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Recent Advances and Future Prospects of Phthalimide Derivatives

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ABSTRACT

Among bicyclic non-aromatic nitrogen heterocycles, phthalimides are an interesting class of compounds with a large range of applications. Phthalimide contains an imide functional group and may be considered as nitrogen analogues of anhydrides or as diacyl derivatives of ammonia. They are lipophilic and neutral compounds and can therefore easily cross biological membranes in vivo and showing different pharmacological activities. In the present work compounds containing phthalimide subunit have been described as a scaffold to design new prototypes drug candidates with different biological activities and are used in different diseases as, for example AIDS, tumor, diabetes, multiple myeloma, convulsion, inflammation, pain, bacterial infection among others.

INTRODUCTION

Phthalimides possess a structural feature –CO-N(R)-CO- and an imide ring which help them to be biologically active and pharmaceutically useful. Phthalimides have received attention due to their androgen receptor antagonists (Sharma *et al.,* 2012), anticonvulsant (Kathuria and Pathak, 2012), antimicrobial (Khidre *et al.,* 2011), hypoglycaemic (Mbarki and Elhallaoui, 2012), anti-inflammatory (Lima *et al.,* 2002), antitumour (Noguchi *et al.,* 2005), anxiolytic (Yosuva and Sabastiyan, 2012) and anti HIV-1 activities (Sharma *et al.,* 2010).

Several reports demonstrated the antimicrobial potential of phthalimide derivatives (Santos *et al.,* 2009). Phthalimide derivatives of amino acid analogues possess anthelmintic activity (Srinivasan *et al.,* 2010). There is a growing interest in the usefulness of phthalimides and its derivatives. They have found relevance as inhibitors of tumor necrosis factor production (Okunrobo *et al.,* 2006). Phthalimides have served as starting materials and intermediates for the synthesis of many types of alkaloids and pharmacophores.

Structure of Phthalimide

Phthalimide is an imido derivative of phthalic acid. In organic chemistry, imide is a functional group consisting of two carbonyl groups bound to nitrogen. They are hydrophobic and neutral, and can therefore cross biological membranes in vivo. These compounds are structurally related to acid anhydrides (Azzawi and Razzak, 2011).

In N-Benzyl phthalimide the benzene and imide groups are planar and make a dihedral angle of 74.2 (1)° with one another. There are three weak C-H...O hydrogen bonds, forming a two-dimensional network structure. Most of the imides are cyclic compounds derived from dicarboxylic acids and their names reflect the parent acid.

Examples are succinimide derived from succinic acid and phthalimide derived from phthalic acid. As imide has the formula NH, being highly polar, imides exhibit good solubility in polar media. The N-H centre for imides derived from ammonia is acidic and can participate in hydrogen bonding.

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Effect of neighboring carbonyl groups on acidity of N-Bond

Imides such as phthalimide readily dissolve in aqueous NaOH as water-soluble salts. Imides are more acidic than amides. The order of acidity N- bond given in figure 1:

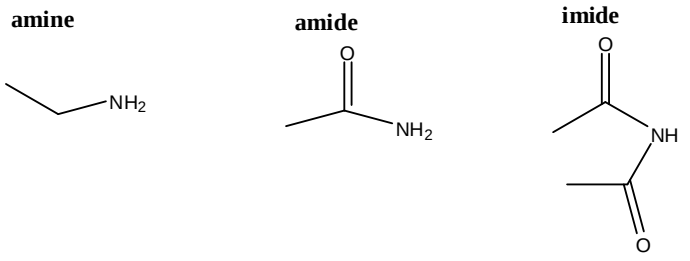


Fig. 1: increasing order of N-H acidity.

Phthalimide is highly acidic in nature due to it easily donate the proton and form water soluble salts with stronger bases. Reaction for salt formation is given in figure 2:

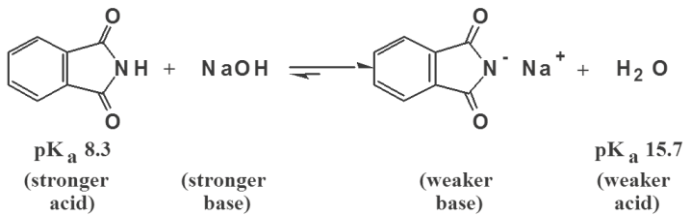


Fig. 2: Phthalimide salt formation with strong base.

Imides are more acidic than amides because:

1. The electron-withdrawing inductive of the two adjacent C=O groups weakens the N-H bond
2. More resonance delocalization of the negative charge.

Phthalimide have resonance stabilized structures which are shown in figure 3:

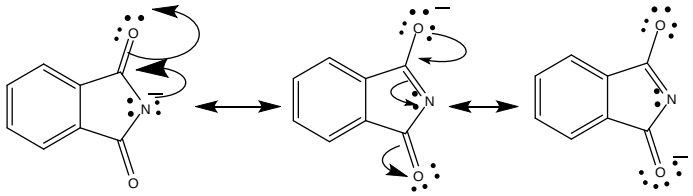


Fig. 3: A Resonance-stabilized anion.

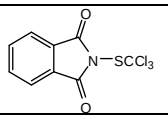
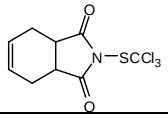
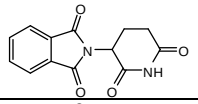
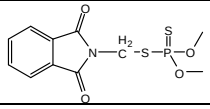
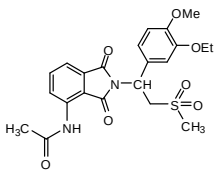
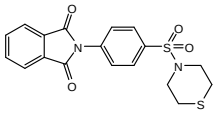
Often, Phthalimides are oxidative stable, heat retardant, solvent resistant, and have superior mechanical properties. The specific reactivity of imides is a result of the relative acidity of the NH group, a direct consequence of the presence of the two carbonyl groups.

It is also observed that the metal complexes are more active than the free organic ligand. Chelation reduces the polarity of the metal ion and enhances the lipophilicity or hydrophobicity of metal chelate which favours its permeation through microbial cell wall. The metal chelates may also disturb the respiration process of the microbial cells and thus protein synthesis and further growth of the microorganism is hindered. Though the co-ordination of aliphatic tertiary amino nitrogen is not sterically favored, the high electron density available on the tertiary amino nitrogen favors its coordination to a metal ion where there is a possibility for chelation (Ramesh and Sabastiyan, 2012).

The phthalimide moiety serves as a 'protected' form of ammonia. The phthalimide carbonyls increase the acidity of the nitrogen (thus allowing formation of its conjugate base). Most importantly, the phthalimide carbonyls protect the nitrogen from 'over alkylation' thus preventing the formation of quaternary ammonium salts. N-benzoyl phthalimide resembles both classical benzodiazepines and barbituric acid structure. It consists of tricyclic hydrophobic structure comparable to that of benzodiazepines and possesses a conjugated ureid functional group as can be found in barbiturates. Size and tridimentional structure of benzodiazepines and phthalimide backbones are similar (Hassanzadeh *et al.*, 2011).

