Pravara Med Rev; September 2026, 18 (03), 49-55
DOI: 10.36848/PMR/2026/8100000008

Original article

Antitumor efficacy of Gloriosa superba and Glycyrrhiza glabra on CA125, membrane bound enzymes, glycoproteins concentration in 7, 12-Dimethylbenz (a) anthracene induced breast cancer in Wistar rats

Beula Christina W[1], Sankar P[2],Santhanagopal L[3], Anitha R[4], Poongkuzhali Shanmugham[5], Muninathan Natarajan[6*], Arumugam Suresh[7], Keerthi S A[8]

[1,5]Research Scholar, Central Research Laboratory, Meenakshi Medical College Hospital and Research Institute, Kanchipuram, Meenakshi Academy of Higher Education and Research, Tamil Nadu, India.
[2]Assistant Professor, Department of Biochemistry, PES Institute of Medical Sciences and Research (PESIMSR), Kuppam, Chittor District, Andra Pradesh – 517425, India.
[3]Assistant professor, Department of General Surgery in Meenakshi Medical College Hospital and Research Institute, Meenakshi Academy of Higher Education and Research, Kanchipuram, Tamil Nadu, India
[4]Assistant Professor, Department of Foods and Nutrition, Muthurangam Govt Arts College (A), Vellore, Tamil nadu, India
[6]Associate Professor and Scientist, Central Research Laboratory, Meenakshi Medical College Hospital and Research Institute, Meenakshi Academy of Higher Education and Research, Kanchipuram, Tamil Nadu, India.*
[7]Scientist, Central Research Laboratory, Meenakshi Medical College Hospital and Research Institute, Meenakshi Academy of Higher Education and Research, Kanchipuram, Tamil Nadu, India.
[8]Assistant Professor, Department of Biochemistry, Sree Balaji Medical College and Hospital, Chromepet-600044, Chennai, Tamil Nadu, India.

**Corresponding Author: Dr. Natarajan Muninathan*

Abstract

Although there have been considerable improvements in the diagnosis and treatment of breast cancer, it remains the most common cancer in women globally, and a major cause of cancer-related death. The present study is designed to compare the anti-tumour activity of the root extract of Gloriosa superba with Glycyrrhiza glabra against 7, 12-dimethylbenz[a]anthracene (DMBA) induced breast cancer in female Wistar rats. Thirty six rats were randomly allocated into six groups as normal control, disease control, combination treated (rats treated with paclitaxel), Gloriosa superba treated, Glycyrrhiza glabra treated. DMBA was administered once orally and treatment was provided with the respective plant extracts or paclitaxel for induction of breast carcinogenesis. A single oral dose of DMBA was used for breast carcinogenesis, along with the treatment. Biochemical changes involved in mammary carcinogenesis were evaluated by measuring the concentrations of serum CA125 levels, membrane-bound enzyme activities (Na^+/K^+-ATPase, Ca^{2+}-ATPase, and Mg^{2+}-ATPase) and tissue glycoproteins (hexose, hexosamine, fucose, and sialic acid) levels. The neoplasticization caused by DMBA administration significantly elevated serum CA125 concentration and glycoproteins, and significantly decreased membrane-bound ATPase activities when compared with normal animals. The biochemical changes were significantly restored towards normal with Gloriosa superba and Glycyrrhiza glabra treatments. Glycyrrhiza glabra was the most potent among the extracts in terms of protective efficacy, which was almost similar to the paclitaxel. This biochemical improvement that has been observed could be due to some of the phytoconstituents found in both medicinal plants which have been known to have antioxidant, anti-inflammatory, antiproliferative and apoptosis inducing properties. They further demonstrated their chemoprotection by membrane integrity recovery and normalization of tumor-associated biomarkers. Based on the results obtained, both plant extracts showed high antitumour effect against mammary carcinogenesis induced by DMBA and could be promising therapeutic agents for breast cancer therapy after further investigations into their mechanisms of action and clinical trials.

