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(54) Title: FRESHNESS DETECTION

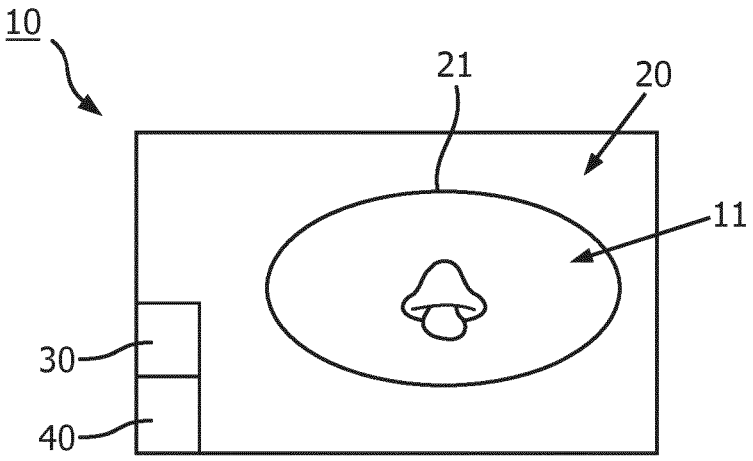


FIG. 1

(57) Abstract: A freshness detection device (10) which comprises a container (20) adapted to form an accommodating space (11) for accommodating an object; a heat transferring surface (21) contacting the accommodating space (11); a sensing unit (30) adapted to provide a sensing parameter representing the heat transfer amount through the heat transferring surface (21); and a processing unit (40) adapted to determine the freshness of the object based on the sensing parameter. This provides a non-invasive and efficient way for consumers to detect the freshness of fruits, vegetables, flowers, mushrooms, etc.

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Freshness detection

FIELD OF THE INVENTION

The present invention generally relates to freshness detection, and particularly to a device and method for detecting the freshness of objects like fruits and vegetables.

BACKGROUND OF THE INVENTION

Freshness is a quality criterion of great importance to consumers. The detection of the freshness of objects, such as fruits and vegetables, especially during a storage process, fulfils an important need of consumers . By way of example, for ordinary private consumers, vegetable and fruit distributors, raw material managers of restaurants and so on, it is important to detect the freshness of fruits and vegetables to avoid undesired wilting, rotting, and the like.

To date, a number of freshness detection methods have already been presented . Normally, the freshness of fruits and vegetables is determined by the detection of the respiration speed, soluble solid content (SSC), ethylene production, color, vitamin loss, and firmness, etc. Some of these existing methods require destruction of the detection targets, while some others are time consuming and have to be performed in labs. In addition, some methods will in practice result in certain amounts of chemical waste, which is also undesirable . As a result, these existing technologies are not suitable for home use, and many consumers still determine whether fruits or vegetables are fresh by observing and smelling.

US5609096A shows such an example. It discloses a freshness keeping device being capable of adjusting the temperature, humidity, pressure, O_2 and CO_2, the quantity of anion and the quantity of ozone in the storage environment based on the freshness detection results. In order to obtain the freshness results, it uses a semiconductor gas sensor to detect trimethylamine (TMA) generated by the food. However, a TMA detection method imposes high requirements on the environment, and this method is only applicable in the late stages of the aging process, so it is not suitable to indicate the freshness over time. In addition, the detection result is not satisfactory and the operation life is short, so it is still unfriendly for home use.

In the paper "*Experimental characterization of airflow, heat and mass transfer in a cold room filled with food products*" of S. Duret, etc., a method for measuring the heat transfer coefficient in a cold room is disclosed. An aluminium heating sphere is heated to raise its temperature. Then the heating is stopped and the aluminium heating sphere is cooled by convection with the surrounding air, by which the heat transfer coefficient can be

calculated. However, this method cannot be used to detect the freshness of the objects in the cold room.

SUMMARY OF THE INVENTION

In view of the foregoing, there is a need in the art for a solution capable of detecting freshness of objects like fruits and vegetables in a non-invasive and efficient way. The invention is defined by the independent claims. The dependent claims define advantageous embodiments.

