



# Consumer Knowledge and Handling of Tree Nuts: Food Safety Implications

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## ABSTRACT

While nut consumption can contribute to a healthy diet, recently nuts have been identified as a source of *Salmonella*. How consumers store and use nuts can guide safe handling information and assist in the development of more accurate risk assessment models. In an online survey, 279 Californian consumers reported that if almonds, pecans, and walnuts are stored up to 6 months, they are typically held at room or refrigerator temperatures. If nuts are stored 7 months or more, freezing is the most common method of storage. Pistachios are usually stored at room temperature and eaten in a short time. Garage storage, in which temperatures can range from -18°C (0°F), to over 38°C (100°F), is rarely used. The majority of nuts are eaten as a snack, but they also are commonly used as an ingredient in foods prepared in the home. Consumers replied that they most frequently use nuts in cookies (almonds 51%, pecans 48%, pistachios 9%, walnuts 70%) or tossed in salads (almonds 50%, pecans 47%, pistachios 11%, walnuts 56%). Data on consumer practices can be used to develop more accurate risk assessment models. Consumers are aware of the nutritional benefit of consuming nuts, but at the time of this survey, few were aware that low-moisture foods such as nuts could on rare occasion be a source of foodborne illness. A majority of consumers reported that they would not change their family's use of nuts to prevent foodborne illness.

## INTRODUCTION

Nuts contribute good taste as well as nutritional benefits to the American diet. Nuts are a good source of mono- and polyunsaturated fatty acids and provide dietary fiber, vitamin E, potassium, Vitamin B-6, magnesium, phosphorus, and iron (32). The United States Food and Drug Administration has approved a health claim stating that as part of a diet low in saturated fat and cholesterol, nuts can help reduce the risk of heart disease (29, 43, 46, 49). Consumption of nuts has increased in the last decade. In 2007, 1.49 kg (3.29 pounds) of tree nuts were eaten per capita, compared with 1.00 kg (2.22 pounds) in 1997 (19). Almonds are the most popular tree nuts consumed in the United States, followed by pecans, walnuts, macadamia, and pistachios (38–41).

*Salmonella* infection can lead to diarrhea, fever, and abdominal cramps (9). If not treated, the immunocompromised, elderly, and young children can be in serious harm. Because the water activity of nuts is below 0.7, they have been considered an unlikely source of pathogens such as *Salmonella*. Historically, low-moisture foods have not been thought to be a source of *Salmonella*. However, outbreaks in the past decade show this assumption to be false. *Salmonella* out-

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**TABLE I. Characteristics of survey volunteers, N = 279**

| <b>Gender</b>   | <b>% (n)</b> |
|---|--------------|
| Male  | 15 (41)      |
| Female  | 83 (232)     |
| <b>Age (years)</b>                                    |              |
| 0–19  | 0.4 (1)      |
| 20–35   | 13 (36)      |
| 36–55   | 39 (110)     |
| 56–65   | 30 (83)      |
| 66+   | 16 (44)      |
| <b>Highest education level completed</b>              |              |
| Some high school                                      | 0.4 (1)      |
| High school graduate                                  | 2 (6)        |
| Some college or technical school                      | 20 (55)      |
| College or technical school graduate                  | 75 (210)     |
| <b>Ethnic group</b>                                   |              |
| Non-Hispanic white                                    | 82 (229)     |
| Hispanic white  | 8 (21)       |
| Asian or Asian American                               | 5 (14)       |
| Black or African American                             | 1 (3)        |
| Native American Indian                                | 0.7 (2)      |
| <b>Where respondent lived</b>                         |              |
| Rural area  | 17 (47)      |
| Town less than 50,000 population                      | 14 (40)      |
| Town of 50,000–100,000 population                     | 28 (77)      |
| City with more than 100,000 population                | 41 (114)     |
| <b>Commercial nut grower</b>                          |              |
| Yes   | 3            |
| No  | 94 (262)     |
| <b>Age in years of household members who eat nuts</b> |              |
| Children younger than 5                               | 6 (16)       |
| Children, 6–12  | 9 (26)       |
| Teens, 13–19  | 14 (40)      |
| Adults, 20–55   | 64 (178)     |
| Adults, 56 +  | 48 (135)     |

