Sauerkraut: A Functional Fermented Food with Therapeutic Significance

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Abstract

Sauerkraut is still one of the most popular fermented foods because of its many useful qualities. Fermented foods have long been beneficial to human nutrition and well-being. Sauerkraut is made by naturally fermenting cabbage, which preserves important nutrients while adding healthy lactic acid bacteria and medicinal chemicals. Its nutritional characteristics and the health advantages associated with its ingestion are summed up in this review. Beneficial lactic acid bacteria, organic acids, vitamins, and antioxidant chemicals are added to cabbage during the fermentation process, which strengthens the immune system and improves digestive health. Bioactive substances produced during fermentation, especially derivatives of glucosinolate, have demonstrated promise in lowering the risk of several types of cancer and reducing inflammation. When taken as a whole, these qualities make sauerkraut an important food ingredient that may help prevent illness and enhance general health. Further investigation could elucidate its mechanisms and promote broader dietary integration.

Keywords: fermentation, sauerkraut, lactic acid bacteria, glucosinolate

Introduction

Numerous facets of human existence, such as culture, technology, nutrition, and general well-being, are greatly influenced by food. Vegetables and other plant-based foods provide minerals, micronutrients, vitamins, antioxidants, phytosterols, and dietary fiber, all of which are important for human nutrition and health [1]. For at least 10,000 years, foods that are fermented have been a significant component of the human diet, and fermentation is one of the earliest processes for generating and storing food [2]. Due to their health-promoting qualities, traditional fermented foods have recently drawn more attention from consumers [3,4]. In addition to preserving food, fermentation is frequently used to enhance its flavor and create unique and innovative dishes. Food availability, consumer dietary habits, ingredient availability, and other factors all affect the types of food products that are often made through the fermentation process, which vary from culture to culture [5]. One of the most popular functional fermented products made using this method is sauerkraut, which is enjoyed in many European nations, originating from fresh white cabbage (*Brassica oleracea L. var. capitata*) that has been malolactically fermented and salted with 2-3% (w/w) sodium chloride [6,7]. Functional fermented foods are becoming more popular because of their physiologically active ingredients, functional qualities, and suggested and proven health advantages [8,9].

Over the years, functional foods have generated a lot of scientific interest, particularly in the fields of technology and better food health [10]. Functional food affects certain bodily systems and may offer (beyond basic nourishment) further health advantages or a cure for certain illnesses once a useful ingredient is added or concentrated, or an ineffective or dangerous ingredient is removed and has additional elements that give people health advantages that go beyond the effects of regular food products (such as pills, supplements, etc.) [11,12]. This type of food offers numerous health advantages, such as strengthening the immune health, lowering the risk of cardiovascular problems, osteoporosis, obesity, and some forms of cancer, and enhancing memory and physical health [13]. Apart from health benefits these functional foods contain nutrient-dense components like fruits and vegetables, but they can also be enhanced with fiber, probiotics, prebiotics, vitamins, and minerals [14]. Probiotics are becoming more popular due to their documented safe use and acknowledged benefits for human health [15].

Probiotics are referred to those living bacteria that colonize the human intestine, bind to epithelial cells, and exhibit resistance to gastric, biliary, and pancreatic secretions. Consequently, probiotics are health-promoting microbes that now have therapeutic effects [16]. The majority of probiotics are members of the lactic acid bacteria (LAB) group, which is made up of various genera, including *Enterococcus*, *Lactobacillus, Leuconostoc,* and *Streptococcus*. Lactic acid is the primary fermentation product of these Gram-positive, oxidase-negative, picky, and purely fermentative microbes [17]. One potential probiotic possibility is sauerkraut, a vegetable product made from cabbage that spontaneously ferments in anaerobic circumstances once salt is added [18]. These probiotic bacteria found in sauerkraut can grow without the use of a starter culture [19]. Strong evidence from experimental research demonstrating the anti-inflammatory, chemopreventive, and antioxidant capabilities of numerous naturally occurring phytochemicals in sauerkraut supports these health-promoting attributes [20]. This review's primary goal is to give a summary of the studies on sauerkraut's nutritional value and possible therapeutic health benefits.

Sauerkraut and its nutritional aspects

Among the most popular and conventional varieties of cabbage preserves, also called sauerkraut, is created by the fermentation of cabbage and has a variety of therapeutic uses [21]. Cabbage is a member of the *Brassicaceae* family. Brassica is a diversified collection of crops that belong to the *Cruciferae* family, which has around 350 genera and 3000

species. The *Brassica oleracea* family, which includes cauliflower, cabbage, and kohlrabi, is the most well-known vegetable crop worldwide because of their high nutritional value and ability to grow in a range of soil types and temperatures [22]. Over a duration of a few weeks, at temperatures between 15 and 20 degrees Celsius, *Lactobacillus plantarum* leads the homofermentative phase of fermentation, whereas *Leuconostoc mesenteroides* leads the heterofermentative phase. This microbial succession is responsible for carrying out fermentation [23,24]. The main lactic acid bacteria (LAB) that ferment cruciferous vegetables include *Levilactobacillus brevis, Latilactobacillus curvatus, Latilactobacillus sakei, Lactiplantibacillus pentosus, Lactiplantibacillus paraplantarum,* and *Lactiplantibacillus plantarum*. These bacteria create lactic acid, which adds to the distinctly tart flavor of plants while lowering pH [25].

