International Journal of Plant & Soil Science

Volume 35, Issue 18, Page 427-437, 2023; Article no.IJPSS.102310
ISSN: 2320-7035

Phytochemical and Biological Properties of Domesticated Capsicum Species: A Review

Bankey Lal [a++], Anshu Kamboj [b#], Vipul Pratap Singh [b++*], Bhanu Prakash Singh [c†], Anup Pratap Singh [d‡] and Sudhir Kumar Mishra [e†]

[a] *School of Agriculture, RNB Global University, Bikaner-334601, Rajasthan, India.*
[b] *School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh-147301, India.*
[c] *Banda University of Agriculture and Technology, Banda-210001, UP, India.*
[d] *ICAR-IIVR, KVK, Deoria-274001, UP, India.*
[e] *National P.G. College, Barhalganj, Gorakhpur-273402, UP, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i183307

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/102310

Review Article

Received: 25/04/2023
Accepted: 29/06/2023
Published: 19/07/2023

ABSTRACT

America is the original home of the *Capsicum genus* (Solanaceae). It is now a significant agricultural crop grown all over the world, not only for its commercial significance but also for the fruits' high nutritional worth. Capsicum and its various variants have many beneficial qualities that set them apart from other vegetables. They are also used as a spice in many foods due to its potent, pungent flavour, which is created during the plant's secondary metabolism. Due to the

[++] *Assistant Professor;*
[#] *M.Sc. (Agriculture) Horticulture;*
[†] *Research Scholar;*
[‡] *Young Professional;*
**Corresponding author: E-mail: svipul804@gmail.com;*

presence of carotenoids, which can be utilised as a natural colouring agent and antioxidant, capsicum fruit displays a diverse colour profile. Capsaicinoids, one of their phytochemical components, give sharp-tasting cultivars their typical pungency. Capsicum and its capsaicinoids, particularly capsaicin, have also received a lot of research attention due to their health advantages. Additionally, the essential oils from capsicum are used in cosmetics as anti-aging ingredients. Thus, this study covers the scientific literature on Capsicum species and their phytochemicals, which have been shown to have protective effects against cancer, diabetes, gastrointestinal disorders, pain, and metabolic syndrome as well as having antibacterial and antioxidant properties. The chemical and functional characteristics of the bioactive chemicals derived from capsicum and their successful application in the pharmaceutical, food, agricultural, cosmetic, and textile sectors.

Keywords: Capsicum; capsaicinoids; capsaicin; carotenoids; metabolic syndrome; pungency.

1. INTRODUCTION

According to Srinivasan [1] medicinal plants are important natural treatments for the treatment of a variety of disorders. According to Masjedi et al [2] natural compounds from higher plants may offer a fresh source of therapeutic agents with potentially novel modes of action. Worldwide cultivation and use of Capsicum spp. is common [3]. They are a part of the 2000 species and 90 genera that make up the Solanaceae family. Vegetables like pepper, tomato, and potato are members of this plant family, which is indigenous to the Americas [4]. Capsicum, sometimes known as pepper, is an annual herbaceous plant that belongs to the Solanaceae family. The most frequently cultivated spice in the world is *Capsicum annuum* L., which is renowned for its pungency, scent, and colour qualities. One of the five domesticated species, together with *C. baccatum* L., *C. chinense Jacq*., *C. frutescens* L., and *C. pubescens*, it belongs to the Capsicum genus, which has about 30 species [5,6]. According to Meghvansi et al. [7], chilli peppers, often known as chiles, chillies, or simply chillies, were the first crops. Furthermore, Aztecs and Mayans have been using Capsicum species in traditional medicine from pre-Hispanic times. Due to its economic significance and the high nutritional content of the fruits, this genus is now grown throughout the world, including in tropical, subtropical, and temperate regions of Africa, Asia, and America as well as the Mediterranean basin (Table 1). *C. chinense*, *C. annuum*, *C. pubescens*, *C. baccatum*, and *C. frutescens* are a few of the five recognised cultivated species of this genus [8], [9]. Vitamins C and E, provitamin A, carotenoids, and phenolic compounds are all abundant in peppers and contribute to the plant food's overall antioxidant activity and bioactive qualities [4]. Capsaicinoids, which are vanillylamine coupled with a branched-chain fatty acid to form capsaicin and dihydrocapsaicin (Fig. 1), are the most distinctive phenolic compounds discovered in pepper fruits and are in charge of 90% of the pungency of peppers [10]. The cultivar and species of *Capsicum* determine how pungent they are. According to Ammar et al. [11], the concentration of these chemicals can range from being undetectable in some non-pungent cultivars to 664 mg/100 g in pungent cultivars. Due to its use in traditional medicines to treat conditions including ulcers, toothaches, rheumatism, alopecia, and diabetes, capsicum has been shown to be quite useful [12]. The chemical makeup of the capsicum fruit is likewise distinct because it contains flavonoids, alkaloids, and carotenoids that are phenolic chemicals that have favourable impacts on human health [13]. Due to the existence of numerous chemical compounds with possible medicinal qualities, *C. annuum* has been the focus of pharmacological study in addition to its usage as a food ingredient [14]. However, the chemical profile varies depending on a number of variables, including species, seasonality, climatic conditions, and plant life cycle [15].

