PLANT EXTRACT MEDIATED C-H FUNCTIONALISATION

A project report submitted in partial fulfilment for the award of the degree of

MASTER OF SCIENCE (M.Sc.)

in

CHEMISTRY

Submitted by

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May 2023

DECLARATION

We, Yashaswy and Riyansha Verma, hereby declare that the work which is being submitted in this major project report entitled "**Plant Extract Mediated C-H Functionalisation**" in the partial fulfilment for the award of the degree of Master of Science at Delhi Technological University is an authentic record of our own work carried out by us under the supervision of Dr. Richa Srivastava (Assistant Professor, Department of Applied Chemistry, Delhi Technological University). We, further declare that the project report has not been submitted to any Institute/ University for the award of any degree or diploma or any other purpose whatsoever. Also, it has not been directly copied from any source without giving its proper reference.

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CERTIFICATE

This is to certify that the Project report entitled "**Plant Extract Mediated C-H Functionalisation**" which is submitted by Yashaswy (2K21/MSCCHE/51) and Riyansha Verma (2K21/MSCCHE/38), Department of Applied Chemistry, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Science, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

The need to protect natural resources and the environment has become increasingly important as illustrated by the definition of “12 Principles of Green Chemistry”. Functionalization and activation of C-H bonds is atom and step economic but sustainability of large number of applications is still hindered. In the first part of this report, we have highlighted the pursuit of abundant metal catalysts in C-H Bond activation. The synthesis of products which are natural by C-H bond functionalisation, catalysed by metals has been reported. Moreover, Plants are a valuable resource for the creation of novel pharmaceutical products, and their secondary metabolites are a rare supply of medicines, food additives, tastes, and other industrially useful substances. In recent times, plant-based catalysts have drawn a lot of interest in an effort to create a catalyst that is simple to make, inexpensive, non-corrosive, and ecologically benign. Ashes catalyst made from plant waste has gained widespread acceptability for C-H functionalization due to its simplicity in manufacture and availability, affordability, biogenic, and environmental friendliness. Hence, with an intention to develop a plant waste-based catalyst, we have taken the kiwi peel and carried out its phytochemical evaluation as well as biological studies. The study emphasises the value of waste management in the food business and the sustainable use of kiwi peels as a source of bioactive chemicals. The extracted product can further be used as a catalyst to carry out the C-H functionalisation.

CHAPTER 1

INTRODUCTION

The synthetic chemistry community has recently begun to pay more attention to the activation of ordinarily inert aromatic C-H bonds (1) by transition metal catalysis (1). Its benefit was that it removed the requirement for pre-functionalization and allowed direct and site-specific alteration of aromatic rings (2).

Figure 1 Recent developments Towards sustainable C-H Activation

Recent developments in this field have made it possible to directly and selectively modify aromatic rings without the use of pre-functionalization. Because of this, these methods have a wide range of applications, including the creation of extended -systems for use in material science. Recent studies of C-H activation processes used to create extended functional materials are covered in this study. Application to the production of C-C and C-heteroatom bonds offers new guidelines for the creation of novel pharmacological substances (3). Rh(III)-catalyzed, N-amino-directed C−H alkenylation generates either olefination products or indoles (in situ annulation) in an atom- and step-economic manner at room temperature (4). The palladium-catalyzed C-H activation and arylation of N-methylpyrrole and N-phenylpyrrole allowed a convenient synthesis of diarylpyrroles (5). Sulfonyl azides, which are easily accessible amidation reagents, are also employed in conjunction with C-H activation to

efficiently amidate aromatic oximes. A base metal catalyst system is used to catalyse this reaction (6). Gold catalyzed C-H activation leads to the formation of heterocyclic compounds, with high atom efficiency (7).

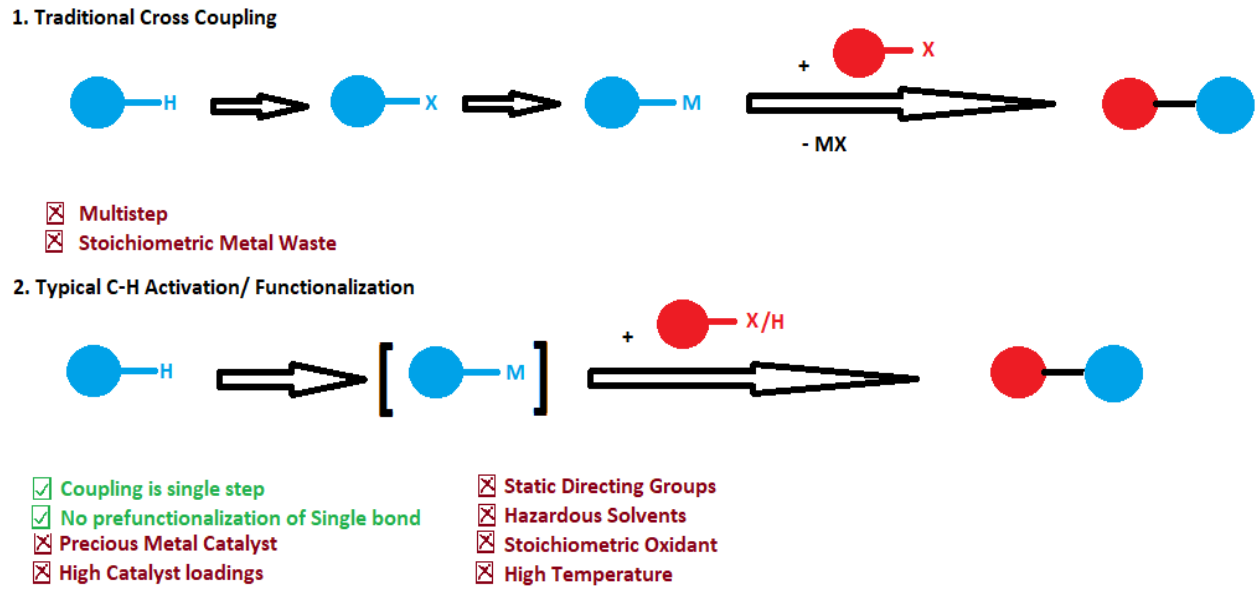


Figure 2 C-H Activation as an Intrinsic Opportunity

1. UTILIZING C-H ACTIVATION AS ESSENTIAL TOOLS

In addition to being an effective synthetic substitute for traditional cross-coupling reactions, C-H activation reactions have become potent instruments for the production of C-C bonds. C-H transformations are particularly useful for shortening multi-step synthesis since they do not require the installation of activated functional groups such as halogens or triflates (3). "C-H bonds have low reactivity (due to their high bond strength, ca 110 kcal/mol) and controlling regio-selectivity of C-H transformations has proven difficult since substrates usually display multiple C-H bonds with close dissociation energies. Also, chemo-selectivity in the presence of sensitive functional groups still presents a challenge" (3).

THE SYNTHESIS OF HETEROCYCLES USING A C-H ACTIVATION-BASED METHOD

In the article Zhou explains how C−H activation catalysed by transition metal has come out as an imperative synthetic tool for the building of heterocycles (8). “The key annulation step, which involves the participation of directing group (with reaction at either the linkage unit site” (9) or directing unit site (10)) and “CH Activation installed structure, can proceed only through the matching of reactivity. Depending on the reactivity profiles of annulation partners, two distinct synthetic manifolds can be envisioned, in situ annulation (either on-cycle” (11) or off-cycle (12), one-pot) and ex situ annulation (off-cycle, stepwise (13)). The in-situ approach offers a simple, step-by-step, cost-effective means to produce a target product, but under C-H Activation-compatible settings, its efficiency and convenience come at the expense of a restricted structural diversity. In actuality, the initial reactive sites are frequently all contained within a single kind of molecular framework. The ex-situ method utilises distinct processes for annulation, enabling the full utilisation of the potential of reactive sites and the creation of diverse frameworks (4).

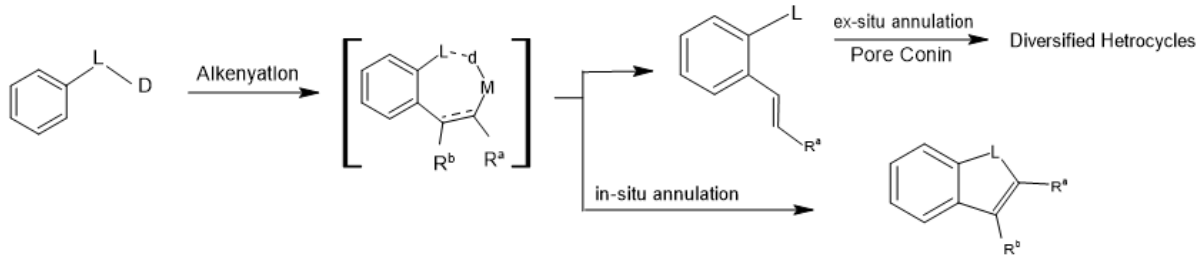


Figure 3 - CHA-Based, ex Situ, and in Situ Synthesis of Heterocycles where L (=Reactive Linkage Unit), D (=Directing Unit), M (=Transition Metal), Pore (=Polarity Relay), Conin (=Configuration Inversion)

C-H ACTIVATION CATALYZED BY METAL

Majorly 6 metal catalysts – Palladium, Manganese, Rhodium, Copper, Gold and Iron have been employed for the activation of C-H bond.

C-H ACTIVATION CATALYZED BY PALLADIUM METAL

Pyrrole synthesis in ionic liquids

Ionic liquids (ILs) have been popular in recent years as catalysts and stable, reusable reaction media in chemical synthesis. ILs are superior to conventional organic agents in that they have

low melting points, little to no vapour pressure, low adverse effects, high conductivities, exceptional chemical and thermal stability, are simple to recycle, and can quickly dissolve a wide range of inorganic as well as organic compounds. To date, Suzuki, Heck, Wittig, and Friedel–Crafts reactions, Michael additions, Diels–Alder cycloadditions, and stereoselective halogenations have all been successfully carried out using ILs (14).

Figure 4 - Metal Catalysts employed for C-H Activation

Cross-coupling processes like the Suzuki-Miyaura, Stille, or Negishi coupling reactions, which use palladium as a catalyst, are used to create arylated pyrroles. Pd-catalyzed C-H activations have emerged as an intriguing substitute for typical cross-coupling reactions in recent years. By using this technology, one may avoid the disadvantages of organometallic reagents, which include their high cost, toxicity, and susceptibility to air and moisture. On the other hand, activation of a comparatively inert CH bond often requires high temperatures and toxic solvents, such as DMF, dimethylamine (DMA), or N-methylpyrrolidone (NMP) (15). The catalyst typically targets just the site with the lowest electron density due to the polarisation of the molecule caused by the heteroatom. The majority of studies that have been published that focus on the direct arylation reactions of heterocycles deal to monoarylations (16). In contrast, multiple C-H activation is rare (17). Using KOAc or K_2CO_3 as the base and DMA as the solvent, Doucet reported the monoarylation of several functionalized pyrroles under phosphine-free conditions in 2009 (18).

