Babol university of Medical Sciences
Current Research in Medical Sciences
ISSN: 2538-6212
Student Research Committee
Current Research in Medical Sciences

Novel formulated form of turmeric oleoresin inhibits cell growth and migratory behaviors of breast cancer cells

Zahede Bahmani [1,2,#] , Faezeh Ghasemi [2,#], Ghazaleh Pourali [2,3,#], Shima Mehrabadi [2,3], Seyed Mahdi Hassanian [2,3], Soodabeh ShahidSales [5], Masoud Saleh Moghaddam [1], Safieh Ebrahimi [2], Amirhossein Sahebkar [3,6,*], Amir Avan [2,3,4*]

1. Department of Biochemistry, Faculty of Science, Payame Noor University, Mashhad, Iran
2. Metabolic Syndrome Research Center, Mashhad University of Medical Sciences, Mashhad, Iran.
3. Basic Sciences Research Institute, Mashhad University of Medical Science, Mashhad, Iran.
4. Medical Genetics Research Center, Mashhad University of Medical Sciences, Mashhad, Iran.
5. Cancer Research Center, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.
6. Biotechnology Research Center, Mashhad University of Medical Sciences, Mashhad, Iran

Article Info

Article type:
Research Article

Received: 12 July 2022
Revised: 20 September 2022
Accepted: 28 September 2022

ABSTRACT

Background and Objective: Curcumin is a polyphenolic compound derived from Curcumin longa L. There is growing body of data showing the antitumor effect of curcumin in different cancers; however, its efficacy is limited by its low absorption rate. Here, we investigated the antitumor activity of turmeric oleoresin alone or in combination with paclitaxel in MCF-7 cells in monolayer cell cultures and spheroids models.

Methods: The antiproliferative activities of 3 different form, curcumin, phospholipidated curcumin, and turmeric oleoresin were assessed by MTT assay. The migratory behaviors of the cells were determined by migration assay before and after treatment with curcumin. The expression levels of CyclinD1, P65, Nf-kB, and E-cadherin were studied.

Findings: Curcumin suppressed cell growth in MCF-7 cells via modulation of CyclinD1 and NF-KB, which was more pronounced with turmeric oleoresin. Curcumin was able to reduce the invasiveness of MCF-7, compared to control cells through perturbation of E-cadherin.

Conclusion: We demonstrated the antitumor activity of curcumin and curcumin oleoresin in breast cancer cells, supporting further investigations on the therapeutic potential of this novel anticancer agent in in vivo models.

Keywords: Breast cancer, Curcumin, Anti-tumor effect, Spheroid, Oleoresin

Cite this article: Bahmani z, et al. Novel formulated form of turmeric oleoresin inhibits cell growth and migratory behaviors of breast cancer cells. *Current Research in Medical Sciences*. 2022; 6(2): 23-31

© The Author(s).
Publisher: Babol University of Medical Sciences

* **Corresponding Author:** Amir Avan, Ph.D. Metabolic Syndrome Research Center, School of Medicine, Mashhad University of Medical Sciences.
Tell: +98 513 8002298 **E-mail:** avana@mums.ac.ir
Amirhossein Sahebkar PhD, Biotechnology Research Center, Mashhad University of Medical Sciences, Mashhad, Iran.
Tell: +98 513 8002299 **E-mail:** Sahebkara@mums.ac.ir
# Equally contributed as first author

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]
[DOI: 10.22088/crms.6.2.23]

