The following conclusions have been reached in this study:

1. Unglazed shrimp can be packed successfully for twelve months storage at 0°F., in a high gloss waxed carton with a satisfactory overwrap. Glazing is not necessary for protection.
2. "Tyton" waxed paper overwrap was as good as the cellophane overwrap from a protective standpoint. The cellophane overwraps were badly damaged during shipment of finished packages whereas the Tyton overwraps withstood shipment without damage.
3. Taste testers could not distinguish between glazed and unglazed shrimp from overwrapped packages. These shrimp were tender and juicy with good flavor, although there was a slight loss of sweetness at 12 months. Glazed and unglazed shrimp from packages without overwrap were slightly tough, with no off-flavor. The texture change appeared to be the main adverse factor resulting from loss of moisture.
4. Elimination of glazing reduced the defrosting time of a five pound frozen shrimp block approximately 36 to 55 per cent.
5. The shipping weight of a corrugated fiber board box, containing ten five-pound packages of frozen shrimp, was reduced fifteen pounds (approximately 21 per cent) by elimination of the glazing process.
6. Glazed shrimp, packaged without an overwrap, showed high weight losses, disappearance of ice glaze, and desiccation of surface shrimp.
7. When tested without overwraps, Marathon shrimp cartons provided considerably more protection for glazed shrimp than the present commercial, stapled cartons.

The laboratory test results have been confirmed by the experience of a number of shrimp packers who have completely converted their packaging line to handle unglazed shrimp in a carton-overwrap combination.

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Comparison of Objective Tests for Quality of Fresh and Frozen Gulf Shrimp

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The goal of the food technologist has been the development of simple rapid objective tests for evaluating the quality of both fresh and frozen foods. In

spite of intensive research no completely satisfactory objective test has been developed to replace organoleptic or tast panel tests for quality. Objective tests would be particularly valuable in the seafood industry, since the catch could be purchased on the basis of quality. It would aid the wholesale dealers and processors in determining and maintaining quality. The consumer would obtain a better product and this in time would create a greater demand for seafood. Thus the whole industry would be benefitted.

During the summer of 1952 freshly caught headless shrimp were stored in ice and examined daily for quality by certain objective tests. During one of these series of tests, shrimp of varying ice storage ages were packaged, frozen, and stored at 0°F. for 12 months. This is a report of the results obtained upon objectively and subjectively testing both the ice stored and the frozen stored shrimp.

Methods

The shrimp used in this study were brown shrimp *(Penaeus aztecus)* and were caught in the Gulf of Mexico 12 to 16 miles south of the west end of Grand Isle, Louisiana, in 12 to 16 fathoms of water. They were a composite taken from two drags caught at 2:30 AM and 5:30 AM. Within one hour after catching the shrimp had been headed, thoroughly washed with sea water, and packed in crushed ice. The shrimp arrived at the laboratory at 6:00 PM, at which time they were washed in cold water, then packed in a single layer in ice in a wooden box 24 x 28 x 36 inches and stored in a refrigerated room at 38°F. (3.3° C.). The layer of ice beneath the shrimp was sufficiently thick so that it was unnecessary to repack the shrimp during the course of the experiment; ice was added when necessary, however, to maintain several inches of ice on top of the shrimp. The temperature of the storage room caused sufficient ice to melt to prevent the serious development of black spots (Fieger, 1952) and to maintain the shrimp at 32° F. (0° C.). For the frozen stored samples, shrimp which had been held for 24 hours, six days and 12 days in ice were removed, washed in ice water, then placed in one-piece Marathon cartons, overwrapped with Tyton and heat sealed. They were then frozen in a plate freezer at -40° F. (-40° C.) and after 24 hours were placed in 0° F. (-18.8° C.) storage. Chemical, bacteriological and organoleptic studies were made daily on samples taken from ice stored freshly caught headless shrimp and for the frozen storage investigation monthly samples were used during a 12 month period. The shrimp were not washed or peeled after taking the sample. For both series of samples the chemical determinations included the following: tyrosine reaction (Wood, Sigurdesen and Dyer 1942), amino nitrogen (Pope and Stevens 1939), trimethylamine nitrogen (Dyer, 1945) and volatile acids (Friedmann, 1938). The bacteriological examination consisted in determining total plate counts (Green, 1949). For the organoleptic test, daily ice stored samples were placed in Marathon one piece telescope cartons, overwrapped with Tyton, frozen and stored at —40°F. (—40°C.). At the termination of the experiments the shrimp were thawed, cooked in tap water for a total boiling time of eight minutes, and panel tasted by four experienced judges. The frozen stored samples were similarly cooked at each date of sampling.