Ehlers has described a catalytic mechanism for the diarylation of N-methyl- and N-phenyl-pyrrole. The reactions took place in "ligand-free" environments. Tetrabutylammonium acetate, an eco-friendly ionic liquid, worked best as the solvent to provide the highest yields. A variety of aryl bromides and electron-poor aryl chlorides were successfully employed in this reaction (5).

Suzuki-Miyaura couplings at room temperature

Suzuki-Miyaura couplings under very mild, room temperature conditions remain very rare (19). High temperatures (>120 °C) are used in aromatic C-H activations along with neutral palladium acetate as a catalyst in the majority of the extremely effective methods used to date. (20). The required bond constructions are frequently facilitated by the increased nucleophilicity of reaction partners and acidic circumstances (21). Carbonate or carboxylate anions are used to activate aromatic C-H bonds regardless of temperature. (22). Alternatively, electrophilic C-H activation (23) with cationic palladium at room temperature has been advanced (24).

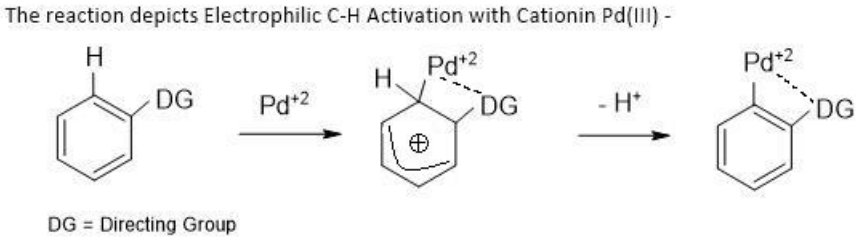


Figure 5 Electrophilic C-H Activation with Cationic Pd(III)

Suzuki Miyaura couplings with aryl ureas catalyzed by a preformed cationic palladium(II) complex, which provide aniline derivatives at room temperature in the absence of metal oxidants or added acid are reported (24). Various neutral palladium catalysts, including $Pd(OAc)_2$, $PdCl_2$, and $Pd_2(dba)_3$, were initially studied, but none were successful. However, the extent of product production was significantly increased when anilide and phenylboronic acid (3 equiv) were combined with $[Pd(MeCN)_4](BF_4)_2$ (10 mol%) and 1,4-benzoquinone (BQ, 5 equiv) (Table 1) (24).

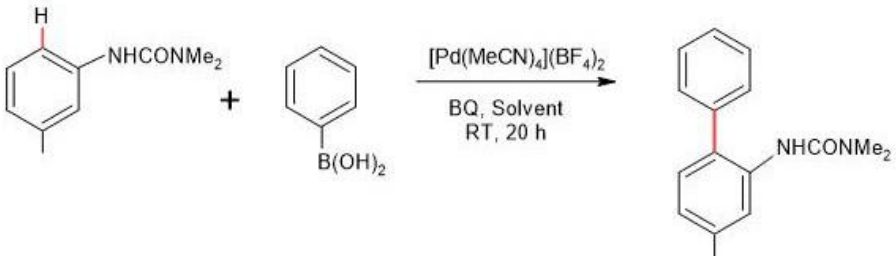


Figure 6 – Depicting the increase in production when Anilide and phenylboronic acid were combined with $[Pd(MeCN)_4](BF_4)_2$ and 1,4-benzoquinone

Table 1 – Effect of various solvents on % yield

Run	Solvent	Yield (%)
1	Hexane	50
2	THF	80
3	Acetone	38
4	EtOH	70
5	DMF	31
6	2% Surfactant/ Water	Trace
7	EtOAc	96
8	EtOAc	94

The dramatic effect of cationic Pd in Suzuki-Miyaura reactions has been uncovered, which enables facile aromatic C-H activation and subsequent cross-couplings at room temperature (24).

MN-CATALYZED OXIME DIRECTED C-H ACTIVATION IN IONIC LIQUIDS

Oximes can be produced easily from ketones and are sometimes referred to as marked ketones. The higher affinity of oxime for transition metal catalysts has led to increased interest in and use of oximes directed C-H functionalizations. (25). The most common catalysts are those based on late transition metals like Ru, Ir, and Rh (26).

Naturally abundant first row early transition metals such as manganese (27) are more sustainable catalyst systems (26).

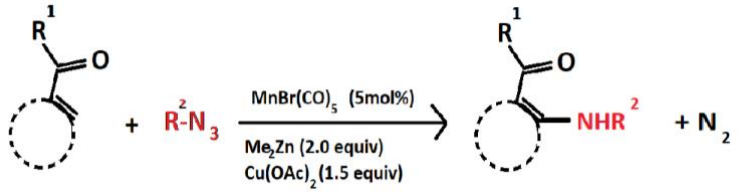


Figure 7 – Classical Reaction of Mn-Catalyzed C-H amidation of aromatic

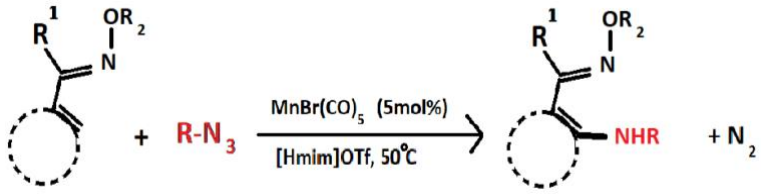


Figure 8 - Reaction of Mn-Catalyzed C-H amidation of aromatic ketones based on recent studies

Catalytic systems like $Cp^*RhCl_2]_2$ /$AgNTf_2$ /ionic liquid have been utilised successfully in C-H Activation and are recyclable solvent systems (26).

According to Xu and Bo, a straightforward mixture of common base catalysts, such as MnBr(CO)5, and an appropriate ionic liquid may have a greater reactivity and be reusable following a straightforward phase separation. They have reported a highly efficient and recyclable manganese /ionic liquid-catalyzed oxime directed C-H amidation protocol using the readily available organo azides as amidation reagents (26). Better product yields were obtained by raising the reaction temperature from 60°C to 70°C or 80°C. However, the chemical yields decreased when the reaction temperature was too high (90°C) (26). The yield of the product only minimally decreased when the loading of Mn catalyst was reduced from 5% to 2.5% (26).

Rh-CATALYZED C-H BOND CYANATION IN IONIC LIQUIDS

A family of significant compounds known as aryl nitriles is frequently found as an essential structural component in pharmaceuticals, agrochemicals, and natural goods. The Rosenmund-von Braun reaction or the Sandmeyer reaction, which require for stoichiometric quantities of CuCN, are the conventional methods for cyanation. To address the aforementioned issues, cross-coupling cyanations of aryl (pseudo)halides were devised, however such processes either call for preactivated arenes or result in halogen byproducts. For the production of aromatic

cyanides, transition-metal-catalyzed direct C-H bond cyanation chemical reactions have emerged as an alluring, effective, and user-friendly substitute, and a variety of environmentally benign cyanating agents have been successfully created for these procedures. Although C-H bond cyanations have previously made substantial progress, their practical application is limited by difficult reaction conditions (heating > 100 °C) and the usage of nonrecyclable reaction systems. Hence, a mild, efficient, and recyclable strategy is still highly desired to facilitate cyanations in organic synthesis (14). Using a mild, effective, and recyclable Cp*Rh(III)/IL system, Songyang et al. have described a direct C-H bond cyanation method (14) as been depicted in the following reaction –

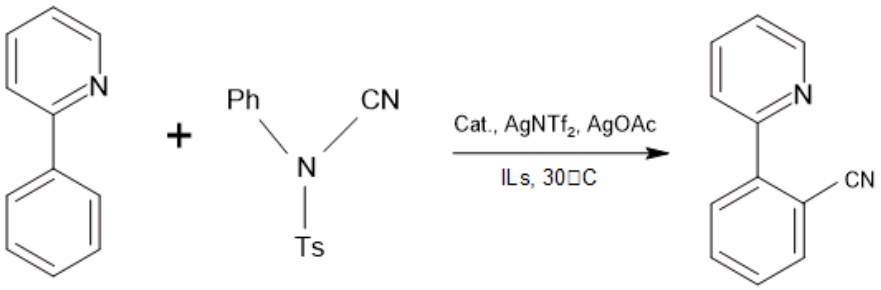


Figure 9 - Direct C-H bond cyanation method

Then, several anions and cations mixtures for the ionic liquids were investigated. Notably, only ILs containing the cation imidazolium were efficacious, with [BMIM]NTf_2 providing the greatest outcome (all at 24h). The yield rose when the reaction time was prolonged to 48 hours, but the reaction outcome was unaffected when the reaction time was increased to 72 hours. In addition, increasing the amount of NCTS and silver salt improved the yield to 78% (14).

