PROPERTIES OF PIPER BETLE LEAF AS ANTIMICROBIAL, ANTIOXIDANT ACTIVITY AND ITS VARIOUS ROLE IN FOOD PRODUCT MAINTENANCE; A REVIEW ARTICLE.

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Abstract

Naturally occurring herbs have long been used for food and medicinal purposes around the world. Betel vine (Piper betle L.), often called pan, is an evergreen perennial vine that belongs to the Piperaceae family. Generally, betel leaves are used after a meal as a digestive stimulant and also as a mouth freshener. It has several medicinal properties, including anti-inflammatory and antioxidant properties. The effectiveness of betel leaf extract depends on the chemical components' availability, which varies depending on the extraction method. As a result, choosing and using the right extraction procedures is essential to the process. An emerging tactic in a developing economy is the use of betel leaf in the production of food. Studying how betel leaves are used in both traditional and contemporary food systems is important. Evaluation of betel leaf's antioxidant and antibacterial capabilities is the main focus of the current investigation. The development of a database and promotion of the use of betel leaf as a therapeutic plant will be aided by research on the antioxidant and antibacterial properties. Betel leaf contains biochemical compounds that have a positive effect on the organic system within the body. Because of these properties, betel leaf can be widely used within the food and beverage industry to provide more advantageous product benefits and fitness benefits with the help of stopping disease-causing elements.

Keywords- Piper betel leaf, antioxidant, medicinal, antimicrobial.

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Introduction-

Plants provide an inexpensive supply of chemical substances and compounds with antibacterial characteristics that are obtained from plants**.** (Cristian B. Mejos ; et al, 2023).Piper betel Linn that is a piperacea family member is a consumable plant that have been traditionally utilized in India, China, and Thailand. This plant of betel is an evergreen and perannalin, creeper, with sleek heart formed and white carkin. The female plant in betel leaf catkin has pendulous spikes, whereas the male plant has thick, cylindrical spikes. Each node produces a root that the plant uses to cling to the host tree or other support. Tropical and subtropical regions of the world both have extensive farming. (Rai MP., et al, 2011).

Betel leaves come in hundreds of distinct types, 40 of which are indigenous to India and 30 of which are native to West Bengal. The plant is dioecious, which means the male and female plants are distinct from one another yet all are perennial root climbers that prefer shade. Piper betel is cultivated global along with India, Srilanka, Malasia, Indonesia, phillipine, Island and east Africa. Leaves, root, stem all components of plant may be utilized. Piper betel has mild yellow aromatic vital oil, with sharp burning flavor. It's also used as mouth freshner after meal. (Silva & Fernandes, 2010). This plant has been shown to very own a selection of medicinal houses, which consist of gastro-protecting, wound healing and also hepato-defensive moves, that are in massive component. (Arambewela, Arawwawala & Ratnasooriya, 2005). All across the world, naturally occurring plants are utilised for food and medicine, but the contemporary lifestyle has destroyed the natural way of life. We have neglected the magnificent natural legacy that our forefathers left for us in recent years. Numerous health problems that affect us on a daily basis, such as digestive disorders and ageing concerns, have been made worse by this misunderstanding. Research is now again being conducted to examine the nutritional, antibacterial, and nutraceutical possibilities of natural plant materials. Piper betle L., sometimes known as betel leaf, is one such significant herb. (Sarma, Rasane et al, 2018)

