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(54) **Title:** METHOD FOR STERILIZING GAS DISPERSED LIQUIDS

(57) **Abstract:** The invention relates to the methods for deactivating microorganisms, including pathogens, in liquids, and may be used in the food industry to sterilize milk. The invention may also be used in the juice and other beverage industries, in drinking water production, as well as in cosmetic and healthcare practices, domestic wastewater and food plant process effluent disinfection, and in the microbiological industry to sterilize liquid nutrient broths. The essence of the invention is that a liquid, more particularly milk, treated to remove mechanical impurities, is dispersed in air to obtain a stable aerosol, and in this particular state is UV-irradiated. Since optical density of the aerosol is incomparably lower than the initial milk optical density, UV radiation's ability to penetrate into the bulk of the product is multiplied. Thus, efficient impact is provided on microorganisms within an aerosol layer with a thickness ranging from tens of millimeters to tens of centimeters depending on the aerosol density.

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Method for sterilizing gas dispersed liquids

TECHNICAL FIELD

The present invention relates to the methods for deactivating microorganisms, including pathogens, in liquids, and may be used in the food industry to sterilize milk. The invention may also be used in the juice and other beverage industries, in drinking water production, as well as in cosmetic and healthcare practices, domestic wastewater and food plant process effluent disinfection, and in the microbiological industry to sterilize liquid nutrient broths.

When employed in any of the above areas, the invention enables pathogen and virus deactivation.

PRIOR ART

Most of the current treatment methods for reducing microbiological activity or completely deactivating various microorganisms in milk and other liquid food products are based on thermal treatment. They primarily include such well-known methods as pasteurization and sterilization.

Relatively simple and reliable, the above methods have a wide range of industrial applications. However, they have a common disadvantage consisting in that achievement of the desired effect requires high power consumption, and in the adverse impact on labile components of milk and other liquid food products that degrades their biological value. For example, pasteurization and, particularly, sterilization of milk entail destructive structural changes of milk proteins undesirably affecting both their biological value and the whole range of their functional properties. Thermal treatment of juices is detrimental to the vitamin activity in them and significantly deteriorates their organoleptic properties.

UV treatment of liquid food products is an alternative method providing an effect similar or close to that of thermal pasteurization or sterilization.

The first device for treating milk with UV-irradiation was designed in France in 1900. A Kühn quartz mercury lamp generating rays with a wave length of approximately 254 nm was used as a UV-radiation source.

It was demonstrated that UV radiation enables sterilization of milk with little or no loss of most of its properties, while preserving all of its organoleptic properties.

Further studies confirmed that using UV radiation allowed deactivating of undesirable microflora in milk by at least 99.9 %, and advancements in the UV radiator design facilitated the development of devices suitable for industrial applications (US2072417; Veisseyre, R., *Techniques laitieres* ("*Dairy Techniques")*, Moscow, Kolos, 1971).

An essential disadvantage limiting wider use of UV radiation to treat milk is the low penetrating power of UV rays, i.e. they are almost completely absorbed by a layer of milk with a thickness of approximately 50 micron without any significant effect on the bulk of the product under treatment.

UV treatment of nearly any liquid food products, including water, provides a similar effect.

Repeated attempts have been made to improve UV radiation's efficiency as a sterilizing agent. They primarily focused on increasing the output of UV radiation sources, hardware design, treatment frequency, and agitation rate (Patents RU 2395461; US 5451791; US 7270748).

One known method for microflora deactivating in milk (SU 1450804) is as follows: milk is poured into quartz tubes and centrifuged to separate insoluble impurities. The treated milk is then UV-irradiated in an approximately 0.1mm-thick layer with an ORK-2 bactericidal lamp as the source of radiation. If agitation, as well as repeated and sufficiently long-time irradiation is provided, nearly all microorganism cells in milk may be killed.

A disadvantage of the above method is its low productivity, frequency and complexity of using thereof for large-scale industrial applications.

Another known method (RU2322811) is free from some of the above disadvantages. According to this method, milk is pre-treated to remove mechanical impurities, homogenized and UV-irradiated 3 to 5 times in leak-tight reactors arranged in series, thoroughly agitating the milk after each irradiation cycle.

Such repeated treatment provides for continuous process and irradiation exposure as required for bacterial DNA degradation, while agitation provides for the treatment of a new layer of milk during each cycle.

However, despite its certain advantages, the method does not address the main issue of inadequate efficiency of irradiating milk with UV rays due to their poor ability to penetrate into the bulk of the product. Though thorough agitation addresses this disadvantage to some extent, it also makes the process and equipment substantially more complex and increases power consumption.

The closest to the claimed invention is a method for sterilizing milk and other liquids that comprises ozonizing the liquid using an injector to form a liquid dispersion, turbulizing, and irradiating it with UV rays, while agitating the liquid, and then separating gas from the liquid (RU 2058096 C1, published 20.04.1996; CA 2139924 A1, published 24.11.1994). The resulting dispersion is a gas emulsion, where the dispersed phase is the gas (ozone), and the liquid is the dispersion phase.

