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# Antimicrobial effect of commercial play dough, safety or not?

*Ticari oyun hamurlarının antimikrobiyal etkisi, güvenli mi değil mi?*

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**Abstract**
Toys have been used increasingly as an aid in the treatment of hospitalized children since the 1950s due to their positive effect on child psychology. Play dough plays a role in children's reflection of their imagination and development of hand skills. In addition to the educational properties of play dough, its chemical and biological safety is also critical. This work investigated the antimicrobial effects of 40 different commercially available play doughs on various pathogenic microorganisms. According to the obtained results 52.5% of play dough samples showed antimicrobial activity against *Bacillus licheniformis*, 20% of play dough samples showed antimicrobial activity against *Escherichia coli*, 20% of play dough samples showed antimicrobial activity against *Pseudomonas aeruginosa*, 12.5% of play dough samples showed antimicrobial activity against *Candida albicans* and 7.5% play dough samples showed antimicrobial activity against *Staphylococcus aureus* (MRSA). In the era of the spread of COVID-19, when antimicrobial toys for reducing microbial load were evaluated, the antimicrobial activity of play dough was reported for the first time in this study.

**Keywords:** Antibacterial, Antifungal, Child, Play dough, Toy

***Öz***
*Oyuncaklar, çocuk psikolojisi üzerindeki olumlu etkileri sayesinde 1950'li yıllardan itibaren hastanede yatan çocukların tedavisinde yardımcı olarak gün be gün artan bir şekilde kullanılmaktadır. Oyun hamuru çocukların hayal güçlerini yansıtmalarında ve el becerilerinin gelişmesinde rol oynar. Oyun hamurunun eğitici özelliklerinin yanı sıra kimyasal ve biyolojik güvenliği de oldukça önemlidir. Bu çalışma oyun hamurundaki tehlikeye dikkat çekmek amacıyla yapılmıştır. Bu çalışmada, piyasada bulunan 40 farklı oyun hamurunun çeşitli patojenik mikroorganizmalar üzerindeki antimikrobiyal etkileri araştırılmıştır. Elde edilen sonuçlara göre oyun hamuru örneklerinin %52,5'i Bacillus licheniformis'e karşı, %20'si Escherichia coli'ye karşı, %20'si Pseudomonas aeruginosa'ya karşı antimikrobiyal aktivite gösterirken, oyun hamuru örneklerinin %12.5'i Candida albicans'a karşı %7,5'i Staphylococcus aureus'a (MRSA) karşı antimikrobiyal aktivite göstermiştir. COVID-19'un yayıldığı bu çağda mikrobiyal yükü azaltmaya yönelik antimikrobiyal oyuncakların değerlendirildiği bu çalışma ile oyun hamurunun antimikrobiyal aktivitesi ilk kez rapor edilmiştir.*

***Anahtar kelimeler**: Antibakteriyel, Antifungal, Çocuk, Oyun hamuru, Oyuncak*

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## 1. Introduction
*1. Giriş*

Comments that teddy bears, which have become children's favorite, could be a source of microorganisms, started in the 1970s. With the increasing number of hospital infections, it is reported that toys in the hands of children can also be a source of infection in studies aimed at detecting infection sources and minimizing infection rates (Davies et al., 2000; Hughes et al., 1986; Prüss-Üstün & Corvalán, 2006; Randle & Fleming, 2006). Play dough is both a game and an educational tool for children. It is an old toy preferred because it is cheap, flexible and simple to use (Girolametto et al., 2000). Play dough not only improves small muscle development, but also improves children's creativity, and also supports children's cognitive and emotional development. In this way, children can relax and express themselves more easily when they play with play dough (Susanti & Trianingsih, 2017).