Numerous studies have been done on the chemical constituents and their pharmacological effects of the primary constituents in betel quid. Along with water, sugars, proteins, fats, minerals, nutrients, tannin, fibre, alkaloids, steroidal chemicals, and significant oils, betel leaves also contain a variety of other substances. Risky oil, betel phenol and chavicol, tannin, sugar, vitamin C, starch, and Distaste are all present in it. (Kamal, Nazir, et al. 2018). Betel phenols have the ability to reduce sialogoue, local anaesthesia, and valuable anxious stimulation. However, hydroxychavicol, sterol, and tannin are the main energy components responsible for the antibacterial effect. Betel leaves have medicinal qualities that include those that are anti-diabetic, anti-ulcer, antimutagenic, respiration -suppressing, anti-helmenthetic, and wound-healing. Because of its antihistaminic and antioxidant properties. Piper betel is used to treat alcoholism, bronchitis, asthma, leprosy, and dyspepsia. (Tarun, Rachana, et al. 2012). Since the beginning of time, medicinal plants and herbal remedies have been utilised to cure a vast array of maladies. Natural substances formed from plants can come from any part of the plant, including the bark, leaves, roots, fruits, seeds, fruit rind, etc. Additionally, traditional medicine has employed betel leaves as a stimulant, antiseptic, antifungal, and antibacterial agent. (Caburian & Osi, 2010). By using the appropriate extraction techniques, the beneficial bioactive components found in betel leaf may be extracted. It consists of both conventional extraction techniques like- distillation, solvent extraction, and maceration, as well as more contemporary techniques, including accelerated solvent extraction, supercritical extraction, thermally and non-thermally assisted extraction techniques, using a variety of solvents, including methanol, ethanol, ethyl acetate, and acetone. These solvents are chosen to increase the extraction yield because of their low or nonexistent toxicity, biogrades, and ease of availability. (Agarwal & Gupta, 2018).

Nutritional benefits of betel leaf:

The immense nutritional richness of betel leaves, which include vitamins, minerals, enzymes, protein, essential oils, and bioactive substances, makes them ideal for treating conditions including liver, brain, and heart problems which is depicted in table. (Rai MP., et al,2011).

S.No	Constituents	Quantity/ Amount (per 100gm)
1	Carbohydrates	64.81g
2	Protein	10.95g
3	Total fat	3.26g
4	Dietary fibre	26.5g
5	Folic acid	10µg
6	Niacin	1.142g
7	Riboflavin	0.240mg
8	Thiamine	0.109mg
9	Carotene- β	156µg
10	Lycopene	6mg

Table 1: Constituents of betel leaf.

Merchandise like leaf pieces, powder, leaf extract, and essential oil can be utilised in a variety of

commercial industries to create better functional food, prescription drugs, and other merchandise, which has limitless fantastic results on human health. The analgesic and cooling homes of betel leaf powder and betel leaf portions cause them to beneficial for treating a ramification of pains, such as headache, joint pain, arthritic pain, sore throat, nerve soreness, debility, and worried exhaustion. (Wendy., et al,2014). Due to their nutritious value, betel leaves are comparable to cow milk (six leaves and a small amount of slaked lime equal 300 mL of milk). (Guha, 2006). Betel leaf extract is essential in various areas, particularly in the field of medicinal science. Because it slows and inhibits oxidation greatly, betel leaf extract has the potential to be an antioxidant. Free radicals are the primary cause of the majority of health problems, including Alzheimer's disease, cancer, rheumatoid arthritis, cardiovascular disease, and neurological disorders. Free radicals formed as a result of protein and lipid breakdown. All of those free radicals are scavenged by the antioxidant in betel leaf extract, which also guards against oxidative illnesses. Betel leaf has potent antiseptic, germicidal, and other pharmacological characteristics that not only treat disorders like nausea, vomiting, indigestion, and flatulence but also successfully combat them.

Phytochemical profile of betel leaf:

Micromolar dosages of betel leaves have been shown to have antiproliferative effects on a variety of cancer cell lines from various sources while having no adverse effects on normal cells. (Noor Azleen., et al, 2022). The chemical composition of betel leaf is related predominantly with phenolic compounds in nature. Betel leaf extract having chemical compounds such as chavibetol, chavibetol acetate, Allylpyrocatechol, α-tocopherol, β-carotene, eugenol, hydroxy chavicol, piperol A, and piperol B, and many others. The important phytochemical has been indexed in table 2. The betel leaf plant additionally carries terpinene, p-cymene, carvacrol, alley catechol, estragole, oxalic acid, Malic acid, amino acid, and chavicol with its derivatives. (Guha P., et al, 2017). The primary volatile compounds and their relative percent fee of critical oil analysed via GC-MS revealed that it had 33 chemical compounds. (Madhumita M., et al, 2019). Those compounds characteristic numerous medicinal and aromatic residences. Alcohol, aldehydes, alkanes, alkenes, ester, ketones, and amines were the predominant risky compounds found in essential oil. Tamluk Mitha variety of betel leaf critical oil had 46 chemical compounds. (Hans N, 2017). Every phytochemical compound contributes to biological pastime like eugenol act as an advanced antioxidant, antifungal, antibacterial, anthelmintic, and nematicidal hobby. (Banu SS., et al, 2021). The use of this eugenol in the food and cosmetic industries is possible since it also functions as an aromatic and fragrance agent. The local anaesthetic can be used to temporarily fill cavities in dentistry. The following substance, anethole, functions as a flavouring agent with a sweet taste and has antifungal, insect, and microbe-killing properties. (Arsad NH., et al, 2016). Estragole is a natural preservative, flavouring agent, and herbal medicine used in the food business. The linalool components in betel leaf are utilised as an anticancer agent and for treating skin conditions including skin irritation. (Arsad et al, 2017).

