

Evaluation of Cytotoxic Properties of Lumichrome-derived compounds on Breast Adenocarcinoma (SkBr3), Colorectal Cancer (BRAF), and Liver Carcinoma (Hep3B)

1. Dave Arthur R. Robledo

2. Ghulam Muhammad

Received 29th Sep 2021,

Accepted 27th Oct 2021,

Online 15th Nov 2021

¹De La Salle University, Manila, Philippines

²Shaheed Benazir Bhutto University, Dir Upper KP, Pakistan

Abstract: Ongoing research into cancer cures and therapeutic agents is being carried out by scientists worldwide to alleviate the rising burden of this insurmountable illness. Research on lumichrome, a photoproduct of the vitamin riboflavin, led us to discover that it has anticancer properties against lung cancer. More research is needed to determine how effective it is. An anticancer ability of lumichrome and its synthetic derivatives against liver, breast, and colorectal cancer was shown in this work. Cytotoxic activity against Hep3B (liver carcinoma), SkBr3 (Breast adenocarcinoma), and BRAF (Colorectal cancer) cell lines was evaluated using the MTT assay, which is a cytotoxicity test. These results ranged from 8.9 to 23.9 micrograms per milliliter. The IC₅₀ for lumichrome and its synthetic derivative was 8.9 and 16.6 µg/ml, respectively, for Hep3B cells. Activation of apoptosis and interference with transcription is assumed to be the primary mechanisms of action of these substances. The mechanism of action of these products will need to be studied in the future.

Keywords: lumichrome; anticancer agent; breast cancer; liver carcinoma; colon cancer

INTRODUCTION

One of the most feared illnesses in the world is cancer. More than 28.4 million people will be diagnosed with cancer in the next two decades, most of them from developing nations [1]. Many people are diagnosed with a variety of different types of cancer each year. Lung cancer was the top cause of death among the almost 9.9 million cancer fatalities, followed by colorectal and liver cancer [2]. However, the number of women diagnosed with breast cancer (2.3 million) has surpassed the number of women diagnosed with lung cancer for the first time [2]. To combat this increasing mortality, cancer cells' developing resistance to anticancer treatments, and the unpleasant side effects of many medications, scientists have always devoted their time and energy to finding new chemotherapeutic agents with higher safety and effectiveness.

Irradiation of riboflavin in neutral or mildly acidic solutions results in the formation of lumichrome, which is one of the essential riboflavin derivatives [3, 4]. Because alloxazine 2 (Figure 1) may be synthesized from lumichrome, the structure of lumichrome is thought stimulating. The reduction of lumichrome1 with sodium borohydride in THF results in compound 2 [4]. The design of alloxazine 2 seems to be very intriguing (Fig.1). The ring on the right side of its structure is identical to uracil, a pyrimidine base found in RNA and other nucleic acids (Fig. 1). Because of this resemblance, alloxazine two may be integrated into RNA during transcription, resulting in the formation of a non-functional analog of RNA, which, in turn, may result in the suppression of protein synthesis and, ultimately, cell development [5]. Lumichrome1 has also been linked to a reduction in the risk of lung cancer [6]. Alloxazine 2 was researched further to compare its anticancer activity with lumichrome1, which was also tested for anticancer activity. In this article, the actions of the chemicals against three distinct cancer cell lines are discussed: Hep3B (liver cancer), SKBR3 (breast adenocarcinoma), and BRAF (colorectal cancer).

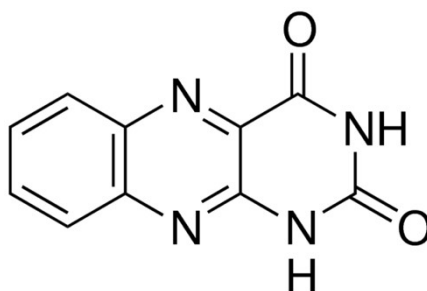


Figure 1. Lumichrome-derived Alloxazine

Materials and methods

Anticancer Agents and Cell Culture

Lumichrome chemicals were bought from Sigma Aldrich. It was made by reducing lumichrome(1) with sodium borohydride in THF [4]. The ATCC (<http://www.lgcstandards-atcc.org/>) provided the Hep3B (liver cancer), SKBR3 (breast adenocarcinoma), and BRAF (colorectal cancer) cell lines. The culture cells were kept in RPMI medium with 100 mg/mL streptomycin, 100 units/mL penicillin, and 10% heat-inactivated fetal bovine serum at 37 °C in a humidified, 5% CO₂ environment.

