The effects of ultraviolet light irradiation and drying treatments on the survival of *Cronobacter* spp. (*Enterobacter sakazakii*) on the surfaces of stainless steel, Teflon and glass

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**A B S T R A C T**

*Cronobacter* spp. (*Enterobacter sakazakii*) are opportunistic food-borne pathogens that might cause severe consequences in infants and neonates. The outbreaks are associated with the consumption of powdered infant formula. Possible contamination sources of these particular microorganisms include the processing equipments and the operation environments. The present research was carried out to study the survival of *Cronobacter* spp. on the surfaces of stainless steel, Teflon and glass under ultraviolet (UV) irradiation and at different temperatures. The results show that *Cronobacter* spp. were susceptible to UV light but could survive at 60 or 70 °C for up to 120 min. The study contributes to a better understanding of the growth behavior of *Cronobacter* spp. on food contact surfaces, thereby enabling the development of more effective strategies and interventions for the control.

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1. Introduction

*Cronobacter* spp., formerly *Enterobacter sakazakii*, are opportunistic Gram-negative food-borne pathogens that might cause severe consequences in infants and neonates (Nazarowec-White & Farber, 1997; Pagotto, Lenati, & Farber, 2007). The *Cronobacter* genus was originally defined as an *E. sakazakii* species (Farmer, Asbury, Hickman, Brenner, & the Enterobacteriaceae Study Group, 1980); but *E. sakazakii* has recently been reclassified as six species in the new *Cronobacter* genus (Iversen et al., 2008). In accordance with the new taxonomic change, the designation “Cronobacter spp.” is used consistently in the subsequent part of this paper with the exceptions when a specific strain is mentioned.

The outbreaks of *Cronobacter* spp. are associated with the consumption of powdered infant formula (Drudy et al., 2006; Iversen & Forsythe, 2004). Because the powdered infant formula is not sterile, low levels of microorganisms including *Cronobacter* spp. have been detected (Lenati, O’Connor, Hébert, Farber, & Pagotto, 2008; Rossot, Noel, & Morelli, 2007). Since *Cronobacter* spp. cannot survive the pasteurization heat treatment (Breeuwer, Lardeau, Peterz, & Joosten, 2003; Iversen, Lane, & Forsythe, 2004; Reich König, von Wiese, & Klein, 2010), possible contamination sources of these particular microorganisms include the addition of non-thermal-treated ingredients (such as vitamins and minerals) and the post-thermal treatment contamination from the processing equipments and environments (Kuda et al., 2012; Mullane et al., 2006; Reich et al., 2010). Therefore, even though significant improvements have been achieved in the processing technology and in the disinfecting protocol on machinery and facility, contamination of *Cronobacter* spp. has not been completely eradicated from powdered infant formula and continues to pose threat to the health of susceptible population (Adekunte et al., 2010).

The microbial contamination on food contact surfaces of processing equipments and from the environments might be caused by accidental splash/spill or air fallout. In fact, *Cronobacter* spp. were detected in the environmental samples in a powdered infant formula processing plant (Reich et al., 2010). If microbes on the processing equipment surfaces cannot be destroyed completely, the microorganisms might be transferred from food contact surfaces to food products through cross-contamination. The contamination originating from the food contact surfaces of utensils and equipments used in the food plants was reported by Shaker, Osaili, Al- Omary, Jaradat, and Al-Zuby (2007). To establish appropriate methods to control this type of cross-contamination, the survival behavior of *Cronobacter* spp. on food contact surfaces is needed. However, survival studies of *Cronobacter* spp. were almost all conducted in food systems such as powder infant
formula, infant cereal, fresh-cut produce etc. (Adekunle et al., 2010; Al-Holy, Lin, Al-Qadiri, & Rasco, 2008; Lin & Beuchat, 2007; Nazarowec-White & Farber, 1997; Rosset et al., 2007; Shaker et al., 2007). Little information can be obtained in the literature to reveal the survival capability of Cronobacter spp. on the food contact surfaces.

