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Therapeutics of Bioactive Compounds from Medicinal Plants and Honeybee Products against Cancer

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Every year, more than 12 million people are diagnosed with cancer worldwide. Cancer diagnosis is difficult for anybody to bear, and dealing with treatment is sometimes more complicated than the disease itself. When it comes to cancer treatment choices, chemotherapy is the most well-known since it is frequently used and recommended by specialists all over the world. On the other hand, chemotherapy is recognized for destroying healthy cells, and this destruction led to several negative impacts on the body. Recent advancements in biology have allowed scientists to better study the possible use of other methods, including phytotherapy and apitherapy for treating or managing many malignant conditions. Phytotherapy and apitherapy are among the best alternatives to chemotherapy as plants and honeybee products are chief sources of phytochemicals with anticancer properties. For example, hesperidin, melittin, apamin, artepillin, 10-hydroxy-2-decenoic acid (10-HDA), Major Royal Jelly Proteins (MRJP), jelleins, royalisin and caffeic acid phenethyl ester are important plant and bee engineered product constituents which by inducing apoptosis and arresting cell cycle control the proliferation of cancer cells. In general, this review highlights problems related to cancer treatment using chemicals. It discusses phytotherapy and apitherapy as an alternative to chemotherapy, while plants and bee products rich in natural anticancer compounds have greater potency to treat cancer.

Keywords: Apitherapy, Bee engineered products, Chemotherapy, Phytochemicals, Phytotherapy, Side effects

Introduction

The word chemotherapy was coined by the German chemist Paul Ehrlich and explained it as using chemicals to medicate cancer. Chemotherapy began in the 1940s with the first use of nitrogen mustard for treating lymphomas.[1] In the 1950s, the effect of plant alkaloids was studied, and it was found that alkaloids from *Vinca rosea* were beneficial against leukemia patients. The studies on different mechanisms of action brought a revolution in the study of cancer using chemicals and thus led to further improvements in patient survival and ultimately declined the mortality rate. Nowadays, chemotherapy has advanced; some drugs are less toxic and more targeted in their effects. Despite significant advances in cancer drugs, the disease is still the primary cause of death, with breast and cervical cancer being the most frequent causes.

Despite the progress made in surgical and radiation treatments, chemotherapy remains a crucial aspect of cancer treatment, particularly in cases of primary, advanced, and metastatic tumors. Chemotherapy is also employed for recurrent tumors, utilizing conventional anticancer therapies. Nevertheless, one of the primary issues with chemotherapy is its tendency to damage healthy cells in addition to cancer cells, resulting in numerous side effects. Chemotherapeutic drugs function by eliminating rapidly dividing cancer cells, but they may also destroy healthy cells in locations such as the bone marrow, digestive tract, and hair follicles.[2]

Chemotherapy can cause significant side effects, which can hinder cancer treatment and negatively impact the patient's health and quality of life. However, advancements in cancer treatment have led to the development of new therapies such as immunotherapy, thermal therapy, gene therapy, phytotherapy, and apitherapy, which can effectively reduce chemotherapy resistance.[3,4] These treatments have varying degrees of effectiveness due to differences in drug resistance mechanisms among patients. In addition, natural products like plant-based and honey bee engineered products have been found to inhibit cancer cell growth and induce tumor cell apoptosis, indicating that their bioactive constituents can be used as an alternative

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treatment or in combination with pharmaceutical drugs to treat cancer.[5]

Natural products, including medicinal plants and honey bee engineered products, are often considered to be less potent than conventional cancer drugs, but they offer a safer alternative and are an important source of anticancer compounds. Although some natural products may harm healthy cells, many work by enhancing the immune system and selectively targeting infected or transformed cells. Despite their potential as a source of novel and effective anticancer drugs and adjuvants, natural products remain an underexplored area of research.[6,7] Therefore, researchers have investigated the use of honey bee engineered products and medicinal plants for the development of anticancer drugs.[8,9]

Chemotherapy Drugs and Treatment

Chemotherapy is a crucial medical field that focuses on using drugs to treat cancer. These drugs are designed to target rapidly dividing or uncontrollably growing cells while minimizing the damage to healthy cells. Chemotherapy works by attacking different stages of the cell cycle, using chemotherapeutic or alkylating agents as part of a standardized treatment plan.[9] The use of these agents can improve symptoms and extend the patient's lifespan, as shown in Table 1.