breaks have been linked to sesame seeds, powdered milk and chocolate (5, 13, 16, 27, 28, 33). Raw almonds were linked to a *Salmonella* outbreak in 2001 and 2004 (8). Peanut butter, a roasted product, was linked to outbreaks of salmonellosis in 2006 and 2009 (10). In 2009, products containing pistachios and pecans were recalled after *Salmonella* was isolated during routine testing (11, 47). In the same year, raw and shelled roasted hazelnuts tested positive for *Salmonella* and were

recalled (48). While *Salmonella* does not grow in low-moisture foods, the organism is able to survive for long periods of time (6, 12, 18, 30, 42, 44). In raw almonds, the same *Salmonella* did not decline over 1.5 years of refrigerated or frozen storage and declined only slowly when nuts were held at room temperature (50).

Storage time, either processor or consumer, influenced the output of a Monte Carlo risk assessment that predicted salmonellosis from consumption

of raw almonds (17). When this risk assessment was conducted, the authors estimated consumers' storage time because no data was available (17). This study was designed to address this data gap, assess consumer use of nuts, and measure awareness of nuts as a source of foodborne pathogens. This information can be used to guide consumer education and to more accurately assess risk associated with these products should they become contaminated.

**TABLE 2. Consumer reported method of obtaining nuts, N = 279**

| Method of obtaining nuts          | Almonds             | Pecans              | Pistachios          | Walnuts             |
|-----------------------------------|---------------------|---------------------|---------------------|---------------------|
|                                   | % (n <sup>a</sup> ) |
| Supermarket or grower store       | 84 (235)            | 68 (191)            | 72 (202)            | 72 (200)            |
| Farmers' market or roadside stand | 26 (73)             | 12 (34)             | 26 (72)             | 21 (59)             |
| Health food store                 | 18 (51)             | 13 (35)             | 12 (33)             | 15 (41)             |
| Receive as a gift                 | 12 (34)             | 6 (17)              | 9 (24)              | 19 (53)             |
| Have my own tree                  | 5 (14)              | 3 (9)               | 1 (3)               | 9 (26)              |
| Never use this nut                | 0.7 (2)             | 17 (47)             | 13 (37)             | 7 (19)              |

<sup>a</sup>n, number of responses; more than one response could be selected.

**TABLE 3. Consumer reported purchase of in-shell or cracked nuts, N = 279**

| The state of nuts          | Almonds             | Pecans              | Pistachios          | Walnuts             |
|----------------------------|---------------------|---------------------|---------------------|---------------------|
|                            | % (n <sup>a</sup> ) |
| Already cracked            | 97 (270)            | 78 (219)            | 29 (81)             | 81 (226)            |
| In-shell, I crack them out | 12 (34)             | 15 (42)             | 73 (204)            | 35 (97)             |

<sup>a</sup>n, number of responses; more than one response could be selected.

## MATERIALS AND METHODS

Focus groups were held in northern California to identify the variety of ways consumers obtain, store and use nuts, and to assess attitudes toward nut safety and health benefits. Focus groups were scheduled for 1 h, and participants received a gift card at the conclusion of the session. Experienced focus group leaders asked participants to describe what nuts they ate, where they obtained nuts, how they stored nuts, and the various ways they used them. Further, participants were asked what they had heard regarding nuts and health. Leaders probed as to positive information, such as nuts and heart health, as well as awareness of foodborne illness traced to nut contamination. Finally, people were asked about their attitudes and knowledge regarding pasteurization of almonds sold commercially. An on-line survey was then designed to quantify the practices reported in the focus groups. The survey was pilot tested among a convenience sample of 10 persons to assure readability prior to its being posted on the Web. Consumers who use nuts and were active

in University of California Cooperative Extension programs such as 4H, gardening, or other activities, as well as the general public, were mailed a flyer inviting them to volunteer either for the focus group or the on-line survey.

