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REVIEW ARTICLES

Promising anticarcinogenic effect of some Nigerian vegetables on cancer cells

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Abstract

Cancer is a non-communicable disease and has become a leading cause of morbidity and mortality in Nigeria. Obesity, a modifiable risk factor conditioned by diet and lifestyle has been linked to the development of many human cancers. Thus, consumption of foods which include vegetables could reduce the risk of this non-communicable disease. Indigenous Nigerian vegetables possess bioactive compounds which have anti-inflammatory, anticarcinogenic, and antioxidant properties. Despite numerous reported beneficial effect, Nigerian vegetables are still underutilised in the food system due to improper knowledge on their health benefits. Therefore, this review aims to provide scientific anticarcinogenic information that will promote consumption and utilisation of Nigerian vegetables such as Ebolo, African spinach, Zobo, jute mallow, dandelion, and African basil.

Keywords Nigerian vegetables · Cancer cells · Cancer prevention · Anticarcinogenic

Introduction

Cancer remains a complex disease affecting millions of people globally. In the year 2022, approximately 20 million new cancer cases including skin cancers were recorded worldwide (Ferlay et al. 2008). Cancer is a leading cause of death, accounting for 16.8% of all deaths and 22.8% of deaths from non-communicable diseases worldwide, with the majority occurring in developing countries. It has been estimated that approximately one in five women or men develop cancer during a lifetime, while about one in twelve women and one in nine men die from it. Lung cancer was the most frequently diagnosed cancer in 2022, accounting for 12.4% of all new cancer cases worldwide. This was followed by breast cancers (11.6%), colorectum (9.6%), prostate (7.3%), and stomach (4.9%). Lung cancer was also the leading cause of cancer death, with an estimated 1.8 million deaths (18.7%), then colorectal (9.3%), liver (7.8%), breast (6.9%), and stomach (6.8%) cancers. Breast cancer and lung cancer were the most common cancer in women and men, both in morbidity and mortality (Bray et al. 2024).

The global incidence of cancer is expected to rise from 13.3 million to 21.4 million cases annually between 2010 and 2030, driven by population growth and aging. This projection assumes no changes in the underlying causes of cancer or incidence rates. However, if unhealthy diets and obesity become more prevalent in low- and middle-income countries, these projections may be underestimated. By 2030, low-income countries could see nearly double the number of new cancer cases each year (Ferlay et al. 2008; Wild 2012). The disease is characterised by growth of abnormal cell in the human body to form mass of tumours. Factors such as smoking, diet low in fruits and vegetables, lack of physical exercise, an unhealthy lifestyle, and excessive consumption of alcohol significantly impact the development and progression of cancer(Kolawole and Ong 2022; Kolawole et al. 2024). Cancer is a non-communicable disease that can be prevented and controlled. The World Cancer Research Fund (WCRF) recommends adopting a healthy lifestyle, which includes being physically active, consuming a diet rich in fruits, vegetables, legumes, and reduce the intake of processed foods that are high in sugar and fat (Kolawole et al. 2024).

The increasing occurrence of cancer cases and death over the past few years has led to the development of new drug combinations, anticancer drugs, and chemotherapy approaches involving scientific and methodical exploration

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of an extensive pool of biological, synthetic, and plant products (Li et al. 2012). Radiation and Chemotherapy are the current treatments of cancer but with many adverse effects and are not also affordable specifically to those in the low-income countries (Greenwell and Rahman 2015). Furthermore, there is a risk that surgically removed tumors can recur and become resistant to radiation treatment (Alzate-Yepes et al. 2023). Therefore, the search for alternative compounds that are less toxic and more effective remain a major priority. Some plant derived compounds such as resveratrol, genistein, camptothecin, quercetin, lycopene, chlorogenic acid among others have been reported to be effective in cancer prevention and treatment (Li et al. 2012; Tosoc et al. 2021). In the search for effective anticancer agents, plant products including vegetables are becoming more relevant as an alternative source of anticancer agent (Tosoc et al. 2021; Adewale et al. 2020).

For decades, plant-based products have been used in different countries for prevention and treatment of different kinds of health problems including hypertension, stroke, cancer, arthritis, diabetes, inflammatory bowel diseases and dyslipidemia (El-Dahiyat et al. 2020; Woo et al. 2012). In general, herbal medicines are efficient, more accessible, available, affordable, and less or non-toxic compared to conventional medicines (Jeong et al. 2012; Lynch and Berry 2007). Many bioactive dietary compounds including phenolic compounds, alkaloids among others are of certain interest in epigenetics (Jagetia 2021; Yi et al. 2005). Epigenetic is an inheritable change in gene expression without altering DNA nucleotides sequences and these changes are caused by environmental factors including diet which has a significant effect on epigenetic modifiers. (Chen and Xu 2010; Kumaria et al. 2020). DNA methylation and histones modification are the main epigenetic mechanisms studied in mammalian cells, and this induces chromatin remodelling resulting in cellular phenotype changes (Carlos-Reyes et al. 2019). In cancer cells, several epigenetic modifications of cancer-related genes take place at the initial stage of cancer development. Interestingly, these epigenetic changes in comparison to genetics are reversible and occur in a gradual manner, which makes them attractive targets to prevent the initiation and progression of cancer (Lee and Herceg 2014). Recent studies indicated that bioactive compounds that are found in herbs, dark green vegetables, cruciferous vegetables, tea, soy products, and grapes are generally acceptable to prevent the development of many types of cancer and act as epigenetic modulators that impact the progression of oncogenesis (Khan et al. 2011; Boivin et al. 2009; Hardy and Tollefsbol 2011).

