild plum has not been viable due to very small fruits (labour intensive) and the flesh being only 10% of the total weight, it has been suggested that the wild plum tree be used for home gardens, city and park landscaping so that the fruits may still be picked and enjoyed by "children and others".[51] A lemonade-type fruit juice and rosé wine has been made from the pulp, as well as jam and jelly.

Colpoon, in second place, had the highest TAC. Wild olive was ranked third in the APCI, with the third highest TAC; blueberry, ranking fourth, had the highest was TPC (FCR); whereas Christmas berry in fifth place had the second highest TAC. Wild olive, colpoon and Christmas berry would not be consumed as food due to their bitter taste but could be prepared rather as medicine, similar to European bitters. The Khoe are reported to have used the fruit and leaves of Christmas berry as a bitter tonic to treat stomach ulcers as well as diarrhoea.

Crossberry, ranked sixth, has been collected traditionally and dried to use as flavouring for milk.[52] The fruits have been said to be eagerly eaten by humans for their sweet fruity taste.

Waterberry took seventh position, with cranberry in eighth position, yet waterberry scored double the ORAC points of cranberry. Waterberry was one of the three indigenous fruits containing anthocyanins. When fully ripe, it has a dark blue skin similar to blueberries and has a pleasant sweet, faintly resinous taste. It has been made into jellies and fermented to give alcoholic beverages.

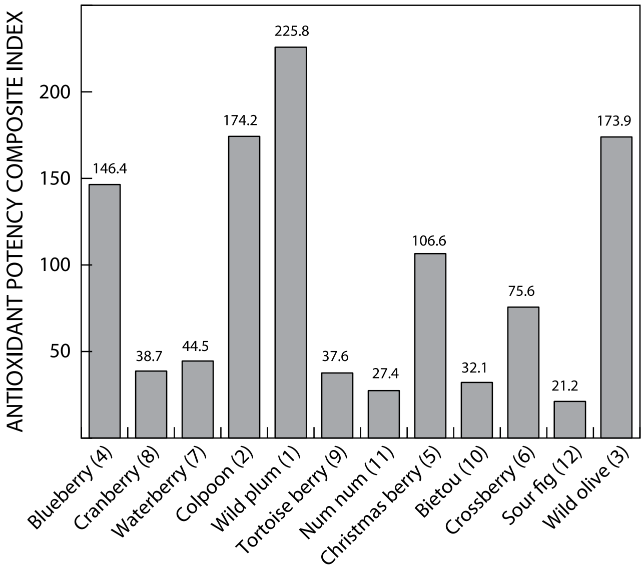

Chart 1: Antioxidant Potency Composite Index for ten indigenous fruits and two controls, with the ranking order in brackets.

Tortoise berry was placed ninth in the sample rank order. It produces small red fruits, high in vitamin C, said to be a popular snack with children.[53]

Bietou ranked tenth overall. The Zulu traditionally add these berries to their porridge, which provides protection against the post-prandial surge associated with consumption of high glycaemic index foods.[52] These small sweet black fruits have also been made into nourishing syrup or jam; the juice has also been taken in water or tea; and, combined with other herbs for blood strengthening or purification.

Num num, ranking eleventh, could be a very useful addition to any home garden as it flowers and fruits continuously throughout the year. Its thorny branches make a good hedge. The delicious sweet red fruits, rich in vitamin C, can also be made into jam. It has been suggested that this fruit should be promoted much more than it is at present.[52]

And finally, sour fig ranked twelfth. It is an easy-to-grow creeping succulent, producing fleshy fruit capsules which turn reddish brown when ripe. The fruit contains an edible sweet-sour gelatinous pulp with shiny brown seeds. It is already successfully commercialised, being sold in open markets as dried figs, or made into jam.

From a TAC or ORAC perspective, the contribution to ORAC from fruits in the diet may come from a high consumption of low ranking fruits or from high ranking fruits that are consumed in small amounts.[54] By adding as little as 25 g of certain indigenous fruits (excluding seeds) to the average diet consumed in South Africa, increases in Trolox Equivalents (units µmol TE) per day could be achieved (shown in Table 2).

As seen from the values in Table 2, these indigenous fruits compare favourably with blueberry and cranberry.

Table 2. The Trolox equivalent (units µmol TE) for certain indigenous fruits found in South Africa

Indigenous fruit	µmol TE
Colpoon	9 475
Christmas berry	8 559
Wild olive	8 413
Crossberry	6 284
Wild plum	3 825
Waterberry	3 134
Blueberry	2 981
Cranberry	1 611
Sour fig	1 587
Num-num	1 249
Bietou	1 224
Tortoise berry	1 199

Conclusion

As the results show, freely available indigenous fruits that have been traditionally used by rural peoples in South Africa have relatively high levels of antioxidant capacity and, therefore, constitute an untapped resource that deserves to be promoted more extensively in the community by health educators. As affordable, yet nutritionally superior alternatives to the relatively expensive "exotic" fruits, these could help in diversifying monotonous diets.[55,56] As dietary diversity correlates strongly with longevity and a decreased risk of mortality,[57] indigent groups need to be empowered to increase their intake of essential nutrients[58] and polyphenols that have been implicated in chronic disease prevention. They can do this by tapping into our rich South African flora.

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