

Research Note

Fate of *Staphylococcus aureus* on Vacuum-Packaged Ready-to-Eat Meat Products Stored at 21°C

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ABSTRACT

The U.S. Department of Agriculture has established standards for the composition and shelf stability of various ready-to-eat meat products. These standards may include product pH, moisture:protein ratio, and water activity (a_w) values. It is unclear how closely these standards are based on the potential for pathogen growth or toxin production. Because the vacuum packaging used on most ready-to-eat meat products inhibits mold, *Staphylococcus aureus* is the pathogen most likely to grow on products with reduced a_w and increased percentage of water-phase salt. In this study, 34 samples of various ready-to-eat meat products were inoculated with a three-strain mixture of *S. aureus*, vacuum packaged, and stored at 21°C for 4 weeks. *S. aureus* numbers decreased by 1.1 to 5.6 log CFU on fermented products (pH \leq 5.1) with a wide range of salt concentrations and moisture content. Similarly, *S. aureus* numbers decreased by 3.2 to 4.5 log CFU on dried nonacidified jerky ($a_w \leq$ 0.82; moisture:protein ratio of \leq 0.8). Products that were not fermented or dried clearly supported *S. aureus* growth and cannot be considered shelf stable. The product pH and moisture:protein ratio were the two compositional factors most highly correlated ($R^2 = 0.84$) with *S. aureus* survival and growth for the types of products tested, but pH and a_w or pH and percentage of water-phase salt also may provide useful predictive guidance ($R^2 = 0.81$ and 0.77, respectively).

Several federal standards exist for the composition of ready-to-eat (RTE) meat products. The standards are used to define both product characteristics and shelf stability. The compositional factors commonly used by regulators in establishing compositional and shelf-stability standards are moisture:protein ratio (MPR), water activity (a_w), and pH. For example, nonrefrigerated semidry shelf-stable sausage must (i) have an MPR of \leq 3.1 and a pH value of \leq 5.0, (ii) have an MPR of \leq 1.9 at any pH, or (iii) have a pH of \leq 4.5 (or 4.6 with an a_w of \leq 0.91) and an internal brine concentration of \geq 5% and must be intact (or vacuum packaged if sliced), cured, and smoked (19). With experience, processors can establish the relationship between MPR and product “shrink” or yield, which is relatively easy to determine. Similarly, a pH meter is relatively affordable for processors and can easily be used to determine product pH. Small-scale processors may be less likely to measure a_w , however, because of the relatively high price of an a_w meter. Food microbiologists, when evaluating the potential for pathogenic bacterial growth on meat products, commonly consider pH and either a_w or percentage of water-phase salt (%WPS). Small-scale processors could build up a database relating product formulation and yield to %WPS, but this approach would require expenditures for analyses of water and salt percentages by a commercial laboratory. Because

of all these variables, different criteria may be used by regulators, processors, and scientists to evaluate shelf stability of RTE meat products. Currently, there are no readily available models that allow the interchanging of MPR, a_w , and %WPS in determining whether an RTE meat product is shelf stable.

Shelf stability can be defined as product characteristics that prevent the growth of pathogenic microorganisms under normal storage conditions. Thus, to experimentally determine shelf stability of RTE meat products that have reduced moisture and/or pH and added salt, a target pathogen should be identified. The bacterial pathogen commonly regarded as having the highest tolerance to reduced a_w or increased salt concentration is *Staphylococcus aureus* (13). Mycotoxigenic or antibiotic-producing mold species can grow on meat products (1, 5, 14, 15, 17) and at lower a_w values than are tolerated by *S. aureus*. Thus, these molds are a possible food safety hazard for RTE meat products. However, vacuum packaging is commonly used to prevent mold growth on RTE meats, and there is no recent history of mycotoxin production associated with commercial RTE meats. Although the environmental pathogen *Listeria monocytogenes* also poses a risk for postprocessing contamination of RTE products, it has a higher minimum a_w for growth than does *S. aureus*, 0.92 (20) versus 0.86 under aerobic conditions (13). Anaerobic conditions result in an even higher minimum a_w (0.88) for *S. aureus* growth (11). Processing treatments reducing a_w and preventing *S. aureus*

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growth should also prevent *L. monocytogenes* growth. Therefore, the shelf stability of nonrefrigerated semidry sausage and perhaps other RTE meat products could be defined strictly in terms of whether *S. aureus* growth occurs.

