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Vikas Patil, Vikas S. Padalkar, Nagaiyan Sekar, Satish V. Patil, Jamatsing Rajput

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Synthesis of 2-Methyl-5-(5-phenyl substituted-1,3,4 oxadiazole-2-yl) quinazolin-4-one Fluorescent Brightening Agent: Computational and Experimental Comparison of Photophysical Structure Vikas Patil^{ab}*, Vikas S. Padalkar^b, Nagaiyan Sekar^b, Satish V. Patil^c, Jamatsing Rajput^c

a) University Institute of Chemical Technology, North Maharashtra University, Jalgaon 425001(India) Email: ce12vs.patil@pg.ictmumbai.edu.in
b) Department of Intermediate and Dyestuff technology, Institute of Chemical Technology, ,Mumbai - 400 019. India.
c) School of Life Sciences, North Maharashtra University, Jalgaon 425001(India)

Abstract: Report is about the synthesized new range of oxadiazole substituted quinazoline and studied its electronic distribution to attribute fluorescent properties. B3LYP Density Functional Theory (DFT) computational optimization was studied to observe the effect of electron donor and acceptor substituent's on photophysical properties, electronic state and energy level. DFT computational optimization was performed by Polarizable Continuum Model (PCM) of solvation strictly in the gas phase and DMF maintaining C_1 symmetry in ground state geometry structure. UV-vis and fluorescence spectroscopic methods help in understanding the relationship between the electron donor and acceptor functional groups on the photophysical properties. Eventually comparing experimental spectral emission and DFT computations were envisage understanding the changes of the electronic transition, energy levels, and electronic orbital distribution in the substituted quinazoline structure. These compounds have good fluorescent brightening properties hence studied and applied as fluorescent brightening agent on polyester fiber.

Keywords: quinazoline, oxadiazole, TD-DFT, fluorescent, vertical excitation

Introduction

In dyestuff industry quinazoline plays an important role to carry chromatic di-azo and water solubilizing sulphonic acid group [1-3]. Quinazoline core structure were widely utilized as the fluorescent brightening agent. While substituted quinazolines being fluorescent in nature and was used in many functional applications [3]. Naphthotriazole and annelated quinazoline were reported as fluorescent whitening agents for synthetic fibers well before in 1970 [4]. Similarly, more advanced methods are also reported for the synthesis of fluorescent compound by fused azoles and respective components which are useful as functional application [5, 6]. Quinazoline as well as other organic fluorescent dyes plays the role of heat-resistant fluorescent whitening agents which has π bond conjugation [2, 7]. As an application point of view quinazoline was synthesized and used as a luminescent paper ink containing unique sulphonamide (λ max 523 nm) and carboxamido

phenyl substituent's [1, 2, 4]. Fluorescent compounds gain the attention of organic chemist due to its very high sensible level thereby acts as ON-OFF agents for decent applications [8]. Where the size of synthetic dyes plays an important role, which may be reduced by physical method to the desire extent for high sensitive and functional applications [8, 9].

Fluorescent properties of organic compounds are governed by the electronic distribution of the core motif thereby active substituent plays a vital role in the final fluorescent properties of the molecule [10-12]. The single molecular fluorescence aspects are also important while screening against the protein and large biomolecules [12-16]. Hence; it becomes phenomenal to study and understand the structural relationship between electron donating-withdrawing groups on the fluorescent properties. While fluorescent properties are truly controlled by the rate of photoinduced electron transfer from the electron donor to the singlet excited state of the electronic properties plays important role in probing the molecular behaviour [20, 21]. On the contrary oxidation and reduction potential of the core structure of fluorophore has also plays vital role in the fluorescence properties. The oxidation potential and reduction potential of any fluorophore more likely dependable on electron density on central core structure. Which often controlled the fluorescence properties of substituted fluorophore [22, 23]. It is noted that electron donor substitution at 2-position and an acceptor at 6-position gives red-shifted absorption and complimentary red-shifted emission **1** [4-9, 24].



In the present study, we have reported combined experimental and theoretical photophysical properties of novel quinazolinone derivatives. The effects of various substituent groups significantly influence absorption and emission properties of structure in DMF solvent. The experimental photophysical properties are compared with the computed properties obtained from DFT and TD-DFT computations.

