EFFECT OF FLUCTUATING STORAGE TEMPERATURES ON QUALITY OF FROZEN FISH FILLETS

By S. R. Pottinger *

ABSTRACT

VERY LITTLE DEFINITE INFORMATION OR ACTUAL DATA CAN BE FOUND IN SUPPORT OF THE MUCH-REPEATED STATEMENT THAT FLUCTUATING TEMPERATURES HARM THE QUALITY OF FROZEN FOODS. BECAUSE OF THE NEED FOR THIS TYPE OF INFORMATION FOR FISH, A STUDY OF THE EFFECT OF FLUCTUATING STORAGE TEMPERATURES ON FISH QUALITY WAS INITIATED AT THE COLLEGE PARK (MARYLAND) FISHERY TECHNOLOGICAL LABORATORY OF THE U. S. FISH AND WILDLIFE SERVICE.

A TOTAL OF APPROXIMATELY 500 SAMPLES OF CELLOPHANE-WRAPPED STRIPED BASS AND BOSTON MACKEREL FILLETS WERE HELD AT CONSTANT TEMPERATURES OF -10° F., 0° F., AND 15° F., AND AT TEMPERATURES FLUCTUATING BETWEEN -10° F. AND 0° F., AND BETWEEN 0° F. AND 15° F. AT CYCLES OF ONE, THREE, AND FOUR DAYS FOR VARIOUS LOTS.

THE STRIPED BASS FILLETS HELD AT -10° F. AND 0° F. REMAINED IN A SATISFACTORY CONDITON FOR 8 TO 9 MONTHS, WHILE 3 MONTHS WAS THE LIMIT OF THEIR STORAGE LIFE AT 15° F. THE BOSTON MACKEREL FILLETS HAD A STORAGE LIFE OF ABOUT TWO MONTHS AT 15° F., AND APPROXIMATELY TWICE THAT TIME AT -10° F. AND 0° F.

AS BASED ON PALATABILITY SCORES, VOLATILE ACID NUMBERS, "DRIP" DETERMINATIONS, AND VISUAL EXAMINATIONS, THERE WAS NO ADVERSE EFFECT ON THE QUALITY OF FROZEN FISH FILLETS DUE TO FLUCTUATING STORAGE TEMPERATURES IN THE TEMPERATURE RANGES COVERED IN THESE EXPERIMENTS. THE AVERAGE STORAGE TEMPERATURE ENCOUNTERED DURING THE FLUCTUATIONS WOULD SEEM MORE LIKELY TO BE THE DECIDING FACTOR.

- - - - -

INTRODUCTION

In many articles dealing with the storage of frozen foods, considerable emphasis has been placed on the need for keeping foods at a constant storage temperature at all times. That such a condition is very difficult and often impossible to satisfy is quite obvious when some of the problems connected with the maintenance of constant temperatures are considered. Some of the causes of fluctuations are: using storage rooms for freezing; overloading of the refrigeration equipment; power failure; equipment breakdowns; improper setting of control devices; transferring frozen products from one storage room to another; and transporting frozen products from producer to consumer. Considering the number of opportunities for the temperature to change, it is quite possible that some products may undergo a series of fluctuations in temperature before reaching the ultimate consumer.

Very little definite information or actual data can be found in support of the much-repeated statement that fluctuating temperatures harm the quality of frozen foods. In many cases, the statement is undoubtedly based on hearsay and has been passed along for many years. Very often, the statement is based on a theoretical estimation of the effect of temperature changes on the increase and decrease in vapor pressure and its effect on the water transfer in the stored product. This would supposedly affect the rate of desiccation and size of ice crystals.

* CHEMIST, FISHERY TECHNOLOGICAL LABORATORY, BRANCH OF COMMERCIAL FISHERIES, U. S. FISH AND WILDLIFE SERVICE, COLLEGE PARK, MD.