Experimental Results

Ice Storage Studies

Five separate experiments in which freshly caught shrimp were stored in ice were undertaken. Although the five lots of shrimp were caught in different locations, were of different size count, and were in one case brown shrimp while the other four were white shrimp (*Penaeus setiferus*), the analytical data were consistent. Data will be presented, therefore, only for the brown shrimp. Two advantages of using these data are that samples have been frozen and analyzed, as previously mentioned, and that accurate information of their history is on record.

Of the chemical tests used, the values for the tyrosine reaction showed no definite trends. It was concluded that this test was of no value as an indicator of quality or length of storage of fresh headless Gulf shrimp.

The values for both trimethylamine nitrogen and volatile acids are of limited usefulness as a measure of quality or length of storage of shrimp. During the first nine to 14 days in the case of trimethylamine determinations and 11 to 17 days for analysis of volatile acids, both gave values which remained relatively constant (Table 1). After this initial period both gave values which increased significantly, and lagged two or three days behind a similar increase in total bacterial plate counts. The initial rise in trimethylamine values corresponded to a plate count of 25,000,000.

TABLE 1

COMPARISON OF CHEMICAL BACTERIOLOGICAL AND OGANOLEPTIC TESTS OF ICE STORED SHRIMP

Length of Ice Storage (days)	Trimethylamine Nitrogen Mg. per 100 g. Shrimp	Volatile Acids Ml. .01N NaOH per 100 g. Shrimp	Amino Nitrogen Mg. per 100 g. Shrimp	Bacterial Plate Counts X 10° per g. Shrimp	Organo-leptic Score
1	0.3	47	333	0.5	12
2	1.0	20	396	2.5	11
3	0.3	21	318	2.8	11
4	0.9	18	278	2.6	11
5	0.6	20	297	0.1	11
6	0.4	38	276	0.8	8
7	0.6	23	303	0.7	8
8	0.7	18	272	0.7	6
9	0.4	18	253	1.6	7
10	0.5	19	251	3.0	6
11	0.6	18	230	4.2	7
12	1.0	25	238	28.6	7
13	1.5	26	227	46.0	7
14	2.0	24	210	57.0	4
15	3.4	35	186	44.0	2
16	5.4	29	118	190.0	3
17	6.9	44	196	107.0	4

The chemical test which appeared to have greatest merit was the determination of amino nitrogen. These values decreased in magnitude as the length of ice storage time increased (Table 1). It is to be noted, however, that rather wide fluctuations occurred in the values obtained,

particularly during the early period of storage. The decrease in the values for amino nitrogen reported here agree with similar changes reported by Beatty and Collins (1939) in their studies on press juice from cod tissue. They are opposite, however, to that reported by Campbell and Williams (1952) for shrimp, and Sigurdsson (1947) for herring, both obtaining increases in amino nitrogen during refrigerated storage. Beatty and Collins (1939) found the decrease in amino nitrogen approximately equals the increase in ammonia nitrogen and they suggest that bacterial de-amination of amino acids liberated from tissue proteins would account for the results obtained. It should be pointed out that in all our experiments on ice storage of freshly caught shrimp the amino nitrogen values decreased with increased storage time.

The results of taste panel experiments showed that the palatability and flavor of the shrimp decreased slightly during the first five days of storage (Table 1). Following this initial period a sharp break in the curve occurred and by the eighth day the shrimp had lost their characteristic sweet shrimp flavor. During the following seven-day period they were flat tasting and no off flavors associated with spoilage were noted. The cooked meats did not have the opaque white appearance of cooked fresh shrimp, but rather a faint bluish translucent appearance, which one would associate with insufficiently cooked shrimp. This second period was followed by another sharp break in the flavor curve. At this time off flavors were evident and in our opinion these shrimp were inedible.

