Indian Journal of Biochemistry & Biophysics
Vol. 63, June 2026, pp. 621-636
DOI: 10.56042/ijbb.v63i6.26567

A Review

The oncological significance of plant oils: A synthesis of their anti-proliferative and pro-apoptotic effects on breast cancer pathogenesis

Abdelalim Yacoub Abusabha[1], Maysa Alhawamdeh[2]*, Idris Ali Alyami[1], Nawaf Mohammed Alyami[1], Faisal Hussain Alyami[1], Dhafer Mahdi Alyami[1], Abdullah Mana Alzelyq[1], Hamad Mohammed Balhareth[1], Ayidh Mahdi Alnajrani[1], Rakan Mohammed Al Sharyah[1], Mohammed Mahdi Al Sharih[1], Sara Ahmed Mekkawy[3] & Mohamed Omar Mohamed[4]

[1]Dar Al-Ahfad School for Education, Al Athaybah District, Najran 66258, Saudi Arabia

[2]Department of Medical Laboratory Sciences, Faculty of Allied Medical Sciences, Mutah University, Al Karak 61710, Jordan

[3]Molecular Biotechnology program, Chemistry Department, Faculty of Science, Helwan University, 11795, Cairo, Egypt

[4]Ain Shams University, Faculty of Agriculture, Agriculture Biotechnology Program, P.O. Box 68, Hadyek Shoubra, 11241, Cairo, Egypt

Received 18 December 2025; *revised 25 March 2026*

Breast cancer continues to be a significant global health issue, prompting the continuous pursuit of innovative therapeutic and adjunctive approaches. This review offers an extensive examination of the existing scientific evidence regarding the anti-cancer efficacy of plant-derived oils in relation to breast cancer pathogenesis, with a specific emphasis on differentiating their two primary categories: fixed oils (vegetable oils) and essential oils. Fixed oils, such as extra-virgin olive oil and flaxseed oil, mainly exert their effects by their fatty acid compositions and non-volatile phenolic compounds, demonstrating mechanisms such as estrogen receptor modulation and HER2 inhibition. Plant-derived essential oils, which are rich in volatile terpenes and phenols, such as frankincense and Zataria multiflora, primarily provoke apoptosis by oxidative stress and mitochondrial dysfunction. We conduct a systematic analysis of the *in vitro* and *in vivo* evidence that substantiates their anti-proliferative and pro-apoptotic effects across diverse breast cancer subtypes. This review essentially focuses on the significant gap between actual *in vitro* concentrations and doses that can be reached *in vivo*. We underscore the necessity for subsequent research to transcend descriptive studies and address critical issues in bioavailability, standardized efficacy, and the advancement of sophisticated delivery systems. The review seeks to elucidate this intricate domain, repositioning plant-derived oils from simple alternative medications to a significant repository of bioactive compounds, pioneering pharmaceutical strategies and requiring rigorous scientific validation for their oncology integration.

Keywords: Effects of therapy, Essential oils, Oncological mutations, Phytotherapy, Plant oils

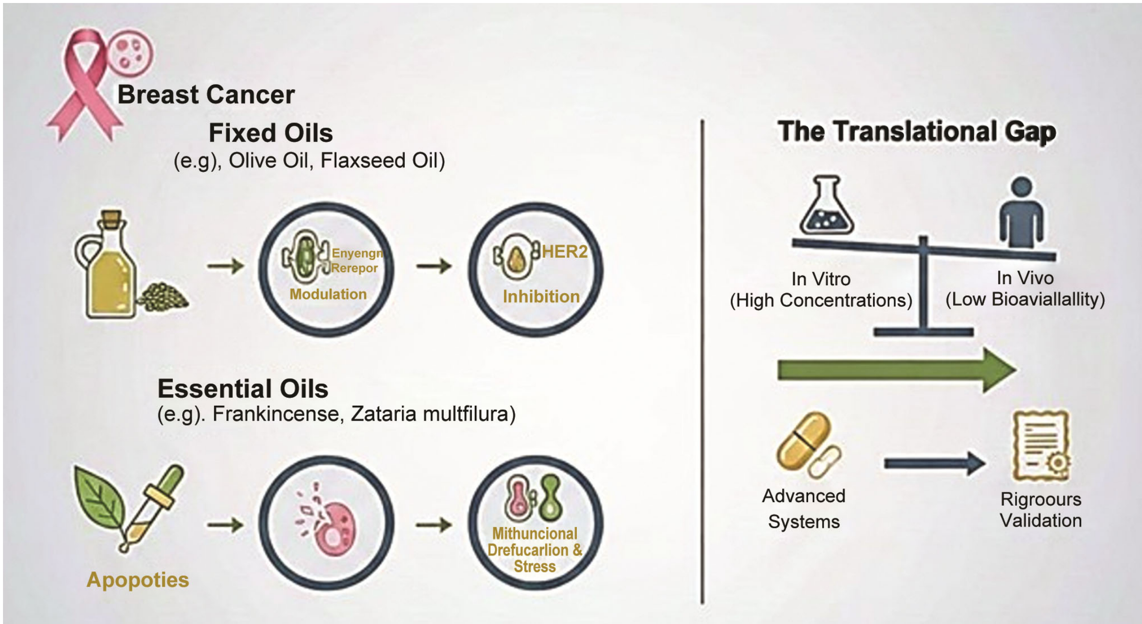
Introduction

Phytotherapy, or plant-based medicine, has been used for a long time in traditional medicine and is becoming more popular in modern medicine. It uses plant extracts and compounds for medical purposes, usually because of their natural chemical properties. Phytotherapy is not the same as traditional herbalism because it employs a scientific methodology to identify and elucidate the active properties of plant materials. These plants have been used in traditional medicine for hundreds of years, and scientists are now working to make them safer and more effective. Phytotherapy is a promising area for new ideas in both personalized and preventive medicine. It is a long-lasting and cheap alternative to traditional drugs. It is especially helpful in places where there are not many resources and medicinal plants are the main source of health care[1]. Many plants under cultivation are used as sources of oils, including trees, palms, and herbaceous plants. Genetic engineering has provided many vegetable oils with different formulations of amino acids.

More recently, the oils are chemically extracted using hexane, macerated oils, or infused oils, and other materials such as herbs and flowers are added to them. Essential oils are volatile aromatic compounds and are often utilized in aromatherapy; they are considered a type of alternative medicine and are used for health purposes and can be easily extracted via the distillation process.

Merchants who offer medicinal oil often advocate for its use in medical treatments, from skin conditions to cancer, which is based on past accounts of the

*Correspondence:
E-mail: maysa5005@mutah.edu.jo



Graphical abstract

Table 1 — How to differentiate between Fixed Oils and Essential Oils?

Feature	Fixed Oils (Vegetable Oils)	Essential Oils
Chemical Nature	Mainly triglycerides (fatty acids)	Aromatic Volatile compounds (terpenes, phenols, etc.)
Extraction Method	Solvent, pressing extraction (hexane)	Distillation (steam/water), cold pressing (citrus)
Solubility	Hydrophobic (organic solvent)	Hydrophilic (water solvent)
Primary Use	Nutrition, cosmetics, and cooking	Flavouring, aromatherapy, and topical applications
Pharmacological Focus	Fatty acid profiles, antioxidant phenols	Bioactive volatiles, receptor interactions
Examples in Review	Olive, Coconut, Flaxseed, Safflower	Frankincense, Geranium, Pine Needle, *Zataria multiflora*

medicinal qualities of essential oils. However, the claims of its efficacy in medical practices and cancer treatments are now monitored and regulated in various countries. Vegetable oils, also known as plant oils, come from plants and are thought to oppose animal fat and petroleum. The primary two plant oils are fixed oils (triglyceride-based) and essential oils (volatile compounds), which differ in how the plant is extracted and the oil is produced[2].

Vegetable fats and oils were traditionally extracted by applying pressure to a section of the plant and pressing it. These are the most used oils, even to this day. Triglyceride-based cooking oils include the famous canola oil, as well as solid oils such as cocoa butter, oil used in paints, and industrial oils. One of two kinds of oil presses can be used to obtain pressed vegetable oils from plants, typically from the seeds. The screw press, largely widespread, consists of a metal screw in a large-diameter metal housing. Oil seeds are kept in a box where torches flush the seeds. This exerts pressure on the seeds to release the oil through the small holes in the press's side.

The human diet gets most of its calories and essential fatty acids from triacylglycerol-rich vegetable oils. TAG fatty acid concentration is essential in measuring the nutrition and health benefits in vegetable oils. This also relates to the characteristics of the oil. Oil seed crops originated by selecting and duplicating fatty acid biosynthetic differences in vegetable oils with nutritional characteristics (Table 1).

These accomplishments have been effective in producing oils with modified contents of fatty acids in the seeds' TAG. Nonetheless, their genetic diversity is not enough to produce "healthy" oils and is usually not present in the main oleaginous seeds. However, such efforts are not sufficient. Instead, the evolution and use of biotechnological tools have allowed numerous oil seeds to be generated that develop new compositions of fatty acids of enhanced nutritional values, including plants, bacteria, and fungi, through genetic engineering[3].

Plant-derived oils: chemistry and sources

Plant-derived oils come from a variety of places. The seeds or seed coats of plants are the prevalent sources. These oils enhance the flavor of foods and can be used as a cooking medium. Plant oils have become more diverse in recent decades.

