INTRODUCTION

The most common malignant tumor among women throughout the world is cervical cancer. It is found to be the second most common type of tumor. It is found to have high mortality rate [1] which accounts for more than 500,000 new cases and approximately 275,000 deaths occur [2]. There are various methods used to treat cervical cancer with chemotherapy, radiotherapy, and surgery. It is recommended for patients at an early stage, and fertile women could undergo surgical treatment. The effectiveness of chemotherapy and radiotherapy is specific for cancer cells, and it may possibly destroy the whole normal cell.

In cases, where platinum-based chemotherapy is used for the treatment of locally advanced cervical cancer, it is known that up to 35% of the patients already treated with radiation or surgery, develop recurrent metastatic disease. Effective therapies and innovations are required for treating advanced and refractory cervical cancer, as the response post-treatment is often substandard and temporary [3]. Researchers believed that the dietary phytochemical agents may influence chemotherapy treatment and help cure patients with cancer [4]. In this, plants continue to play a significant role both medically and economically [5]. There are several sources of anti-cervical cancer drugs which are derived from spices, herbs, and vegetables, and a variety of plants are used in folk medicine. One of the strategies is to consider natural products. In the modern system of medicine, about 25% of prescriptions contain active principles derived from plants. Plant-derived drugs play dominant roles in the treatment of various ailments [6].

HERBS IN THE CURING OF CERVICAL CANCER

Traditional medicine is still used by approximately 65–80% of the world’s population in developing countries as a source of primary health care. The main reason for the use of traditional medicine is due to their affordability, accessibility, and cultural beliefs [7]. The World Health Organization estimates that majority of the people depend on herbs for their health care. The most commonly used treatments are surgical, radiation, and hormone treatments but they have severe side effects. Medicinal plants can be promising source of novel therapeutic agents, especially for cancer. It has been estimated that out of 250,000 plants species existing on earth approximately 1000 species are known to have anticancer potential. Thousands of species have been screened through bioassays for the search of novel plant-based anticancer drugs [8].

Anisomeles malabarica is an herb that belongs to the family of Lamiaceae which possess antispasmodic, diaphoretic, antipyretic, and antiperiodic properties. It is also reported to contain secondary metabolites such as anisomic acid, ovatodiolide, geranic acid, citral, betulonic acid, and beta-sitosterol. Thus, the study proved that the n-hexane and chlormform extracts of A. malabarica inhibit proliferation and induce death in human papillomaviruses (HPV) 16-positive cervical cancer cells by apoptosis and necrosis [9].

Berries contain a wide range of phytochemicals with biological properties that include antioxidant, anticancer, anti-neurodegenerative, and anti-inflammatory activities [10]. Black raspberries (Rubus occidentalis) are a rich natural source of chemopreventive phytochemicals [11]. Ethanol extract of black raspberries induced apoptosis in all cervical cancer cell lines (HeLa, SiHa, and C-33A) with varying degrees of potency and demonstrated a significant growth inhibitory and apoptotic activating activities in a dose- and time-dependent manner. Hence, the study found that black raspberries and their bioactive components represent promising candidates for food-based chemoprevention strategies for cervical cancer [12].

Boswellia serrata is an important medicinal plant from Burseraceae family. It possesses various pharmacological properties that include anti-inflammatory, antimicrobial, and anti-tumor property [13]. The plant is obtained from species B. sacara, B. frereana, and B. serrata. Monoterpene, diterpene, and triterpene, and boswellic acid are the main constituents of B. serrata, which can induce apoptosis in cancerous cells and the hydroalcoholic extract of this plant causes the death of cervical cancer cells (HeLa cell) [14].

Boerhavia diffusa L. (Nyctaginaceae), which is commonly known as "punarnava" [15], is a perennial creeping herb that is used for the treatment of various ailments [16]. It is containing phenolic compounds, namely alkaloids and amino acids and is reported to exhibit strong antioxidant properties [17]. Pharmacological studies have demonstrated that it exhibits a range of properties such as diuretic antifibrinolytic, anti-inflammatary, and antibacterial. The extract of this plant is found to shown analgesic and anti-inflammatory property, hepatoprotective activity, immunomodulatory activity, and anti-proliferative properties. Thus, the study reports that, at a concentration of 300 µg/mL, the ethanolic crude root extract exhibits cytotoxic effect and causes 50% cell death in HeLa cell line. Moreover, a...
methanol:chloroform fraction could inhibit the proliferation of human cervical cancer cell line (HeLa) through S-phase inhibition, induced antiproliferative activities, inhibition of DNA synthesis and induction of apoptosis [16].

