

Research Article

Triple Cascade Synthesis of Dihydropyrimidones Using Lawsone and Heterocyclic Scaffolds with a Zinc Acetate Catalyst: Dyeing Efficiency on Nylon and Polyester Fabrics

Nilam Patel¹ , Prashant Kumdale^{2,*} , Sneha Kulkarni³ , Paresh Patel⁴ ,
Suchitra Savant¹ 

¹Department of Chemistry, VanitaVishram Women's University, Surat, India

²Department of Chemistry, Shivneri College Shirur Anantpal, Dist, Latur India

³Department of Chemistry, KLS ViShwanathro Deshpande Institute of Technology, Haliyal, India

⁴Department of Chemistry, Uka Tarsadia University, Bardoli, India

Abstract

This report presents an efficient triple cascade protocol for synthesizing new disperse dyes derived from different heterocyclic scaffolds, urea, and lawsone. This study proposes a novel modification protocol for disperse dyes that enhances their affinity for nylon substrates through the use of Zinc acetate catalyst, without inducing structural changes in the nylon fibers. Zinc acetate, which is favored due to its low-priced, low toxicity, and environmental benefits, has emerged as a valuable catalyst for this reaction. Triple cascade reactions (TCRs) represent a pivotal strategy in modern synthetic chemistry for the efficient construction of diverse organic molecules, owing to their high atom economy, operational simplicity, and environmentally benign nature. The recently synthesized disperse dyes demonstrate excellent dyeing properties on mutually nylon and polyester fibers. The Experimental finding demonstrated that the newly established dispersed dye had a significant effect on the dyeing performance and overall coloration properties of the substrates. The novel dyes show superior dyeing properties compared to lawsone, especially in term of vibrant shades, higher affinity, improved adsorption capacity and advanced tinctorial strength. Additionally, the percentage exhaustion, fixation, color strength (K/S), washing fastness & sublimation fastness properties are notably better in nylon-dyed samples than in polyester. These findings highlight the significant potential of these novels disperse dyes for nylon & polyester fiber. With commercialization, these dyes could provide a better alternative to conventional disperse dyes, offering broader benefits across various industries.

Keywords

Triple Cascade Reaction, Disperse Dyes, Fastness, Color Strength (K/S), Exhaustion and Fixation

*Corresponding author: pkpk7389@gmail.com (Prashant Kumdale)

Received: 13 September 2025; **Accepted:** 22 September 2025; **Published:** 14 October 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Triple cascade reactions (TCRs) are one of the quintessential, proficient and fascinating synthesis strategies which have paying attention of many chemists or researchers due to distinctive properties such as high stability, high activity with less energy and higher efficiency [1]. One of the familiar TCRs protocol is the Biginelli one pot reaction in which three or more reactants react together to form 3, 4-dihydropyrimidin-2(1H)-ones (DHPMs) [2-4]. This group of heterocyclic system displays a broad range of biological and pharmacological property such as calcium channel modulators [5], antitumor, antiviral, antibacterial, antifungal, antioxidant [6-9] Melanin concentrating hormone receptor (MCH1-R) antagonists [10] chemical modulators of heat shock protein 70 (Hsp 70) [11] dyes, polymers, adhesive [12-14]. Undoubtedly, a heterocyclic framework is the crucial categories of hydrocarbon compounds that hold significance in chemicals, biomedical, veterinary products, and industrial applications [1, 15]. These heterocyclic aromatic compound include their application as pesticide, herbicide, fungicide, insecticide [16] anticorrosive agent, photographic developer, sensitizer, fluorescent whitener & boosters agents. (Figure 1) [17-22]

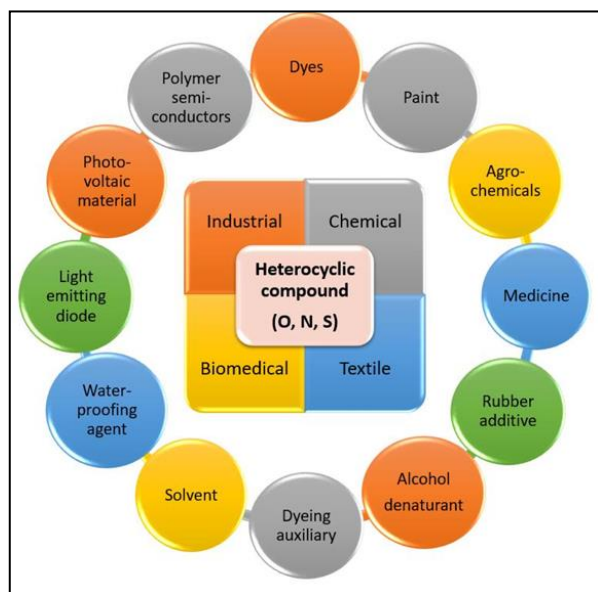


Figure 1. Applications of Heteroatom containing compounds.

Two isomeric dyes based on naphthaquinone, lawsone and juglone, are used to create heterocyclic scaffold DHPMs [23, 24] Lawsone, a unique naphthoquinone found in natural orange 6 and CI 75480, is also recognized chemically as 2 hydroxy-1, 4 naphthoquinone and has numerous uses in a range of scientific and technological domains [25] Lawsone also demonstrates brighter coloring, which is comparable to disperse dyes, with a high resem-

blance for hydrophobics textiles and greater tinctorial strength [26] Currently, the largest sector in the dye industry is dispersed dyes. Disperse dyes, which are non-ionic, are frequently applied to synthetic fibers like polyester and polyamide. According to literature study they showed luminous colors, good chromophoric strength, leveling &immigration properties, excellent light, wash and sublimation fastness as well as elevated level dye properties in the dyestuff industry. [27]

While of the many uses and characteristics of lawsone, we have already made its dispersion colors using basic substituted aromatic aldehydes [23] We have created a straightforward effective procedures for the production of new 3, 4-dihydropyrimidin-2(1H)-ones (DHPMs) employing a cost-effective and green catalyst, zinc acetate which has a 98% yield at RT. High activity, superior selectivity, non-corrosiveness, environmental friendliness, and affordability make zinc acetate catalysts highly desirable for research [24, 25] As a result, there is ongoing worry about creating new synthetic techniques and researching innovative approaches to target heterocyclic compounds at a important level of molecular convolution and atom economy. We expand on our research by introducing a new DHPMs that are synthesized from various heterocyclic compounds. After being synthesized, each of the unique compounds was described and use of dispersion dye on polyester & nylon fabrics. This research evaluates and presents their physical characteristics, color assessment, washing and sublimation properties, and exhaustion and fixation property on polyesters and nylon fabrics.

