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PRELIMINARY INVESTIGATION OF METHODS FOR FREEZING AND STORING FILLETS OF SOME PACIFIC NORTHWEST FISH

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INTRODUCTION

During the past fifteen years the production of frozen fillets from such east coast fish as haddock and cod has shown tremendous expansion. More recently an even more phenomenal development has occurred with respect to the production of frozen rose fish fillets. At the present time a total of over fifty million pounds of frozen fillets is being prepared annually from these three species. During a similar period no comparable increase in the production of frozen fillets from west coast fish has taken place, the total output of all species being only slightly over 350,000 pounds during 1940.

The reason for this huge difference are both economic and technological. The higher prices which many west coast fish command have not been favorable to the expansion of the packaged fish business and, in addition, various difficulties of a technical nature have hindered successful freezing of some of the more important species. The present report relates to some of these difficulties and possible methods for overcoming them.

SCOPE OF INVESTIGATION

The investigation was undertaken initially as a preliminary survey to determine changes occurring in packaged fishery products when frozen and stored under conditions comparable with existing local commercial facilities. Since, under this circumstance it would be impractical to attempt a study of too broad scope, the investigative work was limited to but four species of fish: silver salmon (*Oncorhynchus kisutch*), pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*Oncorhynchus keta*), and cape "sole" (*Eopsetta jordani*). These species, on account of their price and relative available supply, were chosen as being among those most suitable for frozen fillet production, and besides, the writers believed they would offer typical technical problems for study.

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Attention was directed to observations which would indicate the effect of pretreatment, rate of freezing, storage temperature, and method of packaging on the general appearance of the frozen and cooked fillets, flavor of the cooked fish, drip in thawed fish, and rancidity of extracted oils. These factors have been found to be of importance in the case of other species of frozen fish and hence were suspected of being of importance in the present instance.

The observations were intended to form the basis for future studies of more detailed nature, after the various problems had been evaluated. However, when the work was completed, a number of findings seemed to be of sufficient importance to be of value to the commercial fish freezer, and it was decided to publish the results even though they do not represent a completed investigation.

EXPERIMENTAL PROCEDURE

Fish were obtained from local wholesale dealers in as fresh a state as possible, the fish usually being not more than 24 hours out of the water when received.

Fillets were prepared in the accepted manner by regular skilled fillet cutters and were then transferred to the laboratory for preliminary treatment and packaging. Some were immersed for 20 seconds in a 15% brine prepared from a pure grade of butter salt; others were packaged untreated.

Freezing was accomplished by both a quick and a slow process. A plate froster was used for the quick freezing, 2 hours in the froster being sufficient to completely freeze the fillets. Slow freezing was carried out in a conventional sharp freezer at about -20°F. for 24 hours.

Fillets which were quick frozen were wrapped after freezing, and those slow frozen wrapped before freezing. Most samples were wrapped in a moisture-vapor-proof transparent paper. In one series a number of different wrappers were tried, including latex rubber bags, and in another experiment some "sole" fillets were frozen in a block and protected with an ice glaze.

The frozen fish were stored in a commercial cold storage warehouse, the temperature of which averaged about 10°F., and at the laboratory in an ice cream storage cabinet, the temperature of which was adjusted to -5°F. After 1-, 2-, 4-, and 6-month intervals, samples were withdrawn for examination.

The frozen fillets were first examined for any alteration in appearance. The fillet with wrapper removed was then weighed and

allowed to thaw overnight in a closed container which prevented loss through evaporation. The next day the excess moisture on the surface of the samples was removed with blotting paper, the fillets reweighed, and the loss in weight was calculated as drip. In all cases three fillets were used for samples and the average drip calculated.

The thawed fillets, wrapped in parchment paper, were cooked by immersing in boiling water. The appearance, flavor, and texture of the cooked fish were then carefully noted. Finally, the fillets were ground and pressed in a hydraulic press. The oil so obtained was tested for rancidity by tasting and by the peroxide method of Wheeler (1932)[2/] with slight modifications.

One series, wrapped by different methods, was weighed at monthly intervals to determine desiccation losses. An inexpensive greaseproof paper, unwaxed vegetable parchment paper, and two brands of transparent moisture-vapor-proof paper were used. In the last case, some samples were put in cardboard cartons and sealed by a commercial method in a heat sealing machine. The other papers were wrapped around the fillet without using a cardboard carton, and were held in place in some cases by rubber bands, in others by a special sealing compound.

SUMMARY

The following alterations were observed during the cold storage of the frozen fillets:

1. Alteration in color was of minor importance in the case of "sole", but drastic changes occurred with salmon. Pink salmon became yellow to grey in two months; chum salmon was badly discolored in six months; silver salmon showed some fading in six months but not nearly so much as the other salmon fillets. Definite fading could be observed in the unthawed fillets but was much more pronounced after cooking, especially in the case of the pink salmon.

2. Changes in flavor occurred with all species. The first change noted was a loss of the normally occurring flavors. A salt-fish flavor became quite pronounced after six months' storage in the case of "sole". Rancid flavors developed in the salmon, pink salmon becoming rancid in about two months, and other off-flavors forming simultaneously. Chum salmon remained relatively fresh for four months, but was rancid after six months' storage. Silver salmon was still fairly fresh after six months, with only small amounts of rancidity.

2/ Publications referred to parenthetically by date are listed in the Literature Cited, p. 38.

3. The texture of all samples became less firm and drip exuded upon thawing. Texture was altered much more in the "sole" fillets than with any of the salmon samples.