Experimental

Materials and Methods:

All the commercial reagents and solvents were purchased from S. D. Fine Chemicals Pvt. Ltd. and they were used without purification and all the solvents were of the spectroscopic grade. The absorption spectra of the dyes were recorded on a Spectronic Genesys 2 UV-Visible spectrophotometer with the measurement range of 250-600 nm in DMF at 1×10^{-6} mol L⁻¹

concentration and emission spectra were recorded on Varian Cary Eclipse fluorescence spectrophotometer with the range of 350-600 nm using freshly prepared solutions in DMF at the concentration of 1×10^{-6} mol L⁻¹. The excitation wavelength used for fluorescence measurements was absorption maxima of the compounds in DMF. The FT-IR spectra were recorded on a Perkin-Elmer Spectrum 100 FT-IR Spectrometer with resolution of 0.5 cm⁻¹, range of 4000 to 500 cm⁻¹, 4 (four) number of scan and with cooling MCT (Mercury Cadmium Telluride) detector. ¹H NMR spectra were recorded on VXR 300 MHz in deuterated DMSO [(CD₃)₂SO] instrument using TMS as an internal standard. Mass spectra were recorded on Finnigan mass spectrometer by Electro Ionisation (EI) technique due to low molecular weight compound. All the final compounds were gravity column purified before analysis and use as a fluorescent brightening agent.

Relative Fluorescence Quantum Yield Calculations:

The fluorescence quantum yields of compounds in DMF were estimated for which anthracene was used as the standard [12, 25]. Fluorescence quantum yields were calculated using the comparative method [12, 25]. Absorption and emission characteristics of the standards and compounds **6a-6g** were measured in DMF at different concentrations (1, 2, 3, 4, and 5 ppm). Further a linear plots of emission intensity against the absorbance intensity were obtained and a gradient were calculated for the standard and compound **6a-6g**. All the measurements were done by keeping the parameters such as solvent and slit width constant. Emission and excitation slit width was 2.5 unit maintained in all measurements. Equation (1) was used to calculate relative fluorescence quantum yields of synthesized compounds **6a-6g** [12, 25].

$$\phi_x = \Phi_{st} \times \frac{Grad_x}{Grad_{st}} \times \frac{\eta_x^2}{\eta_{st}^2}$$
-----Equation (1)

Where:

 Φ_x

 η_x

= Fluorescence quantum yield of compound

- Φ_{st} = Fluorescence quantum yield of standard sample
- $Grad_x$ = Gradient from the plot of integrated fluorescence intensity against absorbance of the studied compound
- $Grad_{st}$ = Gradient of standard sample
 - = Refractive index of solvent used for synthesized compound
- η_{st} = Refractive index of solvent used for standard sample

Experimental:

Synthesis of Ethyl 2-methyl-4-oxo-3, 4-dihydroquinoline-5-carboxylate 4

The esterification of 5 g of 3-nitrophtallic acid was performed at reflux in 15 mL of ethanol. The dehydration catalyst *p*-toluene sulphonic acid (0.1 g) was used in catalytic amount. 3-Nitrobenzene-1,2-dicarboxylate ester was separated after 2 hours of reflux the completion of reaction was checked by TLC. Extraction was performed in ethyl acetate to separate un-esterified 3-nitrophtallic acid which was separated as neutralization salt with the treatment of Na₂CO₃. 3-Nitrobenzene-1,2-dicarboxylate was reduced in presents of 5% Pd supported on carbon in hydrogen gas pressure reactor at 5 Kg/cm². Methanol was used as solvent for reduction of diethyl 3-nitrobenzene-1,2-dicarboxylate. The crude diethyl 3-aminobenzene-1,2-dicarboxylate was used for further reaction after vacuum distillation. Acetonitrile (100 mL) and 3-aminobenzene-1,2-dicarboxylate (2.5 g) was reacted by continuously aerated dry hydrochloric acid gas. HCl gas catalyzed cyclisation reaction yielded intermediate ethyl 2-methyl-4-oxo-3,4-dihydroquinoline -5-carboxylate (4) separated in cold water under continuous stirring **Scheme 1**.

Yield: 58 %, Melting point = 212 °C (Lit 212 °C) [10, 11, 26].

FT-IR (**KBr**): 2978 (CH₃ Out of plane), 2910 (-CH₂ methylene), 1739 (-C=O ester), 1674 (-C=O Amide), 1613 (C=N), 1503 (C=C Aromatic), 1468 (C-C-O), 1322 (C-H ion phase), 1273 (-CH₂), 1180, 1024, 873, 779, 678 (C-O-C sting) cm⁻¹.

¹**H-NMR** (**CD**₃)₂**SO** (**300 MHz**): $\delta = 1.41$ (t, 3H, -CH₃), 2.55 (s, 3H, -CH₃), 4.40 (q, 2H, -CH2), 7.42 (d, 1H, J = 8.4 Hz, Ar-H), 7.7 (d, 2H, J = 9.9 Hz, Ar-H), 11.88 (s, 1H, NH). **Mass**: m/z 235 (M+H)⁺.