Using a mild, effective, and recyclable Cp*Rh(III)/IL system, Songyang et al. have described a direct C-H bond cyanation method (14). According to research, (28) (29) (30) (31) the following was suggested as a potential mechanism for the C-H cyanation:

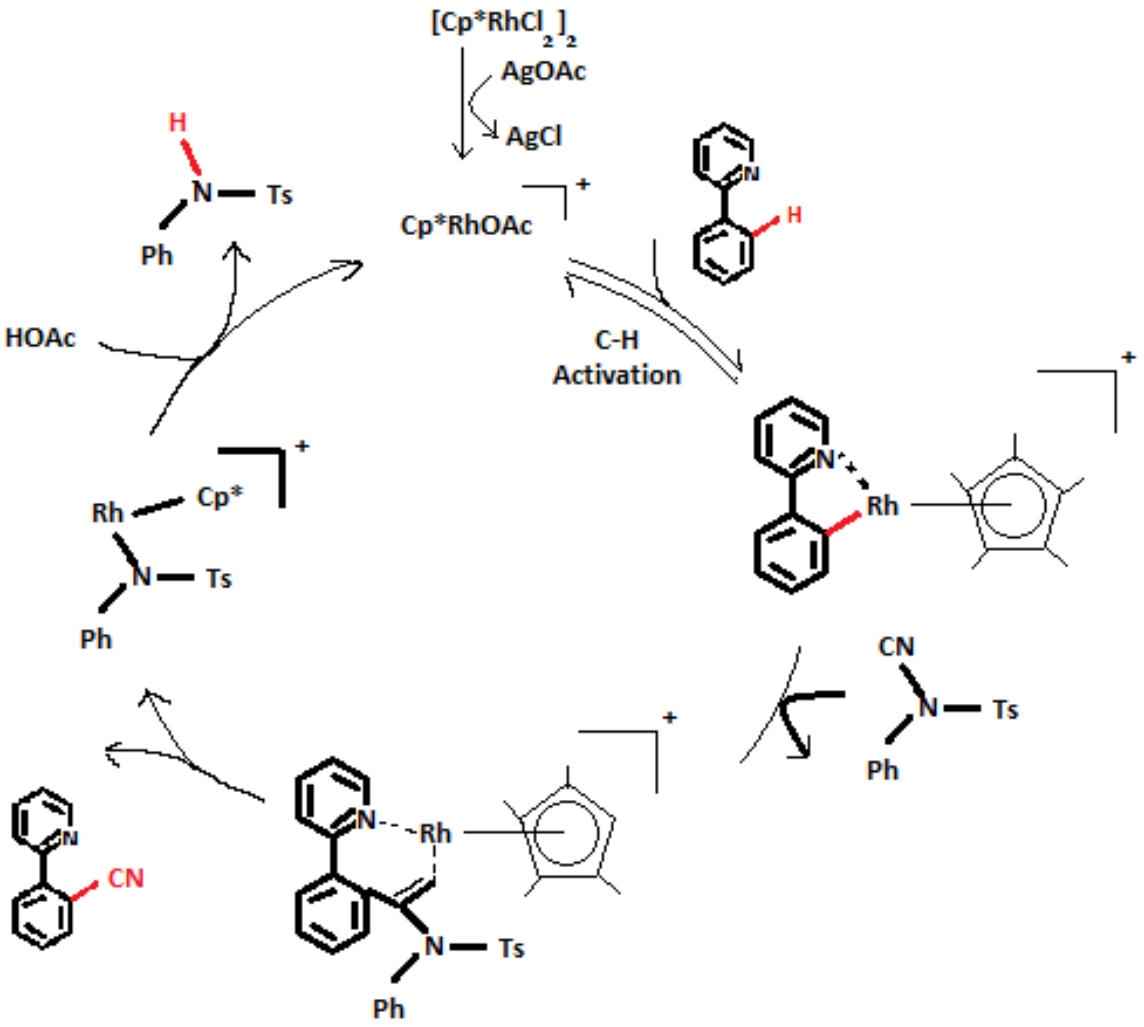


Figure 10 – Potential mechanism for C-H Cyanation

First, treatment of the Rh precursor with AgOAc generates reactive cationic Rh species. When this is combined with 2-phenylpyridine, cyclic Rh species with an open coordination site are produced. It subsequently interacts to generate the crucial intermediate in this process, tight transition states. The product and rhodium complex are then produced as a result of transition states. Finally, in the presence of protons, active Rh species is obtained and participates in the next catalytic cycle (14). A potent synthetic method for obtaining complex structures from simple precursors is the transition metal-catalyzed multi-component reaction. Activation of a terminal alkyne C–H bond by transition metal catalysts (32) is a reaction of fundamental interest in organic synthesis (33).

Cyclization of Indoles and Pyrroles: Synthesis of heterocycles

These polycyclic heterocycles, which (Indoles and pyrroles) are either difficult to synthesise or have a limited range of substrates. Therefore, the development of new approaches that allow rapid establishment of these scaffolds in simple operation from readily available precursors remains challenge and importance (34).

Indoles and pyrroles can be easily converted into their N-carboxamide derivatives as an oxidative bidentate directing group, which can then be coupled to various alkynes, alkenes, and diazo compounds to produce interesting heterocycles. This Rh(III)-catalyzed C-H activation of indoles and pyrroles at the 2-position (34).

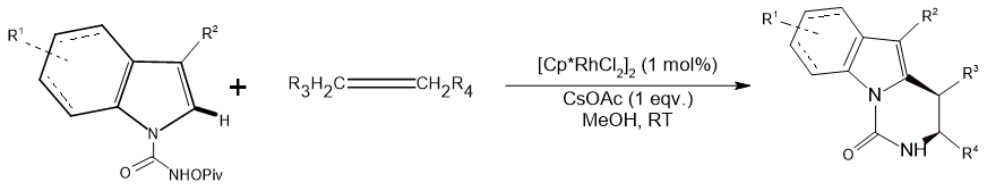


Figure 11 - Reaction showing the Rh(III)-catalyzed synthesis of 3,4-Dihydropyrimido[1,6-a]indol-1(2H)-one

Divergent synthesis of heterocycles was accomplished by coupling indoles and pyrroles with various alkynes, alkenes, and diazo compounds utilising Rh(III)-catalyzed C-H activation/cyclization. This approach has the advantages of readily available starting materials, a benign reaction environment, a wide range of substrates, and the absence of exogenous oxidants (34).

DEVELOPMENTS IN NATURAL PRODUCT SYNTHESIS USING C-H BOND ACTIVATION

The C–H bond is fairly unreactive because it is strong and of low polarity. Although it is known that stoichiometric concentrations of transition metals may activate C-H bonds, this process has never proven profitable. Since the use of catalytic quantities of metals has been realised only recently, it has resulted in a rapid expansion of the field (35).

The direct formation of a C–O or C–N bond at a traditionally unreactive site of an intermediate or natural product can enable powerful alternative disconnection strategies that facilitate complex molecule synthesis (36).

Metal-catalysed addition: Inserting nitrene or carbene into C–H bonds -

Corey's synthesis of the penicillin core structure is the first reported examples of the use of carbene or nitrenes for C–H functionalisation. Early examples required intramolecular carbene insertion to obtain selective reaction but greater control of reactivity has been achieved through the use of metal-nitrenoid (37) or carbenoid species, which have significantly improved the efficacy of this type of process (36).

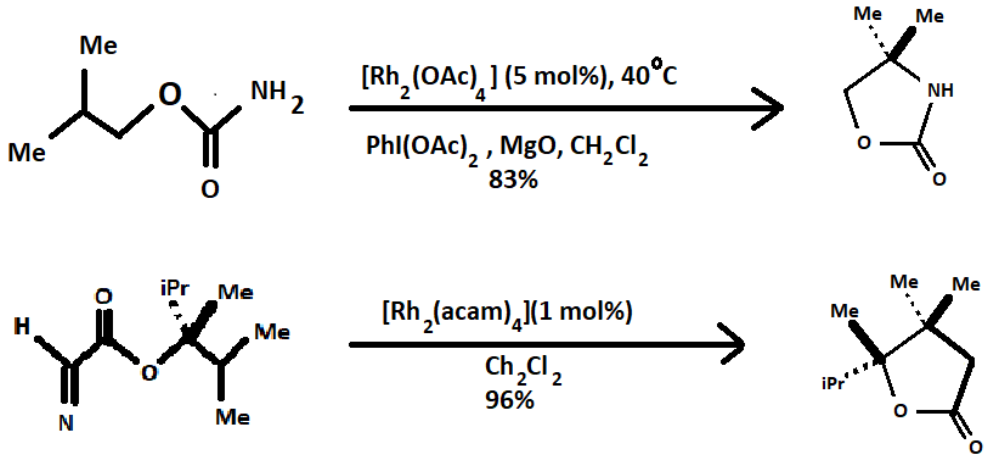


Figure 12 shows examples of Rh-catalyzed carbenoid and nitrnoid C-H insertions

C–H oxidation by metalloporphyrin systems -

Finding substitutes for the cytochrome P450-haem system to speed up C-H oxidation processes has been the focus of a lot of study. To generate reactive radicals that functionalised a remote C–H bond Grieco, based on Breslow's functionalisation concept, developed an oxidation strategy using metalloporphyrins tethered to steroids (38). The use of biomimetic C–H bond oxidation on steroids was further developed by Groves and Breslow who investigated the possibility of selectively binding a substrate in proximity to a metalloporphyrin as a means to get selective and predictable C–H oxidation under catalytic conditions using a cyclodextrin derived system or vesicle bilayer (39) based binding pocket.

These chosen examples show how these tactics might lead to synthesis and offer fresh solutions for complex architectures. There have been a variety of difficulties, which include:

a. the creation of more novel reactions to increase the existing C-H toolset;
b. to identify reactions that are effective in moderate reaction environments,
c. issues with using C-H activation in complicated systems, and
d. to concentrate on the creation of catalytic, enantioselective C-H activation methods (36)

The future of metal-catalysed C–H activation possesses many exciting challenges and new developments will continue to push forward the frontiers of chemical synthesis.

C-H ACTIVATED OLEFINATION OF ARENES IN IONIC LIQUIDS

The aromatic olefins are regarded as a significant chemical intermediate since they are frequently used in the production of pharmaceutical intermediates, natural compounds, and functional materials. The olefination of unreactive aryl C–H bonds catalyzed by transition metals is among the most significant chemical transformations in organic synthesis (40) as it has drawn a considerable attention for a single reaction step and a few side reactions compared with conventional methods (2). Since the catalysts such as ruthenium, rhodium, palladium, cobalt, and iridium generally show high reactivity and broad substrate scope with high temperature and organic solvents, they are known for their achievements in the olefination of arene via the C–H activation (41).

In most reactions, a solvent is typically needed in significant quantities, and it is essential to an organic synthesis. The C-H olefination frequently uses numerous organic solvents that are hazardous to the environment and volatile (42). Water and polyethylene glycol are extensively studied and successfully applied in some chemical transformations (42). However, the limited solubility of starting chemicals and metal catalysts severely limits their uses. With this in mind, it is better to discover a fantastic medium that enables the C-H olefination to proceed without difficulty under favourable circumstances and reusing the metal catalyst. The method for the very first catalyst-controlled selective mono- and di-olefination of arenes uses C-H activation at room temperature and includes the following crucial elements:

(a) It was possible to selectively mono- and di-olefinate arenes for the very first time at room temperature, which saved energy in industrial production without the use of heating apparatus.

(b) Mono- and di-olefination are significantly regulated by the catalysts. High selectivity $[Cp^*RhCl_2]_2$ provided the diolefination products, while $[Ru(p\text{-cymene})Cl_2]_2$ provided monoolefination products.

(c) The noble metal catalytic system was able to be recycled at least six times thanks to the better solvents $[BMIM]NTf_2$ and $[BMIM]PF_6$, which were used in place of an organic solvent. This was cost-effective and ecologically benign from an industrial perspective, and the process was more safer without the requirement for pressure-tight machinery.

(d) The reaction tolerated a broad substrate with appreciable yields and excellent selectivity (41).

