

# Frozen Storage Characteristics of Whiting Blocks

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## Introduction

The total catch of whiting, also known as silver hake, *Merluccius bilinearis*, in 1977 in the northwest Atlantic ranging from the Gulf of Maine to the Middle Atlantic States was 80,773 tons (Anonymous<sup>1</sup>). Of this total amount, the U.S. commercial catch amounted to 21,960 tons. The optimal yield for the whiting stocks for 1977 was set at 115,000 tons (Anonymous, 1977). It is obvious that the United States is not utilizing this resource to the fullest potential.

There is a limited domestic market for whiting which is sold either in the round for the fresh trade, or as frozen fillets or frozen headed and gutted (H&G). Only the large whiting which represent a small portion of the catch are filleted (by hand) for freezing. The market for the traditional H&G pack, which probably represents the major processed form sold, has at times been jeopardized by a similar imported product offered for sale at a lower price (Anderson and Mendelsohn, 1971). This competition has stimulated an interest among processors for new product forms and new markets.

Up to this time, there has not been available a filleting machine capable of handling the small, average-sized (about 12 inches) whiting in a large-scale operation, and hand filleting small whiting is impractical because of the economics involved (Peters et al., 1964). However, recently two different

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machines, the Arenco<sup>2</sup> SFA-4 and the Baader 121, which are reputed to automatically fillet small whiting, have been developed. It is realized that the production of fillets from average size whiting offers the greatest hope for expansion of the domestic whiting industry (Combs<sup>3</sup>). Skinless fillets could be used for the production of frozen blocks for which a potentially large market would be created for the manufacturers of fish sticks and portions.

A most efficient method for recovering fish flesh from small, bony, or otherwise difficult to fillet fish is by use of meat-bone separators. With this equipment, the yield of flesh from headed and gutted whiting was found to be 86 percent (King and Carver, 1970) compared with about 60 percent by hand filleting. The comminuted flesh produced by this process can be formed into frozen (minced) blocks which also would be potentially suitable for the production of fish sticks and portions, though not as desirable as fillet blocks. Thus, these two primary product forms of whiting, fillet and

minced blocks, could serve as a market outlet to support an expanded fishery.

The purpose of this study was to determine the frozen storage characteristics of minced or fillet whiting blocks at various temperatures to evaluate their suitability as a raw material basically for fish stick-portion production or as an adjunct for other products.

## Materials and Methods

Skinless fillets were produced by hand filleting 1-2 day old whiting obtained from a local processing plant July 1975. The fillets were formed in a plate freezer into 5.3-pound blocks measuring 6 x 10 x 2 $\frac{3}{8}$  inches and packaged in the conventional dimpled waxedboard carton material.

Minced whiting was prepared by passing scaled, washed, headed and gutted fish with black belly lining removed through a Bibun meat-bone separator equipped with a drum with holes of 0.2 inch (5 mm) diameter. Minced blocks were formed in the same manner as described for fillet blocks.

The blocks were stored at various subfreezing temperatures which included 20°F, 5°F, -5°F, and -22°F and were tested periodically for eating quality, thiobarbituric acid (TBA) number (Yu and Sinnhuber, 1957; Sinnhuber 1958), dimethylamine (DMA) and trimethylamine (TMA) nitrogen content (Castell et al., 1974), and extractable protein nitrogen (EPN) content (Ravasi and Anderson, 1969).

The organoleptic evaluation was conducted by an experienced 12-member taste panel on oven-reconstituted, frozen, blanched, breaded fish sticks prepared from the

<sup>1</sup>Anonymous. 1978. Summary of stock assessments. Lab. ref. 78-40, 29 Aug. 1978. Resour. Assess. Div., NMFS, NEFC, Woods Hole Lab., Woods Hole, Mass.

<sup>2</sup>Mention of a commercial company or product does not constitute an endorsement by the National Marine Fisheries Service, NOAA.

<sup>3</sup>Combs, Earl R., Inc. 1977. Venture analysis and feasibility study relating to whiting and Atlantic mackerel. Contract Report No. 3-7-073-35121, 111 p. Fish. Dev. Div., NMFS, NOAA, P.O. Box 1109, Gloucester, MA 01930.