Nearly all types of capsicum, including the green, sweet, and hot forms, are abundant in significant phytochemicals including flavonoids and polyphenols, which are recognised as bioactive food elements [16]. The glycosides and aglycones quercetin, myricetin, luteolin, kaempferol, and apigenin are among the other phytochemicals found in capsicum [17]. While the glycosyltransferase enzymes naturally occur in the secondary metabolites of plants and catalyse the synthesis of glycosides. Aglycone and glycone (the sugar moiety) are two functionally distinct portions of glycosides that are only loosely linked by glycosidic linkage [18,19]. The most common plant glycosides are O-glycosides, which are generated by the glycosidic bond with oxygen, and C-glycosides, which are formed by the glycosidic bond with carbon and are the most resistant to hydrolysis [20]. Numerous researches have been done to identify carbon and oxygen glycosides utilising methods including ultraviolet spectrum analysis and mass spectrometry fragmentation. These studies' findings point to the presence of four different types of quercetin (3O-rhamnoside, 3-O-glucoside-7-O-rhamnoside, and

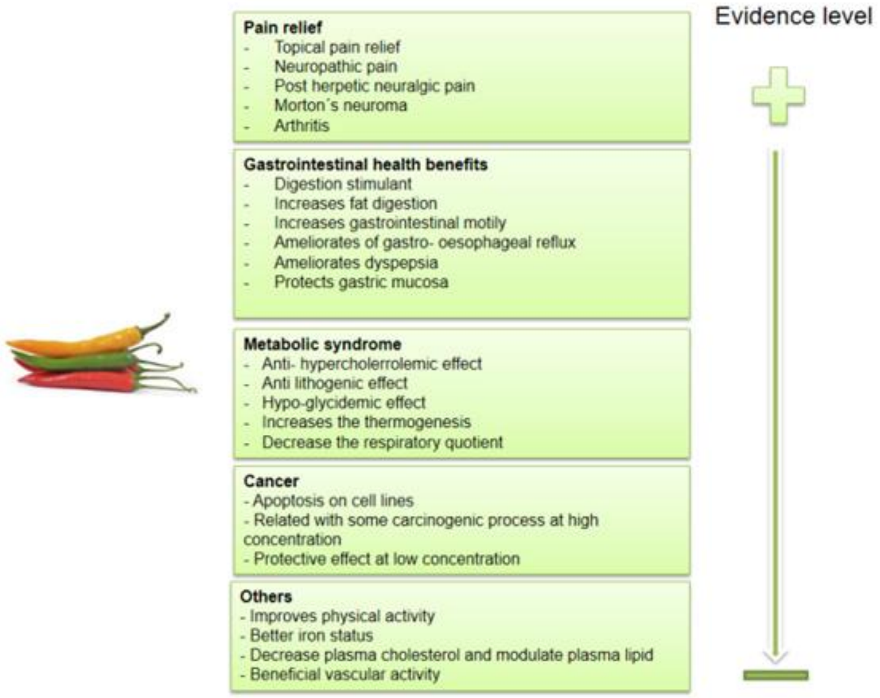

Fig. 1. Example of health benefits of the consumption of *Capsicum* spp.

Table 1. Nutritional composition of *Capsicum* spp. fruit (per 100 g of edible portion) [21]

Nutrients	Spices, pepper, red or cayenne	Peppers, sweet, green, raw	Peppers, hot chili, green, raw	Peppers, sweet, yellow, raw
Water (g)	8.05	93.89	87.74	92.02
Protein (g)	12.01	0.86	2.00	1.00
Energy (kcal)	318	20	40	27
Carbohydrate (g)	56.63	4.64	9.46	6.32
Calcium (mg)	148	10	18	11
Phosphorus (mg)	293	20	46	24
Selenium (µg)	8.8	0.0	0.5	0.3
Iron (mg)	7.80	0.34	1.20	4
Sodium (mg)	30	3	7	2
Copper (mg)	0.373	0.066	0.30	0.107
Potassium (mg)	2014	175	340	212
Fatty acids, total saturated (g)	3.260	0.058	0.021	0.031
Fatty acids, total monounsaturated (g)	2.750	0.008	0.011	
Total lipids (fat) (g)	17.27	0.17	0.20	0.21
Ash (g)	6.04	0.43	0.60	0.45
Niacin (mg)	8.701	0.480	0.950	0.890
Vitamin C, total ascorbic (mg)	76.4	80.4	242.5	183.5
Thiamin (mg)	0.328	0.047	0.090	0.028
Vitamin B-6 (mg)	2.450	0.224	0.278	0.168
Carotene, beta (mg)	21.84	0.208	0.671	0.120
Cryptoxanthin, beta (mg)	6.252	0.007	0.050	

Composition data obtained from the National Nutrient Database for Standard Reference Release 28, USDA Food Composition database (https://ndb.nal.usda.gov/ndb/; accesed 18/11/2017) quercetin glycosylated), two luteolin O-glycosides (apiosyl-acetylglucoside and 7-O-2-apiosylglucoside), five luteolin C-glycosides (6-C-hexoside, 8- In capsicum fruits, the concentration of various bioactive substances varies depending on the species, genetic characteristics, growth and developmental stages, as well as ecological factors. Among all the fruits in this family, the red fruits of cultivars of capsicum have the highest concentration of bioactive chemicals, and the green fruits have high quercetin content. 3-O-R-Lrhamnopyranoside whose concentration decreases as the fruit ripens.

“But in the case of capsicum, the bioactive substances are present in appreciably sufficient amounts and are in charge of numerous cellular and physiological functions. The major anthocyanin found in some species of red and purple capsicums is delphinidin-3 transcoumaroylrutinoside5-glucoside, whereas the total amount of anthocyanin present in fruits ranges from 0.5 mg per 100 g to 28 mg per 100 g in ripe yellow to ripe red fruit, respectively” [22].