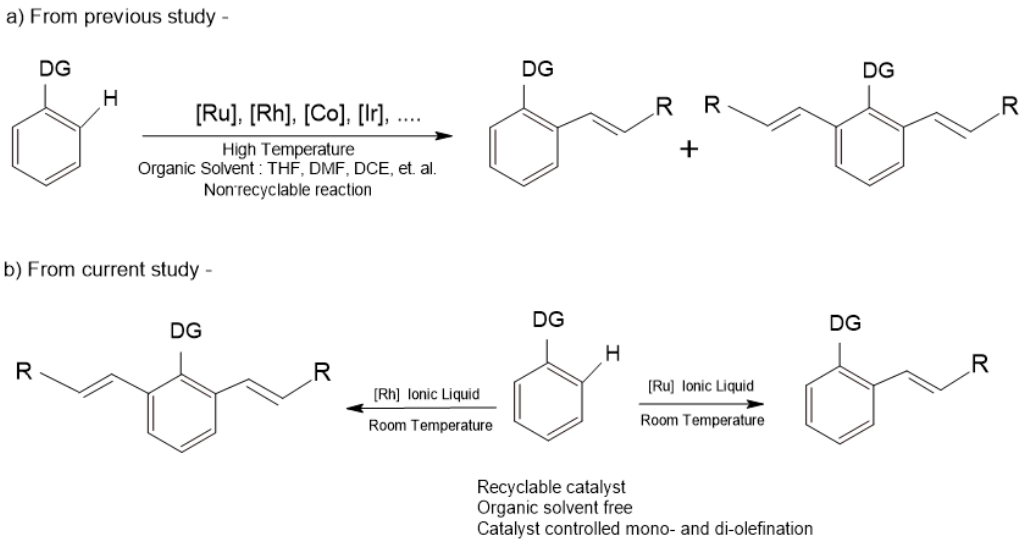


Figure 13 C-H activation olefination of Arene

C−H ACTIVATION OF METHANOL AND ETHANOL AND C-C COUPLING INTO DIOLS BY ZINC-INDIUM-SULFIDE UNDER VISIBLE LIGHT

To produce multi-carbon alcohol or polyalcohol, the selective activation of the inert sp^3 α-C−H bond within an alcohol and direct formation of C−C bond with the coupling partners is a promising way (43). “Among various reactions in this field, the direct coupling of methanol to ethylene glycol (denoted as MTEG) is known as a “dream catalytic reaction”” (44).

$$2CH_3OH \rightarrow HOCH_2CH_2OH + H_2$$

In current industrial process, Ethylene Glycol (EG) is primarily produced from petroleum-derived ethylene via epoxidation and subsequent hydrolysis of ethylene epoxide, which suffers from high price of ethylene, low yield of EG, and high energy consumption (45). In contrast, the MTEG utilizes methanol, which can be produced on a large scale from a wide range of carbon resources, such as natural gas, coal, biomass, and CO_2 (46). The direct coupling of methanol to EG and H_2 is also an economic process with high atom utilization (44).

Yanagida and co-workers have reported that EG could be formed on ZnS (bandgap energy 3.6 eV) under ultraviolet (UV) irradiation, yet with low activity (44).

Metal sulfide is a class of photocatalyst with good visible light response and hydrogen evolution activity, especially ternary metal sulfides, which have shown richer variability in properties and higher activity than binary metal sulfides (47). Therefore, it is possible to develop an environmentally friendly ternary metal sulfide catalyst for efficient photocatalytic conversion of methanol to EG and H_2 under visible-light irradiation (44).

It was discovered that the few-layer $Zn_2In_2S_5$ nanosheets function as a safe visible-light photocatalyst for methanol-to-EG coupling. Significantly more EG is formed when $Zn_2In_2S_5$ nanosheets are modified with CoP nanosheets. It is done by the activation of C−H bond within methanol to form $\bullet CH_2OH$ radical without affecting the O−H group for subsequent coupling to EG, and the α-C−H bond within ethanol was selectively activated to form $\bullet CH(OH)CH_3$ radical for subsequent coupling to 2,3-Butanediol (44).

2. RECENT PROGRESS IN RU(II)-CATALYZED C-H ACTIVATIONS

In the presence of $Ru_3(CO)_{12}$ as a precatalyst,-unsaturated imines, carbon monoxide, and ethylene were reacted with ionic liquids to produce combinations of chiral 2,3-dihydropyrrolones with 2,3-disubstituted pyrroles. The reaction works under milder conditions with regard to reaction time and partial pressures of the gaseous substrates than when performed in classical organic solvents (48).

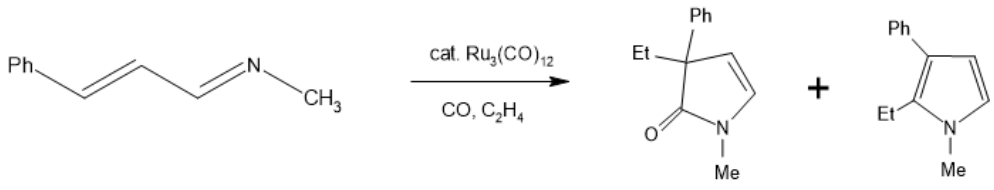


Figure 14 – Reaction showing a,b-unsaturated imines, carbon monoxide, and ethylene (or terminal alkenes in general) to produce chiral 2,3-dihydropyrrolones as the main product in non-polar solvents. As a side-product 2,3-disubstituted pyrroles are formed

Transition metal-catalyzed C-H activation has become one of the most widely pursued topics in organic chemistry during the past decades (49). As a cost-effective replacement for the conventional techniques that need activating groups for the functionalization of arenes, this provides a direct avenue for the creation of C-C or C-X bonds. Thus, various novel processes were developed in recent years under the catalysis of different transition metals (50). Ru(II) catalysis has been found wide applications in annulation and olefination reactions in the last few years as it has high performance at low cost, and because of its combination with the internal oxidant strategy (50).

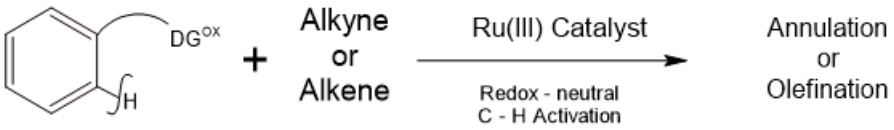


Figure 15 - The recent development in Ru(II)-catalyzed C-H activations under redox neutral conditions

There has been a lot of interest in the use of $[Ru(p\text{-}cymene)Cl_2]_2$ as a cheap and efficient pre-catalyst for C-H activations, and significant progress was made by reactions that took place in an environment free of external oxidants. New reactions from C-H activations of N-substituted benzamides and oximes were the most studied for remarkable annulations with alkynes and olefinations with alkenes, with the N-O bond in the directing group as the internal oxidant (50).

3. C−H ACTIVATION: TOWARDS SUSTAINABILITY AND APPLICATIONS

As compared to the cross-coupling reactions, C−H activation removes the requirement for pre-functionalization of both partners; as such, C−H activation has long promised a means to decrease step-count and hence mass intensity of chemical processes (51). As a result, there is requirement of precious metal catalysts in high loadings, stoichiometric metal-based oxidants, high temperatures, and directing group manipulations (52). There is vast area open for further research in Porphyrin/ Phthalocyanine – mediated Amination and Amidation using manganese, cobalt and iron as catalysts.

The study of natural product extraction is essential due to its significant impact on various fields. This importance is demonstrated in a recent paper titled "Plant Extract Mediated Eco-Friendly Synthesis of Pd@Graphene Nanocatalyst: An Efficient and Reusable Catalyst for the Suzuki-Miyaura Coupling." In this research, it was discovered that the natural plant extract derived from Pulicaria glutinosa played a crucial role in facilitating the eco-friendly synthesis of the Pd@Graphene nanocatalyst. This Pd@Graphene Nanocatalyst is used as a catalyst in Suzuki-Miyaura coupling reaction which is the most versatile methods for the preparation of biaryls. The Suzuki-Miyaura coupling reaction is a highly influential method for creating carbon-carbon (C-C) bonds. It entails the cross-coupling of an organic (pseudo) halide and an organoboron molecule, which is catalysed by a transition metal. Due to the moderate reaction conditions, tolerance of a variety of functional groups, good stability, and accessibility of organoboron reagents, this reaction has become quite common. It serves as a powerful tool in organic synthesis, facilitating the construction of complex molecular structures by efficiently connecting different carbon atoms.

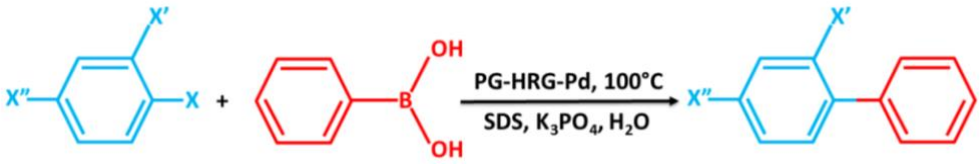


Figure 16 A typical example of Suzuki-Miyaura coupling reaction

Nanocatalysts have emerged as the preferred choice in the Suzuki-Miyaura cross-coupling reaction, despite the exploration of various transitional-metal-based catalysts. These nanocatalysts possess a unique advantage due to their nano-sized nature, which results in a significantly increased surface area. This increased surface area allows for enhanced contact between the substrate and the catalyst, leading to improved reaction efficiency. Additionally, the insolubility of Pd nanoparticles in the reaction solvents facilitates effortless separation of the catalyst from the reaction mixture. These factors contribute to the growing interest in Pd nanoparticle-based heterogeneous nanocatalysts, offering promising prospects for the advancement of catalytic processes in the Suzuki-Miyaura cross-coupling and related reactions. Researchers can further optimize the efficiency and cost-effectiveness of Pd-based nanocatalysts, opening doors for advancements in various catalytic processes.

The conventional methods of using the catalysts involve the use of potentially hazardous and toxic reagents, solvents, and stabilizers, making them difficult to carry out in all laboratories and challenging to scale up. These drawbacks pose environmental concerns as well. In response, the field of nanocatalysis has turned to the principles of green chemistry, aiming to eliminate or reduce harmful chemicals and processes that harm the environment. We have investigated the use of green reductants in nanotechnology, including microorganisms (PEs), amino acids and plant extracts to solve these problems. These environmentally friendly alternatives to chemical reductants not only enhance the energy efficiency and environmental friendliness of the process but also offer economic benefits for large-scale industrial applications. By incorporating the concepts of green chemistry and utilizing these green reductants, we can pave the way for more sustainable and eco-friendly techniques in C-H functionalisation.

