MICROBIOLOGICAL, CHEMICAL, AND ORGANOLEPTIC CHARACTERISTICS OF FROZEN BREADED RAW SHRIMP[1, 2]

C. VANDERZANT, A. W. MATTHYS, AND B. F. COBB III
Animal Science Department
Texas A&M University, College Station 77843

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ABSTRACT

Thirty percent of the samples of fresh or frozen shrimp received for processing into breaded shrimp had bacterial counts in excess of 10^6/g. The bacterial counts of 56% of plant processed samples of frozen breaded raw shrimp exceeded 10^6/g. Counts with plate incubation at 7 or 25 C were significantly higher than at 35 C. Little relationship existed between aerobic plate counts and coliform or enterococcal counts. Neither *Salmonella* nor *Vibrio parahaemolyticus* was isolated from plant processed samples. Frozen storage of breaded shrimp for 3 to 12 months caused minor reductions in aerobic plate count and coliform count and only minor changes in trimethylamine nitrogen (TMN), total volatile nitrogen (TVN), and odor scores. When frozen breaded raw shrimp were exposed to elevated temperatures (0-10 C) increases in count occurred at 0 C after 3-5 days, at 5.5 C after 2-3 days, and at 10 C after 1-2 days. Coliform bacteria increased at 5.5 C, *Escherichia coli* and enterococci at 10 C. In samples held at 0-10 C, marked increases in TMN and TVN and decreases in pH value occurred when bacterial counts had increased sharply and when off-odors became noticeable. Gram-positive forms, *Bacillus, Microbacterium, Micrococcus,* and coryneform bacteria were predominant in retail samples. Many of these samples showed evidence of repeated thawing and freezing. Of the retail samples, 52% had aerobic plate counts of 10^6/g or higher.

Production and distribution of breaded shrimp is an important part of the seafood industry. In 1971 production of breaded shrimp was 104,284,000 lb. with a value at the processors level of $121 million *(18)*. In production of frozen breaded raw shrimp, peeled and deveined shrimp are washed, covered with batter, and coated with breading material. Breaded shrimp then are packed in cartons and frozen. Several reports are available on the conditions that influence number and types of microorganisms on Gulf Coast shrimp at time of landing *(2, 5, 20, 24)*. Microbial counts at time of catch usually are low (10^2-10^4/g) and typical spoilage bacteria are not numerous at that time. Handling and storage procedures on board are primarily responsible for increased counts and introduction of large numbers of psychrotrophic spoilage bacteria.

In tests made on retail samples of frozen breaded raw shrimp in 1961, Silverman et al. *(14)* reported that the bacterial counts of about 28% of the samples exceeded 10^6/g. In a similar study published in 1972, Nickerson and Pollak *(11)* reported that 48% of the samples had bacterial counts in excess of 10^6/g. Surkiewicz et al. *(17)* reported that breaded shrimp samples collected from plants operating under good conditions of sanitation had an average (geometric) MPN of $<$ 1000 coliform bacteria/g and that 85% had an average (geometric) aerobic plate count of $<$ $10/^6$g. In 81% of the samples, *Escherichia coli* was absent from 80% of the units (0.1-g portions). Of the units, 57% were negative for coagulase-positive staphylococci (0.1-g portion) and 95% had $<$ 1000 coagulase-positive staphylococci/g. They showed that production of shrimp of good bacteriological quality requires *(a)* raw shrimp and batter of good bacterial quality, *(b)* clean and sanitized equipment, and *(c)* sanitary handling of the product along the processing line. Little information is available about *(a)* the composition of the microbial flora of breaded shrimp, *(b)* the potential shelf life of products of varying microbial composition, and *(c)* the influence of storage conditions in wholesale and retail channels on the organoleptic and bacteriological quality of this product. This study provides a detailed analysis of the microbiological conditions of raw and plant processed products. Included are tests on samples subjected to warm-up treatments to minic loss of freezer operation during transit or in freezer cabinets.

MATERIALS AND METHODS

Collection of samples

Shrimp and frozen breaded raw shrimp, except for store samples, were obtained from commercial operations along the Gulf Coast. Samples were packed in dry ice at the processing plant and transported immediately to the laboratory. Samples were subjected immediately to the various analyses. If additional analyses were required at a later date, sample units were stored at −23 C. Store samples of frozen breaded raw shrimp were purchased in Fort Worth, Dallas, and Houston, and transported to the laboratory packed in dry ice. These samples were from the same commercial sources as the plant samples.

