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Bacteriostatic Effects of Common Foods and Their Comparison with Antibiotics

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Abstract. In daily life, traditional practices like using vinegar for food preservation and salt for pickling vegetables to prevent spoilage make people curious about whether these substances have bacteriostatic properties. With the rising concern over antibiotic abuse, there is increasing interest in exploring if common foods can serve as natural alternatives to antibiotics. This study investigates four daily ingredients—table salt, white vinegar, brown sugar, and Chinese cabbage—to determine if they contain components that can inhibit bacterial growth. The experimental design involved processing these foods into high-concentration solutions: white vinegar is used directly, brown sugar is dissolved in water, and Chinese cabbage is juiced. Each sample is added to petri dishes inoculated with bacteria, and a control group with no treatment is set up. After standing for 24 hours, the presence and size of bacteriostatic circles in each sample are recorded and compared. The experiment shows there were obvious bacteriostatic circles around the high-concentration salt solution and white vinegar, and brown sugar has a weak bacteriostatic effect. Some common solutions do have natural bacteriostatic effects, but they act more like "environmental regulators". For instance, a high-salt environment dehydrates bacteria, and the acidity of white vinegar destroys the living conditions of bacteria. This is different from the principle of antibiotics that target and attack the structure of bacteria. Therefore, it can be concluded that they cannot be regarded as real "natural antibiotics" and can only be used as simple daily bacteriostatic means.

Keywords: Natural antibiotics in food, Common food ingredients, Antibacterial effect, Food preservation, Natural antibacterial agents

1. Introduction

In recent years, the problem of antibiotic abuse has become increasingly serious, and the emergence of drug-resistant bacteria has posed a huge challenge to human health [1]. Therefore, people are paying more and more attention to natural inhibitory substances [2]. Common foods in daily life, such as garlic, ginger, onions and so on, are widely believed to have bacteriostatic effects. For example, garlic contains allicin, which is said to inhibit the growth of many bacteria, and ginger has long been used in folk remedies for its supposed antibacterial properties. This study aims to explore whether there are "natural antibiotics" in common foods and study the bacteriostatic effects of common food ingredients. The research methods include literature review, experimental exploration,

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etc. For literature review, the author collects and analyzes studies on food bacteriostasis from recent years; for experiments, this study uses methods similar to those used in ingredient tests. The research questions involve the bacteriostatic effects of common foods, the types and action mechanisms of inhibitory substances in foods, and the application prospects of natural bacteriostats. The significance of the research is to provide new ideas for the development of natural bacteriostats, reduce reliance on chemical antibiotics, and promote the development of the food industry by identifying edible ingredients with bacteriostatic functions [3,4].

2. Materials and methods

2.1. Selection and preparation of food ingredients

Four common and easily obtainable daily ingredients—table salt, white vinegar, brown sugar, and Chinese cabbage—were selected for this study. For table salt, commercially available regular edible salt (with a sodium chloride content of ≥99.1%) was used, with a total weight of 500g prepared to ensure sufficient supply for repeated solution preparation. White vinegar was a common brand of brewed white vinegar (with an acidity of ≥3.5g/100mL) purchased from a local supermarket, and three 500mL bottles were reserved to avoid batch differences affecting results.

Brown sugar was traditional handcrafted brown sugar cubes (sucrose content ≥85%) sourced from a rural workshop, with 200g weighed and sealed in sterile containers to prevent moisture absorption. Fresh Chinese cabbage without pests or diseases was purchased from the market, with a total weight of 1kg, and transported to the laboratory within 2 hours. Upon arrival, the cabbage was stored in a 4℃ refrigerator for no more than 6 hours before processing to maintain freshness, as prolonged storage can degrade plant-derived bioactive compounds [5,6].

2.2. Methods of solution preparation

Table salt was poured into 500mL of distilled water in a sterile beaker, and continuously stirred using a magnetic stirrer at 300 rpm for 30 minutes until no more salt could dissolve, resulting in a saturated salt solution (approximately 360g/L at 25℃). The solution was filtered through a 0.22μm sterile filter membrane to remove insoluble impurities before use, a step critical for eliminating potential physical interference with bacterial growth [7]. White vinegar was used directly as an experimental sample after sterilization by filtration through the same type of filter membrane to eliminate potential microbial contamination, as unfiltered vinegar may contain naturally occurring bacteria that could skew results [8]. Brown sugar cubes were accurately weighed (150g) and dissolved in 300mL of distilled water, stirred with a sterile glass rod at 200rpm for 20 minutes until fully dissolved, forming a 500g/L brown sugar solution, which was then filtered sterilely.

For Chinese cabbage, it was first rinsed under running tap water for 3 minutes, then soaked in 0.1% sodium hypochlorite solution for 5 minutes for surface disinfection, followed by three rinses with sterile water to remove residual disinfectant [9]. The outer old leaves and roots were removed, and 500g of the middle leaves were cut into 1cm×1cm pieces, juiced using a sterile juicer, and filtered through double-layer filter paper to remove fiber residues, resulting in approximately 300mL of Chinese cabbage juice, which was stored in sterile centrifuge tubes at 4℃ and used within 2 hours to prevent enzymatic degradation [10].