Joslyn (1932), Finnegan (1938), Plagge (1938), Guest (1939) and Christensen (1945) stressed the need for constant storage temperatures but did not give data. Taylor (1932) stated that the maintenance of constant storage temperatures is highly important. But he further qualified his statement by noting that conclusions are commonly drawn from readings of fluctuating air temperatures in the storage space and that the only temperature fluctuation that has any effect on fish is that in the fish itself. He further mentioned that a considerable period of time is required to change the temperature of the mass of fish in storage, but no data are given. On the other hand, Woodroof and Shelor (1947) gave data showing that more rapid deterioration of fruits occurred at a storage temperature fluctuating from 0° to 10° F., than at a constant temperature of 10° F.

Shrewsbury, et al, (1942) presented considerable data indicating that temperature fluctuations between 4.5° and -15° F. caused no adverse changes in pork. Hustrulid and Winter (1943), working with fruits, vegetables, and meats, found that a constant storage temperature was not important if the product was properly selecte prepared, and packaged, and if the storage temperature was below 5° F. Gortner, et al, (1948) suggested that their data indicated that the quality of frozen foods was not seriously impaired by temperature fluctuation, with the possible exception of that due to a desiccating effect. Hustrulid, Winter, and Noble (1949) studied the effect of temperature fluctuations in the range 0° to -10° F. on the quality of beans, strawberries, beef, and pork. There was no evidence that growth of ice crystals caused greater cell destruction due to fluctuating temperature. These workers believed that the effects of a fluctuating storage temperature, per se, on frozen foods were not important below 0° F. for color, flavor, texture, or nutritive value. The need for good packaging materials was stressed, however.

As with other products, it has been a generally-accepted and frequently-repeated statement that fluctuating freezer storage temperatures are detrimental to the quality of frozen fish. There are, however, very few, if any, data in the literature to support this idea. Because of the need for information of this type for fish, a study of the effect of fluctuating storage temperatures on the quality of fish was initiated at the College Park (Maryland) Fishery Technological Laboratory of the U. S. Fish and Wildlife Service.

PREPARATION OF SAMPLES

Two varieties of fish were used in the tests. Striped bass or rockfish (Roccus saxatilis) was chosen as being representative of a non-fatty type of fish. Since the fat in fish is very susceptible to oxidation and often undergoes rapid changes during frozen storage, a fatty type of fish was included and was represented by Boston mackerel (Scomber scombrus).

The striped bass were obtained from a nearby packing house and had been out of the water less than one-half day when brought to the laboratory. The Boston mackerel were taken directly from the boat in Boston and shipped immediately by railway express, and the shipment arrived at the College Park laboratory on the following day. Both varieties of fish were filleted upon arrival at the laboratory The fillets were washed thoroughly in tap water and allowed to drain. They were then placed in a chilled room with a temperature of 35° F. Wrapping of the fillets was started as soon as possible, and only a few fillets were taken from the chilled room at a time.

Fillets of each variety of fish taken at random were wrapped in pairs in moisture-vaporproof cellophane. They were weighed before and after wrapping. A tightly

applied druggist's wrap was used on half of each lot of fillets. The other half of each lot was wrapped so as to permit large air spaces to remain in the packages in order to determine whether fluctuations in temperature caused increased moisture loss and cavity ice or frost formation within the package. All packages were immediately placed individually on freezer plates in a room at a temperature of -15° F. and held there for approximately two days.

An equal number of packages of both varieties of fish, in tight and loose wraps, were placed in storage at the following temperatures: -10°; 0°; fluctuating between 0° and -10°; 15°; and fluctuating between 0° and 15° F. As planned originally, fluctuations in temperature were to occur every four days by moving the fillets from the one temperature to the other. After the first month of storage, it was apparent that the mackerel would have a relatively short storage life. Therefore, it was decided to subject various mackerel samples to additional fluctuations in temperature in order not to discard a large number of unused samples because of poor quality; consequently, fluctuations at three-day and one-day intervals were also maintained as far as possible. But the striped bass fillets were subjected to the four-day cycle only.