Introduction

Breast cancer is the second most common cause of cancer death among women which contributed to the death of 519,000 people in 2004 (1). Incidence rates of breast cancer vary greatly worldwide, the highest rate was found in North America and western Europe and the low rates were observed in Asia and eastern Europe (2). Taxol is the most commonly used chemotherapeutic agent in the treatment of breast cancer; however, treatment with these drugs results in unwanted side effects and the development of chemo/drug resistance (3, 4). Therefore, it is needed to identify new anticancer agents to increase the efficacy of these drugs and overcome resistance to the current therapy. Curcumin is a polyphenolic compound (1, 7-bis (4-hydroxy-3-methoxyphenyl)-1, 6- heptadiene-3, 5-dione) derived from the rhizomes of turmeric (Curcumin longa L.) It has been reported that curcumin exerts anticancer properties via regulating various signaling pathways, involved in cell proliferation, cell cycle arrest and apoptosis (5-7). In addition it possesses beneficial chemopreventive and chemotherapeutic activity via targeting key signaling pathways, including NF-kB, Signal Transducer and Activator of Transcription (STAT3) (8, 9), extracellular-signal-regulated kinases (ERK1/2) and Epidermal Growth Factor Receptor (EGFR, in different tumor types (10).

Regarding its anticancer properties and safety profile, even in patients who have taken high doses (8 mg/d), several studies has been carried out to investigate the efficacy of combined therapy of curcumin and conventional chemotherapeutic agents. Lev-Ari et al demonstrated that curcumin synergistically enhanced the growth inhibitory effect of celecoxib in colorectal cancer cells through down-regulation of COX-2 expression (10). Curcumin also potentiated the antitumor activities of cisplatin in ovarian cancer cells by suppressing the production of the autocrine IL-6 (11). In addition, curcumin combined with tumor necrosis factor-related apoptosis-inducing ligand (TRAIL) synergistically induced apoptosis in androgen-sensitive prostate cancer cells, suggesting that adjuvant treatment with curcumin could be useful against prostate cancer (12). The combination of chemotherapeutic drugs and curcumin was also effective in cervical cancer (13), colorectal cancer (14), pancreatic cancer (15) and breast cancer. Thus, the aim of the present study was to investigate the antitumor activity of turmeric oleoresin in breast cancer cells in monolayer cell cultures and spheroids models.

Methods

Cell culture

Curcumin was obtained by Sami Labs Ltd. (Bangalore, India). The drugs were dissolved in ethanol or sterile water, and diluted in culture medium before use. MCF-7 cells were obtained from the American Type Culture Collection. The cells were cultured in RPMI-1640, (Gaithersburg, MD) supplemented with 10% heat-inactivated FBS and 1% streptomycin/penicillin (Gaithersburg, MD) followed by incubation at 37 °C. The cells were harvested with trypsin-EDTA in their exponentially growing phase.

Quantitative Reverse-Transcriptase Polymerase-Chain-Reaction (qRT-PCR)

RNAs were extracted from the cells before and after treatment with curcumin at IC50 and 5xIC50 values using the RNXPLOS (CinaColon, Tehran, Iran), according to the manufacturers' protocol. RNAs were reverse-transcribed using the cDNA Synthesis Kit (CinaColon, Tehran, Iran). qRT-PCR was carried out with specific primers for *E-cadherin* (Macrogene co, Seoul, Korea). Gene expression values were normalized to GAPDH (16).

Growth inhibition studies

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]

[DOI: 10.22088/crms.6.2.23]

The cell growth inhibitory effects of curcumin were explored in the cells after treatment for 72 hours. The plates were processed for the MTT assay, as described previously (17).

Effect of curcumin in multicellular spheroids

MCF-7 spheroids were established by seeding 10^5 cells per ml in RMPI/F12+GlutaMAX-I (1:1) in 24-well coated by agarose. The cytotoxic effects were evaluated for 10 days with the inverted phase contrast microscope Leica-DMI300B (Leica, Wetzlar, Germany) (18).

In vitro invasion assay

Transwell chambers with polycarbonate membranes and 8-µm pores were used for invasion assays (19). These assays were carried out via coated transwell filters, with 100 µl of 0.1 mg/mL collagen I solution. A total of 10^5 cells were seeded on the upper side of the filter and incubated with curcumin at IC50 and 5xIC50 in medium free FBS medium. The cells migrated into the lower side were fixed with paraformaldehyde after 24 hours and then stained with Giemsa. The filters were photographed and then counted.