S.No.	Chemical Composition	Quantity(in %)
1	Anethol	2.62
2	Acetyl eugenol	14.05
3	Camphene	0.48
4	Chavibetol	53
5	Chavicol	11.08
6	Eugenol	48.41
7	Estragole	16.12
8	Limonene	1.06
9	Safrole	25.67
10	1,8 cineol	0.04
11	α-pinene	0.21
12	Caryophyllene	1.30
13	Linalool	12.42

Table-2 Chemical Composition of betel leaf.

Antioxidant Property of betel leaf:

Antioxidants are substances that may be found in both natural and manufactured forms. They work by scavenging or destroying oxidative reactive species to prevent oxidation. (Pin KY., et al, 2010). A biological body's RNA, DNA, and proteins can be damaged by reactive oxygen species because they include oxygen molecules that are unstable enough to react with cells. The molecules known as free radicals have one or more unpaired electrons in their outer shells. These free radicals are created by the body's mitochondria organelle as cells use oxygen to make energy. They are caused by adenosine triphosphate. Both reactive nitrogen species (RNS) and reactive oxygen species (ROS) are by-products of the energy production process. Depending on the concentration, these by-products play a key role in both positive and harmful consequences. Oxidative stress, which is brought on by high ROS and RNS concentrations, leads to the destruction of all cell structures. The substance that may be utilised to combat oxidative stress and lessen its negative effects on the biological system is known as an antioxidant. This antioxidant has no

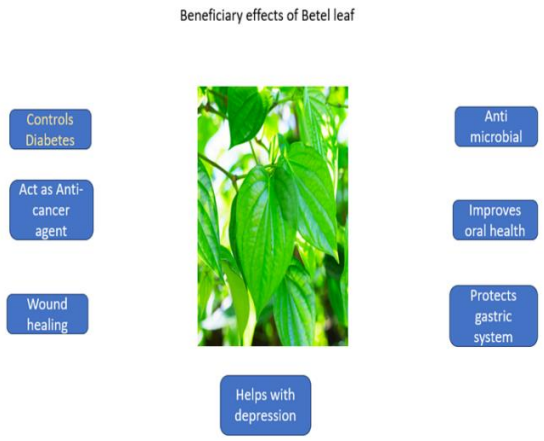
negative side effects and is utilised to stop the illnesses brought on by oxidative stress. Synthetic antioxidants with harmful effects, such as BHA (butylated hydroxyanisole) and BHT (butylated hydroxytoluene), are employed in food and medicines. Attempts have been undertaken to extract natural antioxidants from plant sources, such as polyphenols, saponins, and tannins, in order to overcome these drawbacks. (Arsad NH., et al, 2016).

The antioxidant pastime correlates to the phenolic compounds found in extracts and flavonoid content material which contains the number of hydroxyl groups in their molecular structure, consisting of eugenol, hydroxyl chavicol, and gallic acid which Do what you can to contribute to antioxidative sports. Higher levels of antioxidant interest in the extract are related to better extraction yields from major compounds, such as eugenol, hydroxyl chavicol and gallic acid. (Pin KY., et al, 2010). The extraction of antioxidant compounds from betel leaf is highly influenced by the various solvent used to extract it. More extraction yields from antioxidant compounds can be obtained by using a high polarity solvent. A high concentration of antioxidant compounds has been found in the methanol extract. (Amaresh A., et al, 2017). Maximum antioxidant potential of this extract is shown by the highest polyphenol compounds with more activity against DPPH. (Arsad NH, 2016). The maximum free radicals scavenging activity of 89.46% inhibition was found when the betel leaf extracted with ethanol solvent. Betel leaf extract has a high degree of antioxidative activity due to catechol at higher concentrations. (Pin KY., et al, 2010).