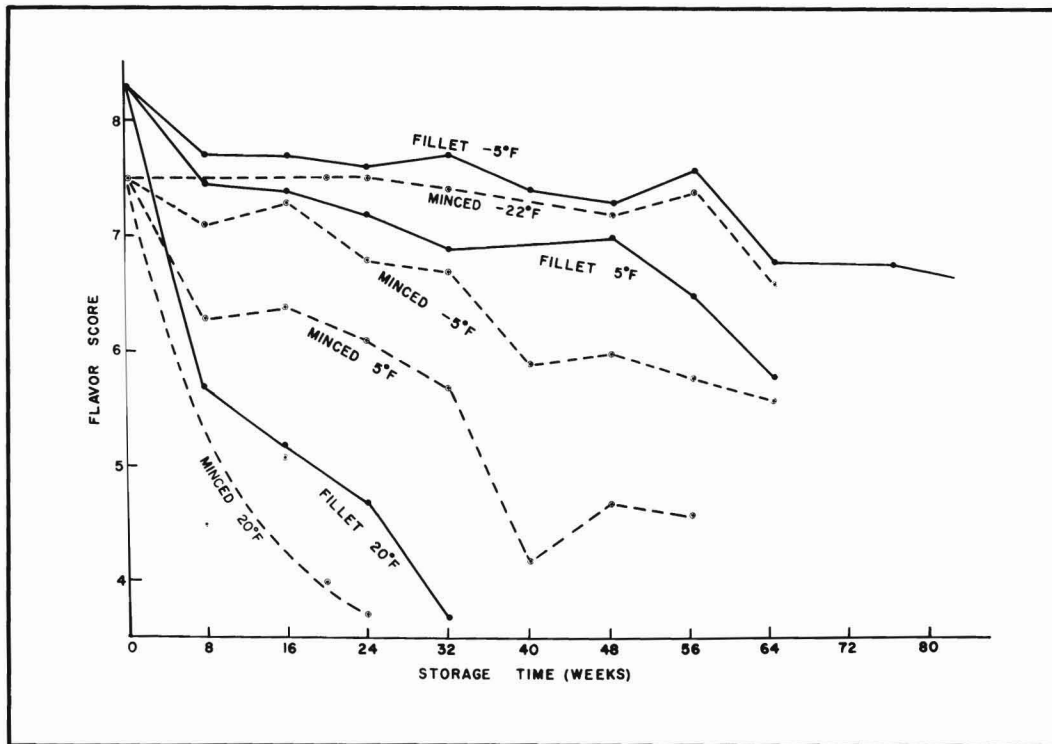


Figure 1.—Effect of storage temperature on flavor score of minced or fillet whiting blocks.

stored blocks. Samples were scored for flavor and texture on a 9 point scale in which numerical values were assigned to the rating categories as follows: 9—excellent, 8—very good, 7—good, 6—fair, 5—borderline, 4—slightly poor, 3—poor, 2—very poor, 1—inedible. A score below 6 was regarded as the index of unsuitability for marketing.

### Results and Discussion

Flavor scores and texture scores of the fillet or minced blocks have been graphed in Figures 1 and 2 as a function of storage time at various temperatures. Although not shown in the figures, the fillet blocks held at  $-5^{\circ}\text{F}$  were still acceptable (score  $> 6$ ) in flavor and texture after 2 years.

Two observations are readily apparent: 1) The beneficial effect of low storage temperature on stabilizing flavor and texture, and 2) the faster

rate of quality deterioration in minced compared to fillet blocks.

The effect of temperature on the storage life of frozen seafoods is well documented (Slavin, 1960; Dyer and Dingle, 1961; Lane, 1964). Storage temperature is probably the single most important variable affecting the shelf life of frozen seafoods. The comparative instability of frozen minced hake blocks has been reported (Hiltz et al., 1976; Crawford et al., 1979). The gadoid species contain either an enzyme or some cofactor which, during frozen storage, degrades TMA oxide to DMA and formaldehyde with the subsequent development of tough texture and loss of water holding capacity caused by protein-formaldehyde interaction (Amano and Yamada, 1965, Yamada et al., 1969). Dark muscle has more of this enzyme activity than light muscle. The order of increasing enzymatic activity among gadoids was stated as: Haddock, cod, pollock,

cusk, whiting, and red hake (Castell et al., 1971). In minced fish, this and other degradative reactions are accelerated (Babbitt et al., 1972; Hiltz et al., 1976) due to the partial disruption of muscle and cellular integrity with subsequent release of enzymes, increased contact of light muscle with the more active dark muscle tissue, and increased opportunity for development of oxidative rancidity due to increased surface area.