Oils with high unsaturated fatty acids

Safflower seed oil

Made from the safflower plant's seeds, with the highest concentration of unsaturated fatty acids. According to certain research, there may be some health advantages to utilizing it on the skin and in the diet. Unroasted safflower oil is comprised of 11.00% oleic, 1.6% stearic, 5.5% palmitic, 81.5% linoleic, and 0.40% linolenic acid. While roasted safflower seed oil at 180°C is comprised of 0.42% linolenic acids, 1.69% stearic, 10.9% oleic, 82.0% linoleic, and 4.99% palmitic acids[4].

Sesame seed oil

Sesame seeds are used to make this oil, which is found in many different cuisines for cooking and for added flavor. It has a characteristic nutty scent and flavor. Sesame seed oil (*Sesamum indicum* L.) was among the earliest known plant-based oils and a greatly vital oil worldwide. Its fatty acid content is as follows: saturated fatty acids: (8.58%) palmitic, (5.44%) stearic, and (0.9%) arachidic acids; and unsaturated fatty acids: (46.26%) linoleic, and (38.84%) oleic acids[5].

Rice bran oil

It is the oil pulled from the tough outer brown coating of rice called chaff (rice husk). It is generally used as a cooking oil in India, Nepal, Bangladesh, Japan, Indonesia, and other East Asian nations.

Rice bran oil has an analogous fatty acid texture to that of peanut oil, with 38% monounsaturated, 25% saturated, and 37% polyunsaturated fatty acids. The antioxidant oryzanol, which accounts for about 2% of the crude oil content in rice bran oil, is one of its major components. The tocols present in rice bran oil are found to exhibit anticancer and antioxidant properties[6].

Coconut oil

In industrial uses, it is utilized as an edible oil. Its sources include coconut palm fruit's kernels, meat (pressed dried or fresh coconut meat called copra), and milk.

Coconut oil's chemical composition: coconut oil (CNO) contains 90% saturated fatty acids (SFAs), believed to be in charge of several therapeutic and nutritional attributes, such as antioxidant qualities. CNO is made up of medium-chain fatty acids (MCFAs), accounting for around 64% of total fats. CNO is also known as lauric acid because it accounts for 40–50% of all fatty acids (Table 2).

CNO is comprised of about 90% SFAs and esterified triacylglycerol (TAGs). CNO also includes other elements such as phospholipids, sterols, tocopherols, and volatile compounds. SFAs are comprised of mono-unsaturated FAs (MUFAs) and polyunsaturated FAs (PUFAs) based on the length of the chain, which can be short (C2-C6), medium (C8-C12), or long (C14-C24) FAs[7] (Table 3).

Palm Kernel Oil

Palm kernel oil contains roughly 48% lauric acid (C12), 16% myristic acid (C14), and 15% oleic acid. Unsaturated fatty acids, which give palm kernel oil and coco oil their high melting properties or rigidity at room temperature, are present in palm kernel oil at concentrations of more than 10%. To this strong preponderance of lauric acid, a low melting point is added. The usage of lauric oils in food crops is determined by this wonderful quality, which also explains why they are typically more expensive than other oils. These natural antioxidants are believed to provide protective roles against cancer, cellular aging, and even Alzheimer's[8].

Omega-3-rich oils

Flaxseed oil

Often referred to as linseed oil, it comes from the seed of the flax plant. Alpha-linolenic acid (ALA), an omega-3 fatty acid, makes up 50–60% of it. The human body is not very good at turning ALA into omega-3 fatty acids once it has been consumed[9]. Researchers demonstrated the medical effect of flaxseed oil, and it was found to exhibit anticancer properties such as breast cancer and prostate cancer; however, only a correlation was described without mentioning cause and effect. Further investigation is required, since available studies aren't efficient enough for flaxseed recommendation as an alternative to chemotherapy.

Walnut oil

The chemical composition of walnut oil[10] is linoleic acid (49–63%) and linolenic acid (8–15.5%). The tocopherol content of walnut oil varies from 268 mg/kg to 436 mg/kg. Walnut oil is a flavorful oil extracted from the suppression of whole walnuts. Walnut oil is used in both unrefined and refined forms and is used in several applications. Walnut oil, like walnuts, includes an assortment of monounsaturated,

Table 2 — Description of the source of plant-derived oils, effect on breast cancer cell lines or samples, and dosage used in different plant-derived oils.

Plant derived-oils	Source	Effect on breast cancer (cell lines/ Samples)	Dosage	Reference
Safflower seed oil	safflower plant	Suppression of cancer cell proliferation in MCF-7 and MDA-MB-231 human breast cancer cell lines.	100 µg/mL	11
Sesame seed oil	sesame seeds	Apoptosis is induced in MCF-7 and T47D cell lines.	250 microM	12
Avocado seed oil	avocado fruit	Causes cytotoxic effect, in a dose-dependent manner, on MCF-7 cell lines.	Genotoxic effect with an IC_{50} value of 379.2 µg/mL	13
Coconut oil	coconut palm	60 patients with breast cancer stages III and IV, divided into 30 as a control group and 30 as an intervention group. The intervention group experienced symptom reduction related to the side effect of chemotherapy. Also, improved global quality of life (QOL).	(10 ML twice daily) virgin coconut oil	14
Flaxseed oil	flax plant's seed	Increases the effect of tamoxifen (TMO) in established estrogen receptor-positive breast tumors (MCF-7). Also, the flaxseed oil increased apoptosis compared to the use of TMO alone.	38.5 g/kg diet, or secoisolariciresinol diglucoside (SDG) lignan and FO combined, which form 10% of the flaxseed diet	15
		Flaxseed oil decreased tumor size, cell proliferation and increased apoptosis by 33%, 38%, and 110%, respectively, on the MCF-7 cell line.	FSO (40 g/kg) for 8 weeks	16
		Induced apoptosis in MCF-7 cell lines.	0.3% or 0.9% (v/v) flaxseed oil	17
Cottonseed oil	cotton seed	Apoptosis induction in MCF-7 and primary cultured human breast cancer epithelial cells (PCHBCEC). Additionally, induced DNA fragmentation.	(-)-GPCSO (0.1 and 0.2%)	18
Walnut oil	whole walnuts	Decrease proliferation of MCF-7 cells. However, long-lasting administration is required for the best possible effect on non-obese people. On the other hand, individuals with obesity showed little response to walnut oil, and cell proliferation levels remained high.	(1 µg/mL) of walnut oil extract	19
Hemp oil	Hemp seed	Can be used to treat triple-negative breast cancer TNBC cells. However, more research is required in this field to determine how effective hemp oil can be as an alternative to chemotherapy.	Median lethal dose, LD-50, was at 9.9 µM	20
Rice bran oil	chaff (rice husk)	80% growth inhibition of cell lines (MCF-7, MDA-MB-231).	Pure peptide at 600–700 µg/mL dose	21
		65% growth inhibition of the cell lines (HTB-26) in a dose and time dependent manner.	maximum sensitivity at 650 µg/mL of <5 kDa	21
		Inhibition of cancer cells growth (MCF-7 and MDA-MB-231) by upregulating p53 in both cell lines, and the downregulation of COX-2 (Cyclooxygenase-2) in ER-positive MCF-7 cells.	rice bran derived pentapeptide (1000µg/mL)	22

IC_{50}: half-maximal inhibitory concentration

polyunsaturated, and saturated fats, with poly-unsaturated fats being the most prevalent. Walnut oil is an adequate source of ALA omega-3 fatty acids, giving nearly 100% of the daily required intake in one tablespoon. Walnuts were primarily developed in ancient Persia and then scattered throughout the world. They became a popular trade item and were often given to royalty. The Romans thought that the nut should be used to treat poison and skin diseases, while in conventional Chinese medicine, it is used to detoxify the kidneys, nourish blood, and encourage favorable gastrointestinal health.

Hemp oil

Hemp oil is a kind of oil created from pressing hemp seeds. Hemp oil that has been cold-pressed and is natural has a nutty taste and a dark to translucent bright green color. Dark in color, grassy in taste. This oil is not hash oil, which is a tetrahydrocannabinol oil derived from cannabis. It has 30% oil, 25% protein, and a lot of fiber, vitamins, and minerals. This oil has

Table 3 — Chemical components of coconut oils (CNO) [23].

Components of CNO	Fraction percentage (%)	Chemical formula
Lauric acid	51	CH3(CH)10COOH
Myristic acid	18.5	CH3(CH2)12COOH
Caprylic acid	9.5	CH3(CH2)6COOH
Palmitic acid	7.5	CH3(CH2)14COOH
Oleic acid	5	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ or $C_{18}H_{34}O_2$
Capric acid	4.5	CH3(CH2)8COOH
Stearic acid	3	CH3(CH2)16COOH
Linoleic acid	1	CH3(CH2)4CH=CH CH2CH=CH(CH2)7COOH

been used in Oriental medicine to cure many ailments. Hemp seed oil (HSO) has been used clinically as a functional food. China has used HSO as a source of nutrition and medicine. PUFAs make up 80% of HSO and are an extremely rich source of the two EFAs (LA and ALA). The omega-6/omega-3 ratio in HSO is naturally between 2:1 and 3:1, which is supposed to be optimal for human health. HSO is found to have anticancer effects and antioxidant properties. Using MH7A human-like rheumatoid arthritis cells, Jeong *et al*. (2014)[23] demonstrated that hempseed oil increased cell apoptosis and upregulated the expression of endoplasmic reticulum stress indicators and C/EBP homologous protein.