Microbiological examination

Aerobic plate counts of shrimp were determined with the

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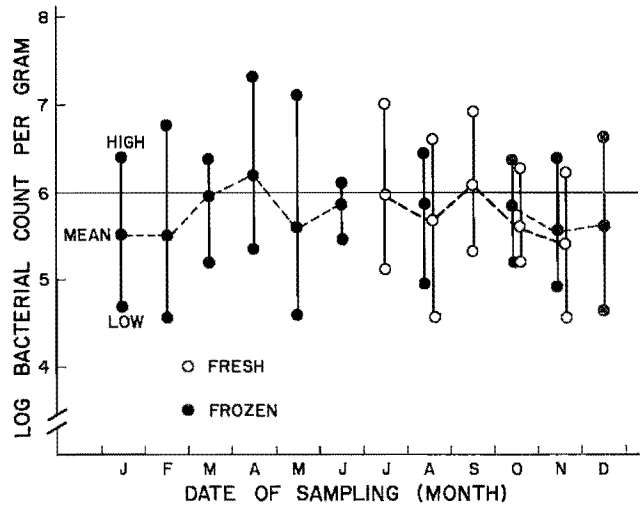

Figure 1. Aerobic plate count at 35 C of fresh and frozen shrimp used in the manufacture of breaded shrimp.

spread plate method by placing 0.1 ml of appropriate dilutions on Standard Methods agar (SMA, BBL) plates. Preparation of samples and dilutions was as described by Surkiewicz *(16)*. Sets of triplicate plates were incubated aerobically at 7 C for 10 days, 25 C for 2 days, and 35 C for 2 days. To determine microbial types, approximately 40 colonies were picked at random from countable plates. Diagnostic procedures and schemes for identification of the microbial flora were presented previously by Vanderzant and Nickelson *(21)*. Previous reports describe the procedures for determining the MPN of coliform bacteria and *E. coli (16)*, coagulase-positive staphylococci *(1)*, and enterococci *(12)*. Established procedures were used to detect *Salmonella (4)* and *Vibrio parahaemolyticus (23)*.

Chemical and organoleptic examination

Trimethylamine nitrogen (TMN) and total volatile nitrogen (TVN) were determined as described in a previous paper *(3)*. Organoleptic evaluations were carried out by a trained three-member taste panel using a 5-point hedonic scale both for taste and odor (1 = excellent, no defect; 5 = marked defect, unacceptable). Breaded shrimp were evaluated fried with breading on and also boiled (4 min) with breading removed before boiling. Shrimp were fried in Wesson oil for 3 min at 191 C. Data were analyzed using analysis of variance, the mean separation technique of Duncan, and simple correlations *(15)*.

RESULTS

Microbiological examination of raw and processed breaded shrimp

In Fig. 1 data are presented on the aerobic plate counts of 276 samples of fresh and frozen shrimp used to manufacture breaded shrimp. For each month, the high, low, and average (geometric) count are presented. About 30% of the samples had bacterial counts of 10^6/g or higher. An examination of 89 plant samples of frozen breaded raw shrimp showed that aerobic plate counts with plate incubation at 35 C ranged from 1.1×10^4 to 6.8×10^8, at 25 C from 6.0×10^4 to 2.7×10^7, and at 7 C from 8.0×10^3 to 3.5×10^7/g (Fig. 2, 3, 4). Geometric means of aerobic plate counts at 35, 25, and 7 C were 2.8×10^5, 1.5×10^6, and 1.2×10^6/g respectively. Analysis of variance (Table 1) indicated that highly significant differences in aerobic plate count resulted from temperature of plate incubation. By Duncan's test *(15)*, counts with plate incubation at 35 C differed significantly from the others and ranked lowest (Table 2). Differences between counts determined at 25 and 7 C were not statistically significant. When plates were incubated at 35 C, 15 samples (17%) had counts of 10^6/g or higher. However, with plate incubation at 25 or 7 C about 50 samples or 56% showed counts of 10^6/g or higher. Although the geometric means of counts at 25 and 7 C remained high during the summer months (July through September), similar values were obtained in April and November.

Coliform counts of processed plant samples (Fig. 5) ranged from 3.6 to 4,600/g with a geometric mean of 66/g. Only 7 samples (8%) had a coliform count in excess of 10^3/g. *E. coli* was recovered from 7 (8%) samples at a level of 3 to 3.6/g. Enterococci in plant samples (Fig. 6) ranged from 9.1 to 11,000/g, with a geometric mean of 6×10^2/g. For plant samples, the correlation between aerobic plate counts at 35 C and enterococcal counts was –0.01, whereas the correlation coefficient between aerobic plate counts and coliform counts was 0.14. Coagulase-positive staphylococci (Fig. 7) were recovered from 45 (50%) samples.

TABLE 1. ANALYSIS OF VARIANCE RESULTING FROM EFFECT OF TEMPERATURE OF PLATE INCUBATION ON THE AEROBIC PLATE COUNT OF FRESHLY PROCESSED AND STORED FROZEN BREADED RAW SHRIMP

Source of variation	d.f.	Mean squares	
		Fresh shrimp	Stored shrimp
Total	266		
Treatment	2	13.7100**	8.7690**
Error	264	0.4505	0.4337

**<0.01 level of probability

TABLE 2. MEAN LOG COUNT OF FRESHLY PROCESSED AND STORED FROZEN BREADED RAW SHRIMP WITH DIFFERENT TEMPERATURES OF PLATE INCUBATION

Plate incubation temperature	Means[1]	
	Fresh shrimp	Stored Shrimp
35 C	5.4510[b]	5.3940[b]
25 C	6.1666[a]	6.0006[a]
7 C	6.0882[a]	5.9000[a]

[1]Means in the same vertical column bearing different superscripts differ significantly (P<0.01).

