

## ORIGINAL RESEARCH



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# Regular Consumption of Sauerkraut and Its Effect on Human Health: A Bibliometric Analysis

酸菜的定期消耗量及其对人类健康的影响：一项文献计量分析

Consumo regular de chucrut y su efecto sobre la salud humana: un análisis bibliométrico

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## Key Words

Sauerkraut, bibliometric analysis, lactic acid, tyramines

## ABSTRACT

**Background:** Sauerkraut is one of the most common and oldest forms of preserving cabbage and can be traced back as a food source to the 4th century BC. It contains a large quantity of lactic acid and tyramines, as well as vitamins and minerals, and has few calories.

**Objective:** We aimed to provide an overview regarding the evidence of the effects of sauerkraut on human health by means of a bibliometric analysis.

**Methodology:** Electronic databases (Medline, AMED, CamBase, CamQuest, the Cochrane Central Register of Controlled Trials, the Database of Abstracts of Reviews of Effects, the Cochrane Database of Systematic Reviews, EMBASE, the Karger-Publisher and the Thieme-Publisher databases) were searched from their inception until September 2012.

**Results:** The search revealed 139 publications ranging over a 90-year period from 1921 to 2012. The majority of publications originated from Europe (48.6%), followed by the United States (30.7%) and Asia (10%). More than half of the research (56.8%) focused on food analysis, and 23.7% evaluated the impact of sauerkraut on health, including risk factors or digestive well-being. Direct research in humans was almost constant over time at about 11.5%. The studies found that sauerkraut induced inflammation locally, but repeated intake may result in diarrhea. Some studies pointed out anticarcinogenic effects of sauerkraut, while others concentrated on the interaction

with monoamine oxidase inhibitors (MAOIs).

**Discussion:** Sauerkraut, one of the oldest traditional foods, has a variety of beneficial effects on human health. However, unwanted effects such as intolerance reactions must be considered when dealing with sauerkraut as a functional food.

## 摘要

背景：酸菜是一种保存白菜的最常见和最古老的方式，其历史可以追溯到公元前 4 世纪白菜作为食物来源时。酸菜含有大量乳酸和酪胺以及维生素和矿物质，并有少量热量。

目的：我们旨在通过文献计量分析提供酸菜对人类健康影响的证据。

方法学：对电子数据库（Medline、AMED、CamBase、CamQuest、Cochrane 对照试验注册中心（Cochrane Central Register of Controlled Trials）、作用综述摘要数据库（Database of Abstracts of Reviews of Effects）、Cochrane 系统综述数据库（Cochrane Database of Systematic Reviews）、EMBASE、Karger-Publisher 和 Thieme-Publisher 数据库）从初创至 2012 年 9 月的数据进行全面检索。结果：检索显示，1921 年至 2012 年的超过 90 年期间，有 139 篇相关文献发表。大多数出版物来自欧洲（48.6%），其次是美国（30.7%）和亚洲（10%）。超过半数的研究（56.8%）集中在食品分析上，23.7% 的研究评估了酸菜对健康的影响，包括风险因素或消化系统健康。随着时间的推移，对人类的直接研究约占 11.5%。研究发现，酸菜对局部炎症有作用，但反复摄取可能导致腹泻。一些研究指出酸菜有抗癌作用，而其他研究则

关注酸菜与单胺氧化酶抑制剂（monoamine oxidase inhibitors, MAOI）的相互作用。

讨论：酸菜是最古老的传统食品之一，对人类健康有多种有益的影响。然而，当按照功能性食品看待酸菜时，必须考虑到其不利作用，如不耐性反应。

## SINOPSIS

**Antecedentes:** El chucrut es una de las formas más comunes y anti-guas de preservar el repollo y se remonta como fuente alimentaria al siglo IV a. C. Contiene una gran cantidad de ácido láctico y tiraminas, así como vitaminas y minerales, y tiene pocas calorías.

**Objetivo:** Nuestro objetivo era proporcionar una visión general en lo que se refiere a las pruebas de los efectos del chucrut sobre la salud humana mediante un análisis bibliométrico.