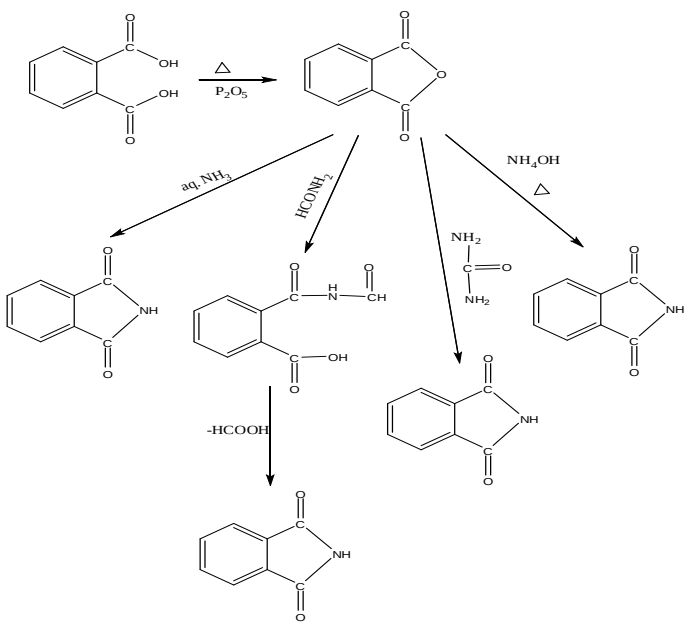
Phthalimide and N-substituted phthalimides are an important class of compounds because they possess important biological activities the identifiable structural features for their activity are as: hydrophobic aryl ring, a hydrogen bonding domain, an electron-donor group, another distal hydrophobic site Bhat and Al-Omar (2011). 4-(phthalimide)-substituted phenoxy propanolamines also possessed cardioselective β-adrenergic receptor binding affinity (Jindal *et al.*, 2005). Some marketed pharmaceutical products of phthalimide derivatives are reported in table 1.

Table 1: List for biological active some reported phthalimide derivatives.

S. N.	Structure	Name	Use
1.		Folpet EFSA (2014)	Fungicide
2.		Capton EFSA (2014)	Fungicide
3.		Thalidomide Wu *et al.*, (2005)	Antineoplastic Antileprotic
4.		Phosmet EFSA (2013)	Pesticide, insecticide and acaricide.
5.		Apremilast Schett *et al.*, (2010)	Phosphodiesterase -4 inhibitors (PDE-4) for the treatment of asthma and chronic obstructive pulmonary disease
6.		LASSBio-468 Barbosa *et al.*, (2012)	Phosphodiesterase -4 inhibitor, anti-inflammatory. It is a useful lead to therapy of rheumatoid arthritis & shock septic syndrome.

Preparation of phthalimide moiety

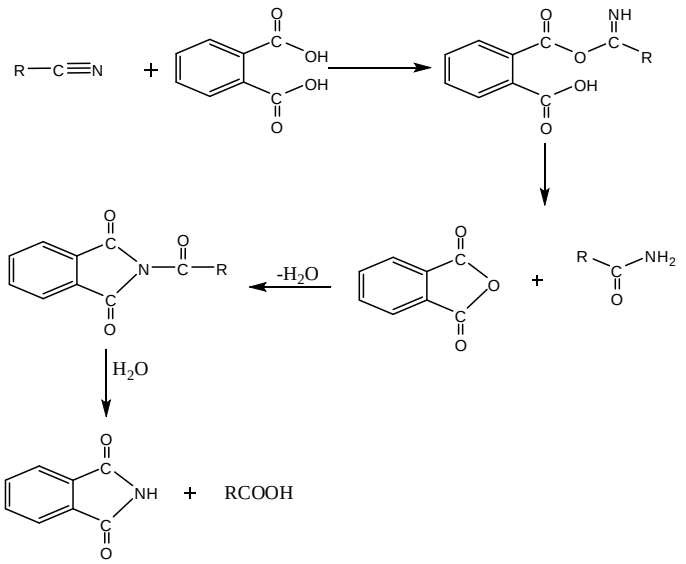
Some synthetic reactions for preparation of phthalimide moity summarized in scheme 1:



Scheme. 1: Reactions for preparation of phthalimide moity.

Mathews Reaction

The Mathews' reaction, a 'dry' hydrolysis procedure of nitriles by phthalic acid or amides by phthalic anhydride to give the corresponding carboxylic acid and phthalimide. Mathews' reaction is given in scheme 2:



Scheme. 2: Synthesis of phthalimide by Mathews' reaction.

Chiriac *et al.,* (2007) reported that aromatic or aliphatic cyclic imides and their derivatives are obtained by the reaction of dicarboxylic acids or their corresponding anhydrides with reagents bearing a reactive amino ($–NH_2$) functional group, through a nucleophilic attack of amino group to a anhydride moiety, by mechanism presented in figure 4:

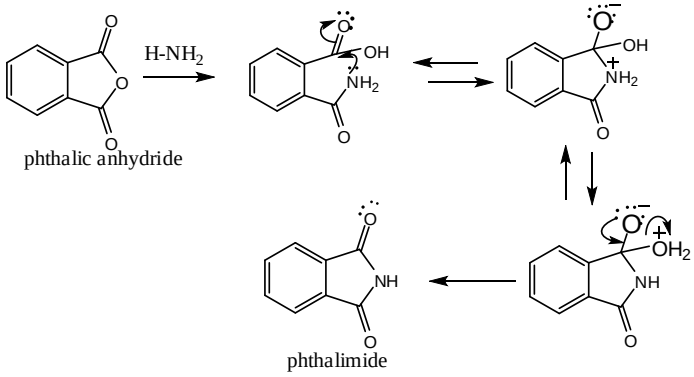
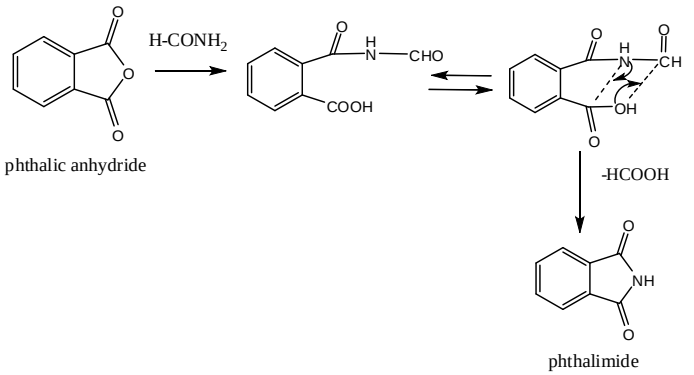


Fig. 4: Mechanism of imide formation by direct condensation.

A general and interesting synthetic pathway for the synthesis of imides by direct condensation using cyclic anhydrides or their corresponding dicarboxylic acids and form amide which is a simple affordable reagent. This approach has the advantage that this specific reagent can also serve as solvent, especially for aliphatic imides. For aromatic cyclic imides with lower solubility in formamide, another appropriate solvent can be supplementary used in order to maintain a homogeneous reaction medium and to allow the main product to be obtained in high yields. Synthesis of phthalimide in presence of formamide reagent given in scheme 3:



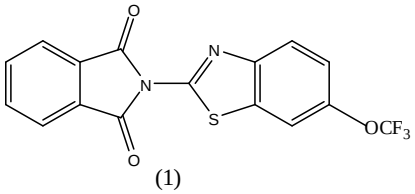
Schem. 3: Synthesis of imides in the presence of formamide as reagent.

