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# TABLE OF CONTENTS

## ABSTRACT

Over 18 tons of 4-day old roe herring were processed under 52 different experimental conditions. The average yield of roe was about 15% by weight, which was considerably greater than the usual yield obtained by industry. All of the roe obtained was subsequently brined and graded.

The yield of roe from frozen herring was about 2% greater than that obtained from brined herring, and subsequent brining of the roe did not generally result in any weight loss.

A high incidence of "spongy" roe was observed in those roe obtained from frozen herring, while this problem was not encountered with those obtained from brined herring.

It is recommended that the period between catching and processing of roe herring be minimized if the yield of premium quality roe is to maximized.

## RÉSUMÉ

Plus de 18 tonnes d'oeufs de hareng âgés de quatre jours ont été traités dans 52 conditions expérimentales différentes. Le rendement pondéral moyen en oeufs a été d'environ 15%, soit beaucoup plus que le rendement habituel de l'industrie. Tous les oeufs obtenus ont été saumurés et classés.

Les harengs congelés ont eu un rendement en oeufs supérieur d'environ 2% à celui des harengs saumurés et le saumurage subséquent des oeufs ne s'est généralement pas traduit par une diminution de poids.

On a observé une forte incidence d'oeufs "spongieux" chez les harengs congelés, tandis que ce problème n'est pas apparu quand les oeufs provenaient de harengs saumurés.

Il est recommandé de raccourcir la période s'écoulant entre la capture des harengs et le traitement des oeufs si on désire obtenir un meilleur rendement en oeufs de qualité supérieure.

## INTRODUCTION

Since 1971, the Japanese market for herring roe ("kazunoko") has attracted a great deal of interest among British Columbia fish processors and fishermen. Prices paid by the Japanese for herring roe increased dramatically in 1972, then peaked in 1973. However, the roe prices in 1974 became stabilized at the previous year's level, then plunged about 25% lower for 1975.

The current softening of the herring roe market is no doubt a reflection of the softening economic conditions in Japan, compounded with the rising competition presented by China and the U.S.S.R. for the Japanese herring roe market. As a result, British Columbia herring roe processors now appear to have become more conscious of the economic advantage of improving the quality of their processed herring roe.

On April 9 of this year, the Vancouver Laboratory was invited by a local fish processor to collaborate with them to perform some experimental work on roe herring processing, using their industrial facilities, processes, and personnel. Specifically, the question to be answered was, "What are the relative yields of roe from brined herring compared with those obtained from frozen herring subsequent to both the primary and secondary processing steps?". Additionally, we sought answers to the question of optimum brining time, optimum brine concentrations, and the effect of sorbate addition to brine solutions on the yield and quality of roe obtained under industrial processing conditions. Furthermore, we wished to examine the effects of freezing and thawing conditions on roe yield and quality.

This report contains a complete summary of our work.

## EXPERIMENTAL

The herring was caught by seining in Cumshewa Inlet, Queen Charlotte Islands, by the Pacific Harvester on April 6, 1975. The fish was transported in unrefrigerated seawater to the Norpac Fisheries plant in Vancouver. Off-loading of the catch at the plant on April 10 was accomplished with an air-lift pump. Due to the long unrefrigerated period between catching and off-loading, the herring appeared to be in only fair condition, and the roe in most of the herring had already begun to turn red at the proximal ends.

### Processing

The primary processing of all experimental herring was begun on April 10 and consisted of either brining or freezing the fish under various conditions.

Brining of Herring - Plastic-lined wooden tote boxes (about 2.7' x 4' x 4'), partially filled with the appropriate volume and concentration of brine, were weighed before and after the addition of herring. The difference in the weights were taken as the original weight of herring in each container.

For the purpose of this report:

- "primary ($1^{o}$) processing" shall mean the processing of whole roe herring, either by freezing or brining, to facilitate roe retrieval.

- "secondary ($2^{o}$) processing" shall mean the processing of roe subsequent to its retrieval from herring.

Approximately one pound of brine solution was used for every two pounds of herring.

The brine concentrations used were 30%, 40%, 60%, 80% and 100% of saturation* at ambient temperatures. Additionally, 0.1-0.2% by weight of potassium sorbate was added to tote boxes containing 30%, 40% and 60% saturated brine in a parallel experiment to examine the effect of this compound upon the quality of roe obtained.

At pre-determined intervals (1,2,3,5 and 8 days), 500 to 1000 lb. batches of brined herring were removed and the roe retrieved by regular plant employees. Herring "popping" (roe retrieval) rates by these experienced workers were approximately 240 to 260 lbs/person/hour.

Freezing of Herring - Herring were frozen either quickly or slowly. "Fast-frozen" herring were obtained from those frozen in 15-20 minutes by passage through an airblast tunnel (-68C), then stored at -26C. "Slow-frozen" herring were obtained by placing 30 lbs of herring into polyethylene bags (final dimensions, 4" x 18" x 24") or into plastic-lined cardboard boxes (5" x 13" x 18"). The herring thus packaged were allowed to freeze slowly over a 24-48 hour period in a cold storage room held at -26C.

Thawing of frozen herring was accomplished either "quickly" or "slowly". Herring was "fast-thawed" by immersion in running tap water overnight (about 16 hours) or "slow-thawed" by allowing the bagged or boxed herring to thaw by being placed on the floor of the plant at ambient temperature for 48 hours.

The salt-cured roe was graded as follows:

| Grade | Criteria used |
|---|---|
| No.1 | Greater than 3" in length; fully-shaped, unbroken. |
| No.2 | 2-3" length, fully-shaped (or greater than 3" with tips broken off). |

* In this report, % brine concentrations are all expressed as % of saturation.

No.3 1/2 - 2" in length; mostly broken roe.

No.4 Misshapen roe; "triangles".

No.5 Immature; soft, spongy roe.

A Residual scraps after grading.

Weights of roe obtained from various experimental conditions were documented after the primary processing step, after the secondary treatment of roe, and final grading. Additionally, the weight of each grade obtained was measured, providing us with the means of assessing the effect of various primary processing techniques on relative economic returns.

The relative economic return for each experimental batch of herring was calculated on the basis of arbitrarily assigning the following values of x units per pound for each grade of roe;

No.1 grade 4.6 x/lb

No.2 grade 3.6 x/lb

No.3 grade 2.4 x/lb

No.4 grade 1.6 x/lb

F & No.5 grades 1.0 x/lb

A grade 0.5 x/lb

For instance, if the yields of processed roe from 330 lb of herring for a particular experimental lot were;

No.1 grade 23.2 lb

No.2 grade 19.5 lb

No.3 grade 5.4 lb

No.4 grade 1.1 lb

No.5 grade 1.1 lb

A grade 1.0 lb

then the economic return was derived as follows;

23.2 x 4.6x = 106.7x

19.5 x 3.6x = 70.2x

5.4 x 2.4x = 13.0x

1.1 x 1.6x = 1.8x

1.1 x 1.0x = 1.1x

1.0 x 0.5x = 0.5x

Total 193.3x

Since 193.3x was obtained from 330 lb herring, then $193.3x \times \frac{2000}{330}$ = 1171x obtained from one ton of herring.

In the Tables to follow, the "% roe yields" refer to the ratio of the wet weight of roe to the initial weight of round herring (multiplied by 100). In our calculations of % roe yields we have assumed that in any given batch of herring, the proportion of males to females would be approximately the same.

## RESULTS AND DISCUSSION

The information obtained during the course of the work are tabulated and presented in Tables I - IV on the following pages.

Note that in each of the brining experiments (Tables I and II), the sum of the brined herring weights exceeds the total weight prior to brining by about 5.5%. We have attributed this apparent increase in weight after brining to the incomplete draining of sample lots of brined herring prior to weighing. Accordingly, we have assumed that any water loss from the tissues of fish was balanced by salt uptake, and that no significant change in overall herring weight occurred during the brining procedure. This assumption was made in order to calculate all % yield of roe, as well as the relative economic return for each experimental condition.

### 1. Effect of Brining Time on Roe Yield

There is a general decline in the percentage of roe recovered upon prolonged brining at all concentrations of brine used (Fig. 1). It is not clear why there appears to be a large discrepancy in the data for the roe retrieved on the 5th day of brining.

In terms of quantity of roe recovered, the data reveal that the recovery is acceptable after only one days' brining, regardless of brine concentration used. However, as shown in Fig. 3 the proportion of No.1 grade roe increased sharply after 2 days in all concentrations of brine, and a corresponding decrease in the proportion of No.2 grade roe (Fig. 4) during this additional day in brine.