2. PUNGENCY – A CHARACTERISTIC TRAIT OF CAPSICUM

The primary characteristic of almost all types of capsicum is pungency, or "heat," which is due to the popularity of the plant's use as a spice. Pun1 and pAMT have been shown to be the two genes that control the synthesis of pungency in capsicum Tsurumaki and Sasanuma [23]. “When plants create different helpful compounds for humans via either of the two methods, i.e. the phenylpropanoid system or the branched-chain fatty acid pathway, they develop this appealing quality of pungency in the capsicum plants” Naves et al*.* [24]. “Capsaicinoids, a type of alkaloids that are biosynthesized and eventually build up in the placental tissue during secondary metabolism in capsicum, are the primary substances accountable for chilli peppers' spiciness. Capsaicin and dihydrocapsaicin are the two main representative families of capsaicinoids involved in pungency” Aza-González et al. [25]. “A hydrophobic, colourless, and odourless molecule known as capsaicin (trans-8-methyl-N-vanillyl-6nonenamide), an HVA derivative, can serve as a deterrent against herbivores as well as microbial and fungal attacks” Basith et al*.* [26]. “In placental tissue (where the seeds connect), inner membranes, and to a lesser extent, the fleshy sections of the fruit, capsaicin is found in high amounts” Srinivasan [1]. Nordihydrocapsaicin (7.4%), norcapsaicin, homocapsaicin I, homodihydrocapsaicin I (2%), homocapsaicin II (2%), homodihydrocapsaicin II, and nonivamide are among the minor capsaicinoids discovered in chilli fruits Guillen et al*.* [27]. The amount of capsaicinoids present directly correlates with the pungency of the capsicum plant; especially they include capsaicins Parvez [14]. The formation of analogues with various levels of pungency in capsicum fruits has been linked to a variation in the acid component of the capsaicin. The fruit of C. chinense is thought to be the most pungent among the domesticated species of the genus Capsicum Chapa-Oliver et al*.* [28].

2.1 Synthesis and Accumulation of Pungent Compounds

The placental tissues, pericarp, seeds, and other vegetative organs all synthesise capsaicinoids including the capsicum plant's stems and leaves. The majority of capsaicinoids are created in the first 20 to 50 days after anthesis, when the fruit is developing, and this rate of synthesis rises as the fruit ages. Genotype, fruit ripeness, as well as environmental elements including water availability and solar energy, are other factors that affect the generation of capsaicinoids [29]. The phenylpropanoid pathway and the branched-chain fatty acid pathway are the two biosynthetic pathways for capsaicinoids. Valine (or leucine), the primary precursor of the fatty acid pathway, is combined with the primary precursor of the phenylpropanoid pathway, phenylalanine, to create vanillylamine, which is crucial for the formation of capsaicinoids and their eventual accumulation in the placental tissue of the fruit [30]. Numerous putative enzymes and genes that code for proteins are thought to be involved in the manufacture of capsaicinoids.

2.2 Coloring Compounds of Capsicum

One of the key markers of quality for both fresh pepper fruit and the food items made from it is colour. The colour of mature and fully ripened fruit of all species in the genus Capsicum is determined by four genes (y, c1, c2, cl), and about 20 carotenoids Mamedov et al*.* [31]. The isoprenoid (or mevalonate) route produces the extremely lipid-soluble terpenoids known as carotenoid colours, which are primarily preserved in the chromoplasts of capsicum fruit. The chemical structure of the carotenoids is made up of 5-carbon isoprenoid groups with an alternate double bond. Carotenoids typically feature a 40-carbon isoprene structural backbone with the aromatic ring structures at one or both ends of the molecule Arimboor et al. [32].

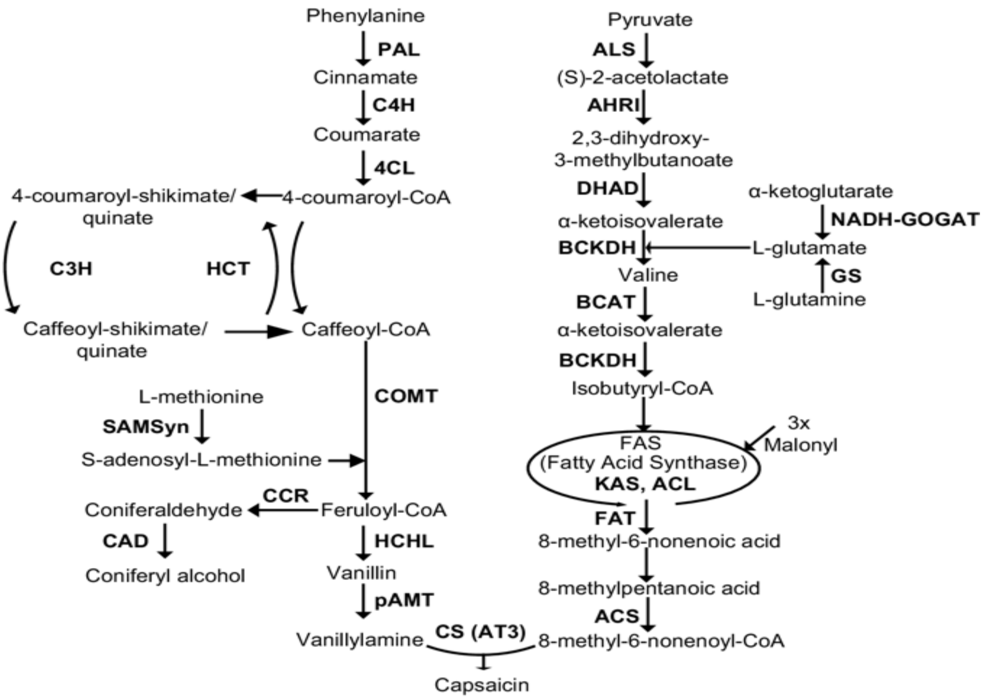

Fig. 2. Model pathway of capsaicin (capsaicinoids) biosynthesis in capsicum [30]