2. Experimental

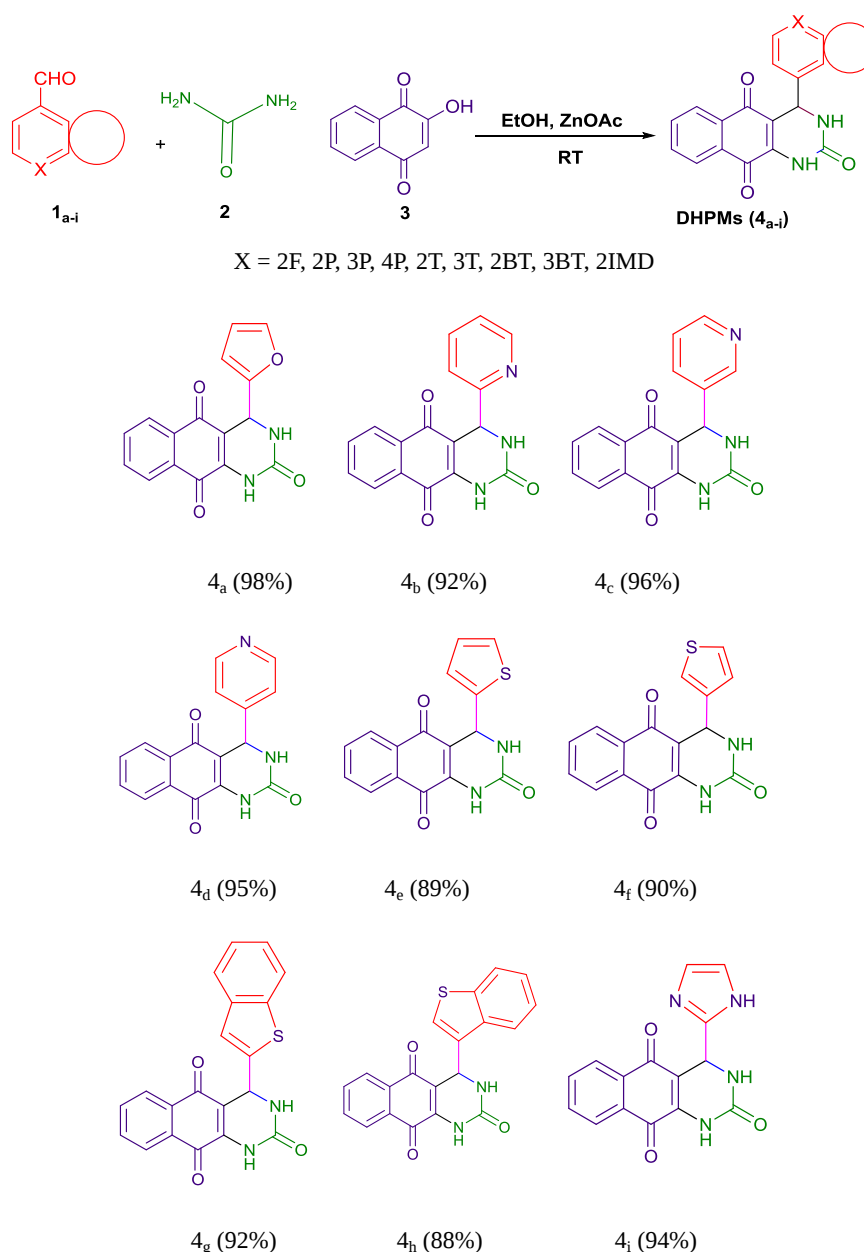
2.1. Materials

All chemicals Purchased from TCI, S-Define, and Sigma Aldrich and used without purification. Nuclear Magnetic Resonance (NMR) were recorded at 300K temperature by using a Bruker Avance- III 500 MHz Ascent FT spectrometer with his working frequency of 500 MHz for ^1H and 125 MHz for ^{13}C . Optical absorption spectra were record on JASCO V-750 spectrophotometers by using a 1 cm path lengths. ATR-FTIR spectra of the solid sample were record on the Perkin-Elmer (Spectrum-Two) instruments. ESI Mass of the complexes were recorded with Waters Synapt-G2S ESI-Q-TOF and AB SCIEX QTRAP 4500 instruments on the positive ion mode. The MP were resolute by using a regular capillary tube technique and are not corrected. 100% nylon and polyester fabrics purchase from Atul Pvt Ltd, company.

2.2. Synthesis of 4-Aryl-3,4-Dihydrobenzo[g]Quinazoline 2, 5, 10 (1-H) Trione Derivative (DHPMs)

A minimum quantity of ethyl alcohol (10 to 15 ml) was used to dissolve various types of heteroaryl aldehyde (1a-i; 10 mmol), urea 0.60 g (2; 10 mmol), and lawsone 0.174 g (3; 10 mmol). To produce a transparent, uniform solution, the reaction material was agitated at RT. The reaction material was then supplemented with 0.05 mole of anhydrous zinc acetate, a catalytic quantity. Solid product development began

within an hour, and TLC was used to track the reaction's development. After the reaction completion the crude product was poured into crushed ice then filtered the product and washed with water. The crude product was purified and dried after that heating in hot water and then recrystallization from hot aqueous ethyl alcohol to afford pure DHPMs (4a-4i; Scheme 1). Remaining molecules prepared by same methods and all new structure prepared molecule are confirmed with ^1H NMR, ^{13}C NMR, HRMS and FT-IR spectroscopies (Supporting information).



Scheme 1. Preparation of DHPMs derivative with heteroaryl carbaldehyde.

3. Results and Discussion

Novel series of 4-Aryl 3, 4 dihydrobenzo [g] quinazoline 2, 5, 10 (1H) trione scaffold were synthesized *via* triple cascade Biginelli reactions amongst different heterocyclic aromatic aldehyde, urea, and 2 hydroxy-1, 4-naphthoquinone (Scheme I). To find the most appropriate solvent for this study, solvent optimization was performed.

3.1. Solvent Optimization

The model reaction was proceeded out for 10 hours at RT while varying the solvent, temperature, reactions time and mole ratio of catalyst (entry 1 to 5, Table 1), and the average yield was achieved at RT. The yield considerably increased in comparison to RT after reactions were approved with all of the solvents at reflux conditions. Hence, we move ache with reflux conditions to observe the result of non-polar solvent on this synthesis, by the using solvent as toluene and benzene, the largest yields up to 24-36% were obtained even underneath refluxed for 10 hours with 1% mole equivalents

of catalysts (entry 6 & 7, Table 1). This indicate that the non-polar solvents are not as much of appropriate for these reactions. Furthermore, to check the suitability of polar solvents, all the optimizations were performed with Tetrahydrofuran and DMF and there were 52 - 60% yields respectively (entry 8 & 9, Table 1). This indicates that the polar solvents were more appropriate for that reaction compare to non-polar. Lastly, all this optimization was also perform in polar protic solvent ethyl alcohol as a solvent. Also tried to check, by changing time in ethanol and observed that yield decreased by reducing time and yield increased by increasing time (entry 11 & 12, Table 1). Then a fixed time of 18 hours, by changing the mole catalyst ratio between 0.5 and 2% and observed the yield decreased by lower the catalyst amount. Though, there wasn't lot dissimilarity in yield by rising the mole ratio catalyst (entry 14 & 15, Table 1). So, under well-optimized conditions 1% mole equivalent of catalyst at RT ethanol gave highest yield 98% at 18 hours (entry 13, Table 1). Hence, we have been used ethyl alcohol as solvents for all remaining reactions (Table 1).