Bullet wood tree, also called Spanish cherry (Mimusops elengi L.), belonging to family Sapotaceae which are widely used in the treatment of different ailments. Studies investigated the cytotoxic potential of methanolic bark and leaf extracts of M. elengi against human cervical cancer cell line (SiHa) by 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide (MTT) assay. There is an increase in apoptotic bodies from 0.24% to 60% and 69% after treatment with extracts. These extracts exhibit significant cytotoxic effect by inducing apoptosis. These findings suggested that extracts and compounds from this plant could be useful for preventing and treating human gynecologic cancer disease especially cervical cancer [18].

Cassia tora Linn (Leguminosae) is a well-known ayurvedic medicinal plant that acts as a laxative, antiperiodic and is used to treat leprosy, ringworm, bronchitis, and cardiac disorders. Seeds of CT express antioxidant activities and contain many active substances including chrysophanol, emodin, and rhein. The antiproliferative activity of C. tora methanolic leaf extract with Giplatin was studied on human cervical cancer cells (HeLa) and the proliferation was measured by MTT assay. The extract is found to induce a marked concentration-dependent inhibition on proliferation, reduced DNA content and apoptosis in HeLa cells [19].

Cinnamon, a spice widely used in culinary, has been shown to exhibit diverse biological functions including anti-inflammatory, antioxidant, antimicrobial, anti-diabetic effects, and anti-tumor activity. Cinnamon could be trusted to be a promising candidate for restricting the growth of cervical cancer cells. The aqueous cinnamon extract, from the bark of Cinnamomum cassia L. (family of Lauraceae) on human cervical cancer cell (SiHa), the study suggested that it could be proposed to be a potent anticancer drug candidate in cervical cancer cells as it significantly affected the growth rate of SiHa cells in a dose-dependent manner and also induced apoptosis through loss of mitochondrial membrane potential [20].

The medicinal plant Cordia dichotoma belonging to the family Boraginaceae is found to have antioxidant, juvenomimetic, anti-fertility, anti-inflammatory, and various other pharmacological activities. The methanolic extract of C. dichotoma on HeLa cancer cell line induced apoptosis by various mechanisms either by DNA fragmentations or by mitochondrial depolarization or accumulation of reactive oxygen species (ROS). The presence of phenolics and carotenoids in their leaves has potent antioxidant and anticancer activity; thus, it could be a new potent cancer chemopreventive or chemotherapeutic agent for human cervical cancer cells because of its anticancerous activity [21].

Curcumin is normally acquired from the rhizome of turmeric (Curcuma longa) and has been generally utilized as a traditional medicine because of the various restorative properties. It has antioxidant and pleiotropic effects by modulating the multichannel signal pathways such as inflammation, invasion, proliferation, metastasis, and cell cycle. Thus, curcumin is found to be a traditional medicine with therapeutic effect against cancer cells. At the concentration of IC50, HeLa and SiHa were treated in the absence as well as in the presence of curcumin. Cur-liposomes showed a significant increase in apoptosis population when treated with the same dose of curcumin when compared with the cells treated with raw curcumin. With the incorporation of didecyldimethylammonium bromide apoptosis in both cells was promoted. Hence, the study recommends that the preparation of curcumin as nano liposome provided higher toxicity than free-curcumin treated at the same concentration [22].

The root of C. longa contains curcumin, a natural compound and the fruits of strawberries, raspberries, and walnuts contain ellagic acid a polyphenol. The combination of curcumin and ellagic acid at various concentrations showed better anticancer properties than either of the drugs when used alone as evidenced by MTT assay. Besides this, curcumin and ellagic acid also restore p53 induce ROS formation and DNA damage. The mechanistic study further indicated that curcumin and ellagic acid show anti-HIV activity as evidenced by a decrease in the HIV-1 reverse transcriptase (RT) on HeLa cells and provides an important lead for anticancer therapeutics for the treatment of cervical cancer [23].