Vegetables are abundant in vitamins, minerals, dietary fiber, and phytochemicals which could reduce the risk of some certain diseases including cancer. These compounds act as great anticarcinogens and antioxidant agents. Phytochemicals from vegetables can modulate mammalian epigenomes largely via regulation of proteins and processes responsible for remodelling of chromatin (Carlos-Reyes et al. 2019). In Nigeria, leafy vegetables are widely cultivated as an inexpensive and reliable source of vitamins, iron, protein, and zinc. In 2017, approximately 16.4million tons of vegetables were produced (Olowe 2020). The most common cultivated commercial tropical vegetables in Nigeria include garden egg, pumpkin, Africa spinach, water leaf, hibiscus sabdariffa, Africa basil, jute mallow, okra, tomatoes, pepper, onions, potatoes, and some exotic ones such as carrot, cabbage, lettuce, cucumber, and celery (Ibeawuchi et al. 2015). Even though these vegetables are great sources of bioactive compounds, their consumption in Nigeria is still below the daily recommended requirement (Adeosun et al. 2022; Obayelu et al. 2018). Nigeria faces a significant burden of malnutrition, characterized by a high prevalence of undernutrition among women of reproductive age and children, which has contributed to increased obesity and nutrition-related non-communicable diseases. These issues are mainly attributed to low income, insufficient food supply, and inadequate education on the benefits of regular vegetable consumption (Hardy and Tollefsbol 2011; Olowe 2020; Ibeawuchi et al. 2015; Adeosun et al. 2022; Obayelu et al. 2018; Billings et al. 2021). Additionally, the lack of processing facilities and storage options in Nigeria impacts vegetable production throughout the year (George et al. 2021).

Carcinogenesis involves three stages: tumor initiation, tumor promotion, and tumor progression. Suppressing the promotion stage may be an effective way to inhibit carcinogenesis, as it is the only reversible stage among the three (George et al. 2021). Since vegetables are rich sources of polyphenols, their role in cancer prevention and treatment should be emphasized. This study provides an overview of some indigenous Nigerian vegetables and their demonstrated anticarcinogenic properties, highlighting their potential benefits.

Effects of indigenous Nigerian vegetables on cancer

The anticarcinogenic activities of some indigenous Nigerian vegetables were briefly reviewed. Many medicinal plants and herbs synthesise different forms of phytochemicals. The preventive properties of phytochemical compounds have been linked to their ability to regulate the cellular signal transduction pathway which affects proliferation, apoptosis, and invasion (George et al. 2021). Most of the anticarcinogenic activities mentioned below; in vitro (Table 1); in vivo (Table 2) are due to the presence of phytochemical compounds.

Table 1 In vitro effect of Nigerian vegetables on cancer cells

Product	Compounds	Cell line	Concentration/period	Results	References
Ebolo leaves aqueous extract	Flavonoids, xantroproteic, amino acids, cardiac glycosides, and fat and oil	Caco-2 and MCF-7	31.5, 62.5, 125, and 250 µg/ml of leaf extract; 24, 48 h	Cytotoxic effect on both cell lines at all concentration at 48 h Significant cytotoxicity (125 & 250 µg/ml) at 24 h	Adewale et al. (2020)
Zobo leaves aqueous extract	Catechin, quercetin, ferulic acid, rutin, p-coumaric acid, protocatechuic acid, epicatechin gallate, ellagic acid and naringenin	LNCaP, PC3, and DU145	0.1–10 mg/ml of leaf extract 0–24 h	LNCaP cell line: IC50:2.5 mg/mL; membrane blebbing, cell shrinkage, nuclear fragmentation, and chromatin condensation	Lin et al. (2012)
Zobo leaves aqueous extract	Ellagic acid, ferulic acid, epigallocatechin, quercetin, gossypin, epicatechin gallate, rutin, protocatechuic acid, and procyanidin B2	LNCaP	0–20 mg/ml of aqueous extract; 24 h, 48, and 72 h	Cell invasiveness and cell migration	Chiu et al. (2015b)
Zobo leaves polyphonic extract	Catechin, ellagic acid, ferulic acid, protocatechuic acid, gossypetin, ρ-coumaric acid, naringenin, gossypin, rutin and epigallocatechin	A375	100, 250 µg/ml; 24 h	IC50:250 µg/mL Induced apoptosis	Chiu et al. (2015a)
Zobo leaf and calyces methanolic extracts	Total flavonoid and phenolic content	MCF-7, OVCAR-3, UACC-62, PC3, K-562, U251, HT29, and 786-0	0.25, 2.5, 25 and 250 µg/ml; 48 h	K-562 cell line: IC50 (calyces):1.16 mg/mL	Formagio et al. (2015)
Zobo calyces aqueous extract		MCF-7	0.05, 0.1, 0.2, 0.3, 0.4 and 0.5 mg/mL; 24, 48, 72 h	Induced apoptosis	Khaghani et al. (2011)
Zobo leaf ethanol-methanol-chloroform–ethyl acetate extracts		Hep3B		Greater cytotoxic effect by methanolic extract	Umamaheswari and Govindan (2007)
Dandelion whole plant methanol-ethanol extracts		BCSCs	10, 100, 500, 1000, and 2500 µg/m; 24, 48, 72 h	Inhibited cell proliferation and induced apoptosis	Trinh et al. (2016)
Dandelion root aqueous extract		SGC7901 and BGC823	0, 0.5, 0.1, 1.5, 2.0, 2.5, 3.0, and 3.5, 4.0 mg/ml; 48 h	Aqueous extract (3.0 mg/mL): suppressed proliferation and migration of both cells	Zhu et al. (2017)
Dandelion root methanolic extract		HCT 116, MCF-7 and HepG2	100, 200, 300, 400, and 500 µg/ml; 24 h	HepG2: reduced cell viability	Rehman et al. (2017)
Dandelion root aqueous extract		PC-3 and DU-145	1.0, 2.0 and 4.0 mg/ml; 48 and 96 h	Induced apoptosis (4 mg/mL) after 96 h in both cells	Deng et al. (2021)
Dandelion whole plant aqueous extract		SGC-7901	0,0.2, 0.25, 0.3 mg/mL	Inhibitory effect	Han et al. (2018)