Statistical analysis

All experiments were performed in triplicate. Data were expressed as mean values±SEM. and analyzed by Student's t-test or ANOVA followed by Tukey's multiple comparison test. Data were analyzed using SPSS v.20 (IBM, Chicago). Statistical significance was set at $P<0.05$.

Results

Curcumin inhibits cell growth

The cell growth inhibitory activity of curcumin in MCF7 cells is shown in Figure 1A. Curcumin inhibited the cell growth in dose dependent manner in MCF7 cells using MTT assay. It has been found that that three-dimensional (3-D) culture models are generally more chemo-/radio-resistant, compared to two-dimensional monolayer cell cultures, indicating the use of 3-D models for drug testing. To assess whether curcumin would be active in 3-D MCF7 models, we determined the activity of curcumin in spheroid cultures of MCF7 cells. Our data showed tumor shrinkage in spheroids after 5 days, compared with the untreated spheroids (Figure 2).

Curcumin inhibits cell invasion and modulates E-cadherin expression

Next, we evaluated the effect of curcumin on breast cell invasion. This data showed that treatment of MCF7 cells with curcumin decreased the invasive behavior of these cells (Figure 3). Since previous studies suggested the lower level of E-cadherin expression in cancer cells with respect to its highly metastatic behavior, we investigated whether curcumin could affect the level of this target. Curcumin increased E-cadherin expression ($P<0.05$; Figure 3).

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]

[DOI: 10.22088/crms.6.2.23]

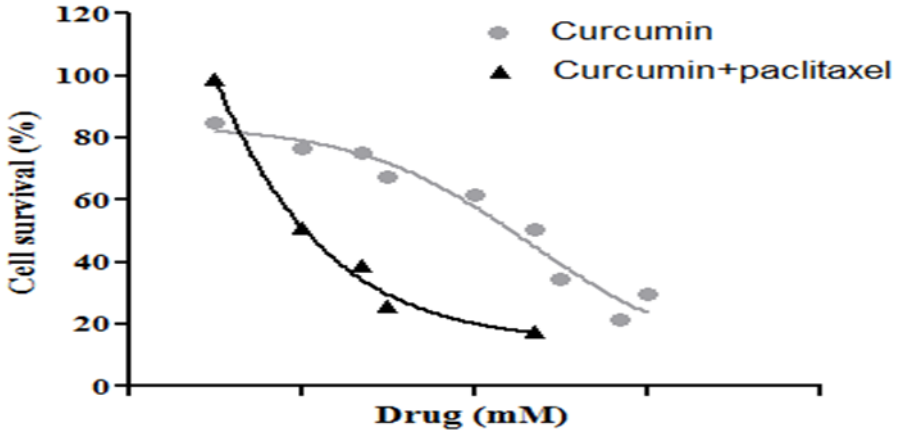

Figure 1. Inhibition of cell proliferation in MCF-7 cells. Growth inhibitory effects after 72 hours; C*olumns* or *Points*, mean values obtained from three independent experiments; *bars*, SEM.
*significantly different from controls.

