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INTERNATIONAL ASSOCIATION OF FISH MEAL MANUFACTURERS

# PRODUCTION OF MAYONNAISE CONTAINING FISH OIL

Sponsored by IAFMM

Final Report

(Part II)

*by*

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Part II

*SUMMARY*


1. Two samples of high quality oils selected from those tested in Part I of the study were used to study the stability of mayonnaise produced from 100% fish oil. Shelf-life of the mayonnaise could be markedly improved by the addition of certain combinations of lipid-soluble and water-soluble antioxidants added to the oil and aqueous phases, respectively. The requirement for the antioxidants was fairly specific. Considerable improvement in storage stability was observed when the samples were refrigerated as compared to storing at room temperature.

2. The use of a combination of glucose oxidase, glucose and catalase in the aqueous phase of the mayonnaise increased the shelf-life when the samples were refrigerated but not when they were stored at room temperature.

3. Both exposure to light and exposure to oxygen were determined to be factors contributing to the instability of mayonnaise processed from fish oils.


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## OBJECTIVES

The objectives of this study were:

1. To determine the chemical composition of fish oils manufactured in various countries, to estimate the sensory quality and stability of the oils and to relate, if possible, the chemical composition to the stability of the oils. IAFMM was to arrange to have the fish oils supplied. (Part I of Report)

2. To incorporate fish oil into food products while obtaining an acceptable shelf-life. Originally two products were to be evaluated, mayonnaise, an oil-in-water emulsion and margarine, a water-in-oil emulsion. Time limitations and difficulty of preparing the product did not allow us to evaluate fish oils in margarine. Thus, only mayonnaise was evaluated. (Part II of Report)

## MATERIALS AND METHODS

Fish oils were supplied to us from Chile, Denmark, Faroe Islands, Iceland, Norway, South Africa, Sweden and the United States. Most of the oils did not have added antioxidants. Three of the eight suppliers provided extra samples with antioxidant mixtures they normally add. These were also evaluated. Additional samples of oil were supplied to us by two companies for the work with mayonnaise.

## Incorporation of Fish Oils into Mayonnaise and Evaluation of the Storage Stability of the Product

All mayonnaises were made with 100% fish oil (in some cases a control of 100% soybean oil was also used). The mayonnaise was composed of the following ingredients: fish oil 70%, egg yolk 14%, vinegar 12%, sucrose 2%, salt 1%, dry mustard 1%. All ingredients except the oil were added to a Waring blender and mixed at low speed for 1 min. The fish oil was then added with mixing in 3 or 4 portions. The first portion was relatively small. Addition of the oil took place during a mixing time of approximately 1 min. The emulsions formed were stable.

The principal means of quality assay of the mayonnaise was by odour evaluation. A panel was trained to detect any off-odour that developed in the stored product. Each panellist was also asked to describe the nature of any off-odour formed. Any off-odour was considered to be unacceptable in the product. The stability of the oil is expressed as the induction or lag time until off-odour developed. There was generally not much difference amongst the panel members in detecting the first off-odour. Chemical analyses such as anisidine values and peroxide values were determined in a few situations.

## RESULTS

### Stability of Mayonnaise Made from Fish Oil

Two different sources of fish oils were tested for their stability in mayonnaise. Menhaden oil and capelin oil were chosen for this work; these had good quality initially and gave reasonable stability in our initial evaluations of the samples of fish oil we received through IAFMM.

Mayonnaise was prepared with 100% fish oil. We needed to evaluate several antioxidative systems and therefore did not want to have to wait too long for the material to undergo spoilage. For this reason, no attempt was made to exclude air from the product. In addition, the product was stored fully exposed to air at room temperature. An initial preliminary survey indicated that the shelf-life of mayonnaise made with fish oil without antioxidants was very short, one to two days. Several phenolic antioxidants were added to the oils to determine the one which was best at extending the shelf-life of the mayonnaise. It was found that propyl gallate (PG) and butylated hydroxytolulene (BHT) were the best antioxidants. Butylated hydroxyanisole (BHA) and a mixed tocopherol preparation were next and t-butyl hydroquinone (TBHQ) was the poorest. Since we had also found that in a mackerel muscle system, propyl gallate was one of the two best, we decided to use this as our propagation inhibitor. Serendipitously we observed that citric acid in the oil was very effective as an antioxidant by itself, even more so than the phenolics. Therefore our standard antioxidant in the oil phase was chosen to be 50 ppm citric acid and 0.02% by weight of propyl gallate.

