Recent updates and perspectives of fermented healthy super food sauerkraut: a review

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ABSTRACT
Sauerkraut is a traditional fermented vegetable product that has numerous health endorsing properties. It is produced by spontaneous fermentation of cabbage that mainly involves heterofermentative lactic acid bacteria. The amount of salt introduces influences the physiochemical, microbial load, and also sensory consistency of sauerkraut. Sauerkraut has a high nutritional and phytochemical profile as well as has some epidemiological attributes. Sauerkraut is rich in vitamins and phenolic compounds, which protect against oxidative stress by serving as powerful free radical scavengers. The sauerkraut is being considered one of the best functional foods across the world due to its therapeutic potential. The current review provides an overview of production technology, nutritional, phytochemical, and different therapeutics (chemo preventive, antioxidant, anti-inflammatory) aspects of sauerkraut.

Introduction

Food serves as a significant source of inspiration for many aspects of human life, including culture, technology, nutrition, and overall well-being. Plant-based foods such as vegetables contribute significantly to human nutrition and health by supplying minerals, micronutrients, vitamins, antioxidants, phytosterols, and dietary fibers. [1] Recently, consumers have shown their interest in functional foods that provide health benefits. Human populations have consumed fermented foods for thousands of years, making them the most common type of food in the marketplace. Fermentation provides a vast number of advantages, including the production of essential amino acids, proteins, vitamins, and fatty acids and also gives the advantage of detoxification of food products. [2] Besides fermented beverages and sauces, vegetable fermentation is another traditional method of preserving foods. Cabbage and cabbage products are appealing from both a marketing and a dietary standpoint as cabbage offers numerous health benefits. [3] From a traditional perspective, sauerkraut made from cabbage is one of the most well-known traditional foods.

The cabbage fermentation results in the formation of sauerkraut, which is one of the most popular and traditional forms of cabbage preserves, as well as possessing a wide range of medicinal characteristics. [4] Cabbage belongs to the family of Brassicaceae. Brassica crops are a diversified category of crops belonging to the Cruciferae family, which include over 350 genera and 3000 species.

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The Brassica oleracea species, which includes cauliflower, cabbage, and kohlrabi; are the most famous vegetable crops in the world due to their high nutritional content and adaptability to a variety of climates and soils.\[^{[6]}\]

Cabbage is a green, leafy vegetable that is part of the cole family. The cultivation of cole crops for the purpose of providing food has been documented in ancient Greek and Roman literature since the time of the Greeks and Romans. Cabbage and many other Cole crops are now grown all over the world for use both fresh and dried, and cabbage is one of the most widely grown.\[^{[6]}\] The head, which is composed of thick leaves that overlap firmly on the developing bud, is the most economically valuable part when eaten as a vegetable. Cabbage is a high-nutrient vegetable crop, it also contains several vitamins and minerals. It is frequently cultivated as a greenhouse crop.\[^{[7]}\] In defending against many ailments cabbage is the king of cruciferous vegetables. It includes vitamin C exactly like citrus fruit and offers protective and healing properties. It has been shown that sauerkraut provides numerous health benefits for humans, including the promotion of digestion, the reduction of cholesterol levels, and the improvement of intestinal function.\[^{[8,9]}\]

Sauerkraut is a naturally fermented cabbage that has been eaten as a food for thousands of years. The fermentation ability of the cabbage is determined by the type of cabbage used. It is a low-calorie food that has retained its vitamin C and other nutrients, as well as its pleasant sensory characteristics.\[^{[10]}\] Fermentation is widely used to improve food’s deliciousness and to produce exclusive and novel foods, in addition to preservation. The varieties of food products usually prepared from the fermentation process, differ from culture to culture and are influenced by food availability, consumer taste preferences, raw materials, and so on.\[^{[11]}\] The fermentation conditions and the resident microbial population have a significant impact on sauerkraut formation and characteristics.\[^{[12]}\] Proper fermentation conditions, such as relative component concentration and temperature make sure that the lactic acid bacteria (LAB) are the leading microorganisms in the final product after the process is complete. It has been demonstrated that fermenting cabbage increases its defensive properties. Historically, because of its high vitamin content, sauerkraut was considered one of the most vital foods for sailors, and it was used to prevent scurvy and several other diseases. This review aims to demonstrate an overview of the research on the nutritional value and potential therapeutic properties of sauerkraut.