Although many materials can be found in food processing plants, the present research was carried out to study the survival of Cronobacter spp. on the surfaces of stainless steel, glass, and Teflon. Stainless steel is the most common material for constructing food processing machines, while Teflon is used as many machinery parts. On the other hand, glass is used in building windows and is the most common material for laboratory apparatus. In the practical operation, food processing equipments are washed, disinfected and rinsed after food manufacture. The wet equipment surfaces are either dried at room temperature for a long period of time or dried at elevated temperature (around 60–70 °C) with or without air flow for a relatively short time duration. Also, ultraviolet (UV) light is commonly used in food plants to reduce microbial load in the environments and on the equipment surfaces. Collectively, the present research was conducted to investigate the effect of UV light on the survival of Cronobacter spp. on these three types of surfaces. The survival of Cronobacter spp. on the surfaces either at elevated or room temperatures was also studied.

2. Materials and methods

2.1. Microbial cultures

Cronobacter sakazakii BCRC14153 (ATCC type strain 12868) was obtained from the Bioresources Collection and Research Center (BCRC), Hsin-Chu, Taiwan. Cronobacter sp. 29T was isolated from a rice flour sample and identified with API 20E identification kit (Marcy I’Etiole, France). The bacteria were streaked on tryptic soy agar (TSA) (Merck, Darmstadt, Germany) plate and incubated at 37 °C overnight. To ensure the correctness of bacteria used in following experiments, typical Cronobacter spp. colonies on TSA plates were identified and confirmed by yellow pigmentation (Kandhai et al., 2010) and API 20E kit (Al-Holy et al., 2008; Drudy et al., 2006). To prepare overnight culture for further tests, a single colony was selected and inoculated into 50-mL sterilized tryptic soy broth (TSB) (Merck, Darmstadt, Germany) and incubated at 37 °C for about 16 h. Although a wide range of incubation temperature (from 25 to 45 °C) for Cronobacter spp. has been reported (Iversen & Forsythe, 2007), relatively fast growth (usually within 1 day) can be obtained at 37 °C (Farmer et al., 1980). Since the growth at 25 °C will take 2–4 days, the incubation temperature of the present study was set at 37 °C in order to meet the cultivation protocol that only 0.5 mL growth medium was applied on material surfaces.

2.2. Effect of UV light on the survival of Cronobacter spp. on the culture medium surfaces

The overnight culture was diluted to cell density of about 10^8 CFU/mL with 0.1% sterilized peptone water. An aliquot of 0.1 mL was evenly spread on the surface of TSA or violet red bile glucose agar (VRBGA, Merck, Darmstadt, Germany) plates with a sterile L-shaped glass rod. The plates were uncovered and placed under an ultraviolet light (TUV ISW/G15 T8, Philips, Holland) at the distance of 20–55 cm for up to 300 s in a laminar flow. Then, the plates were incubated at 37 °C for 2 days and the colonies were counted. The survival rate was calculated against the number of colony detected in plates without UV irradiation.

2.3. Effect of UV light on the survival of Cronobacter spp. on the material surfaces

2.3.1. Inoculation of bacteria on material surface

Because stainless steel, Teflon and glass are among the most commonly used materials for utensils and equipments in food plant and laboratory, the capability of Cronobacter spp. to survive on the utensil and equipment surfaces is worth investigating. Therefore, the present study was conducted to investigate the survival of Cronobacter spp. on these three types of material surfaces.

The stainless steel plates (SUS301; 60 × 40 × 1.33 mm; Yi-Yuan Co., Douliou, Taiwan), glass slides (76.2 × 25.4 × 1.2 mm; Hon-Li Co., Chiayi, Taiwan) and Teflon plates (76.2 × 25.4 × 1.2 mm; Yi-Yuan Co., Douliou, Taiwan) were carefully cleaned and individually placed in a glass Petri dish (90 mm dia.). The glass Petri dishes containing the testing materials were sterilized in an oven (170 °C, 3 h) and then cooled down to room temperature. The overnight culture was diluted to cell density about 10^6 CFU/mL with sterilized 0.1% peptone water and an aliquot of 10 μL overnight culture was placed on the surface of each stainless steel plate, glass slide or Teflon plate.