Several antioxidants and combinations were evaluated in the aqueous phase of mayonnaise prepared from menhaden oil (Table 24). Preliminary evaluation of the various antioxidants was made using a sensory test for the detection of any off-odour.

This was done since it allowed us to screen a large number of antioxidants. Many components which are observed to be effective antioxidants under some conditions were found to have a pro-oxidative effect in this system. For example, adding no antioxidant in the aqueous phase produced a mayonnaise with a shelf-life of ten days, whereas that attained with a large number of antioxidants or potential antioxidants was less. In this experiment it was clear that EDTA (75 ppm) and ascorbate (200 ppm) when added to the aqueous phase were most effective in retarding off-odour development. The combination of citric acid plus PG in the oil phase and EDTA and ascorbate in the aqueous phase gave a shelf-life of 53 days for a sample stored at room temperature and exposed to air.

Combinations of PG, citric acid, EDTA and ascorbate in the oil and aqueous phases were evaluated (Table 25). No sample improved over the antioxidant combination that we used in the first experiment. Substituting sodium citrate for citric acid in the oil phase gave approximately the same shelf-life as did the standard antioxidant system of citric acid and PG in the oil phase and EDTA plus ascorbate in the aqueous phase. The shelf-lives of the samples in this experiment were less than those of comparable samples in Table 24. This oil, however, had been previously thawed and opened to prepare the samples of Table 24. It is possible that this caused some destabilization of the oil.

The next series of experiments again involved the evaluation of mayonnaise made with 100% menhaden oil. This menhaden oil was a different batch than had been used in the experiments in Tables 24 and 25. The purpose of this experiment was to incorporate a variety of additional compounds into the oil phase in addition to the citric acid and propyl gallate and determine their effect on shelf life. The principal interest was oxygen scavenging enzymes and phospholipid compounds. It had been suggested that phospholipids could stabilize fish oil against oxidation. In this case, the standard antioxidants of EDTA and ascorbate were not used in the aqueous phase. This was done so that the period of time for evaluation would not be too long. Although there is the possibility of an interaction between enzyme or phospholipid and EDTA and/or ascorbate being missed by this technique, it was felt that the added time saved would be worth it at this point in the experimentation. Basically what was observed by these procedures was that phospholipids in either the oil or aqueous phase did not result in any improvement of shelf-life (Table 26). In fact, the only addition we saw that was useful was glucose oxidase plus glucose which approximately doubled the shelf-life of the oil from eight (no antioxidants in the aqueous phase) to 15 days. The catalase content of the preparation was sufficient catalase to break down any hydrogen peroxide that was formed.

Next, the most effective antioxidant system was evaluated in more detail using both sensory and chemical analyses. The first set of experiments was done with the same batch of menhaden oil that had been utilized in the experiments described in Table 26. The oil had been thawed and exposed to air during the preparation of the mayonnaise samples described in Table 26. The data indicate (Table 27) that the shelf-life either in the absence of glucose oxidase plus glucose, or in its presence was something less than 21 days. This storage life was less that observed from the previous batch of menhaden oil which gave approximately 50 and 30 days in two consecutive experiments. Although the initial value of the peroxide number was low in this oil, the anisidine value was quite

high. The glucose oxidase plus glucose system seemed to retard oxidation as measured by the peroxide value, as well as the anisidine value, but did not protect the product from developing an off-odour. When the samples of Table 27 were stored at refrigerated temperature the shelf-life of both the mayonnaise without enzyme and with enzyme were greatly increased over the samples that were stored at room temperature (Table 28). In addition, the presence of glucose oxidaze + glucose extended the shelf-life of the mayonnaise much more than it did the mayonnaise which was prepared in the absence of enzyme.