Polyphenol-rich oils

Olive oil

It's popular in cooking, frying, and salad dressing. It is a naturally occurring oil that is obtained by crushing entire olives. Olive oil's chemical make-up is as follows: Triglycerides (the majority of olive oil, molecular formula $C_{98}H_{184}O_{10}$), free fatty acids (FFA), colors, minute olive fragments, phosphatides, sterols, taste compounds, and glycerol. The main dietary source of energy for both humans and animals is triacylglycerol. In a study that was published in the journal BMC Cancer, researchers showed polyphenols' bioactivity (natural antioxidants) found in olive oil has bioactivity against breast cancer cells. Within lineages of said cells, this oil was discovered to have an anti-HER2 impact. The researchers used *in vitro* models to examine the purity and content of the fractions, as well as ELISA-specific HER2 assays to test the influence of polyphenolic fractions on HER2 expression and activation[24].

Cottonseed oil

It has a chemical makeup of around 55% linoleic acid (18:2), 22% to 26% palmitic acid (16:0), and approximately 19% oleic acid (18:1). Because of the oil's greater palmitic acid concentration, it forms a cooling layer of dipalmitoyl glycerol and other high-melting triglycerides. Gossypol (C30H30O8) (GP) is a polyphenol recovered largely from the glands of the cottonseed pigment. It accounts for 20-40% of the gland weight and 0.4-1.7% of the total kernel weight. It can impose a broad set of natural actions, like antifertility, antioxidative, antibacterial, and antiviral properties[25]. Furthermore, GP exhibits antiproliferative effects against a variety of cancers, including breast, ovarian, prostate, and colon cancer. GP also causes apoptosis in human lung cancer cells by increasing the expression of the TNF receptor superfamily.

Other oils with medical and cosmetic importance

Cocoa Butter

It originates from cocoa beans and is a light-yellow fat. It is included in the manufacturing of chocolate, some ointments, cosmetics, and several medications. Chocolate butter has a similar flavor and aroma to cocoa. It has a melting point that is somewhat lower than that of the human body. Cocoa butter can be used in a variety of ways. It's used in a variety of products, including skin treatments, lotions, lip balms, and desserts. Cocoa butter is utilized in the formation and is highly regarded in the industry. It consists of diacylglycerols, unsaponifiable matter, phospholipids, free fatty acids, iron, and primary oxidation products[26].

Peanut oil

The edible peanut plant seeds are sourced to yield this oil. “Arachis” and “groundnut oil” are other names for it. Saponification can be used to create soap from vegetable oils, including peanut oil[27]. Peanut oil (molecular formula $C_{30}H_{45}N_9O_5$) has the following chemical composition: oleic acid (46.8% as olein), linoleic acid (33.4% as linolein), and palmitic acid (10.0% as palmitin). Other fatty acids included in the oil include arachidic acid, stearic acid, behenic acid, lignoceric acid, and others. *Peanut* plant (*Juniperus oxycedrus* L.) is used in traditional medicine to treat cancer.

Cade oils

Moroccan *J. Oxycedrus* L. essential oils (EOs) are efficient against ER+ breast cancer cells. EOs have anti-proliferative properties, and EOs derived from fruits can inhibit cancer cell proliferation and induce apoptosis. Many treatments use Juniperus oxycedrus essential oil, often known as cade oil, due to its bioactive components. Cade oil treats eczema, psoriasis, scabies, and rashes. It also helps with hair loss and dandruff. The oil kills Staphylococcus aureus, Escherichia coli, and Candida albicans, according to antimicrobial properties studies. Juniper EO MNDs have powerful antibacterial activity against a variety of bacterial and fungal species, making them promising wound healers. Use cade oil for bleached, dyed, or thin hair. It treats several hair issues in Ayurveda. These uses demonstrate J. Oxycedrus essential oil's versatility in therapy. Consult a doctor before using essential oils to cure something[28].

Avocado seed oil

Isolated from avocados (*Persea americana)* and recognized by its high smoke point, it can be consumed raw and is excellent for culinary applications. It can also be found in cooking and cosmetics and as a lubricant. It comprises nearly 2% seed. It has a big lipid quantity of nearly 62% (42-51% oleic acid and 20-25% palmitic lipid). The avocado seed oil is nearly 8.47%, which consists of linoleic acid 48.77%, and linolenic acid 12.17%[29].

Characteristics and classification of breast cancer

Breast cancer in its early stage is believed to be potentially curable. This provides hope, considering it is among the top three cancers affecting women worldwide. For the purpose of avoiding over-therapy, therapy has advanced significantly over the previous decade, with a decrease in therapeutic intensity for confined regional and systemic treatment. Yet, under-treatment has taken center stage. Treatment concepts must be decided in a multidisciplinary context and have a curative objective, such as considering molecular subtypes and local-regional tumor burden. Traditional primary surgery is no longer the best option in all circumstances. As a result, neoadjuvant therapy is now widely utilized in triple-negative and HER2-positive early breast cancer. Therapeutic backbones comprising endocrine, HER2 targeting, and chemotherapy, depending on the subtype of the clinical tumor. Treatment aims at extending survival and conserving the quality of life for metastatic breast cancer. The potential for managing the disease long-term in metastatic breast cancer is giving rise to progress in endocrine treatment and targeting HER2, as well as the prospect of new, targeted treatments. Breast cancer is the most prevalent malignancy affecting women, and on the molecular level, it represents a heterogeneous disorder. The concept of therapy has developed to take account of these heterogeneous origins. Breast cancer is curable at early stages, although the metastatic stage is not. When patients of early and metastatic breast cancer receive care from a specialized group of experts, their quality of life and survival are greatly improved. Setting up specialized breast cancer centers, which the European Parliament supports, is a global priority. The majority (~80%) of breast cancers are ductal carcinomas, originating in the ducts, not the lobules. Lobular carcinomas are a distinct and less common type; the differences between normal and cancerous duct cells were illustrated in (Fig. 1). Breast cancers have important implications for the treatment of histological and molecular characteristics. Several classifications have been developed based on molecular and histological characteristics. Based on disease markers, breast cancer tumors are divided across four fundamental groups[30]:

1) Tumors with ER, PR, and HER2 negativity, also known as triple negative (ER- PR- HER2-),
2) Tumors with ER or PR positivity and HER2 positivity (ER^+/ PR^+ $HER2^+$),
3) Tumors with ER and PR negativity and HER2 positivity, or only HER2 positive (ER- PR- $HER2^+$),
4) Tumors with ER or PR positivity and HER2 negativity (ER^+/ PR^+ $HER2^-$).

The epidemiology of human breast cancer

Exogenous estrogen post-menopause may precipitate breast cancer, which is significantly more common in white populations, with the lowest incidence observed in countries characterized by minimal meat consumption. The northeastern part of the United States has the most cases. Incidence rates that are specific to age rise quickly until they reach about 45–50 years. Risk factors encompass exposure to elevated levels of chest radiation, obesity, and a history of ovarian or endometrial cancer. Breast cancer is still a very serious problem in the US, with almost 100,000 new cases and more than 30,000 deaths each year. In 1980, there were 570,000 cases of breast cancer around the world. By

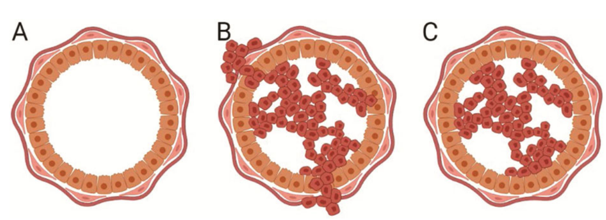


Fig. 1 — (a) Normal breast duct cell; (b) Invasive breast cancer duct cell (cancer cells invade outside duct); and (c) Non-invasive breast cancer duct cell (cancer cells within duct cells)

2020, about 2.3 million women had their first diagnosis of breast cancer. The number of cases keeps going up every year, and this is partly because young women drink too much alcohol, and postmenopausal women are overweight. For instance, Norway sees about 2000 new cases every year. Breast cancer usually starts in the breast ducts and lobular tissues. Ductal breast cancer is the most common type, making up about 85% of cases. It is typically invasive and capable of metastasis, although it can also present as non-invasive, such as in ductal or lobular carcinoma *in situ*. Different types of breast cancer have different death rates. HER2-positive breast cancer has the highest death rate, followed by TNBC, luminal A, and luminal B. In developed nations, breast cancer in young women is comparatively uncommon but tends to exhibit a more aggressive trajectory with inferior outcomes, likely attributable to variations in biomarker expression and an increased likelihood of genetic predisposition. It is the leading cause of cancer-related deaths among women under 40 in developed countries, necessitating special consideration of factors such as fertility, genetics, and social or emotional issues in disease management.

There are many factors that can raise the risk of breast cancer, such as being female, what you eat, how much alcohol you drink, how much you smoke, how much you exercise, your genes, your lifestyle, and your hormones. Exposure to estrogen and progesterone, along with prolonged menstrual cycles resulting from early menarche and late menopause, is linked to an elevated risk. Researchers have looked into plant-based products to see if they can fight cancer by using molecular processes that cause toxicity and cell death. For instance, phytoestrogens do not make breast cells grow as quickly as human estrogen does, and they can also block estrogen receptors. In the United States, about 50–60% of people with cancer use plant-based medicines along with standard treatments as complementary and alternative medicine. About 60% of anticancer drugs come from plants, microorganisms, and marine sources. There is a growing interest in medicinal plants because they are safer and have fewer side effects than chemotherapy and radiotherapy[31].