### 2. Effect of Brining Time on the Relative Economic Value of Roe Obtained.

As might be anticipated, a corresponding general decline in the economic return per ton of herring processed is observed when the fish is kept up to 8 days in brine (Fig.2). Since the x/T values is a reflection of both quantity and quality of roe obtained, and since the trend observed is similar to that shown in Fig. 1, it clearly indicates that the economic returns were strongly influenced by the quantity of roe recovered, rather than on quality. However, it should be emphasized that the herring used in these experiments were transported unrefrigerated for 4 days before being processed at the plant, and yielded a maximum of only 7.2% No.1 grade roe under what appears to be optimum brining conditions Experiment 25. It appears

likely, therefore, that if either freshly-caught herring or herring stored under more favourable conditions had been available, the differences in the x/T values would have been more pronounced than seen in these experiments.

There is a slight increase in the weight of roe after $2^{o}$ treatment, namely about 2.5%. Salt-cured roe are usually drained in baskets overnight after removal from the final brining step; the roe used in these experiments were drained for about 4 hours, with the exception of roes from frozen fish which were drained for 16 hours. It is unlikely that the average increase of 2.5% in weight after the $2^{o}$ processing is due to incomplete draining of the brine.

## 3. Effect of Brining Time and Brine Concentrations on the % Composition of Graded Roe

The data given in Table I show that a good proportion of roe were graded as No. 1, regardless of the brining time or brine concentration used. Nevertheless, it is clear that the percentage of No. 1 roe from brined herring increased after 2 days in brine, then gradually declined with extension of brining time. The only exception is the roe from 100% saturated brine solution which appears to reach a peak at 5 days. Whether this apparent increase in the percentage of No. 1 roe is an indication of the subjective nature of the grading system, or whether it is factual, is difficult to assess. It would appear that for this particular 5-day sample, more No.2 grade roe were included with the No. 1's, as shown by the very low percentage of No.2 roe (Fig. 4).

As might be expected, the proportion of No.3 grade roe increased with increased brining time (Fig.5). The next figure (Fig.6) illustrates more clearly this trend towards greater increases in the proportion of lower grade roe associated with prolonged brining time, regardless of brine concentrations used.

Thus, the results of these particular herring brining experiments reveal that the optimum period (in terms of maximizing the yield of No. 1 roe) appears to be 2 days in 60-100% saturated brine. Longer periods in brine generally result in the reduction of both quality and quantity of roe recovered.

Roe obtained from herring brined up to 5 days did not develop off-odours, but did so when the herring was brined for 8 days.

## 4. Effect of Brining Time, Brine Concentration With Sorbate Added.

The addition of sorbate to 30%, 40% and 60% brine solutions did not appear to have any significant effect on the quality of roe recovered from herring brined up to 8 days. Furthermore, no advantage was gained by the addition of potassium sorbate in terms of improving the yield or the relative economic return (Figs. 7-11). The addition of sorbate

did,however, appear to reduce the level of off-odours in roe obtained from herring brined over 5 days.

5. Effect of Frozen Storage Time on Quality and Quantity of Roe Recovered

The data obtained for this series of experiments are given in Table III. Experiment 47 (40-day frozen herring) was completed at the Vancouver Laboratory using the same source of frozen herring, and the same commercial technique for curing and grading the roe.

It is obvious that the % yield of roe obtained following the primary (frozen) process is significantly higher than those obtained from the brining process. Furthermore, little or no decrease in weight is observed after the retrieved roe underwent secondary processing. Indeed, most experimental lots appear to have gained about the same percentage of weight (about 2.5%) as found for processed roe obtained from brined herring. The reason for the apparently high increase in roe weight (after the secondary process) observed in Experiment 43 is not clear, and warrants further examination.

Whereas the grading of roe from brined lots of herring was relatively straightforward and presented no real problems, the grading of roe obtained from frozen herring was made more complicated by the fact that the primary (freezing) process tends to increase the incidence of "spongy" roe.

The roe from Experiments 42 and 43 were graded in the usual manner, except that a separate grade (Grade "F") was assigned for "spongy" roe. It must be stated at this point that large, "spongy" roe, on cursory observation, appears no different from No.1 grade roe, and requires gentle squeezing between the fingers to identify them. Obviously, this requires a great deal of grading effort and time, and for this reason, the grading for "spongy" roe was discontinued at the plant after Experimental lots 42 and 43 were done. Indeed, Experimental lot 43 was graded a second time and yielded much less "spongy" roe than the first time as shown below.

| # 1 (%) | # 2 (%) | # 3 (%) | # 4 (%) | # 5 (%) | A (%) | F (%) |
|---|---|---|---|---|---|---|
| 40.7(7.9) | 10.5(2.0) | 1.8(0.3) | 0.1(0.2) | 3.9(0.8) | 0.2(0.4) | 45.2(8.8) |

This suggests that the differentiation between "spongy" roe and firm roe is difficult, and is subject to grading discrepancies.

The results of Experiment 47 (40-day frozen herring) reveal a rather large decrease in the yield of roe after the primary processing step. This might be explained on the basis of inadequate numbers of herring used to provide us with a ratio of male to female herring that was similar to previous experiments. On the other hand, the decrease

in roe yield might be real upon extended frozen storage of roe herring, possibly due to physical-chemical factors affecting water loss from the roe. Additionally, there appears to be a decrease in the proportion of spongy roe and a concomitant increase in the proportion of No.1 roe after extended frozen storage.

6. Effect of Freezing and Thawing Rates on Yield and Quality of Roe

Regardless of the manner by which the herring were frozen or thawed, the % yield of roe was higher than those obtained from brined herring. The secondary processing of roe from frozen herring resulted in a slight gain in weight, and confirms the results of the previous series of experiments on frozen herring.

The "% No.1 grade" column in Table IV shows a very high proportion of roe for this grade, but this is probably misleading because no allowance unfortunately was made for the presence of "spongy" roe due to reasons mentioned earlier. Accordingly, we cannot provide at this time any evidence to indicate whether "sponginess" in roe arises from either poor freezing or poor thawing conditions, or perhaps a combination of these factors. It seems very likely, nevertheless, that the condition of "sponginess" arises from freezing, rather than from the brining of herring.

7. Salinity and Odour of Brine during Primary Processing

Approximate estimations of the salinity of the brining solutions were made during the primary processing stage. The salinity of the various brining solutions gave the following average values;

| Initial Brine Concentrations | Brine Concentrations averaged over 8 days |
|---|---|
| 30% | 21% |
| 40% | 24% |
| 60% | 26% |
| 80% | 30% |
| 100% | 33% |

Off-odours developed in 30% brine solutions, even with sorbate added, after only 2 days. It was evident in most of the brine solutions after the third day, particularly with the 30% brine solution. At 8 days, all brine solutions gave strong off-odours, with the 100% brine solution being the least offensive.

## SUMMARY AND CONCLUDING REMARKS

In collaboration with industry, 36,132 pounds of herring were processed under a variety of experimental conditions, and yielded 5398 lbs of roe after 1$^{o}$ processing (14.9%) and 5534 lbs of roe after 2$^{o}$ processing (15.3% yield). These roe yields are not representative of those found by the herring roe industry. Clearly, % roe yield is largely dependent upon the ratio of males to females in a given catch. Yields may also vary with harvesting areas.

Our data shows that the yield of roe is generally greater from frozen herring than from brined herring. Additionally, since no decrease in roe weight was observed after the roe is brined during the secondary processing step, freezing (as opposed to brining) as the primary processing method seems more favourable in terms of over-all roe yield. However, since the economic importance of the quality of recovered roe cannot be neglected, and since the freezing process apparently leads to the production of "spongy" roe, freezing of herring may not necessarily offer a significant economic advantage over brining unless perhaps the herring is kept frozen for some time before the roe is extracted.

Herring brined for only one day produced a lower quality of roe (i.e. less No.1 grade) than those brined for 2 or 3 days, irrespective of the brine concentrations used. If brining time exceeded 3 days, the overall quality tended to deteriorate. On the other hand, herring brined for only one day tended to give a higher yield of roe than those brined for 2 and 3 days, and despite the lower yield of No.1 roe, the relative economic return was no less than those calculated for the 2- and 3-day brined herring.

Our data does not reveal any consistent or significant advantage in the use of 100% brine over less concentrated brine solutions. The results of using different brine concentrations may have yielded different results if the herring used in these experiments had been processed within 24 hours after capture. Indeed, it must be strongly emphasized that the results of all of the experiments described in this report are based on work done on 4-day old herring stored without refrigeration, and cannot be applied to herring stored under optimum conditions for a shorter period of time.

Finally, we believe that deteriorative changes in the roe occur most rapidly during the first 24 hours (and certainly within 48 hours) after the herring is captured. Accordingly, we recommend that roe herring be processed (either brined or frozen) within 24 hours after harvesting if the yield of top quality roe is to be maximized. Given the feverish nature of the roe herring fishery, we recognize the difficult problem of processing all of the landed herring within 24 hours, but if the quality of roe is of paramount importance, this recommendation ought to be seriously considered.