Different types of Capsicum include carotenoids that are present in a variety of colours, including yellow, orange, and red. As the fruit ripens, these carotenoids grow and change colour. The ratio of carotenoids to chlorophyll in capsicum fruit has been found to be 32:68 during the start of fruit ripening, giving the fruits their green colour Mohd Hassan et al. [33]. Capsanthin and capsorubin, two important carotenoids, are in charge of the capsicum's red colour, while lutein is in charge of the green and yellow variations. Additionally, the presence of -carotenes, cryptoxanthin, zeaxanthin, violaxanthin, antheraxanthin, and cucurbitaxanthin A is responsible for the yellow to orange colour of capsicum. According to reports, these carotenoids have crucial roles to play. Besides giving the capsicum fruit colour, they also play several biological and health-related aspects Kim et al. [34].

3. BIOLOGICAL ACTIVITIES OF CAPSICUM PLANT EXTRACTS AND THEIR CONSTITUENTS: POTENTIAL AS A FUNCTIONAL INGREDIENT

3.1 Antioxidant Activity

Among the phytochemicals found in capsicum, carotenoids play an important role in colouring peppers and protecting cells and tissues from damaging reactive oxygen species (ROS) by scavenging singlet molecular oxygen, peroxyl radicals, and reactive nitrogen species (RNS). However, a large portion of Capsicum spp.'s total antioxidant activity is linked to its phenolic composition, not just to its vitamin and carotenoid content. In general, the quantity of antioxidants (carotenoids, flavonoids, phenolic acids, and ascorbic acid) increases with fruit maturation in C. annuum, C. frutescens, and C. chinense along with the antioxidant activity measured in vitro. Additionally, compared to other vegetables, capsicum has a stronger antioxidant activity. In this regard, [4] recent study revealed that, among the red 'California' pepper, the 'Fino' lemon, and the red onion all showed the highest antioxidant capacity in the TEAC (trolox equivalent antioxidant capacity), FRAP (ferric ion reducing antioxidant power), and ORAC (oxygen radical absorbance capacity) assays, respectively, of 44 cultivars of fruits and vegetables grown in Andalusia (Spain). Note that the major components of this red pepper are hydroxycinnamic acids and flavonoid glycosides, and that it is nonpungent. In other trials, however, the presence of metal ions may result in a possible pro-oxidant impact of capsicum flavonoids Howard et al. [35]. Additionally, capsaicin has demonstrated antioxidant properties similar to butylhydroxyanisole (BHA), preventing the oxidation of human low density lipoprotein (LDL), which inhibits the lipid peroxidation caused by cooper ions and lessens the production of TBARS Naidu and Thippeswamy [36].

3.2 Antimicrobial Activity

Both helpful and harmful bacteria strains have been successfully combated by the polyphenolic chemicals found in capsicum. Standard gram-positive and gram-negative bacterial strains were employed as test organisms to determine antibiotic sensitivity. Salmonella enterica serovar Typhimurium ATCC 13311, Bacillus subtilis ATCC 6633, Listeria monocytogenes sub sp. lactis Bb12, Lactobacillus acidophilus CECT 4529, Lactobacillus plantarum CECT 748, and six wild-type strains of S. aureus (8, 14, 26, 32, 550, 319) are among the bacteria that have been identified Mokhta et al. [37]. In terms of preventing the growth of several bacterial and fungal organisms like L. monocytogenes and Aspergillus flavus, C. annuum ethanol extracts demonstrated remarkable effectiveness Anikwe et al. [38]. The methanolic extract from red pepper was examined and found to be efficient against the drug-resistant Vibrio cholerae strains, according to a study by Yamasaki et al. [39]. According to a different study, *C. frutescens* seed extracts in n-hexane and chloroform were highly effective against a variety of pathogenic microbes, including *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Staphylococcus aureus*, *Candida albicans*, *Candida krusei*, *Alternaria alternata*, and *Aspergillus niger*.

3.3 Antitumor Properties

Regarding its use in a variety of medical applications, capsaicin has attracted a lot of interest. By triggering apoptosis in these cells, it has been discovered to be efficacious and to exhibit protective characteristics against numerous mutagenic and tumor-causing cells. The tumor-associated NADH-oxidase (tNOX) enzyme, which contributes in promoting cellular growth close to the plasma membranes, is responsible for this action of capsaicin Della et al. [40]. Carotenes, which have antimutagenic and anticarcinogenic characteristics, are abundant in chilli peppers. According to the research, using the red pepper extract decreased the genotoxic activity of urethane in yeast cells, bacteria, and mammal cells. According to the findings, carotenoids and capsaicinoids have a significant anti-mutagenic effect Laohavechvanich et al. [41].