Keywords: *DMBA, Breast Cancer,Gloriosa superba, Glycyrrhiza glabra, CA125*

Introduction

Breast cancer is the most common form of cancer in women worldwide, and among the most common cancer death causes in women. Breast cancer is one of the most common new cases of cancer among women and its prevalence has been increasing in both developed and developing nations, accounting for about 25% of all new cancer cases in women [1]. In fact, although there has been a significant improvement in the chances of survival for patients with breast cancer, breast cancer still causes high medical, social and economic costs, because of recurrence, metastasis and adverse effects of treatment [2-11]. Therefore, discovery of better and safer therapeutic agents is still significant in oncological research.

The MUC16 gene encodes the high-molecular-weight mucin glycoprotein, cancer antigen 125 (CA125), which is a clinically useful tumor marker. While it is a marker of ovarian carcinoma, there is growing evidence that CA125 levels rise in other types of cancer including breast cancer. The elevated levels of serum CA 125 have been correlated with the advanced stage of the disease, the presence of metastases and poor prognosis [12, 13]. Therefore, CA125 can be combined with the measurement of membrane-bound enzymes and glycoprotein components to give a full biochemical picture of the progression of tumors and the effectiveness of therapy.

While the individual pharmacological effects of Gloriosa superba and Glycyrrhiza glabra have been reported, a comparative study of these two plants in experimental breast cancer to determine their effects on tumour associated biochemical markers, membrane bound ATPases, glycoprotein metabolism and serum CA125 concentration is still limited [3, 8]. Hence, the present investigation was aimed to evaluate the anti-tumor activity of these two medicinal plants with standard chemotherapeutic drug paclitaxel on the mammary carcinoma induced by DMBA in female Wistar rats. This discovery will likely bring a lot of insight to their chemoprotective mechanisms and help develop potential plant-based therapy for breast cancer.

Materials and Methods

Chemicals

Analytical grade 7, 12-Dimethylbenz[a]anthracene (DMBA) was purchased from Sigma-Aldrich (St. Louis, MO, USA). Paclitaxel injection used as the standard chemotherapeutic drug was obtained from a licensed pharmaceutical manufacturer. Biochemical analysis was carried out using all commercial chemicals, solvents and reagents of analytical reagent (AR) grade. Commercial enzyme-linked Immunosorbent assay (ELISA) kits were used for the estimation of serum CA125 according to the manufacturer's instructions.

Collection and Preparation of Plant Materials

Roots of Gloriosa superba L. Glycyrrhiza glabra L. (Leguminosae) and Colchicum spp. (Liliaceae). The plants (Fabaceae) were bought from known herbal suppliers and botanically verified by a qualified botanist. The collected roots were washed with distilled water thoroughly to remove soil and foreign substances, shade dried for two weeks at the ambient temperature (25-30°C) and then ground into coarsely powdered form in the mechanical grinder. It was extracted by 70% ethanol by Soxhlet extraction. The extracts were concentrated in a rotary vacuum evaporator under reduced pressure and further dried, to get a semisolid mass. The dried extracts were kept in air-tight containers under refrigeration at 4°C till further use. Extracts were suspended in 0.5% carboxymethyl cellulose (CMC) and re-suspended every day prior to oral administration.

Experimental Animals

Female Wistar rats aged 6-8 weeks and weighing 150-200 g were purchased from an approved animal breeding facility. Animals were kept in polypropylene cages with sterile paddy husk bedding under standard laboratory conditions at 22 ± 2°C having a 12 h light/12 h dark cycle with a relative humidity of 50-60%. Rats were offered a normal laboratory pellet diet and water ad libitum during the experimental period. Animals were acclimatised for one week before the experiment was started.

Induction of Mammary Carcinoma

A single dose of 0.5 ml DMBA, 50 mg/kg b.w., dissolved in olive oil given orally following overnight fasting, was used to induce experimental mammary gland cancer. Animals were subjected to weekly palpation of mammary gland, and monitored regularly for tumour development after carcinogen administration. The incidence, latency period and

body weight of the tumour were observed during the study. Mammary tumors (palpable) were confirmed and treatment with the plant extracts and paclitaxel was started and continued for the experimental period.

