I. Introduction

Special kinds of canned herring products have long been made in the Scandinavian countries. They are mostly used as hors d'oeuvres, but from time to time they have also formed an integral part of the basic food of at least parts of Scandinavia. There is a whole series of various items: anchovies made from sprats (Clupea sprattus L.), and all the different tidbits known as gaffelbitar in the Swedish smorgasbord and produced mainly from Icelandic herring (Clupea harengus L.). Finally, when Baltic herring (Clupea harengus var. membras), a small-sized subspecies of herring, undergo bacterial fermentation in the presence of salt a specific kind of fermented herring is obtained (surströmming). This is a product of entirely different character from the tidbits and anchovies. The fermentation process gives rise to a strong odor but pleasing taste. Other fishes may be prepared in a similar way, e.g., gwyniad (Coregonus lavaretus L.), perch (Perca fluviatilis L.), and trout (Salmo salar var. trutta L.). In Norway such fermented trout is known as rakørret.

All these products can be characterized as semipreserved. This indicates they have not been submitted to sterilizing or pasteurizing treatment. They contain a specific flora of bacteria, which exerts a certain influence on the flavor of the anchovies and tidbits. In the case of fermented herring they are of fundamental importance. All the active bac-
teria are, however, haloduric or halophilic, as all these herring products contain rather large amounts of salt, 10–12%. Sugar and several spices are added to anchovies and tidbits; fermented herring is made without additions other than salt.

Moreover, the growth of the bacteria is controlled by conditions in the cans. Anchovies and tidbits are kept under anaerobic conditions during the whole process. They are packed in airtight containers, which are filled with herring and brine. Thus only obligately or facultatively anaerobic salt-tolerant organisms can grow in these products.

Microbial growth is furthermore mostly suppressed by the addition of preservatives, such as benzoic acid or hexamethylenetetramine. Boric acid, used until quite recently by many packers, has been prohibited through recent government rulings. Some manufacturers use no preservatives at all.

The fat content of the raw material plays an important role in the quality of anchovies and tidbits. A high fat percentage is desirable. As herring fat readily becomes rancid, the anaerobic conditions in the containers are of utmost importance in preventing fat oxidation, particularly as these reactions appear to be activated by the presence of salt.

The fermentation of Baltic herring is accompanied by gas formation. In this process therefore the barrels are not entirely filled with herring and brine; some head space is left. It is not known whether the fermentative bacteria require oxygen. The fat content of this herring is lower than of that used for anchovies and tidbits. No preservatives are added in this special type of herring product.

Briefly, the manufacture of anchovies and tidbits proceeds as follows. Fresh herring are packed with dry salt, sugar, and spices. Under the high osmotic pressure created by the salt, fluid is extracted from the herring, salt and sugar are dissolved, and a brine is formed. After a day or two, the container is filled with extra brine and tightly sealed. The containers are allowed to stand for some time, during which the “maturing” of the herring takes place. In this ripening stage the general character of the herring is greatly changed. Owing to proteolytic enzymes from the herring itself, and probably also from the bacteria in the medium, the protein of the muscle tissue is decomposed into smaller peptides and amino acids. The finished product acquires a soft and pleasant consistency. Aromatic substances are formed and, together with the spices, serve to create an appetizing flavor.

In fermented herring, which are packed directly in brine, the degradation of the proteins is evidently brought about by the bacterial enzymes. In this case the aromatic compounds give the herring a distinctive
taste and odor, prized by the initiated but hard to tolerate by the novice. Fermented herring is a specialty of the northern part of Sweden.

Different types of semipreserved herring products are sold: (1) beheaded and degutted herring, fillets, or fillets cut into pieces, (2) directly packed anchovies, and (3) fermented herring. Tidbits, matjes fillets, and skinless and boneless anchovy, which belong to group (1), are the most common products.

The shelf-life of these products is limited. The enzymic activity is not suppressed when the maturing period is completed and the bacteria continue to grow. It is therefore necessary to store these products at refrigerating temperature. Under such conditions they keep very well. At higher temperature, the bacteria may start fermentation with gas formation, causing cans to swell, and the proteolytic enzymes may break down the herring flesh to the point of liquefaction.