It is believed that the i (ICD), a process involving the early surface exposure to calreticulin (CRT), a multifunctional chaperone protein, is the mechanism underlying the activity of capsaicinoids. In a study, it was discovered that the chemotherapeutic drug cisplatin and the capsaicin compounds boosted CRT expression, which increased ICD induction and increased cell death in human osteosarcoma cells (OCs) MG-63. In particular, capsaicin therapy has been linked to the translocation of calreticulin from the internal membranes to the outer cell surface, increasing MG-63 cell phagocytosis and stimulating interferongamma (IFN-) release. As a result, this led to the induction of apoptosis, which ultimately prevented the proliferation of bladder cancer cells by inhibiting their activity. Comprising the sirtuin 1 (SIRT1) protein and the tNOX enzyme. In addition, it was found that capsaicin significantly decreased the expression and activity of numerous proteins linked to cell cycle progression, which in turn decreased the rates of cancer cell proliferation and migration Jin et al. [42]; Lin et al. [43]. The majority of the findings published in the literature demonstrated that high doses of capsaicin used to treat malignancies stimulate the proliferation of tumour cells while modest doses of capsaicin used to treat cancers suppress the growth of numerous human cancers.

3.4 Antidiabetic Role

Since capsaicin's alkaloids have been shown to be helpful at controlling blood glucose levels, they may one day be utilised to treat diabetes in people. A study revealed that the capsicum fruit's crude extract assisted in preventing the intestinal absorption of glucose and likely helped lower blood sugar levels. GDM poses a serious health danger to both expectant mothers and their unborn children in the future. 42 women who were between 22 and 33 weeks pregnant participated in a trial in which capsaicin pills (5 mg/day) were given to them. According to the study's findings, capsaicin-rich supplements for chilli helped women with gestational diabetes' postprandial hyperglycemia and hyperinsulinemia as well as their fasting lipid metabolic abnormalities. They also dramatically decreased the incidence of large-forgestational-diabetes [44].

3.5 Cardiovascular Role

Dihydrocapsaicin is one of several capsaicinoids that have been shown to lower inflammatory cytokines like interleukin 1 beta (IL-1 beta), IL-6, tumour necrosis factor-alpha (TNF-alpha), and C-reactive protein (CRP), as well as plasma cholesterol, LDL-C, VLDL-C, and triglycerides. Apolipoprotein A1 (apoA1) and high-density lipoprotein cholesterol (HDL-C) levels in plasma also significantly increased. The findings of capsaicinoids inhibited cholesterol absorption by lowering plasma cholesterol levels were further supported by the plasma sterol study. Due to its role in raising HDL levels, dihydrocapsaicin actively enhanced the CRT pathway, which in turn suppressed the formation of atherosclerosis plaques and promoted cholesterol efflux in THP-1 macrophagederived foam cells Hu et al. [45]. The metabolic syndrome, which includes high blood sugar, obesity, dyslipidemia, and hypertension, is frequently considered to be a significant risk factor for the onset of CVDs and subsequent death. The effects of capsaicin on lowering blood cholesterol levels, lowering blood glucose levels, preventing hyperglycemic episodes, and atherosclerosis incidence and prevalence have been the subject of several investigations, both in vivo and in vitro. The findings of the research showed that capsaicin reduced intestinal cholesterol absorption and had an anti-hyperlipidemic impact. The activation of the PPAR, or peroxisome proliferator-activated receptor, may possibly be a part in this impact. Capsaicins' favourable antidiabetic, antihypertensive, and anti-obesity properties make them perfect for use and has the potential to greatly lower the risk of mortality from cardiovascular diseases and the treatment of metabolic syndrome [46].

3.6 Anti-Inflammatory Activity

Inflammation is a biological defence mechanism that can be brought on by a variety of things, including injury, infection, and toxic substances If it persists, inflammation can become a pathological disease. Bioactive chemicals derived from capsicum, such as polyphenols, flavonoids, tocopherols, capsaicinoids, and capsinoids, have been shown in several studies to have anti-inflammatory properties Bhattacharya et al. [47]; Luo et al. [48]. The capsicum's ability to reduce inflammation is caused by its ability to inhibit (LOX). Capsicum cultivars showed different levels of lipoxygenase inhibition, with green capsicum recording the greatest level (46.12%), followed by yellow (44.09%), and red capsicum (32.18%). Capsaicin has well-established anti-inflammatory qualities, and it is frequently used in topical gel and cream formulations for pain treatment. Inducing the inflammatory response, capsaicin releases pro-inflammatory mediators that then activate the TRPV1 (transient receptor potential cation channel subfamily V member 1, also known as capsaicin receptors) channels linked to thermoreception and nociception Basith et al. [26]; Luo et al. [48]. Capsaicin suppressed the production of prostaglandin E2 (PGE2) hormone by inhibiting the activity of the cyclooxygenase-2 (COX-2) enzyme and the expression of inducible nitric oxide synthase (iNOS), according to a study to assess the anti-inflammatory effect in murine peritoneal macrophages produced by LPS. Capsaicin administration finally resulted in a decrease in inflammation since prostaglandins, COX-2, and iNOS are important proinflammatory mediators Luo et al. [48].

