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# Synthesis, characterization and anticancer evaluation of some novel 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones

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**ABSTRACT**

*A series of novel 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones (**4a-g**) were synthesized and structurally confirmed by elemental analysis, IR, $^{1}$H NMR, MS spectral data. All the synthesized 1,3-thiazolidin-4-one analogues (**4a-g**) at various concentrations (10, 20, 50, 100 and 200 mcg/ml) have been evaluated for in vitro cytotoxicity against Dalton's lymphoma ascites (DLA) cancer cell line by trypan blue exclusion method, in comparison with standard drug doxorubicin hydrochloride. Out of these seven compounds, five compounds (2Z)-2-[(3,4-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (**4a**), (2Z)-3-phenyl-2-(1,3-thiazol-2-ylimino)-1,3-thiazolidin-4-one (**4c**), (2Z)-3-phenyl-2-(pyrimidin-2-ylimino)-1,3-thiazolidin-4-one (**4b**), (2E)-3-phenyl-2-(pyridin-3-ylimino)-1,3-thiazolidin-4-one (**4d**) and (2Z)-2-[(2,6-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (**4g**) inhibited 100%, 95%, 80%, 73% and 62% DLA tumor cells at 100 mcg/ml concentration, whereas standard drug doxorubicin exhibit 100% DLA inhibition at a concentration of 100 mcg/ml. From the above study, compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** which showed better results (> 60% inhibition) at lowest concentration were further selected for screening in vivo anticancer activity against Dalton's lymphoma ascites (DLA) cancer cell line at the dose of 50 mg/kg body weight/i.p. in comparison with 5-fluorouracil (20 mg/kg body weight/i.p.) by determining different parameters like body weight analysis, packed cell volume, viable tumor cell count, increase in life span (%), followed by hematological profiles [red blood cell (RBC), white blood cell (WBC), hemoglobin (Hb) and platelet count] and serum biochemical parameters [aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), total cholesterol (TC) and triglycerides (TG)] of DLA bearing mice. In the in vivo anticancer evaluation, among five compounds screened, compound **4a** emerged as more potent inhibitor of DLA with an increase in life span (ILS) of 88.23%, whereas standard drug 5-fluorouracil exhibit ILS of 92.13%. The in vivo anticancer experimental results indicated that, compound **4a** and 5-fluorouracil showed significant ($p < 0.01$) decrease in body weight gain, packed cell volume, viable tumor cell count and increased the life span of DLA tumor bearing mice, followed by hematological and serum biochemical profiles were significantly restored to normal levels in compound **4a** and 5-Fluorouracil ($p < 0.01$) treated groups as compared to DLA control mice.*

**Keywords:** Isothiocyanatobenzene, chloroacetic acid, 1,3-thiazolidin-4-one, anticancer activity.

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## INTRODUCTION

Cancer is believed to result from unlimited growth of a given cell, due to inability of cells to undergo differentiation and/ or apoptosis [1]. Two major concerns with currently available anticancer drugs are their inability to

discriminate between normal and tumor cells and hence unpleasant drug toxicities and development of resistance due to expression of drug transporters. Hence, targeting of proliferative pathways resulting in cell death via apoptosis or prevention of cell division via cell cycle arrest, are considered effective strategies for fighting this disease. Hence the discovery and development of new therapeutic agents without side effects is the need of the hour. Therefore, a more reasonable approach would be to synthesize novel compounds which are effective against cancer while at the same time exhibiting minimal toxicity to normal cellular functions.

1,3-thiazolidin-4-one derivatives have been found to exhibit diverse biological activities such as analgesic [2], anti-inflammatory [3], antiangiogenic [4], anti-HIV [5], *in vitro* anti-*Toxoplasma gondii* [6], antimicrobial [6], antimycobacterial [7], antimalarial [8], trypanocidal [9], antischistosomal [10], anticonvulsant [11], antihistaminic [12], antidiabetic [13], antiarrhythmic [14] and antihypertensive properties [15].

To search for more specific and novel 1,3-thiazolidin-4-one analogues with a wide therapeutic window for the cytoselective anticancer activity, we synthesized some novel 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones and evaluated them for their *in vitro* and *in vivo* antitumor activity against Dalton's lymphoma ascites (DLA) cells by trypan blue exclusion method.

## MATERIALS AND METHODS

### Experimental

3,4-dimethylaniline, pyrimidin-2-amine, 1,3-thiazol-2-amine, pyridin-3-amine, 4-methylpyridin-2-amine, 3,5-dimethylaniline, 2,6-dimethylaniline, isothiocyanatobenzene, doxorubicin hydrochloride and chloroacetic acid were commercially obtained from Aldrich (Milwaukee, WI). Triethylamine, anhydrous sodium acetate, diethyl ether, hexane, chloroform, ethylacetate, sodium hydroxide, sodium chloride, sodium bicarbonate, dimethyl sulphoxide and silica gel-G were purchased from Merck, Mumbai, India. 4-aminoantipyrine, potassium ferricyanide, 2,4-dinitrophenylhydrazine and 5-fluorouracil were obtained from Himedia Laboratories Pvt. Limited, Mumbai, India. Melting points were determined in open capillary tubes using Veego melting point apparatus (Model: VMP-DS) and are uncorrected. The purity of the compounds was checked by thin layer chromatography (TLC) on silica gel-G plates of 0.5 mm thickness using Hexane: Ethylacetate (4.5:0.5 v/v) and Benzene: Chloroform (1:1 v/v) as a solvent system and the spots being visualized under iodine vapours. Concentration of the solution after the reaction completion involved the use of a rotary evaporator (Eyela, Japan) operating under reduced pressure. Infrared (IR) spectra were recorded on a Jasco FTIR-4100 spectrophotometer (Jasco Ltd, Tokyo, Japan) using KBr pellet disc technique in the range of 4000-400 $cm^{-1}$. $^1H$ NMR spectra were recorded on a Bruker DPX 300 (operating at 300 MHz) and Bruker DPX 600 (operating at 600 MHz) NMR spectrometer using $CDCl_3$ as solvent and TMS as internal standard (chemical shifts in δ, ppm). Spin multiplets are given as s (singlet), br s (broad singlet), d (doublet), t (triplet), q (quartet) and m (multiplet). Mass spectra (MS) were recorded on a Q-TOF micromass spectrometer by using electronspray ionization (ESI) technique. The elemental analyses (C, H, N) were performed using a Perkin-Elmer 2400 CHN analyzer. Analyses indicated by the symbols of the element were within ±0.4% of the theoretical values. 1,3-thiazolidin-4-one derivatives (**4a-g**) were synthesized as per the reactions outlined in the Scheme 1. The respective physico-chemical characteristics of all the synthesized compounds have been presented in Table 1.

**Synthesis of 1-(substitutedphenyl)-3-phenylthiourea/1-phenyl-3-(heteroaryl)thiourea (3a-g)**

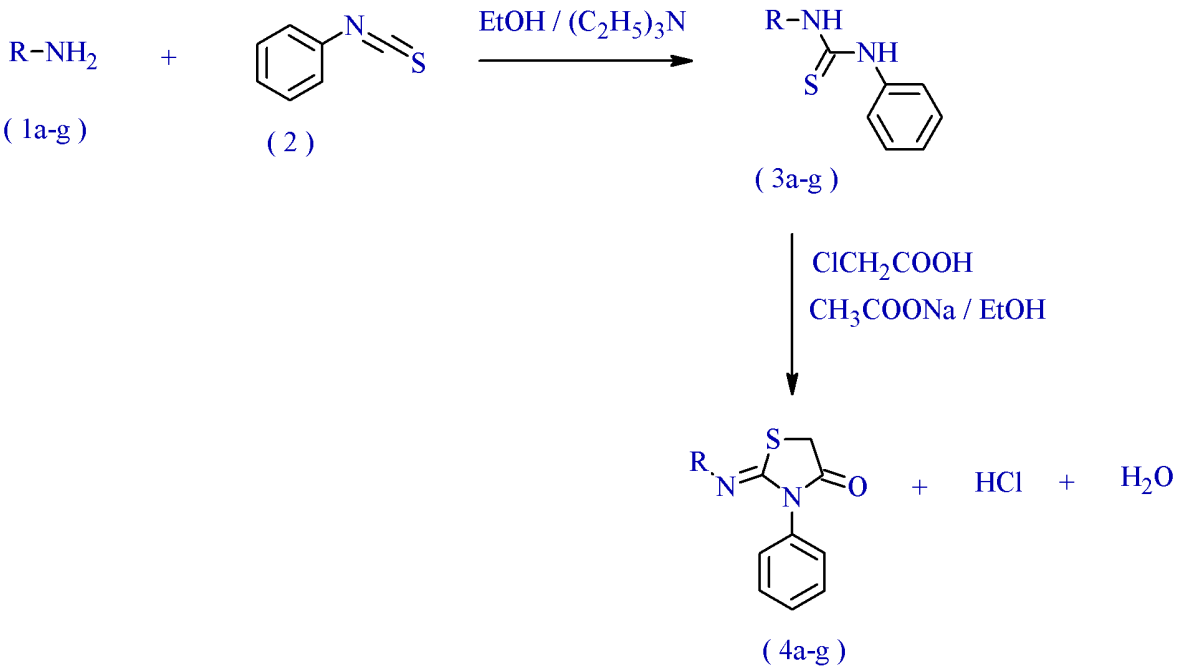
A mixture of different aromatic/heteroaromatic amines (**1a-g**) (3,4-dimethylaniline (**1a**), pyrimidin-2-amine (**1b**), 1,3-thiazol-2-amine (**1c**), pyridin-3-amine (**1d**), 4-methylpyridin-2-amine (**1e**), 3,5-dimethylaniline (**1f**) and 2,6-dimethylaniline (**1g**)) (0.01 mol) and isothiocyanatobenzene (**2**) (0.01 mol) dissolved in absolute ethanol (20 ml) in presence of catalytic amount of triethylamine (0.5 ml) was refluxed for 6-8 h. The progress of the reaction was monitored by TLC using Hexane: Ethylacetate (4.5:0.5 v/v) as eluents. After the completion of the reaction, the reaction mixture was concentrated under rotary vacuum, cooled and kept overnight in the refrigerator. The solid thus separated out was filtered, washed with diethyl ether (3×5 ml), dried and crystallized from chloroform. Adopting the above procedure seven different thioureas (**3a-g**) was synthesized. Percentage yield, melting point and Rf value of the synthesized compound (**3a-g**) were determined and presented in Table 1.