The survey focused on four tree nuts produced commercially in California: almonds, pecans, pistachios and walnuts. For each type of nut, questions addressed how the nut was obtained, stored, and used, as well as who in the household consumed the nut. Information on acquiring and storing nuts was obtained through multiple choice, while volunteers typed into the form the ways they used nuts. The survey also asked consumers if they have heard of health benefits of eating nuts and whether they believe specific health statements. Consumers were asked if they had heard of foodborne illnesses connected with nuts and if the association would affect their family eating habits. Demographic questions were asked at the end of the survey. Consumers were not required to answer every question before moving on to the next question. The survey required about 10 min to complete.

## RESULTS

### Focus groups

Four focus groups with 5 to 12 participants each (total n = 34) were held in northern California. Most participants were women (n = 25). Although a majority of participants were white non-Hispanics, people of Asian (n = 3) and Hispanic (n = 7) heritage were also represented. Focus group participants obtained nuts from non-commercial sources, such as their own or a friend's tree, as well as from commercial sources including farmers' markets, roadside stands, specialty markets and supermarkets. Volunteers ate nuts out of hand or in a wide range of dishes, including additions to breakfast cereal, salads or entrees, or as ingredients in breads, cookies, desserts and candies. Some toasted and flavored raw nuts, and others made nut butters. Most stored nuts in the refrigerator or freezer and used nuts within a short time of purchasing. Most were aware that eating nuts was healthy. The focus groups took place prior to the 2009 peanut but-

**TABLE 4. Consumers who use only roasted or blanched rather than raw nuts, N = 279**

| Only use roasted or blanched nuts ( <u>not</u> raw) | % (n)    |
|---|----------|
| Almonds   | 16 (45)  |
| Pecans  | 29 (81)  |
| Pistachios  | 40 (112) |
| Walnuts   | 12 (33)  |

**TABLE 5. Consumer reported method of storing nuts, N = 279**

| Method of Storage                  | Room                     | Garage                   | Refrigerator | Freezer  |          |
|------------------------------------|--------------------------|--------------------------|--------------|----------|----------|
|                                    | Temperature <sup>b</sup> | Temperature <sup>c</sup> |              |          |          |
| Length of Storage                  | % (n)                    | % (n)                    | % (n)        | % (n)    |          |
| Almonds<br>N = 269                 | Never use                | 38 (102)                 | 94 (254)     | 66 (177) | 54 (145) |
|                                    | Less than 1 wk           | 15 (40)                  | 1 (4)        | 2 (6)    | 0 (0)    |
|                                    | 2 – 4 weeks              | 25 (66)                  | 1 (3)        | 12 (31)  | 1 (4)    |
|                                    | 2 – 6 months             | 17 (46)                  | 1 (4)        | 14 (39)  | 18 (48)  |
|                                    | 7 months to a yr         | 5 (13)                   | 0.7 (2)      | 4 (11)   | 14 (37)  |
|                                    | Over a year              | 0.7 (2)                  | 0.7 (2)      | 2 (5)    | 13 (35)  |
| Pecans<br>N = 268                  | Never use                | 57 (154)                 | 97 (259)     | 72 (194) | 58 (156) |
|                                    | Less than 1 wk           | 11 (30)                  | 0.4 (1)      | 1 (4)    | 0 (0)    |
|                                    | 2 – 4 weeks              | 15 (40)                  | 1 (4)        | 7 (18)   | 1 (4)    |
|                                    | 2 – 6 months             | 11 (30)                  | 0.7 (2)      | 14 (38)  | 16 (44)  |
|                                    | 7 months to a yr         | 3 (8)                    | 0.4 (1)      | 4 (11)   | 14 (37)  |
|                                    | Over a year              | 2 (6)                    | 0.4 (1)      | 1 (3)    | 10 (27)  |
| Pistachios <sup>a</sup><br>N = 267 | Never use                | 53 (142)                 | 99 (264)     | 90 (239) | 89 (236) |
|                                    | Less than 1 wk           | 12 (33)                  | 0 (0)        | 1 (3)    | 0 (0)    |
|                                    | 2 – 4 weeks              | 20 (53)                  | 0 (0)        | 4 (10)   | 0.8 (2)  |
|                                    | 2 – 6 months             | 11 (30)                  | 0.7 (2)      | 3 (9)    | 5 (13)   |
|                                    | 7 months to a yr         | 2 (5)                    | 0.4 (1)      | 2 (5)    | 2 (5)    |
|                                    | Over a year              | 1 (4)                    | 0 (0)        | 0.4 (1)  | 4 (10)   |
| Walnuts<br>N = 279                 | Never use                | 41 (111)                 | 91 (247)     | 65 (176) | 46 (125) |
|                                    | Less than 1 wk           | 12 (33)                  | 0 (0)        | 2 (6)    | 0 (0)    |
|                                    | 2 – 4 weeks              | 23 (61)                  | 2 (5)        | 10 (28)  | 1 (3)    |
|                                    | 2 – 6 months             | 18 (48)                  | 4 (11)       | 16 (44)  | 20 (55)  |
|                                    | 7 months to a yr         | 3 (8)                    | 1 (3)        | 4 (12)   | 15 (40)  |
|                                    | Over a year              | 3 (8)                    | 1 (4)        | 1 (3)    | 17 (47)  |