For evaluating early stages of storage of shrimp, the measurement of trimethylamine nitrogen or volatile acids is of limited value. Only after spoilage has occurred, as shown by organoleptic tests or visual observation, are these tests of value. It is contended that in control work, there is little value in any test which is valid only after definite organoleptic evidence of spoilage. Dyer and Dyer (1949) consider a level of 15 mg. of trimethylamine nitrogen per 100 g. of cod fillet tissue the borderline between acceptance and rejection. Stander, Grewe, Marks and Rowan (1951) state that for stock fish stored in air at 32°F. (0°C.) the first suggested odor change occurred in the range of 6-15 mg. trimethylamine nitrogen per 100 g. of fish. Above 15 mg. the fish were definitely spoiled. When fish were stored in ice, considerable leaching of trimethylamine occurred, and after nine days, when the fish had an off odor the trimethylamine values ranged between two and 10 mg. With shrimp stored as indicated above, off odors and spoilage were evident when the trimethylamine content reached 1.5 mg. nitrogen per 100 g. of shrimp. With respect to volatile acids, the break in the curve occurred one to two days later than for trimethylamine. With unspoiled shrimp neither of these tests are of value in denoting how long the shrimp have been stored, their future probable storage life, or their quality at the time of sampling.

For amino nitrogen the following tentative value are suggested as indicators of probable length of ice storage: greater than 275 mg. amino nitrogen per 100 g. shrimp, 0 to 8 days; 275 to 200 mg., 8 to 14 days; 200 to 150 mg., 14 to 17 days and less than 150 mg. longer than 17 days. The above values apply to shrimp of 28 count per pound. For shrimp of smaller sizes, values for amino nitrogen were somewhat lower so that the suggested values will have to be used with reservation.

From his studies of iced white fish Shewan (1951) divided the course of spoilage into four phases. During the first phase of 0 to 6 days there was no marked spoilage. In the second phase of 6 to 12 days the first definite signs of spoilage became evident. These consisted of softer flesh, staler appearance and strengthening of the odor. From 12 to 16 days these become more intense and are designated the third phase. In the fourth phase of 16 days and longer, rapid deterioration from staleness to putridity occurred. For ice stored shrimp it is suggested that the progressive changes in quality be divided into three phases or stages. During the first period of 0 to 7 days of storage the shrimp gradually lose their characteristic sweet flavor. The flesh of the cooked product is firm and has an opaque white color. The second stage from the eighth to the 14th day of storage is characterized by a tasteless product, the cooked meat is softer and its color changes to a very faintly bluish opalescent appearance. Cooking these shrimp for 30 minutes in boiling water does not change their appearance to the opaque white of fresh shrimp of phase one. In phase three, over 14 days storage, rapid deterioration occurs. The shrimp are softer and off odors of amines become pronounced. At the present time the shrimp industry is attempting to improve the quality of shrimp products placed on the market. The result reported here show that prime quality fresh shrimp, which have the characteristic sweet flavor of the freshly caught product, can result only when the shrimp are ice stored for periods shorter than seven days. If stored for eight to 14 days the consumer will obtain a product poorer in flavor, appearance and texture. These recommendations for storage time are more stringent than those recently suggested by Campbell and Williams (1952).

On the basis of the evidence presented, two types of changes are postulated to account for loss of quality and spoilage of shrimp. One of these causes loss of the sweet flavor and some softening of the tissue. These changes predominate during the first seven days of ice storage and probably are catalyzed by tissue enzymes and can be designated as tissue autolysis. While loss of quality progresses during this period spoilage has not occurred. This indicates there is no ripening process such as occurs with meat. The other type of change predominates during the later storage period and results from the multiplication of bacteria. Some of the products of bacterial action give to the shrimp the odors and flavors associated with spoilage.