The various factors studied were found to have the following effects on the storage life of the frozen fillets:

1. Brine treatment reduced drip markedly in the case of "sole" and to a less extent for the salmon. It also had the bad effect of accelerating the development of salt fish flavor and odor in "sole" and of rancidity in salmon.

2. Use of a low storage temperature was beneficial in all cases. Drip was consistently lower in the fish held at the low temperature, development of discoloration was minimized, and rancidity and salt-fish flavors were reduced or were later in appearing.

3. Quick freezing reduced drip somewhat and improved the texture immediately after freezing. Upon subsequent storage the benefits of quick freezing were less apparent. Some of the improvement sometimes ascribed to quick freezing may actually be due to improved packaging methods which are usually employed when fillets are quick frozen.

4. Satisfactory storage of the fillets was attained only when the fish were adequately protected against desiccation and oxidation by means of suitable moisture-vapor-proof wrappers. Freezing of fillets in blocks of ice gave ample protection as long as the ice glaze remained intact.

EXPERIMENTAL RESULTS

FROZEN "SOLE" FILLETS

Three types of changes were noted during the storage of frozen "sole". These were (1) alteration in appearance, especially color; (2) increase in formation of drip; and (3) development of abnormal flavors and odors.

Changes in Appearance

The brined and unbrined fillets differed in general appearance during the entire test period. The former had a rather glossy surface and the latter a dull appearance. Also, the brined fillets had a very slight blue-grey tint when compared to the rather white unbrined fish. The blue-grey color was barely sufficient to be a disadvantage and was more than compensated for by the glossy "pellicle" associated with the brine treatment.

As oxidation occurred during storage there was a slow darkening of the streaks where the fillets were cut from the backbone. When the fillets were fresh, and during the first month of storage, these streaks were bright red in color, but after the second month, expecially in the case of fillets stored at the higher temperature, the color gradually began to turn brown, deepening in intensity with further storage. The brown color developed much more slowly at the lower temperature and even after six months the fillets held at -5°F. were comparatively unchanged in this respect.

Toward the end of the storage period another abnormal color developed. Although "sole" are considered to be a non-oily fish, actually a small amount of oil is present, and much of this is concentrated just beneath the skin. After six months' storage the color of this oil had darkened, giving a yellow tinge to the surface from which the skin had been removed. The yellow color was much more pronounced in the fillets held at the higher temperature, and in all instances this effect was intensified when the fish were cooked.

The fish wrapped in a cheap grade of paper which was not moisture-vapor-proof desiccated rapidly at the surface. Even after one month's storage they were markedly dried. Also, the red streaks became brown much sooner than with the other samples, and the development of the yellow color in the oil was greatly accelerated. These samples were so unsightly even after only two month's storage as to be no longer salable.

Formation of Drip

Drip consists of water in which is dissolved protein and other nitrogenous substances together with various mineral salts. The chief objection to drip lies in the appearance of the product which at once classifies it as frozen fish. In addition, if the drip is not utilized, as is often the case, considerable nutritive substances are discarded. In the freshly frozen fish the drip is a nearly colorless, clear fluid, but after several months' storage it is often cloudy, contains suspended protein or other material, and sometimes is distinctly yellow. The amount of drip from the thawed "sole" fillets varied from a minimum of a little over 1% in the freshly frozen fish to a maximum of nearly 10% in some of the samples after 6 months of storage. (Table 1.)

Drip formation was markedly reduced by the preliminary brine dip. (Table 2.) In most instances the preliminary treatment caused a reduction of more than 50%, and in every case drip was less in the brined samples. The decrease was greatest immediately after freezing (average 73%), but even after 6 months' storage there was 56% less drip in the brined samples. Of the 20 lots tested, an average decrease of 40% resulted.

TABLE 1.—Average drip in frozen fillets[1/]

Storage Time	Quick frozen				Slow frozen			
	+10° storage		-5° storage		+10° storage		-5° storage	
	Brined	Unbrined	Brined	Unbrined	Brined	Unbrined	Brined	Unbrined
Months	%	%	%	%	%	%	%	%
"Sole" fillets								
0	1.4	5.4	1.4	5.4	1.8	6.5	1.8	6.5
1	2.4	7.1	1.4	3.5	2.3	9.1	2.0	5.3
2	2.7	6.3	1.8	4.6	2.1	7.7	1.8	2.1
4	2.9	7.5	1.3	4.2	3.9	5.7	3.9	8.1
6	4.6	7.1	1.7	5.1	3.9	9.4	2.7	7.8
Pink salmon fillets								
0	-	-	-	-	0.6	1.5	0.6	1.5
1	-	-	-	-	3.4	5.4	4.2	5.4
2	-	-	-	-	3.9	5.6	1.7	4.3
4	-	-	-	-	2.9	5.4	2.5	4.4
5	-	-	-	-	3.3	4.9	3.3	5.0
6	-	-	-	-	6.8	5.5	3.8	5.3
Chum salmon fillets								
0	-	-	-	-	1.2	1.9	1.2	1.9
1	-	-	-	-	2.0	2.8	1.3	1.3
2	-	-	-	-	1.8	3.0	2.6	2.3
4	-	-	-	-	2.8	3.8	1.3	3.6
6	-	-	-	-	4.5	4.3	3.5	3.2
Silver salmon fillets								
0	0.45	1.8	0.45	1.8	1.8	1.2	1.8	1.2
1	1.4	1.6	1.9	3.8	2.5	3.1	1.9	2.8
2	2.0	2.3	1.5	4.2	2.5	3.0	3.5	4.4
4	3.4	1.8	2.4	4.2	2.4	4.2	3.4	3.9
6	4.7	2.4	4.9	8.3	4.3	4.4	1.7	5.8

1/ Each value in table is an average of determinations on three fillets.