One aspect of the invention provides a freshness detection device comprising:

a container adapted to form an accommodating space for accommodating an object that generates respiration heat;

a heat transferring surface contacting the accommodating space;

a sensing unit adapted to deliver a sensing parameter representing a transfer amount of the respiration heat through the heat transferring surface; and

a processing unit adapted to determine the freshness of the object based on the sensing parameter.

The invention is based on the following recognitions. During the growing process of, for example, fruits, vegetables, flowers and mushrooms, nutrients such as carbohydrates, proteins, lipids, etc. together with energy are synthesized and stored in the body. After the harvest, these objects are still alive and have a certain rate of respiration during storage. The heat generated by continuous respiration has been proved to be a driving force for water loss of the object stored, and therefore has a close and direct connection with freshness. By means of the proposed embodiment, the amount of heat passing through the heat transferring surface can be estimated, which value is considered to be related to the total amount of the respiration heat generated by the object. As a result, the freshness of the object can be determined accordingly.

In some embodiments, the heat transferring surface can form at least part of the container. Furthermore, it is also possible for the container to comprise a heat isolation surface. In other words, the heat isolation surface and the heat transferring surface together can form the wall of the container. This provides a simplified structure for the device and the detection accuracy could be improved.

The heat isolation surface can form the whole wall of the container. In this situation, the heat transferring surface can extend across the heat isolation surface. This provides an alternative solution for the arrangement of the container.

Furthermore, the area of the heat transferring surface can be changed. This enables adjustment of the total amount of heat transferred out of the accommodating space at a given temperature difference between the accommodating space and the heat transferring surface.

By way of example, the heat isolation surface could comprise at least one of: a heat isolation film, a polymer foam layer and one side of a vacuum heat isolation layer. The heat transferring surface could comprise at least one of: a metal foil and a thermally conductive plastic plate.

Furthermore, the sensing unit can comprise a first temperature sensor adapted to sense the temperature in the accommodating space and a second temperature sensor adapted to sense the temperature of the heat transferring surface. By means of this arrangement, the temperature difference between the heat transferring surface and the accommodating space can be obtained, which is very important for the calculation of the amount of heat passing through the heat transferring surface. The detailed calculation method will be described when referring to the detailed embodiments.

Preferably, the processing unit can be further adapted to receive information about at least one of: classification, weight and temperature of the object, and determine the freshness of the object based on the received information and the sensing results. This kind of information is important to improve the freshness detection result. The relationship between the freshness and the respiration heat generated varies a lot according to the different types of objects. For example, leafy vegetables like spinach and lettuce tend to generate a higher respiration heat due to a higher respiration rate. However, for root vegetables like carrots, the respiration heat is less due to a lower respiration rate. As a result, to detect the freshness of different objects, different processing algorithms should be applied. It would be great to set an independent algorithm for each kind of object. However, a more economic method is to classify the objects into several groups based on their characteristics, like root vegetable (carrot, beet, parsnip), bulb vegetable (onion, garlic), tuber vegetable (potato), stem vegetable (asparagus), leafy vegetable (spinach, lettuce, celery, cabbage, leek, watercress, Brussels sprout) and floral vegetable (broccoli, cauliflower). Meanwhile, the total amount of respiration heat generated is not only related to the freshness and type of the objects, but also to the quantity, and the temperature of the objects will affect the amount of heat passing through the heat transferring surface as well. As a result, the accuracy of freshness detection can be improved by taking these factors into account. It should be noted that this kind of information can be obtained by sensing or inputting by the users through a user interface.

It is possible for the device to comprise a presenting unit to present the freshness of the object to the users. Based on users' needs, the presenting unit could be freshness indication scales, or an audio alarm to remind a user that the bad objects should be disposed.