<sup>a</sup>Room Temperature, Garage Temperature, and Refrigerator, N = 267; Freezer, N = 266

<sup>b</sup>Room Temperature: 20–25°C

<sup>c</sup>Garage Temperature in California: -18 to 38°C or higher

ter outbreak (10) and the 2009 pecan and pistachio *Salmonella* recalls (11, 47). While some had heard that nuts could be a source of *Salmonella*, most attributed this to mishandling by food processors. Some consumers believed that freezing the nuts would destroy any harmful bacteria.

#### Online survey

Of the 279 volunteers who participated in the survey between March and September 2008, 83% were female, 15% were male and 2% did not respond to this question. The majority of respondents were between the ages of 36–55 years (41%), followed by 56–65 years

(30%) (Table 1). Most participants, 77%, have a college or technical school graduate degree, and the majority, 84%, identified themselves as non-Hispanic white, with 8% Hispanic white and 4% Asian or Asian Americans. Almost half of the survey participants, 43%, live in a city with more than 100,000 people, and

**TABLE 6. Consumer reported method of consumption and usage, N = 279**

|                                   | Almonds             | Pecans              | Pistachios          | Walnuts             |
|-----------------------------------|---------------------|---------------------|---------------------|---------------------|
| Method of consumption and usage   | % (n <sup>a</sup> ) |
| Eat roasted nuts                  | 78 (218)            | 45 (126)            | 66 (184)            | 45 (125)            |
| Eat raw out of hand               | 73 (205)            | 50 (140)            | 46 (127)            | 68 (191)            |
| Use in cookies                    | 51 (141)            | 48 (135)            | 9 (26)              | 70 (196)            |
| Use raw in salads                 | 50 (140)            | 37 (102)            | 11 (32)             | 56 (156)            |
| Use raw nuts in stir fry          | 34 (95)             | 11 (31)             | 3 (7)               | 20 (56)             |
| Roast this nut myself             | 30 (85)             | 22 (60)             | 5 (13)              | 29 (80)             |
| Add raw nuts to breakfast cereal  | 28 (77)             | 20 (55)             | 3 (8)               | 30 (83)             |
| Use in cakes                      | 27 (76)             | 32 (89)             | 4 (12)              | 48 (133)            |
| Use in pesto or other sauce       | 24 (67)             | 5 (14)              | 4 (10)              | 23 (63)             |
| Use in homemade candy             | 19 (53)             | 19 (52)             | 4 (10)              | 22 (62)             |
| Bake in casseroles                | 19 (52)             | 9 (25)              | 3 (9)               | 16 (45)             |
| Other, please describe            | 16 (46)             | 15 (43)             | 6 (16)              | 14 (40)             |
| Make nut butter from raw nuts     | 4 (12)              | 0.7 (2)             | 0.4 (1)             | 1 (4)               |
| Make nut butter from roasted nuts | 3 (7)               | 0.4 (1)             | 0.4 (1)             | 1 (4)               |

<sup>a</sup>n, number of responses; more than one response could be selected.