Table 1 (continued)

Product	Compounds	Cell line	Concentration/period	Results	References
Dandelion flower, mature leaves and roots aqueous extract		LNcaP and MCF-7	0, 20, 40, 60 and 80 µg/ml; 96 h	Leave extract: blocked LNcaP cell line Root extract: blocked invasion of MCF-7 cell line	Sigstedt et al. (2008)
Dandelion dried whole plant ethanolic extract	Luteolin, 9,10,11-trihydroxy-9,11-trihydroxy-9,11-octadecadienoic acid, caftaric acid, esculetin, hesperidin, chlorogenic acid, vanillic acid, syringic acid, 4-hydroxybenzoic acid, isorhamnetin3-β-D-glucoside, caffeic acid, picrasinoside F, P-coumaric acid, octadecadienoic acid, ferulic acid, 9,10,11-trihydroxy-(12Z)-octadecadienoic acid	MDA-MB-468 and MDA-MB-231	40 and 80 µg/ml	Decreased proliferation and invasion of the cells	Deng et al. (2021)
African spinach aerial part (*A. spinosus*, *A. dubius*, *A. viridis*, *A. tricolar*) methanolic extracts	Rutinosides, quercetin, kaempferol glycosides, ferulic acid derivatives and caffeic acid and derivatives	MDAMB231 and MCF7	10, 20, 40, 50, and 100 µg/ml; 48 h	*Amaranthus spinosus:* inhibits proliferation of MDAMB231 *Amaranthus dubius*: cytotoxic effect on MCF7	House et al. (2020)
African spinach (*A. viridis*) ethyl acetate and ethyl ester extracts		Ht-29 and HepG2	400 µg/ml; 24 h	Ethyl acetate extract: cytotoxicity and antiproliferative	Jin et al. (2013)
African spinach (*A. spinosus*) crude methanolic extract	Flavonoid and alkaloid fraction	MDA-MB 231	0–50 µg/ml (crude extract), 0–100 µg/ml (flavonoid and alkaloid)	Apoptotic and cytotoxic effect	Al-Tamimi et al. (2021)
Jute mallow leaf crude extract	Isoquercetin (IQ) and chlorogenic acid (CGA)	AGS, A-375 and SUIT-2	0–400 µg/ml (jute mallow); 0–500 µM (IQ and CGA)	Jute mallow: AGS: IC50:2.5 mg/mL; SUIT: IC50:2.5 mg/mL; A375:IC50:4.0 mg/mL Isoquercetin: antiproliferative activity on SUIT-2	Tosoc et al. (2021)
Jute mallow ethanolic extract		HepG2	2.5–25 µg/ml; 24 h	Reduce cell viability and inhibit cell proliferation	Li et al. (2012)
Jute mallow ethanolic extract		Colo-741 and Colo-320	5, 10, 20, 50 and 100 µg/ml; 24 and 48 h	Cell inhibition at 50 µg/ml	Soykut et al. (2018)
African Basil leaf ethanolic extract		PC3.AR	25, 50, 100, 200, 400, and 800 µg/ml; 48 h	Inhibited cell proliferation	Ekunwe et al. (2014)

Table 1 (continued)

Product	Compounds	Cell line	Concentration/period	Results	References
African Basil leaf aqueous extract		MDA-MB-231 and MDA-MB-435	0.01, 0.05, 0.1, 0.2, and 0.5 µg/ml	Inhibited cell proliferation, inhibited angiogenesis, inhibited migration of the cells	Nangia-Makker et al. (2007)
African Basil methanolic extract	3-epi-ursolic acid, 3-O-methyl ursolic acid and oleanolic acid	MCF-7, NCI-H460, SF-263, HT-144	10, 60, 100, and 200 µg/ml; 24 and 48 h	Cytotoxic effect against MCF-7	Qamar et al. (2010)
African Basil aqueous extract	Anthraquinones, anthocyanins, tannis, amino acid, flavonoids, reducing sugar and glycosides	MCF-7	50, 150 and 250 µg/ml; 24 and 48 h	Inhibited cell development and multiplication	Alkhateeb et al. (2021)