Earlier mayonnaise samples had been stored at room temperature to allow the experiments to be completed more rapidly so that more factors and conditions could be evaluated. It now seemed prudent to evaluate the effect of low temperature on the shelf-life of fish oil mayonnaise. Mayonnaise was prepared with our usual antioxidant mixture in the oil and aqueous phases. One sample was stored at room temperature and one at refrigerated temperatures (Table 29). The shelf-life of the samples stored at room temperature was 35 days while that stored under refrigerated conditions was 85 days, again showing that marked improvement can be attained by storing the product in the refrigerator. Peroxide values and anisidine values of the oils were compared at comparable intervals for the first 35 days of storage. Anisidine values changed very little with storage of the mayonnaise in the refrigerator while a clear increase was observed for the room temperature sample. The increase in peroxide value of the refrigerated sample was much less than that of the sample stored at room temperature.

A study similar to that described in Table 29 was conducted for mayonnaise that was prepared from 100% capelin oil (Table 30). Capelin oil has a lower iodine number and lower content of the highly unsaturated 20:5 and 22:6 fatty acids. It might be expected to be somewhat more stable. The shelf-life of the capelin oil mayonnaise stored at room temperature was 54 days, somewhat greater than the product made from the menhaden oil. The refrigerated sample, however, had a shelf-life of 81 days which is very close to the 85 days obtained when the mayonnaise was prepared from menhaden oil. In other words, the extension of shelf-life by refrigeration was less with the capelin oil than it was with the menhaden oil. The chemical indices of the capelin oil in mayonnaise stored at refrigerated temperature showed less change than did the comparable menhaden oil. Changes occurring in the capelin oil and the mayonnaise held at room temperature over the first 35 days did not vary greatly from the values observed with the mayonnaise prepared from menhaden oil. In the case of the mayonnaise prepared from capelin oil, however, 35 days represented only about 2/3 of its total shelf-life.

To re-check the role of temperature on the effectiveness of glucose oxidase in increasing the shelf-life of mayonnaise prepared with fish oil, samples of mayonnaise made with the same batch of menhaden and capelin oils used to prepare the mayonnaise of Table 29 and Table 30 were examined with respect to their shelf-life in the presence of glucose oxidase + glucose. Table 31 gives the results of mayonnaise made with menhaden oil and Table 32 with capelin oil. As observed previously, when the enzymes were added to the samples at room temperature there was no improvement in the shelf-life of the product. Some increase in shelf-life was observed in the mayonnaises prepared from both oils when the samples with enzyme added in the aqueous phase were stored at refrigerated temperature.

The amount of oxygen in contact with the mayonnaise should be an important factor in its shelf-life. Light might also be critical since it is known that certain sensitizing molecules can be activated by light; these in turn can activate triplet oxygen to singlet oxygen or to reduction compounds of molecular oxygen such as superoxide or hydrogen peroxide. To test the role of oxygen and light in the stability of mayonnaise prepared with fish oil, mayonnaise was prepared with 100% menhaden oil and stored in either clear glass jars, amber coloured glass jars, or clear glass jars that had been wrapped with aluminum foil. The mayonnaise was prepared and stored under either nitrogen gas or air. Shelf-life of products under these conditions are given in Table 33. Light appeared to have an effect on the shelf-life of the mayonnaise since the 3 samples in which light was reduced or excluded had shelf-lives of 65, 62 and 65 days whereas those packed in clear bottles had shelf-lives of 56 and 50 days. In the latter case, the sample with the shelf-life of 56 days was prepared and stored under nitrogen while the sample with the shelf-life of 50 days was prepared and stored under air. There was an effect of oxygen as well. The relatively strong effect of light compared to oxygen (at least from what we expected) may be explained by the way the experiments were done. The samples that were prepared under nitrogen were placed in bottles, the headspace of which was flushed out with nitrogen gas. However, at regular intervals, it was necessary to open these jars in order to evaluate their odour quality. After the jar was opened and evaluated by the panel (7-10 people), the headspace was re-flushed with nitrogen, the cover put on, and the sample was re-stored either at room temperature or in the refrigerator. It is possible, however, that during the time in which the oil was being evaluated some oxygen from the air was able to diffuse into the surface of the mayonnaise such that with time the sample did not remain as anaerobic as was desired.

