

**STERILIZER, ORAL CAVITY STERILIZER, STERILIZATION METHOD,  
STERILIZATION APPARATUS, AND STERILIZER EVALUATION METHOD**

Specification

Technical Field

[0001] The present invention relates to a sterilizer, an oral cavity sterilizer, a sterilization method, a sterilization apparatus, and a sterilizer evaluation method.

Background Art

[0002] As one of conventional sterilization methods, a method of bringing a sterilization target into contact with an oxidizer such as hydrogen peroxide and then irradiating the sterilization target with light of 400 nm to 1000 nm has been known (for example, see Patent Literature 1). According to the method, hydroxy radicals are generated by irradiating the hydrogen peroxide with the light of 400 nm to 1000 nm, and the sterilization is attained by the thus-generated hydroxy radicals.

Citation List

Patent Literature

[0003] Patent Literature 1: JP 2008-284312 A

Summary of Invention

Technical Problem

[0004] The method described in Patent Literature 1

has a problem that a sterilization effect on cells and microorganisms existing on the sterilization target diminishes since a part of the hydrogen peroxide is decomposed by catalase possessed by the cells and microorganisms.

[0005] The present invention was accomplished in view of the above-described problem, and an object thereof is to provide a sterilizer, an oral cavity sterilizer, a sterilization method, a sterilization apparatus, and a sterilizer evaluation method capable of enhancing a sterilization effect.

#### Solution to Problem

[0006] The inventors found that catalase of cells and microorganisms existing on a sterilization target decomposes hydrogen peroxide which is a matrix for generation of hydroxy radicals having a high antibacterial property. The inventors used *Streptococcus aureus* ATCC 12693 which is a catalase-positive bacterium and *Candida albicans* JCM 9061 which is a fungus and measured DMPO-OH changes in reactions between the microorganisms and hydroxy radicals to analyze the reactions employing Lineweaver-Burk Plot. The results are shown in Fig. 1.

[0007] As shown in Fig 1, all of the straight lines which are different in number of cells intersect at a point on the 1/DMPO concentration negative side to show not only that *S. aureus* and *C. albicans* react with the hydroxy radicals but also that catalase possessed by the

microorganisms reacts with hydrogen peroxide. It should be noted that all of the straight lines different in number of cells intersect on the 1/DMPO-OH concentration axis if *S. aureus* and *C. albicans* reacted only with the hydroxy radicals and that all of the straight lines different in number of cells are parallel to each other if catalase reacted only with hydrogen peroxide.

[0008] The experiment shown in Fig. 1 was conducted by: adding 50  $\mu\text{L}$  (microliter) of DMPO (5,5-dimethyl-pyrroline N-oxide) which is a 25-300 mM radical scavenger to 200  $\mu\text{L}$  of each of samples which are varied in number of cells of *S. aureus* and *C. albicans*; further adding 450  $\mu\text{L}$  of 0.5 M hydrogen peroxide; irradiating the mixture with LED light having a wavelength of  $400\pm 20$  nm for one minute; and performing the ESR (electron spin resonance) measurement one minute after the irradiation.

[0009] From the results shown in Fig. 1, the inventors acquired knowledge that it is possible to perform efficient hydroxy radical sterilization by reducing catalase activity of cells and microorganisms by adding a catalase activity inhibitor, which led to this invention.

[0010] More specifically, a sterilizer of the present invention is characterized by comprising hydrogen peroxide and a catalase activity inhibitor.

An oral cavity sterilizer according to the present invention is characterized by comprising hydrogen peroxide and a catalase activity inhibitor.

[0011] The sterilizer and the oral cavity sterilizer according to the present invention are used as follows. The sterilizer or the oral cavity sterilizer according to the present invention is brought into contact with a sterilization target by applying or spraying the sterilizer or the oral cavity sterilizer onto the sterilization target. Here, owing to the catalase activity inhibitor contained in the sterilizer or the oral cavity sterilizer, catalase activity of cells and microorganisms such as catalase-positive bacterium and fungus can be reduced even when the cells and microorganisms exist on the sterilization target, and therefore a reaction between catalase and hydrogen peroxide is prevented.