TABLE 2.--Reduction in formation of drip

Storage time	Reduction due to brining				Reduction due to low storage temperature				Reduction due to quick freezing			
	Quick frozen		Slow frozen		Quick frozen		Slow Frozen		Brined		Unbrined	
	+10 F. storage	-5 F. storage	+10 F. storage	-5 F. storage	Brined	Unbrined	Brined	Unbrined	+10 F. storage	-5 F. storage	+10 F. storage	-5 F. storage
Months	%	%	%	%	%	%	%	%	%	%	%	%
"Sole" fillets												
0	74	74	72	72	-	-	-	-	29	29	17	17
1	67	57	75	62	42	53	13	42	41/	33	22	38
2	57	60	73	14	33	27	14	73	291/	0	18	1121/
4	61	69	67	52	55	44	0	301/	26	67	311/	48
6	35	66	58	65	63	28	31	17	181/	37	24	35
Pink salmon fillets												
0	-	-	60	60	-	-	-	-	-	-	-	-
1	-	-	37	22	-	-	231/	0	-	-	-	-
2	-	-	30	48	-	-	56	23	-	-	-	-
4	-	-	46	43	-	-	14	19	-	-	-	-
5	-	-	33	34	-	-	0	2	-	-	-	-
6	-	-	-	28	-	-	44	-	-	-	-	-
Chum salmon fillets												
0	-	-	37	37	-	-	-	-	-	-	-	-
1	-	-	29	0	-	-	35	54	-	-	-	-
2	-	-	40	131/	-	-	44	23	-	-	-	-
4	-	-	26	64	-	-	53	5	-	-	-	-
6	-	-	51/	91/	-	-	22	26	-	-	-	-
Silver salmon fillets												
0	75	75	501/	501/	-	-	-	-	75	75	501/	501/
1	13	50	19	32	261/	1381/	24	10	48	16	0	361/
2	13	64	17	16	25	831/	401/	471/	20	23	29	32
4	891/	43	43	13	30	1111/	471/	7	421/	57	29	71/
6	961/	41	2	71	41/	2461/	60	321/	91/	45	1901/	261/

1/ Denotes increase rather than reduction in formation of drip.

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Temperature of storage also influenced formation of drip. Among 16 sets of samples examined, 14 lots showed a decrease in drip formation attributable to low storage temperature, 1 lot showed no change, and 1 an increase. The quick frozen samples were affected more by subsequent storage at a low temperature (43% less drip) than the slow frozen samples (19% less drip).

Formation of drip was less consistently decreased by quick freezing than by the other treatments. Of 18 lots examined, 12 showed less drip in the quick frozen fish, 5 less drip in the slow frozen samples, and in 1 lot there was no difference. Immediately after freezing, the quick frozen samples had 23% less drip than the slow frozen ones, but upon subsequent storage the difference became less. The average reduction in drip formation caused by quick freezing for all the lots tested was only 11%.

A few samples were wrapped in a cheap grease proof paper which was not moisture-vapor-proof. On account of the dehydration which had taken place these fish had considerably less drip than the others. Other undesirable changes in these samples, however, preclude surface desiccation as a means for reducing drip.

Changes in Flavor and Odor

Odor is sometimes more intense than flavor, yet there are types of flavors which do not have corresponding odors. In the discussion to follow, therefore, the main emphasis will be placed on flavor with the implication that corresponding changes in odor may accompany them.

The flavor of all (cooked) samples was unaltered after 1 month's storage. After 2 months the fillets at 10°F. showed a slight development of off-flavors. The fish had a faint bitter or acrid taste and a very slight salt-fish flavor which was more noticeable in the case of the brined samples. The salt-fish flavor in the samples stored at the higher temperature increased upon further storage, the brined fillets always having the stronger flavor, until after 6 months this flavor was quite pronounced.

The samples stored at the lower temperature retained their fresh flavor longer, the unbrined sample being still fresh after six months. The brined fish held at this temperature first showed indication of the salt-fish flavor at four months' storage. (Table3.)

"Salt-fish flavor" is difficult to describe, being the flavor typical of salt cod. It also somewhat resembles certain types of rancidity, and since it usually is more pronounced in the oily layer of flesh next to the skin, it appears likely that oxidation of the oil is associated in its development.

TABLE 3.--Flavor of frozen sole fillets

Storage time Months	Flavor			
	-5° F. storage		+10° F. storage	
	Brined	Unbrined	Brined	Unbrined
0	good	good	good	good
1	good	good	good	good
2	good	good	Slight salt-fish	Very slight salt-fish also bitter flavor
4	Slight salt-fish	good	Salt-fish	Bitter flavor; slight salt-fish
6	Salt-fish	good	Strong salt-fish	Moderate salt-fish
6 1/	--	--	--	Very slight salt-fish

1/ Fish frozen in block.

FROZEN PINK SALMON FILLETS

Changes similar to those noted in the frozen "sole" were observed for the pink salmon. In addition, a rapid development of rancidity occurred which was evaluated by both organoleptic and chemical tests. The changes in the pink salmon, however, developed much more rapidly so that the fish were nearly unsalable even after only two months' storage. The pink salmon fillets were all slow frozen.