80% of the world's population uses medicinal herbs for their fundamental health requirements. The revitalised systems of traditional medicine, including Siddha, Ayurveda, and Unani, originated in India. A single plant or mixtures of many plants are used to produce traditional systems of medicine. This efficacy depends upon the current knowledge about taxonomic features of plant species, plant parts and biological property of medicinal plants which in turn depends upon the occurrence of primary and secondary metabolites (53)**.**

METABOLITES

The intermediaries and end products of metabolism are known as metabolites. Small molecules often fall under the definition of a metabolite. Metabolites have various functions, including fuel, structure, signalling, stimulatory and inhibitory effects on enzymes, catalytic activity of their own (usually as a cofactor to an enzyme), defence, and interactions with other organisms (54).

Plant synthesizes a wide range of chemical compounds which are classified based on their chemical class, biosynthetic origin and functional groups into primary and secondary metabolites (53) -

1. **“Primary metabolites** are directly involved in growth and development. They are widely distributed in nature, occurring in one form or another in virtually all organisms. They are like chlorophyll, amino acids, nucleotides, carbohydrates etc., which have a

key role in metabolic processes such as photosynthesis, respiration and nutrient assimilation. They are used as industrial raw materials and food additives" (53).

2. **Secondary metabolites** have been used as biocatalysts even if they are not directly engaged. They are created by plants' secondary metabolism. These metabolites are those that are frequently produced in a phase that follows growth, that serve no purpose in growth (although they may serve a purpose in survival), that are produced by specific restricted taxonomic groups of microorganisms, that have unusual chemical structures, and that are frequently formed as combinations of closely related components of a chemical family. In contrast to primary metabolites, the absence of secondary metabolites does not cause instantaneous death; instead, it affects an organism's capacity to survive, reproduce, or look good over the long term, or it may have no effect at all. They are also crucial for protecting plants against herbivory as well as other interspecies defences. Humans use secondary metabolites as medicines, flavourings, and recreational drugs in the recent past (54).

Classification of Secondary Metabolites -

Secondary metabolites can be classified on the basis of (54) –

a. chemical structure (for example, having rings, containing a sugar),
b. composition (containing nitrogen or not),
c. their solubility in various solvents, or
d. the biosynthetic pathway by which they are synthesized (e.g., phenylpropanoid, which produces tannins)

Three large molecule families are generally considered:

i. **Phenolics**

   Phenolics interfere with digestion, slow growth, block enzyme activity and cell division, or just taste awful

ii. **Terpenes and Steroids**

iii. One of the most common and chemically varied families of natural compounds is terpenes. Terpenes are a special class of naturally occurring compounds with hydrocarbon bases, and their structures may be related to isoprene. The number of 5-carbon units determines the terpenes' classification. The ecological and physiological roles of terpenes in plants are usually thought to include allelopathy, insecticidal, insect pollinator, and plant hormone (abscisic acid, gibberellin).

iv. Alkaloids, Flavonoids

The flavonoids make up a sizable class of phenolic natural compounds, with more than 4500 distinct examples now recognised. Flavonoids, which may exist as monomers, dimers, and higher oligomers, are found in the majority of plant tissues, frequently in vacuoles. Flavonoids are a broad group of chemicals that serve a variety of purposes. Additionally, some flavonoids can shield plants from UV-B exposure. The many classes of plant metabolites known as flavonoids, such as chalcones, aurones, flavones, flavanols, flavanones, iso-flavonoids, leucoanthocyanidins, catechins, and anthocyanins, are included in the plant kingdom.

4. CHEMICAL COMPOSITION OF KIWI PEELS: EXPLORING THE NUTRITIONAL AND BIOACTIVE POTENTIAL

Over 4 different varieties of the kiwi, which is cultivated all over the world and is valued for its distinctive flavour and bright green flesh, are known to exist. More than 90 countries are involved in its cultivation, and among them, China is the largest producer of kiwis. Kiwi production has steadily increased over the past few years, reaching over 2,390,287 tonnes in China alone. More than 1300 metric tonnes kiwi production comes from India. Furthermore, the peel, kernel, and seeds of kiwis, which are by-products of their processing, account for between 35 and 60 percent of their total weight. The extraction of bio-based chemicals and materials has a significant potential as a result of this abundance of by-products.

The genus Actinidia includes the kiwi fruit (Actinidia deliciosa). Because of its high ascorbic acid content and potent antioxidant chemicals such carotenoids, phenolics, lutein, flavonoids, and isoflavonoids, which are thought to be a primary type of phytoestrogen, it is a well-known and very nutritious sweet treat. It performs a crucial function as a source of galactose, chlorophyll, and anti-carcinogenic. Kiwi fruit is effective not just for the convenience of consumption, but also for the intake of health-functional substances within the skin (55). Kiwi is the natural source of –

- Anti-inflammatory
- Antioxidant
- antiaging and
- anti-tumoral agents

The *Actinidia deliciosa*, or kiwi fruit, is well known for its bright green flesh and sweet-tart flavour. While the flesh is frequently consumed, the peel is frequently overlooked and wasted. However, recent studies have shown that kiwi peels have a significant nutritional and bioactive composition, making them a great source of organic chemicals (55) .

Carbohydrates:

Dietary fibre is present in kiwi peels in substantial amounts, mostly as insoluble fibres including cellulose, hemicellulose, and lignin. These fibres aid with better digestion, blood sugar control, and the preservation of normal cholesterol levels. Soluble fibres, like pectin, contribute to improved gastrointestinal health and satiety (55).

Proteins:

Kiwi peels contain a sizable amount of both necessary and non-essential amino acids, despite the fact that they are not regarded as a high protein source. These amino acids are essential for many physiological processes, including as hormone generation, tissue healing, and enzyme synthesis (55) .

Lipids:

Due to their low lipid content, kiwi peels are mostly made up of linoleic acid and alpha-linolenic acid, two important fatty acids. These fatty acids are well-known for their advantages for the heart, their capacity to reduce inflammation, and their role in maintaining brain function (55) .

Vitamins:

Vitamin C is notably abundant in kiwi peels, which are a great source of other vitamins. Vitamin C is more concentrated in the peel than in the flesh, making it a viable natural substitute for vitamin C supplements. Kiwi peels also include vitamin K, which is essential for bone health and blood clotting, as well as vitamin E, which supports skin health and functions as a potent antioxidant. Currently kiwi fruits have come to be characterized as super-fruits since the low content of energy and the high amount of water, fibre, vitamin C among other nutrients confirm the high nutritional quality and recommended for the general population (56).

Minerals:

Minerals such as potassium, calcium, magnesium, and trace elements like copper and zinc are all present in kiwi peels. While calcium and magnesium support healthy bones and muscular

function, potassium is essential for controlling blood pressure and fluid balance. Kiwi peels include trace components that are both antioxidant and involved in enzymatic processes in the body. Among all the minerals, Mg was discovered to have the greatest level (8200 ppm), followed by K, Ca, Na, and P at 2300, 2300, 900, and 600 ppm, respectively. Iron content (82.26 ppm) was higher when compared to Mn, Zn and Cu contents 14.83, 9.26 and 6.64 ppm respectively (55).

Bioactive Compounds:

Along with the macro- and micronutrients listed above, kiwi peels also contain a wide variety of bioactive substances that may have health advantages. These consist of carotenoids, flavonoids, phenolic compounds, and antioxidants like lutein and zeaxanthin. Strong anti-inflammatory and antioxidant characteristics found in these substances may help prevent chronic diseases like age-related macular degeneration, some malignancies, and cardiovascular ailments. The utilisation of these by-products hasn't received much attention, but certain studies have caught people's attention by identifying them as an excellent source of bioactive substances, namely since they contain a lot of carotenoids, triterpenes, and polyphenols. The peel of this fruit results in a by-product that is still under-explored, but which has aroused a great interest, due to their high contents in bioactive molecules, such as phenolic compounds (57).

5. NATURAL PRODUCT EXTRACTION

Since the major roles of plant secondary metabolites are to protect plants from attack by insect, herbivores and pathogens, or to survive other biotic and abiotic stresses (54), some strategies for extraction of the metabolites have been developed to improve the yield of such plant secondary metabolites so that they can be extracted and be beneficial to humans in treating ailments and diseases.

Extraction

Natural remedies are said to have "active ingredients" or "active principles" that are recognised to have therapeutic advantages. The main ingredients used in the creation of new drugs have been natural items. Natural products offer more drug-like features to molecules from combinatorial chemistry in terms of functional groups, chirality, and structural complexity (58).

“Extraction is the first step to separate the desired natural products from the raw materials. Extraction methods include solvent extraction, distillation method, pressing and sublimation according to the extraction principle” (58).

The extraction of natural products progresses through the **following stages**:

(1) the solvent penetrates into the solid matrix;

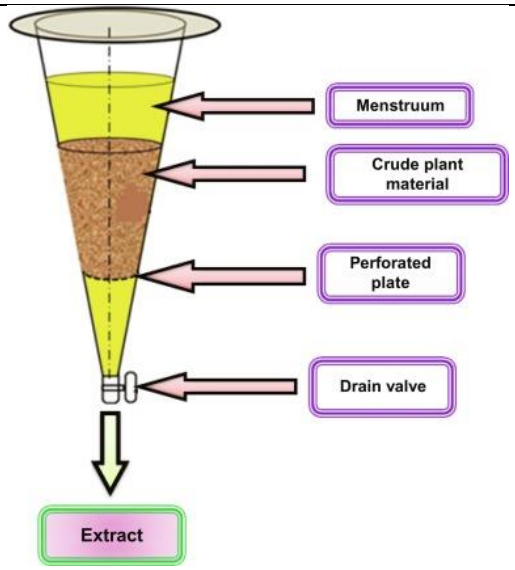
(2) the solute dissolves in the solvents;

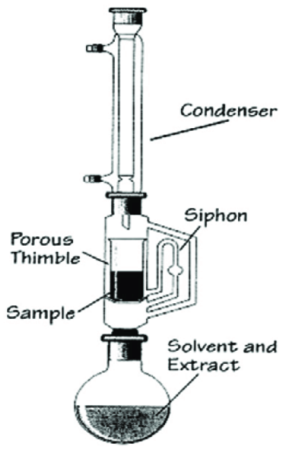
(3) the solute is diffused out of the solid matrix;

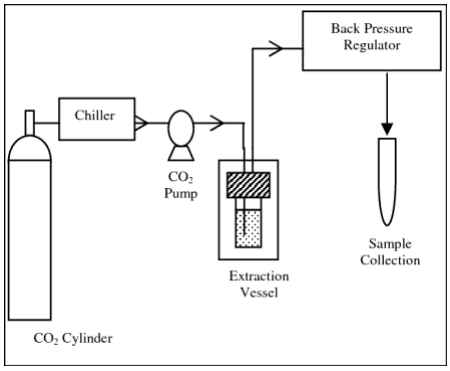
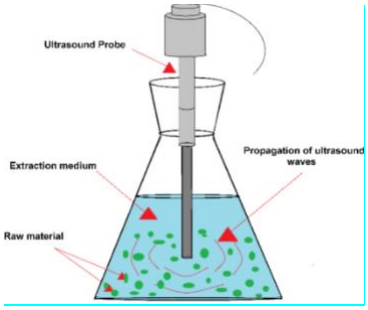
(4) the extracted solutes are collected.