The marketable shelf life of properly packaged minced or fillet whiting blocks at various temperatures was estimated from the curves shown in Figures 1 and 2, and the values are presented in Table 1. These results support the finding of Hiltz et al. (1976) that minced whiting deteriorated about twice as fast as the intact flesh. These workers also reported that there was a negligible deterioration in quality of minced or fillet whiting at  $-15^{\circ}\text{F}$  for up to 6 months' storage. The results of

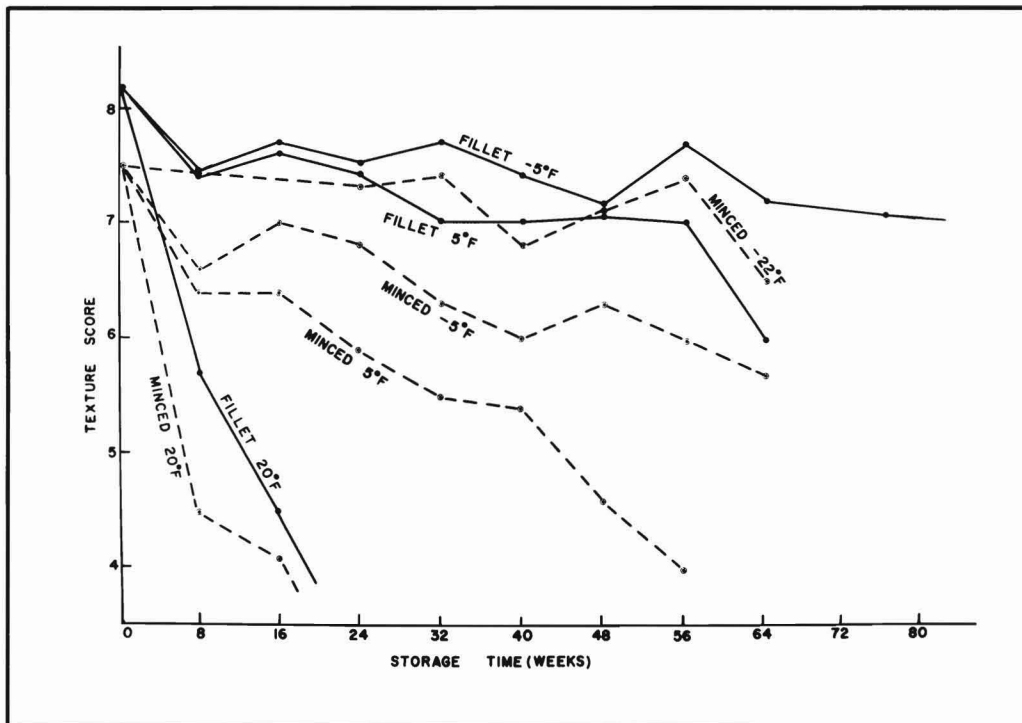


Figure 2.—Effect of storage temperature on texture score of minced or fillet whiting blocks.

the present study also corroborate this stability of whiting at very low temperatures.

A search of the scientific literature to determine what time-temperature relationships have been reported for frozen storage life of whiting revealed some variable data. A partial explanation for this variability is that shelf life estimation based on subjective sensory evaluation can be biased by regional

preferences for what constitutes spoilage or nonacceptability. However, other subtle factors also exert an effect, for example, where and how the fish were caught, rate of freezing, packaging method, etc. (Slavin, 1963; Dyer and Peters, 1969). Whiting caught in summer were found to have a longer frozen storage life either in minced or fillet form compared with fish taken in winter (Hiltz et al., 1976).

The post-mortem age of whiting at the time of freezing has a significant effect on frozen shelf life. Peters et al. (1963) reported storage lives of 12 months at 0°F for whiting initially held 2 days on ice and only 6 months for fish which had been stored 4 days on ice. Storage in refrigerated seawater as compared with ice prior to freezing extended the shelf life of whiting by about 2-4 months at 0°F and about 1-2 weeks at 14°F (Peters et al., 1963; Hiltz et al., 1976).

Another variable which influences

storage life determination is the particular criteria used for evaluating the quality loss. A summary of reported values for the frozen storage life of whiting in various product forms is presented in Table 2. In some instances, the storage life was based on EPN content, which is said to correlate with change in texture; and in other cases, it was based on a taste test on the steamed product. Estimating storage life by measuring a physical or chemical change which correlates with a single quality attribute is acceptable providing no other major changes are occurring. In the case of the whiting stored at 14°F, it was justified since it was shown that quality loss was principally due to textural toughening (Hiltz et al., 1976).