BIOLOGICAL ACTIVITY OF PTHALIMIDE DERIVATIVES ALONG WITH SAR STUDY

Cytotoxic Activity

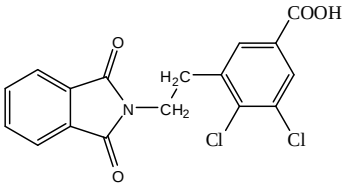
Stanton *et al.,* (2008) demonstrated that presence of *benzothiazole* unit attached to nitrogen of phthalimide, exhibits cytotoxic activity (compound **1**) carried out 'one pot' condensation reaction for the synthesis of phthalic imide derivative (benzothiazole containing phthalimide), exhibiting *in vitro* cytotoxic potential on human cancer cell lines. They further reported that both caspase dependent and independent pathways were involved in the induction of apoptosis in cancer cells. Khokra *et al.,* (2011) synthesized some benzothiazole containing

phthalimide derivatives were found to exhibit *in-vitro* cytotoxic potential on human cancer cell lines.



(1)

Singh *et al.,* (2011) designed and evaluated anticancer activity of some novel *isoindoline-1, 3-dione derivatives*. It may act due to multiple events or apoptosis inducer. The compounds **2** and **3** showed significant anticancer activity. It may be due to chloro-phenyl ring attached to the isoindoline-1, 3-dione with ethyl groups respectively or the compound **2** at 2, 4 positions *di*-chloro-substitution and in compound **3** chloro-substitution at 4 positions of phenyl ring. From the structural point of view, the chloro group which has the electron withdrawing property may be the crucial for tumor weight inhibition and tumor cell inhibition.



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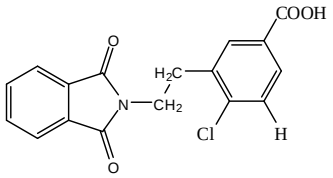
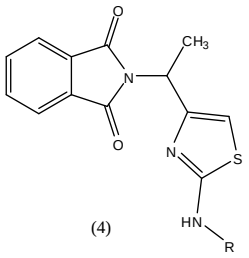


(3)

The isoindoline-1, 3-dione derivatives were evaluated for in vivo anticancer activity against the Ehrlich Ascites Carcinoma bearing mice model. Male Swiss albino mice were used as test animals. The synthesized compounds were administered intraperitoneally at a dose of 20-25 mg/kg body wt. per day for seven days after 24 hrs of tumor inoculation in mice.

The standard drug used was 5-Fluorouracil (20 mg/kg, b. wt.). Compounds treated (III-VII) groups were found to reduce the body weight, tumor volume, packed cell volume, viable cell count and increase the tumor weight (%) inhibition, ascites cells (%) inhibition and non-viable cell count and Increase in life span (% ILS). Compound 2 showed the highest inhibition of cancerous cell growth compared to compound 3. From the present study, it can be concluded that isoindoline-1, 3-dione derivatives might have potent anti-proliferative activity.

Yang *et al.,* (2010) designed and synthesized a series of structurally diverse heterocycle substituted phthalimide derivatives including furan, imidazo-[1,2-a]-pyridine, 1,3,4-thiadiazine, imidazo-[2,1-b][1,3,4]-thiadiazine, pyrazole, thiazole, thiazoline, etc by the reactions of α-bromoketone intermediate with various nucleophiles containing oxygen, nitrogen and sulfur atom. Their cytotoxic activities were also evaluated against five human cancer cell lines *in vitro* and were found to be potent. The researchers concluded that a large number of structurally diverse phthalimide derivatives for drug development can be synthesized by this method.



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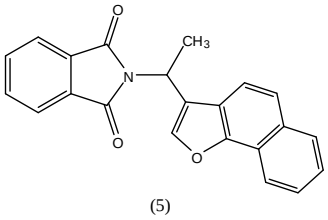
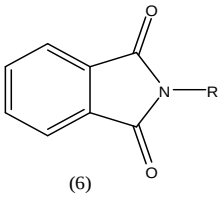


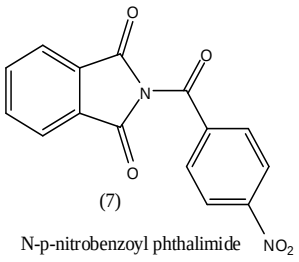
(5)

Selvum *et al.,* (2013) reported some new N-substituted phthalimide derivatives (compound **6** and **7**) been synthesized by condensation of phthalic anhydride and primary amines. Synthesized compounds were screened for antiviral activity against HIV-1 and -2 replication in MT-4 cells. Cytotoxicity was also investigated in uninfected MT-4 cells. All the synthesized compounds exhibited cytotoxicity in MT-4 cells (CC_{50}: 84-125 µg/ml).



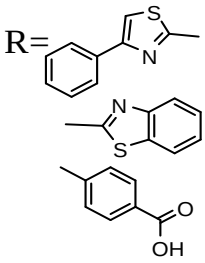
(6)

N-substituted phthalimide derivatives

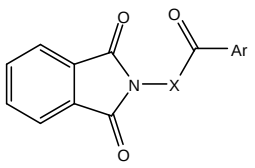


(7)

N-p-nitrobenzoyl phthalimide



Chan *et al.,* (2008) carried out 'one pot' condensation reaction for the synthesis and potent antiproliferative inhibition of a phthalimide based ketones. One of the molecule, *2-Phthalimide-1-(4-fluoro-phenyl) ethanone*, had the best growth inhibition on human MDAMB-231 breast carcinoma and SKHep-1 hepatoma cell lines. The bioactivity of the molecule was reported to be due to the presence of strong electronegative fluorine group at the para-position of the aryl ring (compound **8**).

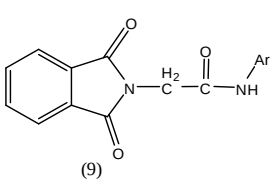


(8)

X=CH_2, $CH(CH_3)$
Ar=Ph, 4-F-Ph

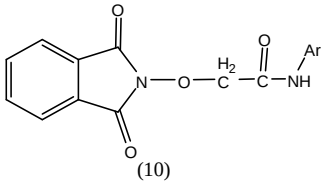
Antimicrobial activity

Pawar *et al.,* (2012) synthesized and investigated structural modifications of phthalimide to various *N-alkyl* (compound **9**) and *N-alkyloxy derivatives* (compound **10**) have been reported to result in modification of biological activity. N-alkyl and N-alkyloxy produce potent fungicidal action due to which they are extensively used as pesticides, preservatives as well as pharmaceuticals.



(9)

N-alkyl phthalimide



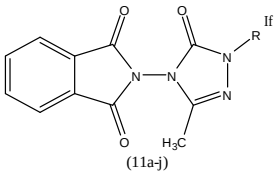
(10)

N-alkoxy phthalimide

Ar = -C_6H_5, -p-CH_3-C_6H_4 ,-p-OCH_3 -C_6H_4, -o-OCH_3-C_6H_4, -p-NO_2-C_6H_4, -$C_{10}H_7$

Atukuri *et al.,* (2011) demonstrated that *1, 2, 4-triazolinone derivatives* of phthalimide (compound **11 a-j**) possess antitubercular activity.

The anti-tubercular activity of the test compounds were evaluated against standard strain of Mycobacterium tuberculosis H37Rv (ATCC-27294) in BACTEC 12B medium using the microplate Alamar blue assay (MABA).29-30Antibiotic standard used was streptomycin at 6.5 µg/mL concentration. The compounds were tested at 5, 10, 15, 20, 25, 30 µg/mL concentrations by serial dilution against the M. tuberculosis H37Rv to determine minimum inhibition concentration (MIC) using MABA.



