

# **Microbial Flora on Restaurant Beverage Lemon Slices**

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Abstract

Restaurateurs often place a lemon slice on the rim of a beverage glass, or afloat in the beverage, as a flavor-enhancer or a decorative garnish. The handling of the lemons before their placement in the beverage may not follow sanitary procedures. The study reported here investigated whether beverage lemon slices contain microbial contamination that could be consumed by a restaurant patron.

Swabbed samples of the flesh and rind of lemon slices on the rims of beverage glasses were analyzed for microbial contents. Seventy-six lemons from 21 restaurants were sampled during 43 visits. Fifty-three (69.7 percent) of the lemon slices produced microbial growth. Twenty-three (30.3 percent) of the lemon slices produced no microbial growth. A total of 25 different microbial species were recovered from the samples.

#### Introduction

The antimicrobial properties of lemons are well documented. One study (Dabbah, Edwards, & Moats, 1970) demonstrated significant inhibition of bacterial growth in nutrient broth when lemon oil was added. Other studies report similar antimicrobial activity by lemons and lemon extract against numerous microbes, including Candida albicans, Escherichia coli, Escherichia coli O157:H7, Helicobacter pylori, Klebsiella pneumoniae, Listeria innocua, Listeria monocytogenes, Mycobacterium tuberculosis, Neisseria gonorrhoeae, Penicillium digitatum, Penicillium italicum, Pseudomonas aeruginosa, Saccharomyces cerevisiae, Salmonella spp., Salmonella typhi, Shigella dysenteriae, Staphylococcus aureus, and Streptococcus faecalis. (Adeleye & Opiah, 2003; Belletti et al., 2004; Brock & Ketchum, 1951; Caccioni, Guizzardi, Biondi, Renda, & Ruberto, 1998; Dabbah et al., 2002; Dada, Alade, Ahmad, & Yadock, 2002; Francis & O'Beime, 2002; Nogueira, Oyarzabal, & Gombas, 2003; Ohno et al., 2003; & Saleem, Afza, Anwar, Hai, & Ali, 2003). Lemon juice has even been shown to be useful as an anti-HIV agent when applied vaginally in sexually active women (Potts, Perlman, Mandara, Prata, & Campbell, 2004; Short, McCoombe, Maslin, & Crowe, 2004). Another study reported significant larvicidal activity by a fresh lemon peel extract (Salvatore, Borkosky, Willink, & Bardon, 2004). Many nonscientific Web sites proclaim the antimicrobial effects of lemons and lemon juice as a benefit in food preparation, sterilization of the rind of fruits and vegetables, sterilization of kitchen cutting boards, and as a sore-throat remedy (Boschen, n.d.; iVillage, 2002; Rall & Center for Unhindered Living, 2005; Podleski, 2006; Weiss, 2005). One site encourages restaurant patrons to squeeze lemon juice into drinking water, onto the hands, and all over the silverware in order to kill microbes (Tufarelli, n.d.).

Water containing lemon, however, was found to actually enhance the growth of Pseudomonas aeruginosa in one study (Ibrahim & Ogunmodede, 1991). Moreover, some lemon exporters spray the fruit with antimicrobial chemicals in order to kill Vibrio cholerae, Penicillium digitatum, Botrytis cinerea, and other microbes that may be contaminating the rind; this procedure indicates a lack of faith in the antimicrobial properties of lemon. (Cheah & Hunt, 1994; Cheah & Tran, 1995; de Castillo et al., 1998).

In restaurants, a lemon slice is commonly placed on the rim of a beverage glass, or afloat in the beverage, as a flavor enhancer or a decorative garnish. Although a patron might ask for this embellishment, frequently the lemon is added without the customer's request. Our study investigated whether these lemon slices contain microbial contamination that might be ingested by restaurant patrons.

### Materials and Methods

Samples were collected surreptitiously, without the knowledge of the restaurant staff. Two StarPlex® brand specimen-collection swabs were used for each sample. Samples were taken as soon as the beverage was served, before a sip was taken, and before the lemon slice was touched by the patron. One swab was rubbed along the rind. The second swab was rubbed along the flesh of the fruit. A total of 76 lemons from 21 restaurants were sampled during 43 visits. Water and soda were the only beverages used in the study.