**Metodología:** Se realizaron búsquedas en bases de datos electrónicas (las bases de datos Medline, AMED, CamBase, CamQuest, Cochrane Central Register of Controlled Trials, Database of Abstracts of Reviews of Effects, Cochrane Database of Systematic Reviews, EMBASE, Karger-Publisher y Thieme-Publisher) desde su inicio hasta septiembre de 2012.

**Resultados:** La búsqueda reveló 139 publicaciones, todas ellas de un período de 90 años comprendido entre 1921 y 2012. La mayoría de publicaciones eran originarias de Europa (48,6 %), seguido de Estados Unidos (30,7 %) y Asia (10 %). Más de la mitad de la investigación (56,8 %) se centraba en el análisis alimentario, y el 23,7 % evaluaba el

impacto del chucrut sobre la salud, incluidos los factores de riesgo o el bienestar digestivo. La investigación directa en humanos era casi constante todo el tiempo, en aproximadamente el 11,5 %. Los estudios descubrieron que el chucrut afectaba a la inflamación localmente,

aunque si se comía repetidamente podía provocar diarrea. Algunos estudios señalaron efectos anticancerígenos del chucrut, mientras que otros se concentraron en la interacción con inhibidores de la monoaminooxidasa (IMAO).

**Discusión:** El chucrut, uno de los ali-

mentos tradicionales más antiguos, presenta una diversidad de efectos beneficiosos para la salud humana. Sin embargo, deben tenerse en cuenta efectos no deseados, como reacciones de intolerancia, al tratar al chucrut como un alimento funcional.

## BACKGROUND AND OBJECTIVE

Nutrition has a major impact on human health. According to a report of a joint expert consultation of the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO), nutrition is seen “as a major modifiable determinant of chronic disease, with scientific evidence increasingly supporting the view that alterations in diet have strong effects, both positive and negative, on health throughout life.”<sup>1</sup> However, nutritional determinants that influence health are often linked to a variety of complex physiological mechanisms and processes at a cellular level and thus are difficult to identify. Overall, nutrition is considered to have a central impact on wellbeing, quality of life, lifespan, and disease occurrence and development.

One food group that has a long tradition of consumption by a variety of human populations is fermented food. According to Steinkrauss,<sup>2</sup> fermentation produces a wide range of flavors and aromas but also enriches food with proteins, vitamins, and essential amino and fatty acids and leads to a detoxification of food during the fermentation process. Apart from fermented drinks and sauces, another classical approach is the fermentation of vegetables. In the case of cabbage, this leads to sauerkraut. Sauerkraut is one of the most common and oldest forms of preserved cabbage (*Brassica oleracea convar capitata var sabauda* L) or pointed cabbage (*Brassica oleracea var capitata falba*). It is produced by the process of malolactic fermentation and can be traced back as a food source to the 4th century BC.<sup>3</sup> Sauerkraut contains a large quantity of lactic acid; vitamins A, B, C, and K; and minerals and has few calories (about 80 kJ/100g). Even today in Germany, approximately 200 000 tons of cabbage are processed into sauerkraut. Between 1975 and 1980, the per capita use of sauerkraut in Germany stayed constant at 2.0 to 2.1 kg per year.<sup>3,4</sup> Sauerkraut is also very popular in the United States and France, where it is also known as “German Kraut” or “Cassoulet.” Hippocrates described sauerkraut as a health food and medicinal remedy in his writing. The Romans have also valued the beneficial effect of sauerkraut. The writer Plinius Secundus wrote, “The cabbage helps to provide plenty of milk for breastfeeding mothers, it helps for cloudy eyes, positively affects headaches and is supposed to work as a cure after alcohol consumption.”<sup>5</sup> Sauerkraut was one of the major foods in seafaring due to its high vitamin content and was used to counteract scurvy.<sup>6</sup> In

addition to these rather generally described health effects, scientific research assessed the effects and efficacy of sauerkraut. Research can be traced back to the early 20th century.

The objective of this article is to provide an overview regarding the evidence of the effects and efficacy of sauerkraut on human health.

## METHODS

A literature search was conducted according to the PRISMA guidelines. Electronic databases were searched from their inception until September 2012 by using the search term “sauerkraut.” Due to the specific nature of this bibliometric analysis on sauerkraut, we did not search for related terms such as “Brassica AND fermentation” or “fermented white cabbage.” A pilot search with these terms found a high volume of articles not relevant for our purpose (eg, on fermentation of pickles, *Brassica rapa*, phenolic compounds in leaves of pak choi).