(11a-j)

If R= p-Cl-C_6H_4, R=p-Br-C_6H_4, R=m-Cl-C_6H_4, R=C_6H_5 — compound show very good antitubercular activity

If R=p-NO_2-C_6H_4, R=m-NO_2-C_6H_4 — compound show moderate antitubercular activity

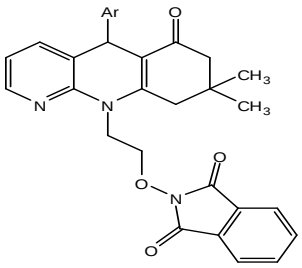
If R=p-OCH_3-C_6H_4, R=m-OCH_3-C_6H_4 — compound show least antitubercular activity

Table 2: Antitubercular activity of synthesized compounds (**11a-j)**

Compound	R	MIC (µg/ml)
11 a	C_6H_5	06.6
11 b	*p*- $CH_3C_6H_4$	07.3
11 c	*p*- ClC_6H_5	05.7
11 d	*p*- $OCH_3C_6H_4$	21.0
11 e	*p*- BrC_6H_4	05.3
11 f	*m*- $CH_3C_6H_4$	07.2
11 g	*m*- ClC_6H_4	05.2
11 h	*m*- $OCH_3C_6H_4$	23.0
11 i	*p*- $NO_2C_6H_4$	15.0
11 j	*m*- $NO_2C_6H_4$	18.0
Standard	Streptomycin	06.5

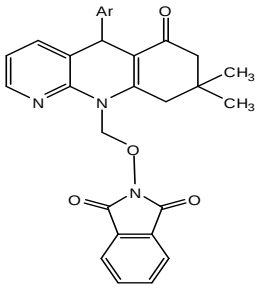
All compounds were tested at 5, 10, 15, 20, 25, 30 µg/mL concentrations by serial dilution.

Bhambhi *et al.,* (2009) reported that alkoxy derivative of phthalimide (compound **12** and **13**) possess potent fungicidal, trypanocidal, they inhibit the growth of *Plasmodium falciparum*. The synthesized compounds were tested for their biological activity against bacteria and fungi.



(12)

Ar = $4ClC_6H_4$

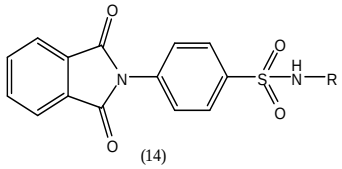


(13)

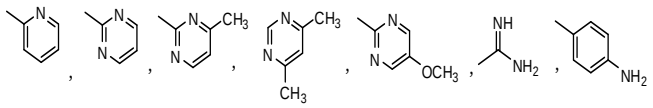
Ar = $4FC_6H_4$

Santos *et al.,* (2009) synthesized a series of phthalimide derivatives. All compounds were evaluated against Mycobacterium tuberculosis $H_{37}Rv$ using Alamar Blue susceptibility. They suggested that the lead compounds have the potency in the treatment of tuberculosis and multi-drug resistant tuberculosis.

It has been shown that hybridization of both phthalimide (Thalidomide) and sulfonamide (Dapsone) moiety leads to compounds with activity against *M. leprae*. In this sense, the design of new products such as anti-TB agents is interesting. SAR study of a series of derivatives (compound **14**) showed that if the pyrimidine ring is substituted in any position or changed by an isosteric, this decreases activity on *M. tuberculosis*. Amino group substitutions by another phthalimide ring also lead to a decrease in anti-TB activity. Modifications in the pyridine ring decrease anti-TB activity. Introduction of a phthalimide group by molecular hybridization did not produce compounds with an activity similar to INH.



(14)

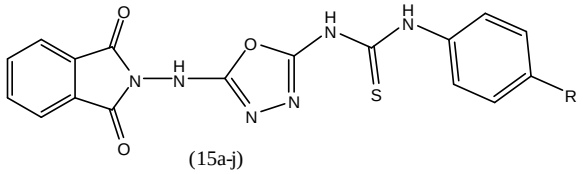
R = 

Anticonvulsant activity

Bhat *et al.,* (2010) synthesized and demonstrated a series of novel *1, 3, 4-oxadiazole derivatives* of phthalimide and evaluated their anticonvulsant and neurotoxicity studies. Compound having methoxy substitution at para position of the distal aryl ring emerged as most promising anticonvulsant agent with low neurotoxicity. The presence of methoxy group in ring B causes more lipophilic character of the molecule. Distal hydrophobic center alters the bioavailibility of compounds. It was established fact that there are at least four parameters for anticonvulsant drugs: lipophilic domain, distal aryl ring

(hydrophobic centre) whose size effects pharmacokinetic properties, (-CONH) acts as hydrogen donor, an electron donor (C=N) system is also present.

Phthalimide derivatives of 1, 3, 4-oxadiazole (compound **15a-j**) were screened for anticonvulsant activity. All the compounds were active in MES test, making them useful for broad spectrum of seizure type.



(15a-j)

1,3,4-Oxadiazole derivatives of phthalimide.

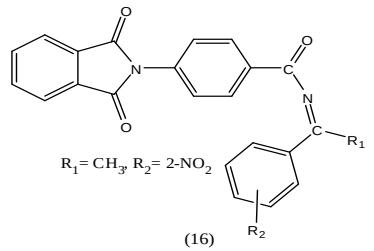
15a: R=H; **15b**: R=2-Cl; **15 c**: R=3-Cl; **15d**: R=4-Cl; **15 e**: R=2-CH3; **15 f**: R=3-CH3; **15 g**: R=4-CH3; **15h**:R=2-OCH3; **15i**: R=3-OCH3;**15j**: R=4-OCH3.

Table 3: Anticonvulsant and neurotoxicity results of the titled compounds (15a-j).

Compound	Intrperitoneal injection in Mice[a]			
	MES Screening		Toxicity Screening	
	0.5 h	4 h	0.5 h	4 h
15 a	300	300	300	300
15 b	300	300	300	300
15 c	300	300	300	100
15 d	300	300	300	300
15 e	300	300	300	300
15 f	300	300	300	-
15 g	100	300	100	300
15 h	100	300	300	300
15 i	100	300	300	-
15 j	30	300	300	-
Phenytoin[b]	30	30	100	100
Carbamazepine[b]	30	100	100	300
Phynobarbital[b]	100	30	100	300

[a] Doses of 30, 100 and 300 mg/kg were administered. The figure in the table indicates the minimum dose whereby bioactivity was demonstrated in half or more of the animals. The animals were examined 0.5 and 4 h after administration. The (-) indicates an absence of activity at maximum dose administered (300 mg/kg). [b]Data from references.

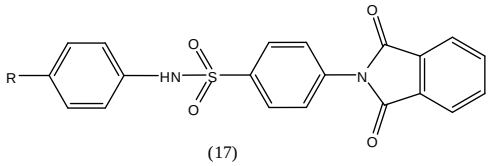
Bhat *et al.,* (2011) synthesized and investigated *Schiff bases* (compound **16**) with phthalimide pharmacophore and evaluated for anticonvulsant and neurotoxic properties. Anticonvulsant screening was performed using MES test. All the Schiff bases of phthalimides were active in the MES test indicative of their ability to prevent seizure spread. All the compounds were less neurotoxic than phenytoin. The evaluation of compounds indicated the importance of the size of the group at the carbimino carbon atom. Replacement of the hydrogen atom on the carbimino carbon atom by methyl group is leading to an increase in the size at this position of the molecule and has shown a change in activity. This modification may increase the anticonvulsant activity because of additional vander walls bonding or alternately steric impedance to alignment at the binding site causing lower activity or its loss. The attachment of distal aryl ring to the proximal aryl ring increases the vander Walls bonding at the binding site and increases potency. The distal aryl ring at carbimino terminal (benzylidene ring) is essential for the pharmacokinetic properties of compounds since the variation in the substitution at the distal aryl ring was found to affect biological activity. During metabolism, the distal aryl ring is expected to be p-hydroxylated. Introduction of nitro substitution showed more protection at as compared to methyl, chloro and hydroxy substitution at distal aryl ring. Compound with nitro substitution at ortho-position of distal aryl ring have emerged as the most promising anticonvulsant agent with low neurotoxicity.