Apoptosis is an important way to get rid of sick or cancerous cells. Essential oils derived from plants can facilitate apoptosis by elevating pro-apoptotic factors (*e.g.*, Bax, Bak, and Bad) and diminishing anti-apoptotic factors (*e.g.*, Bcl-2 and Bcl-xl), thereby inducing cytotoxic effects on cells such as MCF-7. For example, Oliveria decumbens from Iran produces an essential oil (OEO) that impedes viability and promotes apoptosis in murine mammary carcinoma 4T1 tumors and in MDA-MB-231 breast cancer cells. In the same way, the essential oil from Decatropis bicolour specifically targets MDA-MB-231 cells by activating Bax and caspases 9 and 3, which starts intrinsic apoptosis (Fig. 2). Carvacrol, a principal constituent of Zataria multiflora essential oil, promotes apoptosis in both 2D and 3D cultures of breast cancer cells through the elevation of reactive oxygen species (ROS), mitochondrial membrane disruption, caspase-3 activation, and DNA damage[32].

The main way to fight this disease is still to find it early. According to the health belief model, education has been demonstrated to markedly enhance the self-care practices of first-degree relatives of breast cancer patients. It is very important to look into effective treatments like tamoxifen[33]. It protects women who have a genetic risk factor that makes them 3–5 times more likely to get cancer after menopause, treats cancers that have not yet been diagnosed, and improves lipid profiles by raising HDL cholesterol and lowering LDL cholesterol.

Genetic predisposition

Roughly 10% of breast cancers are based on genetic factors and have a family history, but these often differ according to ethnicity and in the context of early-phase, bilateral, and/or triple-negative breast cancer (TNBC) cells in various countries. First-grade family members who have breast cancer face a great relative risk (RR) of early-stage breast cancer before the age of 35. The risk of a person having breast cancer comprises various variables, including family size, environmental aspects, and family history of breast cancer. Models like the family history record were developed to assess the family risk. The pattern of autosomal dominant inheritance due to a mutation in two highly penetrative tumor suppressor genes, BRCA1 (17q21) and BRCA2 (13q13), whose proteins are involved in homologous repair of DNA. The mutations of BRCA1 and BRCA2 have an average

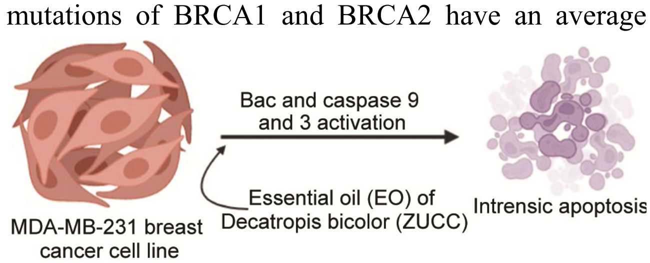


Fig. 2 — Essential oil of *Decatropis bicolor* causes intrinsic apoptosis in breast cancer cell line MDA-MB-231

total risk of BRCA2 mutations at the age of 80. The respective dangers are 72% and 69%; the relative danger of BRCA2 mutations in men is 6%. More than 2000 BRCA gene differences (mutations and vast rearrangements) have been defined so far, but few have been found various times in unrelated families, for example, founding mutations in Jewish Ashkenazi families (BRCA1 185delAG or BRCA2 6174delT) or Jewish families in Iceland (BRCA2 999del5). In a U.S. national study, the majority of mutations in BRCA1 and BRCA2 differed among ethnic groups, with fewer within the Asian group (0.5%) and more among Ashkenazi (10.2%). The germline BRCA test is now being performed in patients with metastatic breast cancer as a complementary diagnosis. The poly ADP-ribose polymerase (PARP) inhibitors can lengthen progression-free survival (PFS) and improve the quality of life[34].

Mechanism of breast cancer development and its pathophysiology

However, big efforts have been made to illustrate the molecular improvement and advancement of breast cancer. The detailed mechanism by which breast cancer is provoked is not known. At the beginning level, the clonal evolution model (which comprises mutations and the survival of the 'fittest' tumor cells) is indicated and complicated by the fact that cancer stem cells also develop clonally, in which precursor cancer cells are just able to result in and sustain progression. There are permanent lesions and genetic changes at a morphological level from familiar glands that induce cancer. At the molecular level, there is an indication that demonstrates that breast cancer can be either ER-related or proliferation-associated (described in the intrinsic classification). Also, identification of the vulnerable genes of breast cancer has highlighted various aspects of both sporadic and hereditary pathogenesis. The low-grade pathway has a 1q increase, a 16q loss, a rare amplification of 17q12, and an impression of gene expression. In this way, the luminous A group and the luminal B group fall to some extent. The second pathway is the high-grade, 13q loss-like path[35].

Regarding molecular alteration, genes like TP53 (41% of the tumors), PIK3CA (30%), MYC (20%), PTEN (16%), CCND1 (16%), ERBB2 (13%), FGFR1 (11%), and GATA3 (10%), as recorded from numerous early breast cancers, are the most often mutating and/or magnified genes in tumor cells. These genes encode modulators of the cell cycle, which can be either repressed (*e.g.,* p53) or initiated (*e.g.,* cyclin D1) in order to assist proliferation or restrict apoptosis and oncogenic pathways (MYC, HER2, and FGF1) or inhibit non-repressed elements (PTEN). There are very rare cases of most mutations comprising 100 possible breast cancer drivers, 64; therefore, the prevalence of breast cancers is caused by different low-penetrant cumulative mutations. The majority of PIK3CA mutations exist in luminal A tumors (49%), while the increased prevalence of TP53 mutations is a characteristic of basal tumors (84%). TNBC emphasizes its subtypes by several molecular drivers (Box 2). Specific prediction changes, such as PIK3CA mutations, can effortlessly be found noninvasively in the plasma of the circulating tumor DNA in a metastatic phase rather than in the tumor biopsy. The DNA copy number and somatic mutations of the Cancer Genome Atlas data were utilized to determine the frequency of every genetic change[36].

Description regarding fundamental normal and malignant breast cancer cells: How they react to immunostimulatory compounds and chemotherapy

The primary cultures of human breast tissue are cancer cells (BC5), chemotherapy-treated tumor cells (BrCH1), and normal cells (BN1). These have been developed for comparison with immortalized breast cells, including MCF6, MDA-MB-231, and MCF10A. In human breast cells, progesterone (PGR), estrogen receptor (ER), 2 and 3 human epidermal growth factor (HER), and CYP119 (aromatase) receptor, along with tetratricopeptide repetitive expression of interferon-induced protein 3 (IFIT3) mRNA, were identified[36]. The therapy for anti-tumour cells for the main culture has shown that BrCCh1 cells are resistant to doxorubicin and cisplatin. There was little tamoxifen and cisplatin sensitivity in BC5 cells. IFIT3 was increased to various extents in primary and immortalized breast cell lines (MCF7, MDA-MB-231, and MCF10, respectively) by innate immunity activators (interferon-α and an artificial small nucleolar RNA analog). The inverse correlation between the relative level of IFIT3 activation in breast cell lines and the baseline of IFIT3 mRNA expression[36]. IFIT3 mRNA expression can be utilized to predict the sensitivity of breast cancer cells to therapeutic immunostimulants. According to this concept, large cancer cells serve as a good model for developing novel cancer medicines.

Researchers used silicon MEMS (micro-electromechanical systems) resonators and atomic force microscopy to calculate the biophysical properties of human breast cancer cells. Researchers found that the mechanical properties of cancer cells are associated with metastatic action and disease advancement. For that, in this study, we provide details about breast cancer cell measurement stiffness using a novel silicon MEMS resonant sensor[36]. The sensor extracts the entire cell's average stiffness value and allows the stiffness of various cell types to be comparable. This method results in a multimodal assessment of single-cell development and physical features since it is known that a cell has a highly integrated structure and a functional, complex dynamic system. Numerous cells' mechanical features allow them to protect themselves from the physiological environment in which they exist. Variations in the mechanical properties, including cellular growth, differentiation, spread, migration, and apoptosis, will influence the biological behavior of the cell. Viscoelasticity studies of personal cells are focused primarily on cancer cells. It is determined by how rigidly a cell interacts mechanically with its microenvironments. This affects mechanical signals, containing cell growth, which ultimately affects the cell's behavior[36].

Recently, cell growth rate studies facilitated developmental technologies for the mass measurement of each cell individually. Measurements of the mechanical characteristics of cells with silicon MEMS resonant sensors are utilized for breast cancer. Measurements shall take place of the viscoelasticity of adherent objects by resonance frequency change. The array of these devices can give high-performance measurements of the whole cell against flexible properties. MEMS resonant sensors measure the mass of the adhered objects by using resonant frequency shift; however, these devices are commonly able to measure physical properties that affect the resonant frequency. When fluffy cells are fastened to a sensor, for instance, the platform vibrates out of phase, and its mass and viscoelasticity affect the change in resonance frequency. Another part describes the circumstances of the resonant sensor and its experimental setup. A 60x60 m^2 pedestal is a resonant sensor that is suspended by four-pole springs having 81 sensors[37].