A. DEVELOPMENT OF THE SCANDINAVIAN HERRING INDUSTRY

The earliest manufacture of this kind of product was the packing of anchovies. It is difficult to say when or in which country this practice started. There are indications in Swedish publications that in the middle of the seventeenth century this type of product was being manufactured in well-to-do rural mansions. The practice gradually spread among other layers of society in both Norway and Sweden. The product was packed in wooden barrels and kegs or sometimes in clay pots. Small Baltic herring were formerly prepared as young anchovy but rarely nowadays. For a history of the industry, the reader is referred to a review by Borgstrom (1950), from which a few salient features will be related below.

Commercial manufacturing started only in the nineteenth century. The first Scandinavian factory packing anchovy in cans is documented in 1841 from Drammen in Norway. This country remained the leading producer of Scandinavian anchovy for several decades. A substantial portion of its pack was exported to Sweden. The Swedish industry started about 15 years later and soon developed in size.

In 1865 it was reported that more than one third of the sprats caught in the district of Bohuslän, the principal fishing region of Sweden, was prepared as anchovy. In 1869 the anchovy industry at Gullholmen, managed by Hallgren was singled out as producing a superior quality product, and received international recognition at commercial exhibits in the United States, Russia, and Europe.

In 1874 more than 5000 barrels of sprats were processed as anchovy at several places along the coast of Bohuslän. Small sprats were used for this purpose, yielding products with a fine aroma and few conspicuous
bones. When the technique of soldering cans was discontinued in favor of seaming, the Swedish anchovy industry advanced with rapid strides.

According to a Norwegian description of the Swedish fisheries published in 1869, the Swedish anchovy was smaller and contained less fat than the Norwegian. Consequently it was considered of inferior quality. The finer households of Sweden bought Norwegian anchovies, but most of the Swedish restaurants used the domestic product. This difference no longer exists, and today Sweden is the leading manufacturer of Scandinavian anchovies (Borgstrom, 1950).

The Danish industry for semipreserved herring products started in 1895. A number of canning factories in Denmark now manufacture these products. Earlier this industry was based chiefly on imported sprats, mainly from Norway. Today, fish caught in Danish waters or by Danish fishermen are employed almost exclusively. Anchovy was always a minor item.

In the Baltic, sprats were caught and packed as “anchovy” and certain other products. They were brined and spiced in the ordinary way, as described in a 1671 Swedish publication. In a book on Swedish fisheries (published in Stockholm in 1778), the Baltic sprat, biologically identical to that along the western coast of Sweden, is said to be in all essential respects similar to the sardel. It can be prepared in the same way and renders the same products. No anchovy is prepared from Baltic sprats today.

The manufacture of fermented herring from Baltic herring, a variety or subspecies of Clupea harengus L., also has a long history. Not only Baltic herring, but many different kinds of fish were prepared in this manner. In the middle of the seventeenth century, fish of this kind were commonly consumed in large areas of northern Sweden and Norway. This practice probably developed during times when common salt was expensive. People used less salt than was necessary to prevent bacterial growth and thus got a fermentation of the fish. This was not dangerous to health and gave the fish that strange odor and taste characteristic of these products. Most fermented herring nowadays is made and used only as a “delicacy”; it is made on a large scale in factories along the northeastern Baltic coast of Sweden.