Frozen Shrimp Results

The results of the frozen shrimp study for all three samples showed that no significant changes occurred in the values obtained for the tyrosine reaction, volatile acids or amino nitrogen determinations during 12 months of frozen storage. Of the trimethylamine-nitrogen determinations the 24 hours ice storage sample showed no change over the same period of frozen storage, the values fluctuating between 0.2 and 0.6 mg., average 0.44 mg., of trimethylamine nitrogen per 100 g. of shrimp. A similar range in values was obtained for the six days ice storage sample during the first six months of storage, with longer periods of frozen storage the values fluctuated around one mg. The average over the 12 months period was 0.56 mg. For the 12 days ice storage sample, the trimethylamine nitrogen values fell

from an initial amount of 1.2 mg. to a low of 0.7 mg. after four months storage and then rose maintaining values which fluctuated around 1.5 mg. per 100 g. shrimp, the average value for these samples was 1.26 mg. It should be noted that in raw shrimp as well as in frozen shrimp the odor of trimethylamine can be detected with values as low as 1.5 mg. trimethylamine nitrogen per 100 g. shrimp.

The bacterial plate counts for both the 24 hour and six days ice storage samples remained in the low ten thousands after the first month of frozen storage. With the 12 days ice storage sample, however, the count was considerably higher and fluctuated quite widely, probably because of the variable quality of the individual shrimp at the time of packaging and freezing.

With frozen shrimp the subjective organoleptic test was the best quality indicator of the methods studied. During the first seven months of frozen storage, the 24 hour ice storage sample gradually lost its characteristic sweet flavor. The six days ice storage sample, however, had become tasteless after three months of frozen storage. During the remainder of the frozen storage period for both samples the shrimp were tasteless, and no off flavors were evident. At each time of sampling, however, the 24 hour ice storage sample rated better than the six days ice storage sample. Since the 12 days ice storage sample had lost its sweet shrimp flavor prior to freezing, it was rated of poorer quality than the other two samples at each time of testing. They were tasteless the first nine months of frozen storage and then developed a bitter taste on longer storage. From these results it is evident that the length of time shrimp are stored in ice prior to freezing affects both the quality of the frozen product and the length of time they remain an acceptable product during frozen storage.

Summary

Chemical, bacteriological and organoleptic studies were made daily on samples taken from ice stored fresh headless shrimp, and monthly on samples of these same shrimp which had been frozen after 24 hours, six days and 12 days ice storage.

On the ice stored fresh headless shrimp the tyrosine reaction was shown to be of little or no value as an indicator of quality. Determinations of trimethylamine nitrogen and volatile acids were of value in indicating whether spoilage had occurred, but did not give information of pre-spoilage changes. Significant increases in bacterial plate counts preceded by two or three days similar increases in volatile acids and trimethylamine nitrogen values. Amino nitrogen values decreased with increasing length of ice storage and correlated quite well with taste panel tests of flavor and quality.

The results of our taste panel studies showed that during the first five days of ice storage the shrimp retained their characteristic sweet flavor. During the sixth and seventh days of ice storage there was a rapid loss of flavor and from the eighth to the 14th day they were characterized by being flat tasting. Beyond 14 days storage spoilage occurred with the simultaneous development of off flavors. It is postulated that loss of quality during the early period of ice storage is caused mainly by autolysis and with longer storage spoilage occurs mainly through bacterial action.

On the frozen samples no significant changes occurred in the values

obtained for the tyrosine reaction, the amino nitrogen or the volatile acids determinations during 12 months of frozen storage for the three series of samples. A small increase in the amount of trimethylamine nitrogen was observed for the six days and 12 days ice storage samples after seven and four months of frozen storage respectively. No change was obtained, however, for the 24 hour ice storage sample. It is concluded that none of the objective chemical tests studied are of value in indicating changes in quality of stored frozen shrimp. Bacterial plate counts are also of doubtful value, a very high count, however, would indicate that the shrimp were of poor quality at the time of packaging and freezing. The converse is not necessarily true, namely, that a low plate count indicates shrimp of high quality.

Of all the tests studied, the subjective organoleptic or taste panel test was the only one which revealed changes in quality during frozen storage. The 24 hours ice storage samples retained their sweet flavor during seven months of frozen storage, while the six days ice storage samples had become tasteless after three months of frozen storage. The 12 days ice storage samples were tasteless the first nine months of frozen storage and then developed a bitter taste on longer storage.

From these results it is evident that changes induced by bacteria or catalyzed by enzymes are proceeding too slowly at 0°F. (−18.8°C.) to be used to measure modification in quality. This also explains why foods retain their quality during relatively long periods of frozen storage.

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