Changes in Appearance

The fillets receiving the preliminary brine dip developed the usual glossy pellicle, but this was not nearly so pronounced as was the case with the "sole", and after several months' storage, the difference in the sheen of the brined and unbrined fish diminished until at the end of the series there was no perceptible difference.

Alteration in the appearance of frozen pink salmon fillets occurs in both the pink muscle and in the dark muscle and associated oil, the latter being the more phenomenal. Two types of change develop. First, there is an intensification in the yellow pigments which tends to give a generally yellow appearance to the fish, and second, a deepening of the color of the dark muscle tissue. These changes are also accompanied by an increase in the grey-blue hue on the surface from which the skin has been removed. The unnatural colors develop very rapidly, so that within a month or two very little of the normal pink color is evident on the surface.

Apparently the disappearance of the normal pink color is less a matter of its fading than of its being obscured by the intensification of the yellow pigments, although both changes occur. Upon prolonged storage the grey color becomes spotted with dark yellow to brown patches, making a very unsightly product. On the basis of color alone the samples were unsalable after four months, and even after two months were decidedly altered in appearance. The change in color was most noticeable after the fish had been cooked, but the unthawed samples also showed decided discoloration.

The samples which received the preliminary brine dip developed the yellow color slightly more rapidly than did the unbrined fillets. On the other hand, the brined samples seemed to retain the normal pink color better than the untreated ones. Both of these effects were very slight, however.

The fillets wrapped in the paper which was not moisture-vapor-proof showed all the above described changes to a much more marked extent, and they were evident after a shorter storage period.

When the various samples were cooked the yellow color usually darkened to brown, especially after the fish had been stored for four months or longer, and at the same time much of the remaining pink color faded. Even the fish stored at the low temperature which had a minimum of the yellow color, developed a rather intense brown when cooked.

In most cases the skinned pink salmon fillets (average weight 21 oz.) had been folded over lengthwise with the skin side on the outside of the fold, and then wrapped in the moisture proof paper which did not fit absolutely tightly over the surface. Each fillet also contained a small oblong identification tag consisting of a piece of cardboard cut from a filing index card. These tags fitted tightly against the fish. It was observed that the flesh directly beneath the cardboard was of the original pink hue, while the adjacent flesh was of a nondescript grey to yellow color with no evidence of pink whatever. It was also noted that the flesh on the inside of the fold where the fillet was turned over remained pink almost to the end of the series. It was only on the outer surface that discoloration occurred.

It is therefore evident that the intensification of the yellow pigment and later development of the brown color is due to an oxidation by air, and furthermore, that even the extremely small amount of air contained within the sealed package is ample to cause the extreme discoloration encountered.

It was also noted that in a few instances where the fillets were folded so as to have the skin side inside, considerably less

discoloration resulted. It is apparent that the exact procedure used in packaging the fillets is of critical importance in determining the storage life of the product, and future tests are planned to cover this point.

Formation of Drip

Drip is less of a problem with the pink salmon than with the "sole". Thus the maximum amount of drip found in any case was 6.8% after six months' storage, and in most instances much less. In general, the various treatments showed the same trends as for the "sole". (Table 1.)

The preliminary brining process invariably resulted in less drip, the average decrease being 40%. (Table 2.) The maximum effect due to the brine treatment occurred immediately after freezing (60% reduction in drip) with a steady decline in the difference between brined and unbrined samples with increasing storage time, until after 6 months the brined sample had 28% less drip.

Storage at a low temperature also reduced the formation of drip, but to a much less extent. Of nine lots of fish examined, six stored at the low temperature had less drip, one had more drip, and two showed no difference. The average reduction in drip formation when the fillets were stored at the low temperature amounted to only 15%.

Fish wrapped in the cheap paper which was not moisture proof had very little drip, but in these cases as with the "sole", other changes in appearance and flavor of the fish stored in this way were so extreme as to eliminate the advisability of permitting surface desiccation as a method of reducing drip.

Changes in Flavor and Odor

After one month's storage the principal change in flavor was a lack of the normal salmon flavor rather than the presence of undesirable off-flavors. The fillets stored at the higher temperature were especially tasteless. The samples which had received the preliminary brine treatment had a very slight degree of rancidity which was somewhat more pronounced in the case of the fillets at the higher temperature. All samples also had a slight saltfish flavor.

After two months' storage off-flavors began to become pronounced. The samples which had been brined were definitely though not extremely rancid and all samples had a pronounced aromatic flavor and odor resembling amyl alcohol. Since this odor resembled that of the compound used in sealing the packages originally, it

is possible that this is the source of the odor. After four months' storage all fish were definitely rancid and with further storage the rancidity increased to an extreme degree completely overshadowing any other flavors.

Rancidity

The degree of rancidity was followed by means of peroxide values determined on oil extracted from the cooked fish. Peroxide values varied from 2.6 in the fresh fish to a maximum of nearly 20 after 6 months' storage (Table 4.) In experiments of this kind a small increase in peroxide value indicates a larger increase in rancid flavor than would be the case with a quantity of stored oil. This is true because not all of the oil in the flesh is oxidized to such a large extent as that at the surface of the fillet. Actually, we can suppose that when the oil near the surface (and hence with ready access to air) is quite rancid, that near the center of the fillet it is still relatively fresh. The small amount of rancid oil at the surface, however, is sufficient to give the entire fillet a rancid flavor. Thus a peroxide value of 20 in this case corresponds to an extreme degree of rancidity. Peroxide values up to 5 indicate a fresh to slight degree of rancidity and values of about 10 correspond to definite rancidity.

