Effects of Suspension of Air-Conditioning on Airtight-Type Racks

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Abstract: Although isolation racks are superior to open-type racks in terms of securing breeding conditions for laboratory animals, the contingency-proofing capability of the former has yet to be determined. Therefore, from the view of risk management, we studied the environmental change in isolation racks by forcibly suspending ventilation and air-conditioning and confirming the maximal time length for complete recovery to the original condition after restarting their operations. The isolation racks were placed in a room that was equipped with an independent air-conditioning system. When the inside condition of the racks reached 22–24°C and 59–64% of relative humidity, the air-conditioning and ventilation were forcibly suspended and the subsequent temperature, relative humidity, ammonium and CO₂ concentrations in the racks were measured over time. We found that after suspending the air-conditioning and ventilation, it took 40–60 min for temperature, and about 10 min for relative humidity to exceed the maximum values (temperature and relative humidity) referred to in the Showa 58 Nenban Guideline Jikken Doubutsu Shisetsu no Kenchiku oyobi Setsubi (Guidelines of buildings and facilities for experimental animals in Japan; Year 1983 edition). After 17 hr 25 min of the suspension of air-conditioning and ventilation, two rats were found dead. Then, the air-conditioning and ventilation were restarted. It took about 2 hr for temperature, and 50 min for relative humidity to regain the guideline values. The ammonium concentration stayed within the guideline value with a maximum concentration of 2 ppm in the experimental period, whereas the CO₂ concentration was found to exceed 9% at the time of animal death.

Key words: emergency, environment, isolator, rack

Introduction

Recently, we have more and more opportunities to use high-airtightness breeding racks (which are also referred

to as isolation racks or airtight-type racks) for securing better control over breeding conditions for laboratory animals. These racks are superior to open-type racks in terms of ensuring an appropriate breeding condition for

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laboratory animals. However, the length of time isolation racks can maintain an appropriate environment for animals in contingencies such as air-conditioning breakdown and power failure has yet to be determined.

Therefore, from the view of risk management, we studied the environmental change in isolation racks by forcibly suspending ventilation and air-conditioning and confirming the maximal length of time for complete recovery to the original condition after restarting their operations.

Materials and Methods

Rack

Isolation rack (Charles River Type, manufactured by Nippon Shokubai Co., Ltd.) (Fig. 1)

The dimensions of the rack body are H 1000 mm × W 1900 mm × D 910 mm, and it is placed on a staging of H 840 mm × W 1900 mm × D 910 mm.

The rack is equipped with two pairs of gloves for operation on its plastic front surface, where a passbox and a HEPA filter for exhaust air are also set on the left; and a HEPA filter for supply air, a control valve for air volume, a fan for the inside ventilation (at 15 air changes per hour) and a differential pressure gauge (for differential pressure measurements between the inside and the outside of the rack) on the right. A transparent top board made of mainly FRP (fiber-reinforced thermoplastic) is fitted on the top of the rack.

Luggage racks with a depth of 360 mm are placed in the isolation rack for arranging animal cages for rats. Each luggage rack can accommodate 15 rat cages in an arrangement of 3 layers × 5 rows. In addition, a free space of H 980 mm × W 1880 mm × D 470 mm is available at the front as working space for exchanging cages and other operations.

Breeding condition for animals

KE-3102 (manufactured by SEOBiT, H 200 mm × W 265 mm × D 420 mm) was used as the cage and Betachip (Northeastern Products Co.) as the floor covering. The rats (SD: 8 weeks of age) were freely watered and fed. Forty-six rats in total were allocated to fifteen cages with 14 cages containing three rats each and one cage containing four rats. The floor covering chips of all 15 cages were completely renewed 4 hr before suspending ventilation and air-conditioning.

Fig. 1. The external appearance of the rack and the arrangement of the measurement devices.

Room for experiment

The room was equipped with an independent air-conditioning unit for changing temperature alone and a ventilating fan. The room size was H 2600 mm × W 4550 mm × D 4900 mm. The isolation rack was supplied with temperature-controlled air and rack exhaust was discharged into the room. The ventilating fan was used for ventilating the room.

Measurement devices

To measure temperature, humidity and gas concentrations, a thermocouple sensor (Data logger: THERMODAC E, ETODENKI Co.), two different capacitance-type sensors (for indoor: Anemometer with humidity sensor, AM-06, RION Co., Ltd, and for rack inside: Humidity and temperature indicator, HMI-32, Visala Oyj) and two different detector tubes (for NH₃ concentration: Detector tube, 3L (0.5–60 ppm), GASTEC Co., and for CO₂ concentration: Detector tube, 2H (0.5–20%), GASTEC Co.) were used, respectively (Table 1).

The isolation racks were placed in the room at a temperature of 21.2–21.5°C (preset temperature: 22°C) and humidity of 51.9–56.2% (arbitrary value). After the floor coverings has been exchanged and then the rack inside conditions had stabilized at a temperature of 22.5–23.1°C and humidity of 59.9–63.8% (Table 2), the room air-conditioning as well as both the room and rack ventilations were suspended. After 17 hr 25 min, the room air-conditioning (preset temperature: 22°C) as well as the room and rack ventilations were resumed.

The room humidity decreased from around 60% to

Fig. 2. The outline of the rack and measurement sites.

Fig. 3. Temperature/humidity changes before suspension of the air-conditioning and ventilation systems. Upper and lower limit temperatures and humidities are the maximum and minimum temperatures and humidities established as standards in “1983 version of Standards on Construction and Equipments of Experimental Animal Facilities” (Temperature: 20–26°C, Humidity: 30–70%).

around 56% within 5 min, then increased to 60% after 20 min, and stabilized at between 50 and 55% after 50 min.