Experimental Design

Wistar rats were randomly divided into three groups of six female rats for each group (n = 6).

Group 1: Normal control rats

Group II: Control of breast cancer induced by DMBA

Group III: DMBA + Paclitaxel treated group

Group IV: Group treated with DMBA and Gloriosa superba root extract.

Group V: DMBA + Glycyrrhiza glabra root extract treated group.

Group VI: DMBA + combination treatment (Gloriosa superba + Glycyrrhiza glabra).

The plant extracts were orally administered at the therapeutic dose which was pre-determined while paclitaxel was administered according to the standard therapeutic schedule. The treatment regimen was continued for the entire experimental period. The body weight, food consumption, incidence of tumor, volume of tumor and general health status were measured periodically.

Sample Collection

Anesthetised with ketamine, animals were fasted at the end of the experimental period. Blood sample was taken by the cardiac puncture using plain tubes and centrifuged at 2,500 rpm for 10 minutes for serum separation. Biochemical analysis was conducted on serum samples which were stored at −20°C. The animals were then sacrificed and mammary tumor tissue was carefully excised, washed with ice-cold physiological saline, blotted dry, weighed and used for biochemical assays and histopathological examination. Tissue homogenates (10%, w/v) were prepared by homogenization of tissues in ice-cold Tris-HCl buffer (0.1 M, pH 7.4) with a Teflon-glass homogenizer, and then centrifuged at 10,000 rpm for 20 min at 4°C. The supernatant was used for the estimation of the membrane-bound enzymes and glycoprotein components.

Estimation of Serum CA125

CA125 levels in serum were measured by a commercially available sandwich ELISA kit according to its instructions. The antibody coated into the microplate wells was mixed with standards and serum samples and then incubated as instructed in the kit. Washed, then enzyme-conjugated secondary antibody and chromogenic substrate solution were added. Stop solution was added to stop the reaction and absorbance was read at 450 nm on a microplate reader. The concentrations of CA125 were determined from the calibration curve and presented as U/mL.

Assay of Membrane-Bound ATPases

The activities of membrane bound ATPases were measured in homogenates of mammary tissue. Na+/K+-ATPase, Ca2+-ATPase and Mg2+-ATPase activity had been estimated by assaying the inorganic phosphate released from ATP under specific conditions by standard biochemical methods. Enzymatic activities were reported as the amount of inorganic phosphate (Pi) released in micromol/mg protein/h.

Estimation of Glycoprotein Components

Estimation of glycoprotein constituents such as hexose, hexosamine, fucose and sialic acid was carried out in the homogenates of mammary tissue using well-established colorimetric methods. Appropriate solvent systems were used for the extraction of tissue glycoproteins prior to analysis. Hexose content was measured by phenol-sulfuric acid method, hexosamine by Elson-Morgan method, fucose by Dische-Shettles method and sialic acid by the Warren thiobarbituric acid method. The protein concentrations of glycoprotein components were presented as mg/g of wet tissue.

Histopathological Examination

The mammary tissues from each experimental group were fixed in 10% neutral buffered formalin for 24-48 hours before being dehydrated in graded alcohol, cleared in xylene, and embedded in paraffin wax. Sections of tissue were cut on a rotary microtome and stained with hematoxylin and eosin (H&E) (about 5 µm thick). A blinded histopathologist evaluated the histopathological changes such as tumour architecture, cellular atypia, mitoses, necrosis, inflammatory cell infiltration and restoration of normal mammary gland morphology using light microscopy.

Statistical Analysis

All the experimental data were presented as mean ± standard deviation (SD). Data were analysed statistically using GraphPad Prism Software (Version 9.0, GraphPad Software Inc., San Diego, CA, USA). One-way analysis of variance (ANOVA) was used to compare differences between experimental groups, with Tukey's multiple comparison post hoc tests used to determine which groups were significantly different. Statistically significant was defined as a value of $p < 0.05$.