The preliminary brine treatment caused an increase in peroxide value averaging about 19%. (Table 5.) An increase was observed for 10 of the 11 lots examined, the eleventh lot showing a slightly higher peroxide value for the unbrined fish. This increase in peroxide value is paralleled by increase in rancid flavor and is in agreement with other findings (Banks, 1938).

The samples stored at the lower temperature had lower peroxide values in 8 out of 9 lots tested, averaging 19% less. Again, as with brine treatment, the peroxide values ran parallel to organoleptic rancidity.

FROZEN CHUM SALMON FILLETS

The chum salmon fillets developed changes upon storage similar to those occurring in pink salmon, but at a considerably slower rate.

Changes in Appearance

The brined samples had the customary pellicle surface contrasted to the dull appearance of the untreated fillets. The difference in sheen between treated and untreated fillets decreased somewhat with storage but a definite difference was still apparent even after six months.

TABLE 4.—Development of rancidity in frozen salmon fillets

Storage time	Peroxide value			
	10°F. storage		-5°F. storage	
	Brined	Unbrined	Brined	Unbrined
Months	Value1/	Value1/	Value1/	Value1/
Pink salmon fillets				
0	2.6	2.7	2.6	2.7
1	9.2	4.2	4.6	3.1
2	17.2	13.6	10.8	10.5
4	20.8	17.6	12.4	9.0
5	19.6	14.3	13.4	12.0
6	16.2	-	18.9	20.0
Chum salmon fillets				
0	3.4	1.6	3.4	1.6
1	2.1	1.8	1.5	1.7
2	5.0	3.1	1.8	1.0
4	5.5	-	3.5	3.5
6	18.7	11.3	9.4	6.4
Silver salmon fillets				
0	1.4	1.4	1.4	1.4
1	2.0	2.1	1.5	1.9
2	4.6	3.6	3.6	2.8
4	5.6	4.7	3.6	2.9
6	10.5	7.2	4.6	5.0

1/ Milliequivalents of peroxide per kilogram of oil.

TABLE 5.—Effect of test conditions on development of rancidity in frozen salmon fillets

Storage time	Change in peroxide value			
	Increase due to brining		Decrease due to lower storage temp.	
	10° F. storage	-5° F. storage	Brined	Unbrined
Months	%	%	%	%
Pink salmon fillets				
0	4	4	-	-
1	12	48	50	26
2	26	3	37	23
4	18	38	40	49
5	37	12	32	16
6	-	5 1/	17 2/	-
Chum salmon fillets				
0	112	112	-	-
1	14	12 1/	29	6
2	61	80	64	68
4	-	0	36	-
6	66	47	50	43
Silver salmon fillets				
0	-	-	-	-
1	5	21 1/	25	10
2	28	29	22	22
4	19	27	36	38
6	46	8 1/	56	31

1/ Denotes decrease.
2/ Denotes increase.

Detection of changes in the color of the chum salmon series was rendered difficult by the wide variation in the depth of the original pink color of the flesh of these fish which ranged from a very light orange-pink to a fairly deep pink color. It was necessary to compare the shade of pink at the surface of these fillets with the color of the flesh at the center. Wherever any alteration in color occurred, it was most pronounced at the surface and either entirely unaltered, or at least at a minimum, at the center of the fillet. By comparing the color at the surface with that within the fillet, it was possible to follow any changes occurring in the color in spite of the lack of uniformity among the original unfrozen fish.

Since the chum fillets were all slow frozen and were fairly large (average weight 1-3/4 lb.), the texture after freezing and thawing was somewhat soft with evidence of ice crystals at the center. The color showed no perceptible alteration at the end of the first month of storage. After two months the samples stored at the high temperature had developed a decided off-yellow shade which was mixed with the normal pink color. The latter, however, had faded somewhat to an orange shade. These fish appeared a salmon-orange hue with an overlying network effect of the yellow color. The samples at the low temperature showed but little change from their original color. The unbrined fish had only a very slight fading of the pink color to orange and no trace of yellow, while the brined fillets were orange-pink with some slight patches of yellow and they were definitely of a poorer color. These changes were all evident before thawing and were intensified considerably by cooking.

After four months' storage the appearance of the samples was similar to that after two months, but with an increase in the amount of yellow color, especially in the samples held at +10°F. The samples at the lower temperature were still almost normal in color, and there was less difference between the brined and unbrined samples, both showing some fading and a small amount of yellow color.

After six months there was a very pronounced difference in color between the fish at the low and at the high storage temperatures. The former were still close to the color of the fresh fish with very little difference in color between the surface and center of the fillet. The fish held at the high temperature were completely yellow at the surface with no evidence of pink color whatever. The difference in color at this stage was the greatest encountered in any samples examined. No difference was perceptible between brined and unbrined fish.

Formation of Drip

Drip, as with pink salmon, was a relatively minor problem varying from an average value of 1.5% in the freshly frozen fillets to an average of 3.9% after 6 months' storage (Table 1).

The preliminary brine treatment was relatively unimportant in influencing the formation of drip (Table 2). In the 9 lots of fillets examined, 5 of the brined samples and 3 of the unbrined had less drip, and in 1 lot there was no difference. Immediately after freezing the brined samples had 36% less drip, but this difference decreased with prolonged storage so that the overall average reduction in drip formation brought about by the brining treatment was only 18%. The samples held at the high storage temperature were benefited the most by the brine treatment, showing a 25% reduction in drip as compared with 16% for the samples held at the lower temperature.

