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Impact of Different Technologies and Methods to Increase the Shelf Life and Maintain the Sulforaphane Content in Broccoli: A Review

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Authors' contributions

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

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ABSTRACT

Broccoli, a nutrient-rich vegetable known for its sulforaphane content and health benefits, faces challenges related to its short shelf life and susceptibility to spoilage. This study explores various techniques to maintain sulforaphane content and extend broccoli's shelf life. Freezing, although effective for long-term preservation, involves blanching that inactivates myrosinase, preventing sulforaphane formation. Cold storage at 4-5°C slows respiration and senescence, extending shelf

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life up to 14 days while preserving bioactive compounds. Modified atmosphere packaging (MAP) enhances shelf life by altering the package atmosphere, with active packaging using 15% CO2 and 7.5% O2 at 0°C proving particularly effective in reducing bacterial growth and preserving quality. Light exposure, especially with yellow LED lights and moderate UV treatment, retains high levels of glucosinolates and phenolic compounds. Irradiation effectively eliminates pathogens and preserves visual quality, with gamma irradiation slowing the oxidation of phenols and ascorbic acid, although further research is needed on its sensory and nutritional effects. High-pressure processing (HPP), a non-thermal method, significantly boosts sulforaphane bioactivity by converting glucosinolates at pressures up to 600 MPa, despite challenges such as high costs and operational safety, and prevents microbial growth, extending shelf life while maintaining nutritional quality. Additionally, techniques like steaming for optimal durations, microwaving at high power for short times, and stir-frying help preserve sulforaphane content during cooking. Preharvest chemical treatments like chitosan and calcium also enhance broccoli's defence mechanisms and bioactive compound levels. Overall, these methods offer a comprehensive approach to preserving sulforaphane content and extending broccoli's shelf life, providing valuable insights to enhance the storage, quality, and health benefits of broccoli for consumers.

Keywords: Broccoli; health benefits; methods; shelf life; sulforaphane; technologies.

1. INTRODUCTION

Broccoli, scientifically known as *Brassica oleracea* var. italica, is rich in vitamins, minerals, polyphenols, and a group of phytochemicals called glucosinolates (GSLs). It is widely recognised for its high nutritional content. GSLs, or glucosinolates, are secondary metabolites that are abundant in sulphur [1]. They are distinctive features of the *Brassicales* order and play significant roles in plant defence and human nutrition, making them economically important. These chemicals have regained attention due to their significant hydrolysis products, such as sulforaphane, which have chemoprotective properties via interacting with the endogenous enzyme myrosinase [2,3]. Glucoraphanin (GRA) is the most prevalent glucosinolate found in broccoli. It can be converted into sulforaphane by the process of hydrolysis by myrosinase. Sulforaphane exhibits potent anticancer, hepatoprotective, and cardioprotective properties, effectively inhibiting the development or progression of malignancies, hepatic steatosis, and cardiovascular disorders. Broccoli exhibits elevated rates of respiration and transpiration, rendering it extremely susceptible to spoilage [4]. This leads to significant economic losses and presents difficulties in storing, transporting, and managing the supply of crops once they have been harvested. Hence, optimal storage conditions are crucial for retarding the process of deterioration and maintaining the high quality of the perishable item [5]. The high concentration of phytochemicals in cruciferous vegetables is responsible for many of their positive effects. The health advantages have specifically been linked to sulforaphane, which is generated when endogenous myrosinase acts on glucoraphanin, a type of glucosinolate. Sulforaphane is also known as 1-isothiocyanato-4-methylsulfinylbutane [6,5]. Sulforaphane has been associated with diminishing the chances of developing cancer, enhancing cardiovascular well-being, and exhibiting advantageous impacts on neurological disorders, autism, and osteoporosis. An alternate approach to providing glucoraphanin-rich *Brassica* products, together with a source of myrosinase, is to increase the sulforaphane content in broccoli-based products. The initial requirement for producing sulforaphane-rich foods is to optimize the production of sulforaphane during food processing [7].