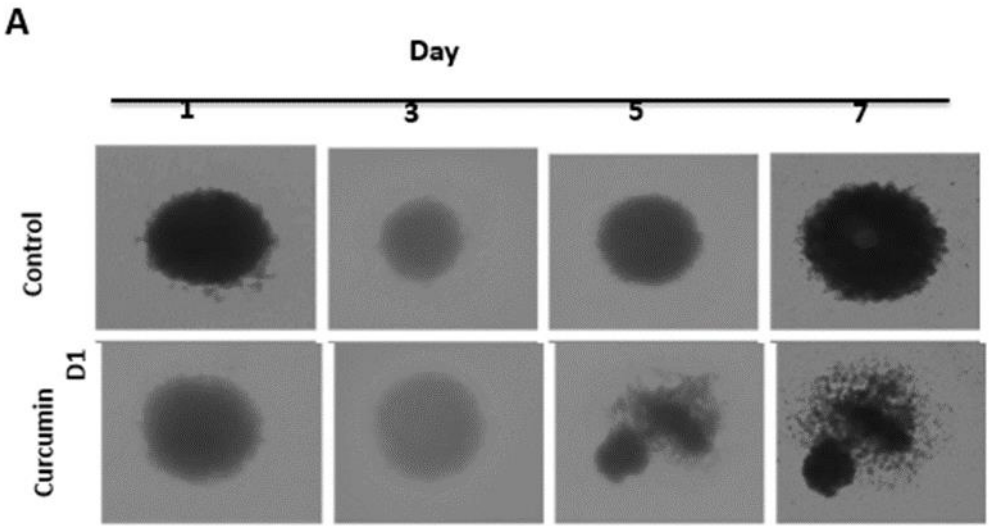

Figure 2. Inhibition of cell proliferation in MCF-7 cells. Effect of curcumin on the PDAC spheroids

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]

[DOI: 10.22088/crms.6.2.23]