4. PAIN RELIEF

As topical painkillers, natural capsaicinoids from chilli peppers have drawn a lot of interest. The use of creams, ointments, and patches to treat many types of pain, particularly neuropathic pain, has taken advantage of this distinctive feature of capsaicin Derry et al. [49]. In two studies, topical creams containing 0.075% or 0.025% of capsaicin Deal et al. [50] reduced pain in 21% and 70%, respectively, of individuals with osteoarthritis and rheumatoid arthritis. Topical application of 0.075% capsaicin reduced pain in a trial including 219 men and women with severe diabetic neuropathy and researchers from 12 sites, improving daily activities and improving patient quality of life Group [51]. Adults appear to experience some alleviation from chronic neuropathic pain when a low dose capsaicin cream (0.075%) or a high dose patch (8%) is applied repeatedly. In individuals with neuropathic pain, a single 60-minute application of a capsaicin 8% patch provided excellent pain relief for up to 12 weeks. This finding suggests that high-concentration capsaicin products offer the advantages of a longer duration of action and a lower risk of systemic side effects. Additionally, lotions containing capsaicin are used to treat psoriasis, lowering swelling and irritation. In post-herpetic neuralgia pain, a painful condition that happens after the dormant herpes zoster virus reactivates, the application of an 8% capsaicin patch has shown to be effective and long-lasting Mankowski et al. [52] [53].

5. CONCLUSIONS

Different types of capsicum and its derivatives have become more and more popular over the past few years. The capsicum plant has significant uses in a wide range of industries, including food, agriculture, medicine, pharmaceuticals, and cosmetics. It also includes a huge diversity of bioactive chemicals. Historically, the majority of capsicum research has concentrated on the biosynthesis, characterization, and potential extraction techniques of these bioactive components utilizing various solvents. However, more lately, the research agenda has undergone a paradigm change in favour of the idea of using capsicum for a variety of purposes. An effort has been made to highlight the chemical and functional characteristics of capsicum in the writing of this review paper.

6. FUTURE PROSPECTS

The fruit of the cayenne pepper and its related parts are potential resources that have a wide range of applications. The agro-food and textile industries have both benefited from this plant's byproducts. The importance and possibilities of this plant are numerous as the trend away from synthetic chemicals towards natural substances is accelerating. Due to the presence of capsaicinoids, carotenoids, and polyphenolic chemicals, products generated from capsicum, such as chilli powder, oleoresins, refined extracts, and enhanced fractions, are frequently utilized in food and medicine. To create more adaptable and healthier food items, greater research into these bioactive components is necessary.

Additionally, these items must be standardised in order to improve their marketing from the standpoint of pungency, colour, flavour, and scent, which are now lacking. There are no standardised recommendations in the literature for preserving the stability, security, and quality of goods made from capsicum, particularly those used in food, medicine, and cosmetics. Therefore, further study is needed to develop creative methods for boosting extraction effectiveness, developing bioactive chemical isolation methods, and increasing the uses of these functional components across many industries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Srinivasan K. Biological activities of red pepper (*Capsicum annuum*) and its pungent principle capsaicin: A review. Critical Review in Food Sciences and Nutrition. 2016;56(9):1488-1500.
2. Masjedi J, Sharifi-Rad R, Setzer WN, Sharifi-Rad M, Kobarfard F, Rahman AU, Choudhary MI, Ata A, Iriti M. Medicinal plants used in the treatment of tuberculosis - Ethnobotanical and ethno-pharmacological approaches. Biotechnology Advances; 2017.
   Available:https://doi.org/10.1016/j.biotechadv.2017.07.001
3. Hebbar SS, Balakrishna B, Prabhakar M, Srinivas V, Nair AK, Ravikumar GS, Ganeshan G, Sharma D, Sudhakar Rao DV, Doijode SD, Hegde MR, Rao MS. Protected cultivation of *Capsicum*. Indian Institute of Horticultural Research, Technical Bulletin. 2011;22.
4. Morales-Soto A, Gómez-Caravaca A M, García-Salas P, Segura-Carretero A, Fernández-Gutiérrez A. High-performance liquid chromatography coupled to diode array and electrospray time-of-flight mass spectrometry detectors for a comprehensive characterization of phenolic and other polar compounds in three pepper (*Capsicum annuum* L.) samples. Food Research International. 2013;51:977-984.
5. Gebhardt C. The historical role of species from the Solanaceae plant family in genetic research. Theoretical and Applied Genetics. 2016;129(12):2281-2294.
6. Kraft KH. Multiple lines of evidence for the origin of domesticated chili pepper, Capsicum annuum, in Mexico. Proceedings of the National Academy of Sciences. 2014;111(17):6165-6170.
7. Meghvansi M, Siddiqui S, Khan MH, Gupta V, Vairale M, Gogoi H, Singh L. Naga chilli: a potential source of capsaicinoids with broadspectrum ethnopharmacological applications. Journal of Ethno-pharmacology. 2010;132:1-14.
8. Igbokwe G, Aniakor G, Anagonye C. Determination of β-carotene & vitamin C

content of fresh green pepper (*Capsicum annum*), fresh red pepper (*Capsicum annum*) and fresh tomatoes (*Solanum lycopersicum*). Bioscientist. 2013;1:89-93.