## ADDITIONAL READING

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TABLE I - EFFECT OF BRINING TIME AND BRINE CONCENTRATION

| Expt. No. | Wt.of Herring Before 1° Process | 1° Processing Conditions | | Wt.of Herring After 1° Process | Total Wt. of Roe After 1° Process | % Yield | Total Wt. of Roe After 2° Process (Before Grading) |
|---|---|---|---|---|---|---|---|
| | | Brine Concentration | Days in Brine | | | | |
| | lb | | | lb | lb | | lb |
| 1 | 415 | (unbrined) | 0 | - | 57 | 13.7 | 54.0 |
| 2 | | 30% saturation | 1 | 445 | 60.7 | 13.6 | 61.5 |
| 3 | | 30% saturation | 2 | 1129 | 149.5 | 13.2 | 151.7 |
| 4 | 3945 | 30% " | 3 | 796 | 108.7 | 13.7 | 112.0 |
| 5 | | 30% " | 5 | 580 | 68.0 | 11.7 | 69.7 |
| 6 | | 30% " | 8 | 1343 | 170.2 | 12.7 | 176.0 |
| | | | | Total 4293 | | | |
| 7 | | 40% saturation | 1 | 410 | 59.0 | 14.4 | 58.5 |
| 8 | | 40% " | 2 | 967 | 128.2 | 13.3 | 130.7 |
| 9 | 3805 | 40% " | 3 | 708 | 97.1 | 13.9 | 99.2 |
| 10 | | 40% " | 5 | 610 | 76.2 | 12.5 | 77.0 |
| 11 | | 40% " | 8 | 1295 | 170.2 | 13.1 | 174.4 |
| | | | | Total 3990 | | | |
| 12 | | 60% " | 1 | 410 | 56.7 | 13.8 | 56.5 |
| 13 | | 60% " | 2 | 1070 | 145.5 | 13.6 | 149.7 |
| 14 | 4620 | 60% " | 3 | 837 | 112 | 13.4 | 116.2 |
| 15 | | 60% " | 5 | 840 | 96.5 | 11.5 | 97.7 |
| 16 | | 60% " | 8 | 1652 | 220.7 | 13.4 | 226.2 |
| | | | | Total 4809 | | | |

| Expt. No. | % change in roe wt. after 2° process | Individual Wts. (in lbs.) & % Yields of Graded Roe Obtained | | | | | | Sum of Graded Roe Weight (lb) | Relative Economic Return per ton of herring Processed |
|---|---|---|---|---|---|---|---|---|---|
| | | #1 (%) | #2 (%) | #3 (%) | #4 (%) | #5 (%) | A (%) | | |
| 1 | (-5.3) | 16.7(4.0) | 22.0(5.3) | 11.0(2.6) | 1.8(0.4) | 1.5(0.4) | 1.0(0.2) | 54.0 | 903 |
| 2 | +1.3 | 33.9(7.6) | 18.5(4.2) | 6.4(1.4) | 1.0(0.2) | 0.9(0.2) | 0.5(0.1) | 61.2 | 1080 |
| 3 | +1.5 | 91.6(8.1) | 32.3(2.9) | 18.7(1.7) | 3.7(0.3) | 3.5(0.3) | 1.0(0.1) | 150.8 | 924 |
| 4 | +3.0 | 65.7(8.2) | 23.1(2.9) | 16.9(2.1) | 1.5(0.2) | 3.7(0.5) | 0.9(0.1) | 118.8 | 1087 |
| 5 | +2.5 | 32.7(5.6) | 13.5(2.3) | 13.3(2.3) | 1.9(0.3) | 7.3(1.3) | 1.0(0.2) | 69.7 | 836 |
| 6 | +3.4 | 55.7(4.1) | 44.7(3.3) | 32.6(2.4) | 3.2(0.2) | 31.3(2.3) | 3.9(0.3) | 171.4 | 796 |
| 7 | (-0.8) | 40.5(6.3) | 10.5(5.4) | 4.5(1.6) | 1.1(0.3) | 1.2(0.3) | 0.2(0.1) | 58.0 | 1166 |
| 8 | +1.9 | 83.9(8.3) | 24.4(2.7) | 14.0(1.7) | 3.4(0.3) | 3.9(0.2) | 0.9(0.1) | 130.5 | 1069 |
| 9 | +2.2 | 59.0(8.1) | 20.6(3.2) | 13.6(2.0) | 2.1(0.3) | 2.9(0.5) | 1.0(0.2) | 99.2 | 1086 |
| 10 | +1.0 | 32.1(5.0) | 20.2(2.6) | 10.1(2.8) | 2.2(0.3) | 5.6(0.8) | 1.4(0.3) | 71.6 | 834 |
| 11 | +2.5 | 66.4(3.8) | 41.9(2.8) | 36.2(3.3) | 2.9(0.2) | 20.9(2.2) | 2.9(0.3) | 171.2 | 880 |
| 12 | (-0.4) | 31.0(7.6) | 16.5(4.0) | 5.5(1.3) | 1.2(0.3) | 1.4(0.3) | 0(0) | 55.6 | 1066 |
| 13 | +2.9 | 92.7(8.7) | 30.5(2.8) | 16.6(1.5) | 4.4(0.4) | 4.6(0.4) | 1.0(0.1) | 149.8 | 1100 |
| 14 | +3.7 | 66.5(7.9) | 24.4(2.9) | 16.0(1.9) | 3.4(0.4) | 4.6(0.3) | 1.1(0.1) | 116.0 | 1058 |
| 15 | +1.2 | 40.7(4.8) | 23.9(2.8) | 11.7(1.4) | 2.9(0.3) | 15.7(1.9) | 2.4(0.3) | 97.3 | 769 |
| 16 | +2.5 | 71.0(4.3) | 55.1(3.3) | 49.5(3.0) | 4.5(0.3) | 38.5(2.3) | 4.4(0.3) | 223.0 | 837 |

TABLE I - EFFECT OF BRINING TIME AND BRINE CONCENTRATION Contd. ...

| Expt. No. | Wt.of Herring Before 1° Process lb | 1° Processing Conditions | | Wt.of Herring After 1° Process lb | Total Wt. of Roe After 1° Process lb | % Yield | Total Wt. of Roe After 2° Process (Before Grading) lb |
|---|---|---|---|---|---|---|---|
| | | Brine Concentration | Days in Brine | | | | |
| 17 | 4120 | 80% saturation | 1 | 330 | 50.5 | 15.3 | 51.2 |
| 18 | | 80% " | 2 | 1080 | 150.5 | 13.9 | 156.2 |
| 19 | | 80% " | 3 | 820 | 113.7 | 13.9 | 118.0 |
| 20 | | 80% " | 5 | 650 | 85.2 | 13.1 | 87.0 |
| 21 | | 80% " | 8 | 1306 Total 4186 | 152.7 | 11.7 | 158.7 |
| 22 | 3965 | 100% " | 1 | 490 | 71.5 | 14.6 | 74.5 |
| 23 | | 100% " | 2 | 901 | 121.5 | 13.5 | 124.2 |
| 24 | | 100% " | 3 | 776 | 105.2 | 13.6 | 109.7 |
| 25 | | 100% " | 5 | 566 | 80.7 | 14.3 | 83.2 |
| 26 | | 100% " | 8 | 1357 Total 4090 | 182.5 | 13.5 | 190.2 |

| Expt. No. | % change in roe wt. after $2^0$ process | Individual Wts. (in lbs.) & % Yields of Graded Roe Obtained | | | | | | Sum of Graded Roe Weight (lb) | Relative Economic Return per ton of herring Processed |
|---|---|---|---|---|---|---|---|---|---|
| | | #1 (%) | #2 (%) | #3 (%) | #4 (%) | #5 (%) | A (%) | | |
| 17 | +1.4 | 23.2(7.0) | 19.5(5.9) | 5.4(1.6) | 1.1(0.3) | 1.1(0.3) | 1.0(0.3) | 51.3 | 1173 |
| 18 | +3.4 | 100.0(9.2) | 28.5(2.6) | 18.7(1.7) | 3.2(0.3) | 3.2(0.3) | 1.2(0.1) | 154.8 | 1134 |
| 19 | +3.8 | 69.2(8.4) | 26.5(3.2) | 15.5(1.9) | 2.2(0.3) | 2.7(0.3) | 0.7(0.1) | 116.8 | 1117 |
| 20 | +2.1 | 44.4(6.8) | 15.0(2.3) | 10.7(1.6) | 1.7(0.3) | 14.0(2.1) | 1.0(0.1) | 86.8 | 928 |
| 21 | +3.9 | 53.1(4.1) | 38.4(2.9) | 38.4(2.9) | 2.7(0.2) | 21.0(1.6) | 3.1(0.2) | 156.7 | 768 |
| 22 | +4.2 | 35.1(7.2) | 25.0(5.1) | 7.5(1.5) | 1.7(0.4) | 1.1(0.2) | 0.6(0.1) | 71.0 | 1118 |
| 23 | +2.2 | 77.2(8.6) | 23.9(2.6) | 14.0(1.5) | 5.5(0.6) | 2.6(0.3) | 0.9(0.1) | 124.1 | 972 |
| 24 | +4.3 | 61.2(7.9) | 26.4(3.4) | 16.0(2.1) | 2.4(0.3) | 2.5(0.3) | 1.0(0.1) | 109.5 | 1087 |
| 25 | +3.1 | 57.9(10.2) | 4.0(0.7) | 7.7(1.4) | 1.5(0.3) | 10.7(1.9) | 0.9(0.1) | 82.7 | 1105 |
| 26 | +4.2 | 73.2(5.4) | 44.0(3.2) | 36.9(2.7) | 3.5(0.3) | 26.4(1.9) | 2.9(0.2) | 186.9 | 910 |

