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Sauerkraut–A Healthy Way to Maintain Our Health

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Abstract—*Human body is the bag of cells. It contains human cells as well as normal microbiota which number is trillions to human cells. Normal microbiota are beneficial to our body in providing vitamins, improving digestion and thus maintaining good gut health. Our modern eating habits, infections and use of antibiotics disturb the normal microbiota and pave the way for opportunistic microorganisms in establishment of infections. This condition can be naturally challenged with the intake of probiotics. Probiotics are the live microbial feed supplement which beneficially affects the host animal by improving intestinal microbial balance. The traditional fermented foods help to maintain the probiotic number of human body. Sauerkraut is one of the best studied probiotic food which has been overlooked by most of the people. The present study makes every individual to get inspired by the benefits of sauerkraut because it is a friendly food.*

Keywords*: Normal microbiota, opportunistic microorganisms, probiotic food, sauerkraut, traditional fermented food.*

1. INTRODUCTION

1.1 Normal microbiota of Human gastrointestinal tract and benefits:

The mucosal surface of the human gastrointestinal (GI) tract is about 200–300 m^2 and is colonized by $10^{13–14}$ bacteria of 400 different species and subspecies. Savage [1] has defined and categorized the gastrointestinal microbiota into two types, indigenous flora (resident flora) and (transient flora). Resident flora colonize particular habitats, i.e., physical spaces in the GI tract, whereas transient flora cannot colonize particular habitats except under abnormal conditions. Most pathogens are transient of which some of them can become resident to the ecosystem and normally live in harmony with the host, except when the system is disturbed [2]. The prevalence of bacteria in different parts of the GI tract appears to be dependent on several factors, such as pH, peristalsis, redox potential, bacterial adhesion, bacterial cooperation, mucin secretion, nutrient availability, diet, and bacterial antagonism. Because of the low pH of the stomach and the relatively swift peristalsis through the stomach and the small bowel, the stomach and the upper two-thirds of the small intestine (duodenum and jejunum) contain only low numbers of microorganisms, which range from 10^3 to 10^4 bacteria/mL of the gastric or intestinal contents, mainly acid tolerant *Lactobacilli* and *Streptococci*. In the distal small intestine (ileum), the microbiota begin to resemble those of the colon, with around 10^7–10^8 bacteria/mL of the intestinal contents. With decreased peristalsis, acidity, and lower oxidation-reduction potentials, the ileum maintains a more diverse microbiota and a higher bacterial population [3]. Probably because of slow intestinal motility and very low oxidation-reduction potentials, the colon is the primary site of microbial colonization in humans. The colon harbors tremendous numbers and species of bacteria. However, 99.9% of colonic microbiota are obligate anaerobes.

1.1.1 Effects of Gastrointestinal Microbiota: The most important beneficial effect of the indigenous microbiota is to make it more difficult for exogenous pathogenic bacteria to colonize the GI tract and cause disease, a phenomenon known as colonization resistance [4]. Indigenous microbiota create this barrier effect by occupying available habitats (adhesion sites) at the mucosal level, competing for metabolic substrates and the production of regulatory factors such as short-chain fatty acids and bacteriocins. On the other hand, indigenous microbiota may have potentially deleterious influences on the host's health. There are strong links among dietary factors, the metabolic activities of the indigenous GI microbiota, and bowel cancer [5]. In fact, it is well known that indigenous GI bacteria transform certain dietary substances into precarcinogens or carcinogens. Colonization of bacteria is a prerequisite to affect the host, and the process of colonization is directly dependent on the ability of a resident to adhere to the substratum.

A key example of the importance of this metabolic relationship was the finding that germfree mice require supplementation with vitamin K and some B vitamins (i.e., folate, B_{12}, and biotin) since these vitamins are microbially derived products [6,7]. Indeed, these vitamins are synthesized by several intestinal genera, including *Bacteroides*, *Eubacterium*, *Propionibacterium*, and *Fusobacterium*.

1.2 Probiotics and benefits: Probiotic foods are foods containing probiotic microorganisms: living microorganisms that impart health benefits to the host. These bacteria can help to maintain internal microbial balance and defend against harmful bacteria. The exact mechanisms of probiotics are complex; there is a delicate balance of gastrointestinal gut flora for which the interactions of the various bacteria, as well as their interaction with the rest of the human body, are not entirely understood [8].

