SPOILAGE DETECTION USING ELECTROMAGNETIC SIGNAL AND MATHEMATICAL MODELING

[0001] This application claims priority to U.S. Provisional Application No. 61/428,637, filed December 30, 2010, ~~the disclosure of which is herein incorporated by reference in its entirety~~.

FIELD OF THE INVENTION

[0002] The present disclosure relates to non-destructive inspection of packages for contaminants. More particularly, the present disclosure relates to the non-destructive inspection of packages for spoilage by analyzing electromagnetic signals from the packages.

BACKGROUND OF THE INVENTION

[0003] Packaged substances such as liquid products intended for human consumption are subject to spoilage (i.e., growth of undesirable bacteria or other microorganisms) in the packaging. Exemplary such liquid products include, without limitation, infant, toddler and adult nutritional formulas, fortifiers and dietary supplements. Such substances may be kept sterile from production through packaging (i.e., aseptic packaging) or may be sterilized after packaging (e.g., pasteurized). Sterilization after packaging may alter certain properties of the substance. For example, pasteurization may cause desirable proteins in a nutritional formula to break down, reducing the nutritional value of the formula.

[0004] One way of testing such packages for spoilage is to allow a relatively long incubation period before visually examining the package. Visual examination may fail to identify spoilage by certain bacteria or may fail to identify spoilage in a package having a relatively slow growing contaminant. Thus, a consumer could purchase and potentially use a package containing a spoiled substance. Further, visual examination on a commercial scale requires a substantial investment in training and man hours, and packages examined visually must be transparent and individually inspected (i.e., removed from a case containing a plurality of packages). This increases production costs and reduces flexibility in responding to changes in product demand.

pouch 1040 and control the distance between the scan head 1050 and the pouch in order to improve measurement precision. If the pouch 1040 is determined not to be spoiled, an air nozzle 1008 blows the pouch into a first bin 1010, and if the pouch 1040 is determined to be spoiled, the pouch 1040 is dropped into a second bin 1020.

[0035] As used herein, a processor refers to any computing device capable of executing computer executable instructions to accomplish the function of the processor described herein. Examples of a processor are a personal computer, a server, a distributed computing environment, a computing device, and an application specific integrated circuit.

[0036] From the foregoing description, it will be apparent that an improved spoilage detection system and methods have been provided. Variations and modifications of the herein described systems, apparatuses, methods and other applications will undoubtedly suggest themselves to those skilled in the art. Accordingly, the foregoing description should be taken as illustrative and not in a limiting sense.

~~[0037] Any patents or publications referenced in this specification are indicative of the levels of those skilled in the art to which the invention pertains. These patents and publications are herein incorporated by reference to the same extent as if each individual publication was specifically and individually indicated to be incorporated by reference.~~

Claims :

1. An apparatus for determining whether a substance in a package is spoiled, said apparatus comprising:

an electromagnetic source for generating an electromagnetic signal;

an electromagnetic scan system for receiving the generated electromagnetic signal, directing the received signal at the package, and receiving an attenuated electromagnetic signal; and

a processor for determining whether the package contains spoiled substance as a function of the received attenuated electromagnetic signal;

wherein the substance is a biological fluid and is aseptically packaged, and wherein the package is substantially transparent with respect to a frequency of the electromagnetic signal.

2. The apparatus of claim 1 further comprising a sampler for sampling the received attenuated signal and generating a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time; and

wherein the processor analyzes the set of data points, wherein the processor:

detects a peak within the set of data points,

shifts the data points with respect to time based on the detected peak, and

compares the set of shifted data points to at least one mathematical model to determine whether the package contains spoiled substance.

3. The apparatus of claim 1 wherein ~~the substance is a biological fluid and is aseptically packaged, and wherein~~ the package ~~is substantially transparent with respect to a frequency of the electromagnetic signal and~~ comprises at least one of linear low density polyethylene ~~(LLDPE)~~, barrier coated polyethylene terephthalate ~~(PET)~~, aluminum oxide coated polyethylene terephthalate ~~PET~~, ethylene vinyl alcohol ~~(EVOH)~~, silicone oxide~~Silicone Oxide (SiOx)~~, and ~~H~~high ~~D~~density ~~P~~polyethylene ~~(HDPE)~~.