Numerous post-harvest management techniques have been examined to prolong the shelf life and preserve the nutraceutical properties of broccoli. The process of glucosinolates biosynthesis during development or breakdown during storage is difficult. The impact of post-harvest techniques on glucosinolates has been extensively researched, while there is limited literature on the investigation of sulforaphane [8] The green hue and abundant glucosinolates in broccoli florets are often preserved by storing them at low temperatures or treating them with an ethylene production inhibitor called 1-methylcyclopropene (1-MCP). These two techniques delay the glucosinolates' degradation during storage, maintain the green hue, and increase the shelf life by preventing the breakdown of chlorophyll and glucosinolates [9]. The process of frying broccoli florets can affect how quickly glucosinolates or sulforaphane break down. More often than not, people prepare broccoli at home for convenience and taste rather than to preserve its nutrients and health-promoting ingredients [10]. In Chinese cuisine, steaming and frying are traditional methods, whereas boiling and microwaving are used in western nations. Boiling leads to significant reduction in glucosinolates, most likely due to thermal decomposition [11]. The outcomes of steaming and microwaving vegetables were inconsistent, and the alteration in glucosinolates content varies with time for different cooking techniques. Hence, the ideal duration for steaming or microwaving can enhance or maintain the availability of glucosinolates or sulforaphane and avoid their degradation during extended heating [12-16]. This paper aims to present several methods and techniques that can be utilized to enhance the shelf life and preserve the sulforaphane content in broccoli.

1.1 Quality Attributes of Broccoli

The postharvest qualities of fruits and vegetables are often determined by chemical constituents, physical properties, or a mix of both. These criteria encompass several aspects such as flavor (including taste and aroma), appearance (including colour), texture, and nutritional composition [17]. When considering broccoli, the distinct sensory characteristics of this vegetable exhibit variation among different species. As an illustration, broccoli belonging to the *Fabaceae* family has a bitter taste due to its elevated polyphenol concentration [18]. On the other hand, a significant concentration of glucosinolates imparts a pungent flavour to broccoli belonging to the *Cruciferous* family. Colour is an additional significant exterior quality parameter that has an impact on the overall acceptability. The phenomenon of green vegetables undergoing a colour transition from green to yellow during the postharvest storage period is a significant challenge [19]. The concentration of chlorophyll, a pigment responsible for green colouration, undergoes a notable reduction overtime during the storage of broccoli, leading to a yellow hue. Numerous research has been undertaken to examine the nutritional characteristics of broccoli as a determinant of quality. The evaluation of broccoli's storage quality often involves the analysis of various components, including titratable acidity, ascorbic acid, carotenoids, soluble sugar, and protein [20]. The nutritional attributes exhibit a decline throughout the duration of storage. Edible broccoli serves as a valuable reservoir of diverse phytonutrients and bioactive substances. One example is the identification of sulforaphane in broccoli. Elevated levels of these chemicals are associated with the presence of antioxidant, antibacterial, and anticancer attributes [21,22]. Biogenic amines, including histamine, tyramine, tryptamine, putrescine, cadaverine, and phenylethylamine, are often synthesized through the process of decarboxylation of amino acids. These substances possess psychotropic and vasoactive characteristics, hence potentially leading to toxicological repercussions on human well-being [23]. The detection of biogenic amines in food is regarded as a reliable predictor of bacterial deterioration or food safety due to the correlation between elevated levels of amines, including histamine, putrescine, and cadaverine, and microbial presence [24]. Additionally, it has been hypothesized that intensive microbial activity of *Enterobacteriaceae* is related to a high accumulation level of biogenic amines in broccoli. Broccoli sprouts undergo a process known as germination, during which endogenous production of biogenic amines takes place [7]. As quality indices, the total phenol content, flavonoid content, isoflavone content, glucosinolate content, and biogenic amine content of broccoli are also very important factors. In order to improve the overall quality of broccoli and make them more palatable, it is vital to analyze the ways in which their intrinsic and extrinsic features change while they are being stored after harvest [25].