The safety of toys in terms of health is very important. Children play together on non-sterile floors and cause different pathogens to be transmitted to their hands and mouths via their hands (Ibfelt et al., 2015; Martínez-Bastidas et al., 2014; Rogers et al., 2000; Torondel et al., 2015). Sharing toys among hospitalized children increases the risk of cross-contamination of microorganisms. Toy contamination by germs from normal and possibly pathogenic microbiota has been established by several authors (Aleksejeva et al., 2021; Lee et al., 2007). When surfaces are not adequately cleaned and sterilized, some germs may survive for hours, even weeks, and toys can act as a disease reservoir (Mahl & Sadler, 1975). In a study, it was reported that pediatric hospital toys were contaminated with *Stenotrophomonas maltophilia*, *Pseudomonas spp.*, *Staphylococcus spp.*, *Enterococcus spp.* and *Bacillus spp.*, and these contaminated toys caused nosocomial infections in children (Ledwaba et al., 2019). In the study of Bandyopadhyay et al. (2019) microorganisms were isolated from children's clothes and toys. According to this report, isolated microorganisms were defined as *Staphylococcus aureus*, *Bacillus cereus* and *Escherichia coli* (Bandyopadhyay et al., 2019). Play dough must be both nontoxic and microbially safe. Erbas et al. (2017) reported that varied concentrations of heavy metal content of play doughs. In another study by Dülger et al. (2017) the bacteriological safety of commercially sold play dough was evaluated. According to the results of this study, two (20%) out of ten companies were found to have no growth, while growth was found in all cultures of the two companies included in the study (Dülger et al., 2017).

In studies conducted in Turkey and around the world, the microbial load in toys in playgrounds (swimming pools, playgrounds, etc.) and toys used in other different areas have been included in the studies (Ayan et al., 2018; Chedid et al., 2020; Dülger et al., 2017). However, the antimicrobial effect of toys on microorganisms was not mentioned. Also, according to our literature knowledge, this is the first research to study the antimicrobial potential in play dough samples that children use.

## 2. Material and Method
*2. Gereç ve Yöntem*

### 2.1. Material
*2.1. Gereç*

A total of 40 play dough belonging to 6 different brands available in the market and sold commercially were provided for antimicrobial experiments. Brands are symbolized by the letters B, A, R, I, S, G. There are play doughs in different colors in the study. The letters symbolized next to the brands show the color of the play dough. The abbreviations of the colors are as follows: Y=Yellow, O=Orange, W=White, R=Red, B=Blue, G=Green, P=Pink, PU=Purple, GRY=Grey, BLC=Black, BR=Brown, LG=Light Green.

Bacterial and fungal cultures were obtained from Hacettepe University, Biotechnology Department (Ankara, Turkey). All of the chemicals used in the study were obtained from Sigma-Aldrich (Merck).

### 2.2. Method
*2.2. Yöntem*

Mueller–Hinton agar and Sabouraud Dextrose Agar (Merck) media were used to determine the antimicrobial effect in the study. Play dough was cut into antibiotic disc size (6 mm) under sterile conditions. As bacteria, *Bacillus licheniformis*, *Staphylococcus aureus ATCC 43300 (MRSA)*, *Escherichia coli* ATCC 35218, *Pseudomonas aeruginosa* ATCC 27853 and as yeast *Candida albicans* ATCC 10231 strains were used to determine the antimicrobial effect. After the microorganisms spread on the agar, the play dough cut with a diameter of 6 mm was placed separately on media such as antibiotic discs, and bacterial cultures were allowed to grow at 37ºC and yeast

cultures at 30°C. Zone diameters were measured in mm. All experiments were performed in 3 repetitions. The averages of these repetitions were used in the calculation. Results were tabulated as mean ± standard deviation (SD).

Control groups were measured as Gentamicin (10 µg) (13.2 mm ±0.07) for *P. aeruginosa* ATCC 27853, Bacitracin (10 units) (10.6 mm±0.07) for *E. coli* ATCC 35218, Amphotericin B (21.09 mm±0.07) for *C. albicans* ATCC 1023 (Koşarsoy Ağçeli, 2022), Ceftriaxone (30 µg) (8.6 ±0.08) for MRSA (*S. aureus* ATCC 43300), Ampicillin (AMP, 10 µg/disc) (19±0.07) for *B. licheniformis*.

## 3. Results and discussion
*3. Bulgular ve tartışma*

The antimicrobial effect of 40 play doughs of different colors belonging to different companies was measured on various pathogenic microorganisms (Table 1 and Figure 1). In commercial play dough, it was determined that some brands showed antimicrobial effects against many microorganisms used in the study, while in others, no antimicrobial effect was determined against any pathogen used in the study (Figure 2).