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3. Experimental process

3.1. Bacterial culture and inoculation

First, common strains of Escherichia coli (ATCC 25922) and Staphylococcus aureus (ATCC 6538) were obtained from a strain preservation center. They were representative of Gram-negative and Gram-positive bacteria commonly found in food spoilage and human infections [11]. Under sterile conditions in a biosafety cabinet, the strains were inoculated into 100mL of sterilized LB liquid medium using an inoculating loop, and placed in a constant-temperature shaking incubator. Escherichia coli was cultured at 37 ℃ with 180rpm shaking for 12 hours, while Staphylococcus aureus was cultured under the same temperature and shaking conditions for 16 hours to allow mass bacterial reproduction. When the bacterial concentration reached the logarithmic growth phase (OD_{600} = 0.6-0.8, approximately 10^8 CFU/mL), 1mL of bacterial solution was drawn with a sterile pipette and diluted 100-fold with sterile physiological saline to adjust the concentration to 10^6 CFU/mL, a density optimal for observing antibacterial zones [12].

Using a sterile cotton swab, 0.1mL of the diluted bacterial solution was evenly spread onto the surface of sterilized LB solid medium (15g/L agar) in 90mm petri dishes, with three replicates for each strain to ensure consistent inoculation quantity. After inoculation, the petri dishes were left to stand at room temperature for 30 minutes to allow the bacterial solution to fully absorb into the medium, a step recommended to prevent solution runoff during sample addition [13].

3.2. Sample addition and cultivation

On the petri dishes inoculated with bacteria, 20μL of high – concentration salt solution, white vinegar, brown sugar solution, and Chinese cabbage juice were added respectively using a sterile micropipette, with each sample added to three replicate dishes for both bacterial strains. The samples were added dropwise to the center of the petri dishes, ensuring no spillage onto the dish walls. Additionally, a negative control group was set up where 20 μL of sterile distilled water was added, and a positive control group with 20μL of 0.1% penicillin solution (positive for both bacteria) was included to verify the validity of the experimental system [14]. All petri dishes were inverted and placed in a constant – temperature incubator set at 37 ℃ with 5% CO_2, and then cultured for 24 hours. Inverting the dishes prevents condensation from dripping onto the medium surface, which could disrupt bacterial growth [15].

During cultivation, the incubator's temperature and CO_2 concentration were monitored every 4 hours to ensure stability, with fluctuations controlled within ±0.5 ℃ and ±0.2% respectively, as temperature variations can significantly affect bacterial growth rates [16].

4. Result observation and analysis

4.1. Criteria for judging antibacterial zones

After 24 hours of cultivation, the petri dishes were taken out under sterile conditions and observed using a colony counter. Transparent areas (i.e., antibacterial zones) around the sample droplets were identified as regions where no bacterial colonies grew, with the edge of the zone defined as the outermost boundary where colonies were no longer visible to the naked eye. The diameter of the antibacterial zone was measured with a vernier caliper (precision 0.02mm) at three perpendicular directions for each dish, and the average value was calculated to reduce measurement error, a standard practice in antibacterial assay protocols [17].

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A zone diameter ≥6mm was considered to indicate a significant antibacterial effect, 4-6mm as a weak effect, and <4mm as no obvious effect, with reference to standard antibacterial test criteria established by the Clinical and Laboratory Standards Institute [2]. The positive control group (penicillin) showed clear zones (≥15mm) for both bacteria, confirming the bacterial viability and experimental validity, while the negative control group (distilled water) showed no zones, ruling out solvent interference [18].

4.2. Comparison of antibacterial effects of different samples

Observations and measurements of the experimental results in Table 1 showed for Escherichia coli, the high-concentration salt solution produced an average antibacterial zone diameter of 12.3±0.5mm, while white vinegar showed a larger zone of 15.7±0.8mm. The brown sugar solution had a weak zone of 5.2±0.3mm, and Chinese cabbage juice showed only a negligible zone of 3.1±0.2mm. For Staphylococcus aureus, similar trends were observed: salt solution (11.8±0.6mm), white vinegar (14.5±0.7mm), brown sugar (4.9±0.4mm), and cabbage juice (2.9±0.3mm). These results align with previous findings that high osmolarity and acidic conditions inhibit bacterial growth [3, 4]. Statistical analysis, which was performed using one-way ANOVA, showed significant differences between the salt/vinegar groups and the brown sugar/cabbage juice groups ($p < 0.05$), but no significant difference between the two bacteria for the same sample ($p > 0.05$), suggesting the antibacterial mechanisms act on conserved bacterial structures [5].

These results indicated that high-concentration salt solution and white vinegar had relatively strong and consistent antibacterial effects against both tested bacteria, brown sugar had a mild inhibitory effect that barely met the weak effect criterion, and Chinese cabbage juice had no significant antibacterial effect under the experimental conditions.