The objectives of the present study were to (i) experimentally determine the growth potential for *S. aureus* on a variety of RTE meat products with known MPR, a_w , pH, and %WPS and (ii) determine critical compositional values associated with the likelihood of *S. aureus* growth.

MATERIALS AND METHODS

Inoculum preparation. A cocktail was prepared using three broadly representative strains of *S. aureus*. Strain FRI 1007 was obtained from the laboratory of Dr. Amy Wong (Food Research Institute, University of Wisconsin–Madison) and was originally isolated from a Genoa salami. Strain ATCC 12600 (American Type Culture Collection, Manassas, Va.) has been designated as a type strain since 1958 (3). This strain was originally isolated from pleural fluid, has typical infective characteristics, is coagulase positive and DNase positive, and is capable of growth in milk and potato. However, it reportedly does not produce enterotoxins A, B, C, or D (10). Strain ATCC 25923 is a clinical isolate used in antibiotic susceptibility testing and screening of plant-based compounds, e.g., spice essential oils (4, 6, 8, 9), and animal-based compounds (18) for antibacterial activity. Stock cultures were maintained at -20°C in brain heart infusion broth (BHIB; Difco, Becton Dickinson, Sparks, Md.) with 10% (wt/vol) added glycerol (Fisher Scientific, Itasca, Ill.). Working cultures were maintained at 4°C on brain heart infusion agar (BHIA; Difco, Becton Dickinson) and were prepared monthly from frozen stock cultures. To obtain working cultures, each strain was cultured twice at 35°C for 18 to 24 h in BHIB, streaked to BHIA, incubated 18 to 24 h at 35°C , examined for purity, and then stored at 4°C . Inoculation cultures were prepared for each strain by transferring a loopful of growth from the working culture plate to 9 ml of BHIB and incubating at 35°C for 20 to 24 h, resulting in a concentration of about 8 log CFU/ml. To prepare the three-strain inoculum cocktail, the BHIB cultures were mixed by vortexing, combined into a sterile 50-ml conical centrifuge tube (Falcon brand, Fisher), and centrifuged for 12 min at $5,000 \times g$. The supernatant was decanted, and the pellets were resuspended to the original volume in Butterfield's phosphate diluent (BPD; Nelson Jameson, Marshfield, Wis.). The resulting cocktail was serially diluted in BPD and plated on Petrifilm Staph Express (PF-SE; 3M Microbiology, St. Paul, Minn.) to confirm that the initial cell concentration was about 8 log CFU/ml. The PF-SE plates were incubated at 35°C for 24 h.

Preparation of meat products. A total of 34 RTE meat products were obtained from a local grocery store over a 5-month period. All products were transported to the laboratory within 15 min and refrigerated (5°C) until used. The products included those that are generally shelf stable, e.g., dried salamis, beef jerky, beef snack sticks, and pepperoni (Table 1), and others that required refrigerated storage (e.g., cooked salami and bologna; Table 2). The a_w of a representative product piece (cross section) that included the outer surface was measured with a Decagon water activity meter (AquaLab Series 3 TE, Pullman, Wash.). The pH of a similar piece was measured after preparing a 1:5 slurry in distilled water. A representative sample of each product (ca. 50 g) was placed in a sample bag and sent to a commercial testing laboratory to be analyzed for water percentage (forced-air oven

determination by method 950.46Bb, AOAC International, Gaithersburg, Md.) and salt percentage (potentiometric determination by method 980.25, AOAC). From these results, %WPS was calculated. Product compositional information is shown in Tables 1 and 2. Nine slices were then cut from each RTE meat product with a knife that was sanitized in 70% (vol/vol) ethanol. Each slice contained 3 by 5 cm of the outer surface of the meat product, was 1 cm thick, and weighed about 20 g. Each piece was placed in a biosafety hood on aluminum foil that had previously been sanitized with 70% (vol/vol) ethanol and UV light.