Extracts from Inula viscosa (L.) Ait, Retama monosperma (L.) Bois, Ormenis mixta (L.) Dumont, Ormenisierolepis Coss, Rhamnus lycioides (L.), Berberis hispanica Bois and Reut, and Urginea maritima (L.) Baker are studied. The cytotoxic activity of selected plants was studied on the human cervical carcinoma cells lines, SiHa and HeLa, harboring HPV16 and HPV18, respectively. Among the 7 medicinal plants tested, methanolic extracts from Inula viscosa (L.) Ait, R. monosperma (L.) Bois, and Ormenisierolepis Coss. Extracts showed significant growth inhibitory effects in both SiHa and HeLa cells compared to the control due to the presence of active compounds [24].

Ganoderma applanatum, a member of the species of the basidiomycete, is called "Eifengia applanata." This mushroom has been used often in folk medicine for the treatment of various ailments including cancer [25]. The methanolic extract of G. applanatum elicited dose-dependent cell death on HeLa cells after 24 h of treatment, with an IC50 value of 43.2 µg/ml. It exhibited toxicity particularly toward tumor cells compared to normal Vero cells. The anticancerous activity of G. applanatum is due to the presence of β-terpine, D-limonene, cis-2-methyl-4-pentythianes, s-dioue, β-cymene, and α-terpinolene which play a major role in inducing apoptosis [26].

In the southwest region of China, Garcinia nujiangensis, an endemic species is located. A new compound Nujiangexanthone A (NJXA), is isolated from the leaves of G. nujiangensis, which exhibits cytotoxicity against an array of human tumor cell lines. Potent anticancer activity identified that NJXA acts as a crucial agent in treating cervical cancer. The results indicate that NJXA exhibited selective cytotoxicity against cervical cancer cells. It further induced G0/G1 cell cycle arrest in HeLa and SiHa cells by downregulating the cyclins A, B1, and E1, as well as cyclin-dependent kinases 2,4, and 6, during the selective restoration of p27 [27].

Kaffir lime (Citrus hystrix) is a member of the citrus family [28], and the leaf of this plant contains alkaloid, flavonoid, terpenoid, tannin, and saponin compounds. The leaves and fruit extracts are found to have antioxidant activity, free radical scavenging ability, antimicrobial activity, and anti-inflammatory activity. Based on the IC50 values, chloromform extract of Kaffir lime had the effective potential to reduce HeLa cell viability. Hence, the studies suggested that the kaffir lime leaf extract reduced the viability of cervical cancer cells in micromolar concentrations [29].

The crude methanolic extract of the leaves of Leea indica of the family Vitaceae was examined for their antitumor activity against Ehrlich ascites carcinoma cells. The compound at the dose of 40 mg/kg/day significantly decreased tumor weight. Glycosides, molic acid arabinoside and molic acid xyloside, were first isolated from the fresh leaves of L. indica, inhibited the growth of Ca2 + -Ski cervical cancer cells with IC50 of 19.21 µM through two signaling mechanisms - the activation and release of mitochondrial pro-apoptotic proteins known as caspases under the control of Bcl-2 family of proteins or upregulated expression of pro-apoptotic receptors on cancer cells [30].

Paulownia coreana is used as both health food and medicine for the treatment of cancer as well as other major infectious diseases [7]. From the leaves of P. coreana, isoastrilicic acid tiglate (PCAC) was isolated. Anti-proliferation activity is found in cervical cancer cell lines when treated with the chloroform extract of P. coreana. This, in turn, even at a low concentration (~10 µg/mL) subdues the proliferation of cancer cells and cell growth and at a high concentration (~50 µg/mL) induces apoptosis. From this, it has been concluded that PCAC can act
as antiproliferation agents, inducing cell cycle arrest in the S/G2 phase and caspase-dependent apoptosis, particularly against cervical cancers by activates caspase-8, -9, and -3 [31].

*Portulaca oleracea* is a ubiquitous garden weed that has been traditionally used as anti-diabetic and anti-inflammation agent [32]. It has high antioxidant property, vitamins, dietary minerals, and iron. *P. Oleracea* aqueous extracts exhibited antiproliferative and apoptotic effects against HeLa cell line in a dose- and time-dependent manner [33].