Synthesis of 2-Methyl-4-oxo-3,4-dihydroquinazoline-5-carbohydrazide 5

2-methyl-4-oxo-3,4-dihydroquinazoline-5-carbohydrazide **5** was prepared by reaction of Ethyl-2-methyl-4-oxo-3,4-dihydroquinazoline-5-carboxylate (5g) with 80 % hydrazine hydrate (15 mL) under reflux condition for two hours.

Yield: 89 %, Melting point = > 300 °C.

FT-IR (**KBr**): 3165 (-NH₂), 2981 (-CH₃ Out of plane), 2917 (-CH₂), 1665 (Amid -C=O), 1607 (Hydrazide -C=O), 1562 (-C=N), 1478 (C-C-O), 1383 (-CH₃ primary band), 1261 (-CH₂-), 1193 (C-C bond), 1041 (C-O lattise mode), 843 (NH ring mode), 721, 663 (C-O-C ring mode) cm⁻¹.

¹**H-NMR (CD₃)₂SO (300 MHz)**: δ 2.20 (s, 3H, -CH₃), 5.26 (s, 2H, Amine –NH₂), 7.72 (d, 1H, *J* = 22.00 Hz, Ar-H), 7.79 (d, 1H, *J* = 6.7 Hz, Ar-H), 7.82 (dd, 1H, *J* = 22.00, 6.7 Hz, Ar-H). **Mass**: m/z 219 (M+H)⁺.



Scheme 1: Synthesis of ethyl 2-methyl-4-oxo-3,4-dihydroquinazoline-5-carboxylate **4** intermediate and 2-methyl-5-(5-phenyl substituted-1,3,4 oxadiazole-2-Yl) quinazolin-4(3H)-one **6a-6g**.

General experimental procedure for synthesis 6a-6g

2-Methyl-4-oxo-3,4-dihydroquinazoline-5-carbohydrazide **5** (0.0045 moles) and an equimolar quantity of different substituted carboxylic acid were refluxed in phosphorus oxychloride for eighteen hours. Carboxylic acid and substituted hydrazine undergoes the cyclo-condensation reaction. After completion of reaction confirmed by TLC the reaction mixture cooled to room temperature and completely vacuum distilled POCl₃ at low temperature. The compete degassing performed for one hour under vacuum. The dry reaction mass diluted with ice cold water in the reaction flask and neutralized with 10% Na₂CO₃ and filter the product. Wash the product with the copious amount of water. Finally dried the product in an oven at 50° C gave different oxadiazol-2-yl-2-ethylquinazolin-4(3*H*)-one **6a-6g Scheme 1**.

5-[5-(2,4-Dihydroxyphenyl)-1, 3, 4-oxadiazol-2-yl]-2-methylquinazolin-4(3H)-one 6a Yield: 69 %, Melting point = 228 °C **FT-IR** (**KBr**, **cm**⁻¹): 3289 (Phenolic –OH), 2987 (-CH₃ Out of plane), 1789 (C=N oxadiazole), 1616 (C=O amide), 1589 (C=C aromatic), 1567 (C=C aromatic), 1455 (N-H amide), 1289 (C-O aromatic), 1189 (N-N oxadiazole), 988 (-CH₃ primary).

¹H NMR (CD₃)₂SO, 300 MHz): δ 2.49 (s, 3H, -CH₃), 5.38 (s, 1H), 6.10 (s, 1H, Ar-H), 6.33 (d, 1H, J=9.8, Ar-H), 6.64 (d, 1H, J=8.6, Ar-H), 7.45 (dd, 1H, J=9.8, 8.6, Ar-H), 7.59 (s, 1H, Ar-H), 7.76 (d, 1H, 11.8, Ar-H), 7.97 (s, 1H, Ar-H)

Mass: $m/z 337 (M+H)^+$

5-[5-(2-Hydroxyphenyl)-1, 3, 4-oxadiazol-2-yl]-2-methylquinazolin-4(3H)-one 6b Yield: 71 %, Melting point = $295-305 \ ^{\circ}C$

FT-IR (**KBr**, **cm**⁻¹): 3345 (Phenolic –OH), 2890 (-CH₃ Out of plane), 1689 (C=O amide), 1545 (C=C aromatic), 1435 (N-H amide), 1287 (C-O aromatic), 1150 (N-N oxadiazole), 978 (-CH₃ primary).