Of later date is the manufacture of tidbits. In 1906 Alfred Bovik in Lysekil, Bohuslän, carried out experiments with Icelandic herring. He sent with the fishing boats that went to the Icelandic fishing area some bags with a mixture of salt, sugar, and spices for packing herring in barrels in the same manner as practiced for anchovies. This herring was then cut into pieces and packed in tin cans. The experiment succeeded and the product rapidly made its way on the market. Under a series of
<table>
<thead>
<tr>
<th>Year</th>
<th>Anchovy and skinless and boneless anchovy</th>
<th>Tidbits and herring fillets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Denmark</td>
<td>Norway</td>
</tr>
<tr>
<td>1927–29</td>
<td></td>
<td>1101.0</td>
</tr>
<tr>
<td>1930–34</td>
<td></td>
<td>887.4</td>
</tr>
<tr>
<td>1935–39</td>
<td>514.0b</td>
<td>969.0</td>
</tr>
<tr>
<td>1940–44</td>
<td>521.0</td>
<td>466.0</td>
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<tr>
<td>1945–49</td>
<td>533.0</td>
<td>1084.2</td>
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<td>402.0</td>
<td>1417.0</td>
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<td>373</td>
<td>1133</td>
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<td>1051</td>
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<td>1957</td>
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<td>594</td>
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<td>1958</td>
<td>358</td>
<td>983</td>
</tr>
<tr>
<td>1959</td>
<td>259</td>
<td>879</td>
</tr>
<tr>
<td>1960</td>
<td>232</td>
<td>575</td>
</tr>
</tbody>
</table>

\( ^a \) Product weight in metric tons.

\( ^b \) Average for 1938–39.

\( ^c \) Inclusive of anchovies.

\( ^d \) Swedish figures in the years 1927–30 include all semipreserved herring products except anchovies.
trade-marks, with different seasonings and sauces, these products were in great demand in Sweden and also abroad, especially the United States. Production of tidbits is now much greater than that of anchovies (see Table I).

The packing industries originally were small undertakings. The work was done by the proprietor and his family in small boat houses and storehouses. This is still the case in certain localities in Bohuslän, but many grew and presently there are a number of sizable industries. Many remain family concerns. An example is the Ameln Brothers' firm which from the founder, Christian Gerhard Ameln who started in Bergen in Norway in 1838, passed from father to son through five generations. This type of family enterprise is characteristic of the industry.

Manufacturing experience accumulated in the course of time, and the methods employed were kept as secrets within the family concern. Fundamental research was rarely conducted and only in the last decades has work started in this field. The microbiological and biochemical reactions that convert the fresh herring into these delicatessen are far from known in detail.

II. Anchovy

Sprats (*Clupea sprattus* L.) used for manufacture of anchovies are caught mainly in the fjords or just outside the Atlantic coast. Catching methods are the same as for winter brisling sardines, and are dealt with elsewhere (Volume IV, Chapter 6). Fishing starts in the middle of September and ends about the middle of January. During these months sprats have their highest fat content. The raw product for anchovy contains 14-20% fat.

Anchovy is packed in two ways, either in barrels or in retail cans. The first type is used for production of skinless and boneless anchovy, which is packed in small boxes.

Barrel anchovy is packed in wooden barrels, about 95 kg. in each. To this is added a mixture of salt, sugar, and spices such as peppers, mace, coriander, hops, cinnamon, ginger, cardamon, and sandalwood—the last giving anchovies their red color. Saltpeter is also added, together with a preservative, generally benzoic acid.

The rinsed and drained whole sprats are mixed thoroughly on a special table with the proper amount of salt-sugar-spice mixture, each fish being well powdered on the surface and then poured into the well-cleaned barrel, at the bottom of which some of the salt-sugar-spice mixture is placed. The rest of this mixture is put over the sprats. After 1-2 days a brine is formed from the fluids extracted from the fish, in which all the salt and sugar is dissolved. At this moment the barrels
are filled up with extra brine of salt and sugar, sealed by a closely fitting lid, and put aside. Generally the barrels are stored outdoors in the cold season; in the spring they are moved into cold storage or refrigerated rooms.

The maturing depends upon the condition of the raw material and the storage temperature. The products packed at the beginning of the season generally ripen faster than later ones. A mature product is of soft and smooth consistency and the backbone is easily removed from the flesh. Judging the proper maturity is a matter of experience. There are no objective methods; the expert can determine this by biting through the back of the anchovy just behind the head.

When the barrel anchovy is mature, it is cut into fillets. Skin and side ribs as well as belly membranes are removed, and the fillets are packed in boxes. These are generally of the flat rectangular type. Filleting, trimming, and packing are done by hand. There are varying methods for cutting and trimming. Each of the workers—mostly women—may have her own method. This gives variation in appearance of the fillets and in payment to the workers, which is so much per can.