Antibacterial Property of betel leaf:

Based on the inhibitory zone method with a control sample of Iodip at 10%, the antibacterial activity of betel leaf extract against certain mastitis bacteria such as Staphylococcus aureus and Streptococcus agalactiae has been investigated. (Foo LW., et al, 2015). Active substances in the forms of saponins, tannins, flavonoids, alkaloids and terpenoids have been found to form the most inhibitory zones formed by betel leaf extract. The inhibitory zone became progressively wider as the concentration of betel leaf extract increased. Based upon bacterial resistance capabilities and cell wall characteristics of bacteria, the antibacterial activity or inhibition zone is different for individual microorganism. (Wendy Voon et al, 2014).

The effect of betel leaf extract which is extracted by methanol solvent on minimal inhibitory concentration and minimal bactericidal concentration against selected bacterial pathogens study shows that the lowest minimal inhibitory concentration of 0.1 µL/mL and minimal bactericidal concentration of 0.2 µL/mL of betel leaf extract for Salmonella typhi and highest minimal inhibitory concentration of 12.8 µL/mL and minimal bactericidal concentration of 6.4 µL/mL of betel leaf extract for Pseudomonas aeruginosa. (Badola., et al, 2022). The antimicrobial activity of betel leaf extract is also determined by its bioactive constituents such as polyphenol and Sterol compounds in abundance, which are interaction with the bacterial cell wall that results in destruction of bacteria. Studies showed that, in order to prolong the shelf life of food products, ethanolic extracts from betel leaf could be used as antimicrobial agents. The polyphenolic compounds that give rise to the best antibacterial action are flavonoids. It has been shown to be beneficial for human health, acting as an antimicrobial, antitumor, antihemolytic, antiviral and antibacterial agent. (Sivakumar., et al, 2015).



Essential betel leaf oil:

Population increase has created a huge demand for food, which raises questions about the safety and quality of minimally processed fresh food products and causes enormous losses. Therefore, such goods have encouraged the use of naturally occurring components that act as helpful antimicrobials and other components that promote health, such as essential oils. (Foo LW., et al, 2015).

Spices, herbs, and plants all contain a variety of bioactive chemicals with antibacterial characteristics that may be used to extract essential oils. The betel leaves were improperly processed and stored, resulting in their disposal as garbage.

In India's cottage industries, the curing and bleaching of betel leaves results in 25% of the leaves being discarded as unfit for consumption. Therefore, a key factor in lowering post-harvest

losses is the extraction of useful chemicals like essential oil from surplus leaves, unsold leaves, de-chlorophyllized leaves, or stale leaves. This volatile essential oil from betel leaves has a wealth of advantageous qualities, including medicinal, organoleptic, and other favourable traits. The primary secondary metabolites of the complex composition with a distinctive odour make up the majority of the volatile molecules that make up the essential oil. The betel leaf oil has a variety of therapeutic benefits, including the reduction of pain and the promotion of healing. This essential oil also contributes to a number of vital biological processes, including anti-inflammatory, anti-fungal, antidiabetic, anti-amoebic, antibacterial, and other related qualities. This essential oil is employed in important items such as medicines, stimulants, tonics, and aromatics. (Pin KY., et al, 2010).

Implementation of Piper betle leaf extract in Food and beverages:

Betel leaf is owning biochemical compounds which have useful impact withinside the organic system. Due to those traits of betel leaf, it is able to be broadly used withinside the meals and drinks enterprise to offer more advantageous product fine and fitness advantages with the aid of using stopping disease-inflicting elements.

a) Snacks products: The betel leaf may be very nutritious and poses diverse fitness benefits, that's may be used as an component withinside the manufacturing of snacks items. The betel leaf delivered cutlet, ladoo, and namkeen have been in comparison with mint leaf delivered merchandise in phrases of sensory traits with the aid of using T-take a look at with 5-factor hedonic scale. The test found out that organoleptic acceptability of betel leaf delivered namkeen and ladoo became excessive in comparison to mint leaf delivered meals merchandise. (Bhargava A; et al, 2011).