Ebolo (*Crassocephalum rubens*)

Ebolo *(Crassocephalum rubens)* is an annual traditional leafy vegetable belonging to the Asteraceae family. It is mostly grown in Southwestern region of Nigeria but can also be found in other countries such as South Africa, Central Africa, and Islands of the Indian Ocean. In Nigeria, the leaf is often consumed raw or cooked by the Yorubas (Adewale et al. 2016). Studies showed that Ebolo leaves contain many phytochemical compounds such as flavonoids, alkaloids, saponins, Tannins, anthocyanins, anthraquinones and steroids (Adewale et al. 2020). However, combination or single use of the compounds from Ebolo leaves were reported to be responsible for antimicrobial, antioxidant, anticancer, antidiabetic, and antihyperlipidemic (Adewale et al. 2016; Oyebode et al. 2019; Ayodele et al. 2022; Alhassan and Atawodi 2019; Olaoluwa et al. 2018; Adjatin et al. 2012). Despite the above-mentioned phytochemicals, the leaf is underutilised in Nigeria and only consumed by just a few, specifically the aged and rural dwellers (Borokini and Labunmi 2017). To assess its safety profile, acute and subacute toxicity of the leaves aqueous extract was evaluated in rats and no adverse effect was found in both biochemical and haematological parameters (Alhassan and Atawodi 2019). Unlike many seasonal leafy vegetables, Ebolo can be made available throughout the year by preservative techniques. Alhassan and Atawodi (2019) observed that Dietary inclusion of Ebolo leaves at 10% level on colorectal carcinogenesis initiated by N-methyl-N-nitrosourea (MNU) instillations in male Wistar rat lessen lipid peroxidation, serum carcinoembryonic antigen, systemic inflammation, colon epithelial damage and aberrant expression of the mismatch protein mlh-1 (MutL Homolog 1). The cytotoxic effect of AECR-AuNPs (aqueous extract of *Crassocephalum rubens*-gold nanoparticles) against colorectal and breast cancer cells was investigated. However, the cytotoxicity was more significant at higher concentrations (125 and 250 µg/ml) after 24 h (Adewale et al. 2020). The MCF-7 was less sensitive to AECR-AuNPs than Caco-2 at both 24 and 48 h but showed good anticarcinogenic activities (Fig. 1).

Zobo (*Hibiscus sabdariffa* L)

Zobo *(Hibiscus sabdariffa* L) also known as ''roselle'' is an herbaceous plant with lobed leaves, bright red and acidic tasting calyces (Formagio et al. 2015). The genus consists of many species including *H. sabdariffa, H. tiliaceus, H. cannabinus, H. surattensis, H. scotelli, H. physaloides, H. acetosella, and H. lunarifolius*. The plant is native to Africa, Asia, and Central America (Antonia et al. 2019). *H. sabdariffa* is the most popular species in Nigeria with three different varieties grown, one green and two red. The green variety is mostly found in the southern part while the other

Table 2 In vivo effect of Nigerian vegetables on cancer cells

Product	Compounds	Experimental model	Concentration	Result	References
Ebolo leaves aqueous extract		Wistar rats male, colon cancer	2.5% aqueous extract + MNU treatment, 5% aqueous extract + MNU treatment	Lessen systemic inflammation, lipid peroxidation, colon epithelial damage and serum carcinoembryonic antigen	Alhassan and Atawodi (2019)
Zobo leaves aqueous extract	Catechin, quercetin, ferulic acid, rutin, p-coumaric acid, protocatechuic acid, epicatechin gallate, ellagic acid and naringenin	Nude mice, LNCaP	50, 100 µg/ml; 90 days	Almost 100% inhibition, reduced cell volume and weight	Lin et al. (2012)
Zobo leaves aqueous extract	Ellagic acid, ferulic acid, epigallocatechin, quercetin, gossypin, epicatechin gallate, rutin, protocatechuic acid, and procyanidin B2	Nude mice, LNCaP	50 mg/mL; 42 days	Reduced tumour volume, cell inhibition	Chiu et al. (2015b)
Dandelion root aqueous extract		Nude mice, DU-145 and PC-3	40 mg/kg/day; 8 weeks	Reduced tumour weight and volume	Nguyen et al. (2019)
African spinach aqueous extract		Female albino mice, Ehlich's ascites carcinoma cells	25, 50 and 100 µg/ml	Decreased cell viability, cell shrinkage, membrane blebbing, chromatin condensation and nuclear fragmentation	Al-Mamun et al. (2016)
Jute mallow leaf crude extract	Isoquercetin (IQ) and chlorogenic acid (CGA)	Chick embryo, AGS and A-375	10 mg (crude extract), 30 µg (IQ, CGA), and 10:10 µg (IQ + CGA); 8 days	Suppressed tumour progression inhibited angiogenesis and cancer growth	Tosoc et al. (2021)
African Basil leaf aqueous extract		Nude mice, MDA-MB-231	1% leaf extract; 3 weeks	Retard tumour growth	Nangia-Makker et al. (2013)