The cans are then filled with sauce, a solution of salt and sugar in which spices have been boiled. This sauce also contains a preservative, formerly boric acid as a rule. Since this is now prohibited, benzoic acid with or without addition of hexamethylenetetramine is widely used. The brimful cans are sealed and the product is ready for consumption.

Directly made anchovy is packed in cans (106 mm. in diameter and 55 mm. high) which hold 450 g. For export, cans of 48-mm. height containing 400 g. are used. Essentially the same mixture of salt, sugar, and spices as for the barrel anchovy is used for this product. The packing is done by hand. Some of the salt-sugar-spice mixture is poured in the bottom of the can and the sprats are packed in three layers at right angles to each other. Some of the mixture is sprinkled between each layer and the rest placed on top. This product also contains preservatives.

When all salt and sugar are dissolved—about 2 days later—the cans are completely filled with extra brine and then sealed. Maturing is done at 12–15°C. The cans are turned over each fortnight. Now and then samples are taken out to check the maturity. When finished, the cans are put into cold storage. They are now ready for consumption.

During ripening, several degradation products of the herring protein diffuse into the brine, making it very aromatic. The directly made anchovy has therefore more flavor than the skinless and boneless type, where the aromatic substances are diluted by the new sauce added to the boxes. On the other hand, the latter is “ready-to-eat” while the directly made anchovy must be filleted by the consumer. This is, however, a
rather simple procedure as the backbone is very easy to remove; many lovers of anchovies look upon this as part of the delight and a pleasant relaxation.

A. Ripening of Anchovy

The maturing has recently been the subject of extensive investigations by the author (Alm, 1956). Figure 1 shows the changes in drained weight and in amount of brine formed in cans of anchovy packed with 310 g. fresh sprats and 90 g. salt-sugar-spice mixture (12:6:1). All figures are calculated on 100 g. raw herring.

The curves show decreasing weight of the fish during the first few days owing to extraction of body fluids. At this time the fish is very hard and dry. Later the drained weight increases again when salt, sugar, and water diffuse into the fish muscle. After 2 weeks the system is—broadly
speaking—in equilibrium. There is finally another drop in drained weight at the end of the ripening process, apparently depending upon migration of decomposed proteins from the fish into the brine.

Changes in solubility of the muscle proteins at low and high ionic strength have been followed, as well as formation of aminonitrogen compounds (Fig. 2). All values are calculated on the nitrogen content of 100 g. fresh herring. During the first phase of the process the solubility of the protein decreases sharply. This change is most evident in

![Fig. 2. Total nitrogen and different soluble nitrogen fractions in herring fillets, cut from drained herring in cans of anchovies at varying intervals during the maturing process. All values are calculated as per cent of the nitrogen content of the fresh herring packed (Alm, 1956).](image)

that part of the protein which is soluble at high ionic strength, i.e. actomyosin. Other proteins are little influenced. The insolubility of actomyosin makes the herring hard and dry. Apparently the high salt concentration brings about denaturation of actomyosin, a phenomenon quite similar to the effect of salt on cod muscle, which was studied by Duerr and Dyer (1952).

After 1–2 weeks the fish protein solubility has reached its minimum and increases. This is explained by the gradual degradation of the acto-
myosin into smaller peptides and amino acids, which are soluble at low ionic strength; this can be seen from Curve 2 in Fig. 2. These soluble nitrogen compounds consist of one fraction precipitated by trichloroacetic acid (TCA) (Curves 3–5) and another noncoagulable fraction (Curve 6), this latter increasing more rapidly. There is also an increase in aminonitrogen (Curve 7). Part of the nitrogen fractions diffuses into the brine. The nitrogen content of the drained herring itself drops (Curve 8).

The presence of a whole series of amino acids in extracts of anchovies has been established by paper chromatography. These increase in amount during the course of the maturing process. When the solubility of the nitrogen fractions has reached about the same level as that of the proteins of fresh herring at high ionic strength, the anchovy is mature. At that time it has its specific consistency and flavor. In spite of considerable degradation of its proteins, it maintains its structure and is readily cut into fillets.