Results of microbiological analyses of the same plant samples after 3 months of storage at −23 C were in many respects similar to those obtained immediately following processing. Counts at 35 C differed significantly from those determined on plates incubated at 25 or 7 C, and ranked lowest (Tables 1, 2). The range and geometric means of aerobic plate counts of the stored samples were similar to those of the freshly processed samples. At 35 C counts ranged from 1.0×10^4 to 9.3×10^8, at 25 C from 4.1×10^4 to 2.0×10^7, and at 7 C from 3.7×10^3 to 2.0×10^7/g. Average (geometric) counts at 35, 25 and 7 C were respectively 2.5×10^5, 1.0×10^6, and 8.0×10^5/g. Correlations between aerobic plate counts and coliform or enterococcal counts again were low, 0.04 and 0.16 respectively.

Coliform counts of stored samples ranged from 3 to 11,000/g with an average (geometric) count of 55/g. Enterococcal counts of stored samples ranged from 9.1 to >11,000/g with an average (geometric) count of 3.8×10^2/g. Coagulase-positive staphylococci were recovered from 48 (56%) of the stored samples. Storage of plant processed samples for 3 months at −23 C caused small decreases in aerobic plate counts (at 35, 25, or 7 C) and coliform counts in 56-59% of the samples. A statistical analysis indicated that differences in aerobic plate counts and coliform counts between stored and non-stored samples were not significant at the 0.05 level of probability.

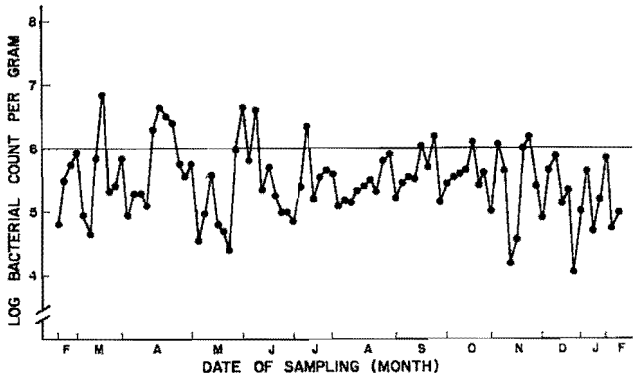

Figure 2. Aerobic plate count at 35 C of freshly processed frozen breaded raw shrimp.

TABLE 3. MICROBIOLOGICAL, CHEMICAL AND ORGANOLEPTIC EXAMINATION OF FROZEN BREADED SHRIMP SAMPLE 8 DURING FROZEN STORAGE

Age (month)	APC[a] at 25 C	Coliform MPN/g	*E. coli* MPN/g	Coag.-pos. staph.	pH	TMN mg/100 g	TVN mg/100 g	Organoleptic evaluation Fried Taste[b]	Fried Odor[c]	Boiled Taste	Boiled Odor
0	2.5×10^6	43	<3	0[d]	7.0	0.3	7.3	2.2	2.2	3.5	3.3
0.5	1.6×10^6	3.6	<3	0	7.2	0.1	7.3	—	—	—	—
1	7.3×10^6	23	3.6	0	7.0	0.3	5.6	1.8	2.5	3.0	3.3
2	4.9×10^6	3.6	<3	0	7.1	0.2	7.6	2.3	2.2	3.8	3.0
3	5.0×10^6	<3	<3	0	—	—	—	2.3	2.7	2.8	3.0
4	7.6×10^6	3.6	<3	0	—	0.2	6.6	2.8	2.8	4.5	3.0
6	3.6×10^6	3.6	<3	0	7.4	—	—	—	—	—	—
8	2.1×10^6	<3	<3	0	7.2	—	—	—	—	—	—
12	1.1×10^6	3.6	<3	0	7.3	0.2	6.6	2.7	2.0	3.8	3.3

[a]APC Aerobic Plate Count
[b]Values are based on a 5-point scale [1 = excellent, no defect;]
[c]Values are based on a 5-point scale [5 = marked defect, unacceptable]
[d]None present in 10^{-1} g.

TABLE 4. MICROBIOLOGICAL, CHEMICAL AND ORGANOLEPTIC CHANGES IN SAMPLE 212 SUBJECTED TO HOLDING AT 0 C[a]

Day	Aerobic plate count/g at 35 C	25 C	7 C	Coliform MPN/g	*E. coli* MPN/g	Coag.-pos. staph.	Entero-cocci MPN/g	pH	TMN mg/100g	TVN mg/100g	Organoleptic evaluation Odor
0	3.9×10^5	1.2×10^6	1.7×10^6	43	7.3	0	43	7.1	0.9	9.6	2.0
0.5	5.3×10^5	2.7×10^6	3.8×10^6	150	<3	10^{-1}[b]	43	7.1	0.8	7.6	—
1	1.7×10^6	6.3×10^6	8.1×10^6	93	<3	10^{-1}	93	7.2	1.2	11.6	3.0
3	7.8×10^5	9.8×10^6	1.7×10^7	93	<3	0	93	7.6	1.1	9.6	2.8
5	4.5×10^6	1.1×10^8	1.7×10^8	93	3.6	0	150	7.4	3.3	15.4	3.3
7	6.8×10^7	7.2×10^8	7.6×10^8	3.6	<3	0	460	6.8	2.5	12.1	4.5
10	4.0×10^7	1.4×10^9	1.6×10^9	16	<3	10^{-1}	460	6.9	6.9	25.6	4.8
15	1.8×10^8	6.7×10^8	5.5×10^9	460	<3	0	93	6.3	7.3	37.6	4.8

[a]Footnotes in Table 3 apply.
[b]Present in 10^{-1} g.