9. Kehie M, Kumaria S, Tandon P. Manipulation of culture strategies to enhance capsaicin biosynthesis in suspension and immobilized cell cultures of *Capsicum chinense* Jacq. cv. Naga King Chili. Bioprocess and Biosystems Engineering. 2014;37:1055-1063.
10. De Jesús Ornelas-Paz J, Martínez-Burrola JM, Ruiz-Cruz S, Santana-Rodríguez V, Ibarra-Junquera V, Olivas GI, Pérez-Martínez JD. Effect of cooking on the capsaicinoids and phenolics contents of Mexican peppers. Food Chemistry. 2010; 119:1619-1625.
11. Ammar S, Del Mar Contreras M, Belguith-Hadrich O, Segura-Carretero A, Bouaziz M. Assessment of the distribution of phenolic compounds and contribution to the antioxidant activity in Tunisian fig leaves, fruits, skins and pulps using mass spectrometry-based analysis. Food and Function. 2015;6:3663-3677.
12. Di Sotto A, Vecchiato M, Abete L, Toniolo C, Giusti AM, Mannina L, Locatelli M, Nicoletti M, Di Giacomo S. *Capsicum annuum* L. var. Cornetto di Pontecorvo PDO: Polyphenolic profile and in vitro biological activities. Journal of Functional Foods. 2018;40:679-691.
13. Chapa-Oliver AM, Mejía-Teniente L. Capsaicin: From plants to a cancer-suppressing agent. Molecule. 2016;21(8): 931.
14. Parvez GM. Current advances in pharmacological activity and toxic effects of various capsicum species. International Journal of Pharmaceutical Sciences and Researches. 2017;8:1900-1912
15. Antonio A, Wiedemann L, VV. The genus Capsicum: A phytochemical review of bioactive secondary metabolites. RSC adv. 2018;8(45):25767-25784.
16. Gurnani N, Gupta M, Mehta D, Mehta BK. Chemical composition, total phenolic and flavonoid contents, and in vitro antimicrobial and antioxidant activities of crude extracts from red chilli seeds (*Capsicum frutescens* L.). Journal of Taibah University Sciences. 2016;10(4): 462-470.
17. Imran M, Butt MS, Suleria HAR. *Capsicum annuum* bioactive compounds: Health promotion perspectives. Bioactive Molecules in Food. 2018;1-22.
18. Sharifi-Rad M, Varoni EM, Iriti M, Martorell M, Setzer WN, Del Mar Contreras M, Salehi B, Soltani-Nejad A, Rajabi S, Tajbakhsh M, Sharifi-Rad J. Carvacrol and human health: A comprehensive review. Phytotherapy Research. 2018;32:1675-1687.
19. Wahyuni Y, Ballester AR, Sudarmonowati E, Bino RJ, Bovy AG. Metabolite biodiversity in pepper (Capsicum) fruits of thirty-two diverse accessions: Variation in health-related compounds and implications for breeding. Phytochemistry. 2011;72:11-12.
20. Bartnik M, Facey P. Glycosides, in Pharmacognosy. Elsevier. 2017;101-161.
21. Vieira Bard GC, Nascimento VV, Oliveira AE, Rodrigues R, Da Cunha M, Dias GB, Vasconcelos IM, Carvalho AO, Gomes VM. Vicilinlike peptides from *Capsicum baccatum* L. seeds are α-amylase inhibitors and exhibit antifungal activity against important yeasts in medical mycology. Biopolymers. 2014;102:335-343.
22. Padilha HKM, Pereira EDS, Barbieri R. Genetic variability for synthesis of bioactive compounds in peppers (*Capsicum annuum*) from Brazil. Food Sciences and Technology. 2015;35(3):516-523.
23. Tsurumaki K, Sasanuma T. Discovery of novel unfunctional pAMT allele pamt10 causing loss of pungency in sweet bell pepper *(Capsicum annuum* L.). Breeding Sciences. 2019;69(1):133-142.
24. Naves ER, Silva L de Avila, Sulpice R, Araujo WL. Capsaicinoids: pungency beyond Capsicum. Trends in Plant Sciences. 2019;24(2):109-120.
25. Aza-González C, Núñez-Palenius HG, Ochoa-Alejo N. Molecular biology of capsaicinoid biosynthesis in chili pepper (*Capsicum* spp.). Plant Cell Reproduction. 2011;30(5):695-706.
26. Basith S, Cui M, Hong S Choi S. Harnessing the therapeutic potential of capsaicin and its analogues in pain and other diseases. Molecules. 2016;21(8): 966.
27. Guillen NG, Tito R, Mendoza NG. Capsaicinoids and pungency in *Capsicum chinense* and *Capsicum baccatum* fruits. Pesquisa Agropecuaria Tropical. 2018;48: 237-244.