**Table 1.** Inhibition zone diameters of play dough on different pathogenic microorganisms (mm).
***Tablo 1.*** *Oyun hamurlarının farklı patojen mikroorganizmalar üzerindeki zon çapları (mm).*

| | ***B.lichenifomis*** | ***S. aureus* ATCC 43300 (MRSA)** | ***E.coli* ATCC 35218** | ***P. aeruginosa* ATCC 27853** | ***C.albicans* ATCC 10231** |
|---|---|---|---|---|---|
| **BY** | 17.80±0.76 | 0 | 0 | 0 | 0 |
| **BO** | 16.10±0.76 | 0 | 0 | 0 | 0 |
| **BW** | 20.67±1.52 | 0 | 0 | 0 | 8.17±2.02 |
| **BR** | 18±2.00 | 0 | 0 | 0 | 0 |
| **BB** | 15±1.32 | 0 | 0 | 0 | 0 |
| **BG** | 16±1.00 | 0 | 0 | 0 | 0 |
| **AG** | 12.70±0.58 | 14.30±0.58 | 10.30±0.58 | 0 | 14.30±1.15 |
| **AB** | 0 | 15.20±0.30 | 0 | 0 | 15.5±2.18 |
| **AY** | 15.70±1.15 | 0 | 0 | 16.83±0.77 | 16.67±2.90 |
| **AR** | 14.83±0.80 | 0 | 0 | 0 | 14.67±1.40 |
| **RR** | 15.50±0.90 | 0 | 0 | 0 | 0 |
| **RO** | 18.17±0.80 | 0 | 0 | 0 | 0 |
| **RB** | 14.17±2.70 | 10.00±1.00 | 10.83±1.00 | 10.67±0.60 | 0 |
| **RP** | 14.00±1.00 | 0 | 0 | 0 | 0 |
| **RG** | 0 | 0 | 0 | 0 | 0 |
| **RY** | 0 | 0 | 0 | 0 | 0 |
| **IG** | 0 | 0 | 0 | 0 | 0 |
| **IGRY** | 0 | 0 | 0 | 0 | 0 |
| **IPU** | 10.50±0.87 | 0 | 0 | 0 | 0 |
| **IBLC** | 0 | 0 | 0 | 0 | 0 |
| **IY** | 0 | 0 | 0 | 0 | 0 |
| **IBR** | 0 | 0 | 0 | 0 | 0 |
| **IB** | 13.20±1.61 | 0 | 0 | 0 | 0 |
| **ILG** | 0 | 0 | 0 | 0 | 0 |
| **IR** | 0 | 0 | 0 | 0 | 0 |
| **IW** | 9.50±0.50 | 0 | 0 | 0 | 0 |
| **IO** | 0 | 0 | 0 | 0 | 0 |
| **IP** | 0 | 0 | 0 | 0 | 0 |

**Table 1.** Continuing
***Tablo 1.*** *Devamı*

| | | | | | |
|---|---|---|---|---|---|
| **SY** | 0 | 0 | 14.67±2.10 | 6.70±1.10 | 0 |
| **SR** | 10.67±1.10 | 0 | 12.30±1.10 | 10.67±1.10 | 0 |
| **SB** | 11.80±1.00 | 0 | 11±1.00 | 10.30±0.60 | 0 |
| **SPUR** | 10.67±0.60 | 0 | 11.67±1.50 | 9.67±0.60 | 0 |
| **SG** | 10.67±1.10 | 0 | 14.67±0.60 | 12.67±0.60 | 0 |
| **SP** | 10.30±0.60 | 0 | 16.67±2.5 | 13.67±0.60 | 0 |
| **GY** | 0 | 0 | 0 | 0 | 0 |
| **GW** | 0 | 0 | 0 | 0 | 0 |
| **GBLC** | 0 | 0 | 0 | 0 | 0 |
| **GG** | 0 | 0 | 0 | 0 | 0 |
| **GR** | 0 | 0 | 0 | 0 | 0 |
| **GB** | 0 | 0 | 0 | 0 | 0 |