*Polygonum aviculare* is a member of Polygonaceae-Dock family. The herbal extract of this plant has astringent properties. It can be a natural poten chemopreventive and chemotherapeutic plant for patients identified with cervical cancer. Hence, the study suggested that methanolic extract of *P. aviculare* has a potent anti-growth effect and showed the cytotoxic and apoptotic effect on Hela-S cervical cell line and may be exploited as a potential source for developing novel drugs against cervical cancer [34].

Acetone extract of *S. discolor* (SDE) inhibited the growth and survival of cancer cells to varying degree, but the inhibition was found to be maximum in cervical cancer cell lines. There was no significant toxicity induced in normal cells. The cell death was mediated through apoptosis. There was increased mitochondrial membrane depolarization, expression of Bax, caspase-9, caspase-3, and cleaved poly ADP-ribose polymerase (PARP) indicating that SDE induced caspase-dependent apoptosis in HeLa cells. Moreover, SDE caused cell cycle arrest in G2 phase in HeLa cells. Cytotoxic nature of the plant led to the isolation of chrysin which was the major phytochemical constituent present in *S. discolor* and also the active principle responsible for the antiproliferative activity for cervical cancer cells [35].

Satureja is from the genus of the mint family Lamiaceae. *Satureja bochtariaca* Bunge was shown that tannins, fatty substances such as terpenoids and phenolics compounds are the main effective and bioactive components in its extracts. The hydroalcoholic extract of *S. bochtariaca* Bunge has an anticancer effect which can inhibit the growth through dose-dependent and time-dependent effect on Hela cancer cells, and in higher doses, the growth of cancer cells was more inhibited, and also it did not have any significant effect on normal fibroblast cells [36].

*Solanum nigrum* is an herbal plant that has been used in traditional folk medicine because of its diuretic and antipyretic effects, and it contains steroidal glycosides, steroidal alkaloids, steroidal oligoglycosides, solamargin, and solasonine. The study indicated that *S. nigrum* aqueous extract could inhibit the uterine cervical carcinoma through multiple functions by stimulating the host immune system which resulted in massive necrosis in tumor tissues. At the same time, by inhibiting PCNA gene expression, it arrested the cell cycle and triggered apoptosis in tumor cells [37].

Violet plant is the Herbaceous plants. It is reported to have a number of medicinal features including antioxidant, anti-inflammatory, antimicrobial, sedative, and also anti-cancer activities [38]. Aqueous extract of this plant has a strong inhibitory effect on proliferation of cervical cancer, and the active ingredient of the plant responsible for this effect is ethyl acetate. Thus, the studies suggest that the plant that has cytotoxic and anticancer effects on HeLa cells [14].

*Vitex agnus-castus* is used as a traditional medicine in gynecological condition. A *V. agnus-castus* fruits extract has been shown to exhibit antitumor activities in different human cancer cell lines. A crude extract was prepared with ethanol from dried ripened *V. agnus-castus* fruits which have cytotoxicity against human cervical carcinoma. Hence, the study showed that the cytotoxic activity of *Vitex* extract may be attributed to the effect on cell growth, and cell death occurs through apoptosis, and this apoptotic cell death may be attributed to increased intracellular oxidation by *Vitex* extract treatment [39].

*Vitae agnus-castus* is a member of *Violacea* plant family. Vigno 5 is a natural cyclopeptide from *V. ignobilis* and its action on cervical cancer cells from a study found that vigno 5-treated HeLa cells were killed off by apoptosis in a dose-dependent manner within 24 h and were characterized by the appearance of nuclear shrinkage, cleavage of PARP, and DNA fragmentation. The mitochondrial pathway of apoptosis is revealed that cytochrome C is released from mitochondria to cytosol, associated with the activation of caspase-9 and -3, and the cleavage of PARP. Thus, the study indicated that vigno 5 induces apoptosis in parts through the mitochondrial pathway, which is associated with a release of cytochrome C and elevated activity of caspase-9 and caspase-3 in HeLa cells [40].