¹H NMR (CD₃)₂SO, 300 MHz): δ 2.42(s, 3H, -CH₃), 7.07(s, 1H, Ar-H), 7.24(d, 1H, J=8.86, Ar-H), 7.07(dd, 1H, J=8.86, 11.65, Ar-H), 7.62(d, 1H, J=11.65, Ar-H), 7.59(s, 1H, Ar-H), 7.76(1d, 1H, J=11.8, Ar-H), 7.97(s, 1H, Ar-H), 8.21(s, 1H, Ar-H).

Mass: $m/z 320 (M+H)^+$

5-[5-(2-Hydroxynaphthalen-1-yl)-1, 3, 4-oxadiazol-2-yl]-2-methylquinazolin-4(3H)-one 6c Yield: 68 %, Melting point = $265 \,^{\circ}C$

FT-IR (KBr, cm⁻¹): 3401 (Phenolic –OH), 2978 (-CH₃ Out of plane), 1667, 1639 (C=O amide), 1556 (C=C aromatic), 1446 (N-H amide), 1267 (C-O aromatic), 1151 (N-N oxadiazole), 965 (-CH₃ primary).

¹H NMR (CD₃)₂SO, 300 MHz): δ 2.61(s, 3H, -CH₃), 6.09(s, 1H), 7.04(s, 1H, Ar-H), 7.79(s, 1H, Ar-H), 8.04(d, 1H, J=9.1, Ar-H), 7.44(dd, 1H, J=9.1, 8.79, Ar-H), 7.53(dd, 1H, J=8.79, 7.4, Ar-H), 8.41(d, 1H, J=7.4, Ar-H), 7.59(s, 1H, Ar-H), 7.76(dd, 1H, J=11.1, 7.65, Ar-H), 7.97(s, 1H, Ar-H), 9.07(s, 1H, Ar-H) Mass: $m/z 372 (M+H)^+$

5-[5-(2-Chlorophenyl)-1, 3, 4-oxadiazol-2-yl]-2-methylquinazolin-4(3H)-one 6d Yield: 73 %, Melting point = $220 \,^{\circ}C$

FT-IR (KBr, cm⁻¹): 3389 (N-H amide), 3018 (-CH₃ Out of plane), 1767 (C=N oxadiazole), 1670, 1569 (C=C aromatic), 1440 (N-H amide), 1397, 1251 (C-O aromatic), 1176 (N-N oxadiazole), 978 (-CH₃ primary).

¹**H** NMR (CD₃)₂SO, 300 MHz): 2.42(s, 3H, -CH₃), 7.56(d, 1H, J=8.19, Ar-H), 7.35(dd, 1H, J=8.19, 7.6, Ar-H), 7.39(dd, 1H, J=7.6, 11.1, Ar-H), 7.73(d, 1H, J=11.4, Ar-H), 7.59(s, 1H, Ar-H), 7.76(d, 1H, J=8.3, Ar-H), 7.97(s, 1H, Ar-H), 9.1(s, 1H, Ar-H). Mass: m/z 339 (M+H)⁺

5-[5-(2, 6-Dichloro-4-nitrophenyl)-1, 3, 4-oxadiazol-2-yl]-2-methylquinazolin-4(3H)-one 6e Yield: 78 %, Melting point = 241 °C

FT-IR (KBr, cm-1): 3401 (N-H amide), 3031 (-CH₃ Out of plane), 1775 (C=N oxadiazole), 1666 (C=O amide), 1581 (C=C aromatic), 1441 (N-H amide), 1254 (C-O aromatic), 1176 (N-N oxadiazole), 978 (-CH₃ primary).

¹**H NMR (CD₃)₂SO, 300 MHz):** δ 2.4(s, 3H, -CH₃), 7.91(s, 1H, Ar-H), 7.67(d, 1H, J=12.5, Ar-H), 7.08(s, 1H, Ar-H), 8.31(s, 2H, Ar-H), 9.21(s, 1H) Mass: m/z 419 (M+H)⁺

2-Methyl-5-[5-(4-nitrophenyl)-1, 3, 4-oxadiazol-2-yl] quinazolin-4(3H)-one 6f

Yield: 78 %, Melting point = $251 \text{ }^{\circ}\text{C}$

FT-IR (**KBr, cm-1**): 3352 (N-H amide), 2988 (-CH₃ Out of plane), 1775 (C=N oxadiazole), 1656, 1622 (C=O amide), 1531 (C=C aromatic), 1443 (N-H amide), 1251 (C-O aromatic), 1176 (N-N oxadiazole), 978 (-CH₃ primary).