2.3.2. Survival of Cronobacter spp. on material surfaces under UV irradiation

After inoculation, the glass Petri dishes containing individual stainless steel plate, Teflon plate or glass slide were uncovered and placed in a laminar flow under the UV light at a distance of 55 cm for up to 300 s. At the end or irradiation, an aliquot of 0.5 mL TSA was carefully placed at the inoculation spot of the material surface. The Petri dishes were incubated at 37 °C for 24 h and the growth of Cronobacter spp. was recorded. The results were expressed as the number of plates or slides with microbial growth over the 16 replicates.

2.4. Survival of Cronobacter spp. on material surfaces at different temperatures

2.4.1. Survival of Cronobacter spp. on material surfaces at elevated temperatures

The inoculation of Cronobacter spp. culture on stainless steel plates, glass slides and Teflon plates was performed as described earlier (2.3.1). In order to study the survival rate of Cronobacter spp. under simulated drying conditions in food processing plants, the Petri dishes were kept in a forced-air convection oven at 60 or 70 °C for up to 120 min. At each time interval, randomly sampled Petri dishes were removed from the oven and left in a laminar flow for about 30 min to cool down to room temperature. After the TSA medium (0.5 mL) was carefully placed at the inoculation spot, the Petri dishes were incubated at 37 °C for 24 h to observe the growth of bacteria. The results were expressed as the number of plates of slides with microbial growth over the 16 replicates.

2.4.2. Survival of Cronobacter spp. on material surfaces at room temperatures

To investigate the survival of Cronobacter spp. on material surfaces at room temperature, the Petri dishes containing inoculated stainless steel plate, glass slide or Teflon plate were placed in an incubator at 25 °C or 30 °C for up to 6 days. The Petri dishes were randomly sampled during the storage period. The growth medium application, incubation and observation of bacterial growth were conducted as described earlier (2.4.1). The results were expressed as the number of plates of slides with microbial growth over the 16 replicates.

2.5. Statistical analysis

The statistical analysis was performed with SPSS software (version 10.0; SPSS, Chicago, IL, USA) on a personal computer. Data
3. Results and discussion

3.1. Ultraviolet light sensitivity test

UV light irradiation is a common practice in food plants to reduce the microbial load on the equipments and in the operation environments. Tryptic soy agar (TSA) and violet red bile glucose agar (VRBGA) are two typical growth media for Cronobacter spp. (Al-Holy et al., 2008; Iversen & Forsythe, 2004). Since the types of medium used might influence the detection of Cronobacter spp., after UV irradiation, the effects of these two media on the growth of UV-stressed Cronobacter spp. were first investigated.

The inhibition of Cronobacter spp. growth by UV irradiation at the distance of 55 cm is shown in Table 1. For both strains, the survival rate was quickly dropped starting from 30 s of irradiation and no growth was detected when the irradiation time reached 300 s. The results showed that the UV light commonly used in the food plant exerts strong inhibitory effect against the growth of Cronobacter spp. As for the medium type, higher survival rates were observed on TSA plates at the irradiation time of 30 s and 60 s with the exception of 180-sec irradiation. Moreover, the results are in consistence with a previous study that Cronobacter spp. could grow rapidly on TSA medium with colony diameter reaching 2–3 mm in 24 h (Farmer et al., 1980).

The effects of irradiation time (30, 60 and 90 s) and distance (20, 30 and 40 cm) against Cronobacter spp. 29T and BCRC14153 growth on TSA and VRBGA medium surface are demonstrated in Table 2. For both strains on TSA and VRBGA medium surface, no growth was observed when irradiation time was 90 s (data not shown). In general, the higher survival rates were also observed on the TSA plates for both strains with the irradiation time of 30 and 60 s at all irradiation distance.