III. Tidbits ("Gaffelbitar")

Tidbits are made from Icelandic herring. By agreement between the Scandinavian countries no herring is caught prior to July 1. The fishing area is north and east of Iceland, though not south of latitude 65°N. After spawning along the Norwegian coast, the herring migrates to the Icelandic region. At this time they have started feeding and their fat content is high, 20–24%. The fishing season is completed by September 15.

During the first 2 weeks if the weather is fine, purse seines are used; later the fish are caught by drift net. The price is settled by agreement between the central organizations of fishermen and the packers, but contracts about quantity of delivery, etc. are made directly between the buyer, i.e. the packer, and the fishing boats, most of which are Norwegian. The packer commits himself for at least 90% of their loading capacity but, on the other hand, demands certain quality, etc.—for instance not more than 4 herrings per kg. when the herring is to be used for tidbits. This figure may vary from year to year. Norwegian fishing boats land their catch in the homeland where quality is controlled by an agency of the government. No Norwegian-caught herring can be delivered for export without a permit.

The packer supplies the fishing boats with barrels, fresh from the factory and 114–117 liters in volume, and the sugar needed for each barrel. This is weighed out in bags by the packer, as is also the mixture of spices. Salt is added by measure on board. No preservatives are used in the barrels.
Packing of the herring is done on deck. The herring is killed by cutting off the head behind the gill fins, and bled. Some boats have machines for these operations but it is usually done by hand. Some packers want their herring degutted, others do not. The fishermen follow the directions of the packer. It is said that the maturing proceeds faster when the herring is not degutted.

No further treatment is started before rigor mortis has ceased, i.e., 4–5 hours after catching. Then salt (14–16 kg. by measure), one bag of sugar (at least 3.5 kg., often more), and one bag of spices are thoroughly mixed in a special tray. Spices are about the same as described for anchovy. A layer of the mixture is spread over the bottom of a barrel, and packing starts. Each herring is well powdered in the tray with salt-sugar-spices, and the fish are packed, one by one, in layers with head end and tail alternating. Some of the salt-sugar-spices is spread between each. The packing is done very carefully, no “naked” surface being allowed to touch another. The barrel is filled over the top and should then contain about 95 kg. herring. More than 100 kg. is undesirable. In this case the barrel is too tightly packed, giving an inferior quality.

Soon a brine is formed in the barrels, in the same manner as described for anchovy. With the proper amount of herring, the “natural” brine should cover the herring. The barrels are then sealed, labeled, and stored in the cargohold.

When the boats return home the herring is inspected. As mentioned before, this is done by the Norwegian government. For Swedish boats this inspection is made by the buyer himself. The goods are graded according to size, fat content, weight, and condition of the brine. This should be at least 18° Bé. Payment is made on the basis of quality.

At first the barrels are stored outdoors, when the temperature is low in the autumn and winter. In the spring and summer they are kept in cold storage at 5°C. The barrels are periodically filled with brine, as the wooden barrels are not quite tight. It is important that the herring be well covered with brine, and the barrels full; otherwise the herring may become rancid. The brine constitutes good protection against fat oxidation. As time goes on, the herring becomes more compact, leaving space in the barrels. Therefore, herring is transferred now and then from one barrel to another to keep all the remaining barrels full.

The herring is kept in the barrels until it is mature. The degree of maturity is judged empirically. The rate at which maturity develops depends on several factors. Temperature is important; the lower this is, the longer the maturing time. Ungutted herring has a briefer maturing period than degutted ones. Herring caught at the beginning of the fishing season matures faster than herring caught later. Barrels packed in
the early part of July may provide mature herring in October of the same year, while herring caught in September may have to be held until September of the next year. The manufacturer tries to regulate the maturing of his herring stock in order to have raw material for tidbits throughout the year and also work for his employees.