**History and current status**

Various fermented vegetables and fruits have been utilized to improve the nutritional status of humans from the beginning of time. Sauerkraut is one of the most well-known and widely accepted fermented foods for human consumption among a variety of other vegetable products. With a long history dating back to the Roman empire, the fermented food sauerkraut is among the most well-known foods. Preserving the nutritional value of cabbage while providing good sensory characteristics was traditionally a source of nutrition during cold weather when fresh food was not commonly available. Central and Eastern European cuisines are known to use it and in American cuisine, sauerkraut has always been a part of the mix, either as an ingredient, side dish, or a condiment. Currently, sauerkraut is widely consumed in Europe, the United States, and Asia.\[^{[13]}\] It is made by chopping white cabbage and fermenting it with lactic acid after which it is salted and served. It is believed that the word sauerkraut comes from the German word meaning “sour cabbage.”

In China 2000 years ago, cabbage was fermented and processed, and it was in Europe 1000 years later that sauerkraut was processed for the first time.\[^{[14]}\] Historically, ancient cultures were well concerned about the health benefits of sauerkraut. Sauerkraut was consumed by the Romans to prevent intestinal infections.\[^{[15]}\] Sauerkraut was an important food for the armies during European wars. Industrial sauerkraut production started at the end of the nineteenth century.

Sauerkraut is considered to be a high-quality source of nutrients such as minerals, vitamins, flavonoids, and biologically active compounds generated from glucosinolates (GLS), a sulfur glycoside molecule found in Brassica vegetables. Several GLS breakdown products were found to have anti-
cancer properties, according to several studies.\cite{AFZ16,AFZ17} Nowadays, sauerkraut is considered to be a healthy and well-balanced food among different varieties of foods. It can be utilized in savory and fruit salads and can also be used in casseroles, soups, stir-fries, and stews.

**Production technology**

Food fermentation is the most ancient form of “biotechnology.” Processing of food and ingredients by microorganisms and enzymes to obtain desirable qualities such as improving safety, increasing shelf life, enhancing flavor and nutrients, and health promotion are all covered under this broader term.\cite{AFZ18} Fermentation is the most important step in the processing of sauerkraut. Fresh cabbage heads are stripped of their outer leaves and their internal cores are removed in the preparation of sauerkraut. After that, the cabbage is shredded into strips that are 0.7–2 mm thick, and it is salted with 0.7–2.5% sodium chloride.\cite{AFZ19} Salt is used for the formation of anaerobic conditions during fermentation process in addition with limiting the spread of spoilage bacteria and the action of natural pectinolytic enzymes, which causes the softening of cabbage during storage. The use of salt influences the variety of micro flora present in sauerkraut and the sensory attributes of the product.

The amount of sodium chloride that is used is normally determined by the fermentation temperature and the preferences of the consumers. It is possible to enhance the flavor of sauerkraut by adding spices, herbs, carrots, and wine during this stage of the fermentation process. After being salted, the cabbage is placed into fermentation tanks and carefully compressed to ensure that no air is allowed to enter. After that, the fermentation container is covered with a lid to facilitate the formation of anaerobic conditions, and the cabbage is left to ferment for about one week to several months. After fermentation, sauerkraut is utilized as fresh, packed in metal cans or glass jars or pasteurized to increase shelf life for later utilization.\cite{AFZ20}

Adding salt is one of the most important steps in sauerkraut production as the amount of salt used affects the type and degree of microbial growth as well as the sensory properties of the final product. The addition of salt inhibits the activities of Gram-negative bacteria thus promoting the development of lactic acid bacteria.\cite{AFZ21} As salt concentrations increase, the microbial population and metabolites decrease. In contrast, high salt concentrations can slow sauerkraut maturation and stop the metabolism of LAB.\cite{AFZ22} Recently, the addition of a starting culture of bacteria is beneficial for the industrial production of sauerkraut. Traditionally the products are made in-home or in small-scale facilities through spontaneous fermentation of indigenous bacteria present in the raw cabbage, as compared to industrial production.\cite{AFZ16} Moreover, the steps involved in the production of sauerkraut are shown in Figure 1.