**Plant Molecules as Anticervical Cancer Agents**

Several classes of anticancer drugs have been developed, and many of them are of natural origin. Natural products have been the mainstay of cancer chemotherapy for the past 30 years. However, most of the currently used anticancer drugs cause undesirable side effects due to lack of tumor specificity and multidrug resistance. Therefore, the search for potent, safe, and selective anticancer compounds is crucial for new drug development in cancer research. Natural products, due to the structural diversity, provide excellent templates for the construction of novel compounds. 60% of currently used anticancer agents are derived in one way or another from natural sources [35]. Many chemical compounds from herbal plants have been explored for their potential anti-tumor activity and safety [42]. Most herbs contain antioxidant agents that could be consumed to prevent cancer or potentiate chemotherapy, and also, a number of phytochemicals isolated from medicinal plants have been shown to decrease cell proliferation, induce apoptosis, retard metastasis, and inhibit angiogenesis [4].

*Amoora rohituka* is an evergreen tree which is used as herbal medicine for cancer, tumor, liver, and spleen diseases [43]. Amooranin is a triterpene acid, isolated from *A. rohituka*. The stem bark possesses significant anticancer potential that inhibits the growth and spread of cervical cancers by arresting G2/M phase of the cell cycle by and inducing apoptosis [44]. Due to the presence of alkaloids including alkaloids rohitukin, amoorenanin, amooreastatin and 12α-hydroxyamoorestatin, and complex limonoids, the chloroform stem bark extract of rohituka, *Aphananikis polysacchary* has cytototoxic effects on HeLa with an IC_{50} of 25 µg/ml by induction of DNA damage in the form of micronuclei and induction of apoptosis [45].

Apigenin, a widely distributed plant flavonoid has also been shown to inhibit the growth of HeLa cells and was reported to be a potential antitumor agent. Significant reduction in the viability of HeLa cells by apigenin at 37-74 µM was observed, and the IC_{50} value was found to be 35.89 µM. Hence, the study reported that apigenin acted by triggering the apoptotic pathway, characterized by induction of G_{1} arrest, DNA fragmentation, increased expression of p21/WAF1, caspase-3, mediators of apoptosis and decreased in the protein expression of an antiapoptotic factor the Bcl-2 protein [31].

Caffeic acid (CA), one of the major bioactive compound of *Rosmarinus officinalis* L. has been identified to possess both anti-inflammatory and anticancer activities. CA, as a phenolic diterpene, exerting protective effects associated with inflammatory cytokines. The researchers found that carnosic acid exerted anti-tumor ability in vitro supported by
upregulation of apoptosis and ROS production in cervical cancer cells. Furthermore, alteration of ROS led to the phosphorylation of c-Jun N-terminal kinase and activation of endoplasmic reticulum stress, promoting the progression of apoptosis through stimulating caspase-3 expression. Hence, carnosic acid seems to be an effective compound used for cervical cancer in clinical treatment [42].

Cisplatin remains one of the most effective current chemotherapeutic agents; however, metal complex synthesis has increased to produce new antineoplastic drugs with DNA binding and apoptotic activities in tumor cells and less toxicity for patients. Studies evaluated the cytotoxic activity of a novel copper (II) complex (LQM402) against cervical cancer cell lines and found that it exhibited selective cytotoxicity against HeLa and Ca Ski cells. Thus, it might be used as a potential therapeutic agent against cervical cancer and may be a promising and safe anti-cervical cancer compound [46].

Cisplatin is the cell cycle non-specific agent and the most common drug that is extensively applied in chemotherapy. Cisplatin inhibits the division of tumor cells by triggering obstacles in DNA replication. Matrine is isolated from Sophora flavesens with functions of clear heat and dry dampness and belongs to tetra cyclic thiadiazole involved in traditional medicinal functions; it also has the functions of protecting the cardiovascular system, improving patients’ immunologic function, and protecting liver along with antiviral and anti-tumor roles. The combined treatment of matrine and cisplatin, with a synergistic effect, can notably inhibit the growth of tumor in U14 rats with cervical cancer, by significantly improve the immunologic function of rats and decrease the toxic reaction in the process of treatment [47].