two varieties are grown in the northern part of the country. The two red varieties are remarkably different in appearance, one variety has bright red calyces while the other one has dark red calyces (Daudu et al. 2015). The fresh and dried green calyces is used in making sauce in the Southern part of the country while a non-alcoholic drink called sobo is made from water extract of dried red calyces across the country (Daudu et al. 2015; Elekima 2016). The plant is used as traditional medicine for diabetes, high blood pressure, constipation, urinary tract infection, and cancer. In China, it is used for treatment of liver damage, pyrexia, leukemia and hypertension due to its protocatechuic acid content (Tseng et al. 2000). Many compounds including ellagic acid, catechin, epigallocatechin, anthocyanins, quercetin, epicatechin gallate, carotenoids, and ferulic acid are reported to be present in *Hibiscus Sabdariffa* L (Formagio et al. 2015; Chiu et al. 2015a; Piovesana et al. 2018). Therefore, the presence of these phytochemicals is probably responsible for the antioxidant, antidiabetic, hypotensive, renoprotective, anticancer, anti-obesity, antimicrobial, diuretic, hypocholesterolaemic, immunomodulatory, anti-urolithiatic, and hepatoprotective properties of the plant (Formagio et al. 2015; Mohd-Esa et al. 2010; Fakeye et al. 2008; Patel 2014).

Zobo leaf extract (HLE) significantly inhibited the proliferation of three human prostate cancer cells and the highest susceptibility was seen in androgen dependent LNCaP cells compared to DU145 and PC3 (Lin et al. 2012). The authors also observed apoptosis in the LNCaP cells after treatment with HLE and its purified compound EA (Ellagic acid) using TUNNEL stain, caspase immunoblot and flow cytometry. According to Chiu et al. Hibiscus leaf polyphenolic extract induced autophagy through regulation of P13K class III/Beclin 1 and Akt/mTOR cascade signalling in human melanoma cells, an aggressive cancer that has not been susceptible to many treatments (Chiu et al. 2015a). In another study, lower concentration (0.1–0.5 mg/ml) of the leaves extract inhibited cell invasion and migration through a sustained inactivation of the P13K/Akt signal in prostate

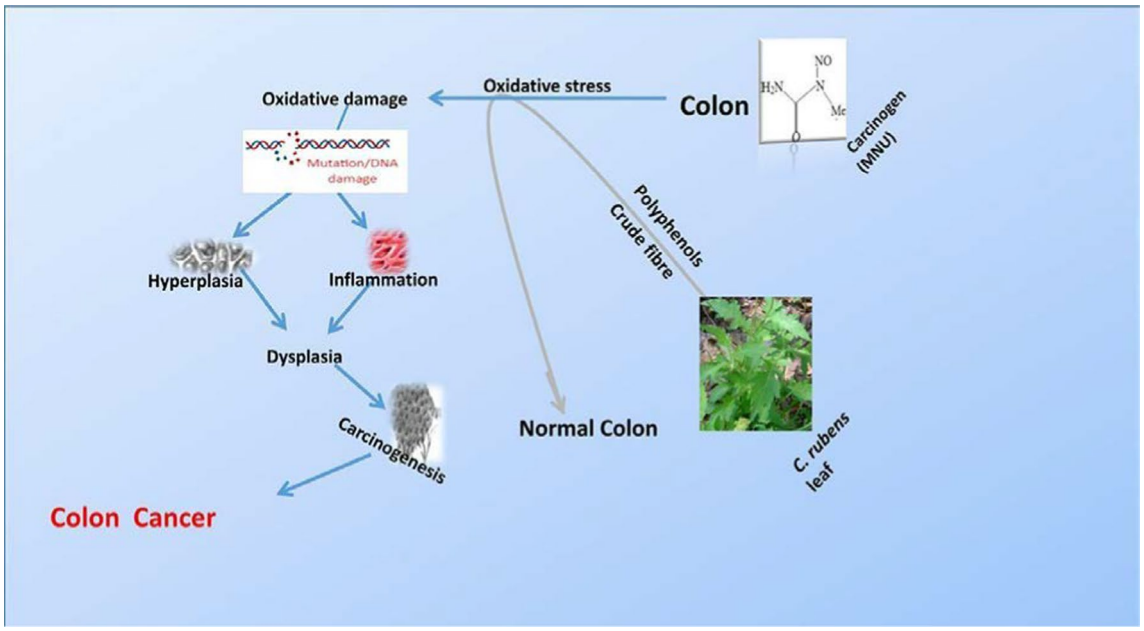

Fig. 1 *Crassocephalum rubens* effect on N-methyl-N-nitrosourea (MNU) induced colorectal carcinogenesis in Wistar rats. The action of catalase and superoxide dismutase *C. rubens* fed were elevated compared with just MNU treatment. For reference interpretation of the coloured figure, the reader is referred to Alhassan and Atawodi (2019)

cancer cells and at higher dose of 2.5 mg/ml induced apoptosis through intrinsic (Bax/cytochrome c-mediated caspase 9) and extrinsic (Fas-mediated caspase 8/t-Bid) apoptotic pathway in apoptotic pathway (Chiu et al. 2015b). The methanolic extract from calyces of Hibiscus sabdariffa in a concentration dependent showed inhibitory effect on leukemia cell lines (K-562) (Formagio et al. 2015). Similarly, aqueous extract of H. sabdariffa calyces in a concentration and time dependent manner demonstrated toxicity towards MCF-7 human breast cancer (Khaghani et al. 2011). Umamaheswari and Govindan (2007) evaluated the anticarcinogenic effect of *H. sabdariffa* leaves using different extracts against different cancer cell lines; NIH3T3, Hep G2, Hep3B, HL-60, AGS, and Caco-2. The methanolic extract suppressed the growth of the cancer cell lines through apoptosis and showed the greatest cytotoxicity potency on HL-60 and Hep 3b. The polyphenolic extract of *H. sabdariffa* leaves also showed a 50% growth inhibition of breast cancer cell lines MDA-MB-231, and its estrogen receptor MCF-7 and T-47-D in a concentration dependent manner (Ahirwar and Ahirwar 2020). These results shows that the anticarcinogenic effect of *H. sabdariffa* is time and dose dependent.