The following databases were searched: AMED, CamBase, CamQuest, the Cochrane Central Register of Controlled Trials, the Database of Abstracts of Reviews of Effects, the Cochrane Database of Systematic Reviews, EMBASE Alert, EMBASE, the Karger-Verlagsdatenbank, Medline, and the Thieme-Verlagsdatenbank.

After we removed duplicates, the articles were introduced to a bibliometric analysis. In this step, articles were fully screened by two of the authors (CR and KB), mined in a structured electronic data sheet, and analyzed in terms of publication year, country, study type, type of sauerkraut, outcome, and main results. In cases in which authors did not identify their approach to duplicate publications, we described the results only once. Descriptive statistics are used to quantify differences with respect to the time of publication. In a second step, articles dealing with sauerkraut addressing issues related to human health in a broad sense were identified and summarized in terms of a structured overview. Articles were excluded from this second step if one of the criteria below was fulfilled:

- articles on the production of sauerkraut only;
- analysis of sauerkraut wastewater;
- biochemical properties of sauerkraut, including its conservation;
- analysis of bacteria cultures; or
- editorials, recipes, and theoretical considerations.

The complete process of the literature search is provided as a PRISMA flowchart in the Figure.

## RESULTS

The search resulted in a total of 251 publications. After removal of duplicates, 148 publications remained. Of those, nine were excluded as they were not available. The remaining 139 publications ranged over a 90-year period from 1921 to 2012 with a median in 1995 (interquartile range 1980-2005). The majority of publications ( $n=68$ ; 48.9%) originated from Europe followed by the United States ( $n=43$ ; 30.9%) and Asia ( $n=14$ ; 10.0%). A more detailed analysis revealed that the origin of the studies changed highly significantly (chi-square: 18.57;  $P<.002$ ) within the course of time from the United States ( $n=28$ ; 40.6%) before 1995 to  $n=15$  (21.4%) after 1995 to Europe ( $n=26$ ; 37.7%) before 1995 to  $n=42$  (60.0%) after 1995. Most of the studies, however, were conducted in the United States ( $n=36$ ; 25.9%) followed by Germany ( $n=24$ ; 17.3%) and Poland ( $n=7$ ; 5%).

More than half of the research ( $n=79$ ; 56.8%) focused on food analysis including content analysis, antimicrobial properties, and fermentation or conservation issues, while  $n=33$  publications (23.7%) evaluated the impact of sauerkraut on health, including risk factors (eg, urticarial reaction) or digestive well-being (eg, food preferences). The remaining publications ( $n=9$ ; 6.5%) concentrated on various evaluations of process technology (ie, in dealing with the retention of biomass). Although food analysis research increased from  $n=35$  papers (50.7%) before 1995 to  $n=44$  (62.9%), this increase was not found to be significant (chi-square=11.02;  $P=.051$ ).

Consequently, most of the studies were experimental ( $n=98$ ; 70.5%), of which  $n=2$  (1.4%) were in vivo studies,  $n=11$  (7.9%) were in vitro studies, and  $n=85$  (61.2%) studies were other types of lab studies. Only

$n=7$  (5.6%) publications were related to a clinical context (4 clinical studies, 3 case reports). Study design characteristics did not change over time (chi-square=11.43;  $P=0.121$ ). Table 1 provides an overview of the publications. In most cases ( $n=50$ ; 36.0%), the investigation concentrated on the food itself closely followed by research on bacteria ( $n=42$ ; 30.2%). Direct research in humans was almost constant over time at about 11.5%. Twenty-three of the 139 publications that were relevant for human health were included in an in-depth description in Table 2.