*Other consumption and usage methods:*

*Almonds—trail mix (n = 7.3%), granola (n = 5.2%), beverage (milk), biscotti, bread, French toast, homemade ice cream, muffins, pancake, add to gelatin*

*Pecans—pie (n = 18.6%), muffins (n = 4.1%), breads, candied and glazed, homemade ice cream, French toast, trail mix, add to gelatin*

*Pistachios—baklava, breads, homemade ice cream, muffins, trail mix*

*Walnuts—bread (n=4.1%), beverage (milk), candied and glazed, granola, homemade ice cream, meat loaf, muffins, pancakes, pie, potato salad, smoothies, trail mix, waffles, wild rice, add to gelatin*

26% live in a town of 50,000–100,000 people. Only 3% of respondents were commercial nut growers. Of the household members, children were the least likely to eat nuts. The majority of people who ate nuts were between the ages of 20–55 years (64%). Adults 56 years and older ate nuts with the second greatest frequency (48%).

### Acquiring nuts

Consumers obtain nuts from multiple sources (Table 2). The majority of those surveyed buy nuts from the supermarket or a grower store, with 84% of almonds, 68% of pecans, 72% of pistachios, and 72% of walnuts purchased from these sources. Almost a quarter buy

almonds (26%), pistachios (26%), and walnuts (21%) from a farmers' market or roadside stand. Walnuts, more than any other nut, are received as a gift (19% of respondents). Of the four nuts, pecans are the least used; 17% say they never use this nut. Overwhelmingly, consumers buy almonds (97%), pecans (78%), and walnuts (81%) that are already cracked out of the shell. Pistachio is the one nut most consumers buy in-shell (73%) (Table 3). A majority of those surveyed buy, eat, and use nuts that are raw (Table 4). Fewer than 20% do not use raw almonds, pecans, pistachios, and walnuts.

### STORAGE

Consumers store nuts at different temperatures, depending on length

of storage (Table 5). Garage storage, in which temperatures can range from -18°C (0°F), to over 38°C (100°F), is rarely used. The most common practice is to store nuts at room temperature. While 2–4 weeks is the most common storage time, 11% or more indicate they store nuts at room temperature for 2–6 months. As the length of storage increases, from several weeks to 2–6 months, 14% or more store tree nuts in the refrigerator or freezer. For consumers storing nuts 7 months to a year, the most common place to store the nuts is in the freezer. Pistachios do not follow this trend. Instead, pistachios are most often stored at room temperature for periods of less than a week to 6 months and are seldom stored for longer than 6 months.

**TABLE 7. Consumer reported familiarity with and belief of health attributes of nuts, N = 279**

| Health Statements  | Yes      | No       | Not Sure   |
|--|----------|----------|------------|
|  | % (n)    | % (n)    | % (n)      |
| The oils in nuts are healthy.  |          |          |            |
| Heard this statement   | 96 (268) | 1 (4)    | 1 (4)      |
| Believe the statement  | 93 (260) | 1 (4)    | 4 (11)     |
| Eating moldy nuts is bad for you.  |          |          |            |
| Heard this statement   | 57 (160) | 25 (70)  | 16 (46)    |
| Believe this statement   | 78 (217) | 1 (4)    | 19 (52)    |
| Nuts get an off flavor if stored too long or in a warm place.  |          |          |            |
| Heard this statement   | 71 (199) | 21 (58)  | 6 (17)     |
| Believe this statement   | 76 (212) | 4 (10)   | 16 (44)    |
|  | Agree    | Disagree | Don't Know |
|  | % (n)    | % (n)    | % (n)      |
| The health benefits of nuts is about the same whether the nuts are raw, pasteurized, blanched, or roasted (with no added oil or salt). | 36 (101) | 33 (92)  | 29 (81)    |