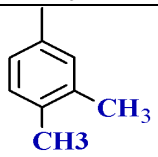
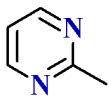
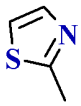
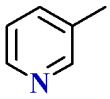
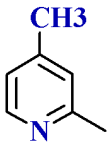
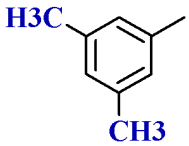
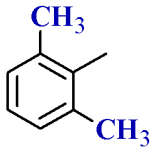
**Synthesis of 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones (4a-g)**

A mixture of 1-(substitutedphenyl)-3-phenylthiourea/1-phenyl-3-(heteroaryl)thiourea (**3a-g**) (0.01 mol), chloroacetic acid (0.01 mol) and anhydrous sodium acetate (0.01 mol) in absolute ethanol (30 ml) was refluxed for 8-10 h. The progress of the reaction was monitored by TLC using Benzene: Chloroform (1:1 v/v) as eluents. After the

completion of TLC, absolute ethanol was removed under reduced pressure. The final residue obtained was poured into crushed ice and the separated solid was filtered, washed with cold water, dried and crystallized from chloroform. Adopting the above procedure seven different 1,3-thiazolidin-4-one analogues (**4a-g**) was synthesized. Percentage yield, melting point and Rf value of the synthesized compound (**4a-g**) were determined and presented in Table 1.

**Scheme 1: Synthetic route for the preparation of novel 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones (4a-g)**




| Compound | a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|---|
| R |  |  |  |  |  |  |  |

***In vitro* Evaluation of Antitumor Activity**

**Cell lines**

Dalton's lymphoma ascites (DLA) cells were maintained *in vivo* in Swiss albino mice by intraperitoneal transplantation (0.2 ml of 1 × $10^6$ cells/ml). DLA cells (9 days old) were aspirated from the peritoneal cavity in mice, washed with saline and given intraperitoneally to develop ascites tumor.

All the synthesized 1,3-thiazolidin-4-one analogues (**4a-g**) were studied for short term *in vitro* cytotoxicity using Dalton's lymphoma ascites (DLA) cells. The DLA cells were maintained in Swiss albino mice by intraperitoneal transplantation of $1\times10^6$ cells/mice. The tumor (DLA) cells were aspirated from the peritoneal cavity of tumor bearing mice were washed thrice with normal saline (0.9% NaCl w/v) and checked for viability using trypan blue dye exclusion method [16].

The DLA suspension ($1\times10^6$ cells in 0.1 ml) was added to tubes containing 5 different concentrations (10, 20, 50, 100 and 200 mcg/ml) of the test compounds and the volume was made up to 1 ml using phosphate buffered saline (PBS). Control tube contained only cell suspension. Doxorubicin hydrochloride was used as standard. These assay

mixtures were incubated for 3 h at 37° C and percentage of dead cells were evaluated by Trypan blue exclusion method. The antitumor screening results were presented in Table 2 and Figure 1.

**Acute toxicity study of the synthesized compounds**

**Animals**

Swiss albino mice of 8-10 weeks old (20 ± 5 g body weight) of either sex were acclimatized to the laboratory conditions for 2 weeks before performing the experiments. The animals were housed in sterile polypropylene cages and maintained under controlled room temperature (23 ± 2° C) and relative humidity (55 ± 5%) with 12:12 h light and dark cycle. All the animals were provided with commercially available standard mice food pellets (Hindustan Lever Ltd., Bangalore, India) and water *ad libitum*. The guidelines of the Committee for the Purpose of Control and Supervision on Experiments on Animals (CPCSEA, Reg. No. 367) were followed and the study was approved by the University Animal Ethics Committee of Jadavpur University, Kolkata, India.

**Acute toxicity study**

The $LD_{50}$ value of synthesized 1,3-thiazolidin-4-one analogues (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) in Swiss albino mice was determined [17] and it was found to be 500 mg/kg body weight/i.p. The biological evaluation was carried out at $1/10^{th}$ of maximum tolerated dose, i.e., 50 mg/kg body weight/i.p.

***In-vivo* Pharmacological Screening**

Based upon the *in-vitro* cytotoxicity assay results *in-vivo* pharmacological screening of few selected compounds (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) were further selected for screening *in vivo* anticancer activity against Dalton's lymphoma ascites (DLA) cancer cell line at the dose of 50 mg/kg body weight/i.p. in comparison with 5-fluorouracil (20 mg/kg body weight/i.p.) by determining different parameters like body weight analysis, packed cell volume, viable tumor cell count, increase in life span (%), followed by hematological profiles [red blood cell (RBC), white blood cell (WBC), hemoglobin (Hb) and platelet count] and serum biochemical parameters [aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), total cholesterol (TC) and triglycerides (TG)] of DLA bearing mice (Table 3-Table 5 and Figure 2-Figure 4).

**Anticancer Activity**

**Animals**

Swiss albino mice of 8-10 weeks old (20 ± 5 g body weight) of either sex were acclimatized to the laboratory conditions for 2 weeks before performing the experiments. The animals were housed in sterile polypropylene cages and maintained under controlled room temperature (23 ± 2° C) and relative humidity (55 ± 5%) with 12:12 h light and dark cycle. All the animals were provided with commercially available standard mice food pellets (Hindustan Lever Ltd., Bangalore, India) and water *ad libitum*. The guidelines of the Committee for the Purpose of Control and Supervision on Experiments on Animals (CPCSEA, Reg. No. 367) were followed and the study was approved by the University Animal Ethics Committee of Jadavpur University, Kolkata, India.

**Preparation of test solution of compounds**

Synthesized 1,3-thiazolidin-4-one analogues (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) were weighed and dissolved in 0.1% v/v DMSO to obtain the required concentrations and administered intraperitoneally on day 1 to day 10 of tumor inoculation in the volume of 0.1 ml/10 g mice. All the compounds were tested at the dose of 50 mg/kg body weight/i.p. The dose of 5-Fluorouracil (5-FU) selected was 20 mg/kg body weight/i.p [18].

**Transplantation of tumor and treatment schedule**

Antitumor activities of synthesized 1,3-thiazolidin-4-one analogues (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) were determined by using Dalton's lymphoma ascites (DLA) tumor model in mice. Swiss albino mice were divided into eight groups (n = 12). The Dalton's lymphoma ascites (DLA)-bearing mice (donor) were used for the study, 15 days after tumor transplantation [19]. Tumor viability was determined by trypan blue exclusion test and cells were counted using haemocytometer. Cell viability was always found to be 95% or more. The ascitic fluid was suitably diluted in normal saline to get a concentration of $10^6$ cells/ml of tumor cell suspension [19].

All the animals were injected with DLA cells (0.2 ml of $1\times10^6$ cells/mouse) intraperitoneally except the normal group, for the development of ascites tumor [20]. The mice were weighed on the day of tumor inoculation and then once in two days thereafter. In this instance, tumor cells multiplied relatively freely within the peritoneal cavity. Ascites were developed in the cavity. A day of incubation was allowed to establish the disease in the body before starting the administration of the drug. Group I served as normal and group II served as the tumor (DLA) control. These two groups received 0.2 ml of 0.1% v/v DMSO [21]. Group III served as a positive control and was treated with 5-fluorouracil (20 mg/kg body weight/i.p.) [18]. Group IV to Group VIII were treated with synthesized 1,3-thiazolidin-4-one analogues (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) at 50 mg/kg body weight/i.p., respectively. All these treatments were given 24 h after the tumor inoculation, once daily for 10 days [22]. After the last dose and 24 h fasting, six mice from each group were sacrificed for the study of antitumor, hematological and biochemical parameters. The rest of the animals were kept to check the average life span and change in the body weight.

**Tumor growth response**

The anticancer effect of 1,3-thiazolidin-4-one analogues (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) was assessed by the determination of body weight gain (g), packed cell volume (%), viable cell count and increase in life span (%).

**Determination of packed cell volume**

The mice were dissected and the ascitic fluid was collected from the peritoneal cavity. The volume was measured by using graduated centrifuge tube, and packed cell volume was determined by centrifuging at 1000 rpm for 5 min. From the packed cell volume (PCV), the percentage of tumor inhibition was calculated [23].

**Estimation of viable and non-viable tumor cell count**

The ascitic fluid was taken in a white blood cell (WBC) pipette and diluted 100 times. Then a drop of the diluted suspension was placed on the Neubauer counting chamber and the cells were then stained with trypan blue (0.4% w/v) dye. The cells that did not take up the dye were viable (non stained) and those took the stain were non-viable. Those viable and non-viable cells were counted.

$$\text{Cell count} = \frac{\text{(number of cells} \times \text{dilution factor)}}{\text{(area} \times \text{thickness of liquid film)}}$$

**Determination of mean survival time and percentage increase in life span**

The effect of compounds (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) on tumor growth was monitored by recording the mortality daily for a period of 6 weeks and percentage increase in life span (% ILS) was calculated. Median survival time (MST) for each group was noted and anticancer activity of the test compounds was compared with that of control group by measuring increase in life span [24]. Total number of days an animal survived from the day of tumor inoculation was counted; subsequently the mean survival time was calculated. The percentage increase in life span [25] was calculated by using the formula:

Mean survival time* = [(day of first death + day of last death)/2]

*Time denoted by number of days.