(16)

Schiff Base of phthalimide

Arti *et al.,* (2011) synthesized and reported that substituted *4-Pthalamido-N-Phenyl-benzene sulphonamide* (compound **17a-e**) derivatives possessed anticonvulsant activity which was evaluated by MES (maximal electric shock-induced seizure) method. In substituted phthalimido sulphonamide series aniline derivative showed least anti-convulsant activity (i.e., R=H), but 4-nitro derivatives ($R=NO_2$) were found to be effective than chloro derivatives (R= Cl). Electron withdrawing nitro derivatives were found to be effective than electron donating aniline derivative which were found to be ineffective.

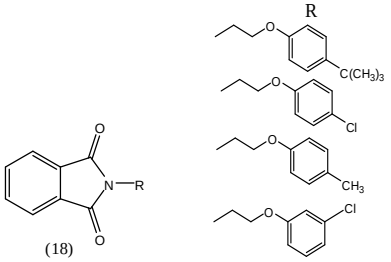


(17)

Substituted 4-Pthalamido-N-Phenylbenzenesulphonamide

17a: H **17b:** 4-NO2 **17c:** 4-Br **17d:** 4-Cl **17e:** 2-Cl

Wiecek *et al.,* (2009) synthesized two series of phthalimides one that possessed an *N-phenoxyalkyl* moiety sustituted at position 3 or 4 of the phenyl ring and a series of N-alkenyl or alkinyl phthalimides (compound **18**). They evaluated their anticonvulsant activity and estimated their lipophilicity *in silico* using computer programs. The anticonvulsant activity of phthalimides containing an unsaturated substituent at the phthalimide nitrogen was superior to that of the N-phenoxyalkyl phthalimides.

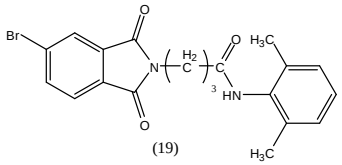


(18)

Phthalimide possessing N-phenoxyalkyl moiety substitute at position 3 or 4 of the phenyl ring

N-alkenyl or alkinyl phthalimides

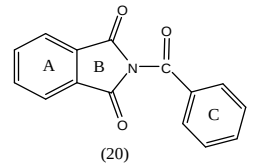
Khan *et al.,* (2009) synthesized and evaluated a series of *4-(5-bromo-1,3-dioxo -1,3-dihydro-2H-isoindol-2-yl)-butyryl N-(substituted phenyl) amides* (compound **19**) for their anticonvulsant activity in MES test according to the protocols of Antiepileptic Drug Development (ADD) programme of National Institutes of Health (NIH, Bethesda, USA). The studies revealed that the alkyl substitution at the aromatic ring was essential for activity being lipophilic in nature.



(19)

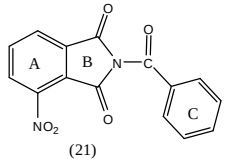
Anxiolytic activity

Hassanzadeh *et al.,* (2007) synthesized and evaluated *N-Benzoyl phthalimide* and *N-Benzylphthalimide* for their anxiolytic activity and demonstrated that N-Benzoyl Phthalimide possesses excellent anxiolytic activity. N-Benzoyl-3-nitrophthalimide (compound **21**) showed a lower activity compare to that of diazepam and *N*-benzoylphthalimide (compound **20**). An electron withdrawing group (Cl, NO_2) on C_7 of benzodiazepines is essential for sedative and anxiolytic activities of classic benzodiazepine agonists. Substitution of Cl or NO_2 on other positions of the aromatic ring (6, 8, and 9) of benzodiazepines dramatically reduce activity. Reduction in activity of N-benzoyl 3-nitro-phthalimide might be due to the improper accommodation of electron withdrawing group (NO_2) in the benzodiazepine active site. Substitution of an electron donating group (CH_3) on the C ring of the parent compound in N-(4'-methylbenzoyl)-phthalimide (compound **22**) and N-(4'-methylbenzoyl)-3-nitro-phthalimide (compound **23**) were also in favor for anxiolytic activity, this also has been seen in benzodiazepine series. Substitution at the 4'-(para)-position of the phenyl ring of benzodiazepines is unfavorable for agonist activity; however, 2'-(ortho)-substituents are not detrimental to agonist activity.



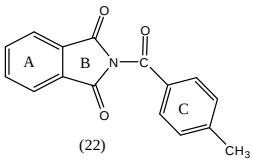
(20)

N-Benzoyl Phthalimide



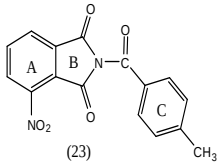
(21)

N-Benzoyl 3-Nitro-Phthalimide.



(22)

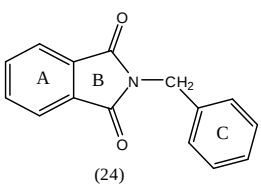
N-(4'-Methylbenzoyl)-phthalimide



(23)

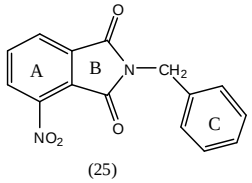
N-(4'-Methylbenzoyl)-3-Nitro-phthalimide

N-Benzyl 3-nitro-phthalimide (compound **25**) distorted from planarity due to the change of C=O group of N-benzoyl phthalimide to CH_2 group. This distortion probably prevents the accommodation of the compound with its receptor and makes the compound ineffective as an anxiolytic agent. In benzodiazepines, the phenyl ring is attached directly to the ring B and its relationship to the ring a planarity may be important for agonist activity.



(24)

N-Benzyl Phthalimide

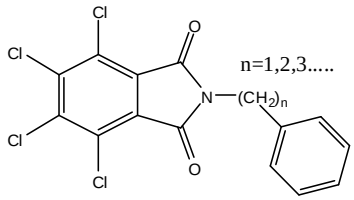


(25)

N-Benzyl 3-Nitro-Phthalimide

α-Glucosidase inhibitory activity

Ibrahim Ali *et al.,* (2009) demonstrated that *N-Phenyl-3, 4, 5, 6-tetrachlorophthalimide and N-(4-phenylbutyl)-3, 4, 5, 6-tetrachloro-phthalimide* (compound **26**) showed very potent α-Glucosidase inhibitory activity. Potency of tricyclic phthalimide derivatives could be achieved by increasing the overall lipophilicity of the molecules and by incorporating halogen substituents in the benzylic aromatic ring attached to the phthalimido nitrogen atom.

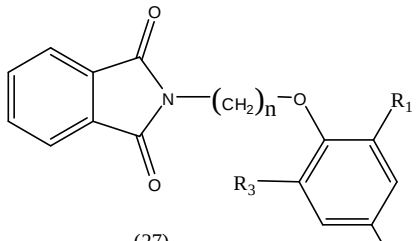


(26)

Pascale *et al.,* (2010) synthesized and investigated alpha glucosidase inhibitors, bearing a phthalimide moiety connected to a variously substituted phenoxy ring by an alkyl chain that inhibited alpha glucosidase which is the key enzyme which catalyzes the final step in the digestive process of carbohydrates in mammalians. Hence, alpha glucosidase inhibitors can retard the liberation of D-glucose of oligosaccharides and disaccharides from dietary complex carbohydrates and delay glucose absorption, resulting in reduced postprandial plasma glucose levels and suppressed postprandial hyperglycaemia.