Side Effects of Chemotherapy

While chemotherapy and radiotherapy are effective in killing cancer cells, they also harm healthy cells, causing harmful side effects that can be more dangerous than cancer itself and even lead to death.[6] The physiological and psychological impact of chemotherapy has both advantages and disadvantages[12] with side effects falling into two categories: short-term effects that occur during chemotherapy and resolve within a few months, and long-term effects that have a delayed onset and can persist for many years.[13] Common short-term side effects include nausea, vomiting, fatigue, hair loss, and decreased appetite.[14–16] while numbness or tingling in the hands and feet, mucosal membrane damage, fever, allergic reactions, diarrhea, skin problems (such as dryness, redness, and itching), flu-like symptoms, hearing loss or ringing in the ears, memory loss, and decreased kidney function are among the other notable side effects.[2]

Regarding the long-term effects, chemotherapy causes osteoporosis, bone marrow toxicity, heart-related or cardiovascular issues, hemorrhagic cystitis, lung related issues, gastrointestinal issues, renal issues, cognitive problems, mental health conditions, hormonal issues, nerve damage, dental issues and chronic effects like infertility.[17–19] In this scenario, chemotherapeutic complications and multidrug resistance are serious threats to deal with.[20] Therefore, research on alternative compounds having minimum side effects and antitumor selectivity is encouraged.

Management of Common Side Effects of Chemotherapy

The conventional treatment for cancer involves surgery, chemotherapy, and radiotherapy. Chemotherapy is administered to kill rapidly dividing cancer cells, but it also damages normal cells since it does not distinguish between the two types of cells. Consequently, the therapy is associated with various short-term or long-term side effects that depend on their frequency of occurrence. To manage chemotherapy side effects and improve the quality of life, different medications and self-care practices have been recommended.[21,22] The World Health Organization (WHO) defines self-care as the management of symptoms, treatment, and its consequences, whether

Table 1 — Chemotherapy drugs, their malignancies and mode of action

Drugs[Ref]	Examples	Malignancy	Mode of action
Alkylating agents[10]	Bendamustine, cyclophosphamide, ifosfamide, carmustine, lomustine, carboplatin, cisplatin, oxaliplatin, Dacarbazine, procarbazine, temozolomide, Busulfan, Thiotepa	Lung cancer, ovarian cancer, breast cancer, leukemia	DNA damage
Anti-metabolites[11]	Azacitidine, decitabine, cytarabine, gemcitabine, methotrexate, pemetrexed, cladribine, clofarabine, nelarabine, fluorouracil (5-FU), capecitabine (prodrug of 5-FU).	Breast cancer, anal cancer, pancreatic cancer, colorectal cancer, ovarian cancer	DNA and RNA damage
Anti-microtubular agents[10]	Doxorubicin,daunorubicin, idarubicin, mitoxantrone,Irinotecan, Topotecan, paclitaxel, docetaxel, cabazitaxel, vinblastine, vincristine, vinorelbine	Lung cancer, ovarian cancer, breast cancer, neuroblastoma, prostate cancer, cervical cancer	Inhibition in DNA repair and disruption in microtubule formation
Miscellaneous[11]	Hydroxyurea, arsenic trioxide, proteasome inhibitors, tretinoin	Used for different cancer	Inhibits cell differentiation

physical or psychological, as well as changes in lifestyle associated with living with a chronic condition. Hence, self-care strategies have been proven to reduce the side effects of cancer treatment and improve physical and psychosocial outcomes[23]

Short-term Side Effects and their Management

One effective way to minimize the impact of medication and eliminate toxins from the body is to increase fluid intake.[24] Hair loss is a common psychological side effect of chemotherapy[25] which can be managed by using a wig[26–28] or by shaving the scalp to reduce itching.[29] Nausea and vomiting are also common symptoms during or after chemotherapy[30], which can be managed with antiemetic drugs such as corticosteroids, serotonin antagonists, and dopamine antagonists, as well as by consuming small and light meals.[31] Chemotherapy-induced fatigue is linked to anemia and can significantly impact the patient's functional status[32–34] but can be relieved by improving the concentration of red blood cells and increasing energy levels. Constipation is another common side effect that often worsens as the disease progresses[35], which can be prevented or minimized by increasing dietary fiber intake, using laxatives, consuming fruits, and engaging in mild exercises.[35, 36]