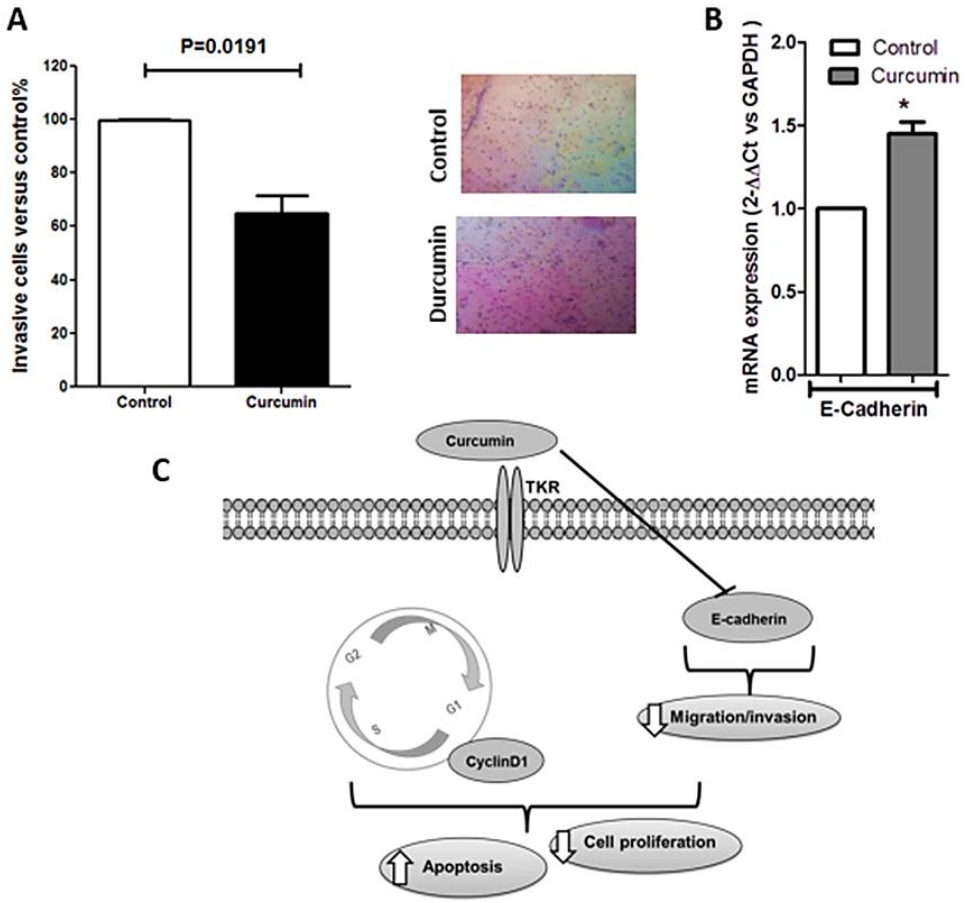

Figure 3. Effects of curcumin on PDAC cells invasion. (A) Results of invasion experiment in the MCF-7 cells exposed for 24 hours to curcumin at 5xIC50 values (insert: representative picture at 24 hours); **(B)** Modulation of *E-cadherin* mRNA levels after 24 hours exposure to curcumin as determined by q-RT-PCR. *Columns* or *Points*, mean values obtained from three independent experiments; *bars*, SEM. *Significantly different from controls. **(C)** curcumin inhibits Wnt and enhances the growth inhibitory effects through its pronounced pro-apoptotic, anti-invasive effects, as well as by inhibiting the cell proliferation.

Discussion

In the present study we evaluated the anticancer effect of turmeric oleoresin curcumin in breast cancer cells. Our findings showed that turmeric oleoresin curcumin inhibited cell growth in breast cancer cells. it has been reported that genistein, a nontoxic flavonoid compound, enhanced the antitumor activity of chemotherapeutic agents (8) by blocking NF-κB activation in prostate, breast, lung, and pancreatic cancer cells (20-23). It has been reported that NF-κB pathway can be inhibited by curcumin and further enhance the antitumor activity of different anticancer drugs that activate NF-KB (7, 24). Ajaikumar et al. indicated that curcumin potentiates the antitumor effects of gemcitabine in pancreatic cancer by suppressing proliferation, NF-κB, and NF-κB–regulated gene products in an orthotopic model of pancreatic cancer (15). Bava et al showed that curcumin enhanced taxol-sensitization in cervical cancer cell via suppression of NF-κB and serine/threonine kinase Akt (18). Notarbartolo et al demonstrated that combination of curcumin with cisplatin or doxorubicin in hepatic cancer HA22T/VGH cell line resulted in a synergistic antitumor activity through blocking NF-kB activation (17). Aggarwal et al showed that curcumin inhibited paclitaxel-induced NF-κB activation in breast cancer cells. Moreover, the