Cytotoxicity Test

Because of its greater simplicity, sensitivity, and resolution, the MTT test has become more widely utilized than the formazan-based assays in recent years [6,7,8]. Based on the interaction of the anionic pink aminoxanthine dye sulforhodamine B (SRB) with the essential amino acids of viable cells, the test determines whether or not the cells are viable. The quantity of dye taken up by the cells is dependent on the number of cells present. After fixation, more vivid color and increased absorbance are generated [9]. As a result, the MMT assay was used to detect the cytotoxic effects of the test compounds on Hep3B (liver cancer), SKBR3 (breast adenocarcinoma), and BRAF (colorectal cancer) cell lines.

The cells were incubated in a complete medium for 24 hours after being suspended in 100L (5x10³ cells) in 96-well plates of each kind of culture (HepG2, SKBR3, and BRAF). The cells were then given another aliquot of 100L medium containing the test chemical at different doses ranging from 0.01g/ml to 100g/ml. Using 150 mL of 10% TCA solution after 72 hours of exposure to the test chemical and incubating the cells for 1 hour at four °C, fixation of the cells could be accomplished. To remove the TCA solution, cells were washed five times with distilled water and incubated for 10 minutes at room temperature with 70L SRB solution (0.4 percent w/v), added at the end of the incubation period. In the last step, plates were allowed to air-dry overnight after washing three times

with 1 percent acetic acid. Then, the protein-bound SRB stain was dispersed by adding 150 mL of TRIS to the plates (10mM). It was necessary to measure the absorbance at 540 nm with the help of a BMG LABTECH®- FLUOstar Omega microplate reader (Ortenberg, Germany).

All studies were carried out in triplicate, each in a separate location. The data were reported as the mean plus standard error of the mean. To calculate IC₅₀ values using concentration-response curves, the following software was used: SPSS version 26.0 (IBM) for statistical analysis and an E-max model equation was used to calculate the following results:

$$\% \text{ Cell viability} = (100 - F) \times \left(1 - \frac{[D^m]}{K_d^m + [D^m]} \right) + F$$

For example, in this equation, D=the concentration of test compound utilized, F=the residual, unaffected portion, K=the test compound concentration that reduces the maximal inhibition rate by 50%, and m=a Hill-type coefficient. To calculate the IC₅₀, researchers looked at the absorbance of the test sample and the control sample's absorbance [10].

Results and discussion

The MTT assay was used to investigate the cytotoxic effects of the test substances on HepG2, SKBR3, and BRAF cancer cell lines, while Valrubicin was used as a control. All three cell lines were shown to be cytotoxic to lumichrome and alloxazine. There were substantial reductions in less than 6 percent viability at 100g/ml for all cell lines tested. The vitality of Hep3B cell lines reduced when the quantity of lumichrome and alloxazine increased, compared to SKBR3 and BRAF cell lines (Fig. 2). However, lumichrome showed a superior cytotoxic profile than alloxazine and affected the viability of HepG2, SKBR3, and BRAF cell lines more following the increase in concentrations. (Fig. 3 and 4).