## Usage

Survey respondents use nuts in a variety of foods (Table 6). The most popular way to eat almonds, pecans, pistachios, and walnuts is to eat the nut raw or roasted as a snack. Raw nuts are used both in methods that involve the application of heat and in those that do not. Consumers most commonly use nuts in cookies, with 70% using walnuts, 51% using almonds, 48% using pecans, and 9% using pistachios, and toss raw nuts in salads, with 56% using walnuts, 50% using almonds, 47% using pecans, and 11% using pistachios. Sixteen percent of almonds, 15% of pecans, 14% of walnuts, and 6% of pistachios are also used in other homemade foods such as ice cream, bread, muffins, pies, smoothies, pancakes, granola, and trail mix.

## Beliefs about nut health and association with foodborne illness

A majority of consumers have heard and believe that nut oils are healthful and eating moldy nuts is harmful (Table 7). People also believe that nuts get off-fla-

vor if stored too long or in a warm place. Slightly more than a third (36%) of respondents believe that the health benefits of nuts is about the same whether the nuts are raw, pasteurized, blanched or roasted. Almost as many (33%) do not believe this statement and 29% are not sure. Only 24% have heard and 26% believe that eating raw nuts could lead to illness from *Salmonella*. Only 18% say this information would affect their family's eating habits. Even fewer, 15%, have heard that outbreaks of salmonellosis have been associated with consumption of peanut butter, and only 11% say the information would affect their family's eating habits. Only 4% have heard that *Salmonella* foodborne illness had been associated with eating sesame seed products. As with peanut butter, only 11% said the information would affect their family's eating habits (Table 8).

## DISCUSSION AND CONCLUSION

Nearly all of the almonds, pistachios, and walnuts produced in the United States are grown in California. In 2007, there were 656 million pounds of

walnuts (20), 416 thousand pounds of pistachios (20) and 1.39 billion pounds of almonds (20) produced in the state. Pecan production is more significant in Georgia and Texas, but California produced 416 thousand pounds in 2007 (7). With an extensive acreage of nut trees, Californians can easily obtain nuts from commercial or personal sources. The majority of the survey respondents buy all four types of tree nuts from retail stores, while the second most common method of obtaining tree nuts is at farmers' markets or roadside stands.

As a response to the 2001 and 2004 *Salmonella* outbreaks in raw almonds, a mandatory 4-log reduction processing step was implemented by the Almond Board of California in September 2007 (3). California vendors selling at non-commercial sources, such as farmers' markets or roadside stands, can sell a maximum of 100 pounds of raw unpasteurized almonds per day (4). Otherwise, all almonds bought from retail commercial outlets are pasteurized; however, they can be labeled as "raw" (2). Consumers may not realize that there may be a difference between raw California almonds sold at farmers' markets or roadside stands, where nuts are not pasteurized,

**TABLE 8. Consumer reported belief and impact of food sources of *Salmonella*, N = 279**

| <i>Salmonella</i> Statements   | Yes     | No       | Not Sure |
|--|---------|----------|----------|
|  | % (n)   | % (n)    | % (n)    |
| Some people got <i>Salmonella</i> food poisoning from eating raw nuts.             |         |          |          |
| Heard this statement   | 24 (67) | 63 (177) | 11 (31)  |
| Believe this statement   | 25 (69) | 25 (71)  | 45 (125) |
| Does this information affect your family's eating habits?                          | 18 (51) | 78 (219) | -        |
| Some people got <i>Salmonella</i> food poisoning from eating peanut butter.        |         |          |          |
| Heard this statement   | 15 (41) | 72 (202) | 11 (31)  |
| Believe this statement   | 16 (46) | 34 (95)  | 44 (124) |
| Does this information affect your family's eating habits?                          | 11 (32) | 83 (231) | -        |
| Some people got <i>Salmonella</i> food poisoning from eating sesame seed products. |         |          |          |
| Heard this statement   | 4 (11)  | 84 (235) | 11 (31)  |
| Believe this statement   | 11 (31) | 27 (76)  | 57 (158) |
| Does this information affect your family's eating habits?                          | 11 (32) | 82 (230) | -        |

and the raw California almonds sold at the supermarket, which would have been pasteurized.