However, despite its certain advantages, the method does not address the main disadvantage related to UV radiation's poor ability to penetrate into the bulk of the liquid product. As a result, powerful sources of UV radiation have to be used, and the process is complicated. Use of ozone, being a powerful oxidizer, typically results in substantial changes in the chemical nature of fats and other milk components.

SUMMARY OF THE INVENTION

The objective of the present invention is to provide a process with improved efficiency of UV radiating liquids by improving penetrating ability of UV radiation. This objective is achieved through a liquid sterilization method, comprising: producing a dispersed liquid, irradiating the resulting dispersion with UV rays, and separating the liquid, wherein the dispersion is produced by filling an intake reservoir of an aerosol generator with the liquid and then by dispersing the liquid in a gas medium to obtain an aerosol, and then the aerosol is delivered to a leak-tight chamber and irradiated with UV rays.

In alternative embodiments of the invention, the liquid is dispersed in a gas medium by hydraulic, or pneumatic, or ultrasonic atomizing.

In alternative embodiments air, or an inert gas, or nitrogen, is used as the gas medium.

In alternative embodiments the liquid is separated by centrifuging or cycloning the aerosol.

In alternative embodiments the hydraulic atomizing is carried out at a rate of 0.1 to 25 l/min.

In alternative embodiments the pneumatic atomizing is carried out at ratio of gas (m3/hour) to liquid (l/min) ranging from 5 to 20.

In alternative embodiments the liquid aerosol is generated preferably at an ultrasonic frequency of 50 kHz with approximately 5 micron liquid particles as the dispersed phase.

In alternative embodiments the total dose of UV-radiation is approximately 20 mJ/cm^2.

The essence of the invention is that a liquid, more particularly milk, treated to remove mechanical impurities, is dispersed in air to obtain a stable aerosol, and in this particular state is UV-irradiated.

Aerosolized milk is in a finely dispersed state and forms a dispersed phase evenly distributed in an air (gas) dispersion phase. Since optical density of the aerosol is incomparably lower than the initial milk optical density, UV radiation’s ability to penetrate into the bulk of the product is multiplied. Thus, efficient impact is provided on microorganisms within an aerosol layer with a thickness ranging from tens of millimeters to tens of centimeters depending on the aerosol density. Estimation results show that the UV-irradiation exposure (16-40 mJ/cm^2), required to obtain a substantially sterile product under static conditions, is achieved by an order of magnitude more efficiently than if liquid milk were irradiated.

It will be noted that low viscosity of the gas medium provides for efficient convective mixing of the whole milk aerosol volume, thus further improving the uniformity and rate of the milk disinfection process.

DETAILED DESCRIPTION OF THE INVENTION

The present invention, method for sterilizing the liquids comprises following steps: pretreating the liquid to remove mechanical impurities; filling an intake reservoir of a aerosol generator with the liquid; producing a dispersed liquid aerosol; delivering the aerosol to a leak-tight cylindrical chamber; irradiating the resulting aerosol with UV rays; delivering the UV-treated aerosol to a cyclone or a centrifuge; separating the liquid by broking the aerosol and leading the resulting liquid out from the cyclone or centrifuge.

The dispersion is produced by dispersing the liquid in a gas medium to obtain an aerosol. The liquid is dispersed for example in a gas medium by hydraulic, or pneumatic, or ultrasonic atomizing. For example air, or an inert gas, or nitrogen, is used as the gas medium. The liquid is separated for example by centrifuging or cycloning the aerosol.

The hydraulic atomizing is carried out at a rate of 0.1 to 25 l/min. The air atomizing with the gas (m3/hour) to liquid (l/min) is carried out at ratio ranging from 5 to 20. The liquid aerosol is generated at an ultrasonic frequency of 50 kHz with approximately 5 micron liquid particles as the dispersed phase. The total dose of UV-radiation is approximately 20 mJ/cm2.

Milk or other liquid may be dispersed in a gas using various methods and devices. For example, such well developed in theory and in practice devices as ultrasonic dispersers of the types described in the patents RU 2254934 or US 4,159,803, operating at an ultrasonic frequency of 40 to 100 kHz, or conventional atomizing aerosol generators having slot atomizers to form a two-dimensional linear jet, generating an aerosol with the dispersed phase particle size of 1 to 10 microns.

Liquid is dispersed for example by hydraulic atomizing at a rate of 0.1 to 25 l/min or air atomizing with the gas (m^3/hour) to liquid (l/min) ratio ranging from 5 to 20.

Liquid may be air, inert gas, or nitrogen-atomized.

Aerosolized milk particle size and density may be changed by varying the dispersing conditions: milk temperature, ultrasonic vibration frequency and strength, or atomizer diameter and gas pressure within the aerosol generator.

Various sources of UV radiation may be used, such as mercury quartz or bactericidal lamps generating radiation with a fundamental wave length of 254 nm, as well as light-emitting semiconductor diodes. To generate UV radiation, most advantageous are low pressure ozone-free lamps. Using them does not result in ozone formation, which, as noted above, is a powerful oxidizer that oxidizes milk fats and adversely changes the chemical structure of other milk constituents.