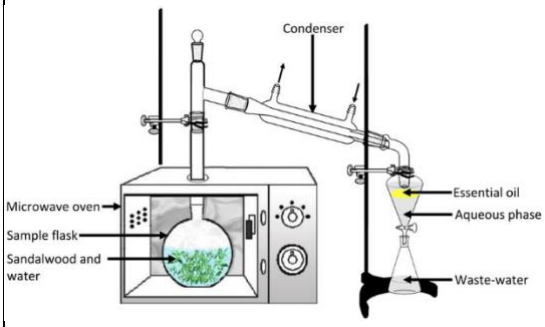
Table 2 - A brief summary of the various extraction methods used for natural products is discussed here (58) –

	EXTRACTION METHOD	**ADVANTAGES**	**DISADVANTAGES**
a.	**Maceration** A method of solid–liquid extraction (59) involving three principals’ steps. First, grinding is used to turn plant materials into powder. This enables good material and solvent interaction. A specified solvent is introduced in a sealed jar after grinding. The liquid is then strained off, but the extraction process' solid byproduct is pressed to recover a significant number of occluded solutions. “During the process of maceration occasional shaking facilitate extraction by increasing diffusion and remove concentrated solution from the sample surface for bringing new solvent to the menstruum for more extraction yield” (60).	1. Simple equipment is used so no skilled operator is required. 2. Energy saving process. 3. Suitable method for less potent and cheap drugs (61).	1. Long duration 2. Not exhaustively extracts the drug 3. Solvent required is more (61).
b.	**Percolation**	1. Takes less time than maceration to complete. 2. Constituents that are thermolabile may be extracted.	1. “Requires more time than soxhlation. 2. More solvent is required. 3. Skilled person is required.

	 **Figure 17 - Percolator** A suitable amount of the prescribed menstruum is used to wet the solid components, which are then left to rest for about 4 hours in a tightly covered container. The mass is then packed and the percolator's top—a small, cone-shaped vessel open at both ends—is then fastened. The combination is mixed with more menstrual fluid to create a thin layer over the bulk, and is then allowed to macerate for 24 hours in a closed percolator. The percolator's outlet is then opened, allowing the liquid within to trickle gradually. "Additional menstruum is added as required, until the percolate measures about three-quarters of the required volume of the finished product. The marc is then pressed and the expressed liquid is added to the percolate. Sufficient menstruum is added to produce the required volume, and the mixed liquid is clarified by filtration or by standing followed by decanting" (59).	3. Appropriate technique for powerful and expensive medications.	4. Special attention should be paid on particle size of material and throughout process" (61).
c.	**Decoction** "Suitable for the extraction of constituents soluble in water (62) as it is a water-based preparation to extract active compounds from medicinal plant materials. The liquid	1. Does not call for pricey equipment. 2. Simple to carry out.	It is not recommended to extract heat-sensitive components.

	preparation is made by boiling the plant material with water. It is the method of choice when working with tough and fibrous plants, barks and roots and with plants that have water-soluble chemicals" (59).	3. No requirement for skilled operators.	
d.	**Soxhlet Extraction** Best technique for hot solvent continuous extraction of a solid. The equipment is a specialised glass refluxing device that is mostly utilised for organic solvent extractions. The equipment is filled with the powdered solid substance, which is contained in a filter paper thimble. The device is attached to a reflux condenser and a round-bottomed (RB) flask holding the solvent. A gentle boil is applied to the solvent in the RB flask, and the vapour that results rises via the side tube, is condensed by the condenser, and then falls into the thimble containing the substance to gradually fill the Soxhlet. The solvent syphons into the flask when it reaches the top of the connecting tube.  **Figure 18** – Soxhlet Apparatus Eliminates the fraction of the material that has been removed in this way. Up till full extraction is accomplished, the procedure is repeated.	1. "Large amount of plants materials can be extracted at a time. 2. Solvent can be used repeatedly 3. Does not require filtration after extraction 4. Does not depend upon the type of matrix. 5. Very simple technique. 6. The displacement of transfer equilibrium by repeatedly bringing fresh solvent into contact with the solid matrix" (61).	1. "The samples are heated to a high temperature for a long period thus there comes a risk of thermal destruction of some compounds that are heat labile. 2. Time consuming and needs labour" (61).

e.	**Supercritical Fluid Extraction (SFE)** "It includes reduced use of organic solvents and increased sample throughput. Cylindrical extraction vessels are used for SFE. The collection of the extracted analyte following SFE is another important step: significant analyte loss can occur during this step, leading the analyst to believe that the actual efficiency was poor. In addition to its favourable physical properties, carbon dioxide is inexpensive, safe and abundant. But it possesses several polarity limitations. Solvent polarity is important when extracting polar solutes and when strong analyte-matrix interactions are present" (59).  **Figure 19** – Method of Supercritical Fluid Extraction	1.Low-temperature component extraction, which rigorously avoids heat and some organic solvents' damaging effects. 2. No traces of solvent. 3. An extraction method that is favourable to the environment.	To overcome the polarity restrictions, organic solvents are typically added to the carbon dioxide extraction solution.
f.	**Ultrasound Assisted Extraction (UAE)** "It involves the use of ultrasound with frequencies ranging from 20 kHz to 2000 kHz which increases the permeability of cell walls and produces cavitation." (59).  **Figure 20** – Set-up of Ultrasound Assisted Extraction of Natural Products	Environment friendly extraction	1. Costlier implementation prevents widespread use. 2. The generation of free radicals from ultrasonic radiation (over 20 kHz) damages the active components of medicinal plants, leading to unfavourable alterations in the drug molecules.

g.	**Microwave Assisted Extraction (MAE)** In MAE: In step 1, heat from the microwave irradiation is transferred directly to the solid without being absorbed by the microwave-transparent solvent. In step 2, intense heating causes instantaneous heating of any remaining moisture that is microwave-absorbing in the solid. In step 3, heated moisture evaporates, creating a high vapour pressure. In step 4, the cell is broken by the high vapour pressure. In step 5, the oil that was trapped inside is released.  **Figure 21** - Set-up of Microwave Assisted Extraction of Natural Products	1. Better "existing" items 2. Enhanced marker retrieval 3. Improved extract quality; 4. Lessened heat degradation 5. Lower processing expenses 6. Considerably quicker extraction 7. Significantly less energy use 8. Significantly reduced (order of magnitude) solvent use 9. Possibility of "new" goods	Need for special equipment, low selectivity, and unavoidable reaction in high temperature are the major drawbacks
h.	**Enzyme Assisted Extraction (EAE)** EAE "is considered a potential alternative to conventional solvent extraction methods. It based on the capability of enzymes to catalyse reactions with high specificity. Some phytochemicals in the plant cell are present as bound to cell wall components, which are not easily extracted by the conventional solvent extraction methods. However, pre-treatment of the sample with an enzyme is an effective way to release some bounded compounds into the solvent and thereby increases the total yield of the compound of interest" (63).	"The compounds present in the cell easily come out into the solvent due to the breakage of the plant cell walls by enzymatic (such as cellulase, hemicellulase, α-amylase, and pectinase) treatment" (63)	Continuous control must be exercised over variables such as pH, sample size, treatment time, and enzyme and substrate concentrations.
i.	**Hydro Distillation and Steam Distillation**	1. "Higher oil yield.	1. "At a high temperature some

	Plant materials are arranged in a still compartment with an adequate amount of water supplied before being heated to a boil. Another option is to introduce direct steam directly into the plant sample. The key influencing variables that liberate the bioactive chemicals from plant tissue are hot water and steam. The vaporised combination of water and oil is condensed by indirect water cooling. The process of obtaining essential oil from various plants and from the various components of those plants has the potential to be highly beneficial. Three basic physiological chemical processes are involved in hydro distillation: hydro diffusion, hydrolysis, and thermal degradation.	2. Components of the volatile oil are less susceptible to hydrolysis and polymerization. 3. No organic solvent needed so this process is cheap and environment friendly" (61).	volatile components may be lost. 2. Complete extraction is not possible. 3. As the plant material near the bottom of the still comes in direct contact with the fire from the furnace, it chars and imparts an objectionable odour to the essential oil. 4. Heat control is difficult, which may lead to variable rates of distillation 6. Requires more space and more fuel" (61).

For the sake of our experiment, we focused on soxhlation method for the extraction of natural products from kiwi peels.

In 1879, von Soxhlet developed the extraction system - The Soxhlet extractor (64), a method that integrates the advantages of the reflux extraction and percolation, which utilizes the principle of reflux and siphoning to continuously extract the herb with fresh solvent.

The sample is put in a thimble holder and condensed new extractant (a word used to refer to the solvent used for extraction) is slowly poured into the holder from a distillation flask. The extracted analytes are transferred into the bulk liquid by a syphon when the liquid reaches the overflow level. The syphon aspirates the solute from the thimble-holder and dumps it back into the distillation flask. Up till the extraction is finished, this process is repeated. Soxhlet extraction is a continuous-discrete approach in terms of operation.

In fact, since the extractant acts stepwise, the assembly operated as a batch system; however, extractant is recirculated through the sample, so the system also operates in a continuous manner somehow (64).

Soxhlet extraction offers a few alluring benefits. As a result, the sample is frequently in touch with new extractant, which helps to disturb the transfer equilibrium. Additionally, the system maintains a reasonably high temperature as a result of part of the heat from the distillation flask entering the extraction cavity. In addition, no filtration is required after leaching and sample throughput can be increased by performing several simultaneous extractions in parallel, which is facilitated by the low cost of the basic equipment (64). The Soxhlet extraction is an automatic continuous extraction method with high extraction efficiency that requires less time and solvent consumption than maceration or percolation (58).

6. Research gap: Various metal-based catalysts are available and used for C-H functionalisation but not much work is available on plant-based catalyst. So, to make C-H functionalisation greener method, plant-based catalyst must be explored.