1.2 Sulforaphane and Its Chemical Structure

Sulforaphane exists in nature as two optical isomers due to the presence of an asymmetric sulfur atom in both sulforaphane and its precursor, glucoraphanin. The glucoraphanin obtained from broccoli and *Arabidopsis thaliana* was determined to be a pure epimer by NMR methods [26]. Additionally, the sulfoxide group of glucoraphanin was found to possess the R-configuration, indicating that this configuration was preserved in the hydrolysis product, R-sulforaphane, catalysed by the enzyme myrosinase. Sulforaphane is a phytochemical found in plants, existing as a biologically inactive precursor called glucoraphanin [27]. It possesses a chemical structure known as 4-methylsulfinylbutyl isothiocyanate or 1-

isothiocyanate-4-methylsulfinylbutane. This particular precursor is classified as a member of the phytochemical group known as glucosinolates, which possess a sugar component integrated into their structural composition, typically d-glucose [3,28]. These chemicals are quickly converted into the equivalent isothiocyanate by the enzyme myrosinase. In addition to glucoraphanin (4-methylsulfinylbutyl), plants frequently include a variety of additional glucosinolates. These include sinigrin [2-propenyl (allyl)], glukobrassicin (3-indolmethyl), and progoitrin [(R)-2-hydroxy-3-butenyl]. The metamorphosis process happens following the disruption of plant tissues by numerous means such as biting, gnawing, slicing, and other types of tissue injury [29]. The plant tissues' internal myrosinase enzyme is released as a result of this disruption. The absence of isothiocyanates can occur when the enzyme myrosinase is destroyed during meal preparation, such as heating, steam cooking, or microwave treatment [30]. In this case, the intestinal microflora's microbial breakdown of glucosinolates becomes a likely source of isothiocyanates. The hydrolysis process mediated by the microflora exhibits limited efficiency. Additionally, in the context of human subjects, the hydrolysis process is characterized by a high degree of diversity and variability [31].

1.3 Health Benefits of Sulforaphane

Sulforaphane is a dietary phytochemical that is routinely and widely ingested with cruciferous vegetables as well as various dietary nutraceuticals, and its administration to humans is often well tolerated [32]. Sulforaphane has a low level of toxicity. Isothiocyanate sulforaphane has been the subject of a great deal of research over the past several years with the purpose of determining whether or not it offers a protective effect against a wide range of in vivo diseases and in vitro investigations on experimental models. The mechanism of action of sulforaphane has been the subject of a significant amount of research, much of which has been published [33]. Oxidative stress and antioxidant capacity, neuro-inflammation, and a wide variety of other biochemical abnormalities are all affected by sulforaphane, which is connected with autism. The positive impacts of regular administration of sulforaphane through oral means on the behavioural patterns of individuals diagnosed with autism spectrum disorders [34,35]. These diseases are characterised by the presence of stereotypic behaviour as well as deficits in social interaction and communication skills. The decision to investigate the potential impact of sulforaphane on the therapeutic approach for autism was motivated by the favourable characteristics exhibited by sulforaphane [36]. In comparison to control children, children diagnosed with autism exhibited notably reduced baseline levels of plasma compounds associated with the methionine cycle, including methionine, S-adenosylmethionine (SAM), homocysteine, cystathionine, cysteine, and total glutathione (GSH). Conversely, these children demonstrated significantly elevated concentrations of S-adenosylhomocysteine (SAH), adenosine, and oxidized GSH [37]. The presence of a diminished ability to undergo methylation, resulting in a notable decrease in the ratio of S-adenosylmethionine (SAM) to S-adenosylhomocysteine (SAH), as well as an elevated level of oxidative stress characterized by a significantly reduced redox ratio of reduced glutathione (GSH) to oxidized glutathione (GSSG), is associated with the metabolic profile observed in children diagnosed with autism [38]. The development and clinical expression of autism may be influenced by a loss in methylation capacity and a diminished tolerance to oxidative stress. Sulforaphane has been recognized as a chemoprotective drug with potential clinical utility. The compound known as sulforaphane, specifically an isothiocyanate, is subjected to metabolic processes via the mercapturic acid route, where it forms a conjugate with glutathione [39]. Subsequently, it undergoes additional biotransformation, resulting in the production of several metabolites. Furthermore, the protective benefits of sulforaphane against apoptosis induced by dexamethasone, with subsequent elucidation of the underlying molecular pathways [31]. The inhibitory effects of sulforaphane on dexamethasone-induced growth suppression and lactate dehydrogenase release were seen in MC3T3-E1 cells. Sulforaphane has been found to exhibit potential protective effects against a range of cancer types, including as pancreatic cancer, colon cancer, leukemia, and prostate cancer [40].