Preferably, the container of the device could further comprise a separation surface between the accommodating space and the heat transferring surface. This could ensure that the object accommodated will not touch the heat transferring surface, otherwise this contact might change the heat transfer to the heat transferring surface and affect the validity of the algorithm used. Here, as an example, the separation surface could be a mesh or a weave which has very limited influence on the heat transfer.

Heat passing through the heat transferring surface comprises two parts: a condensation part and a conduction part. In some embodiments, the amount of the condensation heat is used to represent the total amount of heat passing through the heat transferring surface, because the conduction of heat is weak and therefore ignored. However, it can be envisaged that in some situations, with the generation of the respiration heat, the temperature of the objects accommodated and the temperature of the air in the accommodating space may rise and an amount of heat will be kept in the objects and the accommodating space. In case this happens, to improve the accuracy of freshness detection, the total amount of the respiration heat could be estimated first and then used to determine the freshness of the object. The relationship between the total respiration heat and the condensation heat can be roughly estimated by experiments or theoretical calculation.

In another aspect, this invention also relates to a method for detecting freshness of an object that generates respiration heat, wherein the object is accommodated in an accommodating space, and a heat transferring surface is arranged to contact the accommodating space, the method comprising

- sensing a parameter representing a transfer amount of the respiration heat through the heat transferring surface; and
- determining the freshness of the object based on the parameter.

In some embodiments, a first temperature of the accommodating space and a second temperature of the heat transferring surface are sensed to obtain the temperature difference between the accommodating space and the heat transferring surface.

Preferably, to improve the accuracy of freshness detection, the amount of respiration heat generated by the object could be determined first and then used to determine the freshness of the object based on the amount of respiration heat.

Other features and advantages of embodiments of the present invention will also be understood from the following description of exemplary embodiments when read in conjunction with the accompanying drawings, which illustrate, by way of example, spirit and principles of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Examples of the invention will now be described in detail with reference to the accompanying drawings, in which:

Fig. 1 shows an example of the freshness detection device according to this invention;

Fig. 2 shows another example of the freshness detection device according to this invention; and

Fig. 3 shows a third example of the freshness detection device according to this invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The present invention will now be discussed with reference to several example embodiments. It should be understood that these embodiments are discussed only for the purpose of enabling those skilled in the art to better understand and thus implement the subject matter described herein, rather than suggesting any limitation on the scope of the subject matter.

Fig. 1 shows an example of the freshness detection device according to this invention, used in a refrigerator or a refrigeration house, which will hereinafter be referred to as 10. The freshness detection device 10 comprises a container 20, a sensing unit 30 and a processing unit 40.

The container 20 comprises an inner wall for forming an accommodating space 11. Food or other objects can be preserved therein. In this embodiment, the wall is formed by a heat transferring surface 21 made of, by way of example, metal foil or thermally conductive plastic plate. This surface has a good heat conductivity, and therefore is adapted to allow the respiration heat generated by the object to pass through quickly.

Herein, the term object comprises fruits, vegetables, flowers, mushrooms, or any other alive objects having respiration and being able to generate respiration heat. The respiration heat generated causes water contained in the objects to be evaporated into the accommodating space 11. Later, when the water vapor contacts the heat transferring surface

21, which heat transferring surface 21 has a lower temperature than the accommodating space 11, the water vapor is condensed into liquid water and gives out heat. Because the heat transferring surface 21 has a good heat conductivity, the heat will pass through the heat transferring surface 21 quickly.

The sensing unit 30 is used to sense some parameters representing the amount of heat passing through the heat transferring surface 21. In this embodiment, two parameters, i.e., the temperature of the heat transferring surface 21 and the temperature of the air in the accommodating space 11 close to the heat transferring surface 21, are suitable to be used. To be more specific, two temperature sensors (not shown) are arranged to sense the two parameters. These two parameters can be used to calculate the temperature difference between the heat transferring surface 21 and the accommodating space 11, which is important for the calculation of the amount of heat passing through the heat transferring surface 21. By way of example, the temperature sensor can be a bi-metal sensor, thermocouple sensor, thermal resistance infrared sensor, quartz sensor or silicon band gap sensor. However, it can be easily understood that some other parameters can also be used, which are also considered part of this invention.