The use of low storage temperature (Table 2) was somewhat more successful in reducing drip formation than was brine treatment. In eight of the nine lots tested, drip was less for the fillets held at the low temperature, while in the ninth series the reverse was true. The average for all the tests made showed the samples held at -5°F. to have an average of 22% less drip than those at +10°F., with the brined samples having the greatest reduction in drip (27% compared to 17% for the unbrined samples.

Changes in Flavor and Odor

The flavor of the cooked fish after 1 month of storage, so far as could be judged, was identical with that of the fresh fish. After 2 months the unbrined fish held at the low temperature were still perfectly fresh. Even the oil directly under the skin showed no trace of rancidity. The brined sample stored at -5°F. had a very slightly rancid flavor, especially in the oil under the skin. Both the brined and unbrined samples held at the high temperature had a small but quite definite degree of rancidity. After 4 months' storage the flavors remained much the same. The samples at the low temperature still were relatively free of rancid flavors, but some of the normal salmon flavor seemed to be lacking.

After 6 months' storage a very large difference in flavor existed between the fish at -5°F. and +10°F. The former samples were still free of rancidity except in the oil just under the skin where definite though not pronounced rancidity was evident. The fish stored at +10°F. were quite definitely rancid throughout the main portions of the flesh. The discolored yellow portion at the surface and the oil beneath the skin were extremely rancid.

Rancidity

Peroxide values correlated quite well with organoleptic rancidity. The values increased from a minimum of 1.6 in the freshly frozen fish to a maximum of over 18 after 6 months' storage (Table 4). The brined samples quite consistently had higher peroxide values which averaged 46% higher than the unbrined ones. (Table 5.) The peroxide value of all 9 lots tested was lower in the samples held at the low storage temperature and the values averaged 42% less.

FROZEN SILVER SALMON FILLETS

Changes in the frozen silver salmon were less pronounced than in the case of either of the species previously discussed. Color faded, drip developed, and rancidity and off-flavors increased with storage time, but the rate was so slow that the samples were still in fair condition after six months.

Changes in Appearance

The usual glossy pellicle was present in the brined samples and also to a lesser extent in the untreated ones. The glossy appearance was retained with very little decrease throughout the storage period.

With increasing storage time, the normal red color turned to an orange shade. At the end of six months' storage, none of the samples which had received the ordinary treatment and was wrapped in a good moisture-vapor-proof wrapper had altered to more than a red-orange color, and in most instances much of this alteration did not appear until after the fish had been cooked. The samples stored at the low temperature were the least altered, being of a bright red color with a few orange patches. Those at the higher temperature were of a uniform orange-red shade. No difference in color could be detected between samples which had been brined and those which had not, or between quick and slow frozen samples.

Formation of Drip

Drip increased from an average of 1.3% just after freezing to an average of only 4.6% after 6 months' storage (Table 1). This was a much smaller change than with the other species. With such a small range of drip content it is not surprising that the effect of the various treatments was less significant. Thus the brining process showed an overall average decrease in drip formation of only 19% and in 3 of the 18 lots tested the brined samples had more drip than the untreated ones (Table 2).

Reduction in storage temperature had no consistent effect on drip formation. In ten cases drip was higher at the low temperature and in six cases it was lower. Likewise the rate of freezing did not show any regular influence on drip formation. In eleven cases the formation of drip was reduced by quick freezing and in seven cases it was increased, with one lot showing no difference (Table 2).

Changes in Flavor and Odor

Very little alteration in flavor occurred even after six months' storage. Samples held at the low storage temperature had a fresh flavor which would scarcely be distinguished from that of the fresh unfrozen fish, except for an extremely slight aftertaste. The samples held at the higher storage temperature had a slight degree of rancidity after six months' storage, but these fish were still perfectly edible. No difference in flavor could be detected between brine and unbrined fish, or between quick and slow frozen samples.

Rancidity

The development of rancidity was followed by means of peroxide value determinations. Peroxide values were found for all samples but average values for the quick and slow frozen fish only are shown in the table (Table 4), since no appreciable difference can occur in rancidity due to freezing rate. In the case of silver salmon where differences in flavor are very slight, the determination of peroxide number is of especial value in showing slight differences in the development of rancidity caused by the different treatments.

Brining caused a small increase in rancidity (Table 5). Five out of eight lots tested had higher peroxide values for the brined samples, and the average increase in peroxide value of the brined over the unbrined fish was 15%.

Low storage temperature was a very definite factor in reducing peroxide number and rancidity in the stored fillets. In all lots examined the fish at the low storage temperature had the lowest peroxide values and the reduction caused by this factor amounted to an average of 30%.

SPECIAL PACKAGING EXPERIMENTS

In conjunction with the foregoing tests a somewhat more extensive set of experiments was conducted with silver salmon to

determine further data on packaging methods. Samples were packaged in four types of wrappers: (1) rubber latex bags, (2) moisture-vapor-proof wrappers (two brands), (3) parchment paper (not moisture-vapor-proof), (4) grease-proof butcher paper. The packages were sealed in various ways, including heat sealing for (1) and (2) above, use of a special adhesive for (2), use of rubber bands to hold wrappers in place for (2), (3), and (4), and use of a large overlap of paper but no other sealing for (3) and (4). The samples in the rubber bags were sealed in a vacuum, but the vacuum did not remain for long owing to small snags from handling developing in the rubber.