The usage of betel leaf in everyday existence gives triumph over the deficiency of iron and calcium micronutrients thru numerous recipes. The usage of betel leaf gives financial in addition to fitness benefits. The meals product specifically coconut burfi, cutlet, and muthia with the addition of betel leaf and the betel leaf delivered coconut, burfi confirmed better dietary values, together with protein 11.49g, carotene 114.05 µg, folic acid 51.89g, and iron 5. eighty mg in keeping with 100g, compared to spinach-delivered meals product. (Nande P., et al, 2007). The Khakhra with the incorporation of betel leaf powder at specific concentrations of 5, 7.5, and 10% suggests that amongst the concentration, the 5% betel leaf powder delivered Khakhra gave especially suited sensory traits and increase shelf lifestyles around 60 days beneath neath the ambient temperature. (Jandu R., et al, 2022).

b) Solid foods: The use of betel leaf has improved the quality of noodles. (Nouri L., et al., 2015). Due to the interaction of phenolic compounds found in betel leaf with molecules for amylose reassociation, the hardness of the food product reduced as the quantity of betel leaf extract rose. The chemicals from betel leaves engage with the starch amylose chain and prevent amylose from aggregating through hydrogen bonding in the dough, increasing free volume in the noodle matrix. Because the starch molecules are more hydrated as a result of this interaction event, the noodles' texture is softened and their adhesiveness is increased. The noodles that included 15% betel leaf extract generated the results that the panel found to be the most palatable. These experiments allow us to draw the conclusion that the addition of betel leaf extract to food items results in the alteration of the starch components, producing a softening quality impact. A 0.5% aqueous betel leaf extract has been added to preserve all sweets like Khoa. (Badola R., et al, 2022).

c) Liquid foods: The mango beverage made with whey has 12% mango juice, 7% sugar, and varying percentages of betel leaf distillate (0, 1, 2, and 3%). (Mugale A., et al, 2018). According to the sensory qualities of the beverage, the degree to which consumers find it acceptable relies on the amount of betel leaf distillate present, which affects the beverage's colour, texture, mouthfeel, and flavour on a scale of 1 to 9. The beverages that had 2% betel leaf distillate added were the most well-liked and favoured by the panellists out of all the beverages. Betel leaf extract had an impact on the characteristics of dahi, and it was found that the pH of the substance dropped from 4.40 to 4.03. (Sivakumar GM., et al, 2015). The addition of betel leaf is responsible for the advanced manipulation of the quality traits in Food merchandise. The researcher also used the betel leaf extract to maintain milk because of the high content of phenolic and polyphenolic compounds due to antimicrobial and antioxidant hobby. (Shivakumar GM, 2015).

Future studies:

The green betel leaves as a precious derivative due to their abundance and ability to use of extract or unstable important oil (EO) obtained for the

duration of the extraction system. Using the leaf extract/EO this is included in the aforementioned phase has obtained only a few reviews. Given the dearth of study in this discipline, researchers have focused on its potential application in a ramification of strategies, which include food utility, pharmaceutical industries, cosmetic industries, and so forth. Via using modern-day preservation techniques that's useful and sensible inside the destiny of enterprise, it's miles feasible to reduce the put up-harvest losses of betel leaves. To reduce these losses of betel leaves, greater inventive technologies and medical research are wanted. Most of the Indian people are directly or indirectly addicted to all the process of production, processing, packing, handling, shipping and marketing betel leaves. National and state governments should cooperate to set up a research and development board and take better measures to support various projects and provide subsidies. (Sangeetha Karunanithi; et al, 2022).

Conclusion:

Betel leaf contains phenolic compounds that have a variety of medicinal uses and are associated with various health benefits. Hence, there is a growing interest in Betel leaf extract for various industrial applications such as food supplements, cosmetics and pharmaceutical industry. The high bioactive chemicals in Betel leaves and their derivative products are highly sought after all over the world. In this review, we discussed the different health benefits of Piper betle leaf and also have the product description that have a significant impact on the economic value of the manufacturer. Betel leaf compounds such as essential oil, its potential as bio preservative, and product development that pave the way for business development are discussed in this review. By reading this article, technical readers will be able to understand the most recent research conducted on various topics related to the various aspects of Betel leaf.This article provides almost all the essential information in one place related to Betel Leaf products used for food development.