TABLE 5. PERCENTAGE DISTRIBUTION OF MICROBIAL FLORA OF BREADED SHRIMP SAMPLE 2 A BEFORE AND AFTER STORAGE AT 0 AND 10 C WITH PLATE INCUBATION AT 25 C

Type	Initially	0 C (10 d)	10 C (5 d)
Pseudomonas	63.9	22.5	15.0
Flavobacterium	8.3	—	—
Moraxella	—	10.0	10.0
Aeromonas	5.6	—	10.0
Enterobacteriaceae	2.8	7.5	5.0
Bacillus	2.8	30.0	37.5
Coryneform	8.3	—	2.5
Microbacterium	8.3	22.5	17.5
Micrococcus	—	7.5	—
Sarcina	—	—	2.5

TABLE 6. PERCENTAGE DISTRIBUTION OF MICROBIAL FLORA OF BATTER AND BREADING

Type	Percentage distribution[a]	
	Batter	Breading
Pseudomonas	—	7.5
Moraxella	—	5.0
Bacillus	70.0	50.0
Coryneform	7.5	17.5
Microbacterium	22.5	20.0

[a]Colonies were picked from SMA plates incubated at 25 C.

Neither *Salmonella* nor *V. parahaemolyticus* was isolated from plant samples of frozen breaded raw shrimp. Only plant samples of breaded shrimp were examined for these species.

Microbiological, chemical, and organoleptic examination of stored samples

Ten samples of freshly processed plant samples ranging in aerobic plate count from about 10^4 to 10^7/g were stored in the laboratory for 12 months at –23 C and examined periodically. An example of the analyses for a representative sample (No. 8) is presented in Table 3. Initially, aerobic plate counts of the 10 samples ranged from 1.4×10^4 to 9.1×10^6 and after 12 months of frozen storage from 3.9×10^4 to 2.5×10^6/g. Bacterial counts at 35 and 7 C are not presented here because compared with those at 25 C the pattern of relationship was the same as presented in Fig. 2, 3, and 4. In general, little change in aerobic plate count occurred during frozen storage for 12 months. Initial coliform counts were low (3.6 to 460/g). In 8 of the 10 samples a decrease in coliform count occurred during frozen storage. The available data are too limited to arrive at any conclusions about the effect of the storage conditions on coagulase-positive staphylococci.

Initial TMN values of all samples ranged from 0 to 3.7 (average 0.6) mg/100 g. Initial TVN values ranged from 3.8 to 12.3 (average 7.5) mg/100 g. Including all analyses, TMN values ranged from 0 to 3.8 mg/100 g, TVN values from 3.8 to 13.3 mg/100 g. Both minor decreases and increases in TVN and TMN occurred during frozen storage. The pH of the samples ranged from 6.8 to 7.6.

A comparison of the organoleptic evaluation of fried and boiled shrimp showed that the boiled samples usually were more severely criticized for taste and odor defects. A frequent comment of the judges on the taste of fried breaded shrimp was "taste breading material only." Of the fried samples, only two ranked in the range "slight off-flavor to unacceptable" (score 4-5) and/or "moderate to marked off-odor" (score 4-5). However, four of the boiled samples were in that range. The most common defects recorded were: bitter, stale, iodine, salty, fishy, petroleum, and amine-like.

In most samples only small changes in taste and odor scores were observed between the beginning and end of the storage period. For the fried samples, a difference of one point either in taste or odor score over this period was recorded for two samples.

A comparison of TMN, TVN, and organoleptic evaluations indicated that in some samples high TMN

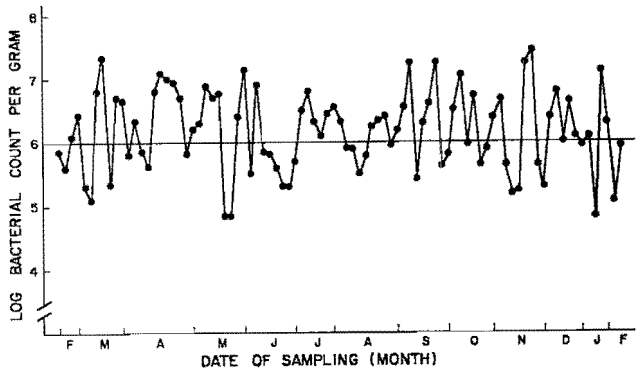

Figure 3. Aerobic plate count at 25 C of freshly processed frozen breaded raw shrimp.