Sauerkraut was mentioned in four surveys. The first review, by Sweet, analyzed the frequency of consumption of tyramine-containing food in 139 psychiatric patients. Compared to other high-risk foods, the intake of sauerkraut was used at least monthly by 50% of the patients.<sup>7</sup> Another German survey about food preferences involving 1234 adolescents aged 10 to 14 years found that sauerkraut was disliked to a high degree.<sup>8</sup> In the same year, Tantcheva et al carried out an epidemiological study on the impact of a variety of lifestyle parameters and sociodemographic data on cytochrome P450 1A2 (CYP1A2) activity, which did not find a significant impact of sauerkraut consumption.<sup>9</sup> Finally, the survey by Hasnip et al from 2007 about fermented foods sold in the United Kingdom in 2004 revealed that samples of sauerkraut contained low levels (29 µg/kg) of ethyl carbamate.<sup>10</sup>

The first lab study included in our review was carried out in early 20th century Germany by Gehlen.<sup>11</sup> In his experiments in cats and frogs, he found that sauerkraut juice affected inflammation locally but resulted in diarrhea after repeated intake. Twenty years later, Knapp et al investigated the viability of typhoid bacteria in barrelled and canned sauerkraut but found no risk to human health.<sup>12</sup> The study of Reece et al 1985 in 25 healthy volunteers found that sauerkraut juice

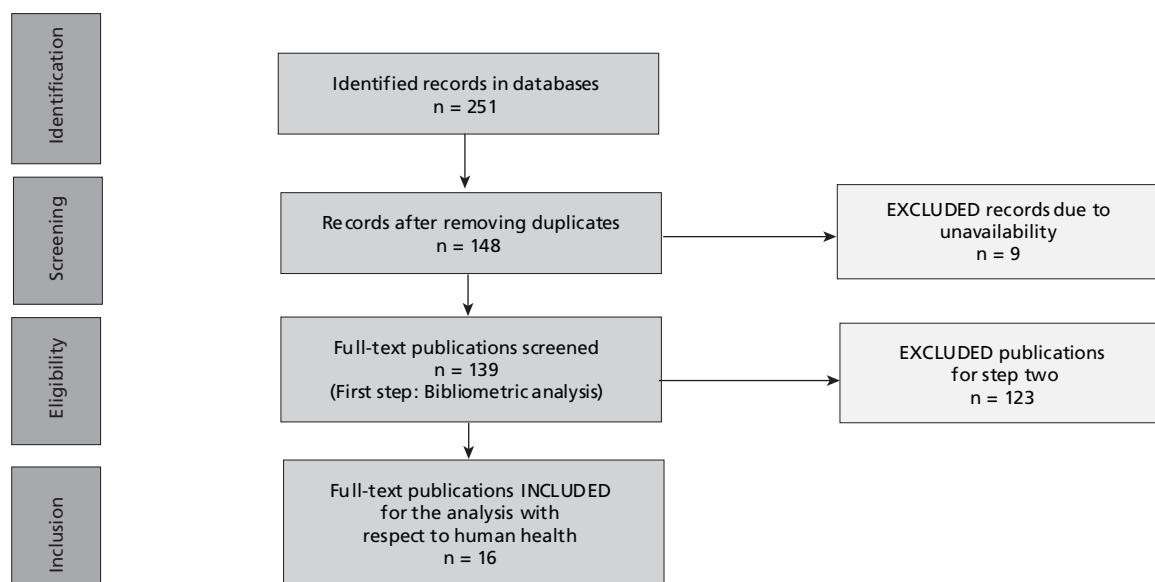


Figure PRISMA chart of the literature search.