References:

1. Agarwal K and Gupta SK. "An improved microwave extraction method for distillation of essential oil from Piper betle L". (2018). International Journal for Research in Applied Science and Enggineering Technology 6.1: 1-4.
2. Amaresh A., et al. (2017). "Comparative Study of Microwave Assisted Hydro-Distillation with Conventional Hydro-Distillation for Extraction of Essential Oil from Piper betle L". Biosciences, Biotechnology Research Asia 14.1: 401-4.
3. Arambewela LSR, Arawwawala LDAM, Ratnasooriya WD. (2005). Antidiabetic activities of aqueous and ethanolic extracts of Piper betle leaves in rats. J Ethnopharmacol 102: 239-245.
4. Arambewela LSR, Arawwawala LDAM, Ratnasooriya WD. (2005). Antidiabetic activities of aqueous and ethanolic extracts of Piper betle leaves in rats. Journal Ethnopharma -cology.; 102:239-245.
5. Arsad NH., et al. (2016). "Effect of operating conditions of supercritical carbon dioxide on piper betle leave oil yield and antioxidant activity". International Journal of Applied Chemistry 12.4: 741-751.
6. Arsad NH., et al. (2017). "Optimization and effect of supercritical carbon dioxide extraction conditions on global oil yield and eugenol from piper betle leaves". Malaysian Journal of Fundamental and Applied Sciences 13.4: 680-684.
7. Badola R., et al. (2022). "Khoa and khoa based traditional dairy products: preparation, spoilage and shelf-life extension". Journal of Food Science and Technology: 1-13.
8. Badola R., et al. (2022). "Khoa and khoa based traditional dairy products: preparation, spoilage and shelf-life extension". Journal of Food Science and Technology: 1-13.
9. Banu SS., et al. (2021). "Evaluation of quality attributes and characterization of bio-active components in betel leaf blended fruit squashes using GC-MS"
10. Bhargava A and Tyagi G. (2011). "Acceptability of betel and mint leaves recipes among the population by sensory evaluation". Asian Journal of Home Science 6.2: 137-139.
11. Caburian AB, Osi MO (2010) Characterization and Evaluation of Antimicrobial Activity of the Essential Oil from the Leaves of Piper betle L. E-International Sci Res J 2: 2-13.
12. Ceriello A. (2004). Impaired glucose tolerance and cardiovascular disease: the possible role of post-prandial hyperglycemia. **American heart journal**. 147(5); 803-807.
13. Cristian B. Mejos, Joshua G. Poblete, Paula Jean C. Sarino, Ma. Fatima I. Cruzada. (2023). Antibacterial Activity of Andrographis paniculata and Piper betle and their Interactive Effects with Amoxicillin Against Selected Respiratory Pathogens.
14. Foo LW., et al. (2015). "Extraction and Qualitative Analysis of Piper Betle Leaves for Antimicrobial Activities". SitiNur Hana Mamat

International Journal of Engineering Technology Science and Research IJETSR 2.2: 2394-3386.