The health benefits associated with probiotics vary widely depending on specific strains and circumstances. Certain types of probiotics have been shown to reduce diarrhea in infants as well as diarrhea caused by *C. difficile*, a common bacteria that proliferates when patients are given antibiotics [9]. Other probiotics have improved eradication of *H. pylori*, which is known to cause peptic ulcers and gastritis. Probiotic strains administered in the vagina also showed vast reduction in urogenital infections.

Studies have shown that probiotics, which normally pass through the GI tract quickly, colonise in the gut for longer periods in the presence of pathogenic bacteria such as *Salmonella* and inhibit pathogenic activity; such research supports the claim that probiotics help to maintain intestinal flora balance and fight infection.

In Canada, probiotic bacterial cultures used in food are considered foods and are subject to regulation according to the *Food and Drugs Act*. This act ensures that the probiotic cultures are not toxic, and that products containing probiotics are properly labeled and advertised so as not to be misleading [10]. Probiotic strains can also be sold as natural health products administered through capsules, powders and other non-food-related media; the specific strains of bacteria used, their

There is great potential for the genetic modification of probiotic bacterial strains, but care must be taken in their development and distribution in the food market.

Overall, probiotics are simply microorganisms that impart health benefits to the host. They are generally bacteria, such as *Lactobacillus* and *Bifidobacteria* strains.

1.3 Fermented foods and benefits: Foods that are prepared by fermentation (the slow decomposition process of organic substances induced by microorganisms, or by complex proteinaceous substances (enzymes) of plant or animal origin [11]), occurs due to biochemical changes brought about by the anaerobic or partially anaerobic oxidation of carbohydrates. In this age of pharmaceuticals, vitamins and other supplements, the relative simplicity of healing food is often overlooked. Fermented raw foods have a long history of consumption as a staple all over the world and can still form the foundation of a healthy diet and nutrition. Fermentation is natural and time - honoured method of food preservation that not only retains the goodness of organic whole foods, but actually enhances their healthy qualities. In addition to being used as part of a healthy meal, some fermented foods should be highly regarded as dietary supplements because they have such incredible healing properties. During lactic acid fermentation, the pyruvate molecules from glycolysis are converted into lactate. Lactic acid bacteria (LAB) consist of homo and hetero-lactic acid organisms, and are a broad category of bacteria, including *Lactobacillus, Streptococcus, Enterococcus, Lactococcus* and *Bifidobacterium* [12], with the ability to produce lactate primarily from sugars. They are among the most commercially used bacteria today [13,14], contributing to yogurt, sauerkraut, kimchi [15] and kefir production [16], the pickling of vegetables, curing of fish, and many other traditional dishes around the world [17,18]. In comparison, ethanol fermentation produces carbon dioxide and ethanol from pyruvate molecules, mainly through the actions of various yeasts. *Saccharomyces cerevisiae* is used in bread making, helping the dough rise through the production of carbon dioxide. A separate strain of S. cerevisiae is also used in alcohol production, including beer and wine, in combination with other yeast species [19]. The ability to create tasty food using microbes reflects human culinary innovation at its best. The use of microbial fermenters has been instrumental in making a large range of foods, popular around the world. Examples of these are given in Table 1, illustrating diversity and opportunism by the originators of the food formulae.

Table 1: Examples of fermented foods and countries in which they are believed to originate and remain particularly popular.

Fermented Food and Main Constituents	Microbes	Country
Yogurt—milk	L. bulgaricus, S. thermophilus	Greece, Turkey
Kefir—milk, kefir grains	Saccharomyces cerevisiae and L. plantarum	Russia
Sauerkraut—green cabbage	L. plantarum	Germany
Kimchi—cabbage	Leuconostoc mesenteroides	South Korea
Sourdough—flour, water	L. reuteri, Saccharomyces cerevisiae	Egypt
Kvass—beverage from black or rye bread	Lactobacillus	Russia
Kombucha—black, green, white, pekoe, oolong, or darjeeling tea, water, sugar,	Gluconacetobacter and Zygosaccharomyces	Russia and China
Pulque—beverage from agave plant sap	Zymomonas mobilis	Mexico
Kaffir beer—beverage from kaffir maize	Lactobacillus sp.	South Africa
Ogi—cereal	Lactobacillus sp., Saccharomyces sp., Candida sp.	Africa
Miso—soybeans	Aspergillus oryzae	Japan
Dosa—fermented rice batter and lentils	L. plantarum	India
Cheddar and stilton cheeses—	Penicillium roqueforti, Yarrowia lipolytica, Debaryomyces hansenii, Trichosporon ovoides	United Kingdom
Surstromming—fermented herring, brine,	Haloanaerobium praevalens, Haloanaerobium alcaliphilum	Sweden