**Microbiological prospective**

Fresh vegetables include a diverse and variable epiphytic microbiota, including a diversity of potentially spoilage microbes and a very limited lactic acid community. As a result, the natural or spontaneous fermentation of vegetables involves a concentrated action of these microbes.\cite{AFZ23} The bacteria that cause spoilage, such as Pseudomonas, Enterobacter, yeasts, and molds, can be found on raw cabbage before it is fermented. On cooked cabbage, the populations of these microorganisms’ range between 104–106 CFU/g, and the LAB population on raw cabbage is typically much lower about 102–103 CFU/g.\cite{AFZ24}

Spontaneous cabbage fermentation is started by heterofermentative lactic acid bacteria (LAB) such as *Leuconostoc mesenteroides*. As the pH of the solution lowers, the number of *L. mesenteroides* cells reduces, allowing *Lactobacillus plantarum* to take over and complete the fermentation process. During the fermentation process, the succession of microorganisms causes some significant changes in the sauerkraut.\cite{AFZ25} The lactic acid bacteria have been widely used as starter cultures for thousands of years, and they have played a significant role in food
preservation, microbiological stability, and the production of aromatic compounds in a variety of food products. A variety of antimicrobial compounds, including organic acid, hydrogen peroxide, diacetyl, inhibitory enzymes, and bacteriocins, can be produced by lactic acid bacteria.\[26\] Several pathogens, including Salmonella and Shigella species, \textit{Aeromonas hydrophila}, \textit{Yersinia enterocolitica}, \textit{Staphylococcus aureus}, \textit{Campylobacter spp.}, and other pathogen have been detected on the surface of vegetables that can be used in the production of fermented foods.\[27\]

Research signifying the sauerkraut as a potential source of probiotics was conducted with the aim of isolating and characterizing probiotic microorganisms from sauerkraut fermentations. Three \textit{Lactobacillus} strains with possible probiotic properties were identified in the study, highlighting the potential of sauerkraut fermentations as a source for probiotic isolation. Considering the origins of the strains the study suggested the potential role of these strains in the food manufacturing businesses, particularly for vegetable products like sauerkraut itself. \[27\]

LAB inhibits bacterial growth by competing for nutrients and producing lactic and acetic acids, which function as bacterial inhibitors. However, testing the safety of sauerkraut salt with brines containing less than 2.5% NaCl is essential.\[24\] It is very important to ensure that (LAB) growth is supported at a lower amount of salt and that sufficient acid is produced to prevent the growth of harmful bacteria without producing any degradation to the sensorial properties of sauerkraut during the fermentation process.

The physicochemical properties, microbial composition, succession, and metabolome profile of samples of traditional sauerkraut were examined in a study. There are positive connections between most volatile compounds and \textit{Clostridium}, \textit{Enterobacter}, \textit{Lactobacillus}, \textit{Leuconostoc}, and \textit{Weissella}. Volatile compounds in sauerkraut were negatively correlated with \textit{Pseudomonas}, \textit{Chloroplast}, \textit{Rhizobium}, \textit{Aureimonas}, and \textit{Sphingomonas}.\[24\] The study provided a comprehensive description of the microbial dynamics and metabolite composition throughout the fermentation of sauerkraut varieties. Understanding the relationship between microbiota and volatile compounds can assist to improve the fermentation process in the future and produce sauerkraut of the finest quality.

\[\text{Figure 1. Schematic representation of Sauerkraut production.}\]
**Nutritional composition**

The nutritional value of Brassica vegetables, including cabbage, is well demonstrated. They are a rich source of valuable vitamins with antioxidant properties such as vitamin C, beta-carotene, folic acid, and -tocopherol, as well as mineral compounds including calcium, selenium, potassium, magnesium, and iron, as well as antioxidants such as flavonoids, polyphenols, and glucosinolates. Cabbage has high nutritional composition and is considered a health-promoting vegetable. The high nutritional value of sauerkraut is attributed to the presence of carbohydrates and dietary fiber as the primary constituents, as well as the presence of vitamin C. Cabbage, is utilized in the preparation of Sauerkraut and contains a high concentration of phytochemicals, which include phenolic compounds and glucosinolates (GLS). For enhancing nutritional profile, glucosinolates (GLS) play an important role by providing flavor and odor due to various metabolites. The environmental conditions and postharvest processing can affect the nutritional profile and content of GLS.

Even though some compounds are lost during fermentation, sauerkraut keeps a high nutritional content and is further enriched with valuable compounds that benefit the health of its consumers. Because of this, it has a far better flavor than raw cabbage, which in turn leads to an increase in its consumption. Lactic acid is a beneficial byproduct of the fermentation process that is produced in a significant amount. Chemically, it is a 2-hydroxypropanoic or -hydroxypropionic acid, which shows preservation qualities due to its capacity to suppress the growth of *Escherichia coli* and *Clostridium* bacteria. Product color, stability, and appearance can be maintained or improved by lactic acid, which acts as a barrier against enzymatic and chemical reactions. This acid works as a barrier for the skin in the human body and is also engaged in the defensive mechanisms that occur in the mucous membranes. Sauerkraut also contains vitamin C and phenolic compounds, which are beneficial to the body. Fermented cabbage contains high levels of vitamin C, which makes it a strong source of antioxidants. Furthermore, the nutritional composition of the sauerkraut is shown in Table 1.