[0012] Next, the sterilization target is irradiated with light of a predetermined wavelength. Since hydrogen peroxide is photolyzed by the irradiation to generate hydroxy radicals, sterilization is realized by the thus-generated hydroxy radicals. Since the catalase activity inhibitor reduces the catalase activity of the cells and microorganisms existing on the sterilization target in the above-described sterilization, too, a reduction in hydroxy radicals to be generated by the reaction between catalase and hydrogen peroxide is prevented.

[0013] As described above, the sterilizer and the oral cavity sterilizer according to the present invention are capable of preventing hydrogen peroxide which generates hydroxy radicals from being reduced due to the reaction

with catalase possessed by the cells and microorganisms existing on the sterilization target and, as a result, are capable of preventing the reduction in hydroxy radicals generated from hydrogen peroxide, thereby realizing enhancement of an effect of sterilization by the hydroxy radicals.

[0014] A sterilization method according to the present invention is characterized by bringing hydrogen peroxide and a catalase activity inhibitor into contact with a sterilization target and irradiating the irradiation target with light having a wavelength of 350 nm to 500 nm.

[0015] Even if cells and microorganisms of catalase-positive bacterium and fungus existed on the sterilization target when the hydrogen peroxide and the catalase activity inhibitor are brought into contact with the sterilization target, the sterilization method according to the present invention enables to reduce catalase activity of the cells and microorganisms due to the catalase activity inhibitor and, therefore, to prevent a reaction between the catalase and the hydrogen peroxide.

[0016] Further, by the irradiation of the sterilization target with the light having wavelength of 350 nm to 500 nm, the hydrogen peroxide is photolyzed to generate hydroxy radicals, and, therefore, sterilization with the thus-generated hydroxy radicals is realized. Since the catalase activity inhibitor reduces the catalase activity of the cells and microorganisms existing on the

sterilization target in the above-described sterilization, too, a reduction in hydroxy radicals to be generated by the reaction between catalase and hydrogen peroxide is prevented.

[0017] According to the sterilization method described above, the catalase activity inhibitor prevents the hydrogen peroxide which generates the hydroxy radicals from being reduced by the reaction with the catalase possessed by the cells and microorganisms existing on the sterilization target, and, as a result, the reduction in hydroxy radicals to be generated by hydrogen peroxide is prevented, thereby realizing enhancement of the effect of sterilization by hydroxy radicals.

[0018] A method for bringing the hydrogen peroxide and the catalase activity inhibitor into contact with the sterilization target in the sterilization method of the present invention may be any method and may be a method of applying or spraying the sterilizer or the oral cavity sterilizer according to the present invention, a method of immersing a sterilization target into a solution of the sterilizer according to the present invention, or the like.

[0019] A sterilization apparatus according to the present invention is characterized by comprising hydrogen peroxide, a catalase activity inhibitor, and a light emitting device which is configured to irradiate a sterilization target after being brought into contact with the hydrogen peroxide and the catalase activity inhibitor

with light having a wavelength of 350 nm to 500 nm.

[0020] The sterilization apparatus according to the present invention is capable of suitably performing the sterilization method according to the present invention. With the use of the sterilization apparatus according to the present invention, the catalase activity inhibitor prevents the hydrogen peroxide which generates hydroxy radicals from being reduced by a reaction with catalase possessed by cells and microorganisms existing on the sterilization target, and, as a result, the reduction in hydroxy radicals to be generated by the hydrogen peroxide is prevented, thereby realizing enhancement of the effect of sterilization by hydroxy radicals.