Results

Effect of *Gloriosa superba* and *Glycyrrhiza glabra* on Serum CA125 Levels

Serum CA125 concentration was significantly elevated in the DMBA-induced breast cancer control group compared with the normal control group ($p< 0.001$), confirming successful induction and progression of mammary carcinoma. Administration of paclitaxel markedly reduced CA125 levels toward normal values ($p< 0.001$ versus DMBA control). Similarly, treatment with *Gloriosa superba* and *Glycyrrhiza glabra* root extracts significantly decreased serum CA125 concentrations compared with the disease control group. Among the herbal treatment groups, *Glycyrrhiza glabra* exhibited a greater reduction in CA125 than *Gloriosa superba*, although the standard drug produced the maximum inhibitory effect. The combination-treated group demonstrated the most pronounced decrease among the plant-treated groups, suggesting a possible synergistic antitumor effect.

Table 1. Effect of *Gloriosa superba* and *Glycyrrhiza glabra* on serum CA125 in DMBA-induced breast cancer

Experimental Groups	CA125 (U/mL)
Normal Control	16.42 ± 1.35
DMBA Control	71.86 ± 4.82*
DMBA + Paclitaxel	23.75 ± 2.14#
DMBA + *Gloriosa superba*	35.82 ± 3.16#
DMBA + *Glycyrrhiza glabra*	29.64 ± 2.71#
DMBA + Combination	24.81 ± 2.05#

Effect on Membrane-Bound ATPase Activities

DMBA administration produced a significant reduction in the activities of Na^+/K^+-ATPase, Ca^{2+}-ATPase, and Mg^{2+}-ATPase compared with the normal control animals ($p< 0.001$). The decreased activities of these membrane-bound enzymes indicate severe membrane damage and disruption of ionic homeostasis during mammary carcinogenesis. Treatment with paclitaxel significantly restored ATPase activities toward normal values. Oral administration of *Gloriosa superba* and *Glycyrrhiza glabra* also significantly increased the activities of all three ATPases compared with the untreated cancer group. Restoration was more pronounced in the *Glycyrrhiza glabra* group than in the *Gloriosa superba* group. The combination treatment exhibited enzyme activities comparable to those observed in the paclitaxel-treated animals.

Table 2. Effect of plant extracts on membrane-bound ATPases in mammary tissue

Groups	Na^+/K^+-ATPase	Ca^{2+}-ATPase	Mg^{2+}-ATPase
Normal Control	7.84 ± 0.42	6.62 ± 0.38	9.34 ± 0.45
DMBA Control	3.18 ± 0.28*	2.76 ± 0.24*	4.41 ± 0.36*
DMBA + Paclitaxel	7.21 ± 0.39#	6.14 ± 0.33#	8.92 ± 0.41#
DMBA + *Gloriosa superba*	5.92 ± 0.31#	5.08 ± 0.27#	7.54 ± 0.38#
DMBA + *Glycyrrhiza glabra*	6.53 ± 0.34#	5.74 ± 0.30#	8.13 ± 0.40#
DMBA + Combination	7.05 ± 0.36#	6.03 ± 0.31#	8.76 ± 0.39#

Effect on Glycoprotein Components

DMBA-induced mammary carcinoma resulted in a significant elevation of tissue glycoprotein components, including hexose, hexosamine, fucose, and sialic acid, when compared with the normal control animals ($p< 0.001$). Elevated glycoprotein concentrations indicate increased glycosylation associated with tumor growth, invasion, and metastasis. Paclitaxel treatment markedly normalized all glycoprotein constituents. Both *Gloriosa superba* and *Glycyrrhiza glabra* significantly reduced the elevated glycoprotein levels, with *Glycyrrhiza glabra* producing greater improvement

than *Gloriosa superba*. The combination-treated group demonstrated values approaching those of the normal control, indicating effective suppression of abnormal glycoprotein metabolism.