There is ample evidence of the nutritional significance of Brassica plants, particularly cabbage. In addition, they are a rich source of essential vitamins with antioxidant properties, such as vitamin C, beta-carotene, folic acid, and tocopherol, as well as mineral components comprising selenium, calcium, magnesium, potassium, iron, and antioxidants, including flavonoids, polyphenols, and glucosinolates. Sauerkraut retains a high nutritional value and is further strengthened with health-promoting substances, although some compounds are eliminated during fermentation. It tastes much better than raw cabbage as a result, which encourages people to eat more of it [26]. Additionally, sauerkraut has phenolic compounds and vitamin C, both of which are good for the body. Due to its high vitamin C content, fermented cabbage is an excellent source of antioxidants [27].

Microbiological outlook

Leuconostoc mesenteroides and other heterofermentative lactic acid bacteria (LAB) are responsible for the spontaneous fermentation of cabbage. *Lactobacillus plantarum* takes over and finishes the fermentation process when the pH of the solution drops because fewer L. mesenteroides cells are present. The succession of bacteria creates certain notable changes in the sauerkraut during the fermentation process [28]. Lactic acid bacteria have been widely used as starting cultures for millennia. They have been crucial to the preservation of food, stability of microorganisms, and the production of aromatic chemicals in a range of food products. Lactic acid bacteria can create a wide range of antimicrobial substances, such as organic acids, hydrogen peroxide, diacetyl, inhibitory enzymes, and bacteriocins [29]. *Lactobacillus spp*. was the predominant genus, closely followed by *Leuconostoc spp*. (33%), according to probiotic LAB isolated from sauerkraut [15]. LAB inhibits bacterial growth by competing for nutrients and producing lactic and acetic acids, which function as bacterial inhibitors. However, it is crucial to assess the safety of sauerkraut salt using brines with less than 2.5% NaCl. It is essential to ensure that (LAB) growth is maintained at a lower salt level throughout the fermentation process and that adequate acid is produced to prevent the growth of harmful bacteria without compromising the sauerkraut's sensory attributes [30].

Therapeutic benefits of sauerkraut

Studies have shown that the important phytochemicals in sauerkraut provide a number of health advantages. Lactic Acid Bacteria are probiotic microorganisms that are good for health and can be found in unpasteurized sauerkraut. A starter culture is not necessary for the growth of the probiotic bacteria present in sauerkraut. All that's required for this tasty fermented dish is cabbage and salt. LABs are among the most significant microorganisms and have been shown to have advantages [19].

Therapeutic benefits are as follows-

Anti-cancer properties: One of the main goals of practically every healthcare system in the world is cancer prevention. Fresh and sour Brassica vegetables, especially white cabbage, contain a number of healthy chemicals that have been shown in several studies to

be helpful in the prevention and treatment of cancer. The inverse link between eating Brassica vegetables and cancer risk is thought to be caused by the presence of glucosinolates in these plants [31]. Ciska et al. [32] investigated the stability of these breakdown products over the prolonged storage of the finished products after fermentation, as well as the changes in glucosinolates (GLS) during the fermentation of white cabbage and the evolution of the end products in sauerkraut and sauerkraut juice independently. The results demonstrated that both of the products are excellent sources of bioactive compounds, particularly the ascorbigen and isothiocyanates. Cabbage and other Brassica plants are especially rich in the glucosinolate ascorbigen. Glucobrassicin is one of the most frequently studied glucosinolates. This substance is a precursor of indole-3-carbinol (I3C) and ascorbigen, both of which are considered potential anticarcinogens [33]. While eating long-cooked pickles had no correlation with breast cancer, eating raw or lightly fermented cabbage can significantly lower the risk, probably because heat destroys the probiotics or active ingredients [34].

Anti-inflammatory and intestinal health properties: The main cause of fermented food's anti-inflammatory and immunomodulatory properties is the elevated antioxidant levels and lactic acid-producing bacteria. Antioxidant substances contained in fermented food products neutralize free radicals, regulate antioxidant enzyme activities, lower oxidative stress, diminish inflammatory reactions, and improve immune system efficiency [35]. According to studies, eating fermented vegetables for six months can reduce the imbalance in gut dysbiosis, and eating fermented vegetables cultured with lactic acid for a while can help reduce the symptoms of irritable bowel syndrome (IBS) [36]. They can also aid in the relief of constipation. The accumulation of fecal pollutants in the intestines may raise the risk of digestive issues, and constipation lowers the quality of life. Most of the time, probiotics found in fermented produce help alleviate constipation [37]. Numerous studies have shown that sauerkraut has anti-inflammatory properties. Some of sauerkraut's anti-inflammatory properties may be attributed to allyl isothiocyanate and indol-3-carbinol [38].

Effect on the immune system: Sauerkraut is another excellent source of LAB. As they improve innate and adaptive immunity and reduce inflammation by altering the gut microbiota, LAB are significant organisms that are considered probiotics [39]. *Leuconostoc mesenteroides* is a Gram-positive bacterium that ferments foods, including milk, sauerkraut, and kimchi, to create various organic acids and aromatic compounds. Zubaidah et al. examined how sauerkraut and *Leuconostoc mesenteroides* culture affected experimental animals' immune systems. The study's findings showed that sauerkraut strengthened both the innate and adaptive immune health [40]. The presence of the well-known phyla (*Firmicutes and Bacteroidetes*) in the gut microbiota, which is recognized to be crucial for the development and defense of the immune system, is triggered by LAB inclusion [41].

Conclusion

Sauerkraut is more than just a traditional fermented food; it's a nutrient-dense functional food with notable potential to promote human health. Naturally fermented cabbage becomes rich in probiotics, organic acids, and bioactive compounds that can benefit health. Frequent consumption may strengthen immunity, reduce inflammation, and preserve a balanced gut microbiota. Additionally, several phytochemicals that are produced or preserved during fermentation have demonstrated potential benefits in reducing the risk of a number of chronic illnesses, including some forms of cancer. All things considered, sauerkraut is a simple, readily available, culturally significant, and health-promoting item that is a great complement to a well-balanced diet.

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