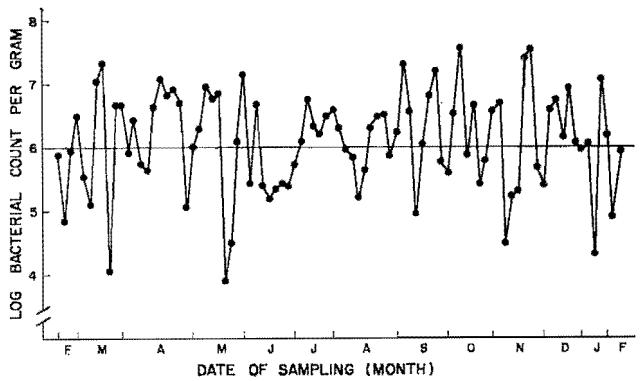

Figure 4. Aerobic plate count at 7 C of freshly processed frozen breaded raw shrimp.

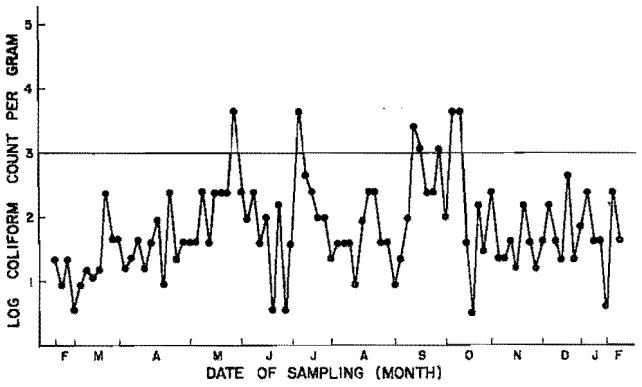

Figure 5. Coliform counts of freshly processed frozen breaded raw shrimp.

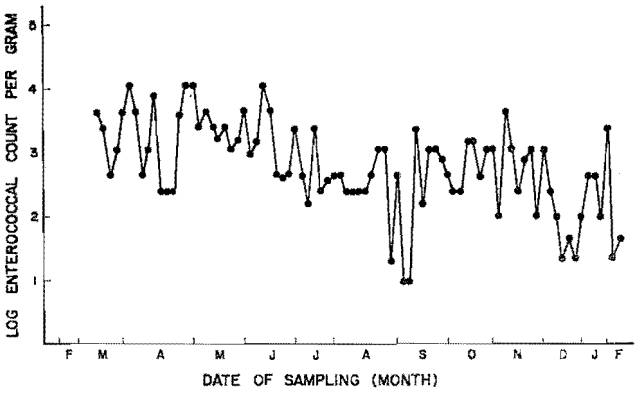

Figure 6. Enterococcal counts of freshly processed frozen breaded raw shrimp.

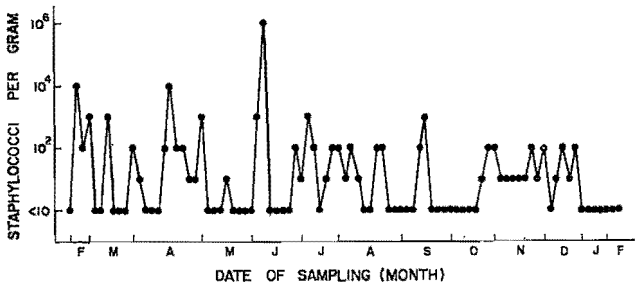

Figure 7. Staphylococci in freshly processed frozen breaded raw shrimp.

and/or TVN values were associated with moderate or marked taste and/or odor defects. In other samples, however, far less serious problems of taste and/or odor were encountered at similar or higher levels of TMN and/or TVN.

Examination of plant samples held at elevated temperatures

Three samples (1-lb. boxes) of plant processed breaded shrimp which were held at −18 to −23 C were placed at 0, 5.5, and 10 C in controlled temperature storage cabinets. Temperature changes in the products were recorded by insertion of thermocouples with a Tele-Thermometer (Yellow Springs Instrument Company). The temperature of the shrimp reached the cabinet temperature of 0, 5.5, and 10 C after 13, 10, and 8 hr, respectively (Fig. 8). An example of the microbiological, chemical, and organoleptic changes of one of the samples (No. 212) during storage for 15 days at 0 C is presented in Table 4. In general, with storage at 0 C, marked increases in aerobic plate count (at 25 C) occurred after 3 to 5 days. Storage for 15 days at 0 C increased bacterial counts from 1.2-4 $\times$ 10^8 to 0.67-2.2 $\times$ 10^{10}/g. With plate incubation at 7 C, increases in count upon storage were recorded a few days earlier. As was observed previously, bacterial counts at 35 C were significantly lower than those with plate incubation at either 25 or 7 C. Although some fluctuations were observed in the coliform, *E. coli*, enterococcal, and staphylococcal counts during the holding period, no definite increases could be attributed to the increased storage temperature.

Holding at 5.5 C caused large increases in aerobic plate count (at 25 C) after 2 to 3 days. At 5.5 C increases also occurred in the coliform count. Usually no significant increases occurred in *E. coli*, enterococcal, or staphylococcal counts at 5.5 C. With storage at 10 C, bacterial counts increased greatly after 1 to 2 days. Within 5 days marked increases were noted in coliform count and enterococci. Smaller increases were noted in numbers of *E. coli*. Coagulase-positive staphylococci were isolated after holding samples for 5 days at 10 C but not from the original samples. Storage at 0, 5.5, and 10 C caused marked decreases in the pH of the breaded shrimp.