Significant difference of irradiation distance was detected for BCRC14153 growing on TSA when the irradiation time was 30 and 60 s. On the other hand, the irradiation distance of 20, 30 and 40 cm showed no significant difference of survival rate of 29T growing on TSA at the irradiation time for 30 s or 60 s. The results indicated that the different strains exert different resistance to UV light. If UV light is used to reduce the microbial load in food plant, the more resistant strain should be used to set the operation standards. As for both strains growing on VRBGA, significant difference was detected among some irradiation distance.

3.2. Effect of UV light on the survival of Cronobacter spp. on the material surfaces

The survival behavior study of Cronobacter spp. is commonly conducted in food systems; and desiccation tolerance and heat tolerance are usually the major topics (Breeuwer et al., 2003). In the practical operations, clean utensils and equipments as well as food processing environments are frequently exposed to UV light to reduce microbial load. However, the effect of UV light on the survival of Cronobacter spp. is rarely reported.

The survival of Cronobacter spp. on material surfaces under UV irradiation is shown in Table 3. The results showed that contamination could be completely removed by UV irradiation for 300 s. The results suggested that very low risk on cleaned and dried surfaces can be achieved if sufficient UV irradiation is performed. However, it should be noted that marked difference does exist between this experiment and the practical conditions in food processing plants. The UV irradiation in present research was performed in a laminar flow of restricted space and the testing material surfaces are uniformly flat. Moreover, the experiments were conducted under well-controlled conditions with specific time and distance. On the other hand, very complicated situations have to be faced in the food processing plants. For example, various processing machines are arranged in a relatively large space. And, varying irradiation distance might be encountered because of the

Table 1
The effects of growth medium and UV irradiation time on the survival rate (%) of Cronobacter spp. BCRC14153 and 29T.

<table>
<thead>
<tr>
<th>Irradiation time (sec)</th>
<th>BCRC14153</th>
<th>VRBGA medium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSA medium</td>
<td>VRBGA medium</td>
</tr>
<tr>
<td>0</td>
<td>100.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>30</td>
<td>98.53 ± 5.87&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30.53 ± 1.34&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>60</td>
<td>48.34 ± 2.93&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11.17 ± 2.75&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>180</td>
<td>5.89 ± 2.98&lt;sup&gt;d&lt;/sup&gt;</td>
<td>9.12 ± 1.12&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>300</td>
<td>N.D.</td>
<td>N.D.</td>
</tr>
</tbody>
</table>

Ultraviolet light: 15W; Irradiation distance: 55 cm.
Mean ± S.D., n = 3; N.D.: no growth detected.
Data in the same column with different lowercase letters are significantly different (p < 0.05).

Table 2
The effects of UV irradiation time (sec) and distance (cm) on the survival rate (%) of Cronobacter spp. BCRC14153 and 29T growing on TSA or VRBGA plate.

<table>
<thead>
<tr>
<th>Bacterial strain</th>
<th>Irradiation time (sec)</th>
<th>VRBGA</th>
<th>Irradiation time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>20 cm</td>
<td>100.00 ± 0.00&lt;sup&gt;e&lt;/sup&gt;</td>
<td>45.32 ± 3.79&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>30 cm</td>
<td>100.00 ± 0.00&lt;sup&gt;f&lt;/sup&gt;</td>
<td>55.21 ± 1.12&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>40 cm</td>
<td>100.00 ± 0.00&lt;sup&gt;f&lt;/sup&gt;</td>
<td>75.03 ± 4.20&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>29T</td>
<td>0</td>
<td>100.00 ± 0.00&lt;sup&gt;e&lt;/sup&gt;</td>
<td>16.34 ± 2.61&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>30 cm</td>
<td>100.00 ± 0.00&lt;sup&gt;e&lt;/sup&gt;</td>
<td>22.06 ± 3.25&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>40 cm</td>
<td>100.00 ± 0.00&lt;sup&gt;e&lt;/sup&gt;</td>
<td>29.35 ± 2.57&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>20 cm</td>
<td>100.00 ± 0.00&lt;sup&gt;e&lt;/sup&gt;</td>
<td>24.80 ± 4.53&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>30 cm</td>
<td>100.00 ± 0.00&lt;sup&gt;e&lt;/sup&gt;</td>
<td>29.33 ± 1.89&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>40 cm</td>
<td>100.00 ± 0.00&lt;sup&gt;e&lt;/sup&gt;</td>
<td>36.80 ± 4.53&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Ultraviolet light: 15W; mean ± S.D., n = 3.
<sup>e</sup>, <sup>f</sup>, <sup>g</sup>, <sup>h</sup> For the same bacterial strain and the same irradiation time, data in the same column with different superscript letters are significantly different (p < 0.05).
<sup>i</sup>, <sup>j</sup>, <sup>k</sup>, <sup>l</sup> For the same medium and the same irradiation distance, data in the same row with different superscript letters are significantly different (p < 0.05).
The survival of Cronobacter BCRC14153 and 29T on stainless steel surfaces after exposure to UV light.