For robust materials with strong elasticity or viscosity, this impact is minimal, and all frequency changes may be ascribed to mass. The cell module has a pressure range of 270 to 340 Pa before installation and 800 to 1200 Pa after mounting. MCF-7 and MDA-MB-231 were the softest of the cell lines. A trend similar to the elastic module indicated viscosity values, where the cells in the cancer cells have lower viscosities than benign cells. The mechanical characteristics of both cell lines are comparable, indicating that cells have a definite structure that impacts the frequency change. MCF-7 cells have a smaller spring constant, even though they have very similar mechanical properties. For about fifteen cells in each line, the area at the height of the confocal microscopy images was measured. The minimum detectable change parameter, or spring and damping resolution, can be further calculated. Constant estimation can be calculated by the minimum frequency noticeable change. The viscoelasticity of cells is measured with several methods. The most common device used for studying living cells rapidly is microindentation with an atomic force microscope (AFM). AFM relies on some hypotheses that the cell is soft, thin, irregularly formed, and fluid. MEMS resonant sensors offer an attractive alternative to traditional cell mechanics due to their scalability, speed response, high performance, and capacity to operate in fluid or gas-free environments. The sensors can measure the entire mechanical properties of the cell rapidly and easily. The viscoelastic characteristics of human breast cancer cell lines were studied using a resonant MEMS sensor. Their integrated sensor, system, and model have a low enough resolution to detect changes in a cell's mechanical characteristics[37].

Breast cancer immunotherapy

Immunotherapies revolutionize multiple solid tumor management, and early data indicated that clinical activities in a small number of people with metastatic brain cancer are programmed cell death-1/programmed ligand-1 (PD-1/PD-L1). If the tumor is triple-negative, PD-L1$^+$, and/or has higher levels of tumor-infiltrating leukocytes, clinical activities are more likely to happen. Atezolizumab and pembrolizumab responses seem to be resistant to metastatic triple-negative breast cancer (TNBC), which suggests that the lives of respondents may be altered by such agents[30].

The goal of present clinical research is to create immunotherapy cocktails that enhance the response and change non-responders and overcome acquired immunotherapy resistance. Finding biomarkers that can foresee a patient's likelihood of responding to just one agent of immunotherapy and determine which immunotherapy regimens are most effective for them is a high priority for clinical development. Close to effective immunotherapy in almost all patients, intelligent clinical trials testing combinations of rational immunotherapy, including robust biomarker tests, will speed clinical progress[30].

With 30% of all new cancer diagnoses and about 41,000 deaths yearly, in the United States, breast cancer still represents a major threat to women's health and their well-being. Despite a 38% reduction in the death rate from breast cancer due to early identification and treatment advancements, almost all patients with metastatic breast cancer will pass away. These alarming findings demonstrated the urgent need for novel approaches to lower the disease's recurrence and death rate. Data collection has been considered to be a key part of the immune system in recent years in determining both the response to standard therapy and long-term survival in breast cancer patients[30]. Antagonists of the PD-1/PD-L1 pathway can induce durable clinical responses in some patients with metastatic triple-negative breast cancer (TNBC). Efforts to extend immunotherapy to patients with HER-2+ and luminal breast cancer are underway. Personalized immunotherapy strategies that utilize vaccines and deliver tumor-specific neoantigens are under rapid development[30].

Types of breast cancer

Non-invasive breast cancer

Breast cancer that has not spread beyond the lobule or ducts in which it is located is referred to as non-invasive breast cancer. When abnormal cells grow inside the milk ducts but do not spread to other tissues or outside, it is known as in situ ductal carcinoma. When managing in situ ductal carcinomas, it is important to remember that the optimal course of action is to preserve the breast[38].

Invasive breast cancer

A generic carcinoma that primarily affects women is invasive breast cancer. Aberrant cells from the milk ducts or lobules detach and come into close vicinity to the breast tissue. The brain, bones, lungs, and liver are the organs to which they most frequently spread[38].

Inflammatory breast cancer

Because the skin's lymph vessels and channels obstruct the breast's lymph cells, inflammatory breast cancer manifests as enlarged, warm, reddish breasts with puckering and wide ribs. While it is rare, tremendously quick-growing and inflammatory breast cancer. All multidisciplinary approaches, encompassing radiation therapy, surgery, chemotherapy, and imaging, must be carefully synchronized. The use of neoadjuvant chemotherapy significantly improves the earliest report's overall survival time and plays an important and sustained role in the local treatments, such as radiation and surgery[38].

Paget's breast disease

This is the uncommon kind of breast cancer that typically exhibits notable breast cancer alterations. This can occasionally migrate to healthy skin and result in nipple rashes that are red and irritating. Men and women can get Paget's breast cancer, which makes up 1-3% of all breast cancer cases[38].

Tumor of phyllodes

Tumors of phyllodes may either be benign or malignant. Phyllode tumors develop and can be treated with operative removal in the connective tissues of the breast. Phyllode tumors are extremely rare; fewer than 10 women die in the U.S every year because of this cancer[38].

Triple-negative breast cancer (TNBC)

This comprises a discouraging outlook, significant metastatic possibility, relapse tendency, and substantial extent of invasion. New TNBC treatment strategies have been developed, as it is an urgent clinical necessity. TNBC is depicted via a negative expression of progesterone and estrogen and HER2. It is frequently categorized as a variant of basal breast cancer based on gene expression analyses. In TNBC patients, the survival time is shorter, and in the first five years after diagnosis, the mortality rate is 40%. TNBC is very invasive, and about 46% of the patients with TNBC have metastasized from a distance.

Approximately 6,500 females in the Czech Republic get breast cancer every year; nearly 1,000 of these women are triple-negative in nature. The shortage of α-estrogen, progesterone, and HER2 receptors characterizes triple-negative breast carcinoma. The majority of these cases are low-intensity carcinomas, most of them from the basal subgroups originally defined by DNA chips. In clinical terms, the rates of local recurrence and organ metastases are higher in aggressiveness. In younger women, this cancer is more common and is related to pathogenic mutations in the BRCA1gene[39].

A heterogeneous group of diseases with limited therapeutic options is triple-negative breast cancer. Detailed knowledge of their clinical, molecular, and predictive biomarkers is key to further shifting into therapy. No further improvement of therapy results can be expected of the three times negative breast cancer before this disease has been targeted. Triple-negative breast cancer is typically antagonistic and poorly predicted. It is still necessary to establish optimal chemotherapy regimens.

Younger and heavier women are more inclined toward breast cancer. Triple-negative breast cancer often manifests at age 53. According to guidelines, women with a TNBC diagnosis aged 60 or under should have their BRCA gene screened. Premenopausal African American women are more likely to have TNBC. Tumors with no mutations in germline BRCA1/2 are called "BRCAness." These tumors have a natural history and act as a response to systemic therapy and are considered to be more similar to BRCA-mutated cancers. TNBC's molecular characterization is an active field of research, but the application and relevance to clinical practice of this research are not yet established.

Triple negativity is a heterogeneous disease, and for a long time, there have been no specific therapies for this. Different subgroups have been identified with triple-negative tumors based on protein expression, mRNA, and genomic alterations. Molecular analysis of this disease identified potential therapeutic intervention options. Multiple factors trigger the development of breast cancer. Increased breast size is considered a risk factor for breast cancer. The evidence for risk reduction is stronger, including extreme subcutaneous prophylactic mastectomy.

Effect of oils on breast cancer

It has been pointed out that extra-virgin olive oil (EVOO) may assist in avoiding breast cancer. The therapeutic traits of EVOO on cancer-related incidences, breast cancer in particular, were stated in multiple studies. Olive oil is primarily constituted of fatty acids, notably oleic acid, as well as a high concentration of several minor components, such as phenols, which researchers physically removed at temperatures below 30°C. Furthermore, hydroxytyrosol is the major phenolic alcohol (HT). Researchers investigated the interaction of hypoxia with hydroxytyrosol (HT) in MCF-7 breast cancer cells. The results revealed that hypoxia has an antioxidant impact on HT. This discovery further revealed that hypoxia downregulates the expression of the PI3K/Akt/mTOR pathway and transcriptional activity of an HIF-1 alpha protein. Moreover, it has been observed that higher concentrations of HT can be considered an aryl hydrocarbon receptor (AHR) agonist[40].

Certain polyphenols (like flavonoids) found in plant-based drinks (like green tea) are capable of inhibiting the function of serine/threonine kinase and tyrosine kinase according to their form. Extra-virgin olive oil (EVOO) is distinct from other vegetable oils due to the substantial amount of natural phenolic components. EVOO is the liquid of the olive that is produced simply by pressing and eaten without any further treatment. Studies found that the *in vitro* altered phenotype caused by the HER2 tyrosine kinase receptor in human epithelial breast cells can be changed by EVOO polyphenols. To overexpress the human HER2 wild-type gene, the researchers used retrovirally transformed MCF10A normal breast epithelial cells. The relationship between the chemistry of phenol compounds obtained from EVOO and their suppression of the tyrosine kinase of the HER2 oncoprotein was next examined[41].

When the phosphorylation condition of HER2 was assessed, secoiridoids reduced HER2 transduction by rapidly reducing the activation of the 1248th tyrosine residue (Y1248), the key autophosphorylation site. HER2 tyrosine kinase activity has not been considerably reduced by phenolic acid (oleanolic acid) or single phenols (tyrosol and hydroxytyrosol) produced from EVOO. Compared to EVOO-generated single phenols and phenolic acids, the IC_{50} values were as much as five counts smaller with the lignans and secoiridoids of EVOO. EVOO polyphenols produced potent tumoricidal effects by specifically increasing apoptosis in HER2-positive MCF10A/HER2$^+$ cells as opposed to in MCF10A/pBABE paired controls. EVOO lignans and secoiridoids reduced MCF10A/HER2 cell colony formation in soft agar, hence preventing the HER2-induced *in vitro* altered phenotype. According to reports, the preventative breast cancer properties of EVOO predominantly influence the incidence of tumors that overexpress the type I receptor tyrosine kinase HER2. This is supported by current epidemiological studies. Therefore, it is hypothesized that the configuration of lignans and secoiridoids produced from EVOO may offer an ideal framework for the development of novel anti-breast cancer therapies aimed at HER2[42].