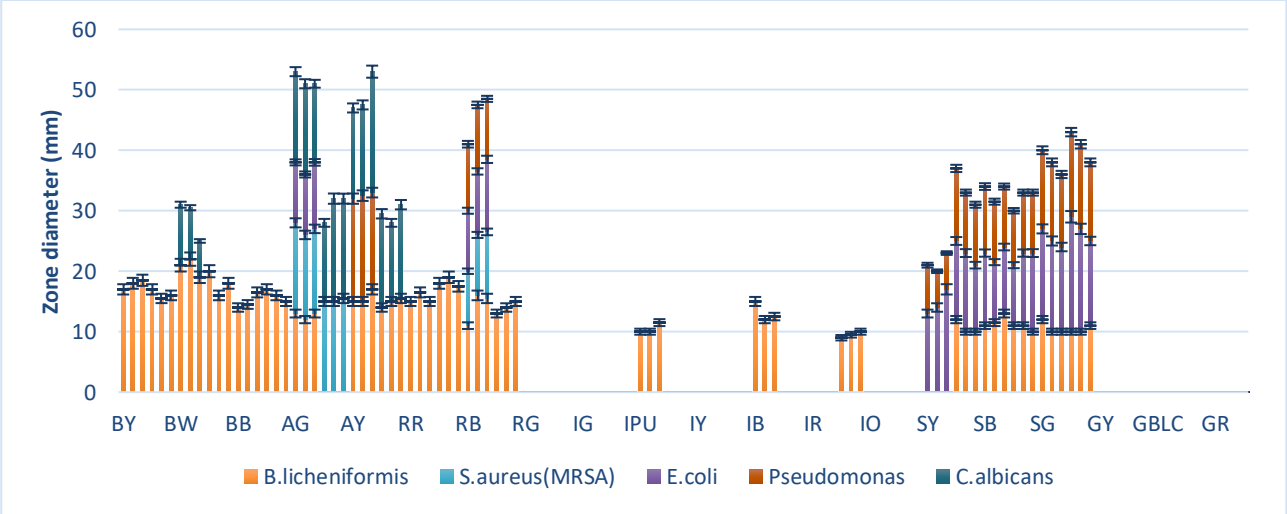


**Figure 1.** Graphical representation of antimicrobial zone diameters in play doughs.
***Şekil 1.*** *Oyun hamurlarının antimikrobiyal çaplarının grafiksel gösterimi.*

*B. licheniformis* is an endospore-forming Gram positive microorganism and it can be easily isolated from plant and soil samples. Although it is considered a nonpathogenic species due to its lack of invasive properties, toxin production, foodborne diarrhea, bovine abotus and infant mortality have been reported in different studies (Banerjee et al., 2007; Nieminen et al., 2007; Salkinoja-Salonen et al., 1999; Sayem et al., 2011; Vinoj et al., 2014). Dülger et al. (2017) reported that 51 (33%) *B. licheniformis* and 104 (67%) *B. cereus* of all *Bacillus* genus grown in play dough prepared in the pre-play period. Similarly, In the present study, 21 of 40 (52.5%) different play dough samples showed antimicrobial activity against *B. licheniformis*.

*S. aureus* is a leading cause of both community-associated and health care-associated invasive infections in children (Custovic et al., 2021). MRSA has long been a important problem in hospitals, dialysis centers and nursing homes where it infects the wounds of patients weakened by disease or injury (Wong et al., 2016). In this study, only 3 of 40 (7.5%) play dough samples showed antimicrobial activity against MRSA.