[0021] In the sterilization apparatus according to the present invention, the hydrogen peroxide and the catalase activity inhibitor may be formed of the sterilizer or the oral cavity sterilizer according to the present invention. Also, in the sterilization apparatus, the sterilization target may be formed of a tooth, a denture, or the like in the oral cavity, and the catalase activity inhibitor may be formed of a tooth paste, a mouthwash, or the like comprising the catalase activity inhibitor. In this case, the hydrogen peroxide is brought into contact with the sterilization target after brushing the teeth with the tooth paste or rinsing with the mouthwash, and then the sterilization target is irradiated with the light from the light emitting device.

[0022] In the sterilization method and the sterilization apparatus according to the present invention, the light emitting device to be used for the light irradiation may be any light emitting device insofar as the light emitting device is capable of emitting the light having wavelength of 350 nm to 500 nm, and examples thereof include an incandescent lamp, a fluorescent lamp, a halogen lamp, a xenon lamp, an LED (light emitting diode), a semiconductor laser, and the like. The light to be emitted may be single wavelength light, may include a plurality of wavelengths, or may be formed of wavelengths of a predetermined band, insofar as the light has the wavelength of 350 nm to 500 nm.

[0023] In the sterilizer, the oral cavity sterilizer, the sterilization method, and the sterilization apparatus according to the present invention, the catalase activity inhibitor may preferably comprise scutellaria, green tea, fennel, loquat, licorice, aloe, salvia, hamamelis, German chamomile, rosemary, *Melissa officinalis*, or peach. Particularly, scutellaria or green tea which has a high catalase activity inhibition effect may preferably be comprised.

[0024] A sterilizer evaluation method according to the present invention is characterized by performing an electron spin resonance (ESR) measurement of a mixture liquid of a sample collected from a sterilization target brought into contact with the sterilizer according to the

present invention and 4-hydroxy-2,2,6,6-tetramethylpiperidine N-oxide (TEMPOL) and then evaluating a sterilization effect of the sterilizer by performing a measurement of catalase activity of cells or microorganisms contained in the sample based on a line width of the obtained electron spin resonance (ESR) spectrum.

[0025] In view of the fact that catalase catalyzes a reaction which causes decomposition of hydrogen peroxide into water and oxygen, the sterilizer evaluation method according to the present invention includes measuring the catalase activity by measuring the oxygen generated from the reaction by employing ESR oximetry. Since a positive correlation is confirmed between the line width of ESR spectrum of TEMPOL and a catalase concentration, evaluation of the sterilization effect of the sterilizer is enabled by measuring the catalase activity of cells or microorganisms contained in the sample based on the line width of the ESR spectrum. The sterilizer may be the oral cavity sterilizer according to the present invention.

#### Advantageous Effects of Invention

[0026] According to the present invention, it is possible to provide the sterilizer, the oral cavity sterilizer, the sterilization method, the sterilization apparatus, and the sterilizer evaluation method capable of enhancing the sterilization effect.

#### Brief Description of Drawings

[0027] Fig. 1 is a graph showing (a) a kinetics analysis of a reaction between hydroxy radicals generated by photolysis of hydrogen peroxide and *S. aureus* and (b) a kinetics analysis of a reaction between the hydroxy radicals and *C. albicans*.

Fig. 2 is a graph showing a relationship between a catalase concentration and a line width of an ESR spectrum of TEMPOL based on a sterilizer evaluation method according to one embodiment of the present invention.

Fig. 3 is a graph showing catalase activity inhibitory actions of various crude drugs of which use as a catalase activity inhibitor of a sterilizer according to another embodiment of the present invention is examined.

Fig 4 is a graph showing an effect of enhancing a sterilization effect on *Streptococcus aureus* by scutellaria of the catalase activity inhibitor of the sterilizer according to the embodiment of the present invention (in the graph, H indicates hydrogen peroxide, L indicates laser irradiation, O indicates scutellaria (1 mg/mL), + indicates positive, and - indicates negative).

Fig. 5 is a graph showing sterilization effects which are exerted by the catalase activity inhibitor according to the embodiment of the present invention on *Streptococcus aureus* and vary depending on concentrations of scutellaria.