**Table 1** Overview of Studies Dealing With Sauerkraut

	Year		
	Before and through 1995	After 1995	Total
<b>Origin</b>			
Europe	26 (37.7%)	42 (60.0%)	68 (48.9%)
Asia	4 (5.8%)	10 (14.3%)	14 (10.0%)
America	28 (40.6%)	15 (21.4%)	43 (30.9%)
Africa	1 (1.4%)	0 (0.0%)	1 (0.7%)
Australia	0 (0.0%)	2 (2.9%)	2 (1.4%)
Not known	10 (14.5%)	1 (1.4%)	11 (7.9%)
<b>Primary focus</b>			
Impact on health	15 (21.7%)	18 (25.7%)	33 (23.7%)
Process technology	6 (8.7%)	3 (4.3%)	9 (6.5%)
Food analysis	35 (50.7%)	44 (62.9%)	79 (56.8%)
Wastewater analysis	0 (0.0%)	2 (2.9%)	2 (1.4%)
Other	5 (7.2%)	2 (2.9%)	7 (5.0%)
Not known	8 (11.6%)	1 (1.4%)	9 (6.5%)
<b>Type of study</b>			
Review	8 (11.6%)	9 (12.9%)	17 (12.2%)
In vivo	1 (1.4%)	1 (1.4%)	2 (1.4%)
In vitro	4 (5.8%)	7 (10.0%)	11 (7.9%)
Clinical study	2 (2.9%)	3 (4.3%)	5 (3.6%)
Survey/epidemiological study	2 (2.9%)	4 (5.7%)	6 (4.3%)
Case report	3 (4.3%)	0 (0.0%)	3 (2.2%)
Lab research	40 (58.0%)	45 (64.3%)	85 (61.2%)
Not known	9 (13.0%)	1 (1.4%)	10 (7.2%)
<b>Investigated item</b>			
Bacteria	18 (26.1%)	24 (34.3%)	42 (30.2%)
Food	21 (30.4%)	29 (41.4%)	50 (36.0%)
Humans	8 (11.6%)	8 (11.4%)	16 (11.5%)
Others	8 (11.6%)	6 (8.6%)	14 (10.1%)
Not specified	14 (20.3%)	3 (4.3%)	17 (12.2%)

inconsistently caused watery stool.<sup>13</sup> Groenen et al found a strong alkylating activity in samples of sauerkraut after incubation with nitrite.<sup>14</sup> Walker et al (1996) analyzed the tyramine content of 51 food samples by means of liquid chromatography. They found a dangerously high concentration of tyramine at 7.75 mg/250 g in sauerkraut.<sup>15</sup>

More recently in 2010, Penas et al investigated storage effects in cabbage and found that low-salt sauerkraut produced with *L. mesenteroides* provided highly beneficial antioxidant and anticarcinogenic compounds.<sup>16</sup> Moreover, they found that the addition of selenium caused a slight reduction of ascorbigen and vitamin C contents in sauerkraut and enhanced the formation of indole-3-carbinol and indole-3-acetonitrile and the antioxidant activity and inhibition of NO production.<sup>17</sup>

A working group from Poland published two papers on sauerkraut. In a first study, they investigated the chemopreventive activity of sauerkraut.<sup>18</sup> They found that sauerkraut juice had a high impact on the expression profile of the estrogen metabolism key enzymes in human breast cell lines compared to indole-3-carbinol (I3C) and 3,3'-diindolylmethane (DIM). In a similar experiment about the activity and expression of CYP1A1, 1A2, 1B1, and 2B in Wistar rat livers and kidneys, the authors found a decreased activity of enzymatic markers of CYP1A1 and CYP1A2 after 10 days of the experiment, while in the kidney an enhancement of the activity of

these enzymes was observed on days 4 and 10, demonstrating potential anticarcinogenic activity.<sup>19</sup>

From a dermatological point of view, the study by Doerglas et al (1968) revealed false positive scratch test results due to urticarial reactions of some brands of sauerkraut due to their high histamine content.<sup>20</sup> A French clinical study by Danchin et al (1999) in eight patients with mesenteric angina found significant differences in disease burden with respect to the intake of French cassoulet and international sauerkraut.<sup>21</sup> Finally, in 2011, Wang et al conducted a matched case-control study to obtain risk factors of laryngeal cancer in the Heilongjiang Province, China.<sup>22</sup> They found intake of sauerkraut to be a risk factor with an odds ratio of 7.26 comparing the highest vs the lowest quintile of intake. Another study by Gillooly et al from South Africa in 1983 investigated the effects of organic acids on iron absorption in 183 humans. Among 17 included vegetables, sauerkraut ranked second in the absorption of iron, which according to the authors might be due to its high lactic acid content.<sup>23</sup>

## DISCUSSION

Popular papers on healthy lifestyle suggest that regular sauerkraut consumption can contribute to a healthy digestive flora. The authors of these papers claim that adding foods like sauerkraut or kimchi to the diet is beneficial as they may deliver probiotics into the gastrointestinal system.<sup>24</sup> However, empirical studies towards this topic are widespread and focus on a variety of aspects. Our bibliometric analysis tried to provide an overview of these publications. While a number of articles on the analysis of sauerkraut are available, the impact on human health is covered by only a minority of the articles found. Some main points of investigation can be identified as described below.