## TABLE 1

#### **Positive Culture Results\***

Ind     Abaumanii, C.guilliarmandii     Ind     I. Ausai     37     Rind     S. windars       Image: I	Sample**	Site	Culture Results	Sample**	Site	Culture Results	Sample**	Site	Culture Results
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16RindB. subtilis34RindC. krusei52RindNo growth17FleshB. subtilisImage: Second		Flesh	No growth		Flesh	No growth		Flesh	C. tropicalis
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FleshC. guilliermondiiFleshC. guilliermondiiFleshNo growth18RindB. subtilis36RindNo growthFleshC. guilliermondiiFleshB. subtilis </td <td>17</td> <td>Rind</td> <td>C. guilliermondii</td> <td>35</td> <td>Rind</td> <td>C. krusei</td> <td>53</td> <td>Rind</td> <td>Enterococcus spp.</td>	17	Rind	C. guilliermondii	35	Rind	C. krusei	53	Rind	Enterococcus spp.
18 <i>B. subtilis</i> 36     Rind     No growth         Flesh <i>C. guilliermondii</i> Flesh <i>B. subtilis</i>		Flesh	C. guilliermondii		Flesh	C. guilliermondii		Flesh	No growth
Flesh C. guilliermondii Flesh B. subtilis	18	Rind	B. subtilis	36	Rind	No growth			
		Flesh	C. guilliermondii		Flesh	B. subtilis			

 $^{\star}~$  53 of the 76 lemon samples produced some microbial growth on the rind, the flesh, or both.  $^{\star\star}~$  Shading denotes one restaurant visit.

Each swab was cultured onto a TSA-II 5 percent sheep's blood agar plate and a MacConkey II agar plate. Plates were incubated at 35°C in a  $CO_2$ -enriched aerobic atmosphere. Since samples were taken from the surfaces of the lemon slices, anaerobe recovery was not attempted. Culture plates were examined for growth at 24 hours, reincubated, and examined again after 48 hours. Isolates were identified by Gram stain, colony characteristics, API 20C Aux<sup>®</sup> for yeast, API 20E<sup>®</sup> for Enterobacteriaceae, PYR Test Kit for *Enterococcus*, H<sub>2</sub>O<sub>2</sub> for catalase, and rabbit plasma for coagulase. Isolates were not quantified.

#### Results

Culture results are found in Table 1, Table 2, Table 3, and Table 4. Twenty-three (30.3 percent) of the lemon slices produced no microbial growth from the rind or the flesh. A total of 25 different microorganisms were recovered, including bacteria and yeasts. Fifty-three (69.7 percent) of the lemon slices produced some microbial growth, either from the rind, the flesh, or both (Table 1). Thirteen (17.1 percent) of the lemon slices had microbes only on the rind; this number represented 24.5 percent of the lemon slices that produced microbial growth (Table 2). Eleven (14.5 percent) of the lemon slices had microbes only on the flesh; this number represented 20.8 percent of the lemon slices that produced microbial growth (Table 3). Twenty-nine (38.2 percent) of the lemon slices had microbes on both the flesh and the rind; this represented 54.7 percent of those lemon slices that produced microbial growth (Table 4). Of the 29 samples that had microbial growth on the flesh and the rind, 9 (31 percent) had exactly the same microorganism or microorganisms on both locations, whereas 20 (69 percent) had some differences in the microorganisms that were recovered from the rind and the flesh (Table 3). In 15 instances (19.7 percent), the microorganisms recovered from the rind were completely different from those that were recovered from the flesh; this situation occurred in 51.7 percent of the 29 slices that produced microbial growth from both the flesh and the rind (Table 3). Six of the lemon slices (7.9 percent) produced three or more species; this number represented 11.3 percent of the lemon slices that produced microbial growth (Table 3).

### Discussion

### Possible Origins of the Microbial Contaminants

It is not possible to definitively identify the origins of the microorganisms. While the En-

### TABLE 2

### Culture Results from Samples with Growth on the Rind\*

Sample**	Site	Culture Results			
1	Rind	S. epidermidis, S. viridans			
	Flesh	No growth			
2	Rind	B. subtilis			
	Flesh	No growth			
3	Rind	C. parapsilosis			
	Flesh	No growth			
4	Rind	C. albicans, Bacillus spp.			
	Flesh	No growth			
5	Rind	A. baumanii, C. parapsilosis			
	Flesh	No growth			
6	Rind	B. cereus			
	Flesh	No growth			
7	Rind	P. fluorescens, P. putida			
	Flesh	No growth			
8	Rind	S. epidermidis			
	Flesh	No growth			
9	Rind	Bacillus spp.			
	Flesh	No growth			
10	Rind	Bacillus spp.			
	Flesh	No growth			
11	Rind	E. coli			
	Flesh	No growth			
12	Rind	Bacillus spp.			
	Flesh	No growth			
13	Rind	Enterococcus spp.			
	Flesh	No growth			
* 12 complex produced microbial growth only on the size					