In general, no difference was observed within a single type of wrapper caused by sealing methods. Accordingly results for each type of wrapper have been averaged, and are presented in Table 6. In 6 months' storage the samples in the rubber bags lost no weight and those in the moisture-vapor-proof wrappers only 0.4%. The other wrappers allowed considerable loss in weight (3.4%, 2.7%) and the surface of the samples showed considerable sign of freezer burn, being covered with white frost and having a coarse, honeycomb appearance. The samples which were wrapped in the moisture-vapor-proof wrappers, although losing very little weight, actually had more desiccation than the figures indicate. The transparent wrappers did not cling closely to the surface of the fish, a considerable air space being left. Within this air space, quite a large amount of frost formed, giving a slight but definite dehydration which caused some fading of color. Dehydration within the wrapper is increased by fluctuation in storage temperature, as well as by large air spaces. The samples within the rubber latex bags had a minimum of frost within the container. Where the rubber fitted tightly against the fish no frost was visible, while at the ends where some air space was left, small amounts were formed. Drip was slightly less in the more desiccated samples, but the improvement in drip was slight compared with the other alterations in these samples.

The color of the samples within the rubber latex bags closely resembled that of the fresh fish. Where small snags had developed, a strictly local discoloration occurred, and in the vicinity of air pockets some fading was observed, but these discolorations were small and on the whole the color was excellent. The samples wrapped in the moisture-vapor-proof wrappers had faded slightly to an orange-red color, the discoloration being fairly uniform over the entire surface. The samples in the other wrappers showed marked discoloration to a yellow color.

None of the samples had a very bad flavor. They ranged from a nearly fresh one with only faint traces of rancidity in the case of the samples in the rubber bags to a definite though not at all

TABLE 6.--Effect of packaging method on alteration in frozen silver salmon

Alteration after 6 months' storage[1]

Packaging method	Color	Flavor	Loss in weight	Drip	Total loss due to dehydration and drip	Peroxide value
			%	%	%	
Latex rubber bag	Same as original fish except for discoloration at air pockets	Nearly same as fresh fish. Very slight rancidity	0.0	2.2	2.2	6.9
Moisture-vapor-proof transparent wrappers	Slight orange discoloration	Nearly same as fresh fish. Slight rancidity	0.4	3.0	3.4	7.9
Parchment paper; not moisture-vapor-proof	Marked fading to orange-yellow	Slightly rancid	3.4	1.5	4.9	8.0
Grease proof butcher paper, not moisture-vapor-proof	Marked fading to orange-yellow	Definitely rancid	2.7	1.7	4.4	12.0

1/ Storage temperature 10°F.

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extreme degree of rancidity for the samples in the grease-proof butcher paper. Peroxide values conformed with organoleptic rancidity ranging from 6.9 for the samples in the rubber latex bags to 12.0 for those in the cheapest wrappers.

Future tests are planned in which an outer protecting wrapper will be added to the rubber bags to prevent development of small snags. These snags not only cause some local discoloration beneath but also cause a loss of vacuum. If a vacuum could be maintained within the bag throughout the storage period, rancidity should be almost completely inhibited and the slight discoloration adjacent to air pockets eliminated.

Another method of minimizing undesirable changes is to package the fish so that it completely fills the container, leaving a minimum of air space. This can readily be attained when the fish are quick frozen in semirigid containers under pressure. When the fish is cut to fit the container properly, freezing under pressure forces it into all the corners, flush with the top of the container, leaving no space for frost to accumulate or for air to oxidize the oil or pigment to produce rancidity or discoloration. One lot of silver salmon frozen in this way showed much less rancidity or discoloration than other fillets which had a small air space left within the package.

GENERAL DISCUSSION

EFFECT OF BRINE TREATMENT

The preliminary brine treatment was very effective in minimizing drip in "sole" and also enhanced the appearance of the fillets. On the other hand, it was definitely detrimental in accelerating the development of rancid and salt-fish odors and flavors. Since salt has no odor the development of more pronounced so-called salt-fish odors and flavors in brined"sole" fillets cannot be attributed to the salt per se, but rather to its contributing to change in the treated fillets.

These results suggest the need for further experiments to try to devise a way in which the beneficial effects of the brine dip can be utilized without encountering the acceleration of off-flavors. Future experiments are contemplated to study the effect of varying the concentration of brine and the time which the fillets are dipped in the brine. Other experiments using different grades of salt of higher purity and different chemical salts may also prove of value.

The brine treatment reduced drip somewhat in the salmon fillets but since drip is not a serious problem with these fish, the advantage of the slight decrease was more than offset by the tendency for the treated samples to develop rancid flavors more rapidly than was the case with the untreated fish.

EFFECT OF RATE OF FREEZING

Immediately after the fillets had been frozen and thawed there was a definite difference between the quick and slow frozen samples, the former being scarcely different from fresh fish, while the latter were of a softer texture which was fairly noticeable when the cooked fish were eaten. Upon subsequent storage at +10°F. and -5°F. this difference diminished rapidly and after two months little difference could be distinguished between the quick and slow frozen fish after they had been cooked. The quick frozen fish, especially the "sole", had somewhat less drip throughout the run, but even this difference was but slight after prolonged storage. Little if any difference in color, odor, or flavor could be distinguished at any point during storage between the quick and slow frozen samples.