15. Foo LW., et al. (2015). "Extraction and Qualitative Analysis of Piper Betle Leaves for Antimicrobial Activities". SitiNur Hana Mamat International Journal of Engineering Technology Science and Research IJETSR 2.2: 2394-3386.
16. Guha P. "Betel leaf: the neglected green gold of India". Journal of Human Ecology 19.2 (2006): 87-93.
17. Guha P., et al. (2017). "Comparative Study of Microwave Assisted Hydro-Distillation with Conventional Hydro-Distillation for Extraction of Essential Oil from Piper betle L". Biosciences Biotechnology Research Asia 14.1: 401-407.
18. Hakim ZS, Patel BK and Goyal RK. (1997). Effects of chronic ramipril treatment in streptozotocin-induced diabetic rats. **Indian journal of physiology and pharmacology**. 41(4); 353-360.
19. Hans N. (2017). "Comparison of ultrasound assisted and conventional methods of extraction of essential oil from betel leaf (Piper betle L.)". M. Tech Thesis (under the Supervision of Prof. P. Guha), Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur (WB), India
20. Jandu R., et al. (2022). "Development and nutritional evaluation of sev prepared by incorporation of fresh betel leaves (Piper betle L.) slurry
21. Kaleem M, Sheema SH, Bano B. (2005). Protective effects of Piper nigrum and Vinca rosea in alloxan induced diabetic rats. Indian J Physiol Pharmacol.; 49(1):65-71.
22. Kamal T, Nazir KHMNH, Parvej MS, Rahman MT, Rahman M, et al. (2018) Remedy of contamination of multidrug resistant Salmonella and Escherichia coli from betel leaves (Piper betle) keeping them fresh for long time. J Adv Vet Anim Res 5: 73-80.
23. Madhumita M., et al. (2019). "Optimization of the exhaustive hydrodistillation method in the recovery of essential oil from fresh and cured betel leaves (Piper betle L.) using the Box--Behnken design". Journal of Food Processing and Preservation 43.11: e14196.
24. Mugale A., et al. (2018). "Sensory analysis of whey-based mango beverage using betel leaves distillate". International Journal of Agricultural Engineering 11: 182-184.
25. Nande P., et al. "Evaluation of nutritive value and acceptability of recipes prepared from spinach and betel leaves". (2007). The Indian Journal of Nutrition and Dietetics 44.10: 476-483.
26. Noor Azleen, Mohamad Amirah, Abdul Rahman Siti,Hamimah Sheikh Abdul Kadir. (2022). "Hydroxychavicol as a potential anticancer agent (Review)".
27. Nouri L., et al. (2015). "Mechanical and Sensory Evaluation of Noodles Incorporated with Betel Leaf Extract". International Journal of Food Engineering 11.2: 221-227.
28. Pin KY., et al. (2010). "Antioxidant and anti-inflammatory activities of extracts of betel leaves (Piper betle) from solvents with different polarities". Journal of Tropical Forest Science 22.4 448-455.
29. Rai MP., et al. (2011). "Piper betel Linn (betel vine), the maligned southeast asian medicinal plant possesses cancer preventive effects: Time to reconsider the wronged opinion". Asian Pacific Journal of Cancer Prevention 12.9: 2149-2156.
30. Rai MP., et al. (2011). "Piper betel Linn (betel vine), the maligned southeast asian medicinal plant possesses cancer preventive effects: Time to reconsider the wronged opinion". Asian Pacif fic Journal of Cancer Prevention 12.9: 2149-2156.
31. Rajkumar L, Srinivasan N, Balasubramanian K and Govindarajulu P. (I1991). Increased degradation of dermal collagen in diabetic rats. I**ndian journal of experimental biology**. 29(11); 1081-1083.
32. Sangeetha Karunanithi, Gnana Moorthy Eswaran U, Proshanta Guha and Prem Prakash Srivastav. (2022). "A Review on Piper betle L.: Antioxidant, Antimicrobial, Extraction and Application in Food Product Development".
33. Sarma C, Rasane P, Kaur S, Jyoti S, Joginder S, et al. (2018). Antioxidant and antimicrobial potential of selected varieties of piper betle L. (Betel leaf). An Acad Bras Cienc 90: 3871-3878.
34. Shivakumar GM and Dhanalakshmi B. (2015). "STUDIES ON ENHANCING THE SHELF LIFE OF RAW MILK USING HERBAL EXTRACTS". STUDIES 2.4
35. Silva NCC, Fernandes A. (2010). Biological properties of medicinal plants: A review of their antimicrobial activity. J Venom Anim Toxins Incl Trop Dis 16: 402-413.
36. Sivakumar GM and Dhanalakshmi B. (2015). "Physico-Chemical and Organoleptic Evaluation of Dahi Prepared with Betel Leaf Extract". Department of Livestock Products Technology (Dairy Science) 3.1: 134-139.

37. Sivakumar GM and Dhanalakshmi B. "Physico-Chemical and Organoleptic Evaluation of Dahi Prepared with Betel Leaf Extract". Department of Livestock Products Technology (Dairy Science) 3.1 (2015): 134-139.
38. Tarun A, Rachana S, Amar Deep S, Imran W, Ankita G (2012) Comparative analysis of antibacterial activity of four piper betel varieties. Adv Appl Sci Res 3: 698-705.
39. Wendy Voon WY., et al. (2014). "Application of betel leaves (Piper betle L.) extract for preservation of homemade chili bo". International Food Research Journal 21.6: 2399-2403.