TABLE II - EFFECT OF BRINING TIME, BRINE CONCENTRATION AND POTASSIUM SORBATE

| Expt. No. | Wt.of Herring Before 1° Process lb | 1° Processing Conditions Brine Concentration | Days in Brine | Wt.of Herring After 1° Process lb | Total Wt. of Roe After 1° Process lb | % Yield | Total Wt. of Roe After 2° Process (Before Grading) lb |
|---|---|---|---|---|---|---|---|
| 27 | | 30% saturation plus sorbate | 1 | 430 | 56.5 | 13.1 | 56.0 |
| 28 | | " " | 2 | 933 | 122.2 | 13.1 | 123.7 |
| 29 | 2750 | " " | 3 | 856 | 115 | 13.4 | 118.7 |
| 30 | | " " | 5 | 668 | 83.5 | 12.5 | 85.7 |
| 31 | | " " | 8 | 1490 | 199.3 | 13.4 | 206.7 |
| | | | | Total 2853 | | | |
| 32 | | 40% saturation plus sorbate | 1 | 365 | 52.5 | 14.4 | 51.2 |
| 33 | | " " | 2 | 1064 | 139.5 | 13.1 | 142.7 |
| 34 | | " " | 3 | 756 | 103.5 | 13.7 | 108.5 |
| 35 | 3960 | " " | 5 | 558 | 67.0 | 12.0 | 67.2 |
| 36 | | " " | 8 | 1407 | 175.2 | 12.4 | 180.5 |
| | | | | Total 4150 | | | |
| 37 | | 60% saturation plus sorbate | 1 | 470 | 71.5 | 15.2 | 70.7 |
| 38 | | " " | 2 | 837 | 114.2 | 13.6 | 116.7 |
| 39 | | " " | 3 | 784 | 110.9 | 14.1 | 114.5 |
| 40 | 3550 | " " | 5 | 513 | 66.7 | 13.0 | 67.0 |
| 41 | | " " | 8 | 1450 | 194.3 | 13.4 | 201.2 |
| | | | | Total 4054 | | | |

| Expt. No. | % change in roe wt. after $2^0$ process | Individual Wts. (in lbs.) & % Yields of Graded Roe Obtained | | | | | | Sum of Graded Roe Weight (lb) | Relativ Economi Return per ton of her-ring Proces-sed |
|---|---|---|---|---|---|---|---|---|---|
| | | #1 (%) | #2 (%) | #3 (%) | #4 (%) | #5 (%) | A (%) | | |
| 27 | (-0.9) | 29.5(6.9) | 18.0(4.2) | 5.0(1.2) | 1.5(0.3 | 1.1(0.3) | 0.5(0.1) | 55.6 | 1006 |
| 28 | +1.2 | 81.1(8.7) | 24.0(2.6) | 12.5(1.3) | 2.9(0.3) | 2.4(0.2) | 0.7(0.1) | 123.6 | 1065 |
| 29 | +3.2 | 66.6(7.8) | 31.7(3.7) | 13.9(1.6) | 2.1(0.2) | 2.9(0.3) | 0.5(0.1) | 117.7 | 1076 |
| 30 | +2.6 | 42.5(6.4) | 20.4(3.0) | 13.0(1.9) | 1.9(0.3) | 6.2(0.9) | 0.9(0.1) | 84.9 | 928 |
| 31 | +3.7 | 82.9(5.6) | 46.9(3.1) | 39.8(2.7) | 3.0(0.2) | 27.2(1.8) | 3.2(0.2) | 203.0 | 912 |
| 32 | (-2.5) | 23.1(6.3) | 19.6(5.4) | 5.9(1.6) | 1.1(0.3) | 1.0(0.3) | 0.5(0.1) | 51.2 | 1064 |
| 33 | +2.3 | 88.2(8.3) | 28.5(2.7) | 17.9(1.7) | 3.5(0.3) | 2.6(0.2) | 1.0(0.1) | 141.7 | 1053 |
| 34 | +4.8 | 61.0(8.1) | 24.1(3.2) | 15.5(2.0) | 2.2(0.3) | 3.6(0.5) | 1.7(0.2) | 108.1 | 1092 |
| 35 | +0.3 | 28.0(5.0) | 14.7(2.6) | 15.6(2.8) | 1.5(0.3) | 4.2(0.7) | 1.5(0.3) | 65.5 | 812 |
| 36 | +3.1 | 53.1(3.8) | 40.0(2.8) | 46.6(3.3) | 2.5(0.2) | 31.4(2.2) | 4.0(0.3) | 177.6 | 764 |
| 37 | (-1.1) | 38.9(8.3) | 20.5(4.4) | 8.0(1.7) | 2.0(0.4) | 1.2(0.3) | 0.5(0.1) | 71.1 | 1177 |
| 38 | +2.2 | 77.7(9.3) | 21.2(2.5) | 22.9(2.7) | 2.2(0.3) | 2.0(0.2) | 0.7(0.1) | 126.7 | 1182 |
| 39 | +3.2 | 64.7(8.3) | 31.6(4.0) | 9.9(1.3) | 2.4(0.3) | 3.5(0.4) | 1.0(0.1) | 113.1 | 1131 |
| 40 | +0.5 | 28.2(5.5) | 18.6(3.6) | 9.7(1.9) | 1.2(0.2) | 7.9(1.5) | 0.8(0.2) | 66.4 | 898 |
| 41 | +3.5 | 65.7(4.5) | 40.2(2.8) | 49.4(3.4) | 5.6(0.4) | 33.7(2.3) | 3.9(0.3) | 198.5 | 842 |

TABLE III - EFFECT OF FROZEN STORAGE TIME

| Expt. No. | Total Wt. Herring Before 1o Process lb | 1o Processing Conditions | | | Total Wt. of Roe After 1o Process lb | % Yield | Total Wt. Roe After 2o Process lb | |
|---|---|---|---|---|---|---|---|---|
| | | How Frozen | How Thawed | Days Frozen | | | | |
| 42 | 502 | FAST | FAST | (0.5 hr.) | 83.1 | 16.5 | 87.7 | |
| 43 | 515 | FAST | FAST | (16 hrs.) | 93.5 | 18.1 | 102.0 | |
| 44 | 525 | FAST | FAST | 1 | 97.2 | 18.5 | 97.0 | |
| 45 | 404 | FAST | FAST | 2 | 71.9 | 17.1 | 73.7 | |
| 46 | 454 | FAST | FAST | 4 | 83.4 | 18.4 | 85.2 | |
| 47 | 104 | FAST | FAST | 40 | 14.4 | 13.8 | 14.6 | |

t = less than 0.06% or .06 lbs.

(No provision made to grade out spongy roe in Expts. 44, 45 and 46)

TABLE IV* - EFFECT OF FREEZING AND THAWING RATES

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 48 | 450 | SLOW[a] | SLOW[a] | 4 | 66.0 | 14.7 | 68.0 | |
| 49 | 500 | SLOW[b] | SLOW[b] | 4 | 74.5 | 14.9 | 75.5 | |
| 50 | 540 | SLOW[a] | FAST[a] | 4 | 90.5 | 16.8 | 91.5 | |
| 51 | 500 | SLOW[b] | FAST[b] | 4 | 79.2 | 15.8 | 81.2 | |
| 52 | 508 | FAST | SLOW | 4 | 77.7 | 15.3 | 82.7 | |
| (46) | 454 | FAST | FAST | 4 | 83.4 | 18.4 | 85.2 | |

a - in plastic bags

b - in plastic lined boxes

(no provision made for spongy roe in Expts. 48-52 inclusive)