Table 3. Effect of plant extracts on glycoprotein concentrations in mammary tissue

Groups	Hexose	Hexosamine	Fucose	Sialic Acid
Normal Control	38.64 ± 2.12	21.83 ± 1.26	8.72 ± 0.54	5.18 ± 0.31
DMBA Control	76.52 ± 4.13*	44.71 ± 2.42*	18.94 ± 1.06*	12.65 ± 0.72*
DMBA + Paclitaxel	42.75 ± 2.36#	24.43 ± 1.34#	9.46 ± 0.57#	5.92 ± 0.34#
DMBA + *Gloriosa superba*	52.68 ± 2.91#	30.82 ± 1.71#	12.86 ± 0.68#	7.83 ± 0.45#
DMBA + *Glycyrrhiza glabra*	46.81 ± 2.63#	26.95 ± 1.48#	10.85 ± 0.61#	6.64 ± 0.39#
DMBA + Combination	43.26 ± 2.41#	24.98 ± 1.36#	9.82 ± 0.58#	6.03 ± 0.35#

Histopathological Observations

Histological analysis of the mammary tissues from the normal control group showed normal ducts, alveoli and stromal connective tissue, and normal glandular architecture. The mammary carcinoma was successfully induced in the DMBA treated group, which exhibited extensive neoplastic changes including pleomorphic epithelial cells, hyperchromatic nuclei, abnormal mitotic figures, disruption of ductal architecture, stromal invasion, inflammatory cell infiltration and areas of necrosis. The mammographic findings in paclitaxel-treated rats were impressive, as the architecture was restored in normal rats, and there was a significant decrease in the number of neoplastic lesions and inflammatory infiltration. Animals treated with Gloriosa superba had moderate improvement with a reduction in cellular atypia, in the number of mitoses per section and partial restoration of glandular organization. Histological improvement was greater in the Glycyrrhiza glabra group compared to the Gloriosa superba group with less tumor cell density and better ductal integrity along with minimal inflammatory changes. Histology of the mammary glands in the combination-treated group was virtually normal, and contained only an occasional neoplastic cell similar to that seen in the paclitaxel treated group.

Antitumor Activity

Biochemical and histopathological results indicated that DMBA-induced mammary carcinogenesis was accompanied by an increase of serum CA125 level, decrease of membrane-bound ATPase activity, increase of glycoprotein component and severe histological abnormalities. Significant amelioration of these alterations was seen when treated with Gloriosa superba and Glycyrrhiza glabra, which suggests considerable antitumour activity. Individual herbal extracts of Glycyrrhiza glabra showed the most beneficial effects on restoring biochemical and histological parameters, while the combination therapy had a similar effect to the standard chemotherapeutic agent, paclitaxel. These results indicate a mechanism of action for both extracts involving the maintenance of membrane integrity, normalization of glycoprotein metabolism, reduction of levels of tumor-associated biomarkers and inhibition of mammary tumor progression.

Discussion

The present study revealed that the root extract of G. superba and G. glabra possess potent anti-cancer effect on mammary carcinogenesis induced by DMBA in female Wistar rats. Biochemical changes observed after DMBA administration were: elevated level of CA125 in serum, reduced activities of membrane-bound ATPases, increased concentrations of glycoproteins and significant histopathological abnormalities. These changes were significantly lessened with treatment using both plant extracts, suggesting their protective effects against breast cancer progression. Of the two herbal treatments, Glycyrrhiza glabra was more effective than Gloriosa superba, and the combination treatment had effects similar to that of the standard chemotherapeutic drug paclitaxel [3, 4, 8].

MUC16, which encodes CA125, encodes a mucin glycoprotein of high molecular weight, a molecule that is important in the progression of breast cancer and is being increasingly used as a biomarker. While mainly utilized for the diagnosis of ovarian cancer, high serum level of CA125 has also been described in advanced breast cancer, and has been correlated with the presence of metastasis and clinical outcome [5, 7, 13]. The present study revealed that the serum CA125 level was significantly elevated following DMBA administration, suggesting active tumor progression and an enhancement in the malignant transformation. The serum CA125 concentration was significantly decreased after treatment with Gloriosa superba and Glycyrrhiza glabra, indicating suppression of tumor growth and decreased

expression of tumor-associated glycoproteins. The results are consistent with other studies indicating that phytochemicals like glycyrrhizin, glabridin, isoliquiritigenin, colchicine, and gloriosine have anti-cancer effects by suppressing the proliferation of cancer cells, inducing cell death, and modulating cellular pathways such as PI3K/Akt, NF-κB, MAPK, and mitochondrial pathways that are involved in the process of cancer [9–11,13].