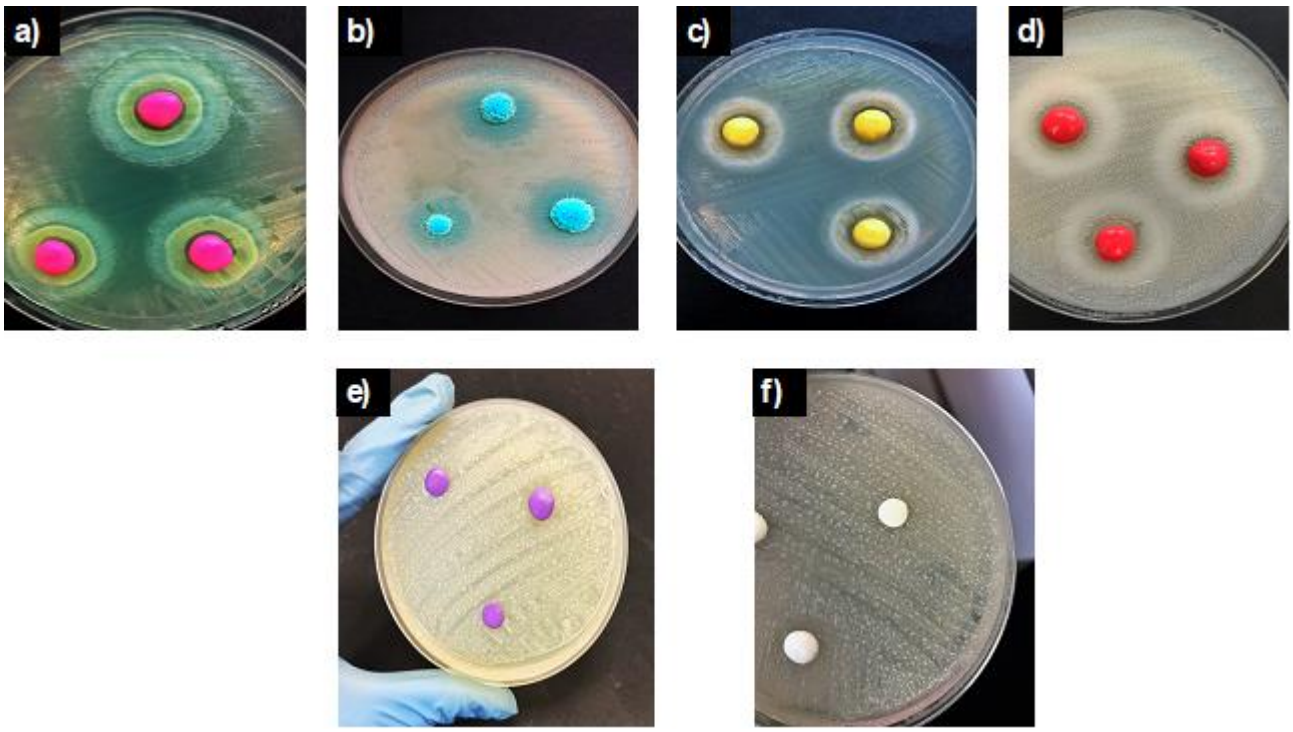


**Figure 2. a)** Antimicrobial effect of SP play dough sample on *P. aeruginosa.* **b)** Antimicrobial effect of AB play dough sample on MRSA. **c)** Antimicrobial effect of BY play dough sample on *B. licheniformis.* **d)** Antimicrobial effect of AR play dough sample on *C. albicans.* **e)** Play dough sample coded SPUR without antimicrobial effect on MRSA. **f)** Play dough sample coded IW without antimicrobial effect on *E.coli*.

***Şekil 2. a)*** *SP kodlu oyun hamuru örneğinin P. aeruginosa üzerindeki antimikrobiyal etkisi.* ***b)*** *AB kodlu oyun hamuru örneğinin MRSA üzerindeki antimikrobiyal etkisi.* ***c)*** *BY kodlu oyun hamuru örneğinin B. licheniformis üzerindeki antimikrobiyal etkisi.* ***d)*** *AR kodlu oyun hamuru örneğinin C. albicans üzerindeki antimikrobiyal etkisi.* ***e)*** *MRSA üzerinde antimikrobiyal etkisi olmayan SPUR kodlu oyun hamuru örneği.* ***f)*** *E. coli üzerinde antimikrobiyal etkisi olmayan IW kodlu oyun hamuru örneği.*

*E. coli* is a gram negative microorganism that is a member of the normal flora commonly found in the human intestine (Moreno et al., 2009). Some strains of *E.coli* are disease-causing due to contaminated food, contaminated water, contact with infected animals or lack of hygiene. *E.coli* infections can cause bloody diarrhea, leading to severe health problems (Ochoa & Contreras, 2011). In this study, 8 of 40 (20%) play dough samples showed antimicrobial activity against *E. coli*.

*P. aeruginosa* is a gram negative and non-fermenting microorganism. It is often resistant to antibiotics and causes severe nosocomial infections, especially in immunocompromised patients (Pilmis et al., 2020). Bath toys were identified as a likely source of multi-drug resistant *P. aerugionsa* cultures which are commonly linked with nosocomial infection in pediatric oncology departments (Buttery et al., 1998). In this study, 8 of 40 (20%) play dough samples showed antimicrobial activity against *P. aeruginosa*. It was observed that only one company was effective against *P. aeruginosa* in all play doughs.

*C. albicans* can be found in the normal flora of 50% of the population, especially in the gastrointestinal, oropharyngeal cavity and vagina (Talapko et al., 2021). However different factors (environmental, nutritional, etc.) cause disruptions in the normal homeostasis of *Candida*, causing a transition from normal flora to pathogenic and opportunistic infections (Mukaremera et al., 2017). *C. albicans* is responsible for about 70% of fungal infections worldwide and the most common causative agent of mucosal infections and systemic infection (Basmaciyan et al., 2019; Chen et al., 2020; Morad et al., 2018). In this study, 5 of 40 (12.5%) play dough samples showed antimicrobial activity against *C. albicans*.

