Food Microbiology 42 (2014) 102–108

Contents lists available at ScienceDirect

Food Microbiology

journal homepage: www.elsevier.com/locate/fm

Use of acetic and citric acids to control *Salmonella* Typhimurium in tahini (sesame paste)

Anas A. Al-Nabulsi [a,*], Amin N. Olaimat [b], Tareq M. Osaili [a], Reyad R. Shaker [a], Noor Zein Elabedeen [a], Ziad W. Jaradat [c], Aisha Abushelaibi [d], Richard A. Holley [b]

[a] Department of Nutrition and Food Technology, Faculty of Agriculture, Jordan University of Science and Technology, Irbid, Jordan
[b] Department of Food Science, Faculty of Agriculture, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada
[c] Department of Biological and Genetic Engineering, Faculty of Science and Art, Jordan University of Science and Technology, Irbid, Jordan
[d] Department of Food Science, College of Agriculture, United Arab Emirates University, Al-Ain, United Arab Emirates

ARTICLE INFO

Article history:
Received 16 October 2013
Received in revised form
21 January 2014
Accepted 25 February 2014
Available online 15 March 2014

Keywords:
Tahini
Sesame paste
Salmonella Typhimurium
Organic acids
Acetic acid
Citric acid

ABSTRACT

Since tahini and its products have been linked to *Salmonella* illness outbreaks and product recalls in recent years, this study assessed the ability of *Salmonella* Typhimurium to survive or grow in commercial tahini and when hydrated (10% w/v in water), treated with 0.1%–0.5% acetic or citric acids, and stored at 37, 21 and 10 °C for 28 d. *S.* Typhimurium survived in commercial tahini up to 28 d but was reduced in numbers from 1.7 to 3.3 $\log_{10}$ CFU/ml. However, in the moist or hydrated tahini, significant growth of *S.* Typhimurium occurred at the tested temperatures. Acetic and citric acids at ≤0.5% reduced *S.* Typhimurium by 2.7–4.8 $\log_{10}$ CFU/ml and 2.5–3.8 $\log_{10}$ CFU/ml, respectively, in commercial tahini at 28 d. In hydrated tahini the organic acids were more effective. *S.* Typhimurium cells were not detected in the presence of 0.5% acetic acid after 7 d or with 0.5% citric acid after 21 d at the tested temperatures. The ability of *S.* Typhimurium to grow or survive in commercial tahini and products containing hydrated tahini may contribute to salmonellosis outbreaks; however, use of acetic and citric acids in ready-to-eat foods prepared from tahini can significantly minimize the risk associated with this pathogen.

1. Introduction

Tahini (sesame paste) is produced from dehulled, ground, roasted or unroasted sesame seeds (*Sesamum indicum*) (Lake et al., 2010). It has high nutritive value since it contains a high amount of lipid (57–65% wt), protein (23–27% wt), carbohydrate (6.4–9.0 wt.) and <1.0% moisture (Abu-Jdayil et al., 2002; Sawaya et al., 1985). Tahini is a common ingredient in many popular ready-to-eat food products in Middle Eastern and Eastern Mediterranean countries, including halva, hummus, various salad dressings, baba ghanoush, mutabbel and tarator sauce (Lake et al., 2010; Unicomb et al., 2005; Abu-Jdayil et al., 2002). The consumption of these products has increased in European countries, Canada and the United States. For example, hummus was present in 12% of American households in 2006 and this rose to 17% in 2009. In 2010, hummus consumption increased by 35%, with sales reaching nearly $300 million (Ferretti, 2010).