In particular, basing on pharmacological studies involving thalidomide, it was found that *phenyl alkyl tetrachlorophthalimide derivatives* exhibited potent α-glucosidase inhibition. The structure activity relationship studies revealed the importance of the distance between the phthalimide ring and the phenyl moiety and the positive influence of electron withdrawing groups attached to the phthalimide moiety. Although tetrachlorophthalimide skeleton is a useful non-sugar type sugar mimic pharmacophore, the above mentioned compounds are characterized by high lipophilicity which could influence their pharmacokinetic properties and biological activity. A large series of *phenoxyalkyl derivatives* (compound **27**), bearing a non-

substituted phthalimide moiety, were prepared in order to investigate structure activity relationships and improve α-Glucosidase inhibitory activity. In particular, the effects of substitutions at the aryloxy moiety and the length of the methylene spacer between the phthalimide group and the phenoxy moiety were investigated.

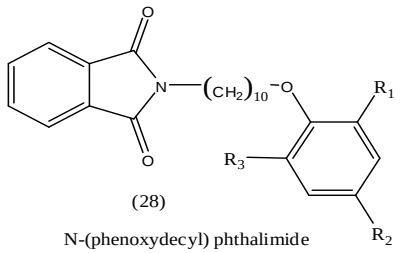


(27)

N-(phenoxyalkyl) phthalimide

The length of the methylene spacer seems to be critical for enzyme inhibition. The potency of the α-glucosidase inhibitory activity increased as the length of the methylene spacer increased to n = 10. Introduction of a chlorine atom at the para-position (R_2= Cl), caused the enhancement of the activity, which seemed to be further increased by the introduction of one or two additional methyl groups at the ortho-positions (R_1=R_2=CH_3).

In *N-(phenoxydecyl) phthalimide derivatives* (compound **28**), presence of an electron withdrawing group (NO_2, CF_3 etc.) at the 4-position (R_3) were more potent than the corresponding 4-methyl derivative. Introduction of a nitro group at the ortho position (R_1) of markedly enhanced the activity giving the most potent compound. However presence of two strong electron-withdrawing groups at the phenoxy ring simultaneously did not increase the activity.

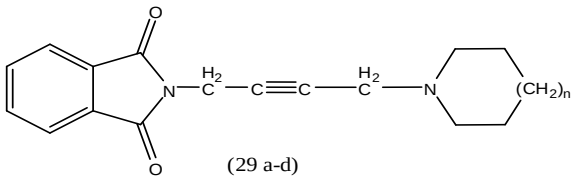


(28)

N-(phenoxydecyl) phthalimide

Anti inflammatory activity

Qaisi Jinan *et al.,* (2011) evaluated *amino acetylenic isoindoline derivative* (compound **29a-d**) for anti-inflammatory activity.



(29 a-d)

aminoacetylenic isoindoline derivatives

Table 4: Aminoacetylenic isoindoline derivatives.

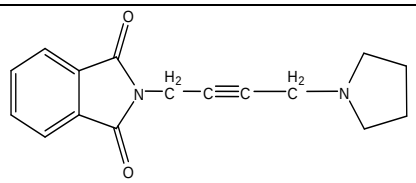
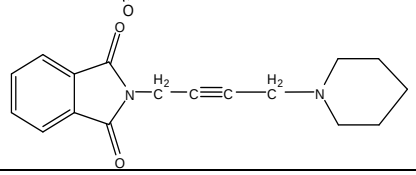
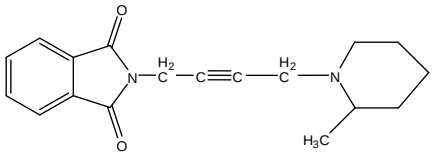
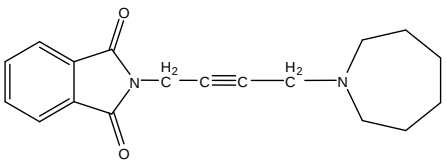
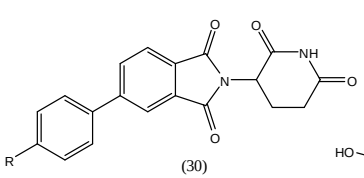
29a	Pyrrolidine	$C_{16}H_{16}N_2O_2$	
29b	Piperidine		
29c	2- methylpiperidine	$C_{18}H_{20}N_2O_2$	
29d	Hexamethyleneimine	$C_{16}H_{16}N_2O_2$	

Table 5: The percent inhibition of COX-1 activity by different concentration of **29 (a-d)** compounds using COX inhibition immunoassay (EIA) as compared with Diclofenac. Each value represents the mean ±SD.

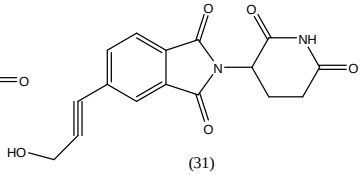
Compound	Concentration		
	2μM	**5μM**	**10μM**
29a	12.5±7.5	73.7±12.6	25.5±3.5
29b	28.1±1.0	72.5±20.5	29.0±1.0
29c	30.5±1.0	72.5±18.0	8.0±2.0
29d	20.5±0.5	74.5±14.3	20.5±0.5
Diclofenac	73.1±3.1	99.44±0.2	98.0±0.2

Stewart *et al.,* (2010) demonstrated that *thalidomide analogues* (compound **30, 31**) containing either a phenyl or alkyne using Sonogashira and Suzuki cross coupling reactions from their aryl halogenated precursors.

All the thalidomide analogues were evaluated for their ability to inhibit the expression of the proinflammatory cytokine Tumor Necrosis Factor (TNF). Orzeszko *et al.,* (2010) Compounds containing an aryl-isobutyl or arylisopropoxy groups were reported to be several times more active than thalidomide in inhibiting TNF expression and apoptotic response.

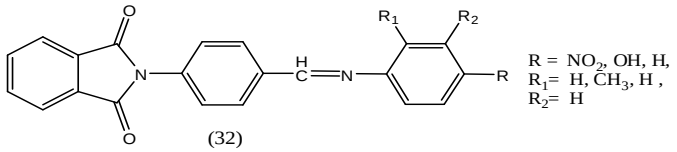


(30)



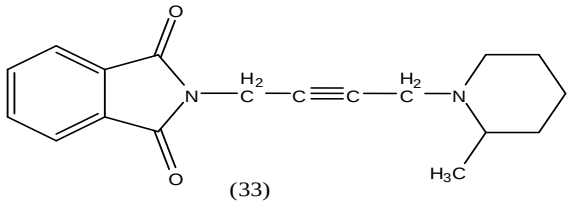
(31)

Sharma *et al.,* (2012) synthesized novel schiff bases of imide moiety (compound **32**) which exhibited anti-inflammatory and analgesic activity.



(32)

Shakir *et al.,* (2007) synthesized *aminoacetylenic isoindoline-1, 3-dione* (compound **33**) and showed their anti-inflammatory activities by reducing carrageenan-induced rat paw edema and modulating proinflammatory and anti-inflammatory cytokines.



(33)

2-(4-(2-methylpiperidin-1-yl)but-2-ynyl)isoindoline-1,3-dione

Table 6: Rats Heamatologiacal parameters following a 10-days administration of compound 33.