N.D. = not determined

t = less than 0.06%

* = same heading as for Table III

| Expt. No. | %Increase or Decrease After 2° Process | Individual Wt. (in lbs.) and % Yields of Graded Roe Obtained | | | | | | | Sum of Graded Roe Wts. lb | X/T |
|---|---|---|---|---|---|---|---|---|---|---|
| | | #1(%) | #2(%) | #3(%) | #4(%) | #5(%) | A(%) | F(%) | | |
| 42 | +5.5 | 5.0(1.0) | 18.3(3.6) | 4.6(0.9) | 0.7(0.1) | 2.2(0.4) | 0.5(0.1) | 57.0(11.3) | 88.3 | 639 |
| 43 | +9.1 | 28.5(5.5) | 8.4(1.6) | 1.6(0.3) | 0.1(t) | 3.9(0.8) | 0.2(t) | 59.7(11.6) | 102.4 | 889 |
| 44 | -0.2 | 75.1(14.3) | 13.3(2.5) | 4.2(0.8) | 1.2(0.2) | 3.7(0.7) | 0.3(0.1) | (N.D.) | 97.8 | - |
| 45 | +2.5 | 60.7(15.0) | 9.9(2.4) | 2.8(0.7) | 0.4(0.1) | 1.0(0.2) | 0.5(0.1) | (N.D.) | 75.3 | - |
| 46 | +2.2 | 73.7(16.2) | 6.1(1.3) | 1.4(0.3) | 0.6(0.1) | 2.7(0.6) | 0.2(t) | (N.D.) | 84.7 | - |
| 47 | +1.0 | 7.6(7.3) | 1.9(1.8) | 0.5(0.5) | 0 (0) | 0.1(0.1) | t (t) | 4.4(4.2) | 14.6 | 913 |
| 48 | +3.0 | 48.7(10.8) | 11.4(2.5) | 3.5(0.8) | 3.4(0.8) | 1.4(0.3) | 0.2(t) | (N.D.) | 68.6 | |
| 49 | +1.3 | 50.2(10.0) | 17.5(3.5) | 4.6(0.9) | 2.1(0.4) | 1.4(0.3) | 0.2(t) | (N.D.) | 76.0 | |
| 50 | +1.1 | 65.7(12.2) | 17.7(3.3) | 3.1(0.6) | 3.7(0.7) | 1.0(0.2) | 0.4(0.1) | (N.D.) | 91.6 | |
| 51 | +2.5 | 57.1(11.4) | 17.5(3.5) | 2.4(0.5) | 3.1(0.6) | 1.6(0.3) | 0.2(t) | (N.D.) | 81.9 | |
| 52 | +6.4 | 65.0(12.8) | 12.1(2.4) | 2.7(0.5) | 0.4(0.1) | 2.9(0.6) | 0.2(t) | (N.D.) | 83.3 | |
| 53 | +2.2 | 73.7(16.2 | 6.1(1.3) | 1.4(0.3) | 0.6(0.1) | 2.7(0.6) | 0.2(t) | (N.D.) | 84.7 | |

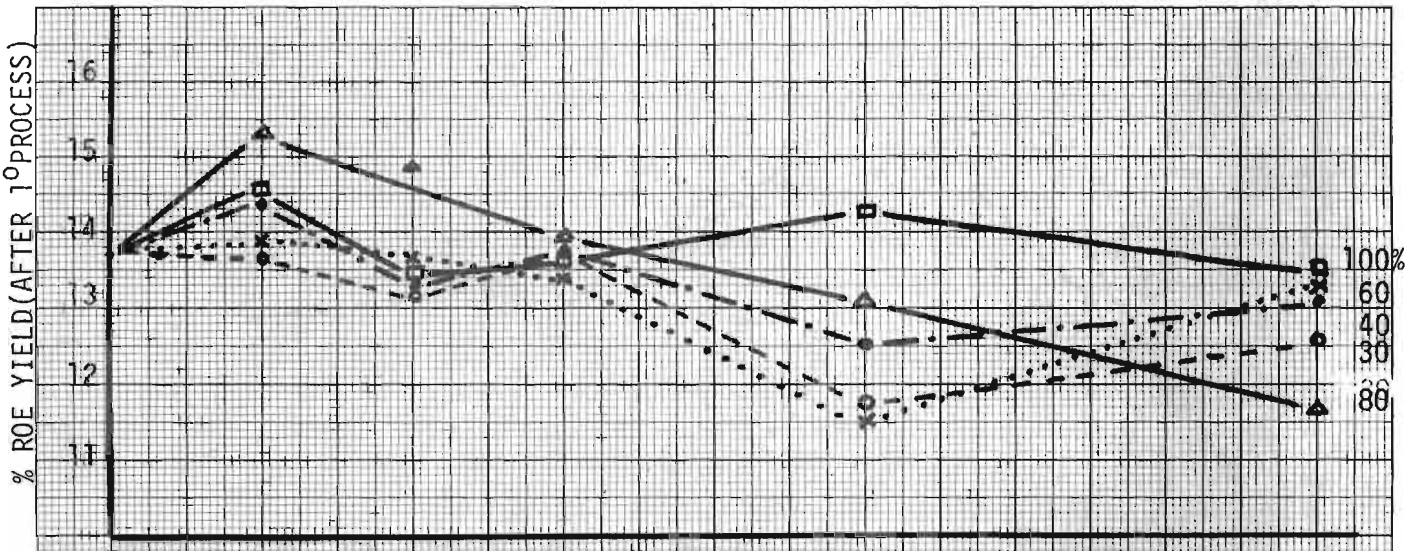
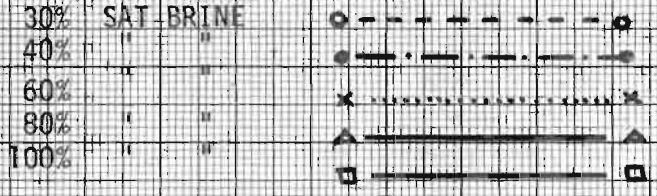