A sufficient number of packages were prepared to make the required number of examinations at monthly intervals. Over the entire storage life of the products, two and, in a number of cases, three examinations each on different packages were made.

EXAMINATION OF SAMPLES

At monthly intervals, two separate packages each of striped bass and mackerel (in a number of instances three separate packages of mackerel) fillets were removed from storage and weighed before and after removing the wrapper. Each package contained two complete fillets. After noting the condition of the frozen fillets, portions from each fillet were taken for palatability tests, determination of "drip" or quantity of liquid that separates upon thawing, and at less frequent intervals, determination of volatile acid numbers. The last is a chemical test sometimes used as an indication of relative freshness of fish. Taste characteristics in particular were noted in determining quality since flavor is a deciding factor as to whether a product is in salable condition.

Palatability tests were made by a panel consisting of 4 or 5 members of the laboratory staff who were experienced in this type of test. Scores were based on appearance, flavor, and texture of the product. A sample receiving a weighted score below 85 was considered unacceptable. In preparing the fillets for the test, they were thawed at room temperature, brushed lightly with vegetable oil, and baked in a preheated oven at a temperature of 500° F. for 10 to 12 minutes, depending on the size and thickness of the fillets.

The quantity of "drip" which formed upon thawing of the fillets was determined as follows:

The frozen fillet was weighed and then placed upon a coarse-meshed wire screen inside of a rectangular-shaped glass dish. The screen was raised slightly above the bottom of the dish so as to permit drainage of the fillet. A sheet of moisture-vaporproof celophane was placed over the top of the dish and taped in place in order to retard loss of moisture from the fillet. After approximately four and one-half hours at room temperature, the thawed fillet was removed, blotted lightly with a paper towel and weighed. The loss in weight represented the "drip."

Volatile acid numbers were determined by the method of Hillig and Clark (1938).

RESULTS

The discussion of the results will be limited to those for the tight-fitting packages, unless otherwise noted, since loose-fitting packages are never to be recommended for use in frozen food storage and were included in these tests only in an attempt to show differences in weight loss and cavity ice formation which might occur as a result of fluctuating storage temperatures.

Table 1 - Average of Two Palatability Scores for Tightly-Wrapped and Loosely-Wrapped Packages of Striped Bass Fillets Stored at Various Temperatures

Storage Temperature	Type of Wrap	Palatability Score 1/ --Storage Period in Months--									
		1	2	3	4	5	6	7	8	9	10
-10° F.	Tight	99	100	98	90	91	89	90	88	88	82
	Loose	98	100	95	88	84	86	81	82	81	72
Fluctuating between -10° F. and 0° F. at four-day intervals	Tight	98	100	97	89	90	89	89	88	88	83
	Loose	95	100	95	89	87	87	83	83	80	72
0° F.	Tight	99	100	98	87	89	87	87	87	84	82
	Loose	98	100	97	86	84	85	78	82	75	75
Fluctuating between 15° F. and 0° F. at four-day intervals	Tight	99	100	97	87	83	81	76	74	74	-
	Loose	98	100	96	79	81	80	80	80	-	-
15° F.	Tight	100	100	94	84	81	81	72	71	69	-
	Loose	95	99	95	77	77	77	77	71	-	-

1/ THE PALATABILITY SCORE WAS CALCULATED AS FOLLOWS: THE FILLET WAS SCORED ON THE BASIS OF 1 TO 10 POINTS EACH FOR APPEARANCE, FLAVOR, AND TEXTURE. THE FLAVOR SCORE WAS DOUBLED IN ORDER TO GIVE ADDITIONAL WEIGHT TO THIS FACTOR. THE MEAN AS A PERCENT OF THESE SCORES RESULTED IN THE PALATABILITY SCORE. A SAMPLE WITH A SCORE BELOW 85 WAS CONSIDERED UNACCEPTABLE.