Moreover, sulforaphane may help with osteoporosis symptoms. Both in vitro and in vivo models of osteoarthritis have shown the protective benefits of dietary isothiocyanate against cartilage degradation in cells [35]. Sulforaphane has been shown to significantly boost the activity of NAD(P) H: quinone

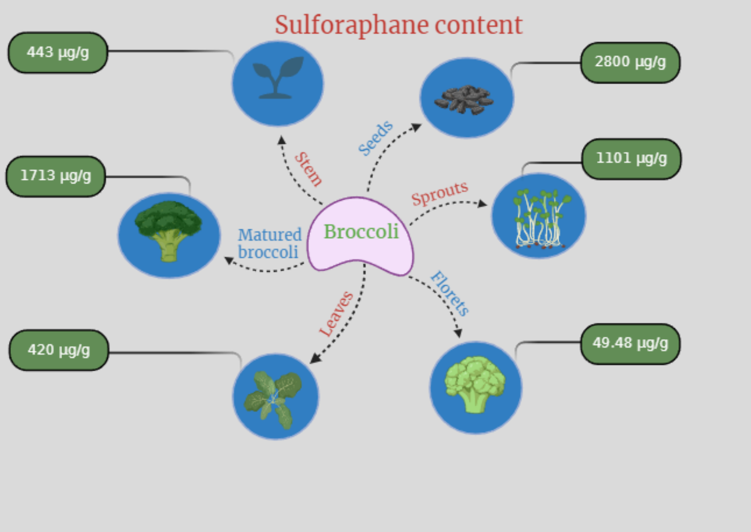

Fig. 1. The allocation of sulforaphane in broccoli

oxidoreductase 1 in chondrocytes, while suppressing the production of matrix metalloproteinase-1, -3, and -13 in chondrocytes stimulated by pro-inflammatory cytokines [41]. It has been shown that sulforaphane dramatically reduces the production of pro-inflammatory cytokines in lymph node and spleen cells stimulated with type II collagen, such as interleukin-17, interleukin-6, tumor necrosis factor alpha, and interferon-c. A similar decrease in synovial hyperplasia occurs with this reduction in cytokine output [26].

2. DIFFERENT METHODS TO MAINTAIN THE SULFORAPHANE CONTENT IN BROCCOLI

Broccoli which is raw and fresh has the most nutrients. While broccoli is sometimes eaten raw, most of the time it is cooked by steaming, cooking, microwaving, stir-frying, etc. The heat processing has a big effect on myrosinase activity. Table 1 discusses the different methods to maintain the sulforaphane content in broccoli. The way food is cooked is a big factor in how much sulforaphane it makes, which is discussed below:

Steaming: Steaming is a widely used cooking technique, particularly in Asian households. Steamed broccoli is considered one of the most nutritious cooking methods for broccoli due to its efficiency and the preservation of minerals and vitamins without loss in the cooking liquid [6]. Steaming broccoli for 1 minute resulted in a greater amount of sulforaphane, which remained higher than the amount found in unheated broccoli even after steaming for 3 minutes [42]. Research has determined that steaming broccoli for a maximum of five minutes is the optimal method for preserving its myrosinase enzyme and thus increasing the sulforaphane concentration. Steaming broccoli for over 5 to 6 minutes, and especially for an extended duration, may result in the loss of its vivid green colour and a significant amount of its nutritional content [43].