FIGURE 1. EFFECT OF BRINING TIME AND BRINE CONCENTRATION ON ROE YIELD



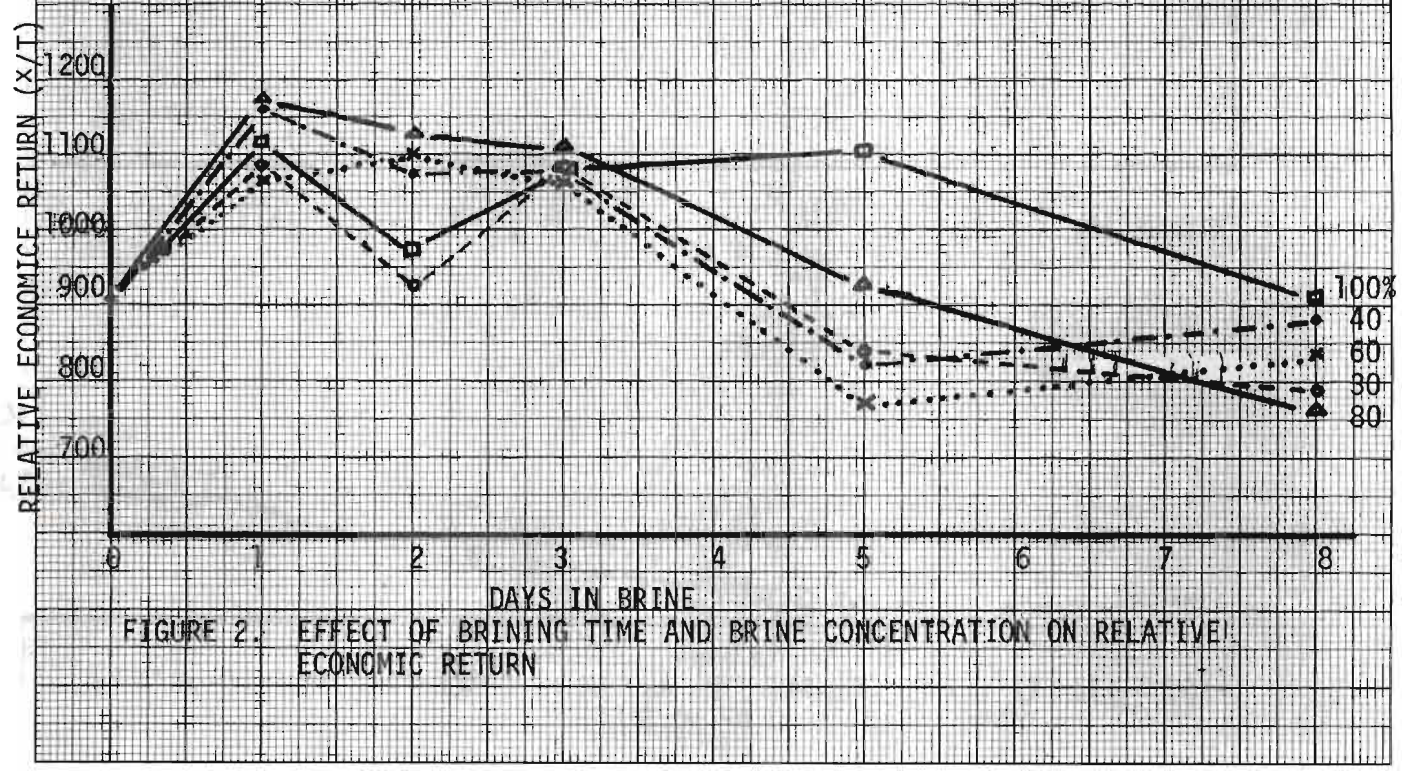




FIGURE 2. EFFECT OF BRINING TIME AND BRINE CONCENTRATION ON RELATIVE ECONOMIC RETURN

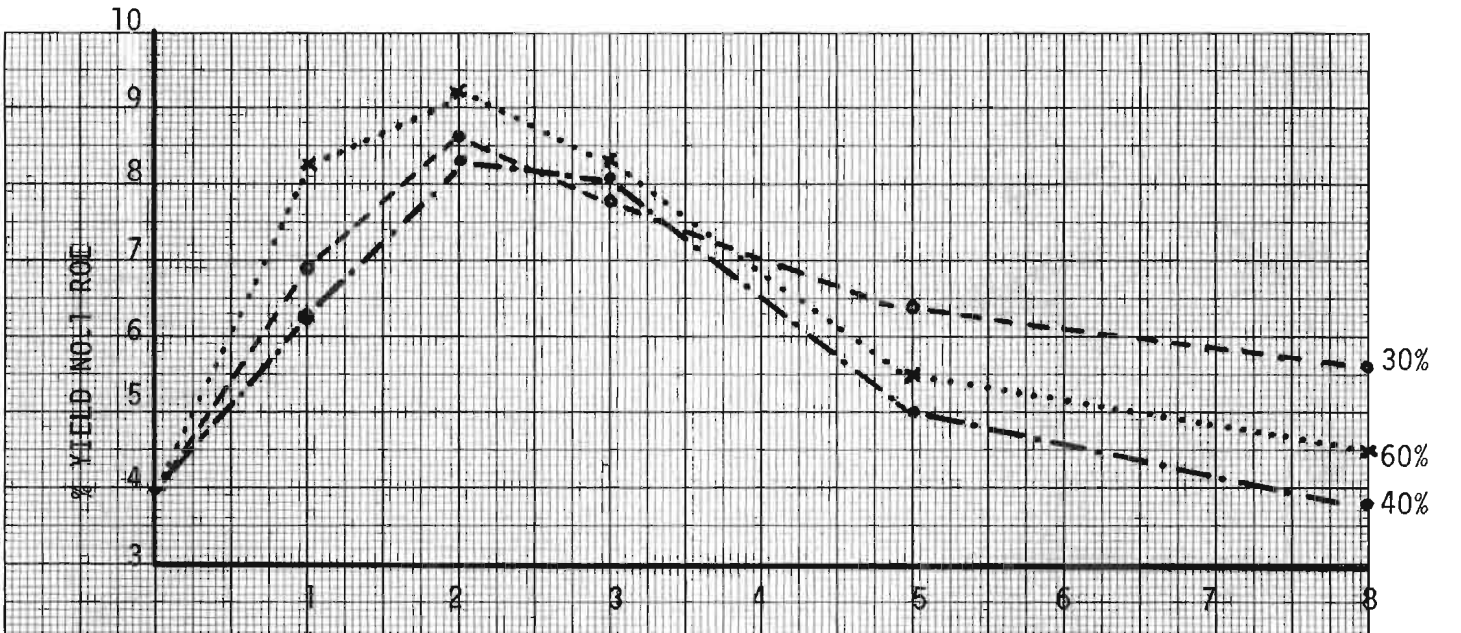



FIGURE 9. EFFECT OF BRINING TIME AND BRINE CONCENTRATION (WITH ADDED SORBATE) ON YIELD OF NO. 1 ROE

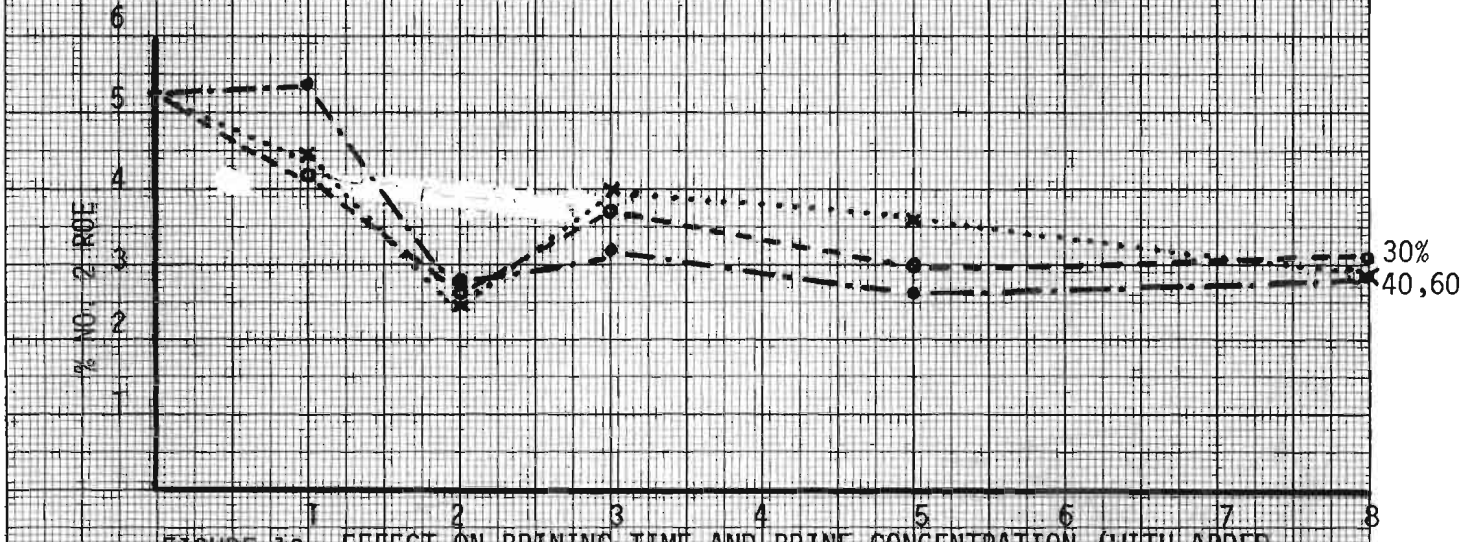



FIGURE 10. EFFECT ON BRINING TIME AND BRINE CONCENTRATION (WITH ADDED SORBATE) ON YIELD OF NO.2 ROE