A comparison of the aerobic plate counts at 25 C, TMN and TVN values, and organoleptic scores indicates that large increases in TMN and TVN oc-

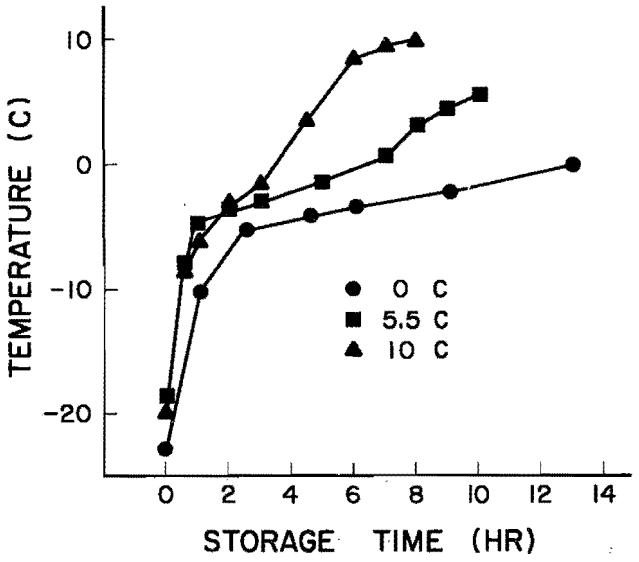

Figure 8. Temperature changes in shrimp stored at 0, 5.5 and 10 C after removal from about −20 C.

TABLE 7. MICROBIOLOGICAL ANALYSES AND pH OF 27 RETAIL SAMPLES OF FROZEN BREADED RAW SHRIMP

Age of sample (month)	Aerobic plate count per g	Coliform per g (MPN)	*Escherichia coli* per g (MPN)	Coagulase-pos. staphylococci per 0.1 g	Enterococci per g (MPN)	pH
1	1.1×10^7	23	<3	–	240	7.0
		70[a]	<3	+		
1	1.8×10^6	3.6	<3	–	240	7.2
		33	<3	+		
1	8.7×10^5	43	<3	+	44	6.8
1	3.2×10^6	43	3.6	+	460	6.9
2	4.9×10^6	9.1	<3	+	440	7.1
		65	<3	+		
2	8.1×10^6	<3	<3	–	240	7.2
		186	<3	–		
3	1.5×10^6	<3	<3	+	1,100	6.7
		146	<3	+		
3	1.1×10^7	<3	<3	+	11,000	7.8
		378	<3	+		
3	2.4×10^7	<3	<3	+	2,800	7.7
		378	<3	+		
3	6.9×10^4	<3	<3	–	11,000	7.0
		20	<3	+		
5	2.4×10^5	<3	<3	+	1,500	7.3
		13	<3	+		
5	3.5×10^6	<3	<3	–	21	7.1
7	8.3×10^4	<3	<3	–	93	6.9
		15	<3	+		
8	8.7×10^3	9.1	<3	–	3.6	6.7
		77	<3	+		
8	2.0×10^5	3	<3	–	7.3	7.1
		30	<3	+		
9	8.9×10^5	9.1	<3	+	150	6.9
		23	<3	+		
9	9.3×10^4	3.6	<3	+	3.6	7.0
		95	<3	–		
12	6.0×10^5	<3	<3	+	43	7.3
		68	<3	–		
12	1.0×10^6	43	<3	+	3.6	7.3
		68	<3	–		
12	2.8×10^6	<3	<3	–	3	7.2
		68	<3	–		
16	1.2×10^5	3.6	<3	+	93	6.9
		23	<3	+		
16	5.2×10^4	9.1	<3	–	240	6.9
19	8.9×10^4	<3	<3	–	23	6.8
		17	<3	–		
23	8.0×10^5	3.6	<3	+	240	6.8
		23	<3	+		
28	1.9×10^4	<3	<3	+	9.1	7.4
		>11,000	<3	–		
28	1.1×10^4	<3	<3	+	43	7.2
		>11,000	<3	–		
31	1.2×10^6	<3	<3	+	30	7.4

[a]Second line of data on coliforms, *E. coli*, and coagulase-positive staphylococci are results of analyses conducted at plant before samples were shipped out.

curred when bacterial counts had increased greatly and when organoleptic scores for taste and/or odor indicated the presence of defects. For example, with sample 212, after 10 days of storage at 0 C, the bacterial count had increased from 1.2×10^6 to 1.4×10^9/g, TMN values from 0.9 to 6.9 mg/100 g, TVN from 9.6 to 25.6 mg/100 g and marked off-odors were present. A similar pattern but occurring earlier was observed during storage at 5.5 and 10 C. When organoleptic defects first became noticeable bacterial counts ranged from 3.2×10^7 to 1.3×10^9/g, TMN from 2.2 to 9.6 (average 5.8) mg/100 g, and TVN