Increase in life span (%) = [(MST of treated group/ MST of control group)-1] × 100

Increase in life span of 25% or more over that of control was considered an effective antitumor response [26].

**Body weight**

Body weights of the experimental mice were recorded both in the treated and control group at the beginning of the experiment (day 0) and sequentially on every 2nd day during the treatment period. An average percentage increase in body weight as compared to day zero was determined.

**Hematological parameters**

At the end of the experimental period, the next day after an overnight fasting blood was collected from freely flowing tail vein and used for the estimation of hemoglobin (Hb) content [25], red blood cell (RBC) count [25, 27], white blood cell (WBC) count [28] and platelet count by standard procedures.

**Serum biochemical parameters**
The blood for serum biochemistry was allowed to clot at room temperature and was centrifuged at 3000 rpm for 10 min for serum separation [29]. The serum thus obtained were used for the estimation of serum biochemical parameters included aspartate aminotransferase (AST) [30], alanine aminotransferase (ALT) [30], alkaline phosphatase (ALP) [31], total cholesterol (TC) [32] and triglycerides (TG) [33] by standard colorimetric assays.

**Aspartate aminotransferase (AST) and alanine aminotransferase (ALT)**
Aminotransferases (AST and ALT) were determined according to the method of Reitman and Frankel (1957) [30].

**Serum alkaline phosphatase (ALP)**
Serum alkaline phosphatase activity was assayed by the method of Kind and King (1954) [26] as described by Wright et al. (1972) [31].

**Total Cholesterol and Triglycerides**
Total Cholesterol and Triglycerides in serum were estimated according to the method of Wybenga et al. (1970) [32] and Mendez et al. (1975) [33], respectively.

**Statistical analysis**
All values were expressed as mean ± standard error of the mean (SEM). Results were analyzed statistically by using one way-analysis of variance (ANOVA) followed by Newman-Keuls multiple range test. Values of $P < 0.05$ and $P < 0.01$ were considered significant.

## RESULTS AND DISCUSSION

**Chemistry**
In the present study, a series of novel 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones (**4a-g**) were synthesized according to scheme 1. Aromatic/heteroaromatic amines (**1a-g**) on condensation with isothiocyanatobenzene (**2**) in presence of catalytic amount of triethylamine in absolute ethanol resulted in the formation of 1-(substitutedphenyl)-3-phenylthiourea/1-phenyl-3-(heteroaryl)thiourea (**3a-g**) with 54.7 - 74.5% yields (scheme 1). The physical data of the synthesized compounds (**3a-g**) and (**4a-g**) are presented in Table 1. The purity of the compounds was checked by thin layer chromatography (TLC) showed disappearance of reactant spot on silica gel-G plates of 0.5 mm thickness using Hexane: Ethylacetate (4.5:0.5 v/v) and Benzene: Chloroform (1:1 v/v) as a solvent system and the spots being visualized under iodine vapours. The structure of the synthesized compounds (**3a-g**) was confirmed on the basis of elemental analysis, FT-IR and $^1$H NMR spectral data (Results and discussion part). The FT-IR spectra of the synthesized compounds (**3a-g**) showed absorbtion bands ranging from 3337.21 - 3208.97 cm$^{-1}$ for N-H, secondary amine and 1256.4 - 1018.23 cm$^{-1}$ for C=S stretch, 3141.47 - 3023.84 cm$^{-1}$ for aromatic C-H and 1667.16 - 1405.85 cm$^{-1}$ for C=N & C=C ring stretch of phenyl ring. The IR spectra of compound (**3a-g**) displayed bands at about 1352.82 - 1322.93 cm$^{-1}$ and 742.46 - 603.61 cm$^{-1}$ associated with C-N stretch, secondary aromatic amine and C-S functions. In the IR spectra of compound (**3a-g**), some significant stretching bands due to methyl C-H asymmetric and methyl C-H symmetric, were observed at 2965.02 - 2917.77 cm$^{-1}$ and 2882.09 - 2858.95 cm$^{-1}$, respectively. In the $^1$H NMR spectra of compound (**3a**), aromatic (5H) protons appeared as a multiplet (5H) at δ 7.090 - 7.183 ppm, NH proton appeared as a broad singlet (2H) at δ 7.8 ppm, aromatic (3H) protons appeared as a multiplet (3H) at δ 7.386 - 7.399 ppm and methyl protons appeared as a singlet (6H) at δ 2.249 ppm, which proved the formation of 1-(substitutedphenyl)-3-phenylthiourea.

Compounds (**3a-g**), which on cyclisation with chloroacetic acid in absolute ethanol in presence of anhydrous sodium acetate offered the corresponding 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-one (**4a-g**) in 65.8 - 78.3% yields (scheme 1). The structure of the synthesized compound (**4a-g**) was established on the basis of elemental analysis, FT-IR and $^1$H NMR and mass spectral data (Results and discussion part).

The FT-IR spectrum of compound (**4a-g**) showed strong absorbtion band at 1725.98 cm$^{-1}$ for C=O of 1,3-thiazolidin-4-one, while the band at 2936.09 - 2918.73 cm$^{-1}$, 2866.67 - 2804.96 cm$^{-1}$, 1374.03 - 1329.68 cm$^{-1}$, 754.031 - 601.682 cm$^{-1}$ and 3116.4 - 3013.23 cm$^{-1}$, respectively confirms the presence of methylene C-H asymmetric, methylene C-H symmetric, C-N stretch of tertiary aromatic amine, C-S and aromatic C-H stretch. This is considered to be a strong confirmation for the 1,3-thiazolidin-4-one nucleus formation. The IR spectrum of compound (**4a-g**) displayed bands at about 2981.41 cm$^{-1}$, 2866.67 cm$^{-1}$ and 1672.95 - 1407.78 cm$^{-1}$ associated with

methyl C-H asymmetric, methyl C-H symmetric, C=N and C=C of aromatic ring functions. In the $^1$H NMR spectra of compound (**4a**), aromatic (5H) protons appeared as a multiplet (5H) at 7.238 - 7.544 ppm, methyl (6H) protons appeared as a singlet (6H) at 2.279 ppm, aromatic (3H) protons appeared as a multiplet (3H) at 6.830 - 7.172 ppm and methylene (2H) protons of 1,3-thiazolidin-4-one $C_5$-H appeared as a singlet (2H) at 3.924 ppm, which proved the closure of 1,3-thiazolidin-4-one ring. The results of elemental analyses were within ±0.4% of the theoretical values. The physico-chemical data of the synthesized compounds (**3a-g**) and (**4a-g**) were presented in Table 1.

**Table 1: Physical data of 1-(substitutedphenyl)-3-phenylthiourea/1-phenyl-3-(heteroaryl)thiourea (3a-g) and 2-(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones (4a-g)**

| Compound | Mol. Formula/ Mol. Weight | Yield (%) | M.p. (˚C) | [a]Rf |
|---|---|---|---|---|
| 3a | $C_{15}H_{16}N_2S$/256.37 | 71.8 (1.84 g) | 142.6-144.4 | 0.43 |
| 3b | $C_{11}H_{10}N_4S$/230.29 | 54.7 (1.26 g) | 188-190 | 0.74 |
| 3c | $C_{10}H_9N_3S_2$/235.33 | 68.4 (1.61 g) | 134-136 | 0.71 |
| 3d | $C_{12}H_{11}N_3S$/229.3 | 59.3 (1.36 g) | 155-157 | 0.69 |
| 3e | $C_{13}H_{13}N_3S$/243.33 | 64.9 (1.58 g) | 160-161 | 0.57 |
| 3f | $C_{15}H_{16}N_2S$/256.37 | 69.8 (1.79 g) | 173-175 | 0.51 |
| 3g | $C_{15}H_{16}N_2S$/256.37 | 74.5 (1.91 g) | 203-205 | 0.46 |
| 4a | $C_{17}H_{16}N_2OS$/296.39 | 64.1 (1.90 g) | 188.2-190.4 | 0.77 |
| 4b | $C_{13}H_{10}N_4OS$/270.31 | 50.3 (1.36 g) | 232.4-234.2 | 0.55 |
| 4c | $C_{12}H_9N_3OS_2$/275.35 | 61.4 (1.69 g) | 182.2-184.4 | 0.52 |
| 4d | $C_{14}H_{11}N_3OS$/269.32 | 52.9 (1.43 g) | 193.5-194.2 | 0.48 |
| 4e | $C_{15}H_{13}N_3OS$/283.35 | 58.6 (1.66 g) | 207.2-208.9 | 0.73 |
| 4f | $C_{17}H_{16}N_2OS$/296.39 | 56.7 (1.68 g) | 218.4-219.9 | 0.84 |
| 4g | $C_{17}H_{16}N_2OS$/296.39 | 65.5 (1.94 g) | 249.5-250.8 | 0.80 |

*[a]Hexane: Ethylacetate (4.5: 0.5 v/v) for compound (**3a-g**) and Benzene: Chloroform (1:1 v/v) for compound (**4a-g**)*

**1-(3,4-dimethylphenyl)-3-phenylthiourea (3a)**

IR (KBr, cm$^{-1}$): 3141.47, 3061.44 (aromatic C-H), 1613.16, 1586.16, 1532.17, 1504.2, 1448.28, 1407.78 (C=C aromatic ring), 3252.36 (N-H, secondary amine), 1328.71 (C-N, secondary aromatic amine), 2917.77 (methyl C-H, γas $CH_3$), 1256.4, 1018.23 (C=S), 875.524, 815.742, 718.354, 686.538 (out-of-plane ring C-H bend), 1532.17 (N-H bending, secondary aromatic amine); $^1$H NMR ($CDCl_3$, δ ppm): 7.090-7.183 (m, 5H, Ar-H), 7.386-7.399 (m, 3H, Ar-H), 7.8 (br s, 2H, NH), 2.249 (s, 6H, 2$CH_3$). Anal. calcd. for $C_{15}H_{16}N_2S$: C, 70.27; H, 6.29; N, 10.93. Found: C, 70.31; H, 6.33; N, 10.90.