Long-term Side Effects and their Management

Chemotherapy often results in chronic side effects such as infertility, osteoporosis, joint pain, and bone loss. However, these can be treated or prevented by adopting various self-care strategies. For instance, infertility can be addressed through embryo cryopreservation.[37,38] Osteoporosis, joint pain and bone loss can be managed with calcium and vitamin D supplementation and regular exercise to promote muscle strength.[39–40] Adopting a healthy lifestyle, including a nutrient-rich diet (low in fatty acids, especially saturated ones, high in fiber-rich fruits and vegetables, and whole grains), physical activities and regular exercise, and avoiding drinking and smoking can prevent cardiovascular diseases, cancer recurrence, and overall mortality rates.[41–45] Neuropathy resulting from chemotherapy can be managed through the use of antiseizure drugs that can relieve tingling sensation, and numbness in the feet and hands.[46] Increasing awareness of the harmful consequences of chemotherapy and promoting self-care techniques for managing its side effects can greatly improve the quality of life of cancer patients.

Alternatives to Chemotherapy

Phytotherapy

Phytochemicals found in plants have significant potential in the treatment of various diseases, including cancer (Table 2). About 75% of the plant-derived drugs currently used in clinical settings have origins in traditional phytomedicines.[82] Plants produce secondary metabolites, such as phytoconstituents, to defend against herbivores and pathogens, and these compounds also have pharmaceutical properties[83] (Fig. 1). Phytochemicals have many potential health benefits, such as reducing inflammation, enhancing the immune system, and inhibiting cancer cell growth. Vegetarian diets, which are rich in phytochemicals, have been linked to a healthier lifestyle and a reduced risk of serious diseases like cancer and cardiovascular disease. Phytochemicals can be categorized into several groups, including phenolics, flavonoids, tannins, saponins, alkaloids, organosulfur compounds, carotenoids, and nitrogen-containing compounds. Studies indicate that phytochemicals work together synergistically to provide potent antioxidant and anticancer effects.[84]

Recent studies have highlighted the significant impact of a nutrient-rich diet on cancer prevention.[85] While all plants and bee engineered products contain phytochemicals, certain foods, such as kale, broccoli, brussels sprouts, berries, tomatoes, garlic, lentils, spinach, carrots, turnips, olives, pears, soynuts, celery, apricots, onions, soybeans, green tea, and cabbage, are particularly rich in these beneficial compounds (Fig. 2). For instance, onions and garlic are a great source of allicin, a chemical that can block certain toxins from microorganisms. Berries, including raspberries and blueberries, are rich in anthocyanins, which help slow down aging, prevent blood clots, reduce inflammation, and protect against heart disease.

Carotenoids, such as those found in deep green vegetables and fruits like spinach, tomatoes, oranges, and pink grapefruit, are known to be rich sources of beneficial compounds. Indoles, which are known to destroy cancer-causing chemicals, are present in cruciferous vegetables such as cabbage, kale, brussel sprouts, and broccoli. Green tea, onions, apples, kale, beans, citrus fruits, cereals, and legumes are excellent sources of phenolics and flavonoids that protect against cancer, heart problems, allergies, and inflammation. Tomatoes are a rich source of lycopene, which reduces the risk of cancer and heart attacks.[86] Incorporating fruits and vegetables that are