Membrane bound ATPases play a crucial role in maintaining transmembrane ion gradients, intracellular calcium homeostasis, membrane permeability and cellular energy metabolism. Oxidative stress caused by DMBA disrupts membrane phospholipids by lipid peroxidation and results in a loss of activity of Na+/K+-ATPase, Ca2+-ATPase and Mg2+-ATPase [6,8,13]. Decreased ATPase activities affect the integrity of the membrane, signaling and uncontrolled proliferation of malignant cells. Significant restoration of ATPase activities after treatment with Gloriosa superba and Glycyrrhiza glabra suggests that the membrane structure has been preserved and ion transport systems have become functional. This improvement could be explained by the high antioxidant activity of flavonoids, saponins, alkaloids and phenolic compounds found in both medicinal plants, where they are responsible for the prevention of oxidative damage in membranes and stabilization of phospholipid bilayers [9-11].

During malignant transformation, there are a number of biochemical events which include changes in glycoprotein metabolism. Hexose, hexosamine, fucose, and sialic acid are important components of glycoproteins that are critical for cell adhesion, receptor activation, interactions with the extracellular matrix, angiogenesis, and metastatic dissemination [7, 12]. Higher glycosylation of membrane proteins can make tumor cells more invasive and can help them escape from the immune system [13]. The present research showed significant increase in the level of glycoprotein components in DMBA induced mammary carcinoma, which indicated that there exists more glycosylation in cancer progression. Both of the herbal extracts significantly normalized these glycoprotein constituents, suggesting the inhibition of abnormal carbohydrate metabolism and restoration of normal membrane architecture. The increased efficacy in Glycyrrhiza glabra could be due to glycyrrhizin and glabridin, which have been reported to inhibit inflammatory mediators, oxidative stress, glycosylation pathways, and induce apoptosis in breast cancer cells [11–13].

Biochemical observations were confirmed by the histopathological findings. Mamary tissues of DMBA treated rats showed marked neoplastic changes with ductal disorganization, pleomorphic cells, hyperchromatic nuclei, inflammatory infiltration and enhanced mitotic activity. Gloriosa superba and Glycyrrhiza glabra, on the other hand, brought back the normal architecture of the mammary gland and decreased the cellular atypia and inflammatory changes. Glandular morphology was virtually restored in the combination-treated group which was similar to the paclitaxel-treated group. The plant extracts positively affect the suppression of the proliferation of tumor cells and the repair of tissue and cellular differentiation, as indicated by the improvements in histopathology [3, 8, 10, 11].

The superior anti-tumor activity of Glycyrrhiza glabra to that of Gloriosa superba in the present study could be attributed to the presence of more antioxidants, anti-inflammatory, antiangiogenic, and antiapoptotic flavonoids, triterpenoid saponins and phenolics [9, 11] in the former. Gloriosa superba also showed excellent chemoprotective activity, which may be due to the inhibition of microtubule polymerization and arrest of mitosis of rapidly proliferating tumor cells by colchicine [10]. The increased response seen after combination therapy indicates that combination of several phytoconstituents may give synergistic effect by targeting different molecular pathways that are associated with the process of carcinogenesis [9–11, 13].

Conclusion

The present study showed that the root extracts of Gloriosa superba and Glycyrrhiza glabra have significant anti-tumor activity against the breast cancer induced in female wistar rats by 7, 12 dimethylbenz[a]anthracene (DMBA). Increased serum CA125 level, lower serum activities of membrane-bound ATPases (Na^+/K^+-ATPase, Ca^{2+}-ATPase, Mg^{2+}-ATPase), and distinct histopathological changes in mammary gland tissues were observed in DMBA-induced mammary carcinogenesis. Such biochemical and structural changes are linked to increased tumor progression, membrane dysfunction, oxidative stress and changes in cellular metabolism in breast cancer.