\*\* Shading denotes one restaurant visit.

terobacteriaceae and nonfermentative Gramnegative bacilli could have come from the fingertips of a restaurant employee via human

# TABLE 3

### Culture Results from Samples with Growth Only on the Flesh\*

0	0.1	0
Sample**	Site	Culture Results
1	Rind	No growth
	Flesh	C. lusitaniae
2	Rind	No growth
	Flesh	C. lusitaniae
3	Rind	No growth
	Flesh	C. lusitaniae
4	Rind	No growth
	Flesh	B. subtilis
5	Rind	No growth
	Flesh	S. marcescens
6	Rind	No growth
	Flesh	B. subtilis
7	Rind	No growth
	Flesh	B. subtilis
8	Rind	No growth
	Flesh	B. subtilis
9	Rind	No growth
	Flesh	B. subtilis
10	Rind	No growth
	Flesh	Micrococcus spp.
11	Rind	No growth
	Flesh	Enterococcus spp.
* 11 sample	es produced	microbial growth only on the flesh.

\*\* Shading denotes one restaurant visit.

fecal or raw-meat or poultry contamination, they might have contaminated the lemons before they even arrived at the restaurant. The Gram-positive cocci and *Corynebacterium* isolates may have been introduced onto the lemons from the skin or oral flora of anyone who handled them, before or after they arrived in the restaurant. The *Bacillus* species are ubiquitous and could have had numerous sources, including airborne spores landing on the fruit or on the knife used to cut the lemon.

There are three possible origins for the various yeasts that were isolated. Some yeasts commonly colonize lemons and other foods, and

# TABLE 4

Culture Results from Samples with Growth on the Flesh and the Rind\*

Sample**	Site	Culture Results	Sample**	Site	Culture Results
1	Rind	A. baumanii, C. guilliermondii	16	Rind	Enterococcus spp., S. epidermidis
	Flesh	E. cloacae, E. sakazakii, S. epidermidis, S. viridans		Flesh	C. guilliermondii
2	Rind	A. baumanii, S. epidermidis	17	Rind	S. epidermidis, C. parapsilosis
	Flesh	A. baumanii		Flesh	C. parapsilosis
3	Rind	A. baumanii	18	Rind	C. guilliermondii
	Flesh	A. baumanii, S. epidermidis, Corynebacterium spp.		Flesh	C. guilliermondii
4	Rind	C. tropicalis	19	Rind	C. guilliermondii
	Flesh	C. krusei		Flesh	E. cloacae
5	Rind	T. glabrata	20	Rind	K. oxytoca
	Flesh	C. tropicalis		Flesh	C. guilliermondii, T. asahii
6	Rind	C. tropicalis, Bacillus spp.	21	Rind	C. krusei
	Flesh	C. tropicalis		Flesh	C. guilliermondii
7	Rind	C. tropicalis	22	Rind	C. krusei
	Flesh	T. glabrata, C. krusei		Flesh	C. guilliermondii
8	Rind	B. subtilis	23	Rind	S. viridans
	Flesh	B. subtilis		Flesh	A. baumanii
9	Rind	C. guilliermondii	24	Rind	E. coli
	Flesh	C. guilliermondii		Flesh	E. coli
10	Rind	B. subtilis	25	Rind	E. coli, P.mirabilis
	Flesh	C. guilliermondii		Flesh	E. coli
11	Rind	C. krusei	26	Rind	<i>S. epidermidis, Bacillus</i> spp., <i>Enterococcus</i> spp.
	Flesh	C. tropicalis		Flesh	<i>S. epidermidis, Bacillus</i> spp., <i>Enterococcus</i> spp.
12	Rind	C. lusitaniae	27	Rind	E. coli
	Flesh	C. lusitaniae		Flesh	E. coli
13	Rind	C. guilliermondii	28	Rind	Bacillus spp.
	Flesh	S. epidermidis		Flesh	Bacillus spp.
14	Rind	Bacillus spp.	29	Rind	S. viridans
	Flesh	C. parapsilosis		Flesh	C. tropicalis
15	Rind	C. parapsilosis			
	Flesh	C. parapsilosis			

\* 29 samples produced microbial growth on both the flesh and the rind.