Table 2 — Chemical compounds from plants and their anticancer activities

Name of the compound[Ref]	Biological activity	Target organ
Garcinol[47]	Anticancer	Pancreatic
Flavonoids[48,49]	Anticancer	Breast
Triterpenoids[50]	Anticancer	Lung
β-Lapachone[51]	Anticancer	Breast
Ellagic acid[52]	Antimetastatic	Ovarian
Diterpenoids, volatile oils, tannins[53]	Anticancer	Breast
Anthraquinones emodin and aloe-emodin[54]	Anticancer	Breast
Ellagic acid[55]	Anticancer	Esophageal
Glycosides, tannins, flavonoids, sterol[56]	Anticancer	Breast
Punicalagin[57]	Anticancer	Breast
Polyphenols[58]	Anticancer	Skin
piperine, piperlongumine, guineensine, chabamide, pellitorine[59]	Apoptosis	Malignant, non-malignant
Gallic acid[60]	Anticancer	Breast
Anthocyanin[61]	Anticancer	Lung
Arginine, oligosaccharides, flavonoids, selenium[62]	Anticancer	Breast
β-sitosterol[63]	Antiproliferative, apoptosis	Colon
Terpenoids, di-terpene alcohols, tri-terpenes, phenolic compounds[64]	Anticancer	Breast
Carotenoids[65]	Antiproliferative	Colorectal
α-linolenic acid[66]	Antiproliferative	Breast
Phloretin[67]	Antiproliferative, apoptosis	Lung
Corilagin[68]	Apoptosis	Ovarian
Epigallocatechin-3-gallate[69]	Antiproliferative	Breast
Curcumin[70]	Apoptosis	Breast
Epigallocatechin[71]	Apoptosis	Blood
Ginsenosides[72]	Antiproliferative	Breast
Curcumin, demethoxycurcumin, and bisdemethoxycurcumin[73]	Anticancer	Variety of tumor cells
Fucoxanthin[74]	Anticancer	Breast
β-sitosterol and 2-hydroxy-1,2,3-propanetricarboxylic acid, 2-methyl ester[75]	Anticancer	Colon
Limonoids[76]	Antiproliferative	Pancreatic
2-hydroxy-1,2,3-propanetricarboxylic acid, 2-methyl ester[77]	Anticancer	Colon
Phenols and flavonoids[78]	Anticancer	Breast
Lectins[79]	Antiproliferative	Breast
Catechins[80]	Anticancer	Skin
Glucosinolates[81]	Anticancer	Lung and colorectal

rich in these secondary metabolites into our daily diet is crucial to reap their health benefits. Furthermore, some active compounds have been isolated from plants and tested in chemotherapy programs.

Anticarcinogenic Agents Derived from Plants

Several natural compounds derived from plants have been tested for their potential anticancer activities. The first such compound was an alkaloid isolated from *Vinca rosea*. Other examples include vinblastine and vincristine, which were extracted from *Catharanthus roseus*, and taxanes, which are a group of molecules derived from plants. Campothecin derivatives have been isolated from *Camptotheca acuminate*, and homoharringtonine is derived from *Cephalotaxus harringtonia*. Acetogenins are extracted from *Annona muricata*, and phenyl-1,3,5-heptatriyne is derived from *Bidens pilosa*. Tubeimoside-V comes from *Bolbostemma paniculatum*, cannabinoids from *Cannabis sativa*, epigallocatechin-3-gallate (EGCG) from *Camellia sinensis*, gossypol from *Gossypium hirsutum*, hypericin from *Hypericum perforatum*, tanshinone-I from *Salvia miltiorrhizae*, quinines and hexapeptides from *Rubia cordifolia*, and apigenin, chrysin, wogonin, baicalin, and scutellarein from *Scutellaria* spp. Other examples include kaempferol-7-O-beta-D-glucoside from *Smilax china*, ellagic acid, tannic acid, and chebulinic acid from *Terminalia chebula*, and withaferin-A from *Withania somnifera* (Ashwagandha).[87]

Apitherapy

Bee engineered products, such as propolis, pollen, honey, bee venom, beeswax, and royal jelly, have been used for centuries as food and medicine due to their rich diversity of phyto-constituents. Pharmaceutical companies have shown interest in these products due to their therapeutic potential as anticancer medicines, and scientific studies have further increased this interest in apitherapy.[88] While