Table 1. Screening of solvent.

Entry	Solvent	Catalyst (% mole eq.)	Temperature (°C)	Time (Hrs.)	Yield (%)
1	Benzene	1	RT	10	20%
2	Toluene	1	RT	10	18%
3	THF	1	RT	10	45%
4	DMF	1	RT	10	53%
5	Ethanol	1	RT	10	87%
6	Benzene	1	Reflux	10	36%
7	Toluene	1	Reflux	10	24%
8	THF	1	Reflux	10	52%
9	DMF	1	Reflux	10	60%
10	Ethanol	1	Reflux	10	90%
11	Ethanol	1	RT	09	80%
12	Ethanol	1	RT	12	93%
13	Ethanol	1	RT	18	98%
14	Ethanol	0.5	RT	18	70%
15	Ethanol	2	RT	18	98%

The bold significance represents the optimized protocol/conditions

3.2. Study of Colors Property by UV Spectroscopy

The examination of UV visible absorptions spectra of freshly synthesized molecules alongside lawsone was conducted to determine their maximum absorption within the sort

of 435 nm to 483 nm (Table 2). The colors of dye DHPMs (4a-4i) in DMF solutions was from brown to maroon, respectively. Amongst all the DHPM, scaffold with hetero moiety has shown notably high absorption maxima. The dye (4a-4g) is red-shifted absorption as compare to the dye 4h and 4i about 50 nm (Figure 2, Table 2).

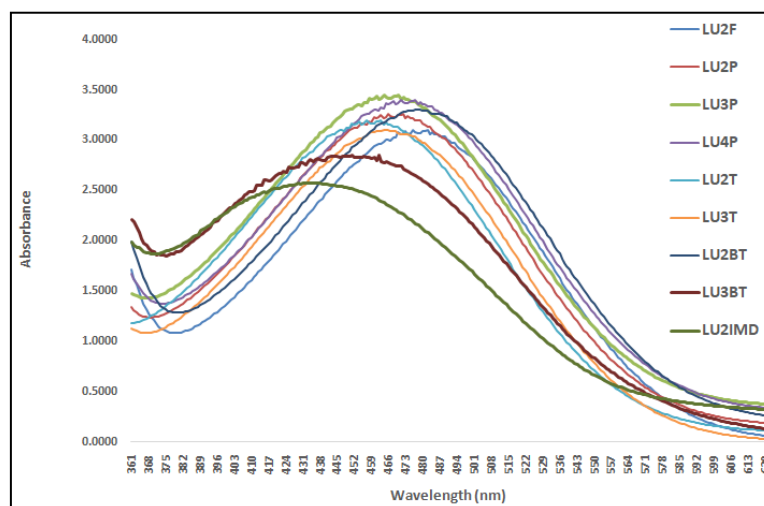


Figure 2. Visible spectrums of dyes (4a-4i) in DMF solvent.

Table 2. Visible absorption spectra of the prepared dyes in DMF.

Dye	$\lambda_{\max}$ (nm)	$\log \epsilon$	$\epsilon_{\max}$ (dm ³ mol ⁻¹ cm ⁻¹)
4 _a	482	4.43	27402
4 _b	472	4.45	28219
4 _c	470	4.47	29736
4 _d	477	4.47	29742
4 _e	463	4.43	27171
4 _f	466	4.42	26493
4 _g	479	4.46	28988
4 _h	451	4.37	23536
4 _i	434	4.31	20446

3.3. Spectral Characterization

The Synthesized all product were confirm by different Spectra. Selected spectral data of 4_aare discussed here. Remaining spectral data are in supporting information file.

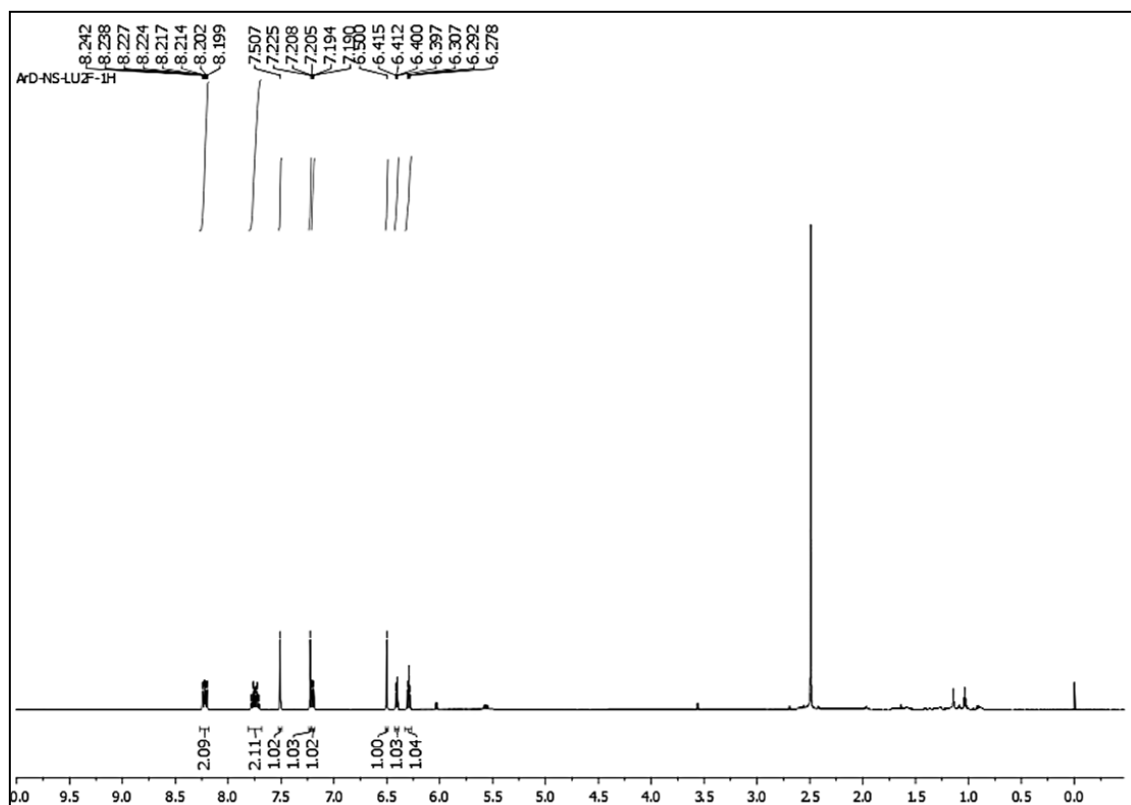


Figure 3. ^1H NMR of 4-(furan-2-yl)-3, 4-dihydrobenzo [g] quinazoline-2, 5, 10 (1H) trione (4_a).