The effect of the surface area exposed to oxygen was evaluated with mayonnaise made from 100% menhaden oil and stored at room temperature (Table 34). Room temperature was used to reduce the time of the experiment which turned out to range from 43-56 days depending on the sample. Sample 1 consisted of approximately 124 g of mayonnaise placed in a 16 oz. glass jar. The surface area was $1.9 \times 10^4$ mm$^2$. Sample 2 was prepared by placing approximately 36 g of mayonnaise in a 2 oz. clear glass jar with an exposed surface area of $4.3 \times 10^3$ mm$^2$. The last sample, 3, was similar to sample 2 except that the mayonnaise was coated all around the jar surface and had an exposed area of $1.1 \times 10^4$ mm$^2$. Sample 2 with the smaller surface area showed a greater shelf-life than the similar sized sample that had a surface area almost 3 times as much. The increase in shelf-life was almost one third. The sample in the 16 oz. jar with the surface area of $1.9 \times 10^4$ mm$^2$ was slightly better than sample 3. It might have been expected that this would be the sample with the shortest shelf-life since it had the largest surface area. However, other factors such as the volume of headspace in the jar and the total amount of mayonnaise may have been factors which influenced the results. The top and bottom halves of the mayonnaise in the 16 oz. jar were removed separately and oxidative chemical indices determined in each half. Essentially all of the changes in anisidine and peroxide values occurred in the top half of the product. These data demonstrate the importance of exposure to oxygen.

## GENERAL DISCUSSION AND FUTURE CONSIDERATIONS

The increase in shelf-life of mayonnaise prepared from unprotected fish oil to that using our best antioxidation system was quite high. Unprotected fish oils gave mayonnaise with stabilities of at most one to two days. We were able to increase this to 180 days in samples stored exposed to light, oxygen, and produced from 100% fish oil. We do not feel we have examined all possible factors in developing stability and hopefully will be able to do additional work on this in the future. We did observe some variability in mayonnaises made from different samples of the same type of fish oil, and even between mayonnaise samples prepared from the same batch of fish oil but at different times. We do not know the cause of this variability; it is something, however, that deserves attention in commercial application. Predictability of shelf-life may be as important as the extension of shelf-life.

## ACKNOWLEDGMENTS

We thank Stephen D. Kelleher for expert technical advice and assistance and all panel members for their help and cooperation.

Table 24. Stability of mayonnaise made with 100% menhaden oil with various antioxidants in the lipid and aqueous phases.

| Sample | AO in the oil phase | AO in the aqueous phase | Days to off-odor |
|---|---|---|---|
| 1 | Citric acid + PG | STPP | 3 |
| 2 | Citric acid + PG | EDTA | 21 |
| 3 | Citric acid + PG | Citrate | 3 |
| 4 | Citric acid + PG | CMC | 6 |
| 5 | Citric acid + PG | Succinate | 3 |
| 6 | Citric acid + PG | Ascorbate | 4 |
| 7 | Citric acid + PG | Desferal | 4 |
| 8 | Citric acid + PG | STPP + Ascorbate | 16 |
| 9 | Citric acid + PG | EDTA + Ascorbate | 53 |
| 10 | Citric acid | None | 5 |
| 11 | Citric acid + PG | None | 10 |
| 12 | PG | None | 6 |
| 13 | EDTA + PG | Citric acid + Ascorbate | 17 |

The concentration of the various components used was as follows:

<u>In the oil phase</u>

Citric acid-50 ppm

PG (propyl gallate)-200 ppm

EDTA (ethylene diamine tetraacetic acid disodium salt)-75 ppm.

<u>In the aqueous phase (concentration based on the aqueous phase)</u>

STPP (sodium tripolyphosphate)-200 ppm

EDTA (ethylene diamine tetraacetic acid disodium salt)-75 ppm

Citrate (sodium salt)-50 ppm

CMC (carboxy methyl cellulose)- 3000 ppm

Succinate (disodium salt)-60 ppm

Ascorbate (sodium salt)-200 ppm

Desferal-50 ppm.