4. The apparatus of claim 1 wherein the electromagnetic scan system comprises a transmitter located on a first side of the package and a receiver located on a second side of the package such that the attenuated signal is the electromagnetic signal after having passed through the package and substance.

5. The apparatus of claim 1 wherein the electromagnetic scan system comprises a scan head for directing the received signal at the package and for receiving a reflected signal, wherein the attenuated signal is the reflected signal.

6. The apparatus of claim 1 wherein the processor determines whether the substance in the package is spoiled by determining that the substance in the package comprises at least one of B. Subtilis, S. Epidermidis, L. Casei, E. Cloacae, Saccharomyces Cerevisiae, or C. Sporogenes.

7. The apparatus of claim 2 wherein the electromagnetic signal is in the range of 0.02 terahertz to 3.5 terahertz and the at least one mathematical model corresponds to a package containing unspoiled substance, and wherein the processor shifts the set of data points with respect to time in order to align the detected peak with a predetermined time.

8. The apparatus of claim 1 further comprising:

a sampler for sampling the received attenuated signal and generating a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time;

a processor for analyzing the set of data points, wherein the processor:

~~analyzing a set of data points~~

detects a peak within the set of data points,

shifts the data points with respect to time based on the detected peak, and

compares the set of shifted data points to at least one mathematical model to determine whether the package contains spoiled substance~~;~~

~~wherein the substance is aseptically packaged into the package~~.

9. A method for determining whether a substance in a package is spoiled, said method comprising:

generating an electromagnetic signal;

directing the generated electromagnetic signal at the package;

receiving an attenuated electromagnetic signal; and

determining, as a function of the received attenuated electromagnetic signal, whether the substance in the package is spoiled;

wherein the substance is aseptically packaged into the package.

10. The method of claim 9 further comprising:

sampling the received attenuated signal to generate a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time;

detecting a peak within the set of data points;

shifting the data points with respect to time based on the detected peak; and

comparing the set of shifted data points to at least one mathematical model, wherein determining whether the substance in the package is spoiled as a function of the received attenuated electromagnetic signal comprises determining whether the substance in the package is spoiled as a function of the comparison of the set of shifted data points to the at least one mathematical model.

11. The method of claim 10 wherein the electromagnetic signal is in the range of 0.02 terahertz to 3.5 terahertz.

~~12. The method of claim 9 wherein the substance is aseptically packaged into the package.~~

~~13~~12. The method of claim 10 wherein the at least one mathematical model corresponding to a package containing unspoiled substance is determined by analyzing a matrix of sets of data points, said sets of data points generated by inspecting a plurality of packages containing the substance wherein a portion of the plurality of packages are known to contain spoiled substance and the remainder of the plurality of packages are known to contain unspoiled substance, and determining a set of variables maximizing discrimination between the packages containing spoiled substance and the packages containing unspoiled substance, wherein each shifted data point is treated as a variable when analyzing the matrix, and wherein said analyzing comprises orthogonal partial least squares analysis.

~~14~~13. The method of claim 9 further comprising:

sampling the received attenuated signal to generate a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time;

detecting a peak within the set of data points;

shifting the data points with respect to time based on the detected peak;

comparing the set of shifted data points to at least one mathematical model; and

determining whether substance in the package is spoiled as a function of said comparing.

~~15~~14. ~~A method of generating a mathematical model for determining whether a substance in a package is spoiled, said method~~ The method of claim 9, further comprising:

~~aseptically packaging the substance in a plurality of packages;~~

inoculating a first group of the plurality of packages with a first contaminant;

maintaining a second group of the plurality of packages in an aseptic state;

inspecting each of the plurality of packages, said inspecting comprising:

directing an electromagnetic signal at a package;

receiving an attenuated electromagnetic signal;

sampling the received attenuated electromagnetic signal to generate a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time;

detecting a peak within the set of data points; and

shifting the data points with respect to time based on the detected peak; and

analyzing the shifted data points to determine the mathematical model that maximizes discrimination between the sets of shifted data points corresponding to the packages of the first group and the sets of shifted data points corresponding to the packages of the second group.