administration of dietary curcumin suppressed breast cancer metastasis to the lung in nude mice which was correlated with the down-regulation of NF-κB, cyclooxygenase 2, and matrix metalloproteinase-9 (18). In accordance with these reports, our results are consistent showing curcumin inhibited the NF-kB activation in breast cancer cells and enhanced the antiproliferative activity of doxorubicin and Taxol.

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]

[DOI: 10.22088/crms.6.2.23]

In addition, Wnt/β-catenin signaling pathway is among the key signaling pathways in breast cancer, which has been reported to be inhibited by curcumin (19, 25). The Wnt-signaling pathway is an evolutionarily conserved and sophisticated signaling cascade which has critical roles in cell proliferation and migration, cell cycle arrest and differentiation and controlling tumor progression. Following the activation of Wnt pathway, β-catenin is released from a cytoplasmic inhibitory complex and accumulates in the cytoplasm which can then translocate to the nucleus and bind to T-cell factor (Tcf) and stimulate the transcription of Wnt target genes (26-28). In this line, PRASAD et al demonstrated that curcumin suppressed Wnt/β-catenin signaling in MCF-7 and MDA-MB-231 breast cancer cells through downregulating the expression of Wnt/β-catenin pathway components including disheveled, β-catenin, cyclin D1 and slug (29). In our study, we demonstrated that curcumin down-regulates the Wnt/β-catenin-signaling and its downstream gene *Survivin*. Curcumin also inhibits proliferation and induces apoptosis by suppressing the Wnt/β-catenin pathway in other human malignancies including hepatocellular carcinoma (30), prostate (31), and colon cancer (32). Furthermore, activation of the Wnt/β-catenin-signaling is correlated with chemoresistance which suggests that the synergistic interaction of curcumin with doxorubicin and Taxol might be mediated by inhibition of Wnt/β-catenin-signaling pathway.