The rack inside temperature decreased from around

32°C to around 26°C after 1 hr 40 min, to around 24°C after 4 hr and then stabilized.

The rack humidity decreased from around 76% to around 70% within 30 min, to around 60% after 2 hr 50

Fig. 4. Temperature/humidity changes during suspension of the air-conditioning and ventilation systems. Upper and lower limit temperatures and humidities are the maximum and minimum temperatures and humidities established as standards in “1983 version of Standards on Construction and Equipments of Experimental Animal Facilities” (Temperature: 20–26°C, Humidity: 30–70%).

Fig. 5. Temperature/humidity changes after resuming the air-conditioning and ventilation systems. Upper and lower limit temperatures and humidities are the maximum and minimum temperatures and humidities established as standards in “1983 version of Standards on Construction and Equipments of Experimental Animal Facilities” (Temperature: 20–26°C, Humidity: 30–70%).

Fig. 6. Ammonium concentration during suspension.

min, then decreased further to around 50% after 6 hr and stabilized.

The average rack inside temperatures at the upper part, the middle part and the lower part, as well as the rack humidity exceeded the corresponding guideline levels established in the guideline [1] (temperature: 20–26°C, humidity: 30–70%, ammonium concentration: 20 ppm), respectively, at around 40 min, around 45 min and around 1 hr 5 min, as well as around 10 min after suspending the air-conditioning and ventilation in the room and the racks.

Two rats were found dead 17 hr 25 min after suspending the air-conditioning and ventilation in the room and racks. At this time the air-conditioning and ventilation in the room and the racks were resumed. It took around 1 hr 55 min, around 1 hr 50 min, and around 1 hr 40 min, as well as around 50 min, respectively, for the rack inside temperatures at the upper, middle and lower parts, as well as the humidity to return to the guideline levels.

Ammonium concentration (Fig. 6)

The ammonium concentration increased from 1 ppm (at the time of suspension of the air-conditioning and ventilations) to 2 ppm at 1 hr, then decreased to 1 ppm after 5 hr, to 0.5 ppm after 8 hr, and then stabilized. The observed concentration never exceeded the guideline value with a maximum value of 2 ppm.

Carbon dioxide concentration

When the rats were found dead 17 hr 25 min after the suspension of the air-conditioning and ventilation in the room and the rack, the carbon dioxide concentration was observed to exceed 9%.

Animals' health condition

The activity level of the rats reduced 5 hr after the suspension of the air-conditioning and ventilation in the room and the rack, and at 8 hr they appeared to be breathing slightly hard. After 17 hr 25 min, one rat was found dead in each of two cages; one cage was placed 4th from the left (when observing the cage arrangement from the front) in the middle layer, and the other was 4th from the left in the bottom layer. Three rats were allocated to both of these cages.

Discussion

Airtight-type racks are being more widely used for breeding laboratory animals, because these racks allow a high level of airtightness and confer several benefits on users. For example, these racks can effectively protect animals, breeding workers and researchers in breeding rooms from infectious agents, odor and other problems. Also they enable many operations such as aseptization of incoming animals, quarantine of animals to be inspected, and isolation of contaminated animals. Therefore, we validated the effectiveness of the high airtightness of the racks under an experimentally generated emergency condition.

Our results suggest that when using the values described in the guideline [1] (for temperature, humidity, ammonium concentration) as the relevant guidelines, we should address emergency situations such as the accidental suspension of air-conditioning and ventilation due to power failure or other circumstances within 40 min and 10 min in terms of temperature and humidity, respectively. The ammonium concentration observed never exceeded the guideline value of 20 ppm during the measuring period (17 hr 25 min), possibly because the floor covering was exchanged only about 4 hr before the measurement, and therefore there was not much excrement and urine which could cause ammonium gas in the racks. However, the carbon dioxide concentration which is not indicated in the guideline [1] exceeded 9% when two rats were found dead. The cause of their death has yet to be determined.

If an open-type rack were exposed to the same condition as we used in this experiment, because of the lack of airtightness of the rack, heat radiated from the rats' bodies and other elements in the racks would diffuse into the room. As we can see in Fig. 4, both the room

temperature and the room humidity were always lower than those in the racks, and it would be expected that it would take longer for both the rack inside temperature and humidity to exceed the guideline values when compared to those in the isolation rack. Also CO₂ concentration in the open-type rack would increase less compared to the isolation rack, because the open-type rack provides a wider inside space and no airtightness.

When using the upper limit temperature (27°C) described in ILAR 1996 edition [2] as the relevant guideline, the open-type rack would provide us with about 1 hr after suspension of the air-conditioning and ventilation to cope with the emergency situation. But when using the upper limit temperature (26°C) described in ILAR 1996 edition [2] as another relevant guideline, only about 40 min would be provided for us to address the situation, even with the open-type rack.

Like temperature, the rack inside status in terms of the gas concentrations after emergency would differ between the open-type rack and the isolation rack. We expect that the isolation rack would provide us with a tighter margin (time length) to cope with emergency situations. Therefore, we believe that in the use of isolation racks with a high airtightness and a small inside space a certain guideline should be established.

In summary, when using isolation racks, we will have a wider margin (time length) to cope with increase in humidity and CO₂ concentration if a secondary power source is available at least for operating the ventilating fan which is attached to the rack.

The guidelines give us the environmental guidelines for normal conditions. In contrast, our study for this report reflected an emergency condition under which the rack inside humidity and temperature exceeded the guideline values only 10 min and 40 min after the suspension of air-conditioning and ventilation, respectively.

Although isolation racks provide us with many advantages compared to open-type racks, we should always be aware of how we should prepare for emergencies. On top of secondary air-conditionings and power sources, we need sufficient human resources for better laboratory conditions.

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