Table 25. Stability of mayonnaise made with 100% menhaden oil with various antioxidants in the lipid and aqueous phases.

| Sample | AO in the oil phase | AO in the aqueous phase | Days to off-odor |
|---|---|---|---|
| 1 | Citric acid + PG | EDTA + Ascorbate | 32 |
| 2 | Citric acid + PG | Citrate + Ascorbate | 2 |
| 3 | Citrate + PG | EDTA + Ascorbate | 31 |
| 4 | EDTA + PG | EDTA + Ascorbate | 15 |
| 5 | Ascorbic Acid + EDTA + PG | EDTA + Ascorbate | 7 |
| 6 | BHT + Citric Acid | EDTA + Ascorbate | 9 |
| 7 | BHT + EDTA | EDTA + Ascorbate | 12 |
| 8 | Citric acid + PG | Citric Acid + Ascorbate | 4 |
| 9 | Ascorbic Acid + PG | EDTA + Ascorbate | 5 |

The concentration of various componants used was as follows:

In the oil phase

Citric acid-50 ppm
PG (propyl gallate)-200 ppm
Citrate (sodium salt)-50 ppm
EDTA (ethylene diamine tetraacetic acid disodium salt)-75 ppm
Ascorbic acid-200 ppm
BHT (butylated hydroxy toluene)-200 ppm

In the aqueous phase (concentration based on the aqueous phase)

EDTA (ethylene diamine tetraacetic acid disodium salt)-75 ppm
Ascorbate (disodium salt)-200 ppm
Citrate (sodium salt)-50 ppm
Citric acid-50 ppm.

Table 26. Stability of mayonnaise made with 100% menhaden oil with various antioxidants in the lipid and aqueous phases.

| Sample | AO in the oil phase | AO in the aqueous phase | Days to off-odor |
|---|---|---|---|
| 1 | Citric Acid + PG + PC | None | 3 |
| 2 | Citric Acid + PG + CA | None | 8 |
| 3 | Citric Acid + PG + CCPS | None | 2 |
| 4 | Citric Acid + PG + PC + Ascorbic Acid | None | 6 |
| 5 | Citric Acid + PG | PC | 2 |
| 6 | Citric Acid + PG | SOD | 7 |
| 7 | Citric Acid + PG | Catalase | 11 |
| 8 | Citric Acid + PG | SOD + Catalase | 11 |
| 9 | Citric Acid + PG | Glucose oxidase + glucose | 15 |
| 10 | Citric Acid + PG | Phospholipase | 2 |
| 11 | Citric Acid + PG | None | 8 |

The oil has the following characteristics: Induction period=4.4 hrs.(70C), Initial peroxide value=0.7, Initial anisidine Value=18.2

The concentration of the various components used was as follows:

In the oil phase

Citric acid-50 ppm
PG (propyl gallate)-200 ppm
PC ( phosphatidyl choline, soybean lecithin)-5000 ppm
CA (centrolene A, from soybean lecithin)-5000 ppm
CCPS (centromix CPS, from soybean lecithin)-5000 ppm
Ascorbic acid-200 ppm
PG (propyl gallate)-200 ppm

In the aqueous phase

PC (phosphatidyl choline, soybean lecithin)-5000 ppm
SOD (superoxide dismutase)-33 ppm
Catalase-33 ppm
Glucose oxidase-133 ppm
Glucose-133 ppm
Phospholipase-33 ppm

Table 27. Sensory and oxidative stability of mayonnaise made with 100% menhaden oil during storage at room temperature.

| Sample | Storage (days) | Peroxide Value | Anisidine Value | % Free Fatty Acids | Sensory Off-Odor |
|---|---|---|---|---|---|
| 1 | 0 | 2.3 | 17.8 | 0.8 | No |
| | 5 | 3.3 | 18.3 | 0.8 | No |
| | 11 | 8.3 | 20.2 | 0.7 | No |
| | 17 | 14.1 | 23.6 | 0.8 | No |
| | 21 | 20.8 | 25.3 | 0.9 | Yes |
| 2 | 0 | 2.5 | 18.5 | 0.7 | No |
| | 5 | 4.2 | 18.7 | 1.1 | No |
| | 11 | 4.4 | 17.6 | 0.8 | No |
| | 17 | 8.2 | 17.1 | 0.9 | No |
| | 21 | 8.9 | 17.6 | 1.0 | Yes |
| 3 | 0 | 0.0 | 3.0 | 0.6 | No |
| | 5 | 1.0 | 3.1 | 0.7 | No |
| | 11 | 3.0 | 2.5 | 0.6 | No |
| | 17 | 12.2 | 2.1 | 0.8 | No |
| | 21 | 6.4 | 2.3 | 0.8 | No |

The oil has the following characteristics: Induction period=5.5 hr. (70C), initial peroxide value=0.7, initial anisidine value=18.2.