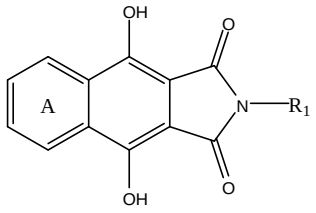
Parameter	Controle		33 Compound 50mg/kg	
	Males	Females	Males	Females
RBC (x10^6/µL)	5.5±0.2	5.4±0.3	6.2±0.1*	8.4±0.8*
HB (g/dL)	14.3±0.4	14.2±0.6	15.2±0.3	21.2±1.6**
PCV (%)	29.6±0.2	29.4±1.0	31.0±0.6	42.9±3.3*
WBC (x10^3/µL)	10.5±1.3	6.3±0.2	9.2±1.0	7.9±1.2
Neutrophil (%)	9.8±1.9	11.7±1.2	12.9±1.3	15.1±1.7
Lymphocytes (%)	78.0±3.2	74.2±1.8	72.3±2.7	70.1±3.2
Monocytes (%)	12.2±1.9	14.1±1.2	14.8±1.5	14.9±1.6
Platelets (x10^3/µL)	663±138	780±96	904±182	679±105

*p < 0.01; **p < 0.001

Anti viral activity

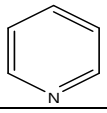
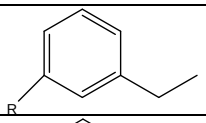
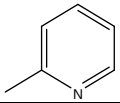
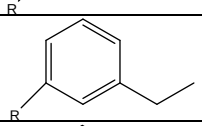
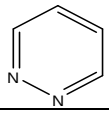
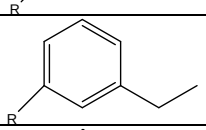
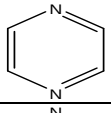
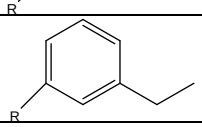
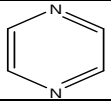
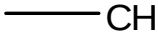
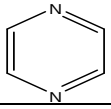
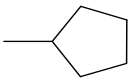
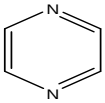
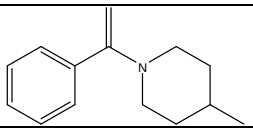
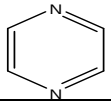
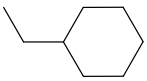
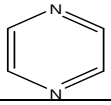
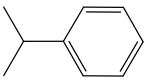
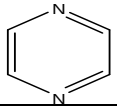
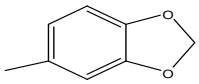
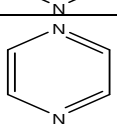
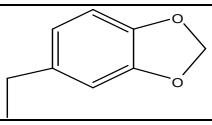
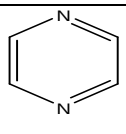
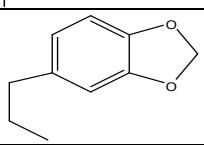
Anti HIV activity

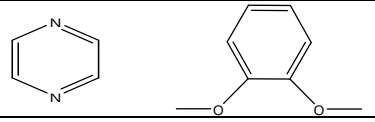
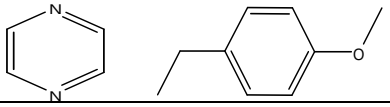
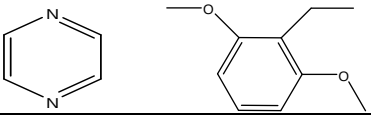
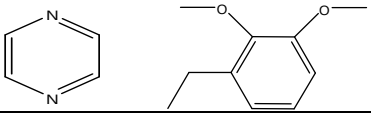
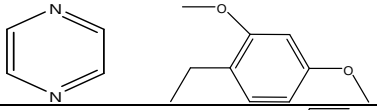
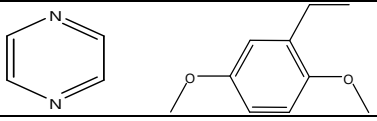
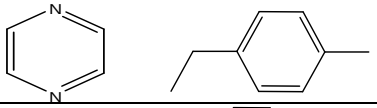
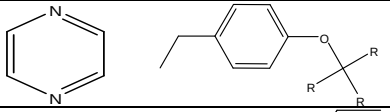
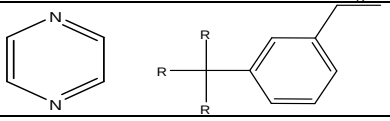
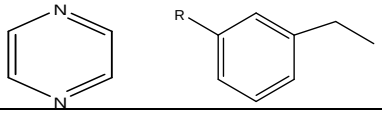
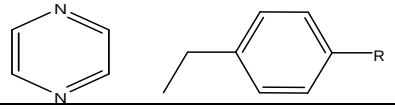
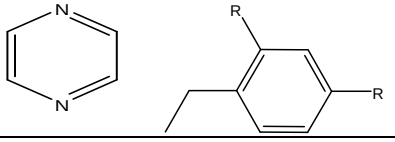
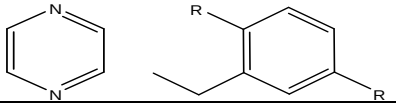
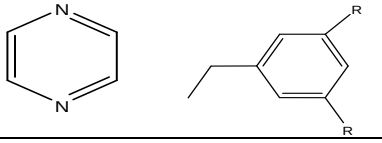
Bansal *et al.,* (2007) demonstrated that increased HIV-1 inhibitory potency of *tricyclic phthalimide derivatives* could be achieved by increasing the overall lipophilicity of the molecules and by incorporating halogen substituents in the benzylic aromatic ring attached to the phthalimido nitrogen atom. Molecular flexibility and hydrophobicity predominantly govern the integrase inhibitory activity of phthalimides. Molecular flexibility increases with the number of flexible bonds in the molecule and the importance associated with flexible bond might be owing to the fact that they play an important role in the orientation of pharmacophoric groups in the active site of the enzyme. Hydrophobic substituents in the molecule might influence enzyme-drug affinity through non-specific interactions with hydrophobic region in the active site of the enzyme. Furthermore, it appears that the halogen substitution in the phenyl ring plays a significant role molecule enzyme affinity, a fact reflected in increased integrase inhibitory potency exhibited by molecules with halogen substituents (compound **34 a-z**). Presence of bulky groups and electronegative atoms in the molecule disfavors the HIV-1 integrase inhibitory affinity of the title compounds.



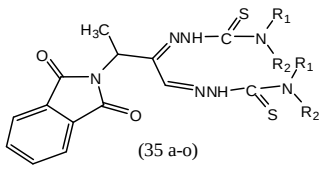
(34a-z)

Table 7: Sructural modification and HIV-1 integrase inhibition data of trycyclic pthalamide analogues 34 a-z.

Compound number	Ring A	R_1	Inhibition of HIV-1 int enzyme (pIC_{50})
34 a			6.42
34 b			6.59
34 c			5.44
34 d			6.68
34 e			4.31
34 f			4.98
34 g			5.62
34 h			5.66
34 i			5.98
34 j			5.00
34 k			6.25
34 l			5.85

34 m		6.09
34 n		6.25
34 o		5.70
34 p		6.37
34 q		6.37
34 r		6.11
34 s		5.80
34 t		5.69
34 u		6.37
34 v		6.25
34 w		6.389
34 x		6.36
34 y		6.45
34 z		6.43

Yang *et al.,* (2010) investigated series of *phthiobutazone analogues*, prepared from potassium phthalimide or phthalandione, have been evaluated for their antiviral activities. Among the candidates, compounds which contain the substituted 4-halogenated phenyl ring (compound **35 a-o**), show more potent antiviral activity against herpes simplex virus.