Boiling: The boiling procedure is effective for broccoli as it helps to tenderize the tissues and deactivate bacteria. When broccoli is boiled, the enzyme that produces sulforaphane is deactivated, resulting in the prevention of substantial quantities of sulforaphane synthesis [44]. Researchers discovered that including powdered mustard seeds into the heat-treated broccoli substantially enhanced the production of sulforaphane.

Microwaving: Microwaving has gained popularity as a convenient and highly efficient alternate method of cooking. Microwave cooking relies on intramolecular friction instead of heat transfer, resulting in more efficient preservation of nutrients compared to boiling or steaming [45]. During microwave heating, materials have the ability to immediately absorb the energy and transform it into heat, leading to faster rates of heating compared to traditional heating methods. The sulforaphane content in broccoli increased by a factor of 4 and 6, respectively, when microwaved for 1 minute each. However, the sulforaphane levels became undetectable after microwaving for an additional 3 minutes for

Table 1. Different methods to maintain the sulforaphane content in broccoli

Technique	Treatment condition	Outcomes	References
Steaming	Time 1, 2, 3 min.	• Extend shelf life and soften tissues • Glucosinolates and sulforaphane preserved	[48]
Boiling	Temp. 85-95 °C Time 1-3 min.	• Maintained flavour, taste • Enhanced shelf life • Maintained sulforaphane content	[49]
Microwaving	Power 475-950 W Temp. 40-60 °C	• Retained bioactive constituents of broccoli • Enhanced shelf life and maintained nutrient content in broccoli	[50]
Stir frying	Time 3-5.9 min.	• Maintained sulforaphane content • Improved shelf life • Retained active constituents	[51]
Chemical treatment	Chemical: Calcium sulphate ($CaSO_4$)	• Avoid microbial destruction • Extend shelf life • Maintained sulforaphane content and retained bioactive compounds	[52]

Table 2. Different techniques to maintain the sulforaphane content in broccoli

Technique	Treatment condition	Shelf life	Outcomes	References
Freezing	Temp. −20 °C	165 days	• Excellent way to preserve broccoli • Preserved vitamin C content • Glucosinolates and sulforaphane preserved	[53]
Cold storage	Temp. −20 °C Low O_2 (0.002-1.3%) High CO_2 (20.6-25.4%)	4 days	• Maintained taste values • Sulforaphane not reduced • Enhanced shelf life and maintained nutrients	[1]
Modified atmosphere packaging	Temp. 4, 8, 15 °C	21 days	• Maintained shelf life • Preserved glucosinolates content • Preserved nutrients	[54]
Light exposure	Temp. 5 °C	14 days	• Enhanced the sulforaphane content • Extend the shelf life and preserved nutrients	[55]
Irradiation	Temp. 0, 4 °C	4-7 days	• Maintained sulforaphane content • Improved shelf life	[56]

Technique	Treatment condition	Shelf life	Outcomes	References
High pressure processing	Time 3 min Treatment at 400 MPa	20 Seconds	• Maintained nutrients in broccoli • Enhanced the enrichment of sulforaphane • Effective for broccoli as a functional food	[57]

broccoli [46]. Utilising higher power and reducing cooking time in microwave cooking resulted in increased sulforaphane content compared to utilizing lower power and longer cooking time. For example, the microwave operating at a high-power level of 60°C exhibited the highest sulforaphane level (2.45 µmol/g DW), whereas the microwave operating at a low-power level of 60°C displayed a lower sulforaphane value (1.42 µmol/g DW) [47].

Stir-frying: The cooking technique known as stir-frying is frequently utilised in the cuisines of East Asia. When using stir-frying, the cooking time is reduced, which helps to maintain the colour. When green vegetables are cooked for 5-7 minutes, whether they are cooked in water or stir-fried, the chlorophyll is protected from the damaging effects of acid [58,51]. As a result of the fact that broccoli is not submerged in water during the steaming process, the florets of broccoli have a greater amount of sulforaphane than they do when they are boiled. Therefore, in order to absorb the maximum amount of sulforaphane, broccoli that has been boiled should be ingested alongside the soup. Sulforaphane is not a volatile molecule, hence the processes of volatilization and heat degradation may not be as significant [21].