1 & 2 have the following antioxidants:

In the oil phase:

Citric acid-50 ppm

PG (propyl gallate) -200 ppm

In the aqueous phase (concentration based on the aqueous phase):

EDTA (ethylene diamine tetraacetic acid disodium salt)-75 ppm

ascorbate (sodium salt)-200 ppm

In addition sample 2 has glucose oxidase-133 ppm, glucose-133 ppm in the aqueous phase.

3 = mayonnaise made from soybean oil.

Table 28. Shelf-life of mayonnaise made with 100% menhaden oil during storage at refrigerated temperature with or without glucose oxidase.

| Sample | AO in the oil phase | AO in the aqueous phase | Days to off-odor |
|---|---|---|---|
| 1 | Citric Acid (50 ppm)<br>PG (200 ppm) | EDTA (75 ppm)<br>Ascorbate (200 ppm) | 68 |
| 2 | Citric Acid (50 ppm)<br>PG (200 ppm) | EDTA (75 ppm)<br>Ascorbate (200 ppm)<br>Glucose oxidase (133 ppm)<br>Glucose (133 ppm) | 190 |

The oil has the following characteristics:
Induction period=5.5 hr. (70C)
Initial peroxide value=0.7
Initial anisidine value=18.2

Table 29. Stability of mayonnaise made with 100% menhaden oil during storage at room and refrigerated temperatures.

| Storage Temperature | Storage (days) | Peroxide Value | Anisidine Value | Sensory Off-Odor |
|---|---|---|---|---|
| Room | 0 | 0.7 | 22.1 | No |
| | 7 | 2.2 | 26.1 | No |
| | 15 | 5.1 | 28.2 | No |
| | 21 | 5.9 | 28.4 | No |
| | 28 | 6.5 | 29.3 | No |
| | 35 | 11.6 | 30.2 | Yes |
| Refrigerated | 0 | 0.7 | 22.1 | No |
| | 15 | 2.6 | 23.6 | No |
| | 21 | 3.1 | 23.9 | No |
| | 28 | 3.2 | 23.9 | No |
| | 35 | 4.5 | 23.6 | No |
| | 42 | | | No |
| | 44 | | | No |
| | 46 | | | No |
| | 50 | | | No |
| | 60 | | | No |
| | 70 | | | No |
| | 77 | | | No |
| | 85 | | | Yes |

The oil has the following characteristics: Induction period (70C)=4.8 hr. Initial peroxide value=0.9, initial anisidine value=21.6, initial percentage free fatty acid=0.3.

In the oil phase

Citric acid-50 ppm

PG (propyl gallate)-200 ppm

In the aqueous phase

EDTA (ethylene diamine tetraacetic acid disodium salt)-75 ppm

Ascorbate-200 ppm

Table 30. Stability of mayonnaise made with 100% capelin oil during storage at room and refrigerated temperatures.

| Storage Temperature | Storage (days) | Peroxide Value | Anisidine Value | Sensory Off-Odor |
|---|---|---|---|---|
| Room | 0 | 0.0 | 1.5 | No |
| | 7 | 1.7 | 1.9 | No |
| | 14 | 2.0 | 4.4 | No |
| | 21 | 4.0 | 5.6 | No |
| | 28 | 5.5 | 6.8 | No |
| | 35 | 10.0 | 7.0 | No |
| | 39 | | | No |
| | 43 | 12.6 | 8.5 | No |
| | 50 | 11.0 | 7.6 | No |
| | 54 | 12.2 | 9.7 | Yes |
| Refrigerated | 0 | 0.0 | 1.5 | No |
| | 14 | 0.5 | 1.6 | No |
| | 21 | 0.5 | 2.0 | No |
| | 28 | 0.7 | 2.0 | No |
| | 35 | | | No |
| | 39 | | | No |
| | 43 | | | No |
| | 50 | | | No |
| | 54 | | | No |
| | 57 | | | No |
| | 64 | | | No |
| | 74 | | | No |
| | 81 | | | Yes |

The oil has the following characteristics: Induction period=6.4 hr. (70C), initial peroxide value=1.1, initial anisidine value=1.2, initial percentage free fatty acid=0.2.
In the oil phase: Citric acid-50 ppm, PG (propyl gallate)-200 ppm.
In the aqueous phase: EDTA (ethylene diamine tetraacetic acid disodium salt)-75 ppm Ascorbate-200 ppm.