Although tahini is considered shelf stable because of low water activity, a_w (~0.16–0.25), the high fat content in such foods allows organisms to survive for long periods (Lake et al., 2010). As a result, a number of illness outbreaks and recalls linked to tahini contaminated with *Salmonella* have been reported recently. Three outbreaks of *S. Montevideo* infection were identified between 2002 and 2003 in Australia and New Zealand, which involved 68 infections due to consumption of sesame seed-based products (Unicomb et al., 2005). In 2001, halva contaminated with *Salmonella* Typhimurium DT104 caused 27 illnesses in Sweden (Andersson et al., 2001), 18 illnesses in Norway (Aavitsland et al., 2001), and 14 illnesses in Australia (O'Grady et al., 2001). In the US in 2011, tahini contaminated with *S.* Bovismorbificans used in the preparation of hummus infected 23 persons in 7 states and the District of Columbia (CDC, 2012). In 2013 in the US, a multistate outbreak of *S.* Montevideo and *S.* Mbandaka infections linked to hummus and tahini involved 16 cases with one hospitalization and one death (CDC, 2013). Further, in Canada, tahini was recalled from the marketplace nine times between March and August 2013 because

* Corresponding author. Department of Nutrition and Food Technology, Jordan University of Science and Technology, Irbid, Jordan. Tel.: +962 02 7201000; fax: +962 02 7201078.
E-mail address: anas_nabulsi@just.edu.jo (A.A. Al-Nabulsi).

http://dx.doi.org/10.1016/j.fm.2014.02.020
0740-0020/

of the possibility of *Salmonella* contamination (Canadian Food Inspection Agency, 2013).

Sesame seeds can be contaminated with *Salmonella* spp. and other organisms during growth, storage or processing. Microbial contamination may originate from either pre-harvest sources (soil, feces, irrigation water, reconstituted fungicides and insecticides, dust, insects, inadequately composted manure, wild or domestic animals and human handling) or post-harvest sources including harvesting equipment, transport containers, insects, dust, rinse water, ice, transport vehicles and processing equipment, and human handling (Olaimat and Holley, 2012). However, use of accepted roasting times and temperatures (110 °C for 60 min, 130 °C for 50 min, or 150 °C for 30 min) for sesame seed treatment is sufficient to inactivate *Salmonella* (Torlak et al., 2013). Therefore, it is likely that contamination of tahini occurs after heat treatment and is due to poor hygiene during grinding, slicing, packaging or transportation (Lake et al., 2010; Brockmann et al., 2004).

Brockmann et al. (2004) isolated a number of *Salmonella* serotypes including *S.* Typhimurium, *S.* Offa, *S.* Tennessee and *S.* Poona from tahini, halvah and sesame seed, which was sold for raw consumption in cereals. In Australia, 17 *Salmonella* serovars were isolated from sesame seeds and their products during 30 evaluations between 1985 and 2001 (O'Grady et al., 2001). Khiyami et al. (2011) isolated *Salmonella* from 7 (8.8%) of 80 mutabbel and hummus samples in Riyadh, Saudi Arabia. In the same country, two of 10 tahini processing plants were positive for 4 *Salmonella* serotypes including *S.* Hadar, *S.* Agona, *S.* Einsbuettel and *S.* Ubrech (Ayaz et al., 1986).

Acidification of foods with organic acids, either by fermentation or by deliberate addition, is a useful and widely accepted method for controlling foodborne pathogens in many foods. Organic acids such as acetic, lactic, and citric acids have been used to control microbial growth, improve sensory attributes and extend food shelf-life (Cortesi et al., 2009). They are generally recognized as safe (GRAS) agents for use in food to eliminate pathogenic bacteria including *Salmonella* (Mani-López et al., 2012). Among the organic acids, citric and acetic are most commonly used for the preparation of tahini products; for example, citric acid is an ingredient in hummus and tarator sauce, while acetic acid used in tahini salad dressing. There is little information published on the survival of *Salmonella* in tahini and no data are available on the control of *Salmonella* in tahini during normal storage. Therefore, the objectives of this study were to examine i) the survival of *S.* Typhimurium in tahini and hydrated (diluted) tahini at different storage temperatures and ii) the effect of acetic and citric acids on the viability of *S.* Typhimurium in tahini and hydrated tahini at different storage temperatures.