These pathological changes were significantly reversed when treated with Gloriosa superba and Glycyrrhiza glabra, due to the reduction of serum CA125 levels, restoration of membrane-bound enzyme activities, normalization of glycoprotein metabolism and improvement of mammary gland architecture. The results showed that both medicinal

plants were able to maintain membrane integrity and control tumour associated biochemical markers and to inhibit tumour progression in the mammary gland. The protective properties observed are probably due to the multiple molecular pathways targeted by their bioactive phytoconstituents with antioxidant, anti-inflammatory, antiproliferative, and pro-apoptotic properties interfering.

Of the individual treatments, Glycyrrhiza glabra was found to be more effective than Gloriosa superba, resulting in biochemical and histopathological improvements that were comparable to those obtained chemotherapeutically with paclitaxel. Also, the joint effect of both plant extracts was more effective in the treatment of tumor, indicating a possible synergistic action between the phytochemicals of both extracts.

In conclusion, this study offers experimental evidence that Gloriosa superba and Glycyrrhiza glabra could be valuable plant-based therapeutic agents for breast cancer. Their ability to modulate tumour biomarkers, maintain membrane function and restore normal glycoprotein metabolism, suggests they might be useful as adjunctive or complementary therapy to conventional chemotherapy. However, additional research on molecular signaling pathways, proteins involved in apoptosis, pharmacokinetic profiling, long-term toxicity studies, and the well-designed clinical trials are justified to confirm efficacy, determine safety, and bring to fruition the translation of these into the clinical arena for breast cancer management.

Reference

1. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: a cancer journal for clinicians. 2021 May;71(3):209-49.
2. Siegel RL, Kratzer TB, Giaquinto AN, Sung H, Jemal A. Cancer statistics, 2025. Ca. 2025 Jan 16;75(1):10.
3. Waks AG, Winer EP. Breast cancer treatment: a review. Jama. 2019 Jan 22; 321(3):288-300.
4. Thomssen C, Balic M, Harbeck N, Gnant M. St. Gallen/Vienna 2021: a brief summary of the consensus discussion on customizing therapies for women with early breast cancer. Breast Care. 2021 May 3;16(2):135-43.
5. Gholikhani T, Kumar S, Valizadeh H, Mahdinloo S, Adibkia K, Zakeri-Milani P, Barzegar-Jalali M, Jimenez B. Advances in aptamers-based applications in breast cancer: drug delivery, therapeutics, and diagnostics. International Journal of Molecular Sciences. 2022 Nov 21;23(22):14475.
6. Kundu JK, Surh YJ. Inflammation: gearing the journey to cancer. Mutation Research/Reviews in Mutation Research. 2008 Jul 1;659(1-2):15-30.
7. Pinho SS, Reis CA. Glycosylation in cancer: mechanisms and clinical implications. Nature Reviews Cancer. 2015 Sep;15(9):540-55.
8. Can MI, Aslan A, Koran K, Uslu H, Agca CA, Ozercan IH, Gorgulu AO. Investigation of the in silico, in vitro, and in vivo effects of a novel amino acid conjugate against DMBA-induced breast cancer in rats. Future Medicinal Chemistry. 2026 Jun 15:1-6.
9. Tirkey R, Saraf S, Saraf S. Ethnopharmacological insights on therapeutic potential of Gloriosa superba. Current Traditional Medicine. 2023 Oct 1;9(5):77-89.
10. Mondal M, Das S, Chandra I. Effect of individual plant growth regulators on modulation of secondary metabolites production in an important medicinal plant Gloriosa superba L. Plant Cell, Tissue and Organ Culture (PCTOC). 2024 Jan;156(1):28.
11. Pastorino G, Cornara L, Soares S, Rodrigues F, Oliveira MB. Liquorice (Glycyrrhiza glabra): A phytochemical and pharmacological review. Phytotherapy research. 2018 Dec;32(12):2323-39.
12. Reily C, Stewart TJ, Renfrow MB, Novak J. Glycosylation in health and disease. Nature Reviews Nephrology. 2019 Jun;15(6):346-66.
13. Hanahan D. Hallmarks of cancer: new dimensions. Cancer discovery. 2022 Jan 1;12(1):31-46.