Results of the study it is observed that when compared with the control group antibiotics, AY and SP coded play doughs showed higher inhibition than Gentamicin (10 µg) antibiotic on *P. aeruginosa*. BW coded play dough showed higher antimicrobial effect than Ampicillin (AMP, 10 µg/disc) on *B. licheniformis*. The antimicrobial effect of play dough on MRSA is limited to only 3

in 40 samples. However, inhibition zones on MRSA of all AG, AB, RB coded play doughs with this antimicrobial effect are higher than Ceftriaxone (30 μg) antibiotic. All of the SY, SR, SB, SPUR, SG and SP coded play dough samples belonging to the S company and the other RB coded play dough sample had a higher zone inhibition diameter on *E. coli* than the zone inhibition diameter given by the Bacitracin (10 units) antibiotic. The antimicrobial effect of all play dough samples on *C. albicans* is lower than the control group Amphotericin B antibiotic.

Antimicrobial zone diameter was not detected in 17 of 40 play dough used in the study. In addition, the contents of commercially purchased play dough (salt, chemicals, dyes, etc.) may have affected the antimicrobial zones. When the colors of the play doughs were evaluated, the antimicrobial effect of play doughs of different brands with the same color varied. It is thought that this is due to different dyestuffs.

## 4. Conclusions
*4. Sonuçlar*

The place of toys in the world of children undoubtedly occupies a crucial place. Toys should not be seen as just an accessory. Toys not only educate children, but also psychologically heal them. Considering the positive effects that children who receive treatment in hospitals have gained with toys, it makes it inevitable for toys to be microbially safe. Studies show that the microbial load in toys cannot be ignored. Play dough is one of the most simple but effective toys that reflect the imagination of children. Today, play dough is an indispensable educational material especially for preschool children. The importance of hygiene is indisputable for these young children whose immune system is not fully established yet. Play dough is a play material that can be played alone as well as shared with groups of friends. Playing and sharing toys by healthy and sick children may cause microorganisms to be transmitted by hand and mouth. It is necessary to be more careful about using play dough, which allows the reproduction of microorganisms that can cause many different health problems. It is very risky for sick children to play with the same play dough as healthy children. The presence of the phrase "edible" in many play doughs can be effective in the transmission of diseases with non-antimicrobial play dough. These can be made safer by adding natural antimicrobial substances to play dough. Reducing the microbial load of toys naturally and keeping pathogenic microorganisms under control is very important for children's immune systems. In the era of the spread of COVID-19, studies on the antimicrobial activity of different toys on microorganisms are expected to intensify. This study draws attention to the fact that more studies should be done on the antimicrobial activities of play dough, which is a "shareable" toy.

## Author contribution
*Yazar katkısı*

Gözde Koşarsoy Ağçeli: Conceptualization, methodology, software, validation, investigation, resources, data curation, writing—original draft preparation, review & editing.

## Conflicts of interest
*Çıkar çatışması beyanı*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## References
*Kaynaklar*

Aleksejeva, V., Dovbenko, A., Kroiča, J. & Skadiņš, I. (2021). Toys in the playrooms of children's hospitals: A potential source of nosocomial bacterial infections? *Children*. https://doi.org/10.3390/children8100914

Ayan, S., Galhan, M., Kaygusuz, S. & Ergene, A. (2018). Microbial characterization of sport facilities and children's playgrounds in Kirikkale Turkey. *Fresenius Environmental Bulletin.*

Bandyopadhyay, R., Ghosh, S., Chatterjee, S. & Shyamapada, M. (2019). Bacteriological profi ling of toys and clothes of children from children's day care centre of Tarakeswar, Hooghly West Bengal, India. *Microbiological Communication, 12(1): 99-*

Banerjee, S., Devaraja, T. N., Shariff, M. & Yusoff, F. M. (2007). Comparison of four antibiotics with indigenous marine *Bacillus spp.* in controlling pathogenic bacteria from shrimp and Artemia. *Journal of Fish Diseases*. https://doi.org/10.1111/j.1365-2761.2007.00819.x

Basmaciyan, L., Bon, F., Paradis, T., Lapaquette, P. & Dalle, F. (2019). "*Candida albicans* interactions with the host: crossing the intestinal epithelial barrier." In *Tissue Barriers*. https://doi.org/10.1080/21688370.2019.1612661

Buttery, J. P., Alabaster, S. J., Heine, R. G., Scott, S. M., Crutchfield, R. A. & Garland, S. M. (1998).