Coffee is a rich source of dietary phenolic phytochemical, including caffeic acid (CA). CA is reported to have a wide variety of biological activities, including antioxidant, anti-inflammatory, anti-arthritic, anti-infectious, anti-fibrosis, antiviral, and anti-tumor properties. The inhibitory effect of CA on cancer cell proliferation by an oxidative mechanism in humans HT-1080 fibrocoma cell line has been reported. The study emphasizes the mechanism by which CA inhibits cell proliferation in human cervical cancer cells (HeLa and ME-180) [48].

Curcumin (1,7-bis (4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione) is a natural polyphenolic compound extracted from the rhizome of the medicinal plant C. longa Linn (also known as turmeric). Curcumin has been used in food additive, cosmetic, and as a traditional herbal medicine for its various biological activities. The therapeutic value of curcumin demonstrated that it possesses anti-inflammatory, antioxidant, anti-carcinogenic, thrombo suppressive, cardioprotective, anti-arthritic, and anti-infectious properties. Several studies reported that curcumin suppresses all three stages of carcinogenesis: Initiation, promotion, and progression. It has been clear that curcumin and its product (ferulic acid) holds great potential for the prevention and therapy of cervical cancer [49].

Epigallocatechin-3-gallate (EGCG), the most abundant and potent tea catechin, has anti-tumor activity against various types of cancers both in vitro and in vivo [50]. EGCG is one of the various polyphenols found in green tea [51]. Studies showed that EGCG suppresses the cervical cancer cell growth in vitro through induction of apoptosis and cell cycle arrest at the G1 phase. It also has an ability to influence gene expression and provides an additional option for a new and potential drug approach for cervical cancer patients [52].

Frutalin is the α-galactose, a binding lectin isolated from breadfruit seeds was obtained from two different sources: Native frutalin, purified from its natural origin, and recombinant frutalin was produced and purified from Pichia pastoris. Similar concentrations of n-frutalin and r-frutalin yielded identical magnitude of cytotoxicity on HeLa cells and possess a remarkable antiproliferative effect on HeLa cells. Hence, the study demonstrated that both lectins, native frutalin, and recombinant frutalin, have similar irreversible cytotoxic effects on HeLa cells, by inducing cell apoptosis and inhibiting cell proliferation [53].

Gallic acid (GA) is a polyhydroxy phenolic compound which is widely distributed in gallnuts, sumac, grape, green tea, oak bark, strawberry, lemon, banana, pineapple, witch hazel, and apple peel and has a wide range of biological functions [54]. GA has the inhibitory effect on HPV-containing cells; inducing apoptosis and kills the cells containing HPV genome. Hence, the study suggested that GA can be a potential candidate for the development of anti-HPV agents and as a new lead for HPV infection therapy [55].

Genistein (4',5,7-trihydroxy isoflavone), the most abundant isoflavone found in soybeans, is believed to be a potent anticancer agent [56]. Genistein on human cervical cell lines (CaSki and ME180) reported that the augmentation of cell apoptosis induced by radiation may be due to the disruptive effect of genistein on the cell cycle, and it possesses a dose-dependent inhibition effect by G1 M arrest, specifically with ME180 cells [57] and also a radiosensitizing effect on CaSki and ME180 cells [58].

Guizhi-Fuling-decoction (GZFLD) is a long-established Chinese medical formulation. GZFLD is composed of five kinds of medicinal plants, C. cassia BLUME (Cinnamonaceae), Paeoniae diffusa PALL (Peonies Radix), Paeonia suffruticosa ANDREWS (Moutain Cortex), Prunus persica BATSCH (Persica Semen), and Pariococcus WOLF (Hoelen). Studies have disclosed that GZFLD could inhibit the development of cancer. It has also been shown that it suppresses the invasive ability of HeLa cells, inhibited matrix metalloproteinase (MMPs) expressions and activities, increased tissue inhibitors of metalloproteinases (TIMPs) expressions and activities, and furthermore restored the MMPs-TIMPs balance in HeLa cells in a concentration-dependent manner. Meanwhile, in vivo, GZFLD had significantly inhibited tumor growth and angiogenesis [59].