At this time, there have been no outbreaks traced to raw pecans, pistachios, or walnuts. However, raw pecans and pistachios have been recalled because of the presence of *Salmonella* (11, 47). Even though tree nuts are harvested in a similar manner, walnuts, pecans and pistachios are not subjected to mandatory pasteurization as almonds are. Pistachios are most commonly soaked in 15% salt, roasted, and sold in shell (26), while walnuts and pecans are sold raw in or out of the shell.

Very few respondents report that they do not eat raw nuts. This suggests that most people are eating raw or pasteurized raw-like, as well as blanched or roasted, nuts. Since some types of pasteurized nuts may retain the organoleptic properties of the raw nut (1), consumers do not know if they are consuming nuts pasteurized for added safety.

In previous studies on tree nuts and nut products, authors have assumed consumers' storage behaviors (6, 17, 30). This analysis found that consum-

ers mostly store nuts at room temperature for less than six months or in the freezer for longer storage. Several survey respondents specifically said that they buy tree nuts in bulk and freeze half and leave the other half on the counter for immediate consumption. Pistachios do not follow this pattern. They are stored at room temperature for short periods of time and eaten quickly. A sensitivity analysis suggested that consumer storage practices have an impact on *Salmonella* (17). Contrary to consumers' belief that freezing and refrigeration kills *Salmonella*, cold storage extends the survival of *Salmonella* (50). Several investigators have shown that *Salmonella* is able to survive for months in low-moisture foods at refrigerated and room temperature (6, 12, 22, 23, 25, 30, 31, 50). Calculated rates of decline in inoculated raw almonds were on average  $0.25 \pm 0.05$  log CFU per month at 23°C and 0 log CFU per month at 4 or -20°C. Both Burnett et al. (6) and Kilonzo-Nthenge et al. (30) also showed that *Salmonella* survives longer at 4°C than 25°C in peanut butter. Current consumer storage practices may not reduce *Salmonella* levels in nuts that are contaminated.

Because nuts are high in monounsaturated and polyunsaturated fat (32), rancidity is an issue. Unsaturated fat stability is dependent on temperature; thus as temperature increases, shelf life of a food lipid decreases. To reduce this phenomenon, nuts should be placed in a cool area (21). Consumers appear aware of this association and store nuts in the refrigerator or freezer if storage time is long. Therefore, recommendations for bacteria reduction and flavor quality are contradictory.

Consumer culinary use of nuts may or may not impact survival of *Salmonella*. Consumers use nuts in a variety of cooking and non-cooking applications. If nuts are consumed raw out of hand, tossed in a salad or added to breakfast cereal, no procedure has occurred to reduce possible contamination. Similarly, little heating occurs if raw nuts are used to make nut butter. Heating serves as a bacterial kill step, but effectiveness in the home kitchen is unknown, especially when raw tree nuts are incorporated in complex food matrixes. Consumers may believe that any application of heat is sufficient to eliminate bacteria. Depending

on the *Salmonella* strain, different heat treatments are required for inactivation (12, 42). *Salmonella* are generally highly heat resistant when in low-moisture foods such as nut butters or on nut surfaces (34).