Multiresistant *Pseudomonas aeruginosa* outbreak in a pediatric oncology ward related to bath toys. *Pediatric Infectious Disease Journal*. https://doi.org/10.1097/00006454-199806000-00015

Chedid, K., Hayashi, M., DeJonge, P., Yancey, O., Siebert, E., Getz, A., Eisenberg, J., Hashikawa, A. & Martin, E. (2020). Antimicrobial bacteria and viruses detected through systematic sampling in the childcare environment. *Infection Control & Hospital Epidemiology*. https://doi.org/10.1017/ice.2020.1134

Chen, H., Zhou, X., Ren, B. & Cheng, L. (2020). The regulation of hyphae growth in *Candida albicans*. In *Virulence*. https://doi.org/10.1080/21505594.2020.1748930

Custovic, A., Smajlovic, J., Husaric, E., Jahic, R., Dzafic, F. & Ibrahimagic, O. (2021). Frequency and etiology of nosocomial infections in a pediatric intensive care unit. *International Medicine*. https://doi.org/10.5455/im.49683

Davies, M. W., Mehr, S., Garland, S. T. & Morley, C. J. (2000). Bacterial colonization of toys in neonatal intensive care cots. *Pediatrics*. https://doi.org/10.1542/peds.106.2.e18

Dülger, G., Çaliskan, E., Kiliç, N. & Ankarali, H. (2017). Reability investigations of bacteriological aspects of play dough. *Turk Hijyen ve Deneysel Biyoloji Dergisi*. https://doi.org/10.5505/TurkHijyen.2016.34603

Erbas, Z., Karatepe, A. & Soylak, M. (2017). Heavy metal contents of play dough, face and finger paint samples sold in turkish markets. *Talanta*. https://doi.org/10.1016/j.talanta.2017.04.025

Girolametto, L., Weitzman, E., Van Lieshout, R. & Duff, D. (2000). Directiveness in teachers' language input to toddlers and preschoolers in day care. *Journal of Speech, Language, and Hearing Research*. https://doi.org/10.1044/jslhr.4305.1101

Hughes, W. T., Williams, B., Williams, B. & Pearson, T. (1986). The nosocomial colonization of T. Bear. *Infection Control*. https://doi.org/10.1017/S0195941700065115

Ibfelt, T., Engelund, E. H., Schultz, A. C. & Andersen, L. P. (2015). Effect of cleaning and disinfection of toys on infectious diseases and micro-organisms in daycare nurseries. *Journal of Hospital Infection*. https://doi.org/10.1016/j.jhin.2014.10.007

Koşarsoy Ağçeli, G. (2022). A new approach to nanocomposite carbohydrate polymer films: Levan and chia seed mucilage. *International Journal of Biological Macromolecules*, *218*(June), 751–759. https://doi.org/10.1016/j.ijbiomac.2022.07.157

Ledwaba, S. E., Becker, P., Traore-Hoffman, A. & Potgieter, N. (2019). Bacterial contamination of children's toys in rural day care centres and households in South Africa. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph16162900

Lee, L., Tin, S. & Kelley, S. T. (2007). Culture-independent analysis of bacterial diversity in a child-care facility. *BMC Microbiology*. https://doi.org/10.1186/1471-2180-7-27

Mahl, M. C. & Sadler, C. (1975). Virus survival on inanimate surfaces. *Canadian Journal of Microbiology*. https://doi.org/10.1139/m75-121

Martínez-Bastidas, T., Castro-del Campo, N., Mena, K. D., Castro-del Campo, N., León-Félix, J., Gerba, C. P. & Chaidez, C. (2014). Detection of pathogenic micro-organisms on children's hands and toys during play. *Journal of Applied Microbiology*. https://doi.org/10.1111/jam.12473

Morad, H. O. J., Wild, A. M., Wiehr, S., Davies, G., Maurer, A., Pichler, B. J. & Thornton, C. R. (2018). pre-clinical imaging of invasive candidiasis using immunoPET/MR. *Frontiers in Microbiology*. https://doi.org/10.3389/fmicb.2018.01996

Moreno, M. A., Furtner, F. & Rivara, F. P. (2009). *Escherichia coli* O157 and children. In *Archives of Pediatrics and Adolescent Medicine*. https://doi.org/10.1001/archpediatrics.2008.535