3. CHEMICAL TREATMENT

Preharvest techniques, such as the use of chitosan and calcium treatments, have demonstrated favourable outcomes by enhancing the defensive mechanisms against oxidative stress in broccoli preservation [50]. A 10 mM $CaSO_4$ spray treatment in broccoli significantly raised the activities of antioxidant enzymes such as superoxide dismutase, peroxidase, catalase, and glutathione peroxidase. It also enhanced the antioxidant capacity by increasing the levels of phenolic compounds and ascorbic acid [59]. Furthermore, this treatment resulted in a rise in the glucosinolate content, particularly glucoraphanin, during the growth phase, and prevented its depletion during storage. Chitosan is a polysaccharide that is extracted from natural resources and is both biodegradable and biocompatible [60]. It serves as an alternative coating material for many food products. It is a method of treating harvested produce with a harmless compound called adenosine triphosphate (ATP) and ascorbic acid has been developed as a promising way to prevent the action of the PPO enzyme. Furthermore, the taste and odour of preserved broccoli were not negatively impacted. However, the postharvest dip/wash and drying procedures significantly decreased the shelf life of these fragile vegetables as a result of mechanical harm [46].

4. DIFFERENT TECHNIQUES TO MAINTAIN THE SULFORAPHANE CONTENT IN BROCCOLI

The main variables that impact the quality of broccoli are its limited shelf life and vulnerability to spoilage. Insufficient storage by distributors leads to accelerated and frequent spoilage of broccoli. Broccoli, typically eaten cooked, can be kept and maintained using different techniques are described in Table 2 and discussed below:

Freezing: Freezing vegetables, such as broccoli, is an efficient method for preserving them for an extended period of time. This approach also reduces the amount of time and money required for preparation, in addition to prolonging the shelf life of the vegetables [53]. Broccoli, on the other hand, is typically blanched before being frozen by being subjected to steam or boiling water. This is done to render enzymes such as peroxidase and lipoxygenase inactive, which would otherwise be responsible for the degradation of the tissues and decrease the shelf life [61]. Peroxidases are rendered inactive by heating the florets at a temperature of 96 °C for 145 seconds. This process also entirely renders myrosinase inactive. The potential to produce sulforaphane is therefore absent in broccoli that has been frozen for commercial purposes [62].

Cold storage: Utilizing low-temperature storage can effectively reduce the deterioration of postharvest quality and prolong the shelf life by decelerating the processes of respiration, senescence, and spoiling growth. The selection of the most suitable storage temperatures mostly relies on the respiration rates and organoleptic properties [1]. Furthermore, it has been advised to store broccoli at a temperature range of 4-5 °C in order to prevent significant degradation of bioactive chemicals and extend its shelf life for up to 14 days. The buildup of bioactive content in broccoli can be influenced by genotypic polymorphism and the timing of harvesting [58].

Modified atmosphere packaging: Modified atmospheric packaging (MAP) is a highly effective technology that improves the quality and extends the shelf life of vegetable crops. This is achieved by reducing the amount of oxygen (O_2) and increasing the amount of carbon dioxide (CO_2) in the package headspace. The inadequate packaging can prove to be ineffectual and diminish the quality of the produce in terms of its shelf life and visual appearance [34]. The efficacy of a modified atmosphere packaging system relies on factors such as the weight and respiration rate of the product, the composition of the atmosphere, the selection of suitable packing material with the desired permeability, and the temperature at which the product is stored. Polypropylene, low-density polyethylene, and polyethylene packaging materials have demonstrated efficacy in prolonging the shelf life of broccoli [63]. Vegetables have more advantages when they are stored in packing film with low temperatures that are close to their genotypic chilling tolerance. The utilization of MAP, in conjunction with both active and passive packaging, is beneficial for prolonging the shelf life and maintaining the quality of postharvest fresh products [64]. According to a recent study, using active packaging with gas concentrations of 15% CO_2 and 7.5% O_2 at a temperature of 0 °C is the best way to extend the shelf life of broccoli. This method was found to be effective in reducing the growth of aerobic mesophilic bacteria, preventing the development of off-flavours, and preventing discolouration of the broccoli. However, there is a lack of adequate published research on the utilization of optimal active packaging technologies and their effects on the biochemical composition, which is another crucial aspect of quality [12,50].