### The Interaction of Sauerkraut With Monoamine Oxidase Inhibitors

Monoamine oxidase inhibitors (MAOIs) inhibit the activity of the monoamine oxidase enzyme family and therefore are prescribed for the treatment of depression, anxiety disorders, obsessive compulsive disorders, and Parkinson's disease. There is evidence that MAOIs are likely to interact with complementary remedies or food supplements like St John's wort<sup>25</sup> or ginkgo.<sup>26</sup> Due to its dangerously high concentrations of tyramine, sauerkraut appears on MAOI diet-restricted food lists.<sup>15</sup> However, the concentration of tyramine as well as other biogenic amines shows a broad variation in samples of sauerkraut. A very early study by Kalac et al<sup>27</sup> found variations of mean tyramine concentrations in different studies between 25 mg/kg and 89 mg/kg. In the authors' own experiments, they found tyramine concentrations of six Czech manufacturers between 107 mg/kg and 436 mg/kg, with the lowest concentrations found in household preparations of sauerkraut. These results are underpinned by another study by Kalac et al,<sup>28</sup> which found significant lower biogenic amine



**Table 2** Publications on Sauerkraut Dealing With Human Health

First author	Year	Country	Study type	Subject	Outcome parameter
Gehlen	1932	Germany	Lab research	Food itself	Pharmacological effect
Knapp	1953	Germany	In vitro	Bacteria	Antibacterial effect
Doeglas	1968	Netherlands	Clinical study	Humans	Urticarial reaction
Gillooly	1983	South Africa	Clinical study	Humans	Iron absorption
Reele	1985		In vivo	Humans	Sorbitol-induced diarrheal illness model
Groenen	1988	Netherlands	Lab research	Food itself	Alkylating activity
Sweet	1995	United States	Survey	Humans	Psychiatric patients' frequency of consumption
Walker	1996	Canada	Lab research	Food itself	MAOI diet by determining the tyramine content of a variety of untested and "controversial" foods
Tantcheva-Poór	1999	Germany	Survey	Humans	Sources of cytochromes
Danchin	1999	France	Clinical study	Food itself	Test comparative effects between 2 types of sauerkraut
Diehl	1999	Germany	Survey	Humans	Food preference in this age group
Saloheimo	2005	Finland	Lab research	Food itself	Scurvy prevention
Hasnip	2007	United Kingdom	Survey	Food itself	In-house survey of fermented foods and beverages sold in the UK
Penas	2010	Spain	Lab research	Food itself	Storage effect
Wang	2011	China	Clinical study	Humans	Lifestyle risk factors
Szaefer	2012	Poland	In vitro	Food itself	Effect of raw cabbage and sauerkraut juices on the activity and expression of CYP1A1, 1A2, 1B1 and 2
Szaefer	2012	Poland	In vitro	Food itself	Investigate the effect of cabbage and sauerkraut juices of different origin
Penas	2012	Spain	Lab research	Food itself	Production of selenium-enriched sauerkraut

levels in sauerkraut being isolated from bacteria from shredding machines, transporters, and silos. Moreover, sauerkraut inoculated with *L. plantarum* or Microsil (Medipharma CZ Ltd, Czech Republic) also showed significantly lower concentrations of tyramine (Table 3). Finally, the same working group found a relationship between storage time and tyramine concentration with significantly higher concentrations of tyramine in long-stored sauerkraut.<sup>29</sup> Thus, dietary restrictions for sauerkraut have to take type, preparation, and storage time of sauerkraut into account.