**Therapeutic potential**

According to the research, eating fermented foods reduces your risk of infections and diseases including cancer and heart disease. Studies have shown that the important phytochemicals in sauerkraut provide a wide range of health advantages. Unpasteurized sauerkraut contains probiotic microorganisms known as Lactic Acid Bacteria, which are beneficial to the body. The probiotic bacteria found in sauerkraut can grow without the use of a starting culture. Cabbage and salt are all that is required for this delicious fermented food. LABs are one of the most important microorganisms, with demonstrated benefits. For example, LAB has been shown to help with diarrhea, constipation, irritable bowel syndrome, as well as other digestive issues (urogenital, urinary, and candida). Research shows that LAB improves immune system function, which helps keep a wide range of diseases away and aids with lactose digestion. Numerous in vitro studies and certain epidemiological data indicate that sauerkraut may have beneficial impacts on health. These health-promoting characteristics are supported by compelling evidence from experimental research revealing that certain phytochemicals found in sauerkraut serve as an anti-inflammatory, chemo preventive, and antioxidant. Additionally, the therapeutic attributes of sauerkraut are shown in Table 2.

A pilot study conducted on a group of individuals suffering from irritable bowel syndrome (IBS) demonstrated that consuming 75 g of sauerkraut daily resulted in a reduction in disease-related illnesses as indicated by the IBS-Symptom Severity Score (IBS-SSS). The consumption of sauerkraut for six weeks also increased the diversity of fecal bacteria. Both pasteurized and unpasteurized sauerkraut were found to have beneficial impacts on the individuals who consumed it. Sauerkraut is excellent weight-loss food due to its low content of calories with high content of fibers and vitamins. It prevents constipation, squeezing, and bulging, making it an ideal food for weight control. Moreover, the therapeutic potential of sauerkraut against various health implications is shown in Figure 2.
Antioxidant benefits

Oxidative stress has been extensively identified as a factor in maturation and the pathogenesis of a variety of major health complications, including cardiovascular and neurodegenerative disease. Sauerkraut is considered to be an excellent source of antioxidants, including vitamin C (14.7–75 mg/100 g fresh weight (fw) and phenolic compounds (0.44–1.06 mg gallic acid equivalents/100 g (fw). Isothiocyanates and other sulfur compounds derived from Brassica plants have therapeutic benefits such as anti-inflammatory, antimicrobial, and antioxidants effects. [44,45]

Table 1. Nutritional composition of sauerkraut.

| Nutrient          | Content (per 100 g fresh weight) |
|-------------------|----------------------------------|
| Protein           | 0.91 g                           |
| Fat               | 0.14 g                           |
| Carbohydrates     | 4.28 g                           |
| Total dietary fibers | 2.9 g                        |
| Sugars (total)    | 1.78 g                           |
| Glucose           | 0.14 g                           |
| Fructose          | 0.04 g                           |
| Calcium           | 30 mg                            |
| Iron              | 1.47 mg                          |
| Magnesium         | 13 mg                            |
| Phosphorus        | 20 mg                            |
| Potassium         | 170 mg                           |
| Sodium            | 661 mg                           |
| Zinc              | 0.19 mg                          |
| Copper            | 0.096 mg                         |
| Manganese         | 0.15 mg                          |
| Selenium          | 0.6 μg                           |
| Fluorine          | 0.7 μg                           |
| Vitamin c         | 14.7 mg                          |
| Thiamin           | 0.021 mg                         |
| Riboflavin        | 0.022 mg                         |
| Niacin            | 0.143 mg                         |
| Pantothenic acid  | 0.093 mg                         |
| Vitamin B6        | 0.130 mg                         |
| Folic acid        | 24 μg                            |
| Vitamin A         | 1 μg                             |
| B-Carotene        | 8 μg                             |
| Vitamin E         | 0.14 μg                          |
| Vitamin K         | 13.0 μg                          |

Source*: [19]

Table 2. Therapeutic potential of sauerkraut.