The mature herring is filleted by hand; the skin is removed, and a certain trimming takes place. The fillet is then cut into pieces of varying shape according to the pack in question. There are of course different qualities of herring, and the packer uses a certain grade for each of his packs. For the most exclusive ones only the best raw material is used, and no more is packed of each grade than available raw material quality permits. The pieces are packed into boxes of varying shape or sometimes glass jars, and a sauce is added. This sauce often contains a preservative. Each pack has its specific sauce. This always contains vinegar and sugar, but kinds of spice vary. Mustard and onions often contribute to the flavor of these products. Herring is also packed as whole fillets in oblong cans, normally two fillets in each. These are called matjes fillets but are not the same product as the authentic Dutch matjes fillets. After sealing the cans or jars are immediately ready for distribution.

IV. Biochemistry of Maturing

As pointed out earlier, the maturing of “anchovy” consists of marked degradation of the proteins. This is also the case in tidbits (Aschelhough, 1952). Whether this decomposition is brought about by proteolytic enzymes of the herring itself, or is a result of bacterial activities, or is a combination of these two processes, is still uncertain. Many observations indicate that the intestines of the herring are particularly important. As mentioned above, maturing is faster in ungutted Icelandic herring than in those eviscerated. Anchovies, which for experimental purposes have been packed with the intestines removed, do not go to maturation. This effect of the intestinal contents may be due to its microbial flora, which give off potent proteolytic enzymes. A second alternative is that the digestive enzymes produced by the intestinal system of the herring itself cause the protein degradation. This latter situation seems to be the case with anchovies.

Aschelhough (1952) has made an extensive study of the microflora in barrels of Icelandic herring. She followed simultaneously the changes in herring proteins (Tables II–IX). In common barrels of ungutted herring she found a marked increase in bacterial count between 69 days of storage, when the herring was still immature, and 98 days, when maturing was complete (Table II). In another experiment, performed at the same time and with herring from the same lot except that this herring before
packing was treated for 3 hours in 3% acetic acid, she found no increase in bacterial count until the herring had matured, in this case after 69 days. Thus, maturing in this experiment proceeded faster than in the other, and without an increase in bacterial population (Table III). In the first experiment there was a definite lowering of the pH after 98 days (Table VI), which points to fermentation with the formation of acids. This may explain the observed increase in the bacterial count. In both experiments, the increase in amino nitrogen formation was of about the same order, but more volatile bases were formed in the herring not dipped in acetic acid. The herring treated in acetic acid was cut into tidbits and packed in cans with and without a preservative. In about 35 days, vigorous fermentation could be observed in cans without a preservative and a correspondingly high bacterial count. In cans with a preservative no microbial growth took place (Table IV and V). Consequently, Aschehough's experiments seem to indicate that it is dubious if bacteria have any decisive influence on the degradation of the herring protein. Furthermore, Icelandic herring matures even when eviscerated, indicating that intestinal enzymes are not necessary for the maturing process in this type of herring. This coincides with findings by Almy (1926) on Maine herring. More research is needed on the ripening mechanism. Christiansen (1962) concludes that visceral enzymes control the protein degradation. Several fishes have active proteolytic enzymes in the pyloric caeca. This conclusion is substantiated by the fact that artificial ripening can be induced by adding commercial proteolytic enzyme preparations (Christiansen, 1962); the trouble in this case is to stop enzymic degradation before it has gone too far.

Recent findings seem to indicate that, contrary to earlier assumptions, the meat tissue as such carries proteolytic enzymes of a cathepsin nature. This autolysis has been studied apart from microorganisms by eliminating them through γ-radiation (Hata et al., 1960). In experiments with Dutch matjes herring, however, the exopeptidases (cathepsins) of the muscles are more strongly inhibited by salt than are the endopeptidases of the intestines (Luijpen, 1959).

Studies of the microflora of anchovies show that the number of bacteria growing on common laboratory media with addition of 7% NaCl and 5% sucrose rapidly decline to low figures during the maturing process. Afterwards the count may mount to high levels, but only if fermentation has started. This phenomenon will be analyzed below.