TABLE 8. DISTRIBUTION OF MICROBIAL FLORA OF 12 RETAIL SAMPLES OF FROZEN BREADED RAW SHRIMP

	No. of samples species were isolated from	Percentage distribution of isolates (Avg.)	Range of percentage distribution
Bacillus	12	33	9-68
Coryneform	7	14	0-42
Lactobacillus	4	4	0-20
Microbacterium	5	9	0-27
Streptococcus	3	3	0-14
Micrococcus	8	22	0-50
Staphylococcus	2	2	0-14
Acinetobacter	3	3	0-13
Flavobacterium	5	5	0-14
Moraxella	2	2	0-14
Enterobacteriaceae	2	2	0-13

from 12.1 to 38.7 (average 22.5) mg/100 g. Correlation between TMN and odor scores was 0.81 and between TVN and odor scores 0.78.

The distribution of the microbial flora of breaded shrimp before and after holding at 0, 5.5, and 10 C also was determined. Differences in the initial microflora of the samples were noted. *Pseudomonas* species predominated in one sample (No. 2A, Table 5), in the others *Achromobacter, Bacillus,* coryneform bacteria, *Microbacterium, Micrococcus,* and *Moraxella* were more prevelant. In some samples, significant differences in the distribution of the initial microbial flora also were associated with plate incubation temperature. Data on distribution of the microbial flora of sample 2A before and after holding at 0 and 10 C are presented in Table 5. With plates incubated at 25 C, holding shrimp at 0 and 10 C caused large decreases in *Pseudomonas* and increases in *Moraxella, Bacillus,* and *Microbacterium.* An analysis of the breading and batter used in commercial operations showed that *Bacillus* and *Microbacterium* species and coryneforms predominated (Table 6).

Microbiological examination of retail samples

Age of the 27 retail samples ranged from 1 to 31 months (Table 7). Aerobic plate counts at 25 C ranged from 8.7×10^3 to 8.0×10^8/g, coliform counts from <3 to 43/g. Bacterial counts of 14 (52%) samples exceeded 10^6/g. Coliform counts in general had decreased somewhat during storage in wholesale and retail channels. Coliform counts before distribution ranged from 13 to >11,000/g. All samples at time of purchase and about 90% before distribution had <1000 coliforms/g. *E. coli* was recovered from only 1 sample. Coagulase-positive staphylococci (in 0.1-g portions) were present in 16 (59%) of the retail samples. Enterococci ranged from 3 to 11,000/g. A wide range of enterococcal counts was encountered both with samples of low and high aerobic plate counts. No relationship existed between coliform counts of products before shipment and enterococcal counts of product at time of purchase.

Bacillus, coryneform bacteria, *Microbacterium,* and *Micrococcus* species were dominant in retail samples (Table 8). Only *Bacillus* species were isolated from all retail samples. A majority of the retail samples showed evidence of thawing and refreezing.

DISCUSSION

Bacterial counts of shrimp received for processing frequently exceeded 10^6/g. The average counts of monthly supplies ranged from 2.5×10^5 to 1.6×10^6/g. Previous studies *(20, 22)* have shown that bacterial counts of freshly harvested Gulf Coast shrimp ranged from about 10^2 to 10^4/g. Low bacterial counts can be maintained if shrimp is handled on board under sanitary conditions, and is iced promptly. Microbial activity frequently causes extensive deterioration of quality characteristics particularly when counts reach levels of 10^8 to 10^7/g *(22)*. Differences in degree of quality losses at similar count level can be caused by a difference in microbial species. In addition, in some instances high counts are caused by bacterial growth, whereas in others contact with heavily contaminated surfaces or equipment may lead to high counts. The present results indicate a need to improve the bacteriological condition of shrimp that is used for processing.

Although the quality of the raw shrimp undoubtedly is in part responsible for the high counts of many processed breaded products, inspection of plant facilities and processing methods showed that factors related to the processing phase can contribute to additional bacterial contamination. Thorough washing of raw shrimp can reduce the microbial load. If strict sanitary procedures were maintained in the plant and batter and breading of low bacterial count were applied, one could obtain processed products with bacterial counts lower than those of the initial fresh or frozen shrimp.

Bacterial counts with plate incubation at 25 or 7 C were significantly higher than those determined with plate incubation at 35 C. This has been reported previously *(10, 19)* with other foods in which psychrotrophic bacteria constitute a significant part of the microbial flora. A high plate incubation temperature probably has a limiting effect on the growth of some psychrotrophic bacteria that are part of the natural flora of the product or enter as contaminants during harvesting, handling and processing. With plate incubation at 35 C, 17% of the samples had counts in excess of 10^6/g. This figure agrees with that reported by Surkiewicz et al. *(17)*. However, when plates in the present study were incubated at

25 or 7 C, 56% of the samples had counts in excess of 10^6/g. In this study, little relationship existed between coliform or enterococcal counts and aerobic plate count of breaded shrimp. Nickerson and Pollak *(11)* made a similar observation.