Objectives:

1. To understand C-H functionalisation and different types of catalysts and their role.

2. To do the phytochemical evaluation of kiwi peel extract.

3. To develop economical, eco-friendly, renewable, and sustainable heterogeneous catalyst from kiwi peel.

4. To characterise the developed catalyst by FTIR, SEM, XRD, BET.

5. To use this catalyst for C-H functionalisation.

CHAPTER 2

MATERIALS AND METHODS

Kiwi peels were collected from local fruit seller. Washed the peels with distilled water and put them to dry for 15-20 days. Powdered the dried peels with the help of mortar in the lab. Transferring target analytes to a liquid phase was the initial step in the production of solid samples. It was carried out by "solid–liquid extraction" or 'Leaching' method. Four solvents of different polarity were taken (Polar – Chloroform & Ethanol, Non-polar - Hexane, and Moderately polar - Ethyl acetate) to check the solubility of powdered kiwi peels. After 15 days, it was filtered off. The retentate having the solid pulp of immiscible powdered kiwi peels was discarded while the filtrate was retained for further study. All the flasks were labelled properly.

Figure 22 – Powdered Kiwi peels put in 4 different solvents– Chloroform, Ethanol, Hexane, and Ethyl acetate

The powdered kiwi peels were put into the thimble for Soxhlation.

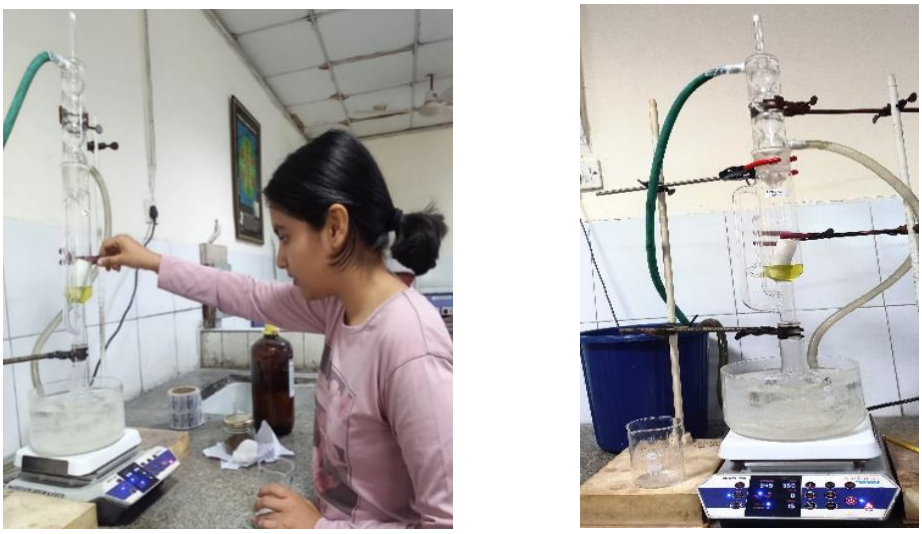


Figure 23 – Soxhlet Apparatus set-up

The filtrate was then put for distillation. Distillation helps in the separation when there are possibilities of having any impurities present that can be removed as the basic principle of distillation is separation of 2 liquids varying in their boiling points.

Another reason of performing the distillation was to concentrate the filtrate obtained from Soxhlation. This was necessary so as to get accurate results for the presence of phytochemicals.

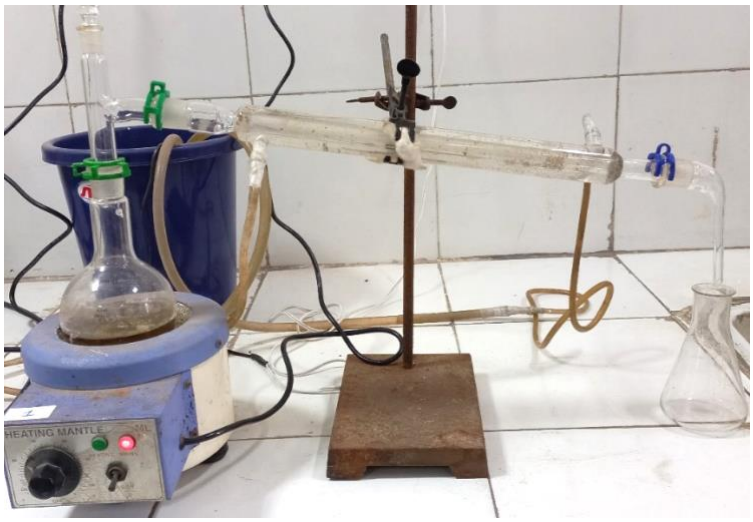


Figure 24 – Distillation set-up

The pure filtrate obtained was then tested through **phytochemical screening** for the presence of various bioactive compounds.

One method for finding novel sources of the therapeutically and commercially significant chemicals found in plant extracts, such as alkaloids, flavonoids, phenolics, steroids, tannins, saponins, etc., is phytochemical screening. Any component of the plant, including the bark, leaves, flowers, seeds, etc., can be used to make these chemicals. Knowledge of the chemical constituents of plants is desirable because such information will be of value for the synthesis of new bioactive compound/s for treating the specific disease. (53)

To utilize the kiwi peels as a potential source for value-added products, antioxidant studies has been performed. The **antioxidant activity (AA)** was evaluated using DPPH method (65).

About DDPH –

The 2,2 diphenyl-1-picrylhydrazyl (DPPH) reagent has a maximum absorption wavelength of 515 nm and is a stable organic nitrogen radical. The colour of the mixture changes from a dark purple to a pale yellow as the radical is snared by antioxidants, and the absorbance at 515 nm

drops. The absorbance of the DPPH will then quickly decrease in response to strong antioxidant compounds. The DPPH test was initially described by Brand-Williams et al. in 1985. Due to the ease of equipment requirements, it is widely used in antioxidant capacity screening. The DPPH technique enables a direct examination of the antioxidant's capacity to provide electrons or hydrogen to quench the DPPH radical. The DPPH method is widely used to determine antiradical activity of phenolic compounds as well as natural plant extracts (66).

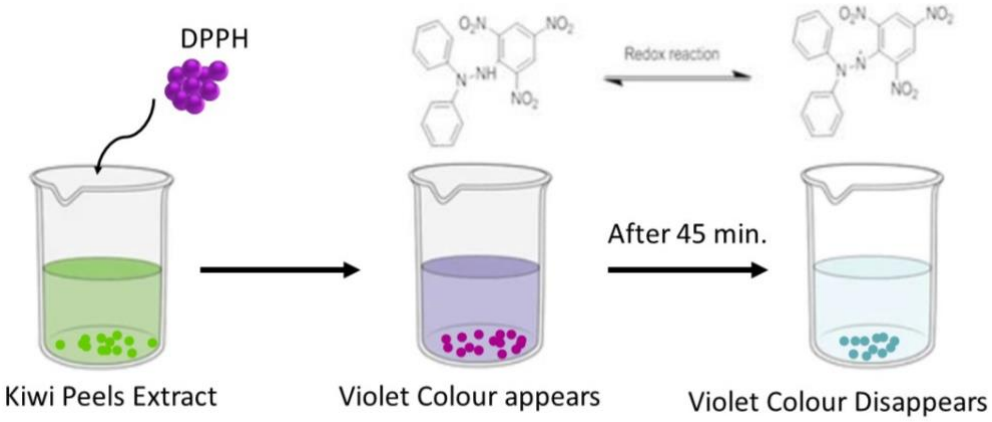


Figure 25 – Chemistry of DPPH for Antioxidant Activity evaluation

The antioxidant study was performed for three different sets of extracts using reported DPPH (2,2 diphenyl-1-picrylhydrazyl) method. Each extract from Set I-III (1 mL) was mixed with freshly prepared DPPH solution (3 mL) and allowed to react for **45 minutes at room temperature in dark**. After that, the mixture was tested for DPPH radical scavenging activity on double beam UV-visible spectrophotometer at 517 nm. The solution of **DPPH in ethanol (1.2 mg in 50 mL) was used as blank** and studied at the same wavelength.

The 0.6 mg of kiwi peel extract in 25 mL of **ethanol** was used as **reference**. As **positive control gallic acid** was used. The samples were run in triplicate and the mean value of three of them was recorded and results formulated in tabular form.

Percentage of antioxidant activity was calculated using the formula (65):

$AA\ (\%) = [(A_b - A_s) / A_b] \times 100$

where AA = Antioxidant activity; A_b = Absorbance of blank; A_s = Absorbance of sample

Set I: The **original chloroform peel extract** (100 mg) was mixed with 25 mL of different solvents (hexane, chloroform, ethyl acetate, and ethanol) and stirred at 25ºC for 1½ h on water bath (50ºC). The extract mixture was filtered and the filtrates were used for antioxidant studies.

Set II: The 5 mL of each solution from set I was subjected on water-bath to evaporate the solvent. To this extract, 1 mL of ethanol was added and shook to dissolve the same filtered and used for antioxidant.

Set III: The original chloroform peel extract (100 mg) was mixed with 25 mL of **ethyl acetate** and stirred at 25oC for 1½ h on water bath (50ºC). The solvent was filtered and the residue was again mixed with **hexane** (25 mL), stirred at 25ºC for 1½ h on water bath (50ºC). This process was repeated for ethanol. The filtrates were used for antioxidant studies.

CHAPTER 3

RESULTS AND DISCUSSION

Phytochemical Screening of extracts (53) **-**

Chloroform, methanol, aqueous and acetone extracts were used for preliminary phytochemical analyses using standard procedures. For both metabolites, several qualitative tests were conducted:

Table 3: A summary of qualitative tests performed for the confirmation of various metabolites

Test for alkaloids ***(Wagner's test):***	Wagner's reagent, which is made by combining 2 g of iodine and 6 g of potassium iodide in 100 millilitres of distilled water, was added to around 10 mg of the extract.	formation of a reddish-brown precipitate	presence of alkaloids was indicated.
Test for Flavonoids (Alkaline reagent test):	2-3 drops of NaOH were added to 2 mL of extract	A bright yellow coloration first appeared, but after adding a few drops of diluted HCL, it gradually turned white.	Flavonoids were indicated.
Test for Phenols ***(Liebermann's Test):***	Warm sulfuric acid is used to dissolve a tiny amount of the test item and a crystal of sodium nitrite. After that, the solution is	formation of a blue-green colour	indicated the presence of a phenol (the main bioactive compound in the kiwi)

	placed into extra aqueous alkali.		
Test for Tannins (Ferric chloride test):	A couple of drops of 10% Ferric chloride solution (bright yellow) were added to the 2 mL of the extract's aqueous solution.	No change in colour	absence of gallic tannins was indicated.
Test for steroids and sterols (Salkowski's test):	A test tube was filled with an equivalent volume of strong sulfuric acid and 5 mg of extract, which had been dissolved in 2 ml of chloroform.	The bottom layer turns yellow with green fluorescence while the top layer turns red.	presence of the steroids and sterols compound was indicated.
Test for Glycosides (Glycoside test):	Aqueous NaOH solution was added after 0.5 mg of the extract had been dissolved in 1 ml of water.	yellow colour was indicated.	presence of glycosides was indicated.