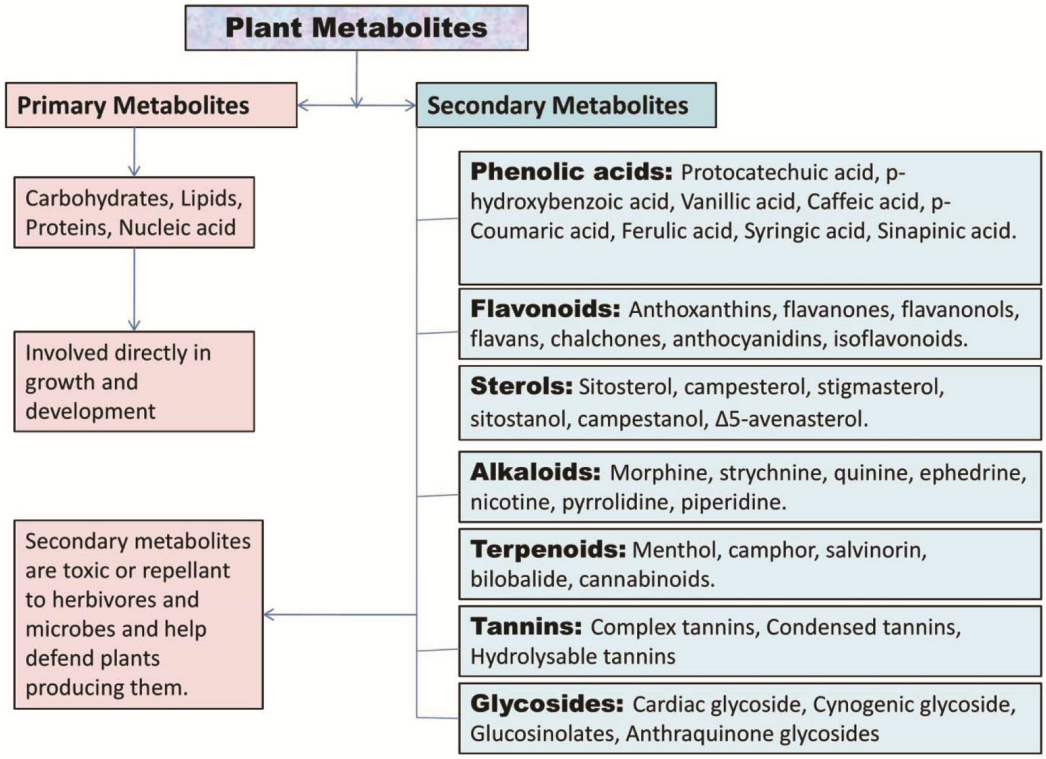

Fig. 1 — Secondary metabolites from plants

Fig. 2 — Fruits, vegetables and bee engineered products that help in preventing cancer

some products, like bee venom, royal jelly, and beeswax, are chemically synthesized by honey bees, others, such as pollen, propolis, and honey, are collected from plants and modified by bees for their use. The bees collect these substances, add their secretions, process them in the hive, and finally allow them to ripen, which then serve as commercial bee hive products. Recently, a new trend has emerged with the use of bee ecological bodies, which consist of bee larvae, bee pupae, and bee corpses. These bodies are rich in proteins, lipids, and sugars, and have therapeutic potential such as antitumor, antimetastatic, and antidepression properties, as well as the ability to inhibit the development of atopic dermatitis-like sun lesions[89–92] (Fig. 3) Compounds such as alkaloids, terpenes, and phenolics obtained from these natural products have shown promise in inhibiting uncontrolled cell growth, preventing metastasis, and inducing cell death in several cancer lines, including liver, lungs, renal, prostate, lymphoid, and thyroid cancers, indicating their potential as alternative therapies[93] (Fig. 3). Overall, honey bee engineered products can be categorized into four types, each with unique therapeutic potential: (a) bee products synthesized by honey bees, (b) bee products derived from plants and modified by bees, (c) bee ecological bodies, and (d) other products such as bee bread (Fig. 3). Among them some of the bee engineered bioactive compounds are competitive with standard drugs such as; melittin, apamin, 10-HDA, artepillin and CAPE (Fig. 4).

Bee Products Synthesized by Honey Bees

Bee Venom: Bee venom, also known as apitoxin, is an essential substance produced by venom glands and stored in the venom sac located at the end of the abdomen of honey bees, both workers and queens. It is primarily composed of peptides, including melittin, apamin, mast cell degranulating peptide (MCD), and enzymes such as phospholipase-A2, hyaluronidase, as well as biologically active amines, like histamine and dopamine.[94,95] The protein content of bee venom ranges from 48–58% consisting of small proteins and peptides, while enzymes constitute 15–17%, and amino acids make up 0.13–1%. Additionally, it contains 2-4% carbohydrates, 4–5% lipids, 4–8% of volatile components (pheromones), and 3–4% minerals.[88,96] Melittin is the most abundant component of bee venom, accounting for 40–60% of its composition. It is known for its potent biological