Through AMPK/mTOR, the natural oils of frankincense, pine needle, and geranium inhibited the cell survival, division, and attack of the human BC cell line MCF-7. All these oils prompted apoptosis, but not the cell cycle. In the human BC mice model, it has been demonstrated that the essential oil of frankincense can suppress tumor development and stimulate tumor cell apoptosis. Intermediate EVOO intake seems to be an advantageous decision, as it can positively impact your likelihood of breast cancer. Additionally, EVOO causes many molecular alterations in malignancies, including shifts in gene expression, signaling protein function, and cell membrane integrity.

Low amounts of saturated fat, along with substantial concentrations of monounsaturated (oleic acid, OA) and polyunsaturated (alpha-linolenic acid, ALA) fatty acids, are found in canola oil (CAN). A large number of studies link ALA and OA with a lowered risk, while omega-6 and saturated fats are linked with a higher risk. The likelihood of breast cancer appears to be lowered by a ratio of 2:1 among omega-6 and omega-3 fatty acids. Breast cancer is one of the many problems that can arise when this ratio is out of balance. Some fatty acids possess anti-cancer suppressive actions. However, the function of omega-6 and omega-3 keeps being debated[43].

Phytotherapy

Herbal preparations are more likely than other complementary therapies to have adverse effects on cancer and have therapeutic interactions. Regardless, phytotherapy by-products are not scientifically assessed by any purity and potency license, as required in conventional drugs. The most common phytotherapeutic agents are garlic, ginkgo, and echinacea. Echinacea, herbal teas, and ginkgo biloba-based products are used by long-term (10 years or more) survivors of breast cancer[44].

Adjuvant systemic therapy

Systemic adjuvant therapy is used to prolong the treatment of latent micrometastasis. Based on multiple anti-cancer mechanisms, endocrine, chemotherapy, and anti-HER2 treatment can enhance disease-free survival (DFS) and overall survival. The choice of these medications is based on a collaborative decision-making process between patients and researchers based on baseline risk, which is determined based on the number of lymph node metastases, invasive tumor size, histological grade, and molecular subtypes. Ki-67 has recently been used to predict the effectiveness of chemotherapy in ER-deficient BC patients, as have the findings of multi-gene testing for cancer cells. Molecular biology of the estrogen & progesterone receptor: Mechanisms are now well established by which estrogen binds to its receptor. The estrogen receptor has two different forms (ER). One is ER-α, which is clinically related, while the clinical importance of ER-β is obscure. Progesterone similarly binds to nuclear receptors[45].

Bioinformatics analysis

A structured data frame was created to compile evidence from scientific literature. Each entry represented a unique study or finding and included the following variables: "oil" is the common name of the plant-derived oil and the source of the botanical oil origin. The effect is referred to as a textual description of the observed biological or clinical outcome. Cell Lines / Samples, which are the experimental models used (*e.g.*, MCF-7 cell line, human patients); dosage, the concentration or amount of oil/extract used in the study. The study type is categorized as *in vitro* (cell culture), *in vivo* (animal model), or *clinical* (human trial).

Data Categorization and Feature Engineering

To enable quantitative analysis, the qualitative data were systematically coded by affect type. The textual "Effect" descriptions were programmatically categorized into three main types: "Anti-proliferative" (*e.g.*, apoptosis, cytotoxicity, growth inhibition), "Symptom Relief" (*e.g.*, improved quality of life), or "Other." Binary effect indicators: Four key biological effects, apoptosis, proliferation inhibition, cytotoxicity, and clinical improvement, were encoded as binary variables (1 for presence, 0 for absence) based on keyword searches within the 'Effect' field. Binary study type indicators: Similarly, binary indicators were created for the presence of *in vitro*, *in vivo*, or clinical evidence for each oil type.

Bioinformatics characteristics for several plant-derived oils and their documented effects on breast cancer

Comprehensive analysis of various plant-derived oils and their documented effects on breast cancer, based on data extracted from scientific literature. The analysis encompasses both laboratory studies (*in vitro* and *in vivo*) and clinical evidence to map the current landscape of research in this field.

Composition of Coconut Oil

The analysis began with a detailed breakdown of the chemical composition of coconut oil (CNO), a commonly studied oil, to understand its fundamental structure as illustrated in (Figs. 3-5).

Overview of the Research Landscape

A broader analysis was conducted to categorize the types of studies and the oils most frequently investigated in (Figs. 6 & 7).

Frequently Used Experimental Models

Understanding the preferred models for this research is crucial for interpreting the results, as shown in (Fig. 8). The reported outcomes of the oils were systematically categorized to identify the most common mechanisms of action. The induction of apoptosis (programmed cell death) is the most frequently reported anti-cancer effect across the studies, followed by the inhibition of cancer cell proliferation, as illustrated in (Fig. 9).

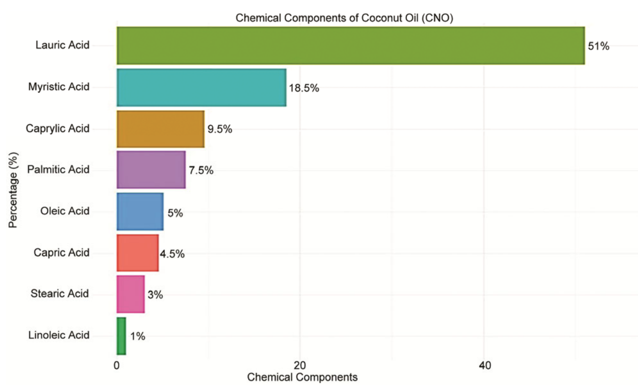


Fig. 3 — Chemical Composition of Coconut Oil (CNO). Horizontal Bar Plot. This horizontal bar chart clearly illustrates that lauric acid (51%) and myristic acid (18.5%) are the dominant fatty acids in coconut oil, constituting nearly 70% of its total composition

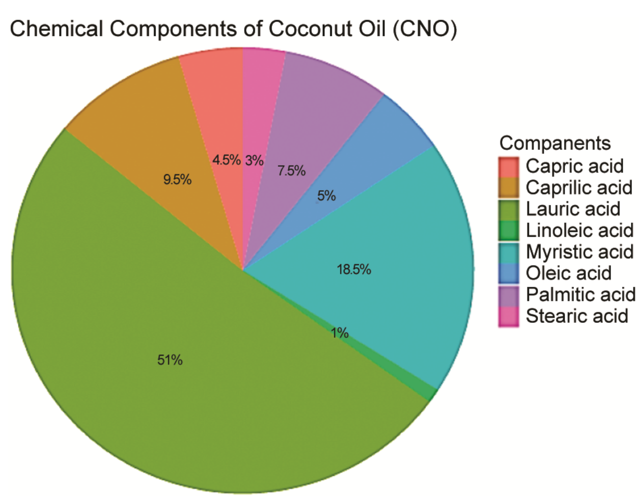


Fig. 4 — Chemical Components of Coconut Oil (CNO). The pie chart provides a visual summary of the relative proportions of each fatty acid, reinforcing the dominance of lauric and myristic acids in the oil's profile

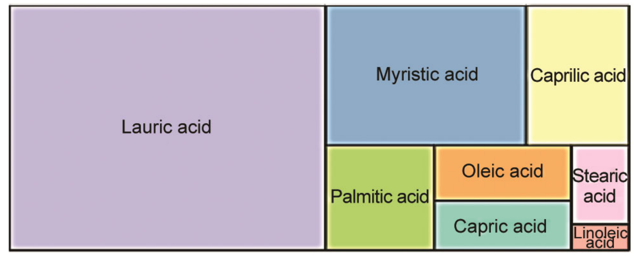


Fig. 5 — Chemical Components of Coconut Oil (CNO). This tree map offers an alternative visualization of the composition, where the size of each rectangle is proportional to the percentage of each component, providing an intuitive grasp of the major and minor constituents

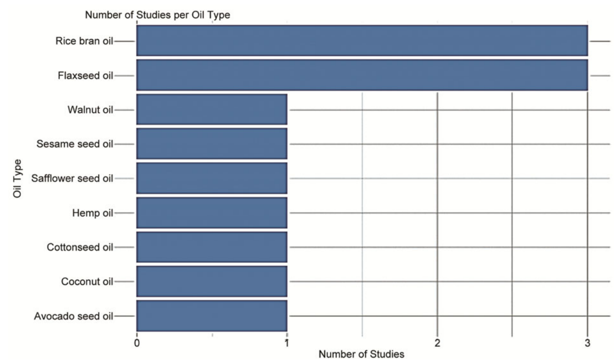


Fig. 6 — Number of Studies per Oil Type. The bar chart shows that flaxseed oil and rice bran oil are the most extensively researched oils in the context of breast cancer, with three studies each identified in this dataset