The processing unit 40 is adapted to receive the sensing results provided by the sensing unit 30 and determine the freshness of the objects. As mentioned before, even after the harvest, fruits, vegetables, flowers, mushrooms or other alive objects still have respiration at a certain rate, which continuously generates respiration heat, and this respiration heat generated has a close and direct connection with the freshness. As a result, the calculation of the respiration heat enables the freshness of the object to be determined accordingly.

The total amount of heat passing through the heat transferring surface 21 comprises two parts: a condensation part and a conduction part. In some embodiments, the amount of the condensation heat is used to represent the total amount of heat passing through, because the conduction of heat is considered to be weak and could be ignored. Another assumption is that, since the heat transferring surface 21 is a good heat conductor, usually the respiration heat generated will be quickly transferred out of the accommodating space 11. Therefore, the temperature rise of the objects and the air in the accommodating space 11 is limited and could be ignored as well. As a result, in these

embodiments, the amount of the condensation heat could be used to represent the total amount of the respiration heat.

Based on the above assumptions, the condensation heat flow rate Φ_{con} and the total amount of the respiration heat Q_{resp} can be calculated by means of the below equations:

$$\Phi_{con} = h_{con} \times A_{surface} \times (T_{air} - T_{surface})$$

$$Q_{resp} = Q_{con} = \int_0^{\Delta t} \Phi dt$$

In said equations, h_{con} is the condensation heat transfer coefficient between the accommodating space 11 and the heat transferring surface 21. $A_{surface}$ is the area of the heat transferring surface 21. T_{air} and $T_{surface}$ are respectively the temperature of the air in the accommodating space 11 and the temperature of the heat transferring surface 21. Δt is the time used for detection. For a more accurate calculation result, T_{air} could be measured at a location close to the heat transferring surface 21.

The connection between the freshness of the object and the total respiration heat generated could be obtained by experiments. It should be noted that this connection varies substantially according to different types of objects with a different thickness, texture, post-harvest physiology, surface area etc. As a result, for the detection of different types of objects, different processing algorithms should be applied. In an economical embodiment, the objects could be classified into several groups based on their characteristics, like root vegetable (carrot, beet, parsnip), bulb vegetable (onion, garlic), tuber vegetable (potato), stem vegetable (asparagus), leafy vegetable (spinach, lettuce, celery, cabbage, leek, watercress, Brussels sprout), floral vegetable (broccoli, cauliflower).

However, it can also be envisaged that in some practical environments, the transferring of the respiration heat generated costs some time, so the temperature of the object and the air in the accommodating space 11 may rise and an amount of respiration heat will be kept in the objects and the air in the accommodating space 11. In case this happens, to improve the accuracy of freshness detection, the total amount of the respiration heat could be estimated based on the condensation heat and then used to determine the freshness of the object. The relationship between the total respiration heat

and the condensation heat can be roughly estimated by experiments or theoretical calculation.

Another possible calculation method is to use the temperature difference between the heat transferring surface 21 and the accommodating space 11 to determine the freshness directly, without the calculation of the condensation heat flow rate Φ_{con} or the total amount of the respiration heat Q_{resp}. The processing algorithms could be directly obtained by experiments. It should be noted that the temperature difference and the algorithms obtained by experiments are still relevant with the amount of heat transferred through the heat transferring surface 21, although it is not calculated. Therefore, this method should still fall within the scope of this invention.

Figs. 2 and 3 show another two examples of the freshness detection devices according to this invention, which will hereinafter be referred to respectively as 100 and 200.

As shown in Fig. 2, the structure of the device 100 is similar to that of the previous device 10, comprising a container 120, a sensing unit 130, a processing unit 140, a presenting unit 150 and an input unit 160.

The inner wall of the container 120 is in the form of a rigid box, defining an accommodating space 101 for accommodating objects, which comprises a heat isolation surface 122 and a heat transferring surface 121. However, it can be easily envisaged that the container 120 can also be soft or elastic with a changeable shape or volume.