| Therapeutic attributes | Therapeutic components | Functions | References |
|------------------------|------------------------|-----------|------------|
| Antioxidant Benefits   | Vitamin E, vitamin C, phenolic compounds, allyl isothiocyanate, phenyl isothiocyanate | Free radical scavengers, Inhibiting LDL oxidation, | [19,36,37] |
| Immunity booster       | Leuconostoc mesenteroides, D-phenyl lactic acid | Regulation of the immune system, activation of immune cells | [38,39] |
| Anti-carcinogenic      | Ascorbigen, Isothiocyanates, | Inhibiting carcinogen activation and increasing their detoxification, DNA protection by modulating enzymes and blocking gene mutations | [16,40,41] |
| Anti-inflammatory      | Allyl isothiocyanate, indol-3-carbinol, | Inhibition of pro-inflammatory cytokine production, expression of pro-inflammatory enzymes | [36,42] |
A high concentration of vitamin C and E, as well as phenolic compounds, are found in sauerkraut, and these chemical compounds function as powerful free radical scavengers, protecting the body against oxidative stress. Vitamin C lowers the inflammation and atherosclerotic plaque disruption which is due to the C-reactive protein (CRP) and acts as an electron donor for eight human enzymes, neutralizing superoxide and hydroxyl radicals. Vitamin C and phenolic compounds are both antioxidants that help to protect against the effects of free radicals.[46] Due to its ability to donate a hydrogen atom, vitamin E exhibits antioxidant activity, protecting against cardiovascular disease by inhibiting LDL oxidation.[47] Vitamin E also has anti-inflammatory properties. Aside from that, some of the GLS hydrolysis products found in sauerkraut, including allyl isothiocyanate and phenyl isothiocyanate, have been proven to exhibit antioxidant properties in vitro.[37]

Shankar et al.[48] studied the therapeutic potential of exopolysaccharides by Lactobacillus paracasei isolated from sauerkraut. Sulfate compounds, carboxyl groups, and hydrogen-bound chemicals were all detected in the prospective bacterial EPS based on the results of the Fourier-transform infrared spectroscopy (FTIR) spectrum analysis.[48] When tested for Total Antioxidant Capacity (TAC), the EPS compound demonstrated 76.34% of total antioxidant capacity (TAC), 71.15% reducing power, 68.65% hydrogen peroxide scavenging activity, and also 60.31% radical scavenging activity (DPPH). Exopolysaccharides from Lactobacillus paracasei have been shown to have potent antioxidant capabilities, and it demonstrates the antioxidant properties of sauerkraut.[48]

**Effect on immune system**

The immune system is critical in preserving the integrity of the body against foreign objects and disease-causing bacteria. Several studies have shown that sauerkraut is a powerful and potent immunomodulator. The beneficial health effects of sauerkraut are attributed to bioactive chemicals derived from glucosinolate hydrolyses, such as indole-3-carbinol, ascorbigen, sulforaphane, and allyl isothiocyanate, which are found in high concentrations in sauerkraut.[19] Additionally, sauerkraut is a good source of the LAB. LAB are important species that are regarded as probiotics because they increase innate and
adaptive immunity while also attenuating inflammation through modifying the gut microbiota. LAB strains were administered to BALB/c mice in one study, and this resulted in a reduction in allergen-induced airway inflammation through modulating Th1/Th2 balance and up-regulation of Tregs.

Foods like kimchi, sauerkraut, and milk are fermented by Leuconostoc mesenteroides, a Gram-positive bacterium that produces different organic acids and aromatic compounds. Zubaidah et al. studied the sauerkraut and Leuconostoc mesenteroides culture for its immunomodulatory activity in experimental animal. The findings of the study showed that sauerkraut enhanced both the adaptive and innate immune systems. Microbiome research demonstrated that LAB inclusion provokes the occurrence of the prominent phyla (Firmicutes and Bacteroidetes) in the intestinal microbiota, which is known to play a significant function in the formation and protection of the immune system.

D-phenyllactic acid, a phenolic compound generated by the sauerkraut LAB, firmly attaches to the hydroxycarboxylic acid receptor 3 (HCR3) in the body. HCA3 is a member of the family of G protein-coupled receptors for hydroxycarboxylic acids, which play a critical role in the regulation of immunological function. In one study, the consumption of sauerkraut increased the level of D-phenyllactic in plasma and urine samples of the participants, as well as the activation of immune cells.