Table 3

<table>
<thead>
<tr>
<th>Materials</th>
<th>Bacterial strain</th>
<th>Irradiation time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td>BCRC14153</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
<tr>
<td>Glass</td>
<td>BCRC14153</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
<tr>
<td>Teflon</td>
<td>BCRC14153</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
</tbody>
</table>

Stainless steel plate: SUS301 stainless steel, 60 × 40 × 1.33 mm, glass slide: 25.4 × 76.2 × 1.2 mm, and Teflon plate: 25.4 × 76.2 × 1.2 mm.

Inoculum size: 10 µL per spot (1 × 10⁶ CFU/mL); medium: tryptic soy agar; n = 16.

UV light: 15W; irradiation distance = 55 cm.

Stainless steel plate: SUS301 stainless steel, 60 × 40 × 1.33 mm, glass slide: 25.4 × 76.2 × 1.2 mm, and Teflon plate: 25.4 × 76.2 × 1.2 mm.

Inoculum size: 10 µL per spot (1 × 10⁶ CFU/mL); medium: tryptic soy agar; n = 16.

The effects of elevated temperature (60 or 70 °C) on the survival of Cronobacter BCRC14153 and 29T on the stainless steel surfaces.

Table 4

<table>
<thead>
<tr>
<th>Materials</th>
<th>Bacterial strain</th>
<th>Temperature</th>
<th>Holding time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td>BCRC14153</td>
<td>60 °C</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
<tr>
<td></td>
<td>29T</td>
<td>70 °C</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
<tr>
<td>Glass</td>
<td>BCRC14153</td>
<td>60 °C</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
<tr>
<td></td>
<td>29T</td>
<td>70 °C</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
<tr>
<td>Teflon</td>
<td>BCRC14153</td>
<td>60 °C</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
<tr>
<td></td>
<td>29T</td>
<td>70 °C</td>
<td>16/16 16/16 16/16 16/16</td>
</tr>
</tbody>
</table>

Stainless steel plate: SUS301 stainless steel, 60 × 40 × 1.33 mm, glass slide: 25.4 × 76.2 × 1.2 mm, and Teflon plate: 25.4 × 76.2 × 1.2 mm.

Inoculum size: 10 µL per spot (1 × 10⁶ CFU/mL); medium: tryptic soy agar; n = 16.

Dimension and non-uniformly flat surfaces of processing equipment. Thus, UV irradiation on the machinery surfaces in food plants is very unlikely to perform uniformly.

3.3. Survival of Cronobacter spp. on the material surfaces at different temperatures

3.3.1. Survival of Cronobacter spp. on material surfaces at elevated temperatures

Since Cronobacter spp. are not thermal resistant (Breeuwer et al., 2003), the post-thermal treatment contamination originating from the food processing environment is one of the reasonable explanations for low level of bacterial count found in the powdered infant formula (Reich et al., 2010). Bacterial attachment and biofilm formation on stainless steel and plastic surfaces were reported (Rivas, Dykes, & Fegan, 2007). Moreover, the attachment and growth of Cronobacter spp. on the surfaces of latex, polycarbonate, silicon and stainless steel were reported in another study (Iversen et al., 2004). As a general practice, food processing equipments are washed to remove food residue and then occasionally dried at around 60–70 °C with or without air flow. Therefore, the survival characteristic of C. sakazakii in the simulated conditions was investigated.