An important difference in this embodiment is that only a part of the inner wall of the container 120 acts as a heat transferring surface, and the remaining parts of the wall are formed by heat isolation materials like a heat isolation film, a polymer foam layer or one side of a vacuum heat isolation layer. By means of this arrangement, the heat transfer will be concentrated on the heat transferring surface 121. This provides some benefits. For example, the temperature distribution over the whole heat transferring surface 121 will be more uniform, so the structure of the sensing unit 130 could be simplified and fewer sensors could be used. Another benefit is that, since the area of the heat transferring surface 121 is reduced, the transferring of a specific amount of total respiration heat to the exterior, will lead to a larger temperature difference being detected between the heat transferring surface 121 and the accommodating space 101 . This can improve the accuracy of the final detection result.

Another difference is that, in this embodiment, the container 120 further comprises a separation surface 123 between the heat transferring surface 121 and the accommodating space 101, to ensure the object accommodated will not touch the heat transferring surface 121. As mentioned above, the processing algorithms for the estimation of freshness are obtained based on some assumptions and experiments. If the object accommodated touches the heat transferring surface 121, the heat conduction will be stronger and therefore the set processing algorithm might not be applicable any more. By way of example, the separation surface 123 could be a mesh or a weave which could separate the object from the heat transferring surface 121 but which has very limited influence on the air convection in the accommodating space 101.

In addition, the input unit 160 can be used to input information like weight, types or classifications of the objects directly by the user or from another source like a database through a wireless receiver. In some embodiments, the devices could also comprise

a weight sensor or a temperature sensor to sense the weight and temperature of the object automatically. Taking these kinds of information into account, the final freshness detection result could be further improved.

The presenting unit 150 could deliver the freshness detection result to the users, in the form of a numerical value, an alarm or any other presenting forms based on the needs of the users.

In the embodiment shown in Fig. 3, the device 200 comprises a container 220, a sensing unit 230, a processing unit 240, a presenting unit 250 and an input unit 260. A difference is that, in this embodiment, the whole inner wall of the container 220 is formed by a heat isolation surface 222, and a heat transferring surface 221 extends across the heat isolation surface 222 so as to enter and contact the accommodating space 201. A separation surface 223 covers the part of the heat transferring surface 221 in the accommodating space 201.

In an embodiment, the separation surface 223 and the heat transferring surface 221 together can form a removable lid. In a preferable embodiment, the depth of the lid extending into the accommodating space 201 is adjustable (not shown), so the area of the heat transferring surface 221 could be changed. This provides a simple application for adjusting Φcon of the heat transferring surface 221 at a given temperature difference, which can be further used to adjust the inner temperature of the accommodating space 201. This is especially useful when the device 200 also acts as a container to preserve food in a refrigerator.

In some other embodiments, the people skilled in this field can envisage easily that a refrigerating unit 270, e.g. a dry ice compartment, can also be included in the device to build up the low temperature environment for e.g. food preservation.

Various modifications, adaptations to the foregoing exemplary embodiments of this invention may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings. Any and all modifications will still fall within the scope of the non-limiting and exemplary embodiments of this invention. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A freshness detection device (10, 100, 200), comprising:

a container (20, 120, 220) adapted to form an accommodating space (11, 101, 201) for accommodating an object that generates respiration heat;

a heat transferring surface (21, 121, 221) contacting the accommodating space (11, 101, 201);

a sensing unit (30, 130, 230) adapted to deliver a sensing parameter representing a transfer amount of the respiration heat through the heat transferring surface (21, 121, 221); and

a processing unit (40, 140, 240) adapted to determine the freshness of the object based on the sensing parameter.

2 The freshness detection device according to claim 1, wherein the heat transferring surface (21, 121) forms at least part of the container (20, 120).

3. The freshness detection device according to claim 1 or 2, wherein the container (120, 220) comprises a heat isolation surface (122, 222).