Table 31. Stability of mayonnaise made with 100% menhaden oil during storage at room and refrigerated temperatures.

| Storage Temperature | AO in the oil phase | AO in the aqueous phase | Days to off-odor |
|---|---|---|---|
| Room | Citric Acid (50 ppm)<br>PG (200 ppm) | EDTA (75 ppm)<br>Ascorbate (200 ppm)<br>Glucose Oxidase (133 ppm)<br>Glucose (133 ppm) | 35 |
| Refrigerated | Citric Acid (50 ppm)<br>PG (200 ppm) | EDTA (75 ppm)<br>Ascorbate (200 ppm)<br>Glucose Oxidase (133 ppm)<br>Glucose (133 ppm) | 113 |

The oil has the following characteristics:
Induction period=4.8 hr. (70C)
Initial peroxide value=0.9
Initial anisidine value=21.6
Initial percentage free fatty acid=0.3

Table 32. Stability of mayonnaise made with 100% capelin oil during storage at room and refrigerated temperatures.

| Storage Temperature | AO in the oil phase | AO in the aqueous phase | Days to off-odor |
|---|---|---|---|
| Room | Citric Acid (50 ppm)<br>PG (200 ppm) | EDTA (75 ppm)<br>Ascorbate (200 ppm)<br>Glucose Oxidase (133 ppm)<br>Glucose (133 ppm) | 54 |
| Refrigerated | Citric Acid (50 ppm)<br>PG (200 ppm) | EDTA (75 ppm)<br>Ascorbate (200 ppm)<br>Glucose Oxidase (133 ppm)<br>Glucose (133 ppm) | 102 |

The oil has the following characteristics:
Induction period=6.4 hr. (70C)
Initial peroxide value=1.1
Initial anisidine value=1.2
Initial percentage free fatty acid=0.2

Table 33. Stability of mayonnaise made with 100% menhaden oil stored in clear glass jar versus amber color jar, with and without oxygen and kept at room temperature.

| Analysis | A,N | C,N | A,O | C,O | CAl,O |
|---|---|---|---|---|---|
| Changes in peroxide value | 4.7 | 11.2 | 18.7 | 23.2 | 18.6 |
| Changes in anisidine value | 5.1 | 6.6 | 10.4 | 13.7 | 10.6 |
| Days to off-odor | 65.0 | 56.0 | 62.0 | 50.0 | 65.0 |

Initial peroxide value = 1.2
Initial anisidine value = 21.5

In the aqueous phase: EDTA-75 ppm , Ascorobate-50 ppm.
In the oil phase: Citric acid-50 ppm , PG-200 ppm.

A - amber jar.
C - clear jar.
CAl- clear jar covered with aluminum foil.
N - prepared and stored under nitrogen..
O - prepared and stored under air.

Table 34. Stability of mayonnaise made with 100% menhaden oil stored at room temperature with different surface areas.

| Analysis | 1 | 2 | 3 |
|---|---|---|---|
| Changes in peroxide value | — | 24.7 | 33.1 |
| Top half | 58.4 | | |
| Bottom half | 0.5 | | |
| Changes in anisidine value | — | 7.7 | 12.8 |
| Top half | 12.1 | | |
| Bottom half | 1.6 | | |
| Days to off-odor | 46 | 56 | 43 |

Initial peroxide value = 1.2
Initial anisidine value = 21.5

In the aqueous phase: EDTA-75 ppm , Ascorbate-50 ppm.
In the oil phase: Citric acid-50 ppm , PG-200 ppm.

Sample 1 weighed 124 g and was placed in a 16 oz clear jar. Its surface area was $1.9 \times 10^4$ mm$^2$. Chemical analyses were performed separately on top and bottom halves.
Sample 2 weighed 36 g and was placed in a 2 oz clear jar. Its surface area was $4.3 \times 10^3$ mm$^2$.
Sample 3 weighed 28 g and was placed in 2 oz clear jar. Mayonnaise was spread around the surface of the jar giving a total area of $1.1 \times 10^4$ mm$^2$.
Samples 2 and 3 were thoroughly mixed before chemical analyses.