The UV-treated milk aerosol may then be broken by centrifuging or cycloning to obtain a homogenous liquid product, i.e. milk, with microbiological content fully complying with applicable sanitation and hygiene standards, while preserving its biological value and organoleptic properties.

The provided method features low power consumption, is readily adaptable to commercial scale production, while ensuring high efficiency of the milk sterilization process.

Below is an example illustrating the essence of the proposed invention.

Example of the method according to the present invention.

Milk, pretreated to remove mechanical impurities, was filled into an intake reservoir of an ultrasonic aerosol generator MUSAG (medical ultrasonic aerosol generator), where a milk aerosol was generated at an ultrasonic frequency of 50 kHz at the temperature 40°C with approximately 5 micron milk particles as the dispersed phase.

Aerosol was then delivered to a leak-tight cylindrical chamber, configured as quartz tube 5 cm in diameter, with three UV lamps arranged outside the quartz tube at equally spaced locations around its circumference, where the milk was exposed to UV-radiation with the wave length 253,7 nm and with a total dose of approximately 20 mJ/cm^2.

The UV-treated aerosol was then delivered to a cyclone, configured as a conical vessel comprising a tangential inlet and a bottom outlet pipe, where the aerosol was broken and the resulting liquid milk exits the cyclone through the bottom drain pipe.

The resulting product features good organoleptic properties and a pathogen and virus content not exceeding the standards established for sterilized milk.

In alternative embodiments other liquids, such as juices, other beverages, drinking water were sterilizes exactly in the same way.

The proposed method for sterilizing of liquids may be employed in the food industry to disinfect milk, in the juice and other beverage production industries, in drinking water production, as well as in cosmetic and healthcare practices, domestic wastewater and food plant process effluent disinfection, and in the microbiological industry to sterilize liquid nutrient broths, using the existing industrial equipment.

Claims

1. A method for sterilizing gas dispersed liquids, comprising: producing a dispersed liquid, irradiating the resulting dispersion with UV rays, and separating the liquid, **wherein** the dispersion is produced by filling an intake reservoir of an aerosol generator with the liquid and then by dispersing the liquid in a gas medium to obtain an aerosol, and then the aerosol is delivered to a leak-tight chamber and irradiated with UV rays.

2. The method of claim 1, **wherein** the liquid is dispersed in a gas medium by hydraulic, or pneumatic, or ultrasonic atomizing.

3. The method of claim 1, **wherein** air, or an inert gas, or nitrogen, is used as the gas medium.

4. The method of claim 1, **wherein** the liquid is separated from aerosolized liquid by centrifuging or cycloning the aerosol.

5. The method of claim 2, **wherein** the hydraulic atomizing is carried out at a rate of 0.1 to 25 l/min.

6. The method of claim 2, **wherein** the air atomizing is carried out at ratio of gas (m3/hour) to liquid (l/min) ranging from 5 to 20.

7. The method of claim 2, **wherein** the liquid aerosol is generated at an ultrasonic frequency of 50 kHz with approximately 5 micron liquid particles as the dispersed phase.

8. The method of claim 1, **wherein** the total dose of UV-radiation is approximately 20 mJ/cm^2.

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
INV. A23L3/00 A23L3/28 A23L3/3409 A61L2/10 A61L2/20
A23C3/07
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A23L A61L A23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, FSTA, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 08500 A A.D. 1913 (EDWARDS REGINALD FRANK [GB]) 19 February 1914 (1914-02-19) page 1, line 13 - line 37; claims 1,2 -----	1-8
A	GANG LU ET AL: "UV inactivation of milk-related microorganisms with a novel electrodeless lamp apparatus", EUROPEAN FOOD RESEARCH AND TECHNOLOGY ; ZEITSCHRIFT FÜR LEBENSMITTELUNTERSUCHUNG UND -FORSCHUNG A, SPRINGER, BERLIN, DE, vol. 233, no. 1, 28 May 2011 (2011-05-28), pages 79-87, XP019918515, ISSN: 1438-2385, DOI: 10.1007/S00217-011-1498-5 table 2 -----	8

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 924 097 A (BROWNER RICHARD F [US] ET AL) 8 May 1990 (1990-05-08) column 3, lines 52-57 -----	1,2
A	KR 2012 0040513 A (LG INNOTEK CO LTD [KR]) 27 April 2012 (2012-04-27) paragraphs [0014], [0015], [0027], [0035] abstract -----	1-8
A	CA 2 139 924 A1 (SHTUKARIN NIKOLAI G [RU]) 24 November 1994 (1994-11-24) page 5, line 5 - page 7, line 26; claims 1-4 -----	1-8

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/025248

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
GB 191308500	A	19-02-1914	NONE		
US 4924097	A	08-05-1990	CA	2016129 C	01-08-1995
			US	4924097 A	08-05-1990
KR 20120040513	A	27-04-2012	NONE		
CA 2139924	A1	24-11-1994	CA	2139924 A1	24-11-1994
			RU	2058096 C1	20-04-1996
			WO	9426131 A1	24-11-1994