Notwithstanding, bacteria may be of importance in forming certain of the aromatic substances in herring products. This has been observed by many authors (Shewan, 1938; Omland, 1955). Messing (1934) and Jermoljewa and Bujanowskaja (1934) have isolated aroma-forming bac-
# Table II

**Microflora of Spice-Cured Winter Herring—Series 1**

<table>
<thead>
<tr>
<th>Days of curing at 12–15°C.</th>
<th>Organoleptic examination of herring</th>
<th>Average bacterial count at 22°C. (in 1000 per gram)</th>
<th>Average yeast count (in 1000 per gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Herring</td>
<td>Brine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aerobes</td>
<td>Anaerobes</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>7,000</td>
<td>250</td>
</tr>
<tr>
<td>21</td>
<td>Taste raw</td>
<td>800</td>
<td>500</td>
</tr>
<tr>
<td>69</td>
<td>Taste raw</td>
<td>600</td>
<td>70</td>
</tr>
<tr>
<td>98</td>
<td>Ripe</td>
<td>34,000</td>
<td>15,000</td>
</tr>
<tr>
<td>154</td>
<td>Overripe &quot;Sour&quot;</td>
<td>74,000</td>
<td>50,000</td>
</tr>
</tbody>
</table>

Aschehoug (1952).
### Table III<sup>a</sup>

**Microflora of Spice-Cured Winter Herring—Series 2<sup>b</sup>**

<table>
<thead>
<tr>
<th>Days of curing at 12−15°C.</th>
<th>Organoleptic examination of herring</th>
<th>Average bacterial count at 22°C. (in 1000 per gram)</th>
<th>Average yeast count (in 1000 per gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Almost ripe</td>
<td>Herring: 100 Aerobes</td>
<td>Brine: 340 Aerobes 50 Anaerobes</td>
</tr>
<tr>
<td>69</td>
<td>Ripe Taste good Consistency normal</td>
<td>Herring: 50 Aerobes 9 Anaerobes</td>
<td>Brine: 30 Aerobes 500 Anaerobes</td>
</tr>
<tr>
<td>154</td>
<td>Overripe &quot;Sour&quot;</td>
<td>Herring: 3,000 Aerobes 500 Anaerobes</td>
<td>Brine: 5,000 Aerobes 10,000 Anaerobes</td>
</tr>
</tbody>
</table>

<sup>a</sup> Aschehouge (1952).

<sup>b</sup> Acid-treated raw material.
### Table IVa

**Microflora of Gaffelbitar of Cured Winter Herring from Series 2b**

<table>
<thead>
<tr>
<th>Days of storage at 22°C</th>
<th>Condition of can</th>
<th>Organoleptic examination of gaffelbitar</th>
<th>Average bacterial count at 22°C (in 1000 per gram)</th>
<th>Average yeast count (in 1000 per gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gaffelbitar</td>
<td>Spiced sauce</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aerobes</td>
<td>Anaerobes</td>
</tr>
<tr>
<td>7</td>
<td>Normal</td>
<td>Normal</td>
<td>1,000</td>
<td>0.1</td>
</tr>
<tr>
<td>35</td>
<td>Blown</td>
<td>Taste sour</td>
<td>10,000</td>
<td>15,000</td>
</tr>
<tr>
<td>59</td>
<td>Highly blown</td>
<td>Taste sour, consistently soft</td>
<td>2,400,000</td>
<td>2,500,000</td>
</tr>
</tbody>
</table>

*a* Aschehoug (1952).

*b* Packed in cans with spiced sauce without preservatives.

### Table Va

**Microflora of Gaffelbitar of Cured Winter Herring from Series 2b**

<table>
<thead>
<tr>
<th>Days of storage at 22°C</th>
<th>Condition of can</th>
<th>Organoleptic examination of gaffelbitar</th>
<th>Average bacterial count at 22°C (in 1000 per gram)</th>
<th>Average yeast count (in 1000 per gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gaffelbitar</td>
<td>Spiced sauce</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aerobes</td>
<td>Anaerobes</td>
</tr>
<tr>
<td>7</td>
<td>Normal</td>
<td>Taste and consistency normal</td>
<td>900</td>
<td>0.6</td>
</tr>
<tr>
<td>35</td>
<td>Normal</td>
<td>Normal</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>59</td>
<td>Normal</td>
<td>Normal</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>142</td>
<td>Normal</td>
<td>Normal</td>
<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>

*a* Aschehoug (1952).