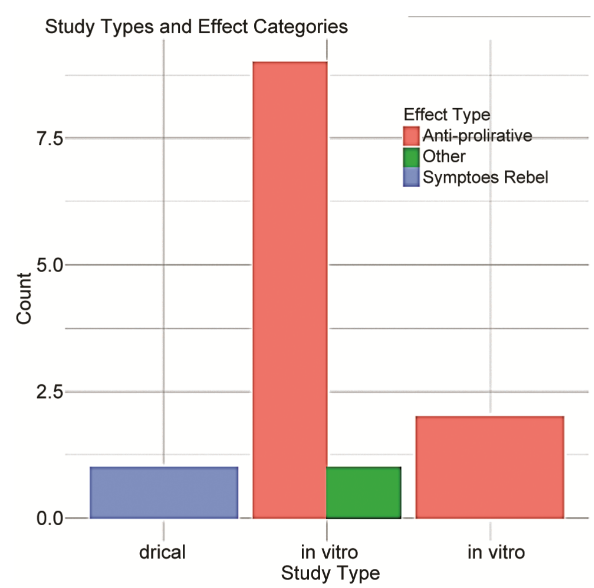


Fig. 7 — Study Types and Effect Categories. This stacked bar chart reveals that the vast majority of evidence comes from *in vitro* (lab-based) studies, with a primary focus on anti-proliferative effects. Clinical evidence from human patients is currently very limited

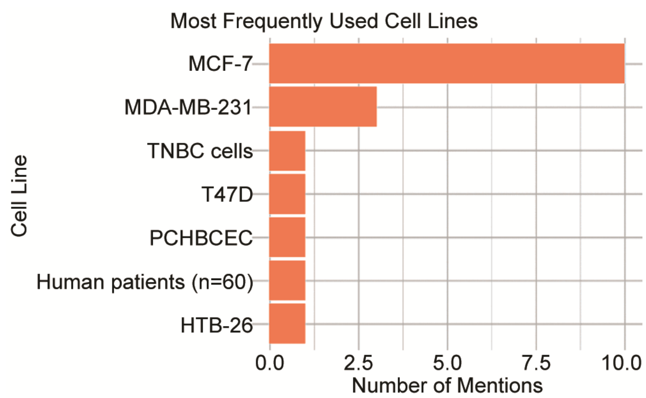


Fig. 8 — Most Frequently Used Cell Lines. The MCF-7 cell line, a model for estrogen receptor-positive breast cancer, is by far the most commonly used experimental model in the studies analyzed, highlighting a potential research bias

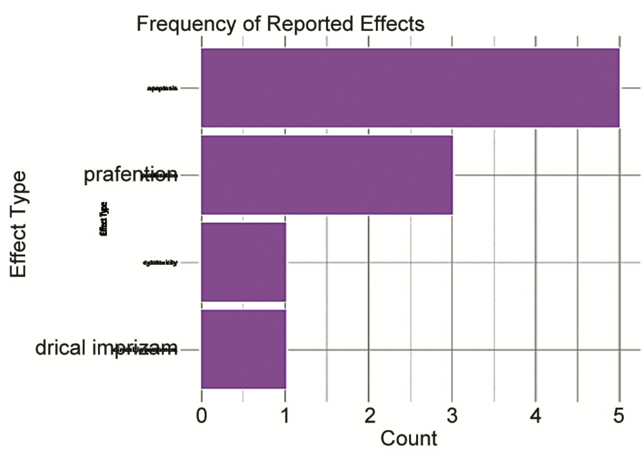


Fig. 9 — Frequency of Reported Effects: The induction of apoptosis (programmed cell death) is the most frequently reported anti-cancer effect across the studies, followed by the inhibition of cancer cell proliferation

Evidence Map of Oil Types

A high-level summary was created to show the distribution of evidence types for each oil. This evidence map provides a quick overview, confirming that while many oils show anti-proliferative effects in lab studies (green tiles), very few have been tested *in vivo* or clinical settings. Coconut oil is the only one with reported clinical data related to symptom relief, as illustrated in (Fig. 10).

Dosage and Traditional Relevance of Critical Analysis

The collected data reveal that many plant-based oils have competing anti-cancer effects *in vitro*, but there is a big gap between the effective concentrations found in the lab and the safe doses that can be used in the treatment of patients. The active dosages in Table 2, which usually range between 10 and 1000 µg/mL for cell culture research, are not always beneficial for direct human use throughout dietary intake or topical application. For instance, it is very unlikely that you could get the same concentration of 100 µg/mL for a certain phenolic compound that is obtained from olive oil just by eating it due to the complicated factors that affect bioavailability, such as how well it is absorbed in the gut, how it is metabolized the first time it is used, how it is distributed, and how quickly it is excreted.

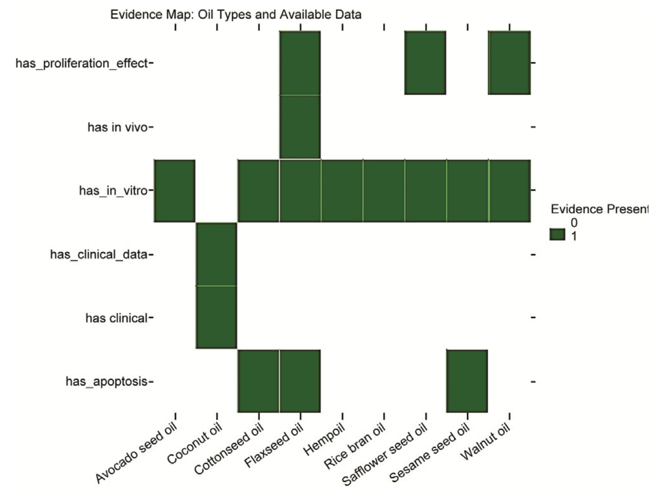


Fig. 10 — Evidence Map: Oil Types and Available Data: This evidence map provides a quick overview, confirming that while many oils show anti-proliferative effects in lab studies (green tiles), very few have been tested *in vivo* or clinical settings. Coconut oil is the only one with reported clinical data related to symptom relief

Also, the therapeutic index, which is the ratio of the toxic dose to the therapeutic dose, is still not well defined for many of these oils and their parts in preclinical *in vivo* models. An extract may exhibit efficacy in MCF-7 cells at 50 µg/mL but may induce cytotoxicity in normal human cells at only slightly elevated concentrations, thereby constraining its clinical applicability. This highlights that *in vitro* efficacy is an essential yet inadequate measure of therapeutic potential. To close this gap, we need to focus on advanced delivery methods. Future research should explore nano-encapsulation, liposomal formulations, or targeted delivery systems aimed at improving the bioavailability of active oil components, safeguarding them from degradation, and promoting their selective accumulation in tumor tissue. Therefore, although the presented *in vitro* data indicate promising leads, their therapeutic potential depends on approaching pharmacokinetic studies and the creation of advanced delivery systems to transfer bioactive concentrations from the cell culture plate to clinical applications.

Conclusion

This review compiles evidence regarding the anti-proliferative and pro-apoptotic properties of various plant-derived extracts in the context of breast cancer. The essential difference between fixed oils (*e.g*., olive, flaxseed) and essential oils (*e.g*., frankincense, Zataria) is a significant finding, as their unique chemistries necessitate divergent mechanisms of action and therapeutic considerations. There are good leads in both groups. Extra-virgin olive oil (EVOO) is different from other fixed oils because it has phenolic compounds like hydroxytyrosol that have specific anti-HER2 activity. Flaxseed oil, on the other hand, has effects on estrogen receptor-positive tumors. Carvacrol (from Zataria multiflora) and other monoterpenes are two of the most important oils that can cause apoptosis through oxidative stress and mitochondrial pathways. Nonetheless, the translational pathway encounters considerable obstacles. The effective concentrations reported *in vitro* are frequently pharmacologically insignificant for standard human consumption, underscoring a significant disparity between biochemical activity and clinical relevance. Moreover, the literature is predominantly characterized by heterogeneous *in vitro* studies, exhibiting a significant deficiency of standardized clinical trials.

Acknowledgement

The authors gratefully acknowledge Ain Shams University and the Department of Biotechnology for their valuable support in this research. The authors also extend their sincere appreciation to the Research Sector, Dar Al-Ahfad School for Education, Al Athaybah District, Najran, for their continuous assistance.

Conflicts of interest

All authors declare no conflict of interest.

References

1 Emeje M, Ogu E, Chidebe I, Roko G, Abdullahi M & Bibinu DS, Therapeutic Potential of Medicinal Plants. Current Situation and Outlook. *Med Plants-Harnessing the Healing Power of Plants*, (2024).

2 Karmakar A, Karmakar S & Mukherjee S, Properties of various plants and animals feedstocks for biodiesel production. *Bioresour Technol*, 101 (2010) 7201.

3 Rauf S, Fatima S & Ortiz R, Modification of Fatty Acid Profile and Oil Contents Using Gene Editing in Oilseed Crops for a Changing Climate. *GM Crops Food*, 14 (2023) 1.

4 Ghareeb SA, Hasan SS, Ali SHS & Ahmad NS, Comparative Analysis of Safflower (*Carthamus tinctorius* L.) Genotypes Based on Seed and Oil Characteristics. *Appl Ecol Environ Res*, 18 (2020) 7587.

5 Nzikou JM, Matos L, Bouanga-Kalou G, Ndangui CB, Pambou-Tobi NP, Kimbonguila A, Silou T, Linder M & Desobry S, Chemical composition on the seeds and oil of Sesame (*Sesamum indicum* L.) grown in Congo-Brazzaville. *Adv J Food Sci Technol*, 1 (2009) 6.

6 Afrose S, Salma U, Ahmmed T, Sohel M & Khatun A, Evaluation of Physiochemical, Phytochemicals, Antioxidant, Micronutrients Properties of Bangladeshi Crude and Commercial Rice Bran Oil. *Int J*, 13 (2024) 147.