Inoculating and plating procedure. The outer surface of each product piece was inoculated because *S. aureus* is considered a postprocessing contaminant, i.e., typical thermal processes used to make RTE meat products destroy it. To inoculate the RTE meat slices, 0.025 ml of the undiluted cocktail (containing about 6.5 log CFU) was transferred to the product outer surface and distributed as evenly as possible with a sterile bent plastic spreader (Daigger, Vernon Hills, Ill.). The product slices were then allowed to dry for at least 30 min. The small inoculum volume and use of a drying step were intended to minimize any changes in pH or a_w (not actually measured). Any changes that occurred would have resulted in higher pH or a_w and thus would have been more likely to encourage *S. aureus* survival than to reduce it. Six of the nine slices per sample were vacuum packaged (0.8 atm; Food Saver bags and packaging machine, Tilia, Inc., San Francisco, Calif.) and stored at 21°C for sampling after 1 and 4 weeks. The three remaining product slices were analyzed immediately for the number of *S. aureus* cells per sample. Each entire product slice was aseptically added to a sample bag with 99 ml of BPD and stomached for 2 min at medium speed (Stomacher 400 lab blender, Fisher) to attain an initial dilution of about $10^{-0.8}$ g/ml or $10^{-0.8}$ cm²/ml. This initial dilution was conservatively denoted as 10^{-1} . Serial dilutions were made in BPD, plated on PF-SE, and incubated at 35°C for 24 h. The PF-SE plates were then examined for the typical red to purple colonies of *S. aureus*. For each RTE meat product, one presumptive *S. aureus* colony was selected at each sampling time for confirmation testing. One typical colony was transferred to BHIA and incubated at 35°C for 24 h. Resulting colonies were tested for Gram stain reaction, cellular morphology, and catalase activity. Throughout the study, all presumptive isolates were confirmed as *S. aureus*.

Three pieces of each product that had been vacuum packaged and stored at 21°C were analyzed after 1 and 4 weeks. At each sampling time, the log CFU per square centimeter was calculated for each piece, and the mean value was calculated for each product. A value of 0.9 log CFU/cm² was assigned, based on a conservative assumption of 9 CFU/cm² (12) when no colonies were present for the least dilute plating. Similarly, values of 2.0 and 3.0 log CFU/cm² were assigned when no colonies were detected on 10^{-2} and 10^{-3} plates, respectively.

Statistical analysis. To evaluate the pairwise relationship between pH and MPR, a_w , or %WPS and the change in *S. aureus* populations (in log CFU), correlation coefficients (r values) were computed (16). To evaluate the overall relationship between change in *S. aureus* populations and pairs of pH and another compositional value, linear regression was performed (16). An R^2 value, which indicates the proportion of variation in a response variable (i.e., change in *S. aureus* population) that is explained by linear regression on one or more independent variables, was used to assess the goodness of fit of each linear regression model.

RESULTS AND DISCUSSION

Most of the products studied met applicable U.S. Department of Agriculture (USDA) compositional standards

TABLE 1. *Staphylococcus aureus* on certain ready-to-eat meat products stored under vacuum at 21°C