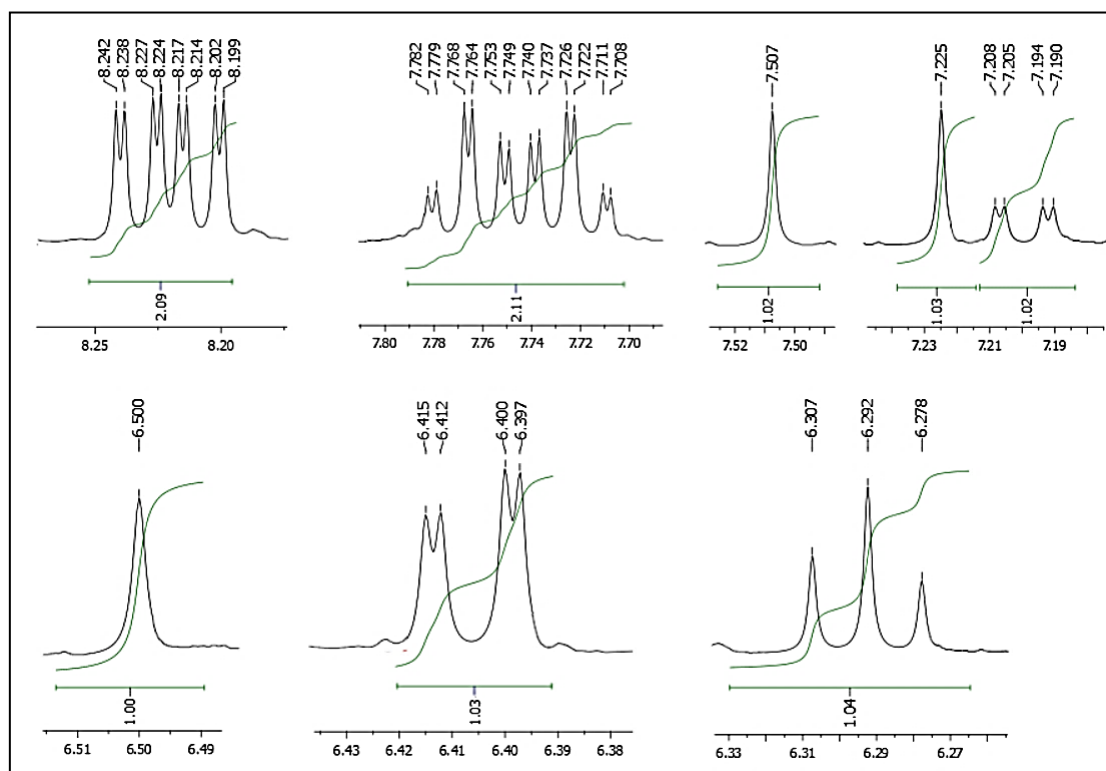


Figure 4. Expanded ^1H NMR of 4-(furan-2-yl)-3, 4-dihydrobenzo [g] quinazoline-2, 5, 10 (1H) -trione (4_a).

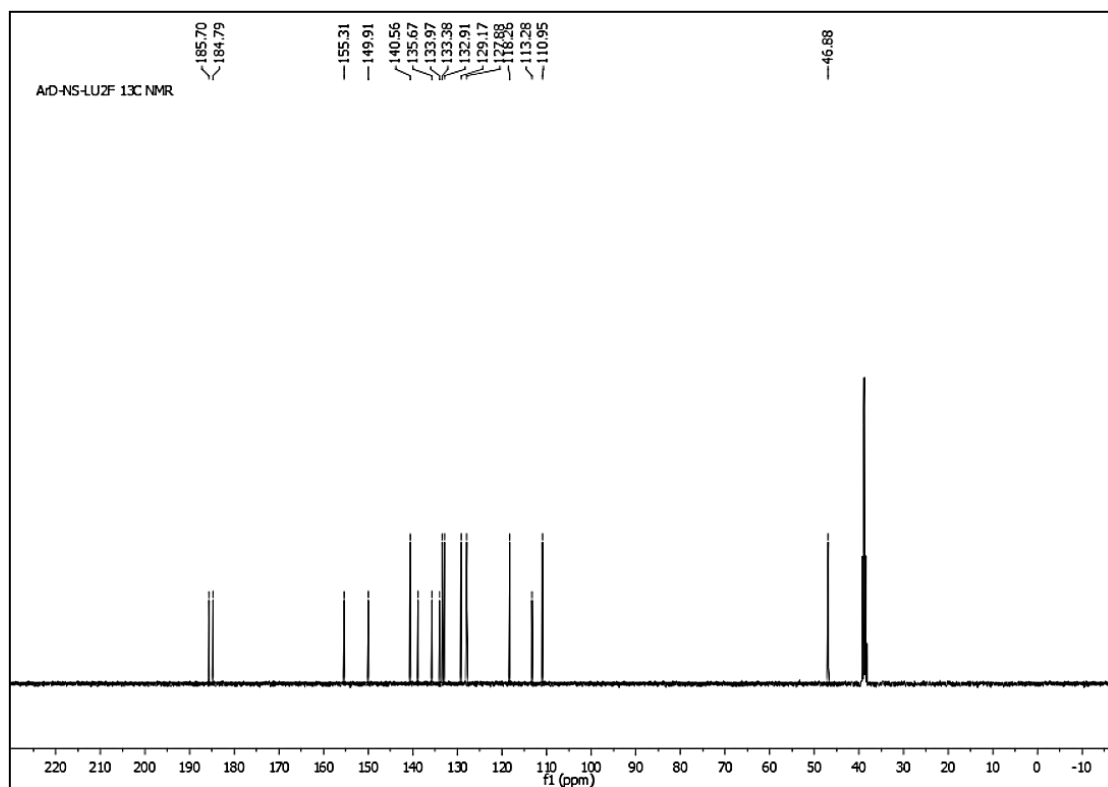


Figure 5. ^{13}C NMR of 4-(furan-2-yl)-3, 4-dihydrobenzo [g] quinazoline-2, 5, 10 (1H) -trione (4_a).