The average palatability scores for the striped bass fillets are given in table 1. The tightly-wrapped products held at constant temperatures of -10° and 0° F., and at temperatures fluctuating between these two points received satisfactory and nearly identical scores at the end of eight months of storage. After nine months of storage, the samples stored under this fluctuating temperature range received the same score as those held at a constant temperature of -10° F. At this time, the samples held at a constant temperature of 0° F. were not considered satisfactory.

All of these striped bass samples, in the raw state, were generally satisfactory in appearance until after the tenth month of storage. Slight, though almost negligible, surface desiccation occurred at that time on the samples in all three lots. A slight fishy odor was noted at the examination after eight months, and this increased somewhat after each succeeding month. The color was not as bright as that of fresh fillets but was commercially satisfactory.

After only four months of storage at 15° F., the striped bass fillets failed to receive an acceptable score. At the same time, those undergoing temperature fluctuations between 15° and 0° F. were still acceptable. No noticeable surface desiccation had occurred in either lot at this time, and the odor and appearance of the uncooked fillets were satisfactory. The early low palatability scores noted were attributable mainly to adverse changes in flavor and texture.

Table 2 - Average of Two (or Three) Palatability Scores for Tightly-Wrapped and Loosely-Wrapped Packages of Boston Mackerel Fillets Stored at Various Temperatures

Storage Temperature	Type of Wrap	Palatability Score --Storage Period in Months-- 1	2	3	4	5
Constant:						
-10° F.	Tight	95	96	92	89	86
	Loose	98	95	89	86	78
0° F.	Tight	97	96	91	84	81
	Loose	98	96	89	81	76
15° F.	Tight	94	89	71	55	-
	Loose	96	90	67	60	-
Fluctuating at four-day intervals:						
Between -10° and 0° F.	Tight	97	97	93	84	-
	Loose	97	96	87	80	-
Between 0° and 15° F.	Tight	98	95	71	73	-
	Loose	95	92	66	66	-
Fluctuating at three-day intervals:						
Between -10° and 0° F.	Tight	1/	97	91	88	84
	Loose	1/	93	91	85	80
Between 0° and 15° F.	Tight	1/	91	75	67	-
	Loose	1/	91	76	59	-
Fluctuating at one-day intervals:						
Between -10° and 0° F.	Tight	1/	97	90	85	85
	Loose	1/	93	88	86	78
Between 0° and 15° F.	Tight	1/	90	74	51	-
	Loose	1/	84	78	51	-

1/ DURING THE FIRST MONTH OF STORAGE, THESE SAMPLES WERE SUBJECTED TO TEMPERATURE FLUCTUATIONS AT FOUR-DAY INTERVALS. THE PALATABILITY SCORES FOR THIS PERIOD ARE GIVEN IN THE GROUP "FLUCTUATING AT FOUR-DAY INTERVALS." (SEE NOTE TO TABLE 1 FOR METHOD USED IN CALCULATING PALATABILITY SCORE).

The palatability scores for the Boston mackerel fillets are given in table 2. On the basis of these scores, there was no apparent deterioration of quality due to fluctuating storage temperatures. The scores for the samples undergoing temperature changes between -10° and 0° F., irrespective of the rate of fluctuation, did not differ greatly from those for samples held at a constant temperature of -10° and a constant temperature of 0° F. In the case of the samples subjected to temperature fluctuations between 0° and 15° F., the scores during the first and second months of storage do not signify any greater deterioration in quality than those for the fillets held at a constant temperature of 15° F. This is also substantially true for the third and fourth months, although the scores at this time were too low to be acceptable.