**1-phenyl-3-pyrimidin-2-ylthiourea (3b)**

IR (KBr, cm$^{-1}$): 3117.37, 3045.05 (aromatic C-H), 1667.16, 1595.81, 1546.63, 1490.7, 1407.78 (C=N, C=C aromatic ring), 3216.68 (N-H, secondary amine), 1330.64 (C-N, secondary aromatic amine), 1200.47, 1095.37, 1034.62 (C=S), 958.448, 903.487, 838.883, 741.496, 693.284 (out-of-plane ring C-H bend), 1546.63 (N-H bending, secondary aromatic amine); $^1$H NMR ($CDCl_3$, δ ppm): 7.168-7.683 (m, 8H, Ar-H, PymH), 8.683 (br s, 2H, NH). Anal. calcd. for $C_{11}H_{10}N_4S$: C, 57.37; H, 4.38; N, 24.33. Found: C, 57.42; H, 4.44; N, 24.35.

**1-phenyl-3-(1,3-thiazol-2-yl)thiourea (3c)**

IR (KBr, cm$^{-1}$): 3117.37, 3044.09 (aromatic C-H), 1595.81, 1546.63, 1491.67, 1407.78 (C=N, C=C aromatic ring), 3215.72 (N-H, secondary amine), 1330.64 (C-N, secondary aromatic amine), 1199.51, 1094.4, 1034.62 (C=S), 742.46, 693.284, 603.61 (C-S), 1546.63 (N-H bending, secondary aromatic amine); $^1$H NMR ($CDCl_3$, δ ppm): 7.092-7.190 (m, 5H, Ar-H), 7.390-7.404 (d, 2H, thiazole-H), 7.701 (br s, 2H, NH). Anal. calcd. for $C_{10}H_9N_3S_2$: C, 57.04; H, 3.85; N, 17.86. Found: C, 57.12; H, 3.91; N, 17.88.

**1-phenyl-3-pyridin-3-ylthiourea (3d)**

IR (KBr, cm$^{-1}$): 3136.65, 3091.33, 3039.26 (aromatic C-H), 1614.13, 1564.95, 1530.24, 1489.74, 1405.85 (C=N, C=C aromatic ring), 3221.5 (N-H, secondary amine), 1352.82, 1322.93, 1270.86 (C-N, secondary aromatic amine), 1180.22, 1115.62, 1030.77 (C=S), 942.056, 899.63, 863.953, 807.063, 751.138, 689.427 (out-of-plane ring C-H bend), 1530.24 (N-H bending, secondary aromatic amine); $^1$H NMR ($CDCl_3$, δ ppm): 6.840-6.848 (d, 1H, Ar-H), 7.239-7.271 (m, 4H, Ar-H), 7.394-7.434 (m, 2H, PyH), 7.679-7.706 (m, 1H, PyH), 8.084-8.093 (d, 1H, PyH), 8.318 (br s, 1H, NH), 13.738 (br s, 1H, NH). Anal. calcd. for $C_{12}H_{11}N_3S$: C, 62.86; H, 4.84; N, 18.33. Found: C, 62.92; H, 4.88; N, 18.35.

**1-(4-methylpyridin-2-yl)-3-phenylthiourea (3e)**
IR (KBr, $cm^{-1}$): 3136.65, 3091.33, 3039.26 (aromatic C-H), 1614.13, 1530.24, 1488.78, 1405.85 (C=N, C=C aromatic ring), 3220.54 (N-H, secondary amine), 1352.82, 1322.93 (C-N, secondary aromatic amine), 2920.66 (methyl C-H, γas $CH_3$), 2882.09 (methyl C-H, γs $CH_3$), 1179.26, 1115.62, 1030.77 (C=S), 942.056, 863.953, 807.063, 751.138, 689.427 (out-of-plane ring C-H bend), 1530.24 (N-H bending, secondary aromatic amine); $^1$H NMR ($CDCl_3$, δ ppm): 6.837-6.845 (d, 1H, Ar-H), 7.240-7.275 (m, 2H, Ar-H), 7.395-7.434 (m, 2H, Ar-H, PyH), 7.691-7.705 (m, 2H, PyH), 8.082-8.091 (d, 1H, PyH), 8.421 (s, 1H, NH), 13.733 (s, 1H, NH), 2.358 (s, 3H, $CH_3$ at $C_4$-Py). Anal. calcd. for $C_{13}H_{13}N_3S$: C, 64.17; H, 5.39; N, 17.27. Found: C, 64.25; H, 5.45; N, 17.29.

**1-(3,5-dimethylphenyl)-3-phenylthiourea (3f)**
IR (KBr, $cm^{-1}$): 3023.84 (aromatic C-H), 1592.91, 1539.88, 1449.24, 1408.75 (C=C aromatic ring), 3208.97 (N-H, secondary amine), 1336.43 (C-N, secondary aromatic amine), 2965.02, 2928.38, (methyl C-H, γas $CH_3$), 2867.63 (methyl C-H, γs $CH_3$), 1193.72, 1130.08, 1047.16 (C=S), 929.521, 835.99, 753.066, 689.427 (out-of-plane ring C-H bend), 1539.88 (N-H bending, secondary aromatic amine); $^1$H NMR ($CDCl_3$, δ ppm): 7.102-7.261 (m, 5H, Ar-H), 7.396-7.423 (m, 3H, Ar-H), 8.559 (br s, 2H, NH), 2.354 (s, 6H, $2CH_3$). Anal. calcd. for $C_{15}H_{16}N_2S$: C, 70.27; H, 6.29; N, 10.93. Found: C, 70.36; H, 6.38; N, 10.92.

**1-(2,6-dimethylphenyl)-3-phenylthiourea (3g)**
IR (KBr, $cm^{-1}$): 3140.51 (aromatic C-H), 1588.09, 1530.24, 1490.7 (C=C aromatic ring), 3337.21 (N-H, secondary amine), 1343.18 (C-N, secondary aromatic amine), 2960.2 (methyl C-H, γas $CH_3$), 2858.95 (methyl C-H, γs $CH_3$), 1246.75, 1205.29, 1029.8 (C=S), 931.45, 846.597, 778.136, 748.245, 699.069 (out-of-plane ring C-H bend), 1530.24 (N-H bending, secondary aromatic amine); $^1$H NMR ($CDCl_3$, δ ppm): 6.830-6.838 (d, 1H, Ar-H), 7.242-7.266 (m, 2H, Ar-H), 7.399-7.425 (m, 2H, Ar-H), 7.676-7.689 (d, 2H, Ar-H), 8.076-8.085 (d, 1H, Ar-H), 8.660 (br s, 2H, NH), 2.350 (s, 6H, $2CH_3$). Anal. calcd. for $C_{15}H_{16}N_2S$: C, 70.27; H, 6.29; N, 10.93. Found: C, 70.33; H, 6.35; N, 10.95.

**(2Z)-2-[(3,4-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (4a)**
IR (KBr, $cm^{-1}$): 3116.4, 3043.12 (aromatic C-H), 1671.98, 1595.81, 1545.67, 1491.67, 1442.49, 1407.78 (C=N, C=C aromatic ring), 1725.98 (C=O, 1,3-thiazolidin-4-one), 2981.41 (methyl C-H, γas $CH_3$), 2866.67 (methyl C-H, γs $CH_3$), 2928.38 (methylene C-H, γas $CH_2$), 2804.96 (methylene C-H, γs $CH_2$), 1373.07, 1329.68 (C-N, tertiary aromatic amine), 740.531, 690.391, 629.644, 601.682 (C-S); $^1$H NMR ($CDCl_3$, δ ppm): 6.830-6.863 (m, 2H, Ar-H), 7.088-7.172 (m, 1H, Ar-H), 7.238-7.544 (m, 5H, Ar-H), 2.279 (s, 6H, $2CH_3$), 3.924 (s, 2H, 1,3-thiazolidin-4-one $C_5$-H). ESI-MS: m/z 297 $[M + 1]^+$. Anal. calcd. for $C_{17}H_{16}N_2OS$: C, 68.89; H, 5.44; N, 9.45. Found: C, 68.93; H, 5.48; N, 9.48.

**(2Z)-3-phenyl-2-(pyrimidin-2-ylimino)-1,3-thiazolidin-4-one (4b)**
IR (KBr, $cm^{-1}$): 2932.23 (methylene C-H, γas $CH_2$), 2866.67 (methylene C-H, γs $CH_2$), 3116.4, 3043.12 (aromatic C-H), 1671.98, 1595.81, 1545.67, 1490.7, 1441.53, 1407.78 (C=N, C=C aromatic ring), 1725.98 (C=O, 1,3-thiazolidin-4-one), 1373.07, 1329.68 (C-N, tertiary aromatic amine), 740.531, 689.427, 629.644, 601.682 (C-S); $^1$H NMR ($CDCl_3$, δ ppm): 6.997-7.258 (m, 3H, PymH), 7.311-7.679 (m, 5H, Ar-H), 4.628 (s, 2H, 1,3-thiazolidin-4-one $C_5$-H). ESI-MS: m/z 271 $[M + 1]^+$. Anal. calcd. for $C_{13}H_{10}N_4OS$: C, 57.76; H, 3.73; N, 20.73. Found: C, 57.82; H, 3.79; N, 20.71.