With regard to evaluating quality by tasting the fish steamed, it has been demonstrated that this particular cooking method allows for better discrimination among samples of frozen fish

Table 1.—Estimated marketable shelf life (weeks) at various temperatures of minced or fillet whiting blocks.

| Block form | Storage temp. (°F) | Shelf life (weeks) |
|------------|--------------------|--------------------|
| Minced     | 20                 | 4                  |
| Fillet     | 20                 | 7                  |
| Minced     | 5                  | 22                 |
| Fillet     | 5                  | 62                 |
| Minced     | -5                 | 48                 |
| Fillet     | -5                 | ≈ 104              |
| Minced     | -22                | >64                |

which had undergone storage deterioration (Dyer et al., 1964). However, fried fish usually receives a higher rating in an organoleptic test than steamed fish (Licciardello et al., 1979); and on a 9 point scale, such as was employed in this investigation, fried whiting was rated one point higher in flavor compared with steamed whiting (Anderson and Mendelsohn, 1971). In the present study, the fish was tasted as fried sticks because it was anticipated that this would be the major product prepared from the blocks. Therefore, it is expected that the shelf life predicted for whiting from this investigation would be longer than that reported for fish tasted after steaming.

The original intent of this study had been to determine the frozen storage life of whiting blocks as handled under commercial conditions, that is packaged in the conventional dimpled waxedboard carton. This is a poor packaging material for frozen fish since it offers no barrier to oxygen and moisture vapor transmission; and as a consequence, the stored blocks in this study showed areas of surface dehydration within 2-3 months, which was sooner than anticipated.

From an industry position, this condition seriously reduces the utility of these blocks since the desiccated portion has to be trimmed off. This alters the dimension of the blocks with the result that the yield in raw fish sticks or portions per block is diminished. To rectify this problem, secondary processors are now specifying that frozen

fish blocks be enclosed in polyethylene bags in addition to the normal packaging. In the present study, the surface dehydrated layer where present was removed prior to sampling.

Although the TBA numbers fluctuated from 1.0 to 2.5 during storage, the values were never indicative of rancidity. A similar variability was reported by other researchers, and it was speculated that this was caused by varying amounts of lipid-rich dark muscle in the sample (Hiltz et al., 1976). The tail muscle of whiting is known to be richer in lipid (dark muscle) than anterior sections. TBA numbers were slightly higher for minced compared with fillet blocks.

It should be pointed out that although a change in flavor did take place during storage, the typical linseed oil-like flavor of rancid fish oil was not detected. Oxidative rancidity as measured by the TBA test in minced whiting blocks (and probably skinless fillet blocks) occurs principally at the surface of the block, and this phenomenon can be suppressed with the proper packaging material (Licciardello et al., 1977). It is probably that in the present study, the process of trimming the outer dehydrated layer may also have removed any oxidized tissue.

Filleting whiting removes some of the fat which is concentrated beneath the skin and in a band of dark muscle along the lateral line. This treatment probably helps to reduce the problem of oxidative rancidity. With skin-on whiting fillets, however, quality loss

during frozen storage at  $-8^{\circ}\text{F}$  was reported to be due to rancidity development rather than textural change (Anderson and Mendelsohn, 1971).

In Figure 3, dimethylamine nitrogen content has been plotted as a function of storage time at various temperatures. The more rapid accumulation of DMA in minced flesh compared with fillets is readily apparent. It has been suggested that the concentration of DMA in frozen gadoid species could be used as a measure of frozen storage deterioration since it was found to correlate with the development of toughening (Castell et al., 1970; Tokunaga, 1974).

In the present study, linear regression analysis performed on DMA content as a function of texture score for blocks held at  $20^{\circ}\text{F}$ ,  $5^{\circ}\text{F}$ , and  $-5^{\circ}\text{F}$  gave correlation coefficients ranging from  $-0.88$  to  $-0.99$  for minced and  $-0.65$  to  $-0.99$  for fillet blocks. This high degree of correlation does indicate a strong association between formation of DMA (and formaldehyde) and deterioration of texture in whiting during frozen storage. From the regression lines, the value of DMA corresponding to the threshold texture score for unacceptability was estimated to range from 4 to 8 mg N/100 g. Hiltz et al. (1976) reported that at the point of complete inextractability of the myofibrillar proteins, which was their criterion for textural unacceptability in frozen whiting samples, the DMA level did not exceed 6 mg N/100 g.