¹**H** NMR (CD₃)₂SO, 300 MHz): δ 2.61(s, 3H, -CH₃), 7.21(s, 1H, Ar-H), 7.46(d, 1H, J=13.9, Ar-H), 7.68(s, 1H, Ar-H), 8.19(d, 2H, J=11.5, Ar-H), 7.95(d, 2H, J=9.2, Ar-H), 9.04(s, 1H) Mass: m/z 350 (M+H)⁺

5-[5-(4-Hydroxyphenyl)-1, 3, 4-oxadiazol-2-yl]-2-methylquinazolin-4(3H)-one 6g

Yield: 69 %, Melting point = 190-198 °C

FT-IR (KBr, cm-1): 3451 (Phenolic –OH), 2985 (-CH₃ Out of plane), 1769 (C=N oxadiazole), 1591 (C=C aromatic), 1529 (C=C aromatic), 1439 (N-H amide), 1396, 1255 (C-O aromatic), 1171 (N-N oxadiazole), 968 (-CH₃ primary).

¹**H NMR (CD₃)₂SO, 300 MHz):** δ 2.49(s, 3H, -CH₃), 7.13(d, 2H, 14.9, Ar-H), 7.96(d, 2H, J=14.9, Ar-H), 7.49(s, 1H, Ar-H), 7.55(d, 1H, J=11.8, Ar-H), 7.79(s, 1H, Ar-H), 9.04(s, 1H), 11.1(s, 1H) Mass: m/z 320 (M+H)⁺

Computational Details:

Effect of electron donor and acceptor on photophysical properties, electronic state and energy level was investigated of oxadiazole substituted quinazoline. The ground state geometry of the compounds in their C_1 symmetry was optimized using the fixed parameter in the gas phase and in

DMF solvent using density functional theory [27] and Polarizable Continuum Model (PCM) solvation model. The functional used in this study was B3LYP. The B3LYP method is a complementary combination of Becke's three parameter exchange functional (B3) [28, 29] with the nonlocal correlation functional by Lee, Yang, and Parr (LYP) [30]. The basic set used for all the atoms was 6-31G(d) [31-33]. The vibrational frequencies of the optimized structures were computed using the same method to verify that the optimized structures correspond to local minima on the potential energy surface. TD-DFT computations were carried out on the optimized structures. Since the fluorophores synthesized here are the largely donor-acceptor type and there are no fused rings in the system. It was decided to do the excited computations at the same level of theory. The excited state computations in terms of optimization in the framework of PCM model has its own implications [34-37] however, considering the fact that we wanted to assess the general trend in the experimentally observed vertical excitations and emissions (in the same series of generic structures) a simple and traditional computational strategy has been chosen. The vertical excitation energies at the ground-state equilibrium geometries were calculated with TD-DFT [38]. The low-lying first singlet excited state (S₁) of each tautomer was relaxed using the TD-DFT to obtain its minimum energy geometry. The difference between the energies of the optimized geometries in the first singlet excited state and the ground state was used in computing the emissions [39]. All electronic structure computations were carried out using the Gaussian 09 program [40, 41]. As depicted in Figure 1 a computational optimized geometry shows quinazoline core in one plane and substituent at 5th position are at out of the plane from quinazoline minimizing stereochemical interactions. Hence the mesomeric effect is very negligible at 5th position and dominating inductive effect governs the absorption and emission properties of the quinazoline core.



Figure 1: Molecular structure of substituted quinazoline 6a extracted from DFT optimization.

General procedure of brightning polyester fabric by fluorescent brightning agent:

Dyeing of polyester fabric was carried out using the high-temperature high-pressure method in Rossari Labtech Flexi Dyer dyeing machine at a material to liquor ratio of 1:20. 2% fluorescent compounds were used for dying (calculated on the weight of the fabric). All the synthesized fluorescent compounds are having less solubility in water. Initially the compounds were dissolved in 5 mL *N*,*N*-dimethylformamide and diluted with 15 mL buffered solution of pH 5 made by using sodium acetate and acetic acid in water. The mixture was ultra-sonicated for 15 min to obtain a fine dispersion. Metamol was used as a dispersant. The polyester fabric was dyed using the above solution and metamol as the dispersing agent. The dye bath temperature was raised at a rate of 3°C min⁻¹ to 130 °C, maintained at this temperature for 60 minutes, and rapidly cooled to room temperature. The dyed fabrics were rinsed with cold water and allowed to dry in the open air [5, 10].