(35 a-o)

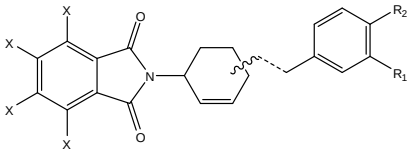
Table 8: Anti-HSV Activity (μ/ml) and Selectivity Index of Compounds **35 a-o** *in-vitro*

Compound	R_1	R_2	CC_{50} [a]	HSV-1		HSV-2	
				IC_{50} [b]	SI [c]	IC_{50}	SI
35 a	Me	Me	21.37	>4.11	-	NT [d]	-
35 b	H	i-Pr	74.07	>24.69	-	NT	-
35 c	H	Cyclohexyl	53.14	>12.34	-	NT	-
35 d	H	Allyl	77.04	>111.11	-	NT	-
35 e	H	Bn	21.38	>12.34	-	NT	-
35 f	H	4-Cl-Bn	21.38	12.34	-	NT	-
35 g	H	Ph	21.38	4.11	5.20	NT	-
35 h	H	2-F-Ph	37.03	5.30	6.90	NT	-
35 i	H	4-Br-Ph	111.11	21.37	5.20	2.85	7.50
35 j	H	4-F-Ph	64.15	8.56	7.49	1.75	36.80
35 k	H	4-Cl-Ph	77.04	2.85	27.03	4.11	18.70
35 l	H	3,4-Cl, Cl-Ph	333.33	25.68	13.00	>111.11	-
35 m	H	3,5-CF3,F3-Ph	53.41	12.34	-	NT	
35 n	H	4-Me-Ph	21.38	>12.34	-	NT	
35 o	H	4-MeO-Ph	21.38	12.34	1.73	NT	
TDA	H	H	384.90	95.44	4.03	74.07	5.19
ACV				1.00		8.98	

a) CC50: 50% cytotoxic concentration; b) IC: 50% Effective Concentration; c) SI (Selective Index) = CC_{50}/IC_{50}; d) NT: Not tested

Anti- influenza activity

Yuma *et al.,* (2010) identified potential and novel anti-influenza agents by screening the synthesized *phenethyl phenylphthalimide analogues* (compound **36**) on PA endonuclease inhibition assay and anti-influenza A virus assay. The four analogs were found to inhibit PA endonuclease and retard the growth of influenza A. The results also indicated that PA endonuclease assay may also be utilised in the screening of anti-influenza drugs and is useful for future strategies to develop novel anti-influenza A drugs and for mapping the function of the influenza A RNA polymerase subunits.

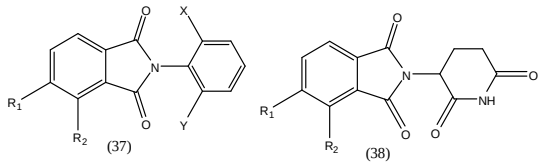


(36)

X= H, Cl
R1, R2 = H, OH

Anti-Angiogenesis Activity

Noguchi *et al.,* (2005) revealed that *5-Hydroxy-2-(2, 6-diisopropylphenyl)-1H-isoindole-1, 3-dione* (compound **37**), obtained from structural development studies on thalidomide, was found to possess potent anti-angiogenic activity in a human umbilical vein endothelial cell (HUVEC) assay. Thalidomide and its metabolite, 5-hydroxythalidomide (compound **38**) showed weak or moderate activity in the same assay.



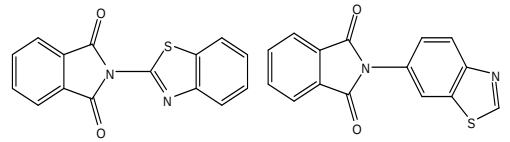
(37)

R_1= H, H,OH
R_2=H,H, H
X= H, CH_3

(38)

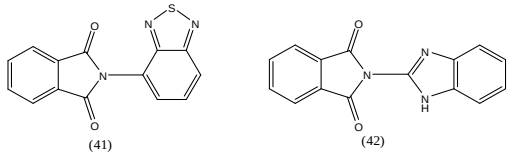
R_1= H, H,
R_2=NH_2, NO_2

Nagarajan *et al.,* (2013) synthesized *benzothiazole* and *benzimidazole* containing phthalimide derivatives (**39, 40, 41 & 42**) and their anti-angiogenic activity was evaluated using ex vivo egg yolk angiogenesis model.



(39)

(40)

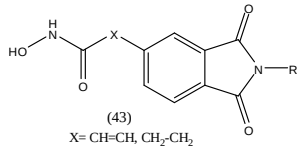


(41)

(42)

Histone deacetylase (HDAC) inhibitors

Chihiro *et al.,* (2007) designed and synthesized several *hydroxamic acid derivatives* with a substituted phthalimide group (compound **43**) as histone deacetylase (HDAC) inhibitors. Further, with SAR studies they concluded that the distance between the N-hydroxyl group and the cap structure are important for HDAC-inhibitory activity.

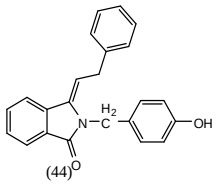


(43)

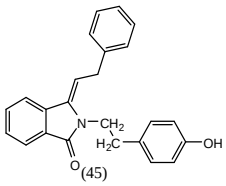
X= CH=CH, CH_2-CH_2

Thromboxane inhibitory activity

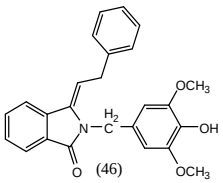
Yoshiaki *et al.,* (1999) synthesized a series of novel *1-isoindolinone derivatives*, which inhibited the contraction of pig coronary artery induced by U-46619, a thromboxane A2 analogue. The activities of p-hydroxybenzyl type and p-hydroxyphenyl-ethyl type compounds **44**, **45** and **46** were inhibitory activity.



(44)



(45)



(46)

CONCLUSION

Among the bicyclic non aromatic nitrogen Heterocycles phalimide are an interesting class of compounds with a large range of applications. Phthalimides have served as starting materials and intermediates for the synthesis of many types of alkaloids and pharmacophores. Recently, phthalimide and some of its derivatives have proved to have important biological effects similar or even higher than known pharmacological molecules and so their biological activity is being a subject of biomedical research. Phthalimides have received attention due to their antibacterial, antifungal, analgesic, antitumour, anxiolytic and anti HIV-1 activities. The present review highlighted exclusively an important class of heterocyclic phthalimide derivatives that can be used as promising and effective drugs for the treatment of different diseases such as AIDS, tumor, diabetes, multiple myeloma, convulsion, inflammation, pain, bacterial infection among others. Thus phthalimide framework plays an immense role in biologically active compounds and therefore represents an interesting template for medicinal chemistry. This paper further shed light on the SAR of the synthesized compounds. Taken together, the examples presented in this paper showed an impressive impact of structural variations and the SAR analysis revealed that the activity profile of these scaffolds relies upon the position and nature of substituents on the parent skeleton, rendering numerous compounds more active as compared to standard drugs. The established track record of significant efforts toward phthalimide scaffolds with impressive therapeutic profile would be the important step to a possible drug development for treatment of many diseases and these comprehensive endeavors will open up new opportunities for researchers to design invaluable therapeutic agents phthalimide scaffold.

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