The results showed that Cronobacter spp. could survive at the temperature of 60 °C and 70 °C for up to 120 min (Table 4). Thus, the contamination of Cronobacter spp. on the cleaned surfaces cannot be removed with the usual drying treatment with elevated temperature. The persistent presence on dried surfaces was in agreement with the previous findings that Cronobacter spp. are very resistant to drying and could survive in low water activity conditions for long period of time (Breeuwer et al., 2003; Lin & Beuchat, 2007). Although, food residues can protect microorganisms on the equipment surfaces (Kuda et al., 2012), it should be noted that no food residues were involved in the present study. Therefore, thorough cleaning of food processing equipment and higher drying temperature are recommended for controlling Cronobacter spp. contamination on the food contact material surfaces.

3.3.2. Survival of Cronobacter spp. on material surfaces at room temperatures

Because the washed and cleaned utensils and equipments might also be left air-dried at ambient temperature, the survival of Cronobacter spp. on these three types of material surfaces at lower temperature (25 and 30 °C) was also studied (Table 5). Although marked reduction of survival rate was observed, the growth can be detected on the stainless steel surface for up to 6 days. The results strongly suggest that if the attachment of Cronobacter spp. on stainless steel surface occurs, the cross-contamination from stainless-steel-made to food products might also occurs. On the other hand, the results also indicate that glass surface seems to be the most suitable material for Cronobacter spp. Thus, the windows in the food processing plants must be carefully cleaned to ensure the safety of food products. Also, it is interesting to note that no growth was detected on Teflon surface starting from day 1. The results suggest that further studies are needed to reveal the inhibitory mechanism of Teflon against the survival of the bacterium.

Table 5

The survival of Cronobacter BCRC14153 and 29T on the stainless steel, glass, and Teflon surfaces at room temperature (25 or 30 °C).

<table>
<thead>
<tr>
<th>Materials</th>
<th>Bacterial strain</th>
<th>Temperature</th>
<th>Holding time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td>BCRC14153</td>
<td>25 °C</td>
<td>0 1 2 3 4 5 6 16/16 13/16 10/16 7/16 5/16 0/16 0/16</td>
</tr>
<tr>
<td></td>
<td>29T</td>
<td>30 °C</td>
<td>16/16 14/16 7/16 6/16 5/16 2/16 0/16</td>
</tr>
<tr>
<td>Glass</td>
<td>BCRC14153</td>
<td>25 °C</td>
<td>0/16 0/16 0/16 0/16 0/16 0/16 0/16 0/16 0/16 0/16 0/16 0/16 0/16 0/16 0/16</td>
</tr>
<tr>
<td></td>
<td>29T</td>
<td>30 °C</td>
<td>16/16 16/16 16/16 16/16 16/16 16/16 16/16 16/16 16/16 16/16 16/16 16/16 16/16 16/16</td>
</tr>
</tbody>
</table>

Stainless steel plate: SUS301 stainless steel, 60 × 40 × 1.33 mm, glass slide: 25.4 × 76.2 × 1.2 mm, and Teflon plate: 25.4 × 76.2 × 1.2 mm.

Inoculum size: 10 µL per spot (1 × 10⁶ CFU/mL); medium: tryptic soy agar; n = 16.
4. Conclusions

The present study provides solid evidence that Cronobacter spp. can survive on the surfaces of stainless steel, Teflon and glass for a certain period of time. With regards to prevention of Cronobacter spp. contamination, processing techniques and equipment cleaning must be accompanied by careful environment control. The above information will be very useful for the infant formula manufacturers and other related food plants. The study does contribute to a better understanding of the behavior of Cronobacter spp. on food-contact surfaces, thereby enabling the development of more effective strategies and interventions for its control.

References