Results and Discussion:

The intermediate ethyl 2-methyl-4-oxo-3,4-dihydroquinazoline-5-carboxylate **4** was prepared from 3-nitro-phthalic acid by esterification, reduction and cyclisation reaction **Scheme 1** [17, 18]. Further the intermediate **5** (2-methyl-4-oxo-3,4-dihydroquinazoline-5-carbohydrazide) was synthesized from **4** reacting with hydrazine hydrate. 2-Methyl-5-(5-phenyl substituted-1,3,4 oxadiazole-2-yl) quinazolin-4(3H)-one (**6a-6g**) was synthesized by reacting the intermediate **5** with different carboxylic acids in a single step. Synthesis of compounds **6a-6g** involves a cyclisation reaction in phosphorous oxychloride at reflux temperature for 18 hrs. On completion of the reaction phosphorous oxychloride was distilled out completely from the reaction mixture under vacuum. The thick reaction mixture was poured into ice cold water and neutralized with 10% Na₂CO₃. The product was filtered, washed with cold water, and dried. The yield of this reaction ranges from 68-78%. The synthesis details are summarized in **Scheme 1**.

Computational Study:

In case of oxadiazole series, the difference between experimental absorption, emission and vertical excited computed by DFT and theoretical emission computed by TD-DFT are in good agreement except for the compound **6e** for absorption and vertical excitation. Observed absorption, emission, computed vertical excitations and emission are summarized in **Table 1.** %D character is expressed as deviation obtained from experimental results. As depicted **Table 1** maximum absorption deviation occur 43 % for **6e**. For emission maxima high deviation % obtained from experimental results in case of **6g** molecule while **6e** has the absorption maxima shifts from 276 to 297 nm with 43 %D. All the other values are in well agreement with experimentally obtained values. This is clue

	λ ^{Expt} (nm)	TD-DFT Vertical Excitation nm eV		f	% D	Orbital Contribution	λ ^{Expt} Em	λ_{Em}^{DFT}	% D	^a Stoke s Shift Δλ (cm ⁻¹)	ьФ
6a	342	335	3.698	0.259	2	$\mathrm{H} \rightarrow \mathrm{L} (98 \ \%)$	427	396	7.0	5820	0.002
6b	282	320	3.873	0.342	13	$\mathrm{H} \rightarrow \mathrm{L} (96 \%)$	402	382	4.8	10585	0.017
6c	300	343	3.613	0.121	14	$\mathrm{H} \rightarrow \mathrm{L} (98 \%)$	485	409	15	12714	0.021
6d	314	306	4.048	0.387	02	$\mathrm{H} \rightarrow \mathrm{L} (93 \%)$	430	369	14	8591	0.102
6e	276	397	3.118	0.005	43	$\mathrm{H} \rightarrow \mathrm{L} (99 \%)$	428	473	10	12867	0.253
6f	312	378	3.272	0.109	21	$\mathrm{H} \rightarrow \mathrm{L} (99 \%)$	431	436	1.3	8849	0.203
6g	376	327	3.791	0.280	13	$\mathrm{H} \rightarrow \mathrm{L} (97 \ \%)$	462	388	15	4850	0.10

for synthesis of molecules before its experimental setup to find out the preliminary absorption and emission properties.

^a Stokes shift, ^b Quantum yield, *f* Oscillator strength, Analyses were carried out at room temperature $(25^{\circ}C)$; λ^{exp} experimentally observed absorption and emission, ([%] D) % Deviation between vertical excitation and experimental absorption and experimental emission and computed (TD-DFT) emission.

Table 1: Observed UV-visible absorption, computed absorption, observed emission and computed emission of compounds **6a-6g** in DMF.

The HOMO-LUMO energies of the compounds **6a-6g** were obtained computationally and summarized in **Figure 2**. The HOMO-LUMO energy difference for all the compounds is almost similar with slight change. In case of the compounds **6b**, **6e** and **6f** the difference between HOMO-LUMO is large as compared to the compounds **6a**, **6c**, **6d** and **6g** accounting for a blue shift in the compounds **6b**, **6e** and **6f**. This is in agreement with the experimental absorption data except for the compound **6g** (**Figure 2**).



Figure 2. Graph of HOMO-LUMO energies of compounds 6a-6g in DMF.

The frontier molecular orbitals of the compounds (HOMO and LUMO) 6a-6g in DMF solvent are summarized in Table 2. The compounds contain two heterocyclic systems - quinazoline and substituted oxadiazole. In excited state compounds 6a-6g are more planar as compared to ground state **Table S1** (supporting material), this clearly indicates that intramolecular charge transfer occurs in the excited state. In the case of the compound 6a HOMO, the electron density is spread across the oxadiazole and phenyl ring substituted at the 5th position of oxazole unit, while in the LUMO, the electron density is localized along the quinazolinone and oxadiazole unit. Such an electron density distribution indicates that quinazoline acts as donor and phenyl ring acts as acceptor via oxadiazole π system, a similar trend is observed for the compound **6b**. In the case of the compound 6c HOMO electron density is spread over oxadiazole and 5-substituted hydroxy naphthalene unit, but in the case of LUMO electrons are migrated from oxadiazole to 5-substituted hydroxy naphthalene unit which indicates that oxadiazole unit acts as donor and hydroxyl substituent at the 5th position of naphthalene as an acceptor. In case of compound 6d HOMO electron density is distributed over oxadiazole and 5-substituted hydroxyl naphthalene unit, while in LUMO the electrons are distributed over the entire molecule. In the case of the compounds 6e and **6f** HOMO, the electron density is distributed over 5-substituted groups of oxadiazole units, while in LUMO the electron density is distributed over quinazolinone and oxadiazole units for compound **6e**. The 5-substituent group acts as an electron donor and quinazoline and oxadiazole as an acceptor for the compound **6e**. In LUMO of **6f** the electron density is distributed over the entire molecule except for heterocyclic unit of quinazoline. This act indicates that oxadiazole and