2. Materials and methods

2.1. Preparation of bacterial culture

S. Typhimurium ATTC 14028 was used and kept at −40 °C in Brain Heart Infusion (BHI, Oxoid Ltd, Basingstoke, UK) broth containing 20% glycerol. One loopful of frozen culture was streaked on xylose lysine deoxycholate agar (XLD agar, Oxoid) plates which were incubated at 37 °C for 24 h. A single colony was transferred to BHI broth and incubated 37 °C for 24 h. Three transfers were performed to resuscitate the culture and the final transfer in BHI broth prior to the experiment was grown for 24 h at 37 °C to reach the stationary phase. The *S.* Typhimurium culture was diluted using peptone water (0.1%) to give a final concentration of about 6 $\log_{10}$ CFU/ml or 4 $\log_{10}$ CFU/ml in tahini or hydrated tahini, respectively.

2.2. Preparation of tahini

To examine the survival of *S.* Typhimurium, tahini paste purchased from a local market and tahini hydrated to10% (w/v) were used. Moisture-enhanced tahini was prepared by adding 5 g tahini to 45 ml sterile distilled water in a sterile 100 ml plastic cup. The commercial tahini was checked before use and did not contain *Salmonella* spp.

Tahini was mixed well with a sterile spatula and samples of 50 g of tahini or hydrated tahini were placed or poured into sterile 100 ml plastic cups. Acetic and citric acids (Sigma–Aldrich, St. Louis, MO, US) were added to the tahini at 0.0, 0.1, 0.3 and 0.5% (v/w) and gently mixed using a sterile spatula. Tahini and hydrated tahini samples were inoculated with one ml of 8.0 or 5.0 $\log_{10}$ CFU/ml *S.* Typhimurium, respectively, and stored at 10, 21 and 37 °C for 28 d.

2.3. Microbiological enumeration

Tahini was sampled after 0, 1, 3, 7, 14, 21, and 28 d of storage at 10, 21 and 37 °C. A 5 ml sample was withdrawn using a sterile syringe, added to 45 ml 0.1% peptone water and then homogenized in a sterile stomacher bag for 2 min with a Stomacher 400 (Seward Ltd., London, UK). Samples were diluted in peptone, plated in duplicate on the surface of XLD agar (3 plates/ml sample), incubated aerobically at 37 °C for 24 h, and colonies typical of *S.* Typhimurium were enumerated. Survival of injured cells was measured using an overlay method (Kang and Fung, 2000; Osaili et al., 2010). The method involved applying a thin layer (10 ml) of Tryptic Soy Agar (TSA, Oxoid) to the surface of 15 ml solidified XLD agar in a plate and when cooled, 100 μl samples were plated on the TSA layer. Plates were incubated at 37 °C for 24 h and the difference in viable numbers on the two agars represented the injured population.

2.4. pH and water activity measurements

The initial and final pH values of tahini and hydrated tahini were directly measured with a pH meter (Cyberscan 500, Eutech Instr., Singapore). Water activity (a_w) was measured using an a_w meter (Hygrolab, Rotronic Instr. Corp, Huntington, NY, US).

2.5. Protein and fat analysis

The fat and protein content of tahini were determined on a dry weight basis according to the standard approved in AOAC (1984). Each analysis was repeated three times.

2.6. Statistical analysis

All data reported are average values of two experiments (six replicates) and are represented by mean ± standard deviation (SD). Differences among treatments were analyzed by Tukey's test using JMP 10.0 software from SAS. Significant differences between treatments were attributed when p was <0.05.

3. Results

3.1. Survival and growth of S. Typhimurium in commercial and hydrated tahini

The viability of *S.* Typhimurium decreased in commercial tahini at all temperatures tested, but the reduction was significantly smaller at 10 °C compared to other storage temperatures. *S.* Typhimurium numbers decreased by 3.3, 2.3 and 1.7 $\log_{10}$ CFU/ml