After phytochemical screening was done, the filtrate was sent for Gas Chromatography – Mass Spectrometer **(GC-MS)** from Advanced Instrumentation Research Facility (AIRF) Jawaharlal Nehru University (JNU), Delhi, however the results could not be obtained till date.

The **antioxidant activity (AA)** of different solvent fractionated crude extracts of the kiwi peels obtained from the original chloroform extracts was evaluated spectrophotometrically following the DPPH method. The objective of the sample preparation (set I-III) was to identify the individual crude fraction possessing better AA. **The highest antioxidant activity**

(>90%) among the analyzed extracts were shown by polar solvent fractions like ethanol. They are found to be closure to the gallic acid. These fractions may be utilized in nutraceuticals and taken up for further investigations.

Table 4 – Antioxidant Activity (AA%) of Methanol Extract of Kiwi Peels

Exp.	**Hexane**	**Chloroform**	**Ethyl Acetate**	**Ethanol**	**A_b**
Set 1	83.09	91.04	88.77	93.31	0.86
Set 2	80.17	89.63	89.28	94.06	0.89
Set 3	81.90	82.90	85.76	93.70	0.95

Gallic Acid – 95.56; Range of UV-Visible spectrophotometer: 400 to 650nm

It can thus be concluded that the kiwi peels are a potential source of antioxidant molecules. The peels can be used as natural antioxidants, nutraceuticals, and preservatives in food and non-food systems and hence utilized in value addition to the products. However, further phytochemical studies are required to authenticate the presence of individual bioactive molecules.

SUSTAINABILITY AND WASTE MANAGEMENT:

Environmental and Economic Benefits of Utilizing Kiwi Peels

This proportion results in approximately 1×10^6 tons of yearly and global waste from the manufacturing of kiwis. The peel, which makes up roughly 7–24% of the fruit's weight when processed for various uses, is frequently thrown away as waste. Notably, earlier research investigated the use of kiwi peel ash for the creation of useful products. Given the vast quantities of kiwis produced, it is inevitable that significant amounts of peel waste will be produced, which presents difficulties in disposing of it. In light of this, the current study suggests using Kiwi waste ash, in particular Kiwi peel ash (KPA), as an economically viable, environmentally friendly, renewable, and long-lasting heterogeneous catalyst. This strategy aims to turn this bio-waste ash into a useful resource, helping to increase the sustainability and effectiveness of the use of kiwi by-products. In this sense, there are two main international concerns, one is the negative impact that the increasing generation of food waste

involves (carbon footprint) and another is the urgent need of improving the throughput of the production systems to make them capable of feeding the rising world population (67).

In the context of the food industry, utilizing by-products and reducing waste not only benefits the environment but also holds significant economic potential. The use of fruit by-products is one of the global trends to address sustainability in food production (68). This section explores the environmental and economic benefits of utilizing kiwi peels, focusing on waste reduction and resource optimization.

Environmental Benefits:

Reduction of Food Waste: Kiwi peels are often discarded as waste during fruit processing. Given that the food industry is facing the handling of thousands of tons of kiwi by-products discarded each year, it is necessary to consider kiwi by-products as good sources of functional ingredients (69). Utilising kiwi peels will help the food industry lower the amount of organic waste dumped in landfills, reducing greenhouse gas emissions and other environmental harm brought on by garbage disposal.

Conservation of Natural Resources: By using kiwi peels as a source of natural compounds, less extra resources, such as land, water, and energy, are needed than would otherwise be needed to produce these compounds from alternate sources. Resource preservation like this promotes the sustainability of the environment as a whole.

Preservation of Biodiversity: It may be possible to lessen the need for additional natural chemical sources by minimising waste and improving resource use. This can lessen the strain that the extraction of these substances from alternate sources may have on ecosystems and biodiversity.

Economic Benefits:

Value-Added Products: Kiwi peel extraction opens up possibilities for the creation of products with additional value. These products can satisfy the rising consumer demand for natural and eco-friendly goods by include functional food ingredients, nutraceuticals, cosmetics, and medications. Businesses in the food industry may see a rise in revenue and better market competitiveness as a result of this diversification.

Cost Reduction: Businesses can save waste management expenses related to disposal and waste treatment by using kiwi peels. In addition, compared to synthetic or alternative natural sources, the extraction of bioactive components from kiwi peels offers a different and maybe more affordable source. The profitability and economic feasibility of operations in the food business may increase as a result of this cost reduction.

Circular Economy Approach: The use of kiwi peels in manufacturing procedures encourages the circular economy concept, in which waste products are recycled and turned into useful resources. By minimising reliance on finite resources and fostering a more sustainable and effective food business, this strategy advances long-term economic resilience and is in line with sustainable development goals. The current trend is aimed at using the residues derived from agricultural production as matrices to obtain bioactive compounds of interest to the industry, integrating the concepts of agriculture, industrial production and circular economy from a sustainable point of view (70), (71).

CHAPTER 4

CONCLUSION

An exciting opportunity for sustainable use and waste reduction in the food business is the extraction of natural compounds from kiwi peels. The purpose of kiwi peel extraction, the characteristics and chemical composition of kiwi peels, and several extraction techniques, including the Soxhlet method, alongwith the study of its anti-oxidant activity were all topics covered in this thesis. Plant-based catalysts have recently come to light as a possible alternative due to the growing need for catalysts that are simple to make, inexpensive, non-corrosive, and ecologically benign. Due to their potential for C-H functionalization, the use of ash catalysts made from plant waste has attracted a lot of interest. This attention can be linked to its benefits, which include simplicity in preparation, abundance, affordability, biological makeup, and environmental friendliness. Notably, several plant waste materials, including as tucuma peels, Musa acuminate peduncle, Musa acuminata peel, Musa balbisiana Colla, rice husk husks, coconut waste, rubber seed shell, cocoa shells, and Lemna perpusilla torrey ash, have been shown to be efficient catalysts in a number of processes. The Soxhlet extraction method served as the foundation for our experimental efforts. C-H activation is a useful tool for accelerating multi-step synthesis and extracts obtained from plants are used as a catalyst for carrying out C-H functionalization. We have also discussed numerous methods for incorporating C-H activation into the synthesis of heterocycles in our study, as well as chances for diverse design approaches employing various metal catalysts. Using C-H activation in a sustainable way by adding toxic-free metals is the need of the hour and this can be mediated through plant-based extracts.

The study of plant-based extraction included experimental work as well, such as the use of GC-MS analysis and extract phytochemical screening. These investigations shed important light on the bioactive substances found in kiwi peels and their potential uses. Our knowledge of the chemical composition and bioactivity of kiwi peel extracts was furthered by the identification and measurement of secondary and primary metabolites.

The study also emphasised the value of sustainability and trash management while demonstrating the financial and environmental advantages of using kiwi peels. The food business can support a circular economy and lessen the environmental impact of waste disposal by reducing food waste and improving resource utilisation.

This thesis identifies several issues that require additional study and inquiry in the future. To further this subject, it is essential to investigate novel extraction methods, investigate additional bioactivities, optimise formulation procedures, and assess the stability and shelf life of products based on kiwi peel extract.

Food waste and other waste products are accumulating as a result of the rapid expansion in the human population and are posing serious environmental problems if not adequately managed. Consequently, it is now very difficult to control these waste elements by turning them into valuable resources. In light of this, we consider the possibility of recycling trash into valuable materials and have chosen kiwi peel as a long-lasting catalyst for C-H functionalization. Based on these guiding principles, we expect major developments and the creation of new technologies in the upcoming years. Future generations may become more resource-efficient and sustainable thanks to the continued study in this area, paving the path for a more promising and sustainable future.

FUTURE PROSPECTS AND CHALLENGES

There are plenty of opportunities for more study and improvement in the area of natural product extraction from kiwi peels. Even though a lot of progress has been covered in our understanding of the chemistry and bioactivity of kiwi peel extracts, there are still a number of questions that demand more research. The problems and opportunities facing this discipline in the future are discussed in this part, along with potential research avenues and areas for advancement.

Exploration of Novel Extraction Techniques:

While natural components from kiwi peels have been extracted using conventional methods, there is a need to research and create new extraction methods. Techniques such as ultrasound-assisted extraction, microwave-assisted extraction, and supercritical fluid extraction which are less popular due to high cost despite the efficiency of the methods (72) hold potential for improving extraction efficiency, reducing extraction time, and maximizing yield. Further research should focus on optimizing these techniques and comparing their effectiveness with conventional methods.

Investigation of Additional Bioactivities:

Even though kiwi peel extracts have been researched for a number of bioactivities, there is always need for more research into their possible health advantages. Future studies can

examine how kiwi peel extracts affect various illness models and how they work. Furthermore, research into the synergistic interactions between various bioactive substances found in kiwi peels may shed light on their combined medicinal potential.

Optimization of Formulation Strategies:

Stability, bioavailability, and sensory qualities must be carefully considered when formulating kiwi peel extract-based products. Future studies should concentrate on formulating products in the best possible ways to protect bioactive components, extend shelf life, improve delivery methods, and increase consumer acceptance. To increase the stability and controlled release of the bioactive substances, strategies like nanoencapsulation and microencapsulation could be investigated.

Evaluation of Stability and Shelf Life:

It is crucial to assess the stability and shelf life of kiwi peel extract-based products in order to assure their commercial viability. The quality and effectiveness of the extracts can deteriorate over time due to factors like temperature, light exposure, and oxidation. Future studies should concentrate on designing appropriate packaging and storage settings, measuring the rates of bioactive chemical degradation, and undertaking long-term stability tests to extend the shelf life of the products.

Sustainable Sourcing and Production:

It is essential to maintain sustainable sourcing and production of kiwi peels as the demand for natural products rises. The development of effective extraction methods that reduce resource consumption, waste production, and environmental impact should be the main emphasis of research. The overall sustainability of the process can also be improved by investigating the use of by-products produced during extraction for other purposes, such as the manufacture of biofuel or agricultural use.

There are many opportunities for study and development in the extraction of natural products from kiwi peels. Key areas that need more focus include studying novel extraction methods, looking into additional bioactivities, enhancing formulation procedures, and assessing stability and shelf life. By overcoming these obstacles, the industry may fully utilise kiwi peels as a sustainable supply of valuable bioactive ingredients, resulting in the creation of novel products with improved functioning and commercial viability.

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