### Sauerkraut and Cancer

Cancer protection is one of the major goals of almost every healthcare system worldwide. Experiments found that high levels of glucosinolates, ascorbigen, and ascorbic acid decrease DNA damage and cell mutation rate in cancer patients, and sauerkraut is known to have a high content of these compounds. However, the level of concentration strongly depends on the fermentation conditions of the cabbage.<sup>30</sup> According to Martinez-Villaluenga,<sup>31</sup> producing cabbage at low-salt concentration improved ascorbigen content, with the highest concentration being observed in low-sodium (0.5% NaCl) sauerkraut produced from cabbage cultivated in winter using natural fermentation (Table 4). Ascorbic acid content, on the other hand, was found to be higher in cabbage cultivated in summer, with fermentation reducing the content. This is

supported by the studies of Penas and Szaefer.<sup>16-19</sup> However, inhibition of enzymatic markers in the liver might not be seen as an indicator for anticarcinogenic activity, even if markers in the kidney show enhanced activity, which might be due to interaction effects. Thus, the evidence base of sauerkraut for cancer currently seems to be inconclusive. This is even more questionable when considering the results of Wang et al, who found sauerkraut to be a risk factor for cancer.<sup>22</sup> Apart from cancer-related aspects, different types of fermentation processes might also explain the results of the CASS-CHOU study on mesenteric angina, which also found significant differences between the sauerkraut products in that study.<sup>21</sup>

### Sauerkraut and Allergic Reactions

Sauerkraut not only has high content of tyramine and glucosinolates but also shows high concentrations of histamine. Histamine in food has been proposed to be a major cause of food intolerance. Allergic reactions go along with a release of histamine; therefore, histamine in food might contribute to allergic symptoms, although the food itself is not a cause of the allergic reaction. The additional histamine load has to be considered, especially, for instance in the high season for people who suffer from hay fever. This is supported by a recent study by Wöhrle et al<sup>32</sup> in healthy volunteers, who found that oral provocation with liquid histamine might result in symptoms like tachycardia, mild hypo-

**Table 3** Content of Tyramine, Histamine in Different Preparations of Sauerkraut

	Tyramine in mg/kg	Histamine in mg/kg
<b>Kalac et al, 1999</b>		
Czech manufacturers	235±213	12.1±31.6
Austrian manufacturers	130±71	2.1±2.4
Household	117±113	4.6±6.8
Sterilized	134±90	4.9±6.4
<b>Kalac et al, 2000</b>		
<b>Early production (Glorie)</b>		
<i>L. plantarum</i>	96	1.4
<i>L. casei</i>	105	1.6
<i>P. pentosaceus</i>	116	2.3
<i>E. faecium</i>	93	7.0
Microsil	97	0.8
<b>Late production (Jaguar)</b>		
<i>L. plantarum</i>	32	2.0
<i>L. casei</i>	86	0.6
<i>P. pentosaceus</i>	100	1.3
<i>E. faecium</i>	107	3.0
Microsil	30	1.0
<b>Late production (Krautkaiser)</b>		
<i>L. plantarum</i>	52	1.1
<i>L. casei</i>	122	0.6
<i>P. pentosaceus</i>	114	2.2
<i>E. faecium</i>	93	2.7
Microsil	70	2.4
<b>Spicka et al, 2002</b>		
<b>Late production (Jaguar)</b>		
<b><i>L. plantarum</i></b>		
5 x 104	183	2.7
1 x 105	157	N/A
5 x 105	162	N/A
<b>Microsil</b>		
5 x 104	180	3.6
1 x 105	144	N/A
5 x 105	180	N/A
<b>Late production (Krautkaiser)</b>		
<b><i>L. plantarum</i></b>		
5 x 104	204	N/A
1 x 105	209	N/A
5 x 105	132	N/A
<b>Microsil</b>		
5 x 104	148	N/A
1 x 105	150	N/A
5 x 105	102	N/A

tension, sneezing, itching of the nose, and rhinorrhea but also and more often in diarrhea or flatulence, headache, or pruritus. Thus, high intake of sauerkraut in sensitive people might result in similar reactions. The study by Doeglas et al revealed false-positive scratch test results due to urticarial reactions caused by high histamine content and therefore must also be taken into consideration.<sup>20</sup> Again, preparation of sauerkraut also influences its level of histamine content. A very early study by Taylor<sup>33</sup> in 50 samples of sauerkraut found the histamine concentration to range between 0.91 mg/100 g and 13.0 mg/100 g. The review by Kalac revealed mean histamine concentrations between 0.6 mg/100 g and 5.6 mg/100 g. Their own experiments found histamine levels below 0.2 mg/100 g in 44% of their samples and above 1 mg/100 g in only 19% of the