Fig. 6 is a graph showing sterilization effects which are exerted by the catalase activity inhibitor according to the embodiment of the present invention on (a)

*Streptococcus aureus* and (b) *Candida albicans* and vary depending on concentrations of scutellaria and sterilization effects which are exerted by the catalase activity inhibitor on (c) *Streptococcus aureus* and (d) *Candida albicans* and vary depending on concentrations of green tea (in the graph H indicates hydrogen peroxide, L indicates laser irradiation, + indicates positive, and - indicates negative).

#### Description of Embodiments

[0028] Hereinafter, a sterilizer, a sterilization method, a sterilization apparatus, and a sterilizer evaluation method according to embodiments of the present invention will be described.

The sterilization apparatus according to the embodiment of the present invention comprises the sterilizer according to the present invention and a light emitting device.

[0029] The sterilizer comprises hydrogen peroxide and a catalase activity inhibitor. The catalase activity inhibitor comprises scutellaria or green tea.

The light emitting device comprises a semiconductor which is capable of emitting light having a wavelength of 350 nm to 500 nm.

[0030] The sterilization method according to the embodiment of the present invention is suitably performed by the sterilization apparatus according to the embodiment

of the present invention. Firstly, the sterilizer comprising hydrogen peroxide and a catalase activity inhibitor is brought into contact with a sterilization target. Here, even if cells and microorganisms of catalase-positive bacterium and fungus existed on the sterilization target, catalase activity thereof is reduced by the catalase activity inhibitor, and therefore the catalase is prevented from reacting with the hydrogen peroxide.

[0031] Next, the sterilization target is irradiated with light having a wavelength of 350 nm to 500 nm from the light emitting device. By the light irradiation, the hydrogen peroxide is photolyzed to generate hydroxy radicals, and sterilization is achieved by the thus-generated hydroxy radicals. Since the catalase activity inhibitor reduces the catalase activity of the cells and microorganisms existing on the sterilization target in the above-described sterilization, too, a reduction in hydroxy radicals to be generated by a reaction between the catalase and the hydrogen peroxide is prevented.

[0032] As described above, with the use of the sterilizer, the sterilization method, and the sterilization apparatus according to the embodiments of the present invention, the catalase activity inhibitor prevents the hydrogen peroxide which generates the hydroxy radicals from being reduced by the reaction with the catalase possessed by the cells and microorganisms existing on the

sterilization target, and, as a result, the reduction in hydroxy radicals to be generated by the hydrogen peroxide is prevented, thereby realizing enhancement of the effect of sterilization by hydroxy radicals.

## Examples

### [Example 1]

[0033] An experiment for detecting a relationship between catalase activity and a line width of an ESR spectrum of TEMPOL was conducted. Five types of mixture liquids having final catalase concentrations of 0, 0.25, 0.5, 1.0, and 2.0 U/mL were prepared by diluting each of 100  $\mu$ L of catalase (Wako Pure Chemical Industries, Ltd.), 25  $\mu$ L of TEMPOL (Sigma-Aldrich Corporation), and 125  $\mu$ L of hydrogen peroxide (Santoku Chemical Industries Co., Ltd.) with ultrapure water, and mixing the thus-obtained solutions to attain the final concentrations shown in Table 1. ESR measurements of the prepared mixture liquids were conducted, and the results are shown in Fig. 2.

[0034] [Table 1]

|                   | Amount      | Final concentration             |
|-------------------|-------------|---------------------------------|
| Catalase          | 100 $\mu$ L | 0, 0.25, 0.5, 1.0, and 2.0 U/mL |
| TEMPOL            | 25 $\mu$ L  | 200 $\mu$ M                     |
| Hydrogen peroxide | 125 $\mu$ L | 250 $\mu$ M                     |

[0035] As shown in Fig. 2, it was confirmed that there is the high positive correlation between the line width of ESR spectrum of TEMPOL and the catalase concentration. From the results, it is possible to measure

catalase activity of a test sample based on a line width of an ESR spectrum.