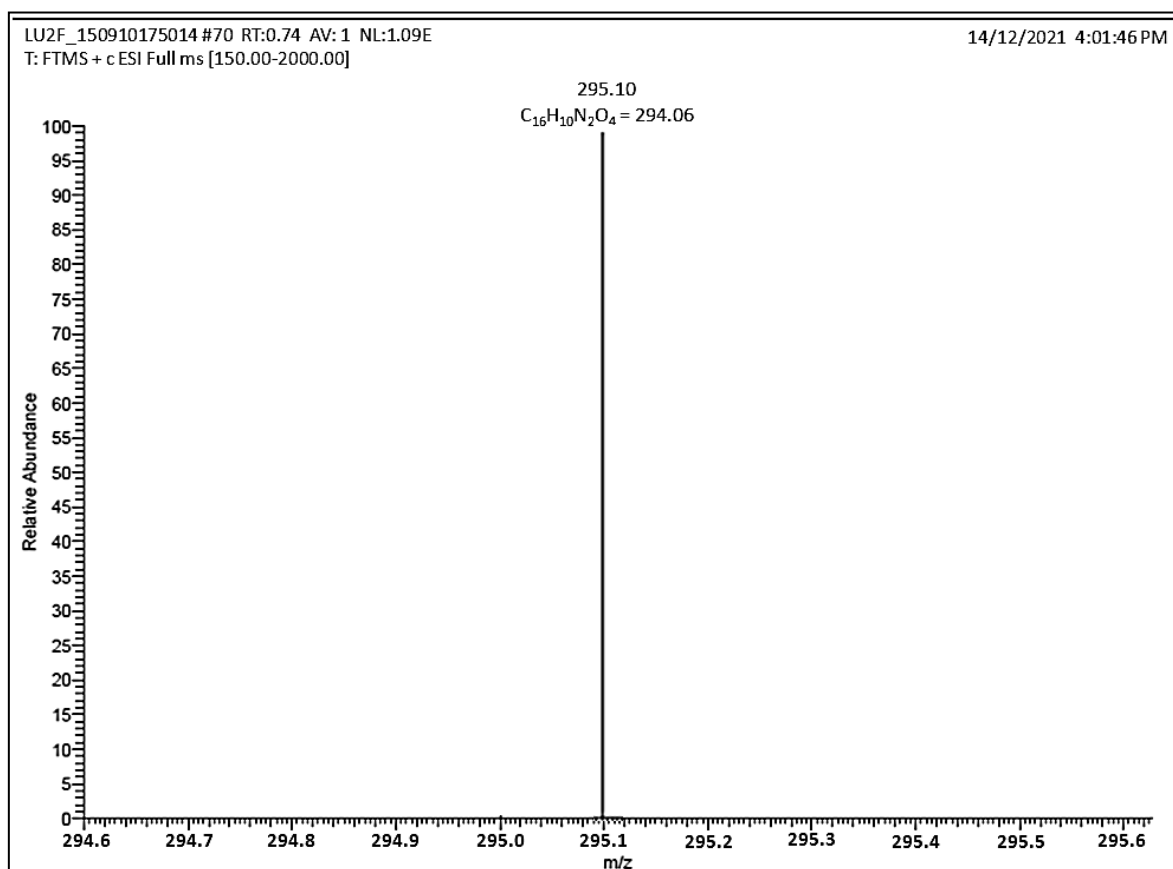


Figure 6. HRMS of 4-(furan-2-yl)-3, 4-dihydrobenzo [g] quinazoline-2, 5, 10 (1H) -trione (4_a).

In ^1H NMR spectrums (Figures 3 and 4) strongly validate the structure of the 4_a molecule. The initial distinct singlet peak at 6.5 ppm relates to a single hydrogen found on the chiral carbon. The two distinct peaks at 7.2 and 7.5 ppm might result from one H on N3 and one H on N1. Since the N1 is located among two carbonyl groups, the hydrogen bonded to it may show up in a more downfield region than the hydrogen on N3. The subsequent peak at 6.3 ppm appears as a triplet with $J = 7.5$ Hz, likely due to a one H on the furan ring. The division of that peak into a triplet with a small coupling constant might result from J^4 interaction with H at the ortho position of the aryl ring. The subsequent peaks at 6.4 and 7.2 ppm, appearing on doublet of doublets with $J = 7.5$ Hz, may result from the occurrence of 2 H on the furan ring. The peaks that remain in the area from 7.7 ppm to 8.2 ppm are observed as two intricate peaks with 4 H, likely due to aromatic hydrogen found in the 4_a molecule. Additionally, the structures were corroborated by the ^{13}C NMR spectrum as well (Figure 5). In ^{13}C NMR spectrum, the peak at 46.8 ppm verifies the asymmetric carbon of the pyrimidine rings. All additional aromatic carbon atoms have been detected in the region of ranging from 110 ppm to 149 ppm. Three carbonyl carbon atoms in the molecules are observed at 155, 184, and 185 ppm. In urea the carbonyl carbon segments could be at 155 ppm due

to the occurrence of 2 N atom at neighboring position. However, lasting two carbonyl carbons of the naphthoquinone system have appear at 184 and 185 ppm. Consequently, NMR Data of 4_a which was lastly support by its HRMS spectrums (Figure 6), where it has been revealed the molecular ion peaks at 295.10 m/z. Furthermore, the structure of 4_a supported its IR spectrum and the occurrence of various functional group in the molecules were confirm by IR spectra. IR bands appear in the molecule 4_a is NH stretching appears at 3372 cm^{-1} , CH stretching appeared at 2931 cm^{-1} , CO stretching appeared at 1689 cm^{-1} , and CN stretching appeared at 1273 cm^{-1} .

3.4. Dyeing and Fastness Properties of the Synthesized Dye on Nylon and Polyester Fabric

The dyes (4_a - 4_i) were prepared and practical on nylon and polyester fabric in 2% shade by utilizing HTHP method.²⁴ These novel routes disperse dyes has diverse colors such as brown, red, orange, maroon, brilliant red shade and dark orange on fiber with strong affinity and strong depth of colors (Tables 3 & 4).

Table 3. Observed depth on nylon fabric.

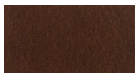
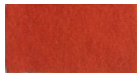
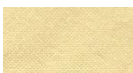
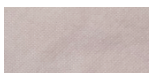
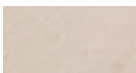
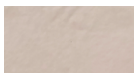
Dyes Sample	3	4_a	4_b	4_c	4_d
Apparent Color					
Dyes Sample	4_e	4_f	4_g	4_h	4_i
Apparent Color					

Table 4. Observed depth on polyester fabric.

Dyes Sample	3	4_a	4_b	4_c	4_d
Apparent Color					
Dyes Sample	4_e	4_f	4_g	4_h	4_i
Apparent Color					

3.5. Fastness to Washing

Washing fastness property has been done by the wash fastness tester ISO 105 CO3.²⁴ The results of (4_a-4_i) dye were originate in high-quality to brilliant ratings (4-5) on nylons and polyester fabric. It means no staining shifted to other

fabrics. The result of lawsone (3) was found reduced to moderate ratings on nylon and polyester fabric. These shows high results in (4_a-4_i) dyes compare to lawsone due to additional hetero atoms presents in products structures (Table 5 & 6).