EFFECT OF STORAGE TEMPERATURE

The two storage temperatures used in these experiments, +10°F. and -5°F., probably represent the upper and lower extremities which are commonly used in the average cold storage houses for storing fish. The results obtained indicate that the lower temperature, -5°F., gives a far better product in every respect, especially after prolonged storage. The lower storage temperature is especially helpful in retaining the normal fish flavor and in minimizing the development of rancid and salt-fish flavors. The use of the low temperature also materially aids in preventing drastic discoloration, and the products stored at this temperature had definitely less drip throughout the tests than had those stored at the higher temperature.

EFFECT OF PACKAGING METHODS

The samples wrapped in the moisture-vapor-proof wrapper showed no signs of desiccation even after six months' storage. When paper which was not moisture-vapor-proof was employed the fillets lost considerable moisture from the surface even within one month of freezing, and this resulted in a dry, tasteless, "woody" fish when it was cooked and eaten. After further storage, oxidation led to considerable discoloration, and both salt-fish and definite rancid flavors were soon evident.

Use of the paper which was not moisture-vapor-proof was to furnish an extreme contrast in order to determine the maximum changes that might occur if the fish had the minimum of wrapping protection. It was not expected that such a wrapper would ever be used commercially. Actually, a compromise wrapper might be selected, one costing less than the very efficient but expensive transparent moisture-vapor-proof wrapper. With such wrappers having intermediate characteristics with respect to resistance to

passage of moisture, vapor, and air, these changes would develop much more slowly. Further tests may be included in future studies to investigate this question.

Some "sole" fillets were frozen in blocks and protected by an ice glaze, as is practiced extensively in the Pacific Northwest. As long as a thick, unbroken ice glaze remained on the surface, excellent protection was afforded, but unless the glaze was renewed by frequent spraying, the fish at the outside of the block became exposed or even if a thin layer of ice remained, the outer fillets showed considerable darkening in color and development of "off-flavors." The fish at the center of the block were always of excellent color, odor, and flavor. They were sometimes, however, of rather porous texture, soft, showed considerable drip, and large ice crystals could be seen in the flesh. This is probably accounted for by the extremely slow rate of freezing which resulted at the center because of the thickness of the block of fish.

COMPARISON OF KEEPING QUALITY OF DIFFERENT SPECIES

After 6 months' storage at +10°F. untreated, slow frozen "sole" samples had nearly twice as much drip as the various species of salmon (Table 7). In all other respects—color, flavor, and peroxide value—the pink salmon were by far the worst, and the silver salmon the best.

The keeping quality of the chum salmon differed from that of the other species in that these fish kept in fairly good condition for four months and then suddenly, sometime between the fourth and sixth months, rapidly deteriorated.

TABLE 7.—Comparison of deterioration in various species of fish fillets after six months' storage1/

Species	Drip	Color	Flavor	Rancidity
	%			Peroxide value
"Sole"	9.4	Some yellow discoloration	Considerable salt-fish flavor	-
Pink salmon	5.0	Extreme discoloration	Very rancid	17.5
Silver salmon	4.4	Some fading of red color	Slightly rancid	5.8
Chum salmon	4.3	Considerable discoloration	Definitely rancid	11.3

1/ All fish were untreated, slow frozen, and stored at +10°F.

From the results obtained, the maximum storage life for the various species is indicated to be as follows:

Species	at -10°F.	at -5°F.
Pink salmon	1 month	2 months
Chum salmon	4 months	over 6 months
"Sole"	4 months	6 months
Silver salmon	6 months	over 6 months

PROBLEMS FOR FUTURE INVESTIGATION

As indicated in the introduction, this report was undertaken with a view of learning the various problems encountered in the freezing of the species studied and to obtain some indication as to how these problems might be solved. The most serious changes observed during the experimental work involved changes in color and flavor. It is believed that both of these types of change are largely caused by atmospheric oxidation of the fish oils and pigments, and hence the most urgent problem is one of finding methods of minimizing this oxidation.

Probably the most promising approach to this problem is by means of improved packaging methods whereby less air is left in contact with the packaged fish. Several methods of accomplishing this are possible. Two fillets might be packaged together with the skin side out, thus exposing a minimum of surface. The use of a wrapper which would stick tightly to the flesh, avoiding any air space might also be of benefit. A third possibility is packaging under vacuum in a moisture and air proof container. Experiments are now being planned to test out these possibilities.

The use of a low storage temperature was so uniformly successful in minimizing deterioration that further experiments will be tried. Possibly a combination of an improved packaging method with the use of a low storage temperature would provide the solution to the problem of successfully storing pink salmon.

Another problem for future consideration is a more detailed study of the preliminary brine treatment. This treatment was highly successful in minimizing drip but caused the development of undesirable off-flavors. It may be possible to work out a treatment which will eliminate these undesirable features and still retain the desired effect. It is also possible that the addition of certain antioxidants or other chemicals to the brining solution would minimize rancidity formation and retard the development of off-colors. Tests of this type are now being started and will be reported in a future paper.

LITERATURE CITED

BANKS, A.

1938. Storage of fish with special reference to rancidity.

I. Cold storage of herring. J. Soc. Chem. Ind. 57: 124-128.

FIEDLER, R. H.

1940. Fishery industries of the United States, 1938. Appendix III to Report U. S. Commissioner of Fisheries, 1939, Washington.

WHEELER, D. H.

1932. Peroxide formation as a measure of auto-oxidative deterioration. Oil and Soap 9: 89-97.