Crème fraîche—soured dessert cream	L. cremoris, L. lactis	France
Fermented sausage—	Lactobacillus, Pediococcus, or Micrococcus	Greece and Italy
Yogurt—milk	L. bulgaricus, S. thermophilus	Greece, Turkey

1.4 Sauerkraut: Sauerkraut is an acidic cabbage which results from natural fermentation by bacteria indigenous to cabbage in the presence of 2 to 3% salt. The addition of salt restricts the activities of Gram negative bacteria, while the growth of lactic acid bacteria is favoured. The dominant lactic acid bacteria involved in sauerkraut production are *Leuconostoc mesenteroides*, *Leuconostoc citreum*, *Lactobacillus curvatus* and *Lactobacillus brevis*. [20] Unpasteurized sauerkraut is a truly extraordinary raw food. It is loaded with naturally occurring beneficial bacteria, digestive enzymes, lactic acid, sulphur and easily digested vitamins and minerals. Traditionally, sauerkraut is made with only two ingredients - Cabbage and salt. Spices may be added, too. However, pasteurization, vinegar, water and preservatives are short cuts to making tasty sauerkraut of poor quality. In the making of sauerkraut, various strains of good bacteria consume the cabbage creating lactic acid. Souring should be caused by lactic acid but not from vinegar. [21]

2. MATERIALS AND METHODS:

2.1 Preparation of Sauerkraut: For the preparation of sauerkraut, the cabbages were obtained from the local market of Visakhapatnam. The cabbage were shredded and added NaCl in 1000:25 ratio. The shredded cabbage and salt was spread as alternating layer in a sterile jar and gently pressed to squeeze out the juice(brine). The jars were covered with sterile lids and incubated at 21 to 24^{0}C for 28 days for the fermentation of the substrate. [22,23]

2.2 Determination of pH: The pH of brine from sauerkraut at different stages of fermentation was determined by the PH paper strips.

2.3 Total Acidity: Total acidity, expressed as percent(%) lactic acid, was determined following the method given by Cuppuccino and Sherman [22]. At each sampling time, ten ml undiluted brine was added to an Erlenmeyer's flask, followed by addition of 10 ml of distilled water. The contents were boiled for 1 minute to drive off the dissolved carbon dioxide. Five drops of phenolphthalein(1%) was added to the cooling contents. The titration with 0.1 N NaOH was carried out until a light pink colour persisted. The per cent lactic acid was calculated by using the formula as give below:

$$\%\text{Lactic acid} = \frac{\text{Vol. of alkali used x Normality of alkali x 9}}{\text{Vol. of sample taken (i.e. 10ml)}}$$

2.4 Isolation of bacteria and fungi from the sauerkraut samples: To procure the information in case of human microbiota and colonizing microorganism of sauerkraut different types of protocols are used. Most of the procedures implemented in this study are incurred from predecessor studies and some are modified according to the convenience of the available laboratory. The methodology involves the following steps: Isolation of different bacteria from sauerkraut from day-0 to day-28 for fermenting bacteria. The samples were inoculated on CLED Agar, Nutrient Agar, PDA, CDA and Meat Extract Agar. Colonies developed within 24 – 48 hours were processed for identification. Typically all the isolated strains are studied to understand the succession.

2.5 Identification of isolates based on the cultural and biochemical characters: Bacteria were identified by using Bergey's Manual of determinative bacteriology [24]. These involved staining techniques such as Gram staining, spore staining and acid-fast staining. Motility was observed by hanging drop method. Biochemical tests such as IMViC, Catalase, Oxidase, Urease, Starch hydrolysis, gelatin liquefaction, nitrate reduction test, Oxidative fermentative test (O/F) (Hugh and Leifson test), coagulase test, novobiocin sensitivity test and fermentation tests with glucose, fructose & lactose were performed. Some of the samples of unknown species were sent for identification to IMTECH, Chandigarh.

The fungi were identified depending on the sporulating structures such as conidial head, types of conidiogenous cells, arrangement of conidia and other spore identification characters.[25]

2.6 Effect of Storage on the Microbial Load of Sauerkraut: Sauerkraut was prepared as per the method described above. The jars were allowed to ferment at room temperature 21 to 24^{0}C and screened for microbial load (CFUs/ml) on the day of preparation, 2nd & 4th day and were observed for microflora after 7th day of storage and repeated ever 7 day until 28 days using plating techniques.