In regard to the condition of the mackerel fillets prior to being cooked, those held at -10° F. had only a slightly rancid odor at the end of the five-month storage period. However, a slight fishy odor became apparent in some samples at the end of two months of storage and became stronger as the storage period progressed. Slight darkening of the flesh occurred after the third month. The color was not too attractive after that time. No "rusting" (extreme discoloration of the fat due to oxidation) was apparent in any of the samples.

Some of the mackerel fillets held at 0° F. had a slightly rancid odor at the examination after the third month and some darkening in color had occurred, though no "rusting" was apparent. This was true also, in general, for the fillets undergoing fluctuations in temperature between -10° and 0° F.

The fillets held at 15° and at temperatures fluctuating between 0° and 15° F. were slightly rancid after the second month of storage and were showing signs of

a yellow discoloration. After further storage, the rancidity became very pronounced and extreme "rusting" and discoloration occurred.

On the basis of these tests, mackerel fillets appeared to have a storage life of about two months at 15° F. and approximately twice this life at the lower temperatures included in the tests.

Table 3 - Volatile Acid Numbers for Tightly-Wrapped Packages of Striped Bass and Boston Mackerel Fillets Stored at Various Temperatures

Storage Temperature	Volatile Acid Number				
	Boston Mackerel Fillets	Striped Bass Fillets			
	... Storage Period in Months				
	4	4	6	8	10
-10° F.	6.4	3.4	4.8	5.0	6.6
Fluctuating between -10° and 0° F. at four-day intervals	6.4	3.8	5.2	5.6	7.0
0° F.	7.6	4.0	5.2	6.0	7.2
Fluctuating between 15° and 0° F. at four-day intervals	9.2	4.0	4.8	5.8	7.4
15° F.	10.4	4.0	5.2	6.6	7.8

Volatile acid numbers, a chemical index used to some extent for expressing relative freshness of fish on a numerical basis, were determined at intervals for both varieties of fillets. These values increase as freshness decreases. Table 3 shows relative values for the different lots after storage for various periods. Although the results cannot be considered statistically significant, they are interesting since they roughly follow the trend shown by the palatability scores. The volatile acid numbers for the samples subjected to fluctuating temperatures generally fall between the numbers for the corresponding samples that were held at a constant storage temperature. No adverse effect due to fluctuating temperatures is apparent. Initial values were not obtained.

The quantity of "drip" occurring upon thawing of both varieties of fillets (tables 4 and 5) remained quite small during the entire course of the tests. A slight increase occurred after a few months of storage for the striped bass fillets but was still too small to be of much consequence. Almost negligible changes in the amount of "drip" from the mackerel fillets occurred during storage. Fluctuating storage temperatures appeared to have very little effect on the amount of "drip," except for possibly a few of the striped bass samples (table 4).

Table 4 - Quantity of "Drip" in Percent for Tightly-Wrapped and Loosely-Wrapped Packages of Striped Bass Fillets Stored at Various Temperatures

Storage Temperature	Type of Wrap	"Drip" in Percent Storage Period in Months									
		1	2	3	4	5	6	7	8	9	10
-10° F.	Tight	1.6	1.8	1.6	1.9	2.1	2.2	2.4	2.0	2.3	2.0
	Loose	1.3	1.3	1.5	1.4	1.7	1.6	2.0	2.1	1.9	2.2
Fluctuating between -10° and 0° F. at four-day intervals	Tight	1.2	1.6	1.6	2.3	2.1	2.4	2.6	2.8	2.4	2.2
	Loose	1.4	1.8	1.8	2.0	1.9	2.4	2.9	2.8	2.5	2.2
0° F.	Tight	1.6	1.5	1.6	1.9	2.2	2.5	2.2	2.1	2.0	1.8
	Loose	1.4	1.8	1.7	1.8	1.7	2.3	2.5	2.5	2.0	2.1
Fluctuating between 15° and 0° F. at four-day intervals	Tight	1.3	1.4	1.5	2.6	2.4	2.6	2.4	3.0	3.2	-
	Loose	1.6	1.9	1.6	1.9	2.6	2.2	2.3	2.7	2.3	-
15° F.	Tight	1.3	1.6	1.7	2.0	2.7	2.4	2.7	2.3	2.0	-
	Loose	1.2	2.0	1.7	1.8	2.6	2.3	2.2	1.6	1.9	-