**(2Z)-3-phenyl-2-(1,3-thiazol-2-ylimino)-1,3-thiazolidin-4-one (4c)**
IR (KBr, $cm^{-1}$): 3098.08 (aromatic C-H), 1633.41, 1568.81, 1530.24, 1460.81, 1400.07 (C=N, C=C aromatic ring), 1725.98 (C=O, 1,3-thiazolidin-4-one), 2918.73 (methylene C-H, γas $CH_2$), 2820.38 (methylene C-H, γs $CH_2$), 1364.39 (C-N, tertiary aromatic amine), 754.031, 696.177, 625.788 (C-S); $^1$H NMR ($CDCl_3$, δ ppm): 7.325-7.551 (m, 5H, Ar-H), 7.690-7.704 (d, 2H, thiazole-H), 3.912 (s, 2H, 1,3-thiazolidin-4-one $C_5$-H). ESI-MS: m/z 276 $[M + 1]^+$. Anal. calcd. for $C_{12}H_9N_3OS_2$: C, 52.34; H, 3.29; N, 15.26. Found: C, 52.42; H, 3.37; N, 15.28.

**(2E)-3-phenyl-2-(pyridin-3-ylimino)-1,3-thiazolidin-4-one (4d)**
IR (KBr, $cm^{-1}$): 3098.08, 3050.83, 3013.23 (aromatic C-H), 1641.13, 1568.81, 1531.2, 1460.81, 1400.07 (C=N, C=C aromatic ring), 1725.98 (C=O, 1,3-thiazolidin-4-one), 1364.39 (C-N, tertiary aromatic amine), 2919.7 (methylene C-H, γas $CH_2$), 2858.95 (methylene C-H, γs $CH_2$), 754.031, 696.177, 625.788 (C-S); $^1$H NMR ($CDCl_3$, δ ppm): 6.843-6.850 (d, 1H, Ar-H), 7.239-7.274 (m, 4H, Ar-H), 7.394-7.435 (m, 2H, PyH), 7.679-7.715 (m, 1H, PyH), 8.086-8.095

(d, 1H, PyH), 4.120 (s, 2H, 1,3-thiazolidin-4-one $C_5$-H). Anal. calcd. for $C_{14}H_{11}N_3OS$: C, 62.43; H, 4.12; N, 15.60. Found: C, 62.48; H, 4.18; N, 15.62.

**(2E)-2-[(4-methylpyridin-2-yl)imino]-3-phenyl-1,3-thiazolidin-4-one (4e)**
IR (KBr, $cm^{-1}$): 3116.4, 3044.09 (aromatic C-H), 1671.98, 1595.81, 1546.63, 1490.7, 1441.53, 1407.78 (C=N, C=C aromatic ring), 1725.98 (C=O, 1,3-thiazolidin-4-one), 2981.41 (methyl C-H, γas $CH_3$), 2866.67 (methyl C-H, γs $CH_3$), 2932.23 (methylene C-H, γas $CH_2$), 2812.67 (methylene C-H, γs $CH_2$), 1374.03, 1329.68 (C-N, tertiary aromatic amine), 740.531, 690.391, 629.644, 602.646 (C-S); $^1$H NMR ($CDCl_3$, δ ppm): 6.838-6.847 (d, 1H, Ar-H), 7.240-7.275 (m, 2H, Ar-H), 7.395-7.434 (m, 2H, Ar-H), 7.692-7.705 (m, 2H, PyH), 8.083-8.092 (d, 1H, PyH), 2.360 (s, 3H, $CH_3$ at $C_4$-Py), 4.098 (s, 2H, 1,3-thiazolidin-4-one $C_5$-H). ESI-MS: m/z 284 $[M + 1]^+$. Anal. calcd. for $C_{15}H_{13}N_3OS$: C, 63.58; H, 4.62; N, 14.83. Found: C, 63.62; H, 4.66; N, 14.85.

**(2E)-2-[(3,5-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (4f)**
IR (KBr, $cm^{-1}$): 3116.4, 3043.12 (aromatic C-H), 1671.98, 1595.81, 1545.67, 1491.67, 1442.49, 1407.78 (C=N, C=C aromatic ring), 1725.98 (C=O, 1,3-thiazolidin-4-one), 2981.41 (methyl C-H, γas $CH_3$), 2866.67 (methyl C-H, γs $CH_3$), 2936.09 (methylene C-H, γas $CH_2$), 2812.67 (methylene C-H, γs $CH_2$), 1373.07, 1329.68 (C-N, tertiary aromatic amine), 741.496, 690.391, 629.644, 602.646 (C-S); $^1$H NMR ($CDCl_3$, δ ppm): 7.109-7.261 (m, 5H, Ar-H), 7.396-7.432 (m, 3H, Ar-H), 2.340 (s, 6H, $2CH_3$), 3.998 (s, 2H, 1,3-thiazolidin-4-one $C_5$-H). Anal. calcd. for $C_{17}H_{16}N_2OS$: C, 68.89; H, 5.44; N, 9.45. Found: C, 68.98; H, 5.53; N, 9.43.

**(2Z)-2-[(2,6-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (4g)**
IR (KBr, $cm^{-1}$): 3116.4, 3044.09 (aromatic C-H), 1672.95, 1595.81, 1545.67, 1490.7, 1407.78 (C=N, C=C aromatic ring), 1725.98 (C=O, 1,3-thiazolidin-4-one), 2981.41 (methyl C-H, γas $CH_3$), 2866.67 (methyl C-H, γs $CH_3$), 2932.23 (methylene C-H, γas $CH_2$), 2812.67 (methylene C-H, γs $CH_2$), 1374.03, 1329.68 (C-N, tertiary aromatic amine), 741.496, 690.391, 602.646 (C-S); $^1$H NMR ($CDCl_3$, δ ppm): 6.832-6.839 (d, 1H, Ar-H), 7.242-7.266 (m, 2H, Ar-H), 7.399-7.425 (m, 2H, Ar-H), 7.676-7.689 (d, 2H, Ar-H), 8.088-8.092 (d, 1H, Ar-H), 2.361 (s, 6H, $2CH_3$), 4.186 (s, 2H, 1,3-thiazolidin-4-one $C_5$-H). ESI-MS: m/z 297 $[M + 1]^+$. Anal. Calcd. for $C_{17}H_{16}N_2OS$: C, 68.89; H, 5.44; N, 9.45. Found: C, 68.95; H, 5.50; N, 9.47.

**Antitumor Activity**
Chemotherapy is the primary therapeutic modality of treatment for the both localized and metastatic cancers. The newly synthesized 1,3-thiazolidin-4-one analogues (**4a-g**) at different concentration (10, 20, 50, 100 and 200 mcg/ml) were evaluated for *in vitro* cytotoxicity against DLA cancer cells by trypan blue exclusion method. The *in vitro* screening results are summarized in Table 2 and Figure 1.

**Table 2: *In vitro* cytotoxicity of some novel 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones (4a-g) against Dalton's lymphoma ascites (DLA) cells**

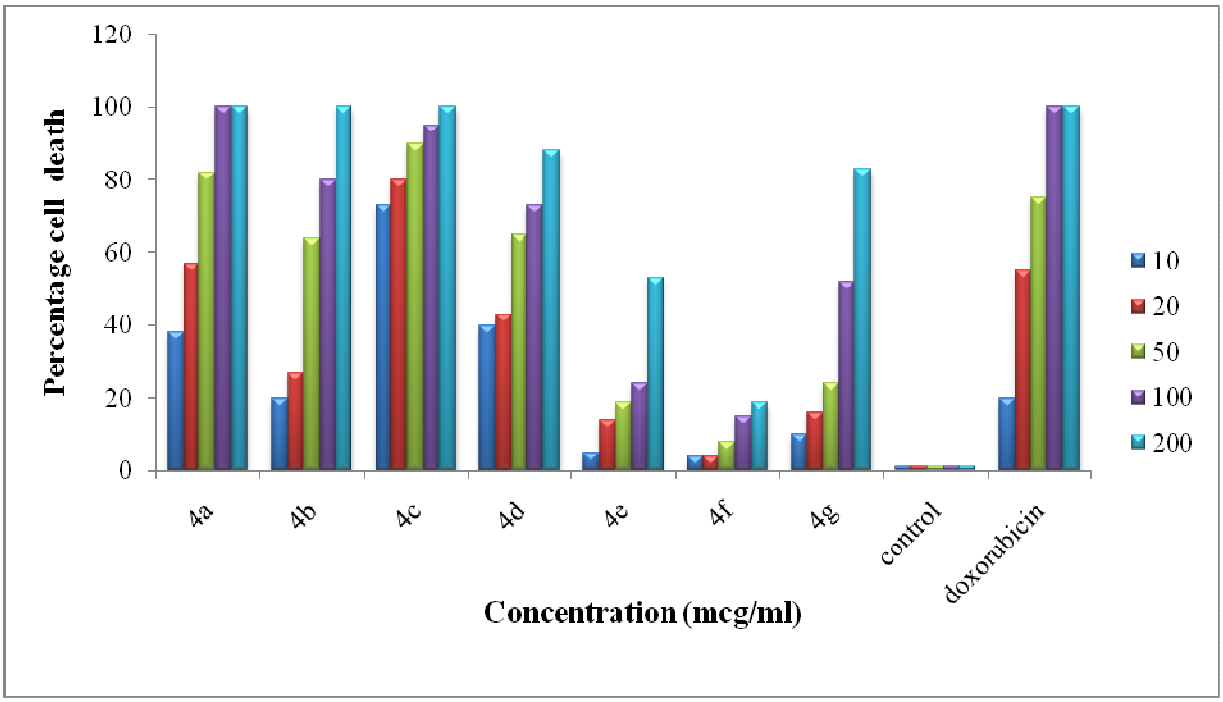
| | Percentage cell death, concentration in µg/ml | | | | |
|---|---|---|---|---|---|
| **Compound** | **10** | **20** | **50** | **100** | **200** |
| 4a | 38 | 57 | 82 | **100** | **100** |
| 4b | 20 | 27 | 64 | **80** | **100** |
| 4c | 73 | 80 | 90 | **95** | **100** |
| 4d | 40 | 43 | 65 | **73** | **88** |
| 4e | 05 | 14 | 19 | 24 | 53 |
| 4f | 04 | 04 | 08 | 15 | 19 |
| 4g | 10 | 16 | 24 | **62** | **83** |
| Doxorubicin | 20 | 55 | 75 | **100** | **100** |