**Table 4** Content of Ascorbic Acid in Different Preparations of Sauerkraut

	Ascorbic acid in mg/100g
<b>Martinez-Villalouenga et al, 2009</b>	
<b>Cultivation in Winter</b>	
<b>Natural fermentation</b>	
NaCl 0.5%	156.72±8.90
NaCl 1.5%	158.00±9.56
<b><i>L. plantarum</i></b>	
NaCl 0.5%	162.63±8.20
NaCl 1.5%	161.47±6.50
<b><i>L. mesenteroides</i></b>	
NaCl 0.5%	159.8 ±5.36
NaCl 1.5%	160.68±7.10
<b>Cultivation in Summer</b>	
<b>Natural fermentation</b>	
NaCl 0.5%	256.31±16.66
NaCl 1.5%	182.83±17.23
<b><i>L. plantarum</i></b>	
NaCl 0.5%	238.00±31.73
NaCl 1.5%	266.25±3.96
<b><i>L. mesenteroides</i></b>	
NaCl 0.5%	229.43±5.06
NaCl 1.5%	239.33±23.36

samples. Looking at the very early studies of Gehlen et al<sup>11</sup> and Reece et al,<sup>13</sup> one has to consider that the effect of sauerkraut on the digestive tract of cats and frogs cannot directly be transferred to humans and that the effect of the use of the juice can be different from the effect of the use of the whole sauerkraut, including the fibers. The main enzyme for metabolism of ingested histamine is diamine oxidase (DAO), which plays a major role in amine degradation in the human body and is mainly produced in the epithelium of the large intestine. However, only limited evidence is available on the interaction of DAO and histamine degradation. Current work by Naila et al<sup>34</sup> used a tuna soup model with a constant concentration of histamine (500 mg/L) and DAO enzyme (2534 units/L) to predict the rate and amount of histamine degradation by DAO. They suggested using this model for food with similar characteristics. In this respect, sauerkraut juice might be one promising option for further basic research. Furthermore, it is unclear whether vitamins, especially vitamin B<sub>6</sub> in sauerkraut, might support the production of DAO. The production of DAO could also be increased by improved gut function due to the fibers, minerals, and vitamins in sauerkraut—and may even benefit allergic patients.

According to personal clinical experience, regular intake of small doses of sauerkraut—7 g to 10 g (or about 1 T) daily—has a very good effect on many patients' gastrointestinal tract. They report better digestion and less constipation. Allergic problems have not been observed. However, clinical studies are needed to support this anecdotal experience.

To evaluate the effect on the gut, further research would have to consider the amount and regularity of the intake of sauerkraut and its effect on digestive markers and clinical symptoms, including a possible benefit for

weight control due to the low content of calories in connection with high content of fibers and vitamins.<sup>35</sup>

### Limitations

Although we tried to be comprehensive in our search, it is possible that studies on sauerkraut were overlooked and thus not included, possibly due to different wording (ie, fermented cabbage, German kraut) or language restrictions. The latter might also result in an underrepresentation of publications from Asia. According to a bibliometric study in the *Journal of Food Science and Technology* from 2000 to 2004,<sup>36</sup> a majority of publications (85%) came from India, and according to Mukherjee et al<sup>37</sup> there is potential research in this field that might have been missed by our analysis.

The initial finding of only 148 publications might be considered low for a literature evidence assessment. However, compared to other specialized bibliometric analyses published—for instance, on randomized clinical trials on acupuncture in the Korean literature with  $n=143$  articles—our number of articles is comparable.<sup>38</sup>

Another limitation of our analysis lies in the absence of a critical appraisal of quality indicators of the articles included in our analysis. Due to the high degree of diversity in research methodology and settings, we abstained from applying corresponding quality checklists.

### CONCLUSION

Although sauerkraut has a variety of claimed beneficial health effects, they need to be interpreted with caution as it can also cause some unwanted or even allergic reactions, in particular in high-risk populations, such as depressive or allergic patients. Future research in this area should include clinical studies investigating further effects in more detail, including an appropriate sample size as well as the assessment of possible adverse events of sauerkraut.

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