3. RESULTS

In the present study, the number of LAB (lactic acid bacteria) and other bacteria were varied from the time of preparation to 28th day of fermentation. Bacteria such as *Corynebacterium sps*, *Arthrobacter sps*, *Nocardia sps*, and *Streptomyces sps* were occasionally found. The variation was shown in the table 3.1 and 3.2. the pH of sauerkraut was initially 4.1 and reduced to 3.1 after 14 days. The pH remained at 3.1 till the end of 28 days. The total acidity (lactic acid) has gradually increased from 0.044(day-0) to 1.66(day-28). The growth of fungi was not observed till 28 days. The results were shown in the table 3.3.

Table 3.1: Showing the average CFU of LAB participated in the preparation of sauerkraut

S. No.	Type of LAB	CFU(average)/ml
1.	*Leuconostoc mesenteroides*	7.0×10^5
2.	*Lactobacillus brevis*	2.5×10^5
3.	*Lactobacillus platarum*	1.2×10^5

4.	*Lactobacillus fermentum*	1.0 x 10^5
5.	*Lactobacillus curvatus*	1.0 x 10^5
6.	*Lactobacillus sakei*	0.9 x 10^4
7.	*Lactobacillus coryniformis*	0.7 x 10^3

Table 3.2: Showing the average CFU of other bacteria observed in the sauerkraut

S. No.	Type of aerobic bacteria	CFU(average)/ml
1.	*Bacillus subtilis*	1.7 x 10^3
2.	*Staphylococcus aureus*	1.4 x 10^3
3.	*Corynebacterium Sps.*	0.5 x 10^2
4.	*Nocardia Sps.*	0.7 x 10^2
5.	*Streptomyces Sps.*	0.9 x 10^1
6.	*Arthrobacter Sps.*	0.3 x 10^1

3.3 Table showing the bacteria isolated from the sauerkraut from day-0 to day-28

Fermentation/storage time (in days)	pH	Acidity	CFU of LAB	CFU of other bacteria
Day-0	4.1	0.044	1.3 x 103	1.4 x 105
Day-2	4.0	0.11	8.5 x 105	1.7 x 103
Day-4	3.9	0.18	1.2 x 106	2.8 x 103
Day-7	3.5	0.48	2.8 x 107	1.3 x 103
Day-14	3.3	1.39	2.1 x 107	1.1 x 103
Day-21	3.1	1.61	1.2 x 106	1.0 x 102
Day-28	3.1	1.62	1.1 x 105	1.6 x 101

4. DISCUSSION

Sauerkraut should be consumed with meals to get the benefits of the digestive enzymes. These are similar to the enzymes produced by the pancreas and help to break down food in the stomach & small intestine. Eating sauerkraut should be started with 1 or 2 forkful doses depending on the strength of digestion. At maximum, it is to be taken 5 to 6 forkfuls at a time eaten during 2-3 meals per day. From ancient times, the production of sauerkraut served the primary purpose of preserving the harvest into the winter when food was scarce and hunger a true threat. The process of lactic acid fermentation used to transform salt and cabbage into sauerkraut increases vitamins, particularly vitamin C and B vitamins, and food enzymes. Sauerkraut is also extraordinarily rich in beneficial bacteria – friendly microorganisms which help to colonize the gut, train the immune system and manufacture vitamins in the digestive tract. For each 5 pounds of cabbage, add about 3 tablespoons of salt. Mix thoroughly, using clean hands. Store the fermentation container at 21^0C to 23^0C while fermenting. At temperatures between 21^0C and 23^0C, sauerkraut will be fully fermented in about three to four weeks.[26] LAB such as *Leuconostoc mesenteroides Lactobacillus brevis Lactobacillus platarum Lactobacillus fermentum Lactobacillus curvatus Lactobacillus sakei* and *Lactobacillus coryniformis* have been observed in sauerkraut. Other bacteria such as *Bacillus* and *Staphylococcus* also observed during the fermentation. Fungi have not been observed during the 28 days of period. But according to the previous studies, the unpreserved sauerkraut will be colonized by fungi such as *Aspergillus* and yeast such as *Saccharomyce.*[20]. So preservation of sauerkraut at low temperatures(refrigeration) is required to increase the shelf life.[27].

5. CONCLUSION

Sauerkraut is a probiotic fermented food with high nutritive values. The probiotic cells has the ability to attack cancer cells. **Sauerkraut is a traditional ulcer treatment Sauerkraut is a good source of vitamin C. Sauerkraut has cancer-fighting properties.[28].**

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