*Control tube contains only 1 dead cell.*

Screening results of *in vitro* antitumor activity (Table 2 and Figure 1) reveal that compound (2*Z*)-2-[(3,4-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (**4a**), (2*Z*)-3-phenyl-2-(1,3-thiazol-2-ylimino)-1,3-thiazolidin-4-one (**4c**), (2*Z*)-3-phenyl-2-(pyrimidin-2-ylimino)-1,3-thiazolidin-4-one (**4b**), (2*E*)-3-phenyl-2-(pyridin-3-ylimino)-1,3-thiazolidin-4-one (**4d**) and (2*Z*)-2-[(2,6-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (**4g**) inhibited 100%, 95%, 80%, 73% and 62% DLA tumor cells at 100 mcg/ml concentration, whereas standard drug doxorubicin exhibit 100% DLA inhibition at a concentration of 100 mcg/ml. At 100 mcg/ml concentration, compound **4e** and compound **4f** inhibited 24% and 15% of DLA tumor cells, exhibited mild antitumor activity. 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones (**4a-g**) exhibited dose-dependent significant

increase in cytotoxicity when compared to those of doxorubicin as a standard drug. From the above study, compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** which showed better results (> 60% inhibition) at lowest concentration were selected for their *in vivo* anticancer activity against DLA cancer cell line by trypan blue exclusion method.

**Figure 1: Antitumor Activity of Synthesized 1,3-thiazolidin-4-one Analogues (4a-g) against Dalton's Lymphoma Ascites Cells**




***In-vivo* Pharmacological Screening**

Based upon the *in-vitro* cytotoxicity assay results *in-vivo* pharmacological screening of few selected compounds (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) were further selected for screening *in vivo* anticancer activity against Dalton's lymphoma ascites (DLA) cancer cell line at the dose of 50 mg/kg body weight in comparison with 5-fluorouracil (20 mg/kg body weight) by determining different parameters like body weight analysis, packed cell volume, viable tumor cell count and increase in life span (%), followed by hematological profiles [red blood cell (RBC), white blood cell (WBC), hemoglobin (Hb) and platelet count] and serum biochemical parameters [aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), total cholesterol (TC) and triglycerides (TG)] of DLA bearing mice.

**Anticancer Activity**

**Antitumor parameters**

Antitumor activity of 1,3-thiazolidin-4-one analogues (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**) against Dalton's lymphoma ascites (DLA) bearing mice was assessed by the parameters such as body weight gain, viable tumor cell count, packed cell volume and increase in life span (%). The results are shown in Table 3 and Figure 2.

The treatment with compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** at 50 mg/kg body weight significantly ($p < 0.01$) increased the average life span of DLA bearing mice from 46.02% to 88.23, 85.16, 86.31, 84.02 and 81.19%, respectively, when compared with the DLA control group ($p < 0.001$). The standard drug 5-Fluorouracil (20 mg/kg) also significantly ($p < 0.01$) increased the life span to 92.13% (Table 3 and Figure 2). The average weight gain of DLA bearing mice was 7.70 ± 0.92 g, whereas it was reduced to 4.65 ± 0.60 g, 4.72 ± 0.62 g, 4.66 ± 0.48 g, 4.75 ± 0.56 g, 4.82 ± 0.70 g and 3.70 ± 0.40 g for the groups treated with compound **4a**, compound **4b**, compound **4c**, compound **4d**, compound **4g** (50 mg/kg) and 5-fluorouracil (20 mg/kg), respectively. Compound

**4a**, compound **4b**, compound **4c**, compound **4d**, compound **4g** and 5-fluorouracil significantly ($p < 0.01$) reduced the body weight gain on day-11 as compared to DLA control (Table 3 and Figure 2). The compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** treated groups exhibited reduction in body weight is due to decreased tumor burden and the compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** were effective in suppressing the proliferation of tumor cells.

In Table 3, the packed cell volume (%) of the DLA control group was 31.60 ± 3.48. When compared to DLA control group, the packed cell volume was reduced significantly ($p < 0.01$) to 20.54 ± 2.88, 21.35 ± 2.70, 21.22 ± 2.65, 21.75 ± 2.62, 21.88 ± 2.58 and 18.32 ± 2.40%, respectively, following treatment with compound **4a**, compound **4b**, compound **4c**, compound **4d**, compound **4g** and 5-fluorouracil. The viable tumor cell count was found to be significantly ($p < 0.001$) increased in DLA control when compared with normal control. Intraperitoneal administration of compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** at the dose of (50 mg/kg) significantly ($p < 0.01$) decreased the viable tumor cell count when compared with DLA control (Table 3 and Figure 2). All these results clearly indicate compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** has a remarkable capacity to inhibit the growth of solid tumor induced by DLA cell line in experimental animals.

In DLA-bearing mice, a regular rapid increase in ascites tumor volume was noted. Ascites fluid is the direct nutritional source for tumor cells and a rapid increase in ascitic fluid with tumor growth would be a means to meet the nutritional requirement of tumor cells [34]. The reliable criteria for judging the value of any anticancer drug are prolongation of life span of the animals [35] and decrease of WBC from blood [36]. Treatment with compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** caused significant reduction in increased body weight, packed cell volume and viable tumor cell count followed by significant increase in the life span of compound treated animals when compared with DLA control, indicating the potent anticancer properties of 1,3-thiazolidin-4-one analogues (compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g**).

Andreani *et al*. [37] have suggested that an increase in the life span of ascites bearing animals by 25% is considered as an indicative of significant drug activity. Roman *et al* [38]., reported *in vitro* antiproliferative activity against human colon cancer cell lines of 1,3-thiazolidin-4-one and few 1,3-thiazolidin-4-one possess *in vitro* antiproliferative activity by acting as inhibitors of translation initiation process. Various 1,3-thiazolidin-4-one [39] have been reported for antitumor activities [40].

**Hematological parameters**

As shown in Table 4, hemoglobin content, RBC and platelet count in the DLA control was significantly ($p < 0.001$) decreased, compared to normal group. Treatment with compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** (50 mg/kg) significantly ($p < 0.01$) increased the hemoglobin content, RBC and platelet count to near-normal levels. The total WBC count was found to be increased significantly in DLA control group when compared with normal group ($p < 0.001$). Administration of compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** (50 mg/kg) in DLA-bearing mice significantly ($p < 0.05$) reduced the WBC count when compared with DLA control (Figure 3).

Usually, in cancer chemotherapy the major problems that are being encountered are of myelosuppression and anaemia [41, 42]. The anaemia encountered in tumor bearing mice is mainly due to reduction in RBC or haemoglobin percentage, and this may occur either due to iron deficiency or due to hemolytic or myelopathic conditions [43]. Treatment with compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** brought back the haemoglobin content, RBC, WBC and platelet count more or less to normal levels. This indicates that compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** possess protective action on the hemopoietic system.

**Serum biochemical parameters**

Alterations in the activities of biochemical parameters like aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), total cholesterol (TC) and triglycerides (TG) in the serum of DLA-bearing mice is summarized in Table 5 and Figure 4. The levels of serum marker enzymes such as AST, ALT, ALP, TC and TG were found to be significantly ($p < 0.001$) increased in DLA control, when compared with the normal group, whereas treatment with compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** (50 mg/kg) and 5-fluorouracil (20 mg/kg) decreased the level of AST, ALT, ALP, total cholesterol and triglycerides

in compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** treated mice when compared to that of DLA control group ($p < 0.01$) as depicted in Table 5 and Figure 4.

Elevated levels of serum enzymes, ALT and AST are indicative of cellular leakage and loss of functional integrity of cell membrane in liver [44]. Alkaline phosphatase activity on the other hand is related to the functioning of hepatocytes, increase in its ability being due to increased synthesis in the presence of increased biliary pressure [45]. Liver damage induced by tumor cells generally reflects disturbances in liver cell metabolism, which lead to characteristic changes in serum enzyme activities. The increased levels of AST, ALT and ALP in serum may be interpreted as a result of liver damage or as changes in membrane permeability indicating the severity of hepatocellular damage by DLA [46]. Treatment with compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** decreased the serum levels of AST, ALT and ALP towards their respective normal value that is an indication of stabilization of plasma membrane as well as repair of hepatic tissue damage caused by DLA.

Liver diseases also exhibit changes in blood cholesterol levels. The significant increase in cholesterol noted in serum in this study might have been due to the inability of the diseased liver to remove cholesterol from circulation. Hepatocellular damage also causes a modest hypertriglyceridemia, which is due to biochemical changes affecting transport of triglycerides out of the liver [47]. It was reported that the presence of tumor in humans or experimental animals is known to affect many functions of the vital organs especially in the liver, even when the site of the tumor does not interfere directly with organ functions [48]. The significant restoration of all the above mentioned biochemical parameters towards normal by treatment with compound **4a**, compound **4b**, compound **4c**, compound **4d** and compound **4g** (50 mg/kg) in the present study indicates the protection of vital organs from damage induced by DLA.