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quinazoline units behave as an acceptor. The electron distribution pattern of the compound 6g is similar to the compound 6d, in 6g oxadiazole and 5-substituted unit act as a donor while quinazoline unit acts as an acceptor.



Table 2. HOMO-LUMO diagrams of compound 6a-6g in DMF.

Photophysical Properties of Compounds 6a-6g:

The absorption and emission properties of all the compounds **6a-6g** were studied in the solvent dimethylformamide. All the absorption-emission studies were performed at room temperature using solutions of concentration 1×10^{-6} M. The synthesized compounds are fluorescent in solution under

irradiation of UV light. The effect of electron donor and electron acceptor groups on the absorption and the emission properties of the compounds were studied. The absorption and emission spectra of all the compounds are shown in **Figure 3**.



Figure 3: Emission spectra of compounds 6a-6g and in DMF

The compounds 6b and 6e showed blue shifted absorption, while compound 6g showed red-shifted absorption. All the compounds absorb in UV and near visible region. The compounds 6g showed red-shifted absorption as compared to the other compounds. The compounds 6a, 6c and 6d show dual intense absorption in UV region. The absorption intensity of the compound 6g is comparatively high as compared to the other studied compounds. The compounds 6a-6g are structurally similar, only aromatic system attached to oxadiazole core are different. The compound 6g shows red-shifted absorption as well as emission; this is due to the electron donor –OH group on the aromatic system para to the oxadiazole core. The compounds 6d, 6e and 6f show blue-shifted emission due to the electron acceptor groups attached to the oxadiazole core. In the case of the compounds 6a and 6b the electron donor – OH group is attached to the aromatic system at the ortho position of the oxadiazole unit and they showed blue-shifted emission. Ortho-substituted carboxylic acids on quinazolinone show blue shift while *p*-substituted carboxylic acids show a red shift in absorption. The fluorescence emission of the compounds ranges from 402-485 nm, all the compounds emit in the near-visible region. The compounds which emit in the near-visible region 13

are generally used as fluorescent brightening agents. The compounds **6c** and **6g** showed red-shifted emission as compared to **6a**, **6b**, **6d**, **6e** and **6f**. The compound **6d** showed high fluorescence intensity as compared to the compounds **6b-6g**. Fluorescence quantum yield of the compounds was calculated in DMF by the relative method. The Fluorescence quantum yield value **6d**, **6e**, **6f** and **6g** is higher than the compounds **6a**, **6b** and **6c**. The fluorescence quantum yield is tenfold higher for the compounds **6d**, **6e**, **6f** and **6g** than for the compounds **6b** and **6c** and hundredfold higher for the compound **6a**. Electron withdrawing groups present on carboxylic acid moiety enhance the fluorescence quantum yield as compared to the electron donating groups presents on the carboxylic acid unit. The photophysical properties of the compounds are summarised in **Table 1**.

Thermo gravimetric analysis: To more deep insight the molecules the thermos gravimetric analysis shows that the molecules are thermally stable above the 300° C. Amongst these molecules **6a** having the sharp peak of weight loss rest of the molecules have the continuous weight loss profile. The thermo gravimetric analysis envisaged to apply these molecules as fluorescent brightening agents. Where the process of fluorescent brightening agent application is at temperature 130° C with pressure and these molecules have thermal stability more than 130° C. (**Figure 4**).



Figure 4: Thermo gravimetric analysis of compounds 6a-6g.

Fluorescent Brightening agent:

The colorimetric parameters of the whitened polyester fabrics using synthesized fluorescent molecules **6a-6g** were recorded on a reflectance spectrophotometer CE-7000A Gretag-Macbeth [5,

10]. CIE 1976 Color Space method was used to evaluate the color values of synthesized compounds **6a-6g** on polyester fabrics in terms of L*, a* and b* (**Tables 3**). All the compounds have a good affinity towards the polyester fabrics at high temperature and gave whitening with a blue tinge on polyester fabrics. The whiteness index values of the fabrics dyed with compounds **6a-6g** are summarized in **Table 3**. The colorfastness properties of these dyes were correlated with commercially used whitening agents.