[Example 2]

[0036] By using the results of Fig. 2, a measurement of a catalase activity inhibitory action attained by a catalase activity inhibitor was conducted. Mixture liquids were prepared by diluting each of 50  $\mu\text{L}$  of catalase, 25  $\mu\text{L}$  of TEMPOL, 50  $\mu\text{L}$  of a crude drug considered to have a catalase activity inhibitory action, and 125  $\mu\text{L}$  of hydrogen peroxide with ultrapure water (Milli-Q water) and mixing the thus-obtained solutions to attain the final concentrations shown in Table 2. As the crude drug, scutellaria, green tea, and lemon balm were used. The crude drug was filtrated through a 0.22  $\mu\text{m}$  filter in order to remove water-insoluble substances. As a comparison, a mixture liquid sample (Milli-Q water: MQ) to which no crude drug was added was prepared.

[0037] [Table 2]

|                   | Amount            | Final concentration |
|-------------------|-------------------|---------------------|
| Catalase          | 50 $\mu\text{L}$  | 1 U/mL              |
| TEMPOL            | 25 $\mu\text{L}$  | 200 $\mu\text{M}$   |
| Crude drug        | 50 $\mu\text{L}$  | 1 mg/mL             |
| Hydrogen peroxide | 125 $\mu\text{L}$ | 250 mM              |

[0038] ESR measurements of the obtained mixture liquid samples were conducted, and catalase activity was measured from Fig. 2 based on line widths of the ESR spectrums. The measurement results are shown in Fig. 3.

As shown in Fig. 3, the significantly high catalase inhibitory actions of significance level of 5% were confirmed with scutellaria and green tea (\* in Fig. 3). From the results, it can be said that scutellaria and green tea are suitable as the catalase activity inhibitors.

[Example 3]

[0039] An experiment for examining an effect of the catalase activity inhibitor of enhancing a sterilization effect was conducted. In the experiment, *Streptococcus aureus* which is a catalase-positive bacterium was used as a target of the sterilization. A bacterium suspension having a concentration of  $10^7$  cells/mL was prepared by using the bacterium and saline, and the suspension was used for the experiment. A semiconductor laser (product name: RV-1000, Ricoh Optical Industries Co., Ltd.) was used as a light emitting device, in which an irradiation light wavelength was set to  $400\pm 20$  nm, an irradiation output was set to 300 mW, and an irradiation time was set to two minutes. 100  $\mu$ L of the bacterium suspension and 150  $\mu$ L of hydrogen peroxide were mixed on a 96-well microplate to attain the final concentrations shown in Table 3. Experiment samples were prepared by using scutellaria as the catalase activity inhibitor, diluting the scutellaria with ultrapure water, followed by sterilization by filtration through a 0.22  $\mu$ m filter, and then adding the scutellaria solution to the mixture liquids of bacterium suspension and hydrogen peroxide to attain final scutellaria concentrations of 0,

1, and 3 mg/mL.

[0040] [Table 3]

|                         | Amount      | Final concentration |
|-------------------------|-------------|---------------------|
| Bacterium<br>Suspension | 100 $\mu$ L | 1 CFU/mL            |
| Scutellaria             | 50 $\mu$ L  | 0, 1, and 3 mg/mL   |
| Hydrogen<br>peroxide    | 150 $\mu$ L | 1 M                 |

[0041] The laser irradiation was performed immediately after preparing the experiment samples, and 50  $\mu$ L of the sample after the irradiation and 50  $\mu$ L of 5000 U/mL catalase were mixed to stop the reaction of hydrogen peroxide. After that, a 10-fold dilution series was prepared and was seeded on a BHI agar culture medium, followed by culturing under an aerophilic condition of 37°C for 24 hours, and then evaluation of the sterilization effect was conducted. Also, the same experiment was conducted on the case of using *Candida albicans* which is a catalase-positive fungus as the sterilization target and green tea as the catalase activity inhibitor. Further, evaluations of sterilization effects varied by the lacking of hydrogen peroxide, catalase activity inhibitor, and/or laser irradiation were conducted as comparative experiments. Results of the experiments are shown in Fig. 4 to Fig. 6.