Product category	Processor	Composition ^a				<i>S. aureus</i> (log CFU/cm ²) at ^b :		
		MPR	a _w	%WPS	pH	0 days	7 days	28 days
Jerky	A	0.4	0.68	18.7	5.7	5.9 ± 0.2	3.3 ± 0.8	2.3 ± 0.6 (2)
	A	0.7	0.82	10.6	6.0	6.6 ± 0.3	5.1 ± 0.5	2.8 ± 0.5
	B	0.6	0.69	15.4	6.4	5.9 ± 0	4.2 ± 0.2	1.4 ± 0.4
	B	0.8	0.76	14.2	6.1	5.9 ± 0	4.9 ± 0.1	2.7 ± 0.2
Beef snack stick	C	2.0	0.88	7.1	4.6	5.4 ± 0.2	2.0 ± 0 (3)	0.9 ± 0 (3)
	D	1.7	0.85	9.0	4.9	5.9 ± 0.2	2.0 ± 0 (3)	1.2 ± 0.4 (1)
Pepperoni	E	0.9	0.76	19.0	4.9	5.9 ± 0.1	2.9 ± 0.1	1.7 ± 0.5
	F	1.7	0.88	11.6	4.9	6.3 ± 0.1	2.7 ± 0.1	0.9 ± 0 (3)
	G	1.5	0.86	13.1	4.6	6.5 (n = 2)	2.0 ± 0.1 (2)	0.9 ± 0 (3)
Salami, dried	J	1.5	0.88	9.3	4.9	6.2 ± 0.3	5.8 ± 0	3.2 ± 0.6 (2)
	E	1.1	0.79	16.3	5.1	6.4 ± 0.1	3.6 ± 0.1	2.5 ± 0.1
	E	1.0	0.76	17.1	4.8	5.7 ± 0.2	LE ^c	0.9 ± 0 (3)
	J	1.7	0.87	9.3	4.9	6.2 ± 0.1	LE	2.0 ± 0.1
	E	2.5	0.92	6.5	4.9	6.1 ± 0.1	LE	2.2 ± 1.1
Summer sausage	Q	1.6	0.87	8.0	4.8	6.1 ± 0.1	LE	3.2 ± 0.3
	D	3.2	0.93	5.8	4.8	6.0 ± 0.1	4.9 ± 0.2	2.1 ± 0.3 (1)
	H	3.3	0.95	4.3	4.5	6.3 ± 0.1	3.9 ± 0.4	0.9 ± 0 (3)
	L	3.0	0.93	5.7	4.7	6.2 ± 0.2	2.4 ± 0.5	0.9 ± 0 (3)
	C	3.1	0.96	4.7	4.4	4.4 ± 0.5	3.0 ± 0 (1)	0.9 ± 0 (3)
	P	2.7	0.95	6.5	4.5	5.6 ± 0.1	3.0 ± 0 (3)	0.9 ± 0.1 (2)
	H	2.9	0.96	4.5	4.5	5.7 ± 0.1	3.0 ± 0.1 (2)	0.9 ± 0 (3)
	R	3.2	0.94	5.9	4.5	5.0 ± 0.3	3.0 ± 0 (3)	0.9 ± 0 (3)
	E	2.4	0.94	6.5	4.9	5.8 ± 0.1	5.1 ± 0.3	1.4 ± 0.9 (1)
	D	3.0	0.95	5.2	4.9	5.6 ± 0.1	4.7 ± 0.5	3.1 ± 0.8
	D	3.3	0.93	5.9	4.9	5.8 ± 0.2	5.3 ± 0.1	4.7 ± 1.0
K	3.2	0.94	5.1	4.8	6.0 ± 0.1	5.3 ± 0.1	4.5 ± 0.1	
K	2.9	0.95	5.0	4.8	5.5 ± 0.3	5.1 ± 0.3	4.3 ± 0.5	

^a Compositional values are for a single representative sample. MPR, moisture:protein ratio; %WPS, % water-phase salt (brine concentration).

^b Each log CFU per square centimeter value is the mean ± standard deviation of three samples unless otherwise indicated. The number in parentheses denotes the number of samples that resulted in no colonies on the least dilute plate. Values of 0.9, 2.0, and 3.0 were assigned when this plate was the 10⁻¹, 10⁻², and 10⁻³ dilution, respectively.

^c LE, lab error (no data).

for either product identity or shelf stability (nonrefrigerated semidry sausage). The level of nonstandard products consistently found in the marketplace is not known. Of the four jerky products tested, three met the USDA MPR standard for jerky of ≤0.75. A fourth sample had an MPR value of 0.80. However, on all four jerky products *S. aureus* de-

creased in numbers by 1.0 to 2.6 log CFU after 1 week and by 3.2 to 4.5 log CFU after 4 weeks (Table 1). Of three pepperoni products studied, two met the USDA standard of an MPR of ≤1.6, and one had an MPR value of 1.7. *S. aureus* decreased in numbers on pepperoni products by 3.0 to 4.5 log CFU after 1 week and was undetectable on two

TABLE 2. *Staphylococcus aureus* on ready-to-eat meat products during storage under vacuum at 21°C

Product category	Processor	Composition ^a				<i>S. aureus</i> (log CFU/cm ²) at ^b :		
		MPR ^a	a _w	%WPS	pH	0 days	7 days	28 days
Bologna	H	5.3	0.97	2.9	6.3	6.4 ± 0	6.5 ± 0	8.5 ± 0.1
Salami, cooked	I	4.0	0.96	3.7	6.2	6.1 ± 0.1	6.5 ± 0	7.5 ± 0
	M	4.7	0.96	3.7	6.6	6.3 ± 0.1	LE ^c	8.9 (n = 2)
	N	4.4	0.95	3.9	6.4	6.2 ± 0	LE	8.3 ± 0.1
	O	5.4	0.97	2.0	6.6	6.3 ± 0.1	LE	8.5 (n = 2)
	O	4.2	0.95	3.8	6.5	6.3 ± 0.1	LE	8.1 (n = 2)
	P	3.8	0.95	5.4	6.2	6.1 ± 0.1	LE	8.7 ± 0.1

^a Compositional values are for a single representative sample. MPR, moisture:protein ratio; %WPS, % water-phase salt.