4. The freshness detection device according to claim 3, wherein the heat isolation surface (222) forms the container (220) and the heat transferring surface (221) extends across the heat isolation surface (222).

5. The freshness detection device according to claim 3 or 4, wherein the heat isolation surface (122, 222) comprises at least one of a heat isolation film, a polymer foam layer and one side of a vacuum heat isolation layer.

6. The freshness detection device according to any of the preceding claims, wherein the heat transferring surface (21, 121, 221) comprises at least one of a metal foil and a thermally conductive plastic plate.

7. The freshness detection device according to any one of the preceding claims, wherein the sensing unit (30, 130, 230) comprises a first temperature sensor adapted to sense

the temperature of the accommodating space (11, 101, 201) and a second temperature sensor adapted to sense the temperature of the heat transferring surface (21, 121, 221).

8. The freshness detection device according to any one of the preceding claims, wherein the processing unit (40, 140, 240) is further adapted to receive information about at least one of: classification, weight and temperature of the object, and determine the freshness of the object based on the information and the sensing result.

9. The freshness detection device according to any one of the preceding claims, further comprising a presenting unit (150) to present the freshness of the object.

10. The freshness detection device according to any one of the preceding claims, wherein the area of the heat transferring surface (21, 121, 221) is changeable.

11. The freshness detection device according to any one of the preceding claims, wherein the container comprises a separation surface (123, 223) between the accommodating space (101, 201) and the heat transferring surface (121, 221).

12. The freshness detection device according to any one of the preceding claims, wherein the processing unit (40, 140) is adapted to determine the amount of respiration heat generated by the object, and then determine the freshness of the object based on the amount of respiration heat.

13. A method for detecting the freshness of an object that generates respiration heat, wherein the object is accommodated in an accommodating space (11, 101, 201), and a heat transferring surface (21, 121, 221) is arranged to contact the accommodating space (11, 101, 201), the method comprising

- sensing a parameter representing a transfer amount of the respiration heat through the heat transferring surface (21, 121, 221); and
- determining the freshness of the object based on the parameter.

14. The method according to Claim 13, wherein the sensing step comprises sensing a first temperature of the accommodating space (11, 101, 201) and a second temperature of the heat transferring surface (21, 121, 221).

15. The method according to Claim 13 or 14, wherein the determining step comprises

- determining the amount of respiration heat generated by the object, and
- determining the freshness of the object based on the amount of respiration heat .