It would be tempting on the basis of these two independent results to propose a DMA-N content of 6 mg/100 g as a biochemical index of textural unacceptability in frozen whiting. However, in more recent studies at this laboratory with whiting, higher DMA levels occurred at the time frozen minced or fillet samples were judged unacceptable in texture. The DMA index level of spoilage for frozen whiting was found to differ for summer-caught and winter-caught fish, and it was suggested that the DMA producing ability of whiting muscle may vary with season or possibly with fishing grounds (Hiltz et al., 1976).

In view of these variable results, it is

Table 2.—Summary of reported values for frozen storage life of whiting.

| Product form     | Storage temp. ( $^{\circ}\text{F}$ ) | Method of evaluation | Storage life | Reference                    |
|------------------|--------------------------------------|----------------------|--------------|------------------------------|
| Fillet           | 14                                   | Chem. test (EPN)     | 7-8 wk       | Hiltz et al., 1976           |
| Minced (fillets) | 14                                   | Chem. test (EPN)     | 4 wk         | Hiltz et al., 1976           |
| Minced (H&G)     | 14                                   | Chem. test (EPN)     | 3 wk         | Hiltz et al., 1976           |
| —                | 0                                    | Not known            | 5-9 mo       | Slavin, 1963                 |
| H&G              | 0                                    | Taste (steamed)      | 12 mo        | Peters et al., 1963          |
| H&G or round     | 0                                    | Not known            | 8-10 mo      | Lane, 1964                   |
| Fillet (skin-on) | $-8$                                 | Taste (steamed)      | $\geq 9$ mo  | Anderson and Mendelsohn 1971 |
| Round (glazed)   | $-8$                                 | Taste (steamed)      | $\geq 11$ mo | Anderson and Mendelsohn 1971 |

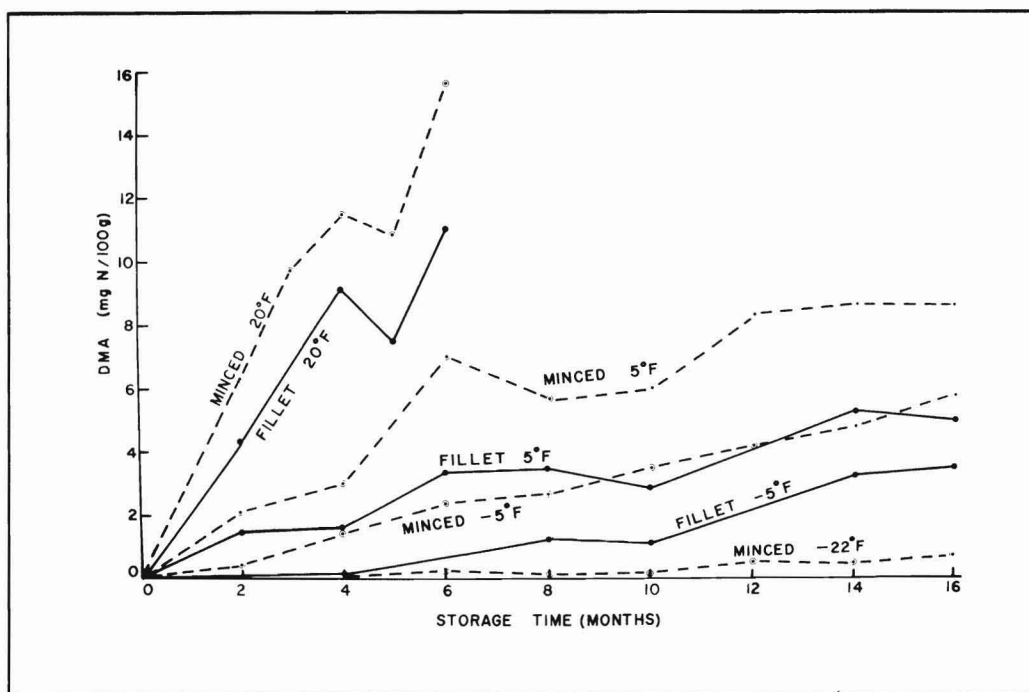


Figure 3. — Dimethylamine-N content of minced or fillet whiting during storage at various temperatures.

concluded that the DMA content of frozen whiting is a useful parameter for monitoring textural change in a controlled study but is not reliable for assessing textural quality in frozen whiting of unknown history.