The most common nut uses that involve heat are additions to cookie or cake batters. Cookie dough and cake, muffin or quick bread batter are often high in fat and sugar. The composition of a food matrix from the fat levels, salt content, pH and water activity can all influence the thermal inactivation of *Salmonella* (24, 35–37). High fat content from either the nut or other ingredients in the dish, is thought to protect *Salmonella* from the acidic conditions of the stomach (51). High sugar content, which lowers water activity levels, is also protective of *Salmonella* (22, 37). Using nuts in homemade candy is fairly common. If the nuts are added after the candy is made, such as in fudge or fondant, no heat is applied, whereas high temperatures during the heating process in brittle or toffee making (350°F/177°C or higher) may be sufficient to inactivate the *Salmonella* (12). Studies indicate that heat inactivation of *Salmonella* in low water activity matrices, such as peanut butter and tree nuts, is non-linear and may in fact be concave (12, 34, 37, 45). Because of this characteristic, the real issue is the extent of heat treatments in these conditions.

Foodborne outbreaks in the past two decades have demonstrated that although low-moisture foods do not support the growth of *Salmonella*, the pathogen can survive for sufficient time and in sufficient numbers to cause illness (6, 12, 30, 42, 44). If *Salmonella* is present in foods, it is often present at low levels. For example, over a 5-year period, only 0.87% of the 100-g samples of raw almonds tested positive for *Salmonella* (18), with levels of less than 3 MPN/100 g. Depending on the food product, the individual, and the *Salmonella* strain, *Salmonella* infection has occurred from consuming low-moisture products contaminated with less than 1 CFU/g (12, 44).

Responses to questions about the health attributes of pasteurized nuts indicate that consumers do not have an accurate understanding of the effect of this process on nut attributes. Some consumers stated that they would buy only

unpasteurized almonds. These people believe that health benefits are decreased as a result of pasteurization, stating that heating nuts changes oil properties or decreases levels of nutrients. A few others said that heating nuts destroys beneficial enzymes, because pasteurized nuts do not sprout. However, certain treatments approved by the Almond Board of California maintain raw-almond characteristics (1, 2). Pecans, pistachios, and walnuts, unlike almonds, are not required to be treated. These tree nuts may go through treatments at the discretion of the processor. Even though some survey respondents believe “raw” is better, the FDA approved health claim for nuts applies to all forms of the product (46).

Consumers expect food, especially ready-to-eat foods such as tree nuts, to be safe. This, and the rarity of nut-related outbreaks, may explain why survey respondents did not recognize that nuts have been a source of *Salmonella* infection (8, 11, 47). This survey was conducted before the 2009 peanut butter outbreak (10) and 2009 pistachio and pecan recalls (11, 47). During the *Salmonella* outbreak in spinach in 2006 (14) and tomato outbreak in 2008 (15), Americans continued to eat these items despite the recall, believing that their lives will not be impacted (14). Individuals exhibit optimistic-bias, believing that unfortunate incidents will not happen to them (52). It is unknown if attitudes toward nut safety would be affected by the more frequent news coverage of nut-related incidences such as the widely publicized 2009 peanut butter outbreak (10) and the 2009 pistachios and pecan recalls (11, 47). An analysis of buying practices after the peanut butter recall indicates that consumers resumed purchasing peanut butter products quickly (53). The bounce back in peanut butter sales reflects consumers’ expectations that ready-to-eat foods are safe and is consistent with their perceived low personal risk of salmonellosis.

In response to consumer information needs, free consumer publications describing safe handling of nuts for the consumer and the home gardener are in press at the University of California Agricultural and Environment Sciences (<http://ucanr.org/freepubs/>). These provide safe handling information, highlight

nutritional attributes of nuts, and provide guidance for dining with a person with a nut allergy.

## LIMITATIONS OF THIS STUDY

Consumers volunteering for this study are a convenience sample of California residents who use nuts. Nut use may be higher in this sample than among the general population, since we specifically sought volunteers who use these items, and the volunteers are from a geographic area where nuts are grown and readily available. Practices reported by this sample may not be representative of the population as a whole. Consumers reported who in the household eats nuts, but not the quantity of nuts people consume at a snacking or meal occasion. Lastly, we inquired as to where consumers obtained nuts but did not ask if the nuts from each source were raw or roasted.

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