In addition to the effects of curcumin on cell growth, we evaluated whether curcumin can affect breast cancer cell migration and explored its possible mechanism. We found that treatment of breast cancer cells with curcumin decreased migratory behavior of these cells. Our result is in line with previous reports demonstrating that curcumin suppresses migration and invasion of human endometrial carcinoma cells (33), gliomas (34), breast (35), lung (36) and colon cancer (37). This effect may be related to increased expression of cell-cell adhesion molecule, E-cadherin, which has been shown to have invasion-suppressing properties (38). In support of this hypothesis, Mukherjee et al demonstrated curcumin inhibited the breast cancer stem cell migration by restoring the expression of the, E-cadherin (39). Consistently, we observed that exposure of breast cancer cells with curcumin significantly increased the mRNA level of E-cadherin. These results reveal that the anti- migratory effect of curcumin is correlated with up-regulation of E-cadherin.

Conclusion

In conclusion, we have shown that curcumin potently inhibits breast cancer cells proliferation, and invasion via perturbation of Wnt and NF-κB signaling pathways. Thus, targeting these proliferative signaling pathways by curcumin might have a great clinical significance in terms of the treatment of breast cancer and enhance the effect of chemotherapy. However, further studies are required to determine the exact molecular mechanisms and therapeutic values of different formulations of curcumin in breast cancer.

Compliance with Ethics Guidelines

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent for Publication

Informed consent was obtained from all individual participants included in the study.

Competing Interests

The authors have no conflict of interest to disclose.

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]

[DOI: 10.22088/crms.6.2.23]

Financial Support

This work was supported by a grant (grant ID nu# 940908; Amir Avan and Amirhossein Sahebkar) from Mashhad University of Medical Sciences.

References

1. M Liu M, Huang Y, Wang J. Developing phytoestrogens for breast cancer prevention. Anticancer Agents Med Chem. 2012;12(10):1306-13.
2. Coleman MP, Quaresma M, Berrino F, Lutz J-M, De Angelis R, Capocaccia R, et al. Cancer survival in five continents: a worldwide population-based study (CONCORD). Lancet Oncol. 2008;9(8):730-56.
3. Vorobiof D, Rapoport B, Chasen M, Slabber C, McMichael G, Eek R, et al. First line therapy with paclitaxel (Taxol®) and pegylated liposomal doxorubicin (Caelyx®) in patients with metastatic breast cancer: a multicentre phase II study. Breast. 2004;13(3):219-26.
4. Sledge GW, Neuberg D, Bernardo P, Ingle JN, Martino S, Rowinsky EK, et al. Phase III trial of doxorubicin, paclitaxel, and the combination of doxorubicin and paclitaxel as front-line chemotherapy for metastatic breast cancer: an intergroup trial (E1193). J Clin Oncol. 2003;21(4):588-92.
5. Chauhan D. Chemotherapeutic potential of curcumin for colorectal cancer. Curr Pharm Des. 2002;8(19):1695-706.
6. Shishodia S, Chaturvedi MM, Aggarwal BB. Role of curcumin in cancer therapy. Curr Probl Cancer. 2007;31(4):243-305.
7. Hour TC, Chen J, Huang CY, Guan JY, Lu SH, Pu YS. Curcumin enhances cytotoxicity of chemotherapeutic agents in prostate cancer cells by inducing p21WAF1/CIP1 and C/EBPβ expressions and suppressing NF-κB activation. Prostate. 2002;51(3):211-8.
8. Aggarwal BB. Nuclear factor-κB: the enemy within. Cancer Cell. 2004;6(3):203-8.
9. Arlt A, Gehrz A, Müerköster S, Vorndamm J, Kruse M-L, Fölsch UR, et al. Role of NF-κB and Akt/PI3K in the resistance of pancreatic carcinoma cell lines against gemcitabine-induced cell death. Oncogene. 2003;22(21):3243-51.
10. Lev-Ari S, Strier L, Kazanov D, Madar-Shapiro L, Dvory-Sobol H, Pinchuk I, et al. Celecoxib and curcumin synergistically inhibit the growth of colorectal cancer cells. Clin Cancer Res. 2005;11(18):6738-44.
11. Chan MM, Fong D, Soprano KJ, Holmes WF, Heverling H. Inhibition of growth and sensitization to cisplatin-mediated killing of ovarian cancer cells by polyphenolic chemopreventive agents. J Cell Physiol. 2003;194(1):63-70.
12. Deeb D, Xu YX, Jiang H, Gao X, Janakiraman N, Chapman RA, et al. Curcumin (diferuloyl-methane) enhances tumor necrosis factor-related apoptosis-inducing ligand-induced apoptosis in lncap prostate cancer cells1. Mol Cancer Ther. 2003;2(1):95-103.
13. Venkatraman M, Anto RJ, Nair A, Varghese M, Karunagaran D. Biological and chemical inhibitors of NF-κB sensitize SiHa cells to cisplatin-induced apoptosis. Mol Carcinog. 2005;44(1):51-9.
14. Pieck A, Drescher A, Wiesmann K, Messerschmidt J, Weber G, Strumberg D, et al. Oxaliplatin-DNA adduct formation in white blood cells of cancer patients. Br J Cancer. 2008;98(12):1959-65.
15. Kunnumakkara AB, Guha S, Krishnan S, Diagaradjane P, Gelovani J, Aggarwal BB. Curcumin potentiates antitumor activity of gemcitabine in an orthotopic model of pancreatic cancer through suppression of proliferation, angiogenesis, and inhibition of nuclear factor-κB–regulated gene products. Cancer Res. 2007;67(8):3853-61.
16. Bava SV, Puliappadamba VT, Deepti A, Nair A, Karunagaran D, Anto RJ. Sensitization of taxol-induced apoptosis by curcumin involves down-regulation of nuclear factor-κB and the serine/threonine kinase Akt and is independent of tubulin polymerization. J Biol Chem. 2005;280(8):6301-8.