Hesperetin is a flavonoid obtained from citrus fruits. It is found to have several bioactivities such as antiatherogenic, anti-inflammatory, and antihypertensive effects. The treatment of SiHa cells with hesperetin (IC50) showed a marked concentration and time-dependent inhibition of proliferation and induced the G2/M phase in a dose-dependent manner. There was an increased expression of caspase-3, caspase-8, caspase-9, p53, Bax, and Fas death receptor due to the attenuation of the mitochondrial membrane. Thus, the study shows that hesperetin exhibits a potential anticancer activity against human cervical cancer cell lines in vitro through the reduction in cell viability and the induction of apoptosis [60].

Iridomyrmecin, which is a plant iroid compound, belongs to the polyphenolic group of naturally occurring compounds with significant antioxidant activity that exhibits potent cytotoxic effects and anti-tumor activity in HeLa cells through inducing early and late apoptosis, loss of mitochondrial membrane potential, sub-G1 cell cycle arrest, downregulation of PI3K/Akt protein expressions, and upregulation of IncRNA CCAT2 expression [61].

Isoquiritigenin (ISL) a flavonoid found in licorice (legume) and shallot (Liliaceae). It has a potent antioxidant, anti-inflammatory, antiplatelet aggregation, and cancer-preventing properties. It also inhibits HeLa cells by blocking cell cycle progression in the G2/M phase inducing apoptotic cell death, changes in the expression of Bax and Bak, decreasing levels of Bcl-2 and Bcl-XL, and subsequently triggering of the mitochondrial apoptotic pathway. Hence, the study suggested that ISL may be a promising chemopreventive agent against human uterine cervical cancer [62].

Kaempferol as flavonoids has antioxidant and anti-tumor properties and also shown to induce apoptosis in cancer cells. Cytotoxic activity of kaempferol against HeLa cells and human foreskin fibroblast (HFF) cell was determined by MTT as say. IC50 values were 10.48 µM for HeLa cells and 707.00 µM for HFF Cells. Kaempferol suppresses the growth of HeLa cells as compared with HFF normal cells. Kaempferol induced cellular apoptosis and aging, by regulating the p13K/AKT and bHERT pathways. Studies suggest that kaempferol may be a useful adjuvant therapeutic agent in the treatment of cervical cancer [4].

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Oleanolic acid ([3β-hydroxy-olean-12-en-28-oic acid]) belongs tooleanane triterpene group of natural products, possesses a range of promising biological and medicinal effects including the antiproliferative activity. Oleanolic acid methyl vanillate ester exhibits antitumor activity on HeLa cervical cancer cells by inducing both early and late apoptosis in a concentration-dependent and time-dependent manner and increase in the ROS production [63].

Polyphenols, a natural and herbal extract is raising great interest as powerful and safe anticancer strategy for their broad range targeting capability and low side effects. It displays a wide variety of biological function including induction of apoptosis, growth arrest, and inhibition of DNA synthesis. Further, they are involved in modulation of signal transduction pathway and also interfere with each stage of carcinogenesis. Hence, polyphenols have been demonstrated to selectively inhibit tumor cell growth and may be a promising therapeutic tool for the treatment of cervical cancer [49].

Protoapigenone, also known as WYCO2, a flavonoid was first isolated from Thelypteris torresiana, which contains in vitro cytotoxic activity against human cancer cells. It is found to be toxic to the cervical cancer cell lines C33A, HeLa, and SiHa. The studies demonstrated that the cervical cancer cells both in vivo and in vitro were suppressed by WYCO2 by the inhibition of PI3K signaling pathway. This pathway has an inhibitory effect on cancer cell proliferation as well as inhibition of AKT/MTOR activity, activation of caspases-9, -8, and -3, also PARP cleavage and promotion of apoptosis [64].

Resveratrol is a polyphenol found in the seeds and skins of grapes, red wine, mulberries, and peanuts. It is demonstrated to inhibit proliferation and induce autophagy and apoptotic death in cervical cancer cells. Hence, the study suggested that resveratrol inhibits NF-kB and AP-1 transactivation suppressing the transcription of MMP-9, leading to suppression of migration and invasion of cervical cancer cells [58].