Dandelion (*Taraxacum*)

Dandelion (*Taraxacum*) is a perennial plant that belongs to the Asteraceae family. The plant is recognizable and common to weeds that are found in almost all the countries of the world. The plant is about 40 cm in height, jagged leaves with yellow to orange flowers. There are over 2500 several species of Taraxacum but the most studied ones are *Taraxacum platycarpum, Taraxacum laevigatum, Taraxacum kok-saghyz* and *taraxacum officinale* (Napoli and Zucchetti 2021). The root extract of *Taraxacum offcinale* has been traditionally used by Arabian and Chinese for treatment of many diseases including digestive ailment and hepatitis. Despite the plant being edible and nutritious, many Nigerians still see it as an ordinary weed because it grows everywhere. According to Agiobu-Kemmer, every part of dandelion is edible and tasty both raw and cooked. The leaves can be eaten raw, steamed, stir fried, added to green salad, and used as vegetable sauce (Napoli and Zucchetti 2021; Zhu et al. 2017). Also, the flowers are crunchy and sweet and can be fried, eaten raw or used in wine making while the root can be roasted, dried, and used as a substitute for coffee (Agiobu-Kemmer 2015). This plant possesses many pharmaceutical properties due to the phytochemicals found in leaves, flowers, stem, and root. Carotenoids, phenolic acid (chicoric acid, chlorogenic, and caffeic acid), flavonoids (chrysoeriol, quercetin, luteolin-7-glucoside), 11β,13-dihydrolactucin, polysaccharides, sesquiterpene lactones, triterpenes, sterols are the major phytochemicals found in Taraxacum officinale (Muhammed et al. 2018; Chatterjee et al. 2011).

The effect of dandelion taraxacum officinale extract on breast cancer stem cells were evaluated in vitro in 2D and 3D cell culture. The methanolic extract significantly inhibited breast cancer stem cells proliferation in 3D more than in 2D model. The result also showed that treatment of

breast cancer stem cells with dandelion extracts indicated enhanced expression of tumor necrosis factor-related apoptosis-inducing ligand and its receptor 2 (Trinh et al. 2016). Zhu et al. examined the anticarcinogenic effect of dandelion root extract in gastric cancer cell lines. The authors reported that the root extract inhibited the proliferation and reduce the metastatic capacity of gastric cancer cells by targeting colon cancer associated transcript 1 (CCAT1). The anti-proliferative effect of dandelion root methanolic extracts on cell viability of MCF7, HCT116, HepG2, and normal Hs27 was examined. The extract at a concentration of 500 µg/mL significantly reduced the growth of HepG2 than HCT116 AND MCF7 and no effect was seen in Hs27. Also, the extract increased the phosphorylation level of AMPK of HepG2, which is important in the treatment of cancer and other metabolic disorders (Rehman et al. 2017). To identify natural health products for long-term, non-toxic cancer treatment, (Nguyen et al. 2019) explored the effects of dandelion root extract in vivo and evaluated its potential to induce apoptosis in prostate cancer cells. The aqueous extract was able to induce apoptosis in concentration and time dependent in prostate cancer without significant effect on healthy cells. Dandelion leaves extract blocked LNCaP prostate cells invasion while the root extract block invasion of breast cancer cells (MCF-7/AZ) (Sigstedt et al. 2008). Han et al. (2018) also examined the cytotoxicity of dandelion extract against gastric cancer. The authors observed a significantly reduced pro-proliferative and antiapoptotic gene expression and identified that the extract inhibited cell proliferation and induced apoptosis probably through regulation of Bcl2, survivin, Bax, Erk gene expression and Pten. Furthermore, dandelion plant extracts blocked proliferation and growth of breast cancer cells, regulating phosphatidylinositol, and 5-bisphosphate 3-kinase/protein kinase pathway, suggesting that dandelion extract could be used to treat breast cancer (Nassan et al. 2018). Dandelion extract exerted a cytotoxic effect on breast and hepatic cancer cells (Muhammed et al. 2018). The presence of flavonoids in dandelion have been reported to be responsible for their anticarcinogenic activities. These compounds maybe responsible for inhibition of protein kinase activity, matrix metalloproteinases 2 and 9 secretion, apoptosis and cell invasion, triterpenoids that inhibit cancer cell proliferation, and luteolin for inducing apoptosis and regulation of DR5 receptor expression in human cells (Muhammed et al. 2018). Also, the effect of dandelion root extract on human melanoma cell lines was investigated in vitro and was reported that dandelion root extract was effective in inducing apoptosis through mitochondria mediated pathways (Chatterjee et al. 2011). The authors noticed that dandelion extract has a distinctive-spectrum cytotoxic action against different human cell lines without affecting non-cancerous cells. In an investigation carried out by Deng et al. (2021) on the effect of dandelion extract on triple negative breast cancer cells when culture with M2 macrophages, 80 µg/ml ethanolic extract of dandelion inhibited cell proliferation, migration and invasion of triple negative breast cancer induced by tumor associated macrophages conditioned medium. Rezaie et al. (Rezaie et al. 2023) reported that dandelion extract, at concentrations of 1.5 and 4 mg/ml, exhibited a potent cytotoxic effect on MCF-7 and MDA-MB231 cells.