**Table 3: Anticancer activity of 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones in Dalton's lymphoma ascites (DLA) bearing mice**

| Groups | Increase in body weight (g) | Packed cell volume (%) | Viable cell count ($\times 10^6$ cells/ml) | Increase in life span (%) |
|---|---|---|---|---|
| Normal (0.1% DMSO) | 2.20 ± 0.46 | - | - | - |
| DLA control ($1\times10^6$ cells/ml per mice) | 7.70 ± 0.92[a] | 31.60 ± 3.48[a] | 2.76 ± 0.36[a] | 46.02 |
| **4a** (50 mg/kg) + DLA | 4.65 ± 0.60[b] | 20.54 ± 2.88[b] | 1.49 ± 0.46[b] | 88.23 |
| **4b** (50 mg/kg) + DLA | 4.72 ± 0.62[b] | 21.35 ± 2.70[b] | 1.65 ± 0.42[b] | 85.16 |
| **4c** (50 mg/kg) + DLA | 4.66 ± 0.48[b] | 21.22 ± 2.65[b] | 1.55 ± 0.42[b] | 86.31 |
| **4d** (50 mg/kg) + DLA | 4.75 ± 0.56[b] | 21.75 ± 2.62[b] | 1.68 ± 0.40[b] | 84.02 |
| **4g** (50 mg/kg) + DLA | 4.82 ± 0.70[b] | 21.88 ± 2.58[b] | 1.70 ± 0.52[b] | 81.19 |
| 5-Fluorouracil (20 mg/kg) + DLA | 3.70 ± 0.40[b] | 18.32 ± 2.40[b] | 1.28 ± 0.25[b] | 92.13 |

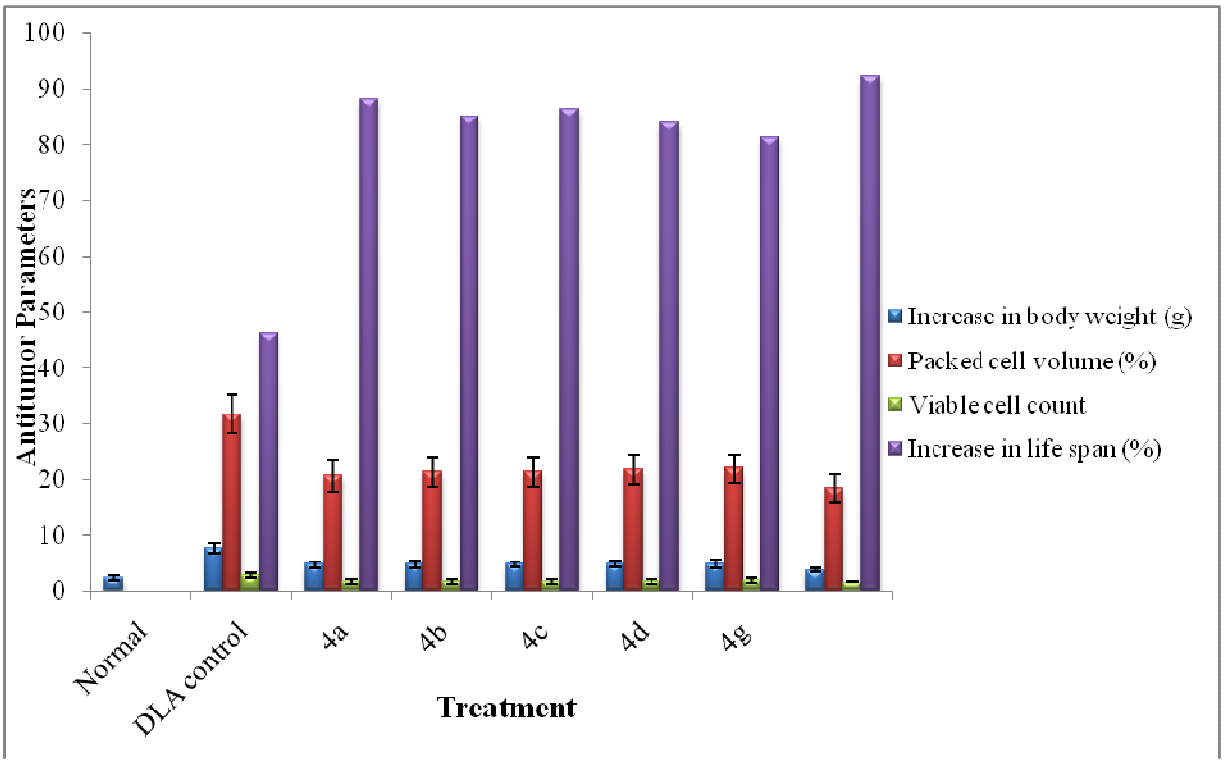
*Values are expressed as mean ±S.E.M., n = 6 mice per group. Data were analyzed by using one-way ANOVA followed by Newman-Keuls multiple range test.*
*[a]P<0.001: between normal and DLA control group.*
*[b]P<0.01: between compound treated groups and DLA control.*

The present study clearly demonstrated the tumor inhibitory activity of the 1,3-thiazolidin-4-one derivatives against transplantable tumor cell line (Table 3-Table 5). In the DLA bearing mice, cells were present in the peritoneal cavity, and the compounds were administered directly into the peritoneum. Thus, tumor inhibition might be due to the direct effect of the compounds on the tumor cells. The standard drug 5-fluorouracil acts cytostatically by interfering with nucleotide metabolism in S phase of the cell cycle [49].

In the *in vivo* anticancer evaluation, among five compounds screened, compound **4a** was the most active, emerged as more potent inhibitor of DLA with an increase in life span of 88.23%, whereas compound **4b**, compound **4c**, compound **4d** and compound **4g** exhibited good activity.

From the *in vitro* and *in vivo* antitumor activity data reported in Table 2-Table 5, it may be inferred that antitumor activity is strongly dependent on the nature of the substituent at C-2 and N-3 of the 1,3-thiazolidin-4-one ring. In a particular, a high activity level was observed for compound **4a** possessing 3,4-dimethyphenylimino group substituted at C-2 and phenyl ring at N-3 position of 1,3-thiazolidin-4-one nucleus.

**Figure 2: Effect of Compounds (50 mg/kg) and 5-Fluorouracil (20 mg/kg) on Antitumor Parameters in Dalton's Lymphoma Ascites Bearing Mice**



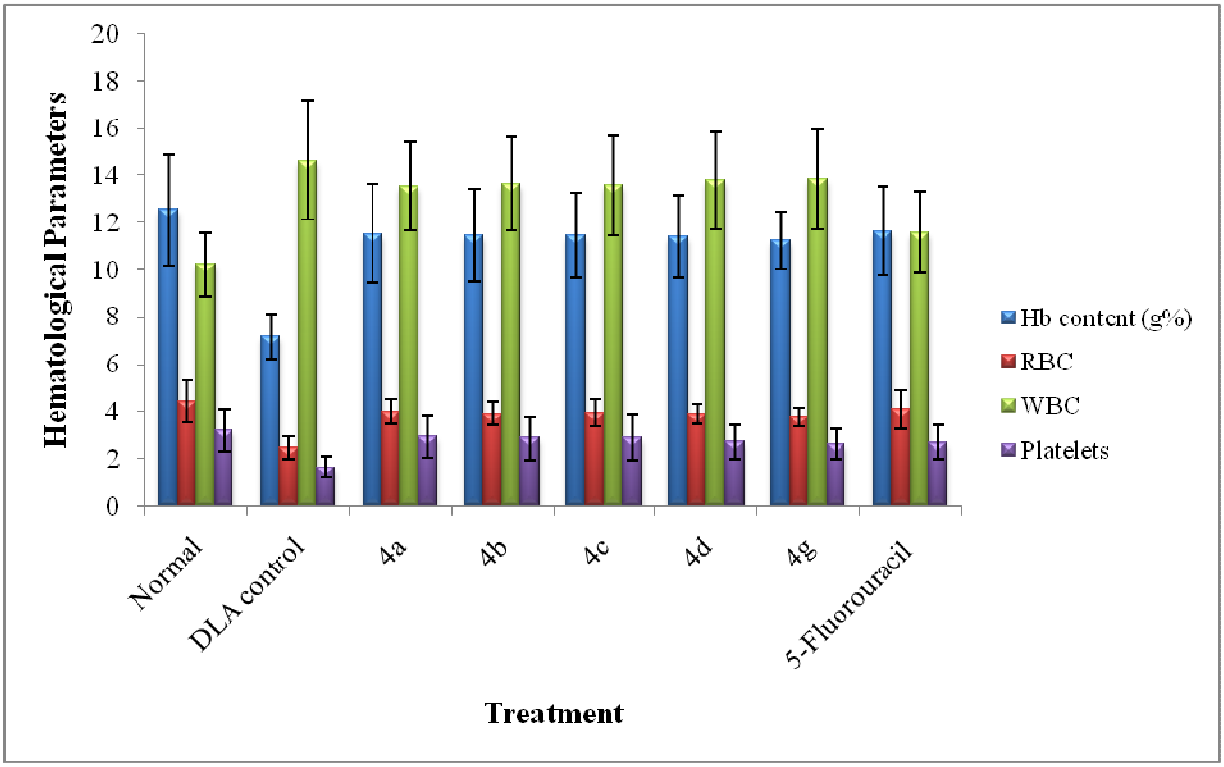

*Values are expressed as mean ±S.E.M., n = 6 mice per group. Data were analyzed by using one-way ANOVA followed by Newman-Keuls multiple range test. [a]P<0.001: between normal and DLA control group. [b]P<0.01: between compound treated groups and DLA control.*