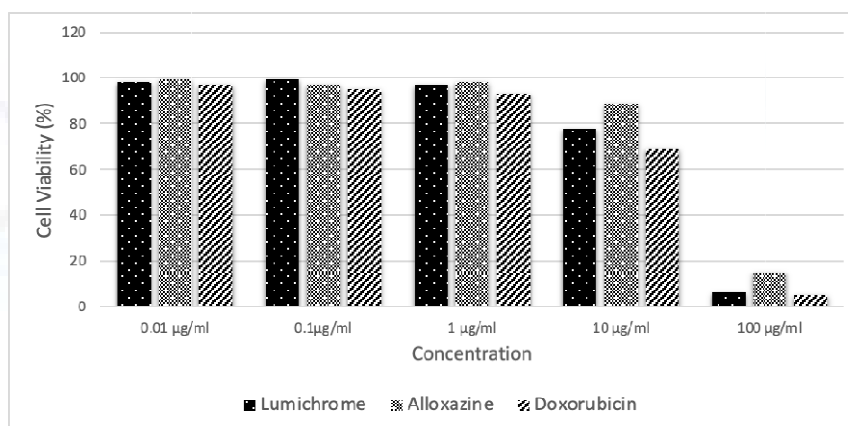


Figure 2. Cell Viability (%) of Hep3B (liver carcinoma),

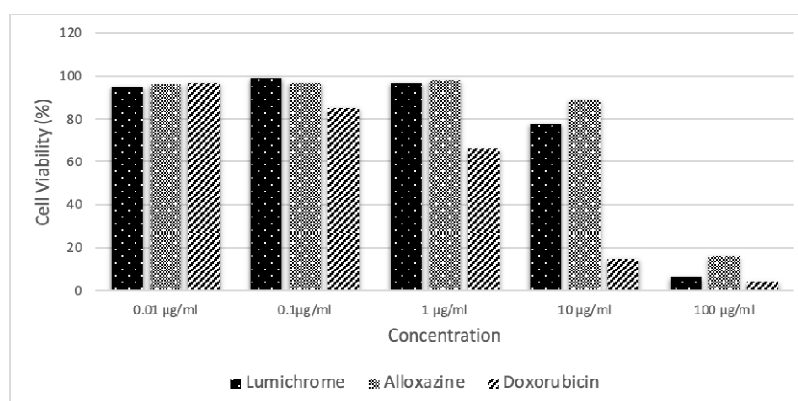


Figure 3. Cell Viability (%) of SkBr3 (Breast adenocarcinoma)

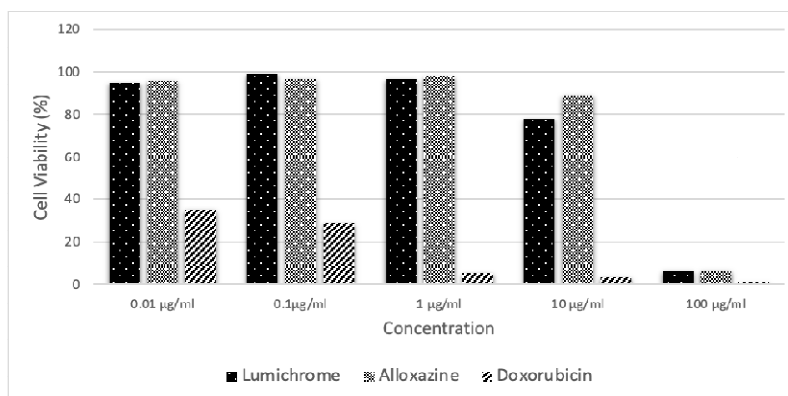


Figure 4. Cell Viability (%) of BRAF (Colorectal cancer)

Table 1: IC₅₀ values for Lumichrome, alloxazine, and Valrubicin determined against HepG2, SKBR3, and BRAF cancer cell lines.

Test Compounds	Cancer cell lines (IC ₅₀ µg/ml)		
	HepG2	SKBR3	BRAF
Lumichrome	8.9	15.3	17.6
Alloxazine	16.6	23.9	19.7
Valrubicin	3.4	0.2	0.003

Table 1 displays the cellular inhibition (IC₅₀) values in graphical form. The IC₅₀ values for lumichrome were 8.9 g/ml, 15.3 g/ml, 17.6 g/ml, and for alloxazine, 16.6 g/ml, 23.9 g/ml, and 19.7 g/ml, respectively, based on the cytotoxic profile. Although the IC₅₀ values of the test compounds against the Hep3B cell line were near to the standard Valrubicin value, the values against SKBR3 and BRAF were over 100 times greater than the norm. The cytotoxic properties of lumichrome and alloxazine against HepG2, SKBR3, and BRAF cancer cell lines were found to be equivalent to Valrubicin at the highest concentration (Figure 2). Lumichrome anticancer activity quickly rose at 10 g/ml (Figure 2). For liver cancer (Hep3B cell line), lumichrome has the highest IC₅₀ value of 8.9 g/ml compared to the standard (IC₅₀=3.4 g/ml). With an IC₅₀ value of 16.6 g/ml, alloxazine was likewise the most effective in killing liver cancer cells. Alloxazine, on the other hand, had a weaker anticancer potential than its precursor lumichrome, as predicted. By activating the tumor suppressor p53 protein and suppressing the protein kinase B (AKT) activity, lumichrome can inhibit lung cancer stem cells' ability to increase, as well as its ability to induce apoptosis. A non-functional RNA analog is formed during transcription by alloxazine (2), which has been shown to have an anticancer impact by targeting numerous oncogenic proteins [5]. The mechanism of action of these drugs has to be studied further in the laboratory.