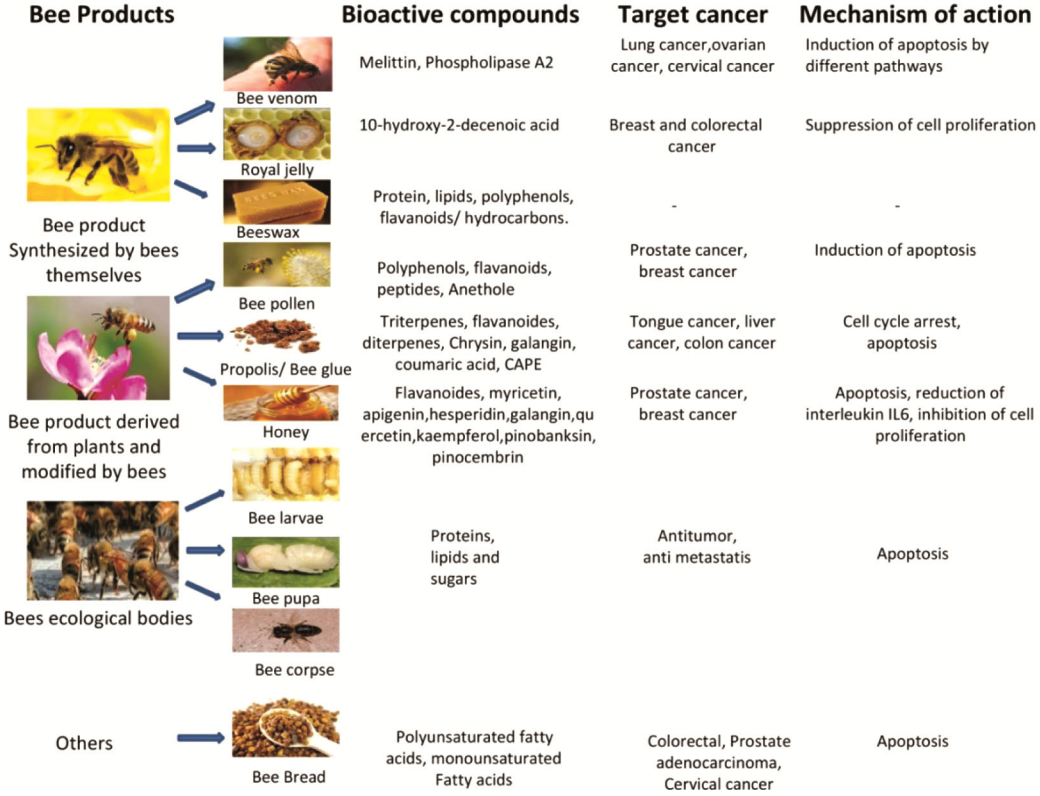

Fig. 3 — Bee products, their anticancerous bioactive compounds and mechanism of action