**Table 4: Effect of 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones on hematological parameters in Dalton's lymphoma ascites (DLA) bearing mice**

| Groups | Hb content (g%) | RBC ($10^6$ cells/$mm^3$) | WBC ($10^3$ cells/ml) | Platelets ($10^5$ cells/$mm^3$) |
|---|---|---|---|---|
| Normal (0.1% DMSO) | 12.55 ± 2.36 | 4.42 ± 0.90 | 10.22 ± 1.35 | 3.20 ± 0.90 |
| DLA control ($1\times10^6$ cells/ml per mice) | 7.18 ± 0.96[a] | 2.45 ± 0.48[a] | 14.65 ± 2.52[a] | 1.62 ± 0.45[b] |
| **4a** (50 mg/kg) + DLA | 11.52 ± 2.10[b] | 3.98 ± 0.54[b] | 13.52 ± 1.88[c] | 2.92 ± 0.90[b] |
| **4b** (50 mg/kg) + DLA | 11.45 ± 1.96[b] | 3.90 ± 0.50[b] | 13.65 ± 1.98[c] | 2.86 ± 0.92[b] |
| **4c** (50 mg/kg) + DLA | 11.46 ± 1.79[b] | 3.95 ± 0.58[b] | 13.55 ± 2.12[c] | 2.90 ± 0.98[b] |
| **4d** (50 mg/kg) + DLA | 11.40 ± 1.75[b] | 3.88 ± 0.42[b] | 13.78 ± 2.08[c] | 2.70 ± 0.70[b] |
| **4g** (50 mg/kg) + DLA | 11.24 ± 1.22[b] | 3.76 ± 0.40[b] | 13.84 ± 2.12[c] | 2.62 ± 0.62[b] |
| 5-Fluorouracil (20 mg/kg) + DLA | 11.62 ± 1.88[b] | 4.08 ± 0.82[b] | 11.58 ± 1.72[b] | 2.68 ± 0.72[b] |

*Values are expressed as mean ±S.E.M., n = 6 mice per group. Data were analyzed by using one-way ANOVA followed by Newman-Keuls multiple range test.*
*[a]P<0.001: between normal and DLA control group.*
*[b]P<0.01, [c]P<0.05: between compound treated groups and DLA control.*

**Figure 3: Effect of Compounds (50 mg/kg) and 5-Fluorouracil (20 mg/kg) on Hematological Parameters in Dalton's Lymphoma Ascites Bearing Mice**



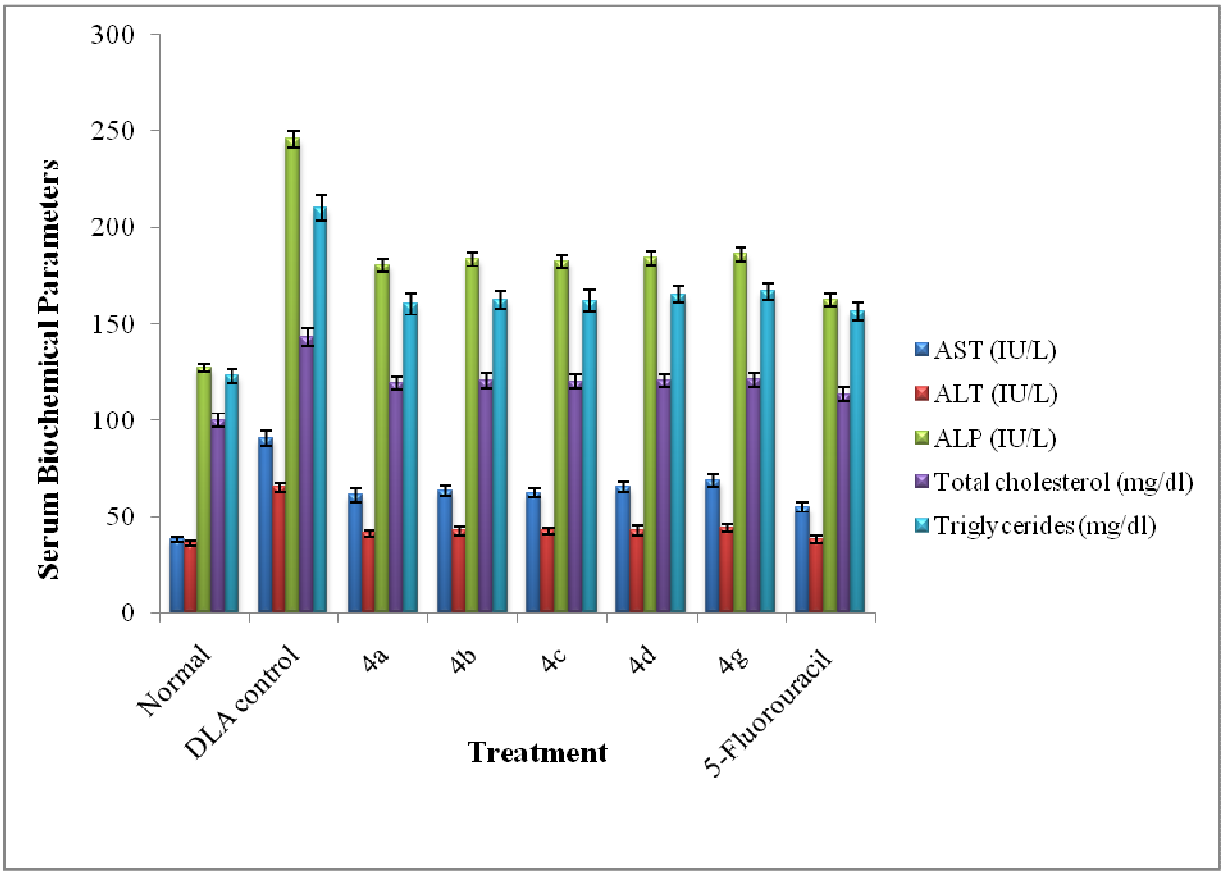

*Values are expressed as mean ±S.E.M., n = 6 mice per group. Data were analyzed by using one-way ANOVA followed by Newman-Keuls multiple range test. [a]P<0.001: between normal and DLA control group. [b]P<0.01, [c]P<0.05: between compound treated groups and DLA control.*

**Table 5: Effect of 2-[(substitutedphenyl/heteroaryl)imino]-3-phenyl-1,3-thiazolidin-4-ones on serum biochemical parameters in Dalton's lymphoma ascites (DLA) bearing mice**

| Groups | AST (IU/L) | ALT (IU/L) | ALP (IU/L) | Total cholesterol (mg/dl) | Triglycerides (mg/dl) |
|---|---|---|---|---|---|
| Normal (0.1% DMSO) | 38.40 ± 1.22 | 36.30 ± 1.34 | 127.10 ± 2.25 | 100.12 ± 3.72 | 122.86 ± 3.46 |
| DLA control ($1\times10^6$ cells/ml per mice) | 90.6 ± 3.72[a] | 65.22 ± 2.44[a] | 245.78 ± 4.44[a] | 142.90 ± 4.60[a] | 210.22 ± 6.62[a] |
| **4a** (50 mg/kg) + DLA | 61.36 ± 3.45[b] | 41.32 ± 1.60[b] | 180.55 ± 3.66[b] | 119.45 ± 3.20[b] | 160.46 ± 5.52[b] |
| **4b** (50 mg/kg) + DLA | 63.48 ± 2.36[b] | 42.78 ± 2.33[b] | 183.60 ± 3.68[b] | 120.42 ± 3.73[b] | 162.54 ± 4.32[b] |
| **4c** (50 mg/kg) + DLA | 62.55 ± 2.22[b] | 42.60 ± 1.75[b] | 182.35 ± 3.36[b] | 120.12 ± 3.42[b] | 162.16 ± 5.58[b] |
| **4d** (50 mg/kg) + DLA | 65.42 ± 2.45[b] | 42.85 ± 2.40[b] | 184.40 ± 3.42[b] | 120.48 ± 3.42[b] | 165.40 ± 4.22[b] |
| **4g** (50 mg/kg) + DLA | 68.86 ± 3.20[b] | 44.32 ± 1.88[b] | 186.32 ± 3.48[b] | 121.12 ± 3.54[b] | 166.95 ± 4.20[b] |
| 5-Fluorouracil (20 mg/kg) + DLA | 55.38 ± 2.56[b] | 38.42 ± 1.82[b] | 162.34 ± 3.20[b] | 113.60 ± 3.52[b] | 156.48 ± 4.60[b] |

*Values are expressed as mean ±S.E.M., n = 6 mice per group. Data were analyzed by using one-way ANOVA followed by Newman-Keuls multiple range test. [a]P<0.001: between normal and DLA control group. [b]P<0.01: between compound treated groups and DLA control.*

**Figure 4: Effect of Compounds (50 mg/kg) and 5-Fluorouracil (20 mg/kg) on Serum Biochemical Parameters in Dalton's Lymphoma Ascites Bearing Mice**




*Values are expressed as mean ± S.E.M., n = 6 mice per group. Data were analyzed by using one-way ANOVA followed by Newman-Keuls multiple range test. [a]P<0.001: between normal and DLA control group. [b]P<0.01: between compound treated groups and DLA control.*

## CONCLUSION

In this study, compound (2*Z*)-2-[(3,4-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (**4a**), (2*Z*)-3-phenyl-2-(1,3-thiazol-2-ylimino)-1,3-thiazolidin-4-one (**4c**), (2*Z*)-3-phenyl-2-(pyrimidin-2-ylimino)-1,3-thiazolidin-4-one (**4b**), (2*E*)-3-phenyl-2-(pyridin-3-ylimino)-1,3-thiazolidin-4-one (**4d**) and (2*Z*)-2-[(2,6-dimethylphenyl)imino]-3-phenyl-1,3-thiazolidin-4-one (**4g**) exhibited significant antitumor activity against DLA cells *in vitro*. In the *in vivo* anticancer evaluation, among five compounds screened, compound **4a** was the most active, emerged as more potent inhibitor of DLA with an increase in life span of 88.23%. However, further investigations are needed to understand the mechanism of action of the compounds and to examine the possible utility of the compounds in cancer therapy. These compounds could be considered as useful templates or leads for the future development and further structural variation to obtain more potent, selective and less toxic antitumor agents.

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