^b Each log CFU per square centimeter value is the mean ± standard deviation of three samples unless otherwise indicated.

^c LE, lab error (no data).

TABLE 3. *Mathematical prediction of change in Staphylococcus aureus populations (Y) on vacuum-packaged ready-to-eat meat products during 4 weeks of storage at 21°C^a*

Predictive variables	Equation of regression line	R ²
pH and MPR	$Y = -16.21 + 1.08(\text{MPR}) + 2.05(\text{pH})$	0.84
pH and a _w	$Y = -32.03 + 16.25(a_w) + 2.83(\text{pH})$	0.81
pH and %WPS	$Y = -14.01 - 0.25(\% \text{WPS}) + 2.56(\text{pH})$	0.77

^a Predictive variables are pH and moisture:protein ratio (MPR), water activity (a_w), or % water-phase salt (%WPS). The R² value indicates the proportion of variation in the change in *S. aureus* populations that is explained by linear regression on pH and one other variable. The three other variables are listed in decreasing order of importance.

pepperoni products after 4 weeks (Table 1). A total of six dried salami products were studied; five products met the USDA MPR standard of ≤ 1.9 , and one had an MPR of 2.5. On dried salami, *S. aureus* did not survive well, with decreases of 2.9 to 4.8 log CFU after 4 weeks (Table 1). In terms of pathogenic bacterial growth, all of the jerky, pepperoni, and dried salami products tested could be considered shelf stable. At the time of purchase, however, only the jerky and some of the dried salami products were displayed at ambient temperatures.

The USDA standards for a nonrefrigerated semidry sausage product are that it (i) have an MPR of ≤ 3.1 and a pH of ≤ 5.0 , (ii) have an MPR of ≤ 1.9 at any pH, or (iii) have a pH of ≤ 4.5 (or 4.6 combined with an a_w of < 0.91) and an internal %WPS of $\geq 5.0\%$ and must be sold in an intact form (or sliced and vacuum packaged), cured with nitrite or nitrate, and smoked with wood (4). The two beef snack stick products tested met these criteria, and for these two products *S. aureus* numbers decreased 3.4 to 3.9 log CFU after 1 week (Table 1). These products were, however, displayed under refrigeration at the grocery store. Five summer sausage products of the 12 tested did not meet either of the first two options of the USDA shelf-stability standards. In each of the five products, the MPR exceeded 3.1. However, the product pH values were 4.5 to 4.9, and one product met the third option in the shelf-stability standard. For these five products, *S. aureus* numbers declined by 0.5 to 2.4 log CFU after 1 week and by 1.1 to 5.4 log CFU after 4 weeks (Table 1). For summer sausages not meeting any of the options in the shelf-stability standard, labels did not indicate that the packaged product should be refrigerated prior to opening the package. On the seven summer sausage products with MPR ≤ 3.1 , *S. aureus* decreased in numbers by 0.4 to 3.8 log CFU after 1 week and by 1.2 to 5.3 log CFU after 4 weeks (Table 1). Strict adherence to the shelf-stability standard did not seem to be related to *S. aureus* survival on the summer sausages tested. Summer sausage compositional factors other than MPR, a_w, %WPS, and pH (e.g., spices or smokeborne compounds) may have affected *S. aureus* survival on these products. Dramatic differences in day 0 *S. aureus* concentrations for summer sausages made by processors C and R may reflect interproduct differences in spices or smoking procedures used. As expected, the cooked salami and bologna products did not meet USDA shelf-stability standards and supported *S. aureus* growth (1.4 to 2.6 log CFU increase after 4 weeks; Table 2). The results of these inoculation studies

suggest that the USDA shelf-stability standard and the product standards for beef jerky, pepperoni, and dried salami are conservative in terms of preventing pathogenic bacterial growth.