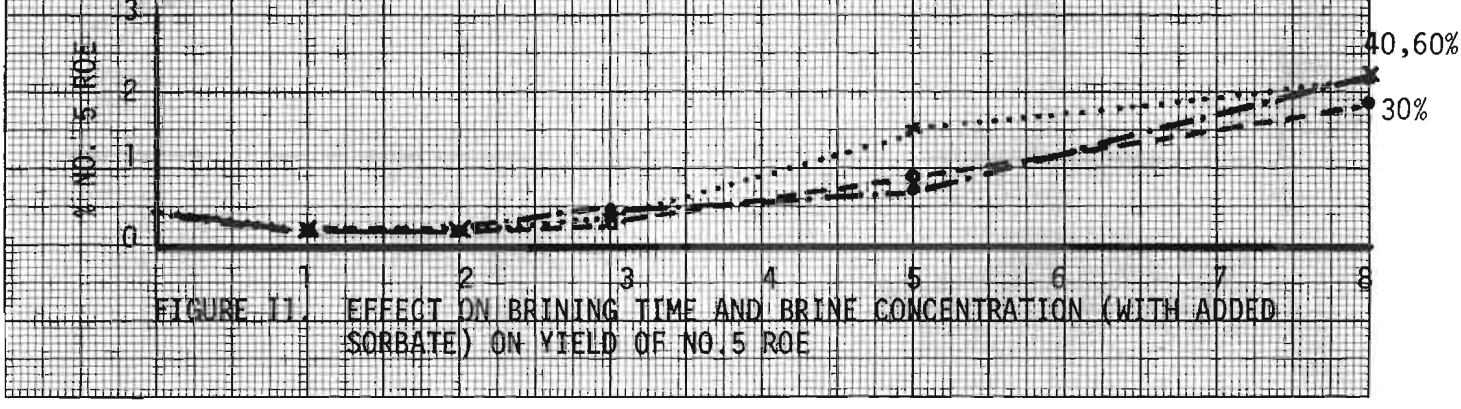



FIGURE 11. EFFECT ON BRINING TIME AND BRINE CONCENTRATION (WITH ADDED SORBATE) ON YIELD OF NO.5 ROE

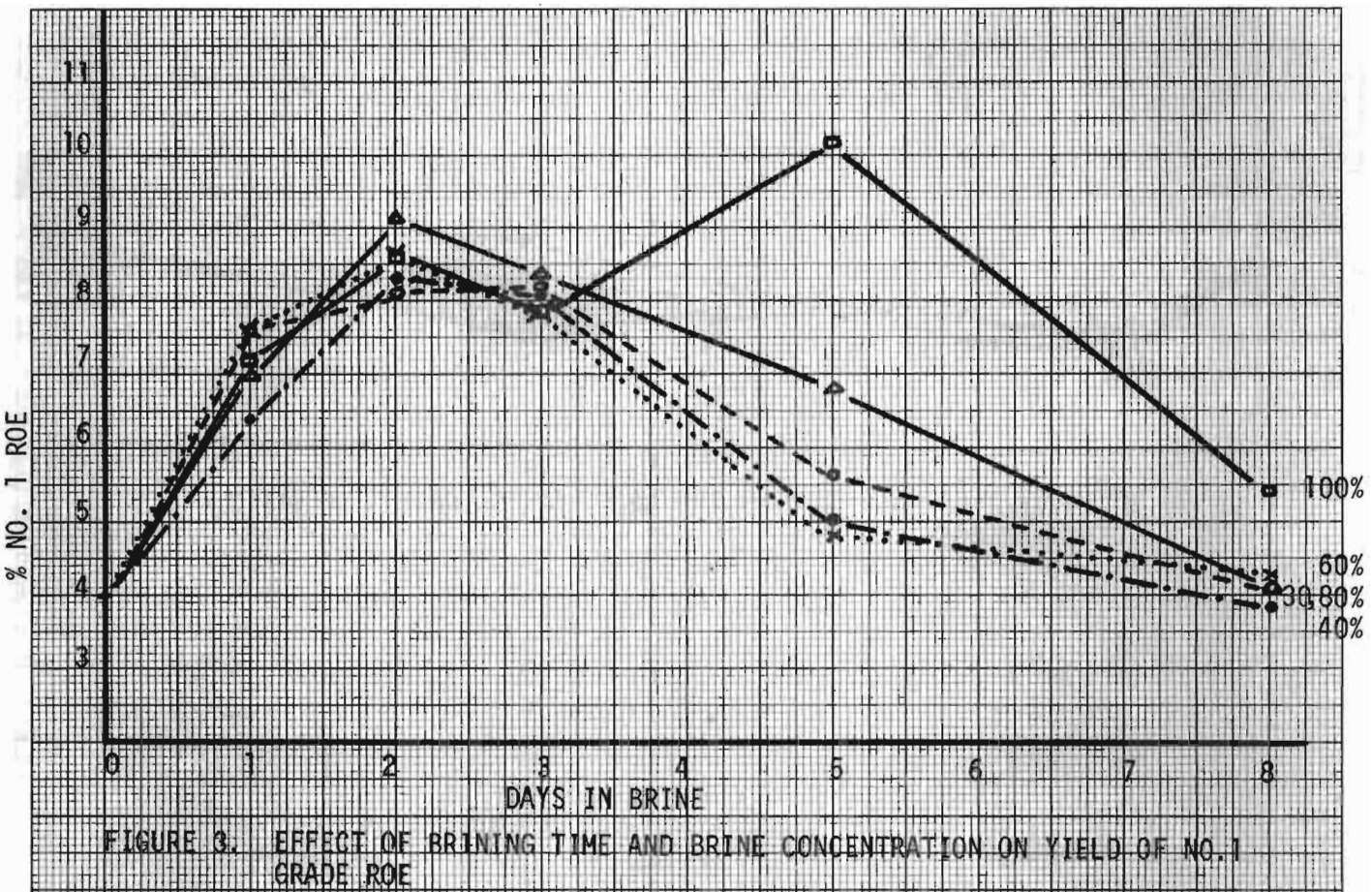



FIGURE 3. EFFECT OF BRINING TIME AND BRINE CONCENTRATION ON YIELD OF NO. 1 GRADE ROE

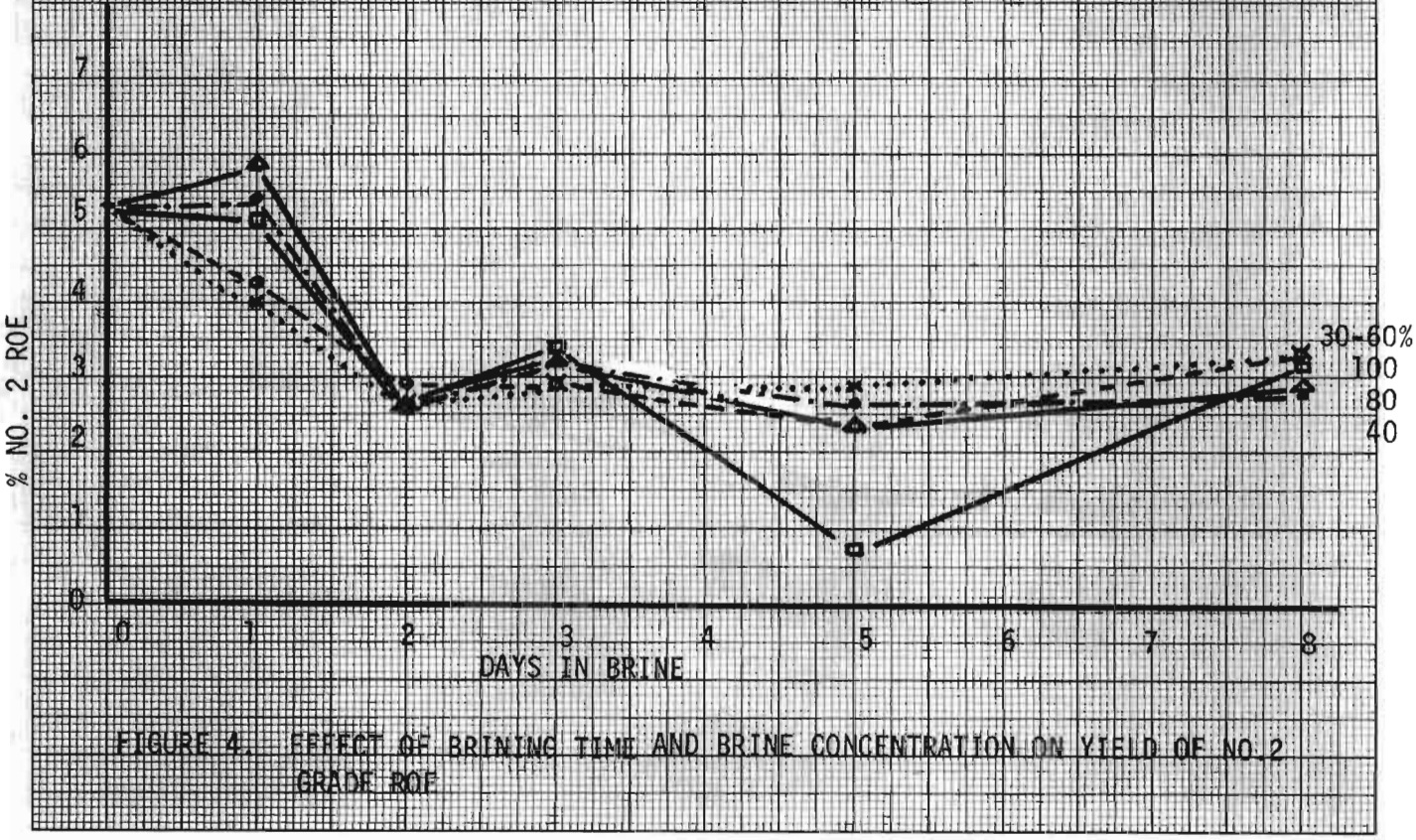



FIGURE 4. EFFECT OF BRINING TIME AND BRINE CONCENTRATION ON YIELD OF NO. 2 GRADE ROE

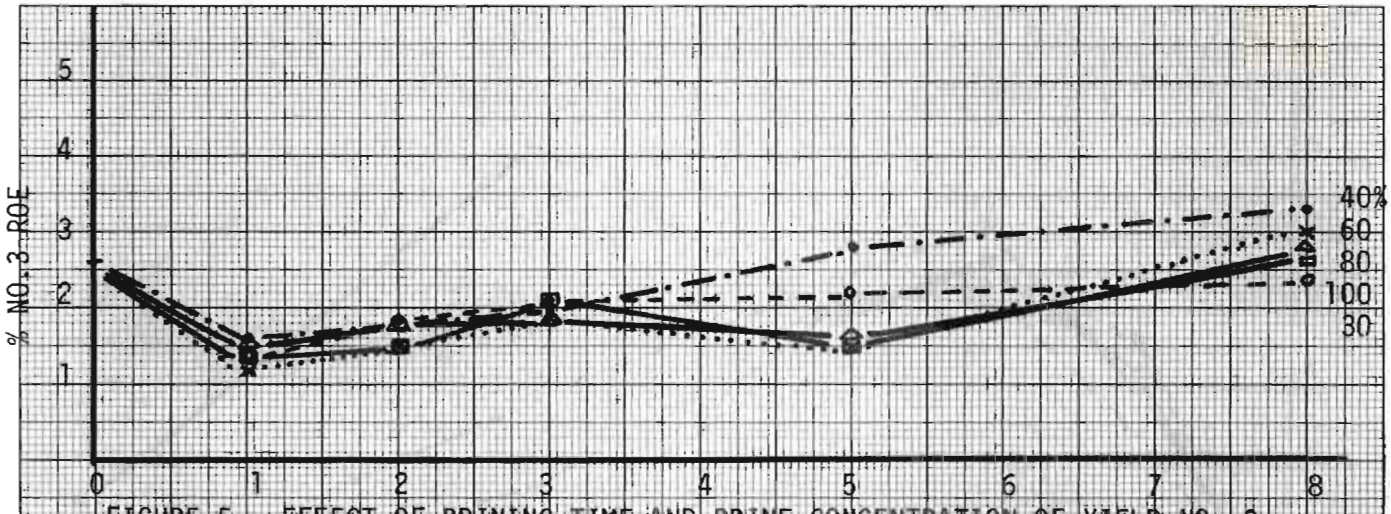