Table 5. Wash fastness properties of disperse dyes on nylon fabric.

Sample	Change in shade	Stain on multifiber					
		Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
4 _a	5	5	5	5	5	5	5
4 _b	4-5	4-5	4-5	4-5	4-5	4-5	4-5
4 _c	4-5	4-5	4-5	4-5	4-5	4-5	4-5
4 _d	5	5	5	5	5	5	5
4 _e	5	5	5	5	5	5	5
4 _f	4-5	4-5	4-5	4-5	4-5	4-5	4-5
4 _g	5	5	5	5	5	5	5
4 _h	5	5	5	5	5	5	5
4 _i	4-5	4-5	4-5	4-5	4-5	4-5	4-5
3	1-2	3	2-3	3	3	2-3	3

Washing fastness: 1-Poor, 2-Fair, 3- Moderate, 4- Good, 5-Excellent

Table 6. Wash fastness properties of disperse dyes on polyester fabric.

Sample	Change in shade	Stain on multifiber					
		Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
4 _a	4-5	4-5	4-5	4-5	4-5	4-5	4-5
4 _b	4-5	4-5	4-5	4-5	4-5	4-5	4-5
4 _c	4-5	4-5	4-5	4-5	4-5	4-5	4-5
4 _d	5	5	5	5	5	5	5
4 _e	4-5	4-5	4-5	4-5	4-5	4-5	4-5
4 _f	4-5	4-5	4-5	4-5	4-5	4-5	4-5
4 _g	5	5	5	5	5	5	5
4 _h	5	5	5	5	5	5	5
4 _i	4-5	4-5	4-5	4-5	4-5	4-5	4-5
3	1-2	3	2-3	2-3	2-3	2	3

Washing fastness: 1-Poor, 2-Fair, 3- Moderate, 4- Good, 5-Excellent

3.6. Fastness to Sublimation

Disperse dye on polymeric fiber undertake sublimation that depend on temperature and is done by sublimations tester ISO 105 PO1.²⁴ The results of dyes (4_a-4_i) showed good quality to

brilliant (4-5) rating and lawsone showed fair to moderate ratings to the international geometric grey scale. The (4_a-4_i) dye display higher value compare to lawsone due to hetero atom enlarge the fixations capability of fabric hence; they give an advanced value of sublimation (Table 7).

Table 7. Fastness to sublimation properties of disperse dyes on polyester fabric.

Fastness to dry heat pleating (Sublimation) (ISO 105 PO1) (180 °C, 30 Sec)			
Sample	Change in shade	Stain on multifiber	
		Cotton	Polyester
4 _a	5	5	5
4 _b	4-5	4-5	4-5
4 _c	4-5	4-5	4-5
4 _d	5	5	5
4 _e	5	5	5
4 _f	4-5	4-5	4-5
4 _g	5	5	5
4 _h	5	5	5
4 _i	4-5	4-5	4-5
3	2	2-3	2-3

Sublimation fastness: 1-Poor, 2-Fair, 3- Moderate, 4- Good, 5-Excellent

3.7. Color Assessment

The color different in the CIE-Lab colors system is the dissimilarity between the sample's and the standard's L*, a*, and b* values. For every dye sample, the colorimetric parameters were established using Computer Colors Matching (CCM) analysis on polyesters and nylon fabric [24] The colors strength (K/s) values have been to be brilliant in all (4_a-4_i) dyed nylon samples compare to polyester sample. A distinction in color evaluation between lawsone (3) and its derivative

(4_a-4_i) was also seen in the occurrence of more electronegative heteroatoms in the products structure. Consequently, the value of (4_a-4_i) dyes is high than that of lawsone. On both materials, the K/S value of dye (4_a) is superior than that of dye (4_c). This might be as a result of the facts that the dye molecule in (4_a) contains more electronegative heteroatom oxygen than the one in (4_c). Additionally, it was noted that a five-member ring attached to the dyes molecule (4_a) added colors intensity and high value to both fabric (Figure 7, Table 8 & 9).

Table 8. Color assessment for disperse dyes on nylon fabric.

Sample	L*	a*	b*	c*	h°	K/S (CV-SWL)
4 _a	28.85	10.25	14.36	17.65	54.49	19.868
4 _b	61.70	24.56	48.85	54.89	63.56	6.969
4 _c	61.45	23.69	49.12	54.25	62.68	6.052

Sample	L*	a*	b*	c*	h°	K/S (CV-SWL)
4 _d	62.50	24.73	50.03	55.81	63.70	7.973
4 _e	53.89	23.13	45.03	50.62	62.81	9.348
4 _f	52.65	22.18	44.78	48.12	61.78	9.319
4 _g	54.89	25.19	48.10	52.98	64.45	12.850
4 _h	53.12	24.78	47.19	51.78	63.51	12.672
4 _i	63.72	25.76	51.18	54.49	64.23	8.996
3	57.06	27.00	39.82	43.27	51.94	5.162

Lightness, C*: Chroma, h°: Hue angle from 0 to 360°C, a* value redness (positive) greenness (negative), b* value yellowness (positive) blueness (negative).

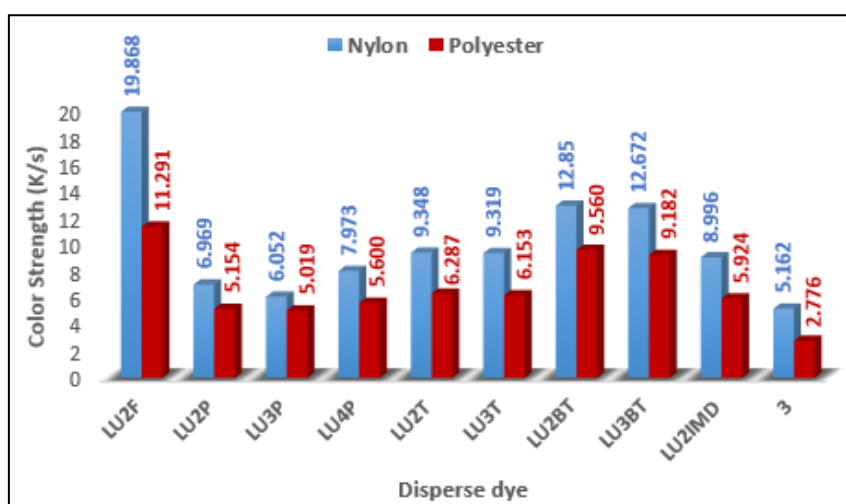


Figure 7. Comparison of colors strength (K/S) value for nylon and polyester.

Table 9. Color assessment for disperse dyes on polyester fabric.