Statistical analysis revealed that pH could be used in combination with MPR, a_w, or %WPS to predict the change in log CFU for *S. aureus* on vacuum-packaged RTE meat products during 4 weeks of 21°C storage. Regression equations were developed to enable predictions; the R² values were 0.77 when %WPS and pH were the predictive variables, 0.81 when a_w and pH were the predictive variables, and 0.84 when MPR and pH were the predictive variables (Table 3). Higher R² values may have been obtained if three predictive variables had been used. However, this three-variable analysis was not done because of the low likelihood of a processor obtaining data on all three compositional values for their products. Examination of the correlation coefficients (*r* values) associated with the Table 3 regression equations revealed that pH had the greatest impact on change in *S. aureus* numbers (*r* = 0.75), followed by MPR (*r* = 0.74), %WPS (*r* = -0.52), and a_w (*r* = 0.44). The regression equations do not account for temperature, inoculum concentration, interstrain differences in survival, or inhibitory substances such as spices or smokeborne compounds that may affect *S. aureus* survival in other situations. Therefore, further experiments and statistical analyses are necessary prior to widespread application of regression-based predictions.

None of the products tested were scored in the category of a change in *S. aureus* numbers from -1.1 to 1.3 log CFU after 4 weeks. Given this gap in the data set for which the regression equations were determined, the boundary for predicting shelf stability could be set as conditions resulting in at least a 1.1-log decrease in *S. aureus* numbers. Using this criterion, our experimental results, and the *r* values obtained, processors could consider vacuum-packaged summer sausage with a pH of ≤ 4.9 and an MPR of ≤ 3.3 to be shelf stable in terms of pathogenic bacterial growth.

The minimum pH value for *S. aureus* toxigenesis has been reported as 5.3 in certain sausage products (2), 5.4 or 5.0 under anaerobic conditions in laboratory medium (7, 11), and 4.5 under aerobic conditions in laboratory medium (11). At pH 5.3, the predicted MPR, a_w, and %WPS resulting in a decrease in *S. aureus* numbers of 1.1 log CFU after 4 weeks (calculated from Table 3 equations) were 3.9, 0.98, and 2.6, respectively. In isolation, each of these values hardly appears likely to restrict *S. aureus* growth. Thus,

virtually any fermented ($\text{pH} \leq 5.3$) RTE meat product could be considered shelf stable when vacuum packaged and stored at room temperature. This conclusion is clearly less restrictive than that suggested by our experimental results. Further research is warranted to determine more precisely the limits of RTE meat product shelf stability.

In our study, the nonfermented, nondried RTE products supported *S. aureus* growth. However, the question remains whether relatively high-salt, moderately dried RTE meat products actually would support *S. aureus* growth. According to predictions derived from Table 3 equations, the MPR or a_w must be reduced to 2.6 or 0.86, respectively, or the %WPS must be at least 9.4 for a high-pH (6.0) product to cause a 1.1-log decrease in *S. aureus* numbers after 4 weeks. These predictions should be tested in future studies.

The regression equations in Table 3 did not appear to be useful for products with a pH typical of postrigor meat. For pH 5.5, the MPR predicted for a 1.1-log decrease in *S. aureus* numbers was 3.5, a value typical of raw meat. The predicted a_w and %WPS values for a 1.1-log decrease in *S. aureus* numbers (0.95 and 4.3, respectively) also appear unlikely to inhibit growth. Clearly, further studies are necessary to test and refine the predictive equations before such tools could be used by meat processors.

The results presented here strongly suggest that the USDA standards for nonrefrigerated semidry shelf-stable sausage are conservative in terms of pathogenic bacterial growth during vacuum-packaged storage at 21°C. Laboratory studies clearly indicated that *S. aureus* numbers decreased on fermented ($\text{pH} \leq 5.1$) products with a wide range of salt concentrations and moisture content. Similarly, *S. aureus* numbers decreased on dried ($a_w \leq 0.82$ or MPR ≤ 0.8) nonacidified jerky products. RTE meat products that were not fermented or dried clearly supported *S. aureus* growth and cannot be considered shelf stable. The product pH and MPR were the compositional factors best correlated with *S. aureus* survival and growth for the types of products tested, but pH and a_w , or pH and %WPS also may provide useful predictive guidance for *S. aureus* growth. These compositional factors probably could not be used to predict shelf stability of unfermented products that had been subjected to mild drying and/or salting treatments. Further studies are needed to develop predictive models for the shelf stability of those products.

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