Ruthenium (Ru) complexes were showed cytotoxic and anti-proliferative effects in different human cancers and also exert lower systemic toxicity in vivo as compared to platinum drugs [65]. It seems to be the most promising among the several metals investigated [66]. Lower systemic toxicity has been accredited to the unique ability of Ru compounds to preferably act on cancer cells. Ru complexes in principle may exhibit anticancer activity and toxic side-effects markedly different from that of Pt drugs. Ru complexes are emerging as most promising anticancer drugs in preclinical development in comparisons to other transition metal group and two complexes NAMI-A and KP1019 are currently in clinical trials. Thus, studies demonstrate that anticancer property of these two complexes was due to induction of apoptosis through p53 mediated pathway as well as the arrest of cells in the G2/M phase of cell cycle [65].

S. nigrum Linn. (Sn), known to be as Black Nightshade, is a dicot weed in the Solanaceae family. It has been in use in traditional Chinese medicine for many centuries [67]. Flavonoids (quercetin) and alkaloids (solasodine, solanine, and solamargine) are the primary phytoconstituents of S. nigrum which have been accounted for to act in different tumors [68]. It has inhibited the growth of cervical cancer [44] and showed significant antioxidant and antibacterial activities [69]. The effect of crude polysaccharide isolated from S. nigrum Linn (SNL-P) was examined both in vivo and in vitro on U14 cervical cancer cells [70]. The study indicated that the tumor growth inhibition of SNL-P administration might correlate with the reduction of tumor necrosis factor-alpha level of blood serum, which resulted in a massive necrosis in tumor tissues and the upregulation of Bax and downregulation of Bcl-2 and mutant p53 gene expression, which, in turn, triggered apoptosis in cervical tumor cells [67,71].

Sulforaphane identified as one of the most widely investigated isothiocyanates and a potential chemopreventive agent which possesses anti-proliferative, anti-inflammatory, and antioxidant agent. The effect of sulforaphane alone or in combination with gemcitabine on HeLa cells by cell viability assay was studied, and the results were confirmed by apoptosis assay. And also the effect of sulforaphane on the expression of Bcl-2, COX-2, and interleukin (IL)-1β by reverse transcription-polymerase chain reaction on HeLa cells was analyzed. A combination of sulforaphane and gemcitabine was found to increase the growth inhibition in a synergistic manner in HeLa cells compared to the individual drug. The expression analysis of genes involved in apoptosis and inflammation revealed significant downregulation of Bcl-2, COX-2, and IL-1β on treatment with sulforaphane. It exerts its anticancer activities through apoptosis induction and anti-inflammatory properties and provides the evidence demonstrating synergism between sulforaphane and gemcitabine which may enhance the therapeutic index of prevention and treatment of cervical cancer [72].

Tea polyphenols (TPP) are potent antioxidants that scavenge reactive oxygen and nitrogen species and chelate redox active transition metal ions. TPP contains several catechins compounds including EGCG, EGC, epicatechin-3-gallate, and other catechins that have a wide range of biological properties, such as anticancer, anti-allergic, anti-inflammatory, and cancer chemoprevention activities. Bleomycin (BLM), an antineoplastic antibiotic based chemotherapeutic agent that is produced by Streptomyces verticillus and it is used primarily to treat various types of redox-influenced cancer, including testicular cancer, lymphoma, and squamous cell cancer of the head, neck, and cervix. The TPP-BLM treatment synergistically induced apoptosis through caspase-3, caspase-8, and caspase-9 activation, Bcl-2 upregulation, and p53 overexpression. Studies suggested that TPP-BLM combination doses that are useful in the treatment of cervical cancer prevention or therapy [73].

Withaferin A (WA) is an active component of the medicinal plant Withania somnifera. It is found to exhibit inhibitory effects against different types of cancers and possesses anti-inflammatory, antitumor, antistress, antioxidant, immunomodulator, hemopoietic, and rejuvenating properties. Studies reported that WA induces p53-dependent apoptosis by repression of HPV oncoproteins and upregulation of tumor suppressor proteins in human cervical cancer cells and can be further explored as a potent therapeutic agent for the treatment and prevention without deleterious effects [39,74].

CONCLUSION

The mortality rate due to different types of cancer has been increasing in spite of several treatment strategies for cancer. Plant-derived molecules or drugs could be an effective alternative for the treatment of different types of cancer. This review is an attempt to understand different types of plants and molecules which are used for the cancer treatment, especially for cervical cancer.

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