[0042] As shown in Fig. 4, it was confirmed that the sterilization effect on *Streptococcus aureus* attained in the case of adding scutellaria at the concentration of 1 mg/mL [H(+)L(+)O(+) in Fig. 4] is about 10 times of the

case of not adding scutellaria [H(+)L(+)O(-) in Fig. 4]. Also, it was confirmed that no sterilization effect on *Streptococcus aureus* was attained in the case where scutellaria was used without using hydrogen peroxide [H(-)L(-)O(+) in Fig. 4], in the case where the light irradiation was performed only on scutellaria [H(-)L(+)O(+) in Fig. 4], in the case where only hydrogen peroxide is used [H(+)L(-)O(-) in Fig. 4], and in the case where the light irradiation was not performed [H(+)L(-)O(+) in Fig. 4].

[0043] As shown in Fig. 5, it was confirmed that the sterilization effect on *Streptococcus aureus* is enhanced along with the increase in concentration of scutellaria in the case where the concentration of scutellaria in the catalase activity inhibitor was varied. For instance, the sterilization effect on *Streptococcus aureus* attained with the scutellaria concentration of 3 mg/mL was about 1000 times of the hydroxy radical sterilization (scutellaria concentration: 0 mg/mL) using hydrogen peroxide only and not using the catalase activity inhibitor.

[0044] Further, as shown in (a) and (b) of Fig. 6, it was confirmed that not only the sterilization effect on *Streptococcus aureus* but also the sterilization effect on *Candida albicans* are enhanced along with the increase in concentration of scutellaria. As shown in (c) and (d) of Fig. 6, it was confirmed that, in the case where the green tea was used as the catalase activity inhibitor, the

sterilization effects on *Streptococcus aureus* and *Candida albicans* are enhanced along with the increase in concentration of green tea. Further, as shown in (a) to (d) of Fig. 6, the sterilization effect is dramatically enhanced by using the catalase activity inhibitor in combination with hydrogen peroxide and the laser irradiation.

[0045] From the results shown in Fig. 4 to Fig. 6, it can be said that more efficient sterilization is realized by using the catalase activity inhibitor in combination with the hydroxy radical sterilization employing the photolysis of hydrogen peroxide. Also, since it is said that there is a correlation between catalase activity of a bacterium and pathogenicity and that a bacterium having a strong defense mechanism against oxidative stress is highly likely to cause an infection, it can be said that the present invention employing the combined use of the catalase activity inhibitor is effective for sterilization of the bacterium having high pathogenicity.

## Claims

1. A sterilizer comprising hydrogen peroxide and a catalase activity inhibitor.
2. The sterilizer according to claim 1, wherein the catalase activity inhibitor comprises scutellaria or green tea.
3. An oral cavity sterilizer comprising hydrogen peroxide and a catalase activity inhibitor.
4. A sterilization method comprising bringing hydrogen peroxide and a catalase activity inhibitor into contact with a sterilization target and irradiating the irradiation target with light having a wavelength of 350 nm to 500 nm.
5. A sterilization apparatus comprising:  
hydrogen peroxide, a catalase activity inhibitor, and  
a light emitting device which is configured to  
irradiate a sterilization target after being brought into  
contact with the hydrogen peroxide and the catalase  
activity inhibitor with light having a wavelength of 350 nm  
to 500 nm.
6. A sterilizer evaluation method comprising

performing an electron spin resonance (ESR) measurement of a mixture liquid of a sample collected from a sterilization target brought into contact with the sterilizer defined in claim 1 or 2 and 4-hydroxy-2,2,6,6-tetramethylpiperidine N-oxide (TEMPOL) and evaluating a sterilization effect of the sterilizer by performing a measurement of catalase activity of cells or microorganisms contained in the sample based on a line width of the obtained electron spin resonance (ESR) spectrum.