Frozen storage of breaded raw shrimp for 3 to 12 months at −23 C frequently caused minor reductions in total and coliform count. Freezing can destroy or sublethally injure bacterial cells. The latter often cannot be recovered under regular conditions of medium composition and plate incubation *(7, 9)*. This may also account for somewhat smaller colonies with plate incubation at 35 C, particularly with samples stored frozen for long periods. Poor recovery of sublethally injured cells on selective media with inhibitors may in part explain the decrease in coliform count.

In most samples of breaded shrimp stored for 12 months at −23 C changes in TMN, TVN, and odor scores were small. Careful control of the temperature probably kept chemical and microbial changes to a minimum. However, it is known that repeated changes in temperature, between the frozen state (−20 C) and the melting point can cause large decreases in bacterial counts of frozen fish *(13)*.

Laboratory conditions for holding frozen breaded shrimp at elevated temperatures were limited and do not duplicate the conditions in a truck or warehouse when freezer equipment fails. The data are useful in so far as they show the conditions of time and temperature at which changes in microbiological, chemical, and organoleptic conditions occur. Increases in coliform counts were recorded at 5.5 C, for *E. coli* and enterococci at 10 C. Storage at 0 to 10 C caused marked decreases in the pH of breaded shrimp. For iced shrimp, extensive holding usually causes an increase in pH *(22)*. In iced shrimp both the arginase-urease enzyme system and microbial activity are responsible for pH changes *(3)*. A difference in microbial activities because of differences in microbial flora of the products may be responsible for this observation. In stored iced shrimp, gram-negative species usually predominate *(20)*. Gram-positive species formed a large part of the microbial flora of breaded shrimp examined in the present study.

Large increases in TMN and TVN of breaded shrimp occurred when bacterial counts had increased significantly and taste and/or odor defects became noticeable. The lower TMN and TVN values of samples with moderate to severe organoleptic defects were respectively 4.4 mg and 24.2 mg/100 g shrimp excluding breading material. These values compare favorably with limits of acceptability reported by Montgomery et al. (5 mg TMN, 30 mg TVN) *(8)* and Iyengar et al. (15 mg TVN) *(6)*. Correlation between TMN, TVN values and odor scores were high.

The initial microbial flora of frozen breaded raw shrimp consisted primarily of *Pseudomonas, Achromobacter, Bacillus, Moraxella, Microbacterium, Micrococcus*, or coryneform bacteria. Holding samples at 0 to 10 C caused increases in *Microbacterium, Micrococcus, Bacillus*, or coryneform bacteria. Gram-positive species contributed 50 to 90% of the microbial flora of these samples. The microbial flora of batter and breading probably contributed to the large number of *Bacillus* and *Microbacterium* species. In retail samples of frozen breaded shrimp gram-positive forms also were predominant. Many of these samples had been held in storage for up to 31 months and showed evidence of repeated thawing and refreezing. This condition may have contributed to a predominance of gram-positive species and apparent lack of typical gram-negative spoilage bacteria. The number of retail samples with counts in excess of 10^6/g was similar to that reported by Nickerson and Pollak *(11)*.

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REPORT OF THE COMMITTEE ON FOOD EQUIPMENT SANITARY STANDARDS: 1971-1972

The IAMFES Committee on Food Equipment Sanitary Standards, known hereafter as the Committee, is charged with the responsibility of cooperating with other interested health organizations and related industries in the formulation of sanitary standards and educational materials for fabrication, installation, and operation of food equipment and to present to the membership those standards and educational materials which the Committee recommends be endorsed by the Association.

The purpose of this cooperative program is to aid industry in improving the design, construction, and installation of equipment so that it will lead to easy cleaning and proper functioning when placed into service in food establishments. It is the Committee's further purpose to cooperate with industry in the preparation of standards or guidelines which public health agencies will accept, thereby securing uniformity in the manufacture and nationwide acceptance of such equipment.

The following report outlines the Committee's activities during the past year in working with two health and industry organizations (National Sanitation Foundation's Joint Committee on Food Equipment Standards and the National Automatic Merchandising Association's Automatic Merchandising Health-Industry Council) and progress in meeting its purposes and objectives. It is expected these organizations will be the two groups that the Committee will work with during the coming year.

NATIONAL SANITATION FOUNDATION (NSF)

The Committee was represented at the 1972 meeting of the National Sanitation Foundation's Joint Committee on Food Equipment Standards, where action was taken on several proposals; and before the meeting, the Committee reviewed and submitted comments on each draft of these proposals. Since the meeting, the Committee has also reviewed and submitted comments on proposed changes to standards.

Basic criteria C-2 for special devices and equipment

Item 4.01 of Basic Criteria C-2 on the cleanability of food contact surfaces was revised as follows:

4.01 CLEANABILITY: All food contact surfaces shall be readily accessible for cleaning and inspection, either in an assembled position or when removed. *4.011*: In equipment where components are of such weight or design that food contact surfaces are not readily removable and/or cleaning without disassembling is intended, the component parts of the equipment shall be so arranged that cleaning and sanitizing solutions can be effectively applied to all food contact surfaces. The equipment shall be self-draining or otherwise completely evacuated, and the manufacturer's recommended cleaning procedures shall result in thorough cleaning and sanitizing of the equipment. *4.012*: In equipment of such design that heavy duty high speed operation is intended and/or

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