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]

[DOI: 10.22088/crms.6.2.23]

17. Notarbartolo M, Poma P, Perri D, Dusonchet L, Cervello M, D'Alessandro N. Antitumor effects of curcumin, alone or in combination with cisplatin or doxorubicin, on human hepatic cancer cells. Analysis of their possible relationship to changes in NF-kB activation levels and in IAP gene expression. Cancer Lett. 2005;224(1):53-65.
18. Aggarwal BB, Shishodia S, Takada Y, Banerjee S, Newman RA, Bueso-Ramos CE, et al. Curcumin suppresses the paclitaxel-induced nuclear factor-κB pathway in breast cancer cells and inhibits lung metastasis of human breast cancer in nude mice. Clin Cancer Res. 2005;11(20):7490-8.
19. Park CH, Hahm ER, Park S, Kim H-K, Yang CH. The inhibitory mechanism of curcumin and its derivative against β-catenin/Tcf signaling. FEBS letters. 2005;579(13):2965-71.
20. Banerjee S, Zhang Y, Ali S, Bhuiyan M, Wang Z, Chiao PJ, et al. Molecular evidence for increased antitumor activity of gemcitabine by genistein in vitro and in vivo using an orthotopic model of pancreatic cancer. Cancer Res. 2005;65(19):9064-72.
21. Hillman GG, Forman JD, Kucuk O, Yudelev M, Maughan RL, Rubio J, et al. Genistein potentiates the radiation effect on prostate carcinoma cells. Clin Cancer Res. 2001;7(2):382-90.
22. Mehta HJ, Patel V, Sadikot RT. Curcumin and lung cancer—a review. Target Oncol. 2014;9(4):295-310.
23. Song X, Zhang M, Dai E, Luo Y. Molecular targets of curcumin in breast cancer. Mol Med Rep. 2019;19(1):23-9.
24. Wang C-Y, Mayo MW, Baldwin Jr AS. TNF-and cancer therapy-induced apoptosis: potentiation by inhibition of NF-κB. Science. 1996;274(5288):784-7.
25. Howe LR, Brown AM. Wnt signaling and breast cancer. Cancer Biol Ther. 2004;3(1):36-41.
26. Gough NR. Focus issue: Wnt and β-catenin signaling in development and disease. Sci Signal. 2012;5(206):eg2.
27. Fodde R, Brabletz T. Wnt/β-catenin signaling in cancer stemness and malignant behavior. Curr Opion Cell Biol. 2007;19(2):150-8.
28. Reya T, Clevers H. Wnt signalling in stem cells and cancer. Nature. 2005;434(7035):843-50.
29. Prasad CP, Rath G, Mathur S, Bhatnagar D, Ralhan R. Potent growth suppressive activity of curcumin in human breast cancer cells: Modulation of Wnt/β-catenin signaling. Chem Biol Interact. 2009;181(2):263-71.
30. Xu MX, Zhao L, Deng C, Yang L, Wang Y, Guo T, et al. Curcumin suppresses proliferation and induces apoptosis of human hepatocellular carcinoma cells via the wnt signaling pathway. Int J Oncol. 2013;43(6):1951-9.
31. Choi HY, Lim JE, Hong JH. Curcumin interrupts the interaction between the androgen receptor and Wnt/β-catenin signaling pathway in LNCaP prostate cancer cells. Prostate Cancer Prostatic Dis. 2010 2010/12/01;13(4):343-9.
32. Jaiswal AS, Marlow BP, Gupta N, Narayan S. β-Catenin-mediated transactivation and cell–cell adhesion pathways are important in curcumin (diferuylmethane)-induced growth arrest and apoptosis in colon cancer cells. Oncogene. 2002 2002/12/01;21(55):8414-27.
33. Chen Q, Gao Q, Chen K, Wang Y, Chen L, Li X. Curcumin suppresses migration and invasion of human endometrial carcinoma cells. Oncol Lett. 2015;10(3):1297-302.
34. Senft C, Polacin M, Priester M, Seifert V, Kögel D, Weissenberger J. The nontoxic natural compound Curcumin exerts anti-proliferative, anti-migratory, and anti-invasive properties against malignant gliomas. BMC Cancer. 2010;10(1):1-8.
35. Chiu T-L, Su C-C. Curcumin inhibits proliferation and migration by increasing the Bax to Bcl-2 ratio and decreasing NF-κBp65 expression in breast cancer MDA-MB-231 cells. Int J Mol Med. 2009;23(4):469-75.
36. Lin S-S, Lai K-C, Hsu S-C, Yang J-S, Kuo C-L, Lin J-P, et al. Curcumin inhibits the migration and invasion of human A549 lung cancer cells through the inhibition of matrix metalloproteinase-2 and-9 and Vascular Endothelial Growth Factor (VEGF). Cancer Lett. 2009;285(2):127-33.

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]

[DOI: 10.22088/crms.6.2.23]

37. Su C-C, Chen G-W, Lin J-G, Wu L-T, Chung J-G. Curcumin inhibits cell migration of human colon cancer colo 205 cells through the inhibition of nuclear factor kappa B/p65 and down-regulates cyclooxygenase-2 and matrix metalloproteinase-2 expressions. Anticancer Res. 2006;26(2A):1281-8.
38. Van Roy F. Beyond E-cadherin: roles of other cadherin superfamily members in cancer. Nat Rev Cancer. 2014;14(2):121-34.
39. Mukherjee S, Mazumdar M, Chakraborty S, Manna A, Saha S, Khan P, et al. Curcumin inhibits breast cancer stem cell migration by amplifying the E-cadherin/β-catenin negative feedback loop. Stem Cell Res Ther. 2014;5(5):1-19.

[Downloaded from crms.mubabol.ac.ir on 2026-11-10]

[DOI: 10.22088/crms.6.2.23]