Light exposure and irradiation: Light treatment resulted in the retention of elevated amounts of glucosinolates and phenolic content in broccoli. Notably, yellow LED light exhibited superior efficacy compared to green and white LED light [55]. This process was also observed in cases of UV exposure, wherein moderate UV exposure exhibited potential advantages in the production of health-promoting bioactive chemicals. The spectrum composition and intensities of postharvest light conditions preserve the optimum levels of bioactive chemicals and ensure consumer satisfaction [22]. Light is crucial in understanding the molecular process of secondary metabolite production in broccoli. Irradiation is a highly efficient method for eliminating pathogenic pathogens in broccoli. Only a limited number of research have discovered that irradiation is important in preserving the sensory and nutritional characteristics of broccoli [30]. Gamma irradiation, even at low doses, proved to be an effective method for preserving the visual quality of broccoli and slowing down the oxidation of total phenols, total ascorbic acid, and chlorophyll degradation during storage. The irradiation, a different form of radiation, did not exert any influence on the quality and duration of broccoli viability [28].

High-pressure processing: High-pressure processing (HPP) is an innovative and non-thermal method of preserving bioactive compounds in broccoli. The transformation of prevalent glucosinolates into isothiocyanates and sulforaphane is significant for increasing their bioactivity. The application of High-Pressure Processing (HPP) at a pressure of 600 MPa resulted in the maximum conversion rate (85%) of the desirable component in broccoli [65]. This conversion occurred when the pressurized broccoli was held at a temperature of 6 °C for a duration of 12 days. HPP technology is commonly utilized to prevent microbial proliferation in broccoli. Typically, microbial cells are rendered inactive by subjecting them to pressures of up to 700 MPa and treatment durations ranging from a few seconds to several minutes [66]. There is a lack of previous studies regarding the impact of HPP on the sensory characteristics and storage duration of broccoli, particularly when combined with the elimination of harmful and spoilage-causing microbes. Furthermore, the utilization of High-Pressure Processing (HPP) within the range of 300 to 700 MPa has notable constraints, including the challenges associated with regulating and overseeing such elevated operational pressures, the substantial expense of equipment, and safety concerns [41].

5. CONCLUSION

Broccoli's perishable nature and the absence of postharvest management technology contribute to its rapid and widespread spoilage after harvest. The sulforaphane content has been shown to inhibit tumor growth, cause cell cycle arrest, and trigger programmed cell death, all of which are favourable to human health. The cytoprotective, antioxidant, and anti-inflammatory characteristics of sulforaphane make it an important compound. Sulforaphane is a phytochemical found in the diet; it has been shown to have a low toxicity profile and to be well tolerated when administered to people. To prevent the spread of rotting bacteria, maintain quality, and keep broccoli fresh for as long as possible, it is necessary to take a holistic strategy that takes into account hygiene, temperature, moisture, and atmosphere. Broccoli's color, flavor, texture, and nutrients are all important qualities, and they can be preserved by careful postharvest handling. However, pre- and postharvest chemical treatment, drying processes after washing, photoperiodic intensity exposure, atmospheric composition, and harvest timing which effect quality and shelf life of broccoli. Broccoli is preserved using a variety of methods to extend its freshness. Broccoli can also be treated with techniques including high pressure processing, modified atmosphere packaging, ultrasound and cold plasma to preserve its sulforaphane content.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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