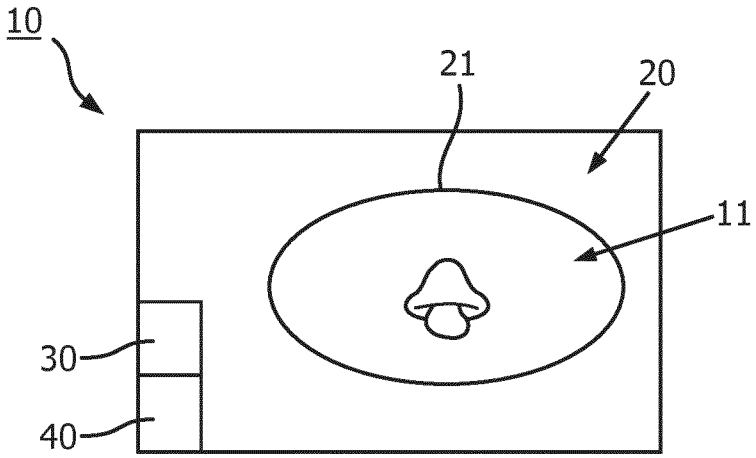


FIG. 1

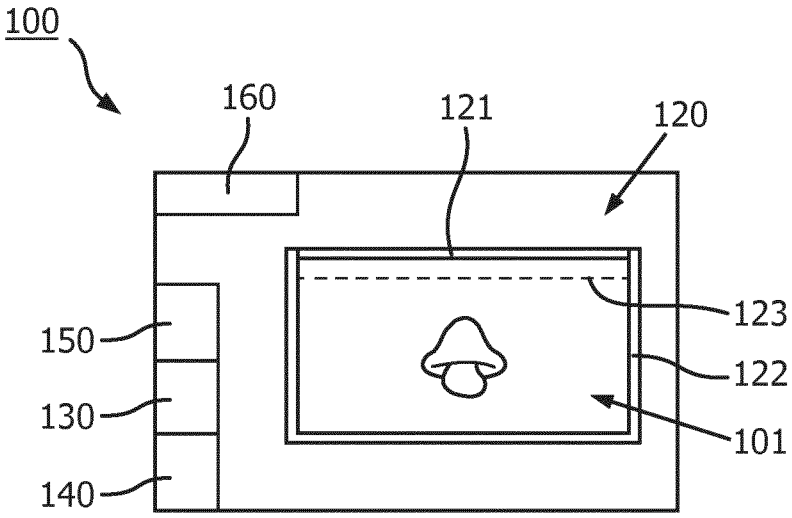


FIG. 2

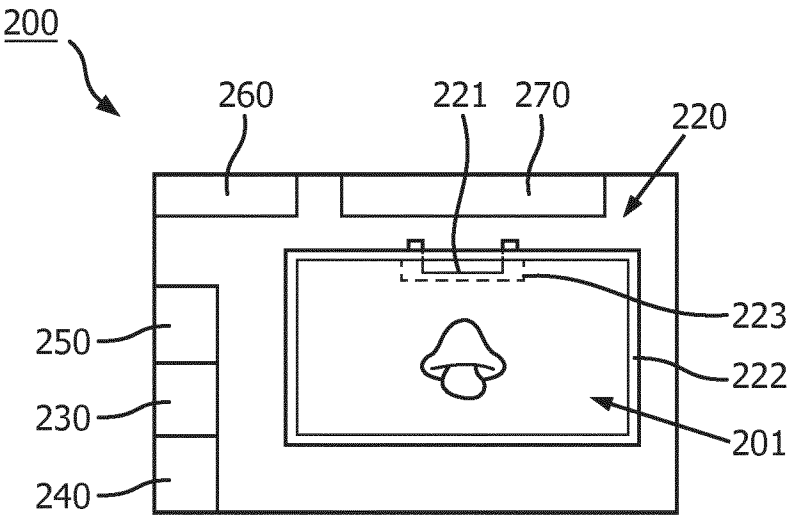


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/056983

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N33/02 G01N25/18
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)
G01N

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, COMPENDEX, 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	R Jedermann ET AL: "MODEL BASED ESTIMATION OF BIOLOGICAL HEAT GENERATION DURING COLD-CHAIN TRANSPORT AND PROCESSING", International Conference on Sustainability and the Cold Chain, 1 June 2014 (2014-06-01), XP055268352, Retrieved from the Internet: URL:http://www.intelligentercontainer.de/fileadmin/Redakteure/pdfs/2014/London_ID_121_Jedermann_v34.pdf [retrieved on 2016-04-25] Abstract; Paragraphs: 1, 2, and 4.; figure 2; table 1 ----- -/--	1-15

[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

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Date of the actual completion of the international search	Date of mailing of the international search report
26 April 2016	04/05/2016

Name and mailing address of the ISA/	Authorized officer
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2

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	O. IJABO ET AL: "Effects of fruit size and initial storage temperature on the heat of respiration of dacryodes edulis", AMERICAN JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH, vol. 3, no. 3, 1 June 2012 (2012-06-01), pages 150-156, XP055268256, DOI: 10.5251/ajsir.2012.3.3.150.156 the whole document	1-15
X	W P GREEN ET AL: "Calorimetric Measurements of the Heat of Respiration of Fruits and Vegetables", TECHNICAL BULLETIN OF UNITED STATES DEPARTMENT OF AGRICULTURE, no. 771, 1 January 1941 (1941-01-01), XP055268261,	1,2,7-9, 12-15
A	Description	3-6,10, 11
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