Table 1. Antibacterial effects of common food ingredients on typical bacteria

Bacterial Species	Sample Type	Antibacterial Zone Diameter (mm)	Judgment Criteria (Effect)
Escherichia coli	High-concentration salt solution	12.3±0.5	≥6mm (Significant effect)
Escherichia coli	White vinegar	15.7±0.8	≥6mm (Significant effect)
Escherichia coli	Brown sugar solution	5.2±0.3	4-6mm (Weak effect)
Escherichia coli	Chinese cabbage juice	3.1±0.2	<4mm (No obvious effect)
Staphylococcus aureus	High-concentration salt solution	11.8±0.6	≥6mm (Significant effect)
Staphylococcus aureus	White vinegar	14.5±0.7	≥6mm (Significant effect)
Staphylococcus aureus	Brown sugar solution	4.9±0.4	4-6mm (Weak effect)
Staphylococcus aureus	Chinese cabbage juice	2.9±0.3	<4mm (No obvious effect)
Positive control (penicillin)	-	≥15mm	Verify bacterial viability and experimental validity
Negative control (distilled water)	-	No antibacterial zone	Rule out solvent interference

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5. Discussion

5.1. Mechanisms of bacteriostatic effects

Salt and vinegar: The significant bacteriostatic effects of high-concentration salt solution and white vinegar are mainly due to their ability to regulate the environment where bacteria live. Salt forms a hypertonic environment. Under the action of osmosis, the water in bacterial cells will flow out, causing the cells to shrink and be unable to carry out normal metabolic activities, thus inhibiting their growth [3]. The acidity of white vinegar ($pH < 4$) can destroy the structure of bacterial cell membranes, make the proteins in the cells denature, and thus prevent the bacteria from growing and reproducing [4]. These mechanisms are non-specific, which is different from antibiotics that target specific structures of bacteria (such as cell walls and ribosomes) [1].

Brown sugar: Its weak bacteriostatic effect may be related to its high osmolarity. However, compared with the salt solution, the sucrose concentration in the brown sugar solution (500g/L) was lower, so the osmotic pressure it forms was relatively small, and the dehydration effect on bacteria was not obvious, resulting in only a weak inhibitory effect [5]. In addition, brown sugar contains some trace bioactive substances, but their content is too low to play a significant bacteriostatic role.

Chinese cabbage juice: It has almost no bacteriostatic effect. One reason may be that the content of antibacterial substances in Chinese cabbage is very low, and the antibacterial effect is not enough to be detected in this experiment [6]. Another reason is that during the juicing process, some antibacterial substances may be destroyed by enzymes or other factors, thus losing their activity.

5.2. Comparison with real antibiotics

Antibiotics have specific targeting. They can interfere with the synthesis of bacterial cell walls, inhibit the function of bacterial ribosomes, or affect the replication of bacterial nucleic acids, so as to specifically kill or inhibit bacteria [1]. However, the bacteriostatic effect of the common foods studied in this paper is based on non-specific environmental regulation, which can not distinguish between beneficial and harmful bacteria. Therefore, these foods can not be regarded as real "natural antibiotics".

5.3. Experimental limitations

The types of tested foods were limited.. Only four common ingredients are selected in this experiment, and the bacteriostatic effects of more common foods need to be explored.

The experimental conditions are relatively simple. Factors such as temperature and pH value in the experiment did not cover all possible situations in actual life, which may affect the evaluation of the bacteriostatic effect of foods.

The detection method is single. Only the size of the bacteriostatic circle is used to evaluate the bacteriostatic effect, and other detection methods (such as bacterial count) can be added to make the results more accurate.

5.4. Application prospects

Although these common foods can not be used as antibiotics, their bacteriostatic effect can still be applied in daily life. For example, salt and vinegar can be used for food preservation in home cooking to extend the shelf life of food. In the food industry, the bacteriostatic mechanism of these

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foods can be studied to develop more natural and safe food preservatives, reducing the use of chemical preservatives.

6. Conclusion

This experiment investigated the bacteriostatic effects of four common food-related samples: high-concentration salt solution, white vinegar, brown sugar solution, and Chinese cabbage juice. The results showed that distinct inhibition zones formed around the high-concentration salt solution and white vinegar, indicating significant bacteriostatic effects. Brown sugar solution exhibited a weak bacteriostatic effect, while Chinese cabbage juice had almost no observable bacteriostatic action.

The bacteriostatic mechanisms of salt and vinegar mainly rely on environmental regulation. A high-salt environment causes bacterial dehydration through osmosis, hindering their metabolic processes. The acidity of white vinegar disrupts bacterial cell membranes and denatures intracellular proteins, thus inhibiting bacterial growth. These mechanisms differ from those of antibiotics, which specifically target bacterial structures like cell walls or ribosomes. Therefore, these common food-derived solutions cannot be classified as true "natural antibiotics" but can serve as simple daily bacteriostatic tools.

However, this research has limitations. The sample size of tested food samples was small, and the experimental conditions, such as sample processing precision and culture environment control, could be improved. In future studies, we ccould optimize experimental methods to enhance the accuracy of sample handling and strictly control culture environment indicators. Additionally, expanding the research scope to include more common foods and exploring their bacteriostatic properties and mechanisms in depth will provide richer theoretical support for the development and application of natural bacteriostatic substances.

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