African spinach (*Amaranthus*)

African spinach (*Amaranthus*) is an erect perennial plant belonging to the Amaranthaceae family with over 60 species spread all over the subtropical and tropical countries including Nigeria. *Amaranthus hybridus, Amaranthus tricolour, Amaranthus viridis, Amaranthus spinosus, and Amaranthus dubious* are the popular species eaten as leafy vegetables (Al-Mamun et al. 2016). In Nigeria, *Amaranthus hybridus* is mostly cultivated and known as Efo green or Efo arowo jeja. The vegetable grows annually and is cultivated almost throughout the year. The leaves are green in colour with hard stems consumed mostly in the southwestern part of the country in making sauce or vegetable soup. *Amaranthus spinosus* is also consumed and used by local communities in Nigeria for other ethnobotanical purposes (Ekeke et al. 2019). *Amaranthus viridis* has been used traditionally in China to treat enteritis, dysentery, haemorrhoids, and kidney diseases (Jin et al. 2013). The presence of phytochemical including flavonoids, carotenoids, phenolic acids, and ascorbic acid has been reported in Amaranthus, and many of these compounds are known for their anti-inflammatory, anticancer, antidiabetic, antioxidant, and antihyperlipidemic (Jin et al. 2013; House et al. 2020). This plant also contains vitamins, minerals, protein, and amino acid (Al-Tamimi et al. 2021).

The variation of anticancer activity among different species of African spinach (*A. spinosus* and *A. dubious*) on two breast cancer cell lines (MDAMB231 and MCF7) cancer was reported. The methanolic extract of the aerial parts of *A. spinosus* exerted inhibition on the proliferation of MDAMB231 cells than *A. dubius*, while extract of *A. dubius* was more toxic to MCF7 in a dose dependent manner. Although, this result could be due to the variation in the hormone receptor status of the two cell lines (House et al. 2020). The alkaloids fraction (23.29 ± 2.19 µg/mL) from *A. spinosus* exerts anticancer activity against human triple negative breast cancer cells (MDA-MB) (Rezaie et al. 2023). The presence of Lectin from Amaranthus seed extract was reported for the anticancer activity against Ehrlich's ascites carcinoma by inducing apoptosis via mitochondrial pathway (Al-Mamun et al. 2016). Jin et al. (2013) examined the cytotoxic and antiproliferative effects of ethyl ester and ethyl acetate extracts of *Amaranthus viridis* on HepG2 (human liver cancer) and HT-29 (human colon cancer) cell lines using the MTT assay. They found that the ethyl ester

extracts inhibited cell growth at a concentration of 400 µg/ml within 24 h in both cell lines. These findings suggest that consuming various species of *Amaranthus* may provide anticancer benefits in humans.

Efinrin (*Ocimum*)

Efinrin (*Ocimum*), commonly known as African Basil, belongs to the Lamiaceae family, which comprises perennial shrubs and herbs native to warm and tropical temperate regions such as Africa, Asia, and Europe. The Lamiaceae family is typically recognized for its herbs and spices, featuring almost 60 species, with the highest diversity found in Africa. Some species include *O. gratissimum, O. viride, O. basilicum, O. tenuiflorum, and O. sanctum* (Nangia-Makker et al. 2013; Nadeem et al. 2022; Ekunwe et al. 2014; Mousavi et al. 2018). In Nigeria, the leaves serve as a natural condiment, flavoring agent, and vegetable for soups, fish, meat, and sauces. Across Africa, the medicinal uses of *Ocimum* vary by country. In Côte d'Ivoire, *Ocimum* formulations treat eye infections, ear infections, and skin diseases; in Nigeria, they remedy diarrhea; and in Cameroon, they address coughs, colds, and headaches (Ugbogu et al. 2021). Additionally, *Ocimum* is used to treat stomach pain, constipation, colic, cancer, inflammation, and hemorrhoids (Ekunwe et al. 2014). Numerous studies have shown that this plant species possesses various pharmacological properties, including free radical scavenging, radioprotective, anti-inflammatory, anticarcinogenic, antidiabetic, and antiplasmodial activities (Mousavi et al. 2018; Nangia-Makker et al. 2007; Inbaneson et al. 2012; Bawankule et al. 2015). These benefits are attributed to its phytochemical content, which includes quercetin, caffeic acid, rosmarinic acid, ellagic acid, apigenin, chlorogenic acid, liquiritigenin, apigenin, kaempferol, luteolin, genistein, catechin, and umbelliferone (Nadeem et al. 2022; Mousavi et al. 2018; Chaudhary et al. 2020). The extract of *O. gratissimum* demonstrated antiproliferative effect on prostate cancer (PC3.AR) cells by modulating androgen receptor and survivin protein level (Ekunwe et al. 2014). Nangia-Makker et al. (2013) reported that the aqueous extract of *Ocimum sanctum* exerted an inhibitory activity on breast cancer cell and angiogenesis with effect on cell proliferation, migration, stromal apoptosis, morphogenesis, and COX-2 induction. The ursolic acid (100 µM) present in this plant inhibited the growth of breast cancer (MCF-7) cells along with mitotic spindle and F-actin aggregation (Qamar et al. 2010). Alkhateeb et al. (2021) reported that phenolic compounds and flavonoids extracted from *Ocimum basilicum* at low temperature inhibited the growth of breast cancer (MCF7) cell via apoptotic and oxidation intervened approach. The ethanolic extract of *Ocimum tenuiflorum Linn* combined with *Cinnamomum burmannii* in a concentration dependent manner exhibited a cytotoxic activity against T47D breast cancer cells (Indrayudha and Hapsari 2021). Flavonoid and anthocyanin, a polyphenol compounds highly present in *Ocimum basilicum* have been reported for their anticancer effect on human gastric cancer cells. These compounds showed their anticarcinogenic effect through multiple biological mechanisms manipulation involved in tumour initiation and progression such as P53 signaling pathway (Hanachi et al. 2021). Luke et al. (2021) used NRU and MTT in vitro assay discovered that *Ocimum sanctum* exhibited cytotoxic effect on oral squamous cancer cell line (Ca9-22) at minimum inhibitory concentrations of 5 mg/L in both dry and aqueous extract.