Sample	L*	a*	b*	c*	h°	K/S (CV-SWL)
4 _a	48.41	19.13	39.83	40.14	54.29	11.291
4 _b	68.25	21.72	47.43	50.76	55.89	5.154
4 _c	67.48	21.29	46.12	50.34	54.75	5.019
4 _d	69.34	22.16	47.82	51.58	55.70	5.600
4 _e	62.39	25.55	40.02	52.77	62.50	6.287
4 _f	61.25	24.39	35.42	53.89	61.41	6.153
4 _g	59.43	24.82	46.49	52.36	63.15	9.560
4 _h	60.45	23.53	45.28	51.96	62.25	9.182
4 _i	60.59	29.34	48.19	53.18	62.45	5.924
3	45.79	4.16	16.07	20.06	47.85	2.776

Lightness, C*: Chroma, h°: Hue angle from 0 to 360°C, a* value redness (positive) greenness (negative), b* value yellowness (positive) blueness (negative).

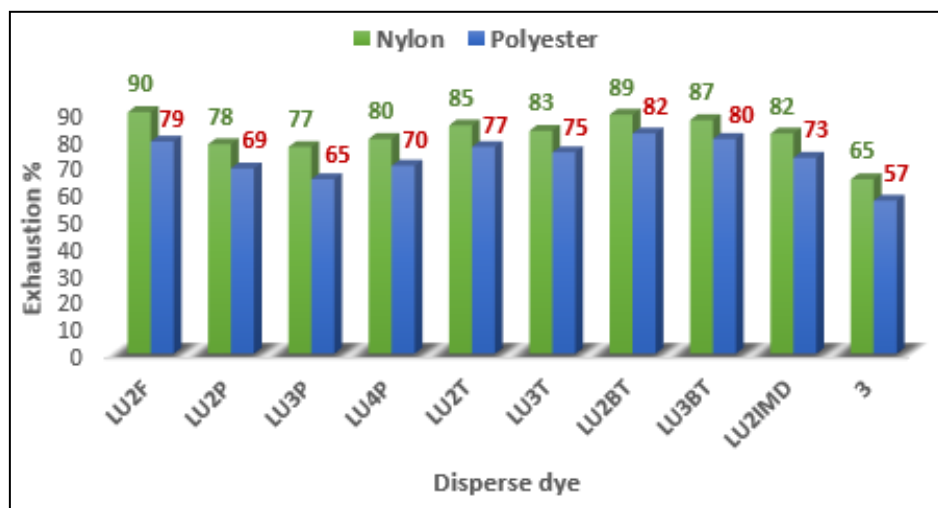


Figure 8. Percentage exhaustion of disperse dyes applied to nylon and polyester fabrics.

3.8. Determination of Dyes Percentage Exhaustions (% E)

By estimating the dyes concentration earlier than introducing fabrics into the dyes bath (A0) and after dyeing (A1) based on the calibration curve, the exhaustion values are dependent on the fabric's structure, diffusion rates and dye molecules [23]. Nylon fabric has a advanced exhaustions value than polyester fabric, according to the % exhaustions of (4a-4i) dyes. While its derivative dyes (4a-4i) yielded results ranging from 77% to 90% on nylon & 65% to 82% on polyester fabrics, the exhaustions values of lawsone are 65% on nylon & 57% on polyester. For the reason that their increased absorption ability, the dyes (4a-4i) exhibit higher values than lawsone (Figure 8).

3.9. Determination of Dyes Percentage Fixation (%F)

When removing the dye capability of the dispersed dye, which is reliant on the pH of the dyes bath, the fixation values were determined by fixed amount of dye that is exhausted on the cloth during the dyeing process 24-. According to the dye bath % fixation data, nylon fabric has a greater fixation value than polyester fabric (4a-4i). Lawson's fixation value is 69% of nylon & 60% on polyester. Its derivative dyes (4a-4i) yield results ranging from 82% to 95% of nylon & 70% to 90% on polyester, respectively. Due to the highest fixation power in (4a-4i), the value is superior than that of Lawsone (Figure 9).

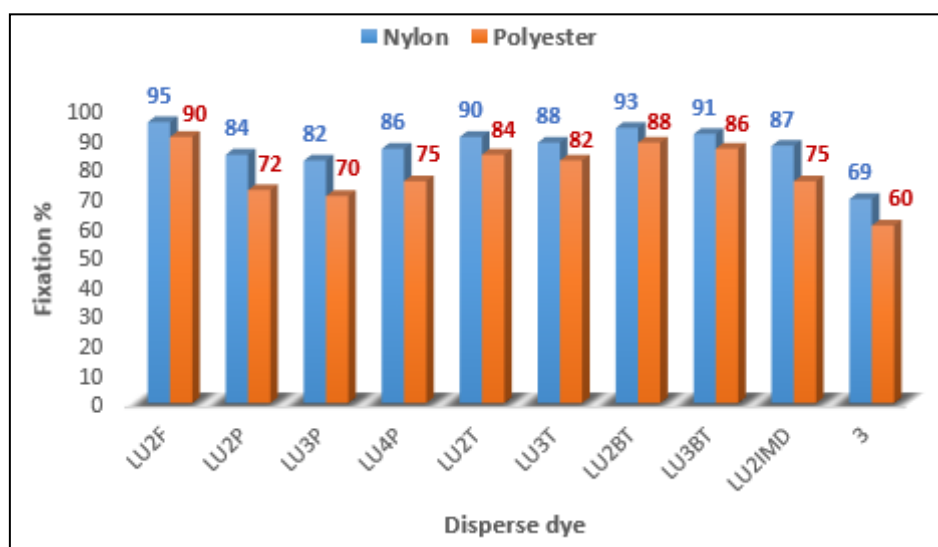


Figure 9. Percentage fixation of disperse dyes applied to nylon and polyester fabrics.

4. Conclusion

By employing Zinc acetate as a proficient catalyst in the preparation of novel DHPMs scaffolds by using different heterocyclic aromatic carbaldehyde, urea, and 2 hydroxy-1, 4-naphthaquinone (lawsone) at RT, a unique methodology has been created. The protic polar solvents i.e., ethanol, was discovered to be more successful for that reactions after a various of solvents were examined to conclude which one would better work. Novel synthesized compounds' structures were verified by a range of spectral investigations, including ^1H NMR, ^{13}C NMR, FT-IR & HRMS. All of these compounds had UV visible absorptions maximums in the visibles range of 434–482 nm. All of the synthesized dyes have a spectrum of colors with good intensity, including brown, mild orange, brilliant red, dark orange, crimson, and beam maroon.

When compare to polyester fabric, every synthetic disperse dye (4a–4i) base on DHPMs exhibit high-quality dyeing performances on nylon fabric. The result of dyes (4a–4i) were determined to have very superior to outstanding order (4-5) for washing and sublimations capabilities based on standard grey scale. When compare to polyester samples, the colors strength (K/s) values of all dyed nylon were determined to be quite good. On both fabrics, the K/S value of the dyes (4a) and (4c) are higher and lower, respectively. All dyed nylons have been determined to have outstanding percentage exhaustion and fixations values.