Conclusion

Because the global burden of cancer is in no way diminishing, novel medicines are required to increase cancer patient survival. Although lumichrome showed the most promising results against liver cancer, this research also offers evidence that both lumichrome and alloxazine had considerable cytotoxic effects against three primary malignancies: breast, liver, and colorectal cancers. To develop Valrubicin-like, more effective anticancer chemicals, more studies on lumichrome and alloxazine may be conducted. For example, the synthesis of other analogs and examination of their anticancer activity may be performed.

Conflict of Interest

The authors declare that this article has no type of conflict of interest.

Acknowledgment

The experimentations were conducted at the Shaheed Benazir Bhutto University, Dir Upper KP, Pakistan.

REFERENCES

1. Zhai XF, Chen Z, Li B, Shen F, Fan J, Zhou WP, Yang YK, Xu J, Qin X, Li LQ, Ling CQ. Traditional herbal medicine in preventing recurrence after resection of small hepatocellular carcinoma: a multicenter randomized controlled trial. *J Integr Med*. 2013;11(2):90–100.
2. Cragg GM, Newman DJ. Plants as a source of anticancer agents. *J Ethnopharmacology*. 2005;100(1-2):72–9.
3. Chantarawong W, Kuncharoen N, Tanasupawat S, Chanvorachote P. Lumichrome Inhibits Human Lung Cancer Cell Growth and Induces Apoptosis via a p53-Dependent Mechanism. *Nutr Cancer*. 2019;71(8):1390-1402. DOI: 10.1080/01635581.2019.1610183. Epub 2019 May 10. PMID: 31074646.
4. Phi LTH, Sari IN, Yang Y-G, Lee S-H, Jun N, et al.: Cancer stem cells (CSCs) in drug resistance and their therapeutic implications in cancer treatment. *Stem Cells Int* 2018, 1, 2018.
5. Yi Yuan, Yongyun Zhao, Lianqi Chen, Jiasi Wu, Gangyi Chen, Sheng Li, Jiawei Zou, Rong Chen, Jian Wang, Fan Jiang, Zhuo Tang, Selective tumor cell death induced by irradiated riboflavin through recognizing DNA G–T mismatch, *Nucleic Acids Research*, Volume 45, Issue 15, 6 September 2017, Pages 8676–8683, <https://doi.org/10.1093/nar/gkx602>
6. Ströch K, Zeeck A, Antal N, Fiedler HP. (2005) Retymicin, gentamycin B, saquayamycin Z, and ribofuranosyllumichrome, novel secondary metabolites from *Micromonospora* sp. Tü 6368. II. Structure elucidation. *The Journal of Antibiotics*, 58, 103–110.
7. Dakora FD, Matiru VN, Kanu AS. (2015) Rhizosphere ecology of lumichrome and riboflavin, two bacterial signal molecules eliciting developmental changes in plants. *Frontiers in Plant Science*, 6, 700.
8. Yamamoto K, Asano Y. (2015) Efficient production of lumichrome by *Microbacterium* sp. strain TPU 3598. *Applied and Environmental Microbiology*, 91, 7360–7367.
9. Phillips DA, Joseph CM, Yang GP, Martinez-Romero E, Sanborn JR, Volpin H. (1999) Identification of lumichrome as a *Sinorhizobium* enhancer of alfalfa root respiration shoot growth. *Proceedings of the National Academy of Sciences*, 96, 12275–12280.
10. Tsukamoto S, Kato H, Hirota H, Fusetani N. (1999) Lumichrome. A larval metamorphosis-inducing substance in the ascidian *Hyalocynthia roretzi*. *European Journal of Biochemistry*, 264, 785-789.