Jute mallow (*Corchorus olitorius* Linn)

Jute mallow (*Corchorus olitorius*) belongs to the Malvacea*e* family, a medicinal and culinary herb generally used as a vegetable in many Africa and Asia countries. The plant is indigenous to subtropical and tropical areas all over the world. It is reported as cultivated or wild vegetables in many countries including Nigeria, Cameroon, Benin, Sudan, Ivory Coast, Egypt, Uganda, Kenya, and Zimbabwe, India, Mexico, Australia, Venezuela, Bolivia, Japan, China, Bangladesh, Philippines, Caribbean, and the Middle East (Oh and Kim 2022; Kuete et al. 2017). In Nigeria, the leafy vegetable is used in making soup and is called Ewedu in Yoruba, Lalo in Hausa, Adigbor or Atiever in Tiv, and Ayoyo in Gbagi (Ipav et al. 2018). Besides polyphenols, jute mallow is a great source of phosphate, calcium, iron, potassium, ascorbic acid, and mucilaginous polysaccharides (Li et al. 2012). Moreover, these compounds have been reported to possess anti-inflammatory, antimicrobial, anticancer, antioxidant, and antihyperglycemic properties (Oh and Kim 2022; Azeez et al. 2019). Also, Jute mallow serves as medicinal foods in many nations and has beneficial effects such as laxative, sedative and diurective; traditionally used in treatment of gonorrhoea, hypertension, diabetes, dysuria, and cystitis (Soykut et al. 2018; Kumari et al. 2019).

An aqueous extract from Jute mallow demonstrated a significant antiproliferative effect on AGS, SUIT-2, and A-375 cell lines at a concentration of 2.54 mg/mL (Tosoc et al. 2021). The authors also validated the anticancer effects of the aqueous extract, isoquercetin (IQ), and chlorogenic acid (CGA) from Jute mallow through in vivo studies. The aqueous extract inhibited the growth and angiogenesis of AGS and A-375 by reducing the availability of essential nutrients and oxygen. IQ suppressed tumor growth and angiogenesis of AGS and A-375 at 30 µg/CAM, while CGA significantly decreased the hemoglobin level of AGS tumors at 30 µg/CAM by inhibiting the angiogenesis process within eight days of treatment. Additionally, HepG2 (hepatocellular carcinoma) cells treated with an ethanol extract of Jute mallow induced

apoptosis via the intrinsic pathway (Li et al. 2012). The aqueous extract also exhibited a cytotoxic effect against the colon adenocarcinoma cell line (Col-741) (Soykut et al. 2018). The effects of phenolic fractions from *Corchorus olitorius L.* were assessed on colon cell phenotypes to evaluate their potential nutraceutical properties. Polyphenol-enriched extracts (PEEs) exhibited selective cytotoxic activity against tumor Caco-2 cells while sparing the healthy CCD841 cell line. PEEs induced oxidative stress and inhibited the activity of glutathione-independent antioxidant enzymes in Caco-2 cells. *C. olitorius* appears to be a promising crop for enhancing both agricultural sustainability and health benefits due to the high content of antioxidant compounds in its leaves (Guzzetti et al. 2021).

Conclusion

Vegetables are key dietary constituents that supply vitamins, minerals, and amino acids to the body. This study revealed that many Nigerian vegetables have anticarcinogenic effects. Although the anticarcinogenic effect of the review vegetables lack sufficient in vivo studies. However, the presence of bioactive compounds such as quercetin, catechin, ellagic acid, rutin, kaempferol, carotenoids, chlorogenic acid among others justifies the anticarcinogenic information, and thus making these vegetables promising constituent for cancer prevention and probably treatment. Therefore, considering the numerous health benefits, frequent consumption of vegetables can reduce the risk factors of cancer and thereby prevent the growing incidence of the disease.

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Declarations

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