\*\* Shading denotes one restaurant visit.

are classified by the food industry as "food spoilage yeasts" (Adegoke, Iwahashi, Komatsu, Obuchi, & Iwahashi, 2000). Some distributors add yeasts to lemons and other fruits in order to retard the growth of other, destructive fungi (Cheah et al., 1994; Cheah et al., 1995; Droby, Chalutz, & Wilson, 1991). Finally, the yeasts could have originated from oral, fecal, or vaginal secretions contaminating the fingertips of a restaurant employee or another food handler.

#### Diseases Caused by the Microbes Found on the Lemon Samples

The microbes found on the lemon samples in our investigation all have the potential to cause infectious diseases at various body sites, although the likelihood was not determined in this study. An extensive search of the literature yielded no reported outbreaks or illnesses attributed to lemon slices in beverages. Establishment of an infection would depend upon the number of microbes introduced; this investigation did not include a quantitative determination of the numbers of microorganisms on the lemons. Other factors that would contribute to the establishment of an infection would include whether the organisms were resistant to multiple antibiotics, the general health and age of the individual, the status of the immune system, and the integrity of the mucous membranes of the lips and mouth.

### Conclusion

Although lemons have known antimicrobial properties, the results of our study indicate that a wide variety of microorganisms may survive on the flesh and the rind of a sliced lemon. Restaurant patrons should be aware that lemon slices added to beverages may include potentially pathogenic microbes. Further investigations could determine the source of these microorganisms, establish the actual threat (if any) posed by their presence on the rim of a beverage, and develop possible means for preventing the contamination of the lemons. It could also be worthwhile to study contamination on other beverage garnishes, such as olives, limes, celery, and cherries, and to investigate whether alcoholic beverages have an effect not seen with water and soda.

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### **REFERENCES** continued from page 21

- Adegoke, G.O., Iwahashi H., Komatsu, Y., Obuchi, K., & Iwahashi, Y. (2000). Inhibition of food spoilage yeasts and aflatoxigenic moulds by monoterpenes of the spice *Aframonum danielli*. *African Journal of Biotechnology*, 2(9), 254-263.
- Adeleye, I.A., & Opiah, L. (2003). Antimicrobial activity of extracts of local cough mixtures on upper respiratory tract bacterial pathogens. *West Indian Medical Journal*, *52*(3), 188-190.
- Belletti, N., Ndagijimana, M., Sisto, C., Guerzoni, M.E., Lanciotti, R., & Gardini, F. (2004). Evaluation of the antimicrobial activity of citrus essences on Saccharomyces cerevisiae. Journal of Agricultural and Food Chemistry, 52(23), 6932-6938.
- Boschen, H. (n.d.). *Organically grown foods*. Retrieved June 5, 2006, from http://www.juiceguy.com/organic.shtml.
- Brock, B.L., & Ketchum, H.M. (1951). The antibacterial action of citrus peel oil on the tubercule bacillus in vitro. *Diseases of the Chest*, 20(6), 671-674.
- Caccioni, D.R, Guizzardi, M., Biondi, D.M., Renda, S., & Ruberto, G. (1998). Relationship between volatile components of citrus fruit essential oils and antimicrobial action on *Penicillium digitatum* and *Penicillium italicum*. *International Journal of Food Microbiology*, 43(1-2), 73-79.
- Cheah, L.H., & Hunt, A.W. (1994). Screening of industrial yeasts for biocontrol of Botrytis storage rot in kiwifruit. Proceedings of the 47th New Zealand Plant Protection Conference. Retrieved January 24, 2005, from http://www.hortnet.co.nz/publications/nzpps/ proceedings/94/94\_362.htm.
- Cheah, L.H., & Tran, T.B. (1995). Postharvest biocontrol of *Penicillium* rot of lemons with industrial yeasts. In *Proceedings of the 48th New Zealand Plant Protection Conference*. Retrieved January 18, 2005, from http://www.hortnet.co.nz/publications/nzpps/proceedings/95/95\_155.htm.
- Dabbah, R., Edwards, V.M., & Moats, W.A. (1970). Antimicrobial action of some citrus fruit oils on selected food-borne bacteria. *Applied Microbiology*, *19*(1), 27-31
- Dada, J.D., Alade, P.I., Ahmad, A.A., & Yadock, L.H. (2002). Antimicrobial activities of some medicinal plants from Soba-Zaria, Nigeria. *Nigerian Quarterly Journal of Hospital Medicine*, 12(1-4), 55-56
- de Castillo, M.C., de Allori, C.G., de Gutiérrez, R.C., de Saab, O.A., de Fernández, N.P., de Ruiz, C.S., de Ruiz Holgado, A.P., & de Nader, O. (1998). Action against *Vibrio cholerae* O1 Tox<sup>+</sup> of chemical products used in the lemon production. *Revista Latinoamericana de Microbiología*, 40(3-4), 120-123.
- Droby, S., Chalutz, E., & Wilson, C.L. (1991). Antagonistic micro-organisms as biological control agents of postharvest diseases of fruits and vegetables. *Postharvest News and Information*, 2(3), 169-173.