7 Sakouhi F, Saadi C, Omrani I, Boukhchina S & Solana RR, Quality parameters and lipid composition of oil extracted from spent coffee grounds: A promising alternative to vegetable oils used for consumption and cosmetic purposes. *Eur J Lipid Sci Technol*, 126 (2024) 2300230.

8 Mukherjee S & Mitra A, Health Effects of Palm Oil. J Hum Ecol, 26 (2009) 197.

9 Yang J, Wen C, Duan Y, Deng Q, Peng D, Zhang H & Ma H, The composition, extraction, analysis, bioactivities, bioavailability and applications in food system of flaxseed (*Linum usitatissimum* L.) oil: A review. *Trends Food Sci Technol*, 118 (2021) 252.

10 Chatrabnous N, Yazdani N & Vahdati K, Determination of nutritional value and oxidative stability of fresh walnut. *J Nuts*, 9 (2018) 11.

11 Park GH, Hong SC & Jeong JB, Anticancer Activity of the Safflower Seeds (Carthamus tinctorius L.) through Inducing Cyclin D1 Proteasomal Degradation in Human Colorectal Cancer Cells. *Korean J Plant Resour*, 29 (2016) 297.

12 Jacklin A, Ratledge C, Welham K, Bilko D & Newton CJ, The Sesame Seed Oil Constituent, Sesamol, Induces Growth Arrest and Apoptosis of Cancer and Cardiovascular Cells. *Ann N Y Acad Sci*, 1010 (2003) 374.

13 Uthirapathy S, Cytostatic Effects of Avocado Oil Using Single-cell Gel Electrophoresis (Comet Assay). ARO Sci J Koya Univ, 11 (2023) 16.

14 Law KS, Azman N, Omar EA, Musa MY, Yusoff NM, Sulaiman SA & Hussain NH, The effects of virgin coconut oil (VCO) as supplementation on quality of life (QOL) among breast cancer patients. *Lipids Health Dis*, 13 (2014) 1.

15 Saggar JK, Chen J, Corey P & Thompson LU, Dietary flaxseed lignan or oil combined with tamoxifen treatment affects MCF-7 tumor growth through estrogen receptor-and growth factor-signaling pathways. *Mol Nutr Food Res*, 54 (2010) 415.

16 Truan JS, Chen JM & Thompson LU, Flaxseed oil reduces the growth of human breast tumors (MCF-7) at high levels of circulating estrogen. *Mol Nutr Food Res*, 54 (2010) 1414.

17 Buckner AL, Buckner CA, Montaut S & Lafrenie RM, Treatment with flaxseed oil induces apoptosis in cultured malignant cells. *Heliyon*, 5 (2019).

18 Ye W, Chang HL, Wang LS, Huang YW, Shu S, Sugimoto Y, Dowd MK, Wan PJ & Lin YC, Induction of apoptosis by (-)-gossypol-enriched cottonseed oil in human breast cancer cells. *Int J Mol Med*, 26 (2010) 113.

19 Heuvel JPV, Belda BJ, Hannon DB, Kris-Etherton PM, Grieger JA, Zhang J & Thompson JT, Mechanistic Examination of Walnuts in Prevention of Breast Cancer. *Nutr Cancer*, 64 (2012) 1078.

20 Dahl H, The Effect of Cannabinoids on Triple Negative Breast Cancer Cells. (2015).

21 Kannan A, Hettiarachchy NS, Lay JO & Liyanage R, Human cancer cell proliferation inhibition by a pentapeptide isolated and characterized from rice bran. *Peptides*, 31 (2010) 1629.

22 Hettiarachchy N, Li R & Mahadevan M, Rice bran derived pentapeptide-induced apoptosis in human breast cancer cell models (MCF-7 and MDA-MB-231). *Int J Biomed Res*, 5 (2014) 599.

23 Jeong M, Cho J, Shin JI, Jeon YJ, Kim JH, Lee SJ, Kim ES & Lee K, Hempseed oil induces reactive oxygen species- and C/EBP homologous protein-mediated apoptosis in MH7A human rheumatoid arthritis fibroblast-like synovial cells. *J Ethnopharmacol*, 154 (2014) 745.

24 Menendez JA, Vellon L, Colomer R & Lupu R, Oleic acid, the main monounsaturated fatty acid of olive oil, suppresses Her-2/neu (erbB-2) expression and synergistically enhances the growth inhibitory effects of trastuzumab (Herceptin™) in breast cancer cells with Her-2/neu oncogene amplification. *Ann Oncol*, 16 (2005) 359.

25 Wang X, Howell CP, Chen F, Yin J & Jiang Y, Gossypol-A polyphenolic compound from cotton plant. *Adv Food Nutr Res*, 58 (2009) 215.

26 Talbot G, Chocolate and Cocoa Butter—Structure and Composition. Cocoa Butter Relat Compd, (2012) 1.

27 Bone Marrow, Thymus And Blood: Changes Across The Lifespan. *Aging Health*, 5 (2009) 385.

28 Battah B, Shbibe L, Ahmad O, Soukkarieh C, Al Okla SM, Chianese T, Rosati L, Vora LK, Zhao L, Marrazzo A & Ferrari M, *Juniperus oxycedrus* L. ssp. Essential Oil Microneedles: A Promising Antimicrobial and Wound Healing Activity. *Pharmaceuticals* (*Basel*), 17 (2023).

29 Bhuyan DJ, Alsherbiny MA, Perera S, Low M, Basu A, Devi OA, Barooah MS, Li CG & Papoutsis K, The Odyssey of Bioactive Compounds in Avocado (*Persea americana*) and Their Health Benefits. *Antioxidants* (*Basel*), 8 (2019).

30 Corbin EA, Kong F, Lim CT, King WP & Bashir R, Biophysical properties of human breast cancer cells measured using silicon MEMS resonators and atomic force microscopy. *Lab Chip*, 15 (2015) 839.

31 Huang S, Qi B, Yang L, Wang X, Huang J, Zhao Y, Hu Y & Xiao W, Phytoestrogens, novel dietary supplements for breast cancer. *Biomed Pharmacother*, 160 (2023) 114341.

32 Mousavi SS, Karami A, Movahhed Haghighi T, Taban A, Nahar L & Sarker SD, Phytochemistry of *Oliveria decumbens* Vent. (Apiaceae) and its therapeutic potential: A systematic review. *Fitoterapia*, 170 (2023) 105647.

33 Alyafei A & Easton-Carr R, The Health Belief Model of Behavior Change. *StatPearls*, (2024).

34 Pal M, Das D & Pandey M, Understanding genetic variations associated with familial breast cancer. *World J Surg Oncol*, 22 (2024) 271.

35 Thomson T, Li G, Strilchuk A, Cui H, Wang B & Li B, Harnessing artificial intelligence to advance CRISPR-based genome editing technologies. *Nat Rev Genet*, (2025).

36 Albakri MM, TP53-mutated MDS and AML: immune dysregulation, tumor microenvironment, and emerging therapeutic strategies. *Front Oncol*, 15 (2025).

37 Moshksayan K, Khanna R, Camli B, Yakay ZN, Harihara A, Zdyrski C, Mondal S, Hegarty E, Mochel JP, Allenspach K & Ben-Yakar A, A microfluidic platform for culturing and high-content imaging of adult stem cell-derived organoids. *Sci Rep*, 15 (2025) 40162.

38 Giaquinto AN, Sung H, Miller KD, Kramer JL, Newman LA, Minihan A & Siegel RL, Breast cancer statistics, 2022. *CA Cancer J Clin*, 72 (2022) 524.

39 Cai Y, Dai F, Ye Y & Qian J, The global burden of breast cancer among women of reproductive age: a comprehensive analysis. *Sci Rep*, 15 (2025) 9347.

40 Lu Y, Zhao J, Xin Q, Yuan R, Miao Y, Yang M, Mo H, Chen K & Cong W, Protective effects of oleic acid and polyphenols in extra virgin olive oil on cardiovascular diseases. *Food Sci Hum Wellness*, 13 (2024) 529.

41 Infante R, Infante M, Pastore D, Pacifici F, Chiereghin F, Malatesta G, Donadel G, Tesauro M & Della-Morte D, An Appraisal of the Oleocanthal-Rich Extra Virgin Olive Oil (EVOO) and Its Potential Anticancer and Neuroprotective Properties. *Int J Mol Sci*, 24 (2023).

42 Menendez JA, Vazquez-Martin A, Oliveras-Ferraros C, Garcia-Villalba R, Carrasco-Pancorbo A, Fernandez-Gutierrez A & Segura-Carretero A, Extra-virgin olive oil polyphenols inhibit HER2 (erbB-2)-induced malignant transformation in human breast epithelial cells: relationship between the chemical structures of extra-virgin olive oil secoiridoids and lignans and their inhibitory activities on the tyrosine kinase activity of HER2. *Int J Oncol*, 34 (2009) 43.

43 Escrich E, Moral R & Solanas M, Olive oil, an essential component of the Mediterranean diet, and breast cancer. *Public Health Nutr*, 14 (2011) 2323.

44 Lopes CM, Dourado A & Oliveira R, Phytotherapy and Nutritional Supplements on Breast Cancer. *Biomed Res Int*, 2017 (2017) 7207983.

45 Yip CH & Rhodes A, Estrogen and progesterone receptors in breast cancer. *Future Oncol*, 10 (2014) 2293.