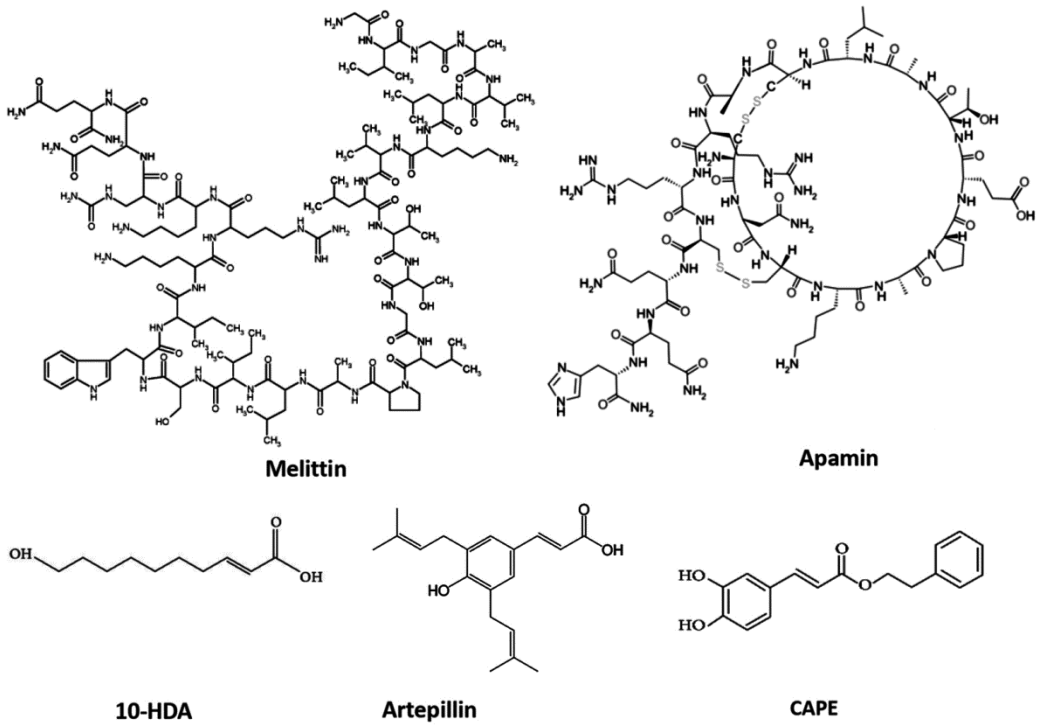

Fig. 4 — Important bioactive components of bee products competitive with standard drugs

activities against tumor cells, as it can create pores in membranes and disrupt their integrity in a non-selective manner, leading to hemolysis, antimicrobial and anticancer activities.[94,95]

Bee venom exerts its anticancer effects by altering the cell cycle, suppressing the activation of growth factor receptors, inducing apoptosis, inhibiting cell migration and proliferation, as well as regulating the activity of caspases and matrix metalloproteinases, which play a role in apoptotic and necrotic cell death. Numerous studies have supported the anticancer properties of bee venom against various types of cancers, including breast, cervical, ovarian, prostate, colon, pancreatic, and malignant hepatocellular carcinoma in humans.[97–101]

Royal Jelly: Royal jelly, a milky secretion produced by worker honey bees from their hypopharyngeal and mandibular salivary glands, is a highly nutritious substance.[102] It serves as the primary source of nutrition for young worker larvae during their first three days of life and for the entire lifespan of colony queens, making it a super food.[103] The major components of royal jelly include water, sugar, proteins and lipids (with 90% of the lipids being free fatty acids), while enzymes, amino acids, vitamins, hormones, and minerals are present in smaller amounts.[104,105] The bioactive peptides, which are the primary proteins found in royal jelly, are responsible for its various pharmacological and therapeutic properties.[106] Recent studies have demonstrated that royal jelly possesses therapeutic potential, including antioxidative, anticancer, anti-aging, antimicrobial, antiproliferative, and anti-inflammatory activities. These properties can arrest or inhibit the proliferation of cancer cells and tumorigenesis by activating immune cells and inhibiting tumor-induced angiogenesis.[107] Due to these benefits, royal jelly is commonly used in the preparation of functional foods, nutraceutical products, and cosmetics.

The mechanism of action behind the anticancer activity of royal jelly is attributed to the presence of 10-hydroxy-2-decenoic acid (10-HDA), a major fatty acid component found exclusively in this milky secretion of worker honey bees. 10-HDA plays a significant role in suppressing tumor metastasis and malignant invasiveness.[104,108,109] In addition to 10-HDA, other compounds identified for their anticancer properties in royal jelly include hesperetin, naringenin, isosakuranetin, chrysin, acacetin, luteolin, coumestrol, apigenin, genistein, and formononetin.[110] It is worth noting that among the various bee products, 10-HDA is unique to royal jelly.

Beeswax: Worker honey bees possess wax glands in their abdominal segments, which produce a crystalline liquid called beeswax, suitable for constructing honeycomb.[111] Beeswax is composed of over 300 constituents, with mono wax esters (35–45%), complex wax esters (15–27%), hydrocarbons (12–16%), and free fatty acids (12–14%) being the main components, along with vitamins and minerals. Although beeswax is commonly used as an additive in the nutraceutical, pharmaceutical, and cosmetic industries, there is limited literature available on its potential as an anticancer therapeutic agent.[112–114]