FIGURE 5. EFFECT OF BRINING TIME AND BRINE CONCENTRATION OF YIELD NO. 3 GRADE ROE

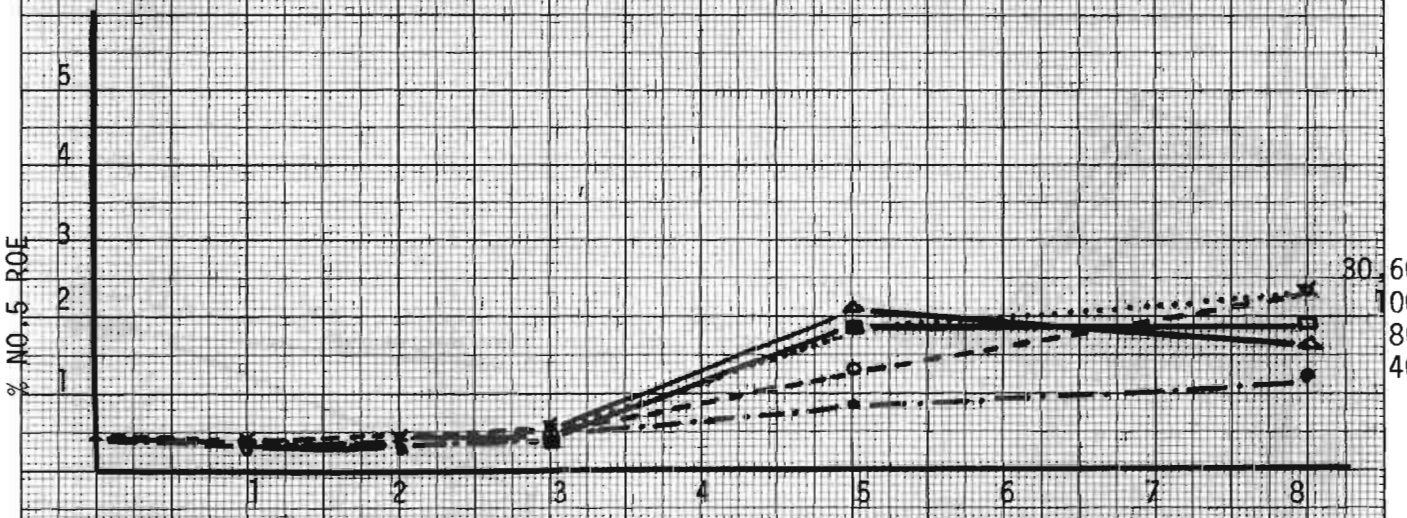



FIGURE 6. EFFECT OF BRINING TIME AND BRINE CONCENTRATION ON YIELD OF NO.5 GRADE ROE

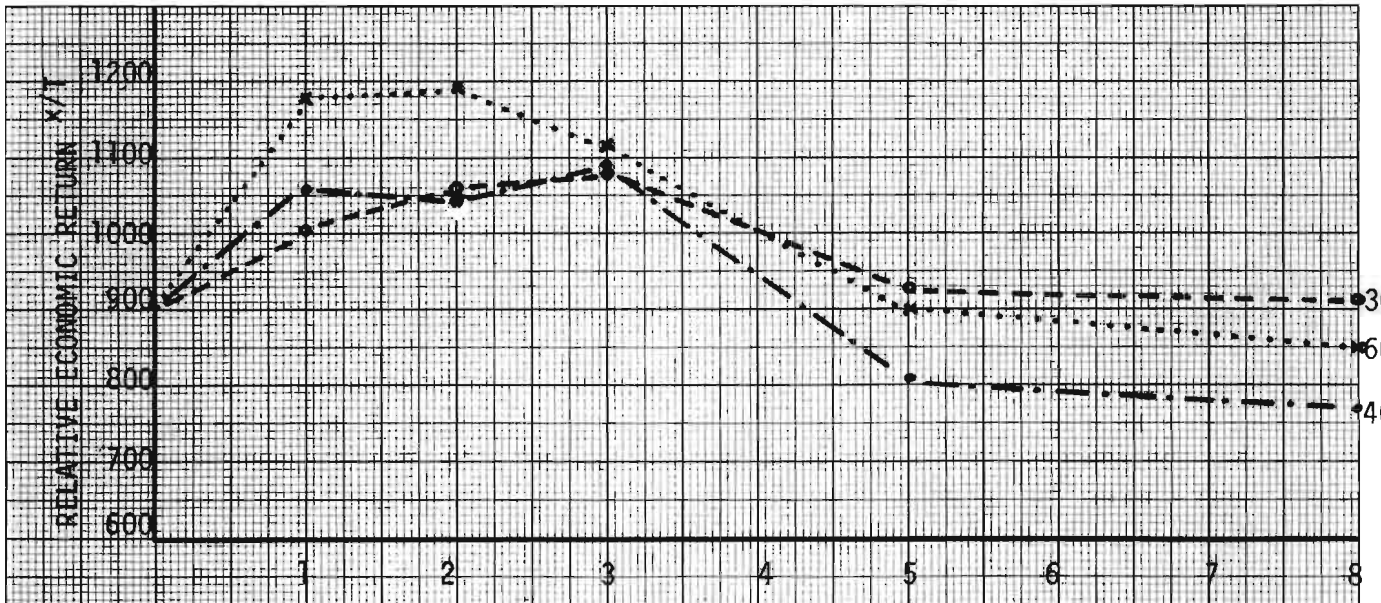



FIGURE 7. EFFECT OF BRINING TIME AND BRINE CONCENTRATION IN THE PRESENCE OF ADDED SORBATE ON ROE YIELD

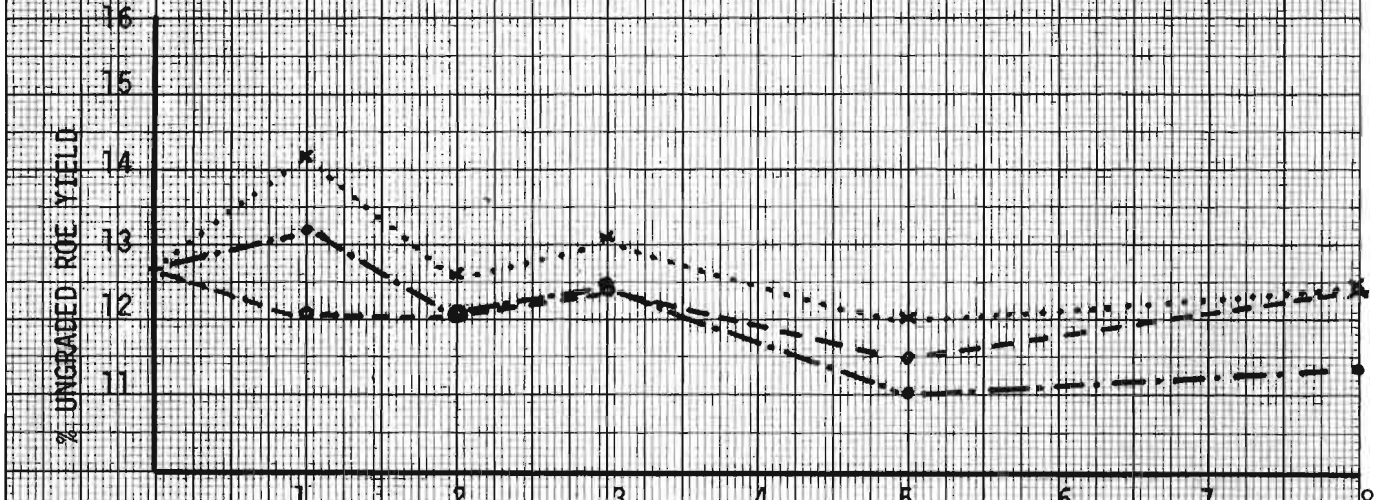



FIGURE 8. EFFECT OF BRINING TIME AND BRINE CONCENTRATION WITH ADDED SORBATE ON ROE YIELD