Table 5 - Quantity of "Drip" in Percent for Tightly-Wrapped and Loosely-Wrapped Packages of Boston Mackerel Fillets Stored at Various Temperatures

Storage Temperature	Type of Wrap	"Drip" in Percent Storage Period in Months 1	2	3	4	5
Constant:						
-10° F.	Tight	3.1	3.0	3.1	3.3	3.1
	Loose	2.4	3.0	3.2	3.3	3.5
0° F.	Tight	3.3	3.1	3.2	3.2	3.3
	Loose	2.9	3.1	3.5	3.4	3.7
15° F.	Tight	3.0	2.9	3.2	3.5	-
	Loose	3.4	2.9	3.2	3.4	-
Fluctuating at four-day intervals:						
Between -10° and 0° F.	Tight	2.9	2.7	3.4	3.7	-
	Loose	2.9	3.1	3.1	3.3	-
Between 0° and 15° F.	Tight	3.1	3.0	3.1	3.5	-
	Loose	3.2	3.3	2.8	3.2	-
Fluctuating at three-day intervals:						
Between -10° and 0° F.	Tight	1/	3.1	3.3	3.8	3.3
	Loose	1/	3.2	3.5	3.7	4.4
Between 0° and 15° F.	Tight	1/	3.4	3.9	3.8	-
	Loose	1/	3.7	3.6	3.8	-
Fluctuating at one-day intervals:						
Between -10° and 0° F.	Tight	1/	2.6	2.9	3.0	3.0
	Loose	1/	2.8	2.9	3.2	3.2
Between 0° and 15° F.	Tight	1/	2.6	3.2	3.3	-
	Loose	1/	2.9	3.1	3.3	-

1/ DURING THE FIRST MONTH OF STORAGE, THESE SAMPLES WERE SUBJECTED TO TEMPERATURE FLUCTUATIONS AT FOUR-DAY INTERVALS. THE PERCENTAGE OF "DRIP" FOR THIS PERIOD IS GIVEN IN THE GROUP "FLUCTUATING AT FOUR-DAY INTERVALS."

Average weight losses for the tightly-wrapped samples remained quite small. Slight increases in weight loss occurred with some of the lots undergoing temperature fluctuations but were still too small to be of any particular significance.

As mentioned previously, fillet samples with loose fitting wrappers were prepared for the tests to permit cavity ice or frost to form in an attempt to measure the desiccating effect due to storage at the different constant temperatures and especially at temperatures which fluctuated. The difference in weight due to the removal of the cavity ice was taken as the measure of the amount of desiccation that occurred. However, there was such a wide variation between amounts of ice found in individual packages and in fact between groups as a whole that no particular relationship or trend was apparent.

One peculiarity was noticed in connection with a number of the tightly-wrapped samples held at 15° F. Some of the mackerel fillets, after only two months of storage, and the striped bass fillets, after six months of storage, showed considerable surface desiccation. This increased as the storage period progressed. Though not as bad, it occurred to some extent with the fillets subjected to temperature fluctuations between 0° and 15° F. This did not happen with the samples held at the other lower temperatures. Weight losses of the affected samples were slightly higher when this occurred. Apparently the cellophane offered less resistance to moisture-vapor transmission at the higher temperatures, though why this occurred sooner with the mackerel fillets is not known.

DISCUSSION AND CONCLUSIONS

The effect of temperature on the storage life of frozen foods has been a subject of considerable controversy. Until quite recently, it was not at all uncommon to find statements in the literature signifying that storage temperatures in the range of 10° to 20° F. were considered satisfactory. Even today, after numerous