Bee Products Derived from Plants

Propolis: Propolis, also referred to as bee glue, is a substance that is gathered by worker bees from the sap flows, tree buds, and other botanical sources. The bees mix this resin-like material with their saliva and beeswax to create a defensive and sealing material for their hive.[115,116] It helps to keep out unwanted intruders and regulate the temperature within the hive for optimal growth. Additionally, it is utilized as an embalming material for larger deceased organisms, which helps to maintain a clean and sterile environment within the hive.[117] The presence of certain chemical components in propolis, such as aromatic acids, phenolic acids, carbohydrates, terpenes, and alkaloids, are responsible for its pharmacological and therapeutic properties.[118–121] Terpenes, in particular, are known for their anticancer potential.[122,123] Compounds like caffeic acid, caffeic acid phenethyl ester (CAPE), quercitin, artepillin C, and other polyphenols found in propolis have been shown to induce apoptosis/necrosis and prevent abnormal cell division in carcinomas and malignant melanomas.[124–131]

The mechanism of action of propolis involves natural cell death, which can occur through either an energy-dependent or independent process known as apoptosis and necrosis.[132–134] In addition to apoptosis and necrosis, secondary necrosis, also known as late apoptosis, can occur when phagocytes are not available, or due to physicochemical injuries.[135,136] The regulation of these pathways is typically governed by intracellular proteolytic enzymes called caspases, as well as the BCL protein family. The BCL family can be subdivided into BH3 proteins, which promote the onset of apoptosis; BCL2 proteins, which support anti-apoptotic action to ensure cell survival; and BAK and BAX, which are pro-apoptotic effector proteins.[137]

Pollen: Pollen, also known as the life-giving dust, is collected by worker honey bees from the male gametophyte of flowering plants, along with floral nectar and salivary secretions, to feed developing larvae in the hive.[138,139] This substance is rich in carbohydrates (35–61%), proteins (14–30%), lipids (1–13%), as well as both saturated and unsaturated fatty acids.[140,141] Pollen is also an abundant source of both micro and macro nutrients, including water-soluble (0.6%) and fat-soluble (0.1%) vitamins.[142, 143] Due to its impressive nutritional composition, pollen is considered the world's best food with pharmacological properties.[144] These therapeutic properties are attributed to the presence of phytoconstituents such as flavonoids (e.g., kaempferol, quercetin, isorhamnetin, apigenin, catechin and epicatechin, naringenin, luteolin, and hesperetin), phenolic acids (e.g., caffeic, p-coumaric, rosmarinic, vanillic, p-hydroxybenzoic, and protocatechuic acids) and tannins.[139,145,146]

Honey: Honey, also known as liquid gold, is produced by honey bees from honeydew and nectar of plants, and is the most important and versatile product of the bee hive in terms of its economic value.[147] The floral nectar is collected, mixed with salivary secretions, and then stored in honeycomb to ripen.[147] The chemical composition of honey is highly dependent on various factors, such as the species of honey bee, the flora of the area, as well as climatic, geographic, and storage conditions.[148] Honey is chemically complex, composed mainly of sugars with small quantities of acids, minerals, vitamins, enzymes (invertase, glucose oxidase, sucrose diastase, acid phosphatase, diastase, catalase, and amylase), antibiotic substances, and amino acids (alanine, asparagine, glutamine, glycine, and proline). The main sugars in honey are reducing sugars, namely dextrose and laevulose/fructose, which are absorbed directly into the bloodstream upon human consumption after passing through the stomach's mucous membrane.[149] The phytoconstituents responsible for honey's anti-cancer properties are primarily flavonoids such as apigenin, catechin, naringenin, quercetin, hesperetin, kaempferol, myricetin, luteolin, chrysin, and galangin.[113]

Conclusions

Cancer is a debilitating disease that affects various cell signaling pathways. Although chemotherapeutic treatments are cost-effective, they often have severe

side effects that may be more harmful than cancer itself. Hence, research on medicinal plants and bee-engineered products is crucial to identify novel therapies that minimize after-effects, enhance the efficacy of current treatments, and facilitate the development of more potent drugs. Some components of these natural products, such as melittin, apamin, artepillin, 10-HDA, MRJP, royalisin, jelleins, and CAPE, have shown promising results and are competitive with standard drugs. However, only CAPE has been reported in online clinical trial databases, indicating a need for clinical trials and standardization of the bio-prospecting potential of phyto-therapeutic and api-therapeutic products.

Conflict of interest

Authors declare no conflict of interest.

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