Acknowledgments

The authors are grateful to Department of Chemistry, Vani Vishram Women's University Surat, Department of Chemistry, Shivneri Mahavidyalaya Shirur Anantpal Dist-Latur, and Laboratory of Bio-Organic Chemistry, Tarsadia Institute of Chemical Science (TICS), Uka Tarsadia University, Bardoli for impart the laboratory facility. The authors are thankful to IIT Gandhinagar for all the spectral characterization. The authors acknowledge to Mr. Arindam Chakraborty (General Manager-TS) and Mr. Kaushik Bhatia (Manager) from Atul Limited for the help and support for dyeing study.

Author Contributions

Nilam Patel: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing

Prashant Kumdale: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing

Sneha Kulkarni: Conceptualization, Formal Analysis, Methodology

Paresh Patel: Supervision, Writing – review & editing

Suchitra Savant: Supervision, Writing – review & editing

Conflicts of Interest

The authors declares that there is no conflict to declare.

Appendix



Figure 10. Graphical abstract.

References

- [1] Huang W; Jiang J; Mandal T. *Synth. Commun.* 2021, 51, 2397. <https://doi.org/10.1080/00397911.2021.1939883>
- [2] Shen C. L.; Lou Q.; Zang J. H.; Liu K. K.; Qu S. N.; Dong L.; Shan C. X.. *Adv. Sci.* 2020, 7, 1903525. <https://doi.org/10.1002/adv.201903525>
- [3] Kazemi A.; Yang S. *J. O. M.* 2019, 71, 1209. <https://doi.org/10.1007/s11837-019-03373-3>
- [4] Mao Q. F.; Shang-Guan Z. F.; Chen H. L.; Huang K. *Ann. Transl. Med.* 2019, 7, 384. <https://doi.org/10.21037/atm.2019.07.45>
- [5] Adib M.; Ghanbary K.; Mostofi M.; Ganjali M. R.; Efficient Ce(NO₃)₃ 6H₂O-Catalyzed Solvent-Free Synthesis of 3,4-Dihydropyrimidin-2(1H)-ones. *Molecules* 2006, 11, 649-654. <https://doi.org/10.3390/11080649>
- [6] Sabir S.; Alhazza M. I.; Ibrahim A. A. "A review on heterocyclic moieties and their applications" *Catalysis for Sustainable Energy*, vol. 2, no. 1, pp. 99-115. <https://doi.org/10.1515/cse-2015-0009>
- [7] Karrouchi K.; Radi S.; Ramli Y.; Taoufik J.; Mabkhot Y. N.; Al-Aizari F. A.; Ansar M. H. Synthesis and Pharmacological Activities of Pyrazole Derivatives: A Review. *Molecules*. 2018 Jan 12;23(1):134. <https://doi.org/10.3390/molecules23010134>
- [8] Driowya M.; Saber A.; Marzag H.; Demange L.; Benhida R.; Bougrin K. *Mol.* 2016, 21 492. <https://doi.org/10.3390/molecules21040492>
- [9] Kumdale P. G.; Shitole N. V.; Orient J. *Chem.* 2022, 38(1). <http://dx.doi.org/10.13005/ojc/380125>

- [10] Basso A. M.; Bratcher N. A.; Gallagher K. B.; Cowart M. D.; Zhao C.; Sun M.; Esbenshade T. A.; Brune M. E.; Fox G. B.; Schmidt M.; Collins C.; Souers A. J.; Iyengar R.; Vasudevan A.; Kym P. R.; Hancock A. A.; Rueter L. E.; *Eur. J. Pharmacol.* 2006, 540, 115. <https://doi.org/10.1016/j.ejphar.2006.04.043>
- [11] Wisen S.; Androsavich J.; Evans C. G.; Chang L.; Gestwicki J. E.; *Bioorg. Med. Chem. Lett.* 2008, 18, 60. <https://doi.org/10.1016/j.bmcl.2007.11.027>
- [12] Dze K. C.; Samad F.; *Int. J. Res. Appl. Sci. Eng. Technol.* 2020, 836. <https://doi.org/10.22214/ijraset.2020.31786>
- [13] Arora P.; Arora V.; Lamba H.; Wadhwa D. *Int. J. Pharm. Sci. Res.* 2012, 3, 2947.
- [14] Mishra B. B.; Kumar D.; Mishra A.; Mohapatra P. P.; Tiwari V. K. *Adv. Heterocycl. Chem.* 2012, 107, 41.
- [15] Awan B.; Sabeen M.; Shaheen S.; Mahmood Q.; Ebadi A.; Toughani M. *Asian. J. Environ. Sci. Technol. Innov.* 2020, 1, 150. <https://doi.org/10.22034/CAJESTI.2020.03.0>
- [16] Kumdale P. G.; Shitole N. V. *IJGHC*, 2022, 11(3). <https://doi.org/10.24214/IJGHC/GC/11/3/30713>
- [17] Mishra B.; Kumar D.; Mishra A.; Mohapatra P.; Tiwari V. *Adv. Heterocycl. Chem.* 2012, 107 42. <https://doi.org/10.1002/chin.201314243>
- [18] Dua R.; Shrivastava S.; Sonwane S. K.; Srivastava S. K. *Adv. Biol. Res.* 2011, 5 120.
- [19] Mathur P.; Misra S.; *Adv. Organomet. Chem.* 2020, 73, 253. <https://doi.org/10.1016/bs.adomc.2019.09.001>
- [20] Balaban A. T.; Oniciu D. C.; Katritzky A. R.; *Chem. Rev.* 2004, 104 2777, <https://doi.org/10.1021/cr0306790>
- [21] Candeias N. R.; Branco L. C.; Gois P. P.; Afonso C. A. M.; Trindade A F.; *Rev.* 2009, 109, 2703. <https://doi.org/10.1021/cr800462w>
- [22] Druzhinin S. V.; Balenkova E. S.; Nenajdenko V. G. *Tetrahedron*, 2007, 63, 7753. <https://doi.org/10.1016/j.tet.2007.04.029>
- [23] Patel N C, Desai D H and Patel P N 2024, *Res. J. Text. Appar.* 28 609. <https://doi.org/10.1108/RJTA-08-2022-0093>
- [24] Patel P. N.; Patel N. C.; Desai D. H. *Russ. J. Org. Chem.* 2022, 58 536. <https://doi.org/10.1134/S1070428022040108>
- [25] Patel P. N.; Patel N. C.; Desai D. H. *Results Chem.* 2022, 4, 100362. <https://doi.org/10.1016/j.rechem.2022.100362>
- [26] Kumdale P. G.; Shitole N. V. *Asian Journal of Organic & Medicinal Chemistry* 2022, 7(2).
- [27] Patil S. R.; Choudhary A. S.; Patil V. S.; Sekar N. *Polym.* 2015, 16, 2349. <https://doi.org/10.1007/s12221-015-5233-x>