**Anti-carcinogenic properties**

Cancer prevention is a primary objective of almost every healthcare system globally. Brassica vegetables, particularly white cabbage, both fresh and sour, include a variety of beneficial compounds that are useful in cancer prevention and treatment in different studies. The presence of glucosinolates in Brassica vegetables are believed to be responsible for the inverse relationship between the consumption of Brassica vegetables and the risk of cancer. Experiments have shown that high quantities of glucosinolates, ascorbigen, and ascorbic acid reduce DNA damage and cell mutation rate in cancer patients, and sauerkraut is known to have these substances in abundance.

Ciska et al. studied the changes in glucosinolates (GLS) during the fermentation of white cabbage and the development of resulting products in sauerkraut and sauerkraut juice separately, as well as the stability of these breakdown products during the prolonged storage of the final products after fermentation. The results demonstrated that both the products are excellent sources of bioactive compounds, particularly ascorbigen and isothiocyanates. The most abundant compound was ascorbigen, which found to be stable at acidic pH in both sauerkraut and sauerkraut juice, even after being stored for an extended period. Moreover, a high concentration of bioactive isothiocyanates was also found in sauerkraut juice. One 250 mL glass of sauerkraut juice (after two weeks) can provide around 75 μmol of bioactive ascorbigen and isothiocyanates, making it a functional food capable of imparting beneficial health effects to the consumer.

Ascorbigen is a glucosinolate that is most abundant in Brassica vegetables like cabbage. Glucobrassicin is one of the most commonly studied glucosinolates. This molecule is a precursor of indole-3-carbinol (I3C) and ascorbigen, which are both considered to be potential anticarcinogens. Furthermore, isothiocyanates are derived from the cruciferous family that is naturally present molecules. Numerous isothiocyanates, both natural and synthetic, exhibit anticarcinogenic activity by inhibiting carcinogen activation and increasing their detoxification. Sulforaphane which is an isothiocyanate derivative has the potential to prevent cancer through DNA protection by modulating enzymes and blocking gene mutations.

Pathank et al. evaluated the relationship between intake of cabbage/sauerkraut foods and the risk of developing breast cancer in Polish-born migrants to the United States. Following the study’s findings, it was found that increased consumption of total and raw/short-cooked cabbage/sauerkraut foods, both during youth and adulthood, was related to a considerably lower risk of breast cancer. These findings add to the emerging body of facts that sauerkraut consumption can have a cancer-preventive effect.
**Anti-inflammatory effects**

The Anti-inflammatory and immunomodulatory properties of fermented foods are mostly due to the high antioxidant content and lactic acid-producing bacteria. Antioxidant compounds from fermented food products are involved in several functions such as neutralizing free radicals, regulating antioxidant enzyme activities, lowering oxidative stress, ameliorating inflammatory reactions, and increasing immune system performance.[54] Therefore, sauerkraut has the potential to defend against chronic inflammatory disorders, which are recognized to be the major cause of death throughout the world.

Several studies have demonstrated the anti-inflammatory potential of sauerkraut. Allyl isothiocyanate and indol-3-carbinol can be responsible for some of the anti-inflammatory activity of sauerkraut, which can be induced through a variety of mechanisms, including the inhibition of pro-inflammatory cytokine production (such as TNF- and IL-1), the expression of pro-inflammatory enzymes (such as iNOS), the activation of the NF-B pathway, and the reduction of pro-inflammatory microRNA-155 levels in induced macrophages.[42] It has been confirmed in a study that sauerkraut has an anti-inflammatory effect by inhibiting the production of NO in LPS-induced murine macrophages RAW 264.7 cells.[36]

Peñas et al. [55] examined the anti-inflammatory and antioxidant characteristics of Se-enriched sauerkraut, which was found to be promising. According to the findings, the addition of sodium selenite during natural cabbage fermentation increased the formation of some GLS breakdown compounds that provide potential health benefits, as well as sauerkraut, showed high antioxidant and anti-inflammatory activity.

**Conclusion**

Sauerkraut is a traditional fermented product with having Lactic Acid Bacteria (LAB) as dominated microbial population. Sauerkraut has various functional and nutraceutical properties such as antioxidant, anticarcinogenic, antidiabetic, and the ability to reduce inflammation. Glucosinolates breakdown during sauerkraut fermentation produces high levels of bioactive compounds. The results of various studies exhibited that sauerkraut has effective immunological properties. There is a dire need for collective research work across the globe to maximize the value addition and market of this fermented food product.

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This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent
For this type of study, formal consent is not required.

Data Availability
Even though adequate data has been given in the form of tables and figures, however, all authors declare that if more data is required then the data will be provided on a request basis.

Consent to Participate
Corresponding and all the co-authors are willing to participate in this manuscript.

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