									Leuco	Sera	Sera	Hostalu
	Blank	6a	6b	6c	6d	6e	6f	6g	phore	white	White	X
	Polyester	0	0.0			00	01	~8	BSB	PB	PN	ESR50
X	48.0	46.3	44.6	45.8	44.6	45.9	44.3	44.5	74.6	73.9	71.2	75.4
Y	50.8	49.2	47.4	48.3	47.7	48.6	47.5	47.6	80.1	77.7	75.0	79.9
Z	54.1	50.6	45.5	49.6	45.4	49.1	43.3	43.8	83.1	105.7	96.8	105.4
L*	76.5	75.6	74.4	75.0	74.6	75.2	74.5	74.6	91.7	90.6	89.4	91.6
a*	-0.3	-0.9	-0.9	-0.1	-1.5	-0.6	-2.0	-1.8	-28.2	1.1	0.6	-0.1
b*	0.4	2.2	5.6	2.3	6.0	3.1	8.2	7.8	2.1	-16.1	-12.2	-14.0
C*	0.5	2.4	5.7	2.4	6.2	3.2	8.5	8.0	3.5	16.1	12.2	14.0
h°	133.6	112.8	99.6	93.4	104.6	100.7	104.1	103.2	142.5	274.0	273.2	269.4
K/S	0.25	0.36	0.53	0.36	0.58	0.40	0.66	0.61	0.04	0.26	0.07	0.09
Stensbay Whitenes	74.1	66.0	54.5	67.4	51.7	63.8	43.4	45.5	0.5	142.4	128.0	134.0
Taube Whitenes	64.0	45.0	53.0	44.7	54.3	47.3	60.1	59.0	92.1	189.7	162.3	181.8

Table 3. Color properties of compounds 6a-6g and commercially used optical whiteners.

Conclusion:

Synthesis and application of novel oxadiazole substituted quinazoline compounds have been performed and characterized by ¹H-NMR, Mass and IR spectroscopy. The novel oxadiazol substituted quinazoline and electronic distribution over the structure concluded the fluorescent properties of compounds. Which states that fluorescent properties are independent of substituents attached to the 5th position. Photophysical properties, electronic state and energy level by B3LYP

Density Functional Theory (DFT) computational optimization confirm the dependency of fluorescence on electron donor and acceptor substituents. Eventually quinazolines show the basic requirements for the fluorescent brightening agent's an absorption in ultra-violet region and emission at visible region (around 400 nm). Compounds gave whitening with a blue tinge on polyester fabrics has potential as emerging new fluorescent brightening agents. The significant a^{*}, b^{*} and K/S values are more for electron withdrawing -NO₂ group substituent 6d and 6f. The K/S value for 6d and 6f are 0.58 and 0.66 which are more than commercial Leucophore BSB (0.04), Sera White PB (0.26), Sera white PN (0.07) and Hostalux ESR 50 (0.09) while the conditions for application of brightening agents was similar. The compared experimental photophysical properties with theoretical data obtained by DFT computation results are in close agreement with theoretical properties. This is a step towards the minimization of laboratorial work before the synthesis of complex structure desirable to find out the essential properties by computational optimization.

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Table and Figure captions

Table 1: Observed UV-visible absorption, computed absorption,

observed emission and computed emission of compounds 6a-6g in DMF.

Table 2: HOMO-LUMO diagrams of compound 6a-6g in DMF.

Table 3: Colour properties of compounds 6a-6g and commercially used optical whiteners.

Figure 1: Molecular structure of substituted quinazoline 6a extracted from DFT optimization.

Figure 2: Molecular structure of substituted quinazoline 8a extracted from DFT optimization.

Figure 3: Graph of HOMO-LUMO energies of compounds 6a-6g in DMF.

Figure 4: Emission spectra of compounds 6a-6g and 8a-8g in DMF

Scheme1. Synthesis of 2-methyl-5-(5-phenyl substituted-1,3,4 oxadiazole-2-Yl) quinazolin-4(3H)-one **6a-6g**.

ACCEPTED MANUSCRIPT

- > New range oxadiazole-quinazoline based of fluorescent brightening agent.
- > C1 symmetry PCM model DFT-TD-DFT computational of molecular structure.
- > Oscillator strength and % deviation by vertical excitation and $\lambda_{abs}/\lambda_{em.}$
- > Studied electronic transition, energy levels, electronic orbital distribution.