Mukaremera, L., Lee, K. K., Mora-Montes, H. M. & Gow, N. A. R. (2017). *Candida albicans* yeast, pseudohyphal, and hyphal morphogenesis differentially affects immune recognition. *Frontiers in Immunology*. https://doi.org/10.3389/fimmu.2017.00629

Nieminen, T., Rintaluoma, N., Andersson, M., Taimisto, A. M., Ali-Vehmas, T., Seppälä, A., Priha, O. & Salkinoja-Salonen, M. (2007). Toxinogenic *Bacillus pumilus* and *Bacillus licheniformis* from mastitic milk. *Veterinary Microbiology*. https://doi.org/10.1016/j.vetmic.2007.05.015

Ochoa, T. J. & Contreras, C. A. (2011). Enteropathogenic *Escherichia coli* infection in children. In *Current Opinion in Infectious Diseases*. https://doi.org/10.1097/QCO.0b013e32834a8b8b

Pilmis, B., Alby-Laurent, F., Fasola, M. L., Seegers, V., Guery, R., Guet-Revillet, H., Postaire, M., Toubiana, J., Bille, E., Lortholary, O. & Zahar, J. R. (2020). *Pseudomonas aeruginosa*

bloodstream infections in children: a 9-year retrospective study. *European Journal of Pediatrics*. https://doi.org/10.1007/s00431-020-03598-4

Prüss-Üstün, A. & Corvalán, C. (2006). Preventing disease through healthy environments. *World Health*.

Randle, J. & Fleming, K. (2006). The risk of infection from toys in the intensive care setting. *Nursing Standard (Royal College of Nursing (Great Britain) : 1987)*. https://doi.org/10.7748/ns2006.06.20.40.50.c4180

Rogers, M., Weinstock, D. M., Eagan, J., Kiehn, T., Armstrong, D. & Sepkowitz, K. A. (2000). Rotavirus outbreak on a pediatric ontology floor: Possible association with toys. *American Journal of Infection Control*. https://doi.org/10.1067/mic.2000.109908

Salkinoja-Salonen, M. S., Vuorio, R., Andersson, M. A., Kämpfer, P., Andersson, M. C., Honkanen-Buzalski, T. & Scoging, A. C. (1999). Toxigenic strains of *Bacillus licheniformis* related to food poisoning. *Applied and Environmental Microbiology*. https://doi.org/10.1128/aem.65.10.4637-4645.1999

Sayem, S. M. A., Manzo, E., Ciavatta, L., Tramice, A., Cordone, A., Zanfardino, A., De Felice, M. & Varcamonti, M. (2011). Anti-biofilm activity of an exopolysaccharide from a sponge-associated strain of *Bacillus licheniformis*. *Microbial Cell Factories*. https://doi.org/10.1186/1475-2859-10-74

Susanti, M. M. & Trianingsih, Y. (2017). Efektivitas terapi bermain play dough dan puzzle terhadap tingkat perkembangan motorik halus pada anak usia dini di paud dahlia godong. *The Shine Cahaya Dunia Ners Jurnal*.

Talapko, J., Juzbašić, M., Matijević, T., Pustijanac, E., Bekić, S., Kotris, I. & Škrlec, I. (2021). *Candida albicans*-the virulence factors and clinical manifestations of infection. *Journal of Fungi*. https://doi.org/10.3390/jof7020079

Torondel, B., Gyekye-Aboagye, Y., Routray, P., Boisson, S., Schimdt, W. & Clasen, T. (2015). Laboratory development and field testing of sentinel toys to assess environmental faecal exposure of young children in rural India. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. https://doi.org/10.1093/trstmh/trv023

Vinoj, G., Vaseeharan, B., Thomas, S., Spiers, A. J. & Shanthi, S. (2014). Quorum-Quenching activity of the AHL-Lactonase from *Bacillus licheniformis* DAHB1 inhibits vibrio biofilm formation in vitro and reduces shrimp intestinal colonisation and mortality. *Marine Biotechnology*. https://doi.org/10.1007/s10126-014-9585-9

Wong, J. G., Chen, M. I., Win, M. K., Ng, P. Y. & Chow, A. (2016). Length of stay an important mediator of hospital-acquired methicillin-resistant *Staphylococcus aureus*. *Epidemiology and Infection*. https://doi.org/10.1017/S0950268815002733