- Francis, G.A., & O'Beime, D. (2002). Effects of vegetable type and antimicrobial dipping on survival and growth of *Listeria innocua* and *E. coli. International Journal of Food Science and Technology*, 37(6), 711.
- Ibrahim, Y.K., & Ogunmodede, M.S. (1991). Growth and survival of *Pseudomonas aeruginosa* in some aromatic waters. *Pharmaceutica acta Helvetiae*, 66(9-10), 286-288.
- iVillage Garden Web Herbalism Forum. (December 2, 2002). *Tea tree for sore throats?* Retrieved June 5, 2006, from http://forums2.gardenweb.com/forums/load/herbal/msg1212325510562.html.
- Nogueira, M.C., Oyarzabal, O.A., & Gombas, D.E. (2003). Inactivation of *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Salmonella* in cranberry, lemon, and lime juice concentrates. *Journal of Food Protection*, 66(9), 1637-1641.
- Ohno, T., Kita, M., Yamaoka, Y., Imamura, S., Yamamoto, T., Mitsufuji, S., Kodama, T., Kashima, K., & Imanishi, J. (2003). Antimicrobial activity of essential oils against *Helicobacter pylori*. *Helicobacter*, 8(3), 207-215.
- Podleski, G. (May 12, 2006). Eat, shrink, & be merry: Lemony snippets. Retrieved June 4, 2006, from http://www.jyi.org/features/ft.php?id=443
- Potts, M., Perlman, D., Mandara, M., Prata, N., & Campbell, M. (2004). Is *lime/lemon juice an effective microbicide*? Paper presented at the XV International AIDS Conference, Bangkok. Abstract (Number C11663) retrieved March 24, 2006, from http://www. iasociety.org/ejias/show.asp?abstract\_id=2170959.
- Rall, J.C., & Center for Unhindered Living. (2005). *House beautiful* ... or house deadly? Retrieved June 5, 2006, from http://forums2.gardenweb.com/forums/load/herbal/msg1212325510562.html
- Saleem, M., Afza, N., Anwar, M.A., Hai, S.M., & Ali, M.S. (2003). A comparative study of essential oils of *Cymbopogon citratus* and some members of the genus *Citrus*. *Natural Product Research*, 17(5), 369-373.
- Salvatore, A., Borkosky, S., Willink, E., & Bardon, A. (2004). Toxic effects of lemon peel constituents on *Ceratitis capitata. Journal of Chemical Ecology*, 30(2), 323-333.
- Short, R.V., McCoombe, S.G., Maslin, C., & Crowe, S. (July 11, 2004). *Lemon and lime juice as potent natural microbicides*. Paper presented at the XV International AIDS Conference, Bangkok. Abstract (Number TuPeB4668) retrieved February 15, 2006, from http://www.iasociety.org/ejias/show.asp?abstract\_id=2167631.
- Tufarelli, M. (n.d.). Love your lemons. *Pioneer Thinking*. Retrieved June 3, 2006, from http://www.pioneerthinking.com/rbt14.html
- Weiss, R. (2005). A quest to understand the spices of life: The antimicrobial powers of spices. *Journal of Youth Investigation*. Retrieved June 4, 2006, from http://www.jyi.org/features/ft.php?id=443.

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