The TMA content did not change significantly during frozen storage as would be expected since its development is contingent upon bacterial action. Values varied from about 0.2 to 1.2 mg N/100 g, which was indicative of very good initial quality fish.

The percent extractable protein nitrogen is plotted as a function of storage time at the different temperatures in Figure 4. The decrease in EPN was accelerated by mincing or by storage at the higher temperatures. Although the graphs clearly show that a loss in protein solubility that was commensurate with temperature occurred, the EPN content could not be used to predict textural storage life since textural unacceptability (determined organolepti-

cally) occurred after the EPN curves had bottomed out. The EPN value represents the combined soluble sarcoplasmic and myofibrillar proteins. The value of EPN at the plateau represents the content of sarcoplasmic proteins, which are relatively resistant to freeze denaturation; however, it is the denaturation of the myofibrillar proteins that is associated with textural deterioration of frozen fish (Dyer, 1951).

Hiltz et al. (1976) concluded that the deterioration in quality of frozen whiting was due principally to its susceptibility to form DMA and formaldehyde, resulting in protein insolubilization. The results of the present study would support this conclusion. At present, the only known deterrent to this adverse reaction is low temperature storage, although the use of heat to inactivate the causative enzyme may have some application (Lall et al., 1975). Nevertheless, in assessing the relative stability of whiting with other gadoids,

it was considered that the storage life at 14°F of whiting fillets was comparable with that of cusk or Atlantic pollock, less than cod, but greater than red hake (Hiltz et al., 1976).

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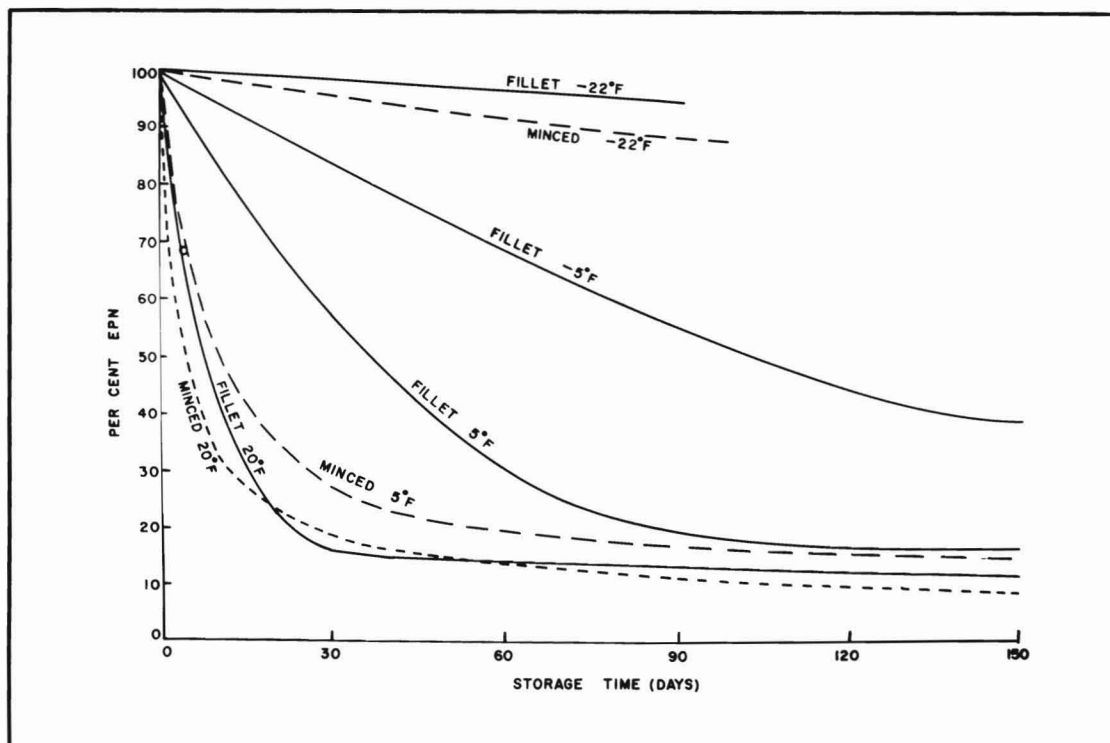


Figure 4.—Percent extractable protein nitrogen content of minced or fillet whiting during storage at various temperatures.

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