28. Chapa-Oliver AM, Mejía-Teniente L. Capsaicin: From plants to a cancer-suppressing agent. Molecule. 2018;21(8): 931.
29. Guillen NG, Tito R, Mendoza NG. Capsaicinoids and pungency in *Capsicum chinense* and *Capsicum baccatum* fruits1. Pesqui Agropecu Trop. 2018; 48:237-244.
30. Arce-Rodríguez ML, Ochoa-Alejo N. Biochemistry and molecular biology of capsaicinoid biosynthesis: Recent advances and perspectives. Plant Cell Rep. 2019:1-14.
31. Mamedov M, Pishnaya ON, Baikov AA, Pivovarov VF, Dzhos EA, Matykina AA and Gins MS Antioxidant contents of pepper Capsicum spp. for use in biofortification. Sel'skokhozyaistvennaya biologiya [Agricultural Biology] 52:5.
32. Arimboor R, Natarajan RB, Menon, KR, Chandrasekhar LP, Moorkoth V. Red pepper *(Capsicum annuum)* carotenoids as a source of natural food colors: analysis and stability—A review. Journal of Food Sciences and Technology. 2015;52(3): 1258-1271.
33. Mohd Hassan N, Yusof NA, Yahaya, AF, Rozali NNM, Othman R. Carotenoids of Capsicum Fruits: Pigment Profile and Health-Promoting Functional Attributes. Antioxidants. 2019;8(10):469.
34. Kim, J.-S, An CG, Park J-S, Lim YP, Kim S. Carotenoid profiling from 27 types of paprika *(Capsicum annuum L.)* with different colors, shapes, and cultivation methods. Food Chemistry. 2016;201:64-71.
35. Howard L, Talcott S, Brenes C, Villalon B. Changes in phytochemical and antioxidant activity of selected pepper cultivars (*Capsicumb*species) as influenced by maturity. Journal of Agricultural and Food Chemistry. 2000;48:1713-1720.
36. Naidu KA, Thippeswamy NB. Inhibition of human low density lipoprotein oxidation by active principles from spices. Molecular and Cellular Biochemistry. 2002;229:19-23.
37. Mokhtar M, Ginestra G, Youcefi F, Filocamo A, Bisignano C, Riazi A. Antimicrobial activity of selected polyphenols and capsaicinoids identified in pepper (*Capsicum annuum* L.) and their possible mode of interaction. Current Micrology. 2017;74(11):1253-1260.
38. Anikwe L, Onoja US, Onyeke CC, Neweze EI. Antimicrobial activities of four varieties of Capsicum annuum fruits cultivated in Southeast Nigeria against multidrug-resistant and susceptible organisms. Journal of Basic Pharmacology and Toxicology. 2017;1(2):21-26.
39. Yamasaki S, Asakura M, Neogi SB, Hinenoya A, Iwaoka E, Aoki S. Inhibition of virulence potential of *Vibrio cholerae* by natural compounds. Indian Journal of Medical Research. 2011;133(2):232.
40. Della Badia A, Spina AA, Vassalotti G. Capsicum annuum L. An Overview of Biological Activities and Potential Nutraceutical Properties in Humans and Animals; 2017.
41. Laohavechvanich P, Kangsadalampai K, Tirawanchai N, Ketterman AJ. Effect of different Thai traditional processing of various hot chili peppers on urethane-induced somatic mutation and recombination in Drosophila melanogaster: Assessment of the role of glutathione transferase activity. Food and Chemical Toxicology. 2006;44(8):1348-1354.
42. Jin T, Wu H, Wang Y, Peng H. Capsaicin induces immunogenic cell death in human osteosarcoma cells. Experimental and Therapeutic Medicine. 2016;12(2):765-770.
43. Lin M.-H, Lie Y-H, Cheng H-L, Chen H-Y, Jhuang F-H, Chueh Pin Ju. Capsaicin inhibits multiple bladder cancer cell phenotypes by inhibiting tumor-associated NADH oxidase (tNOX) and sirtuin1 (SIRT1). Molecules. 2016;21(7):849.
44. Yuan LJ, Qin Y, Wang L, Zeng Y, Chang H, Wang J, Wang B, Wan J, Chen SH, Zhang QY, Zhu JD, Zhou Y, Mi MT. Capsaicin-containing chili improved postprandial hyperglycemia, hyper-insulinemia, and fasting lipid disorders in women with gestational diabetes mellitus and lowered the incidence of large-for-gestational-age newborns. Clinical Nutrition. 2016;35(2):388-393.
45. Hu, Y.-W, Ma X, Huang J-L, Mao X-R, Yang J-Y, Zhao J-Y, Li S F, Qiu Y-R, Yang J, Zheng Li, Wang Q. Dihydrocapsaicin attenuates plaque formation through a PPARγ/LXRα pathway in apoe mice fed a high-fat/high-cholesterol diet. PLoS One. 2013;8(6):66876-66876.
46. Sanati S, Razavi BM, Hosseinzadeh H. A review of the effects of Capsicum annuum L. and its constituent, capsaicin, in

metabolic syndrome. Iran Journal of Basic Medical Sciences. 2018;21(5): 439.
47. Bhattacharya A, Chattopadhyay A, Mazumdar D, Chakravarty A, Pal S. Antioxidant constituents and enzyme activities in chilli peppers. International Journal of Vegetable Sciences. 2010; 16(3):201-211.
48. Luo X-J, Peng J, Li Y-J. Recent advances in the study on capsaicinoids and capsinoids. European Journal of Pharmology. 2010,650(1):1-7.
49. Deal CL, Schnitzer TJ, Lipstein E, Seibold JR, Stevens RM, Levy MD, Albert D, Renold F. Treatment of arthritis with topical capsaicin: A double-blind trial. Clinical Therapeutics. 1991;13:383-395
50. Derry S, Sven-Rice A, Cole P, Tan T, Moore RA. Topical capsaicin (high concentration) for chronic neuropathic pain in adults. Cochrane Database of Systematic Reviews. 2013;2:CD007393.
51. Group CS. Effect of treatment with capsaicin on daily activities of patients with painful diabetic neuropathy. Diabetes Care. 1992;15:159-165.
52. Mankowski C, Poole CD, Ernault E, Thomas R, Berni E, Currie CJ, Treadwell C, Calvo JI, Plastira C, Zafeiropoulou E. Effectiveness of the capsaicin 8% patch in the management of peripheral neuropathic pain in European clinical practice: The ASCEND study. BMC Neurology. 2017;17: 80.
53. Anand P, Bley K. Topical capsaicin for pain management: Therapeutic potential and mechanisms of action of the new high-concentration capsaicin 8% patch. British Journal of Anaesthesiology. 2011;107:490-502.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/102310