*b* Packed in cans with spiced sauce with preservatives.
### TABLE VI

<table>
<thead>
<tr>
<th>Days of curing</th>
<th>Total volatile bases (mg-N/100 g.)</th>
<th>Total amino acids (mg/100 g.)</th>
<th>Total sugar (g/100 g.)</th>
<th>Invert sugar (g/100 g.)</th>
<th>Salt (g/100 g.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 °C.</td>
<td>6.54 16.8 81</td>
<td>6.64 5.84 142</td>
<td>6.38 75.6 117</td>
<td>6.35 138 219</td>
<td>6.55 5.7 130</td>
</tr>
<tr>
<td>5 °C.</td>
<td>5.84 14.2 80</td>
<td>6.30 6.74 111</td>
<td>6.74 118 219</td>
<td>6.74 143 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>10 °C.</td>
<td>5.45 11.2 80</td>
<td>6.20 6.74 111</td>
<td>6.20 118 219</td>
<td>6.20 118 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>21 °C.</td>
<td>4.70 10.3 80</td>
<td>6.00 6.74 111</td>
<td>6.00 118 219</td>
<td>6.00 118 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>69 °C.</td>
<td>4.70 10.3 80</td>
<td>6.00 6.74 111</td>
<td>6.00 118 219</td>
<td>6.00 118 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>98 °C.</td>
<td>4.70 10.3 80</td>
<td>6.00 6.74 111</td>
<td>6.00 118 219</td>
<td>6.00 118 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>154 °C.</td>
<td>4.70 10.3 80</td>
<td>6.00 6.74 111</td>
<td>6.00 118 219</td>
<td>6.00 118 219</td>
<td>6.57 5.7 130</td>
</tr>
</tbody>
</table>

* Aschehoug (1952).

### TABLE VII

<table>
<thead>
<tr>
<th>Days of curing</th>
<th>Total volatile bases (mg-N/100 g.)</th>
<th>Total amino acids (mg/100 g.)</th>
<th>Total sugar (g/100 g.)</th>
<th>Invert sugar (g/100 g.)</th>
<th>Salt (g/100 g.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 °C.</td>
<td>6.54 16.8 81</td>
<td>6.64 5.84 142</td>
<td>6.38 75.6 117</td>
<td>6.35 138 219</td>
<td>6.55 5.7 130</td>
</tr>
<tr>
<td>5 °C.</td>
<td>5.84 14.2 80</td>
<td>6.30 6.74 111</td>
<td>6.74 118 219</td>
<td>6.74 143 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>10 °C.</td>
<td>5.45 11.2 80</td>
<td>6.20 6.74 111</td>
<td>6.20 118 219</td>
<td>6.20 118 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>21 °C.</td>
<td>4.70 10.3 80</td>
<td>6.00 6.74 111</td>
<td>6.00 118 219</td>
<td>6.00 118 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>69 °C.</td>
<td>4.70 10.3 80</td>
<td>6.00 6.74 111</td>
<td>6.00 118 219</td>
<td>6.00 118 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>98 °C.</td>
<td>4.70 10.3 80</td>
<td>6.00 6.74 111</td>
<td>6.00 118 219</td>
<td>6.00 118 219</td>
<td>6.57 5.7 130</td>
</tr>
<tr>
<td>154 °C.</td>
<td>4.70 10.3 80</td>
<td>6.00 6.74 111</td>
<td>6.00 118 219</td>
<td>6.00 118 219</td>
<td>6.57 5.7 130</td>
</tr>
</tbody>
</table>

* Aschehoug (1952).
**Table VIII**

**Chemical Analyses of Gaffelbitar of Cured Winter Herring from Series 2**

<table>
<thead>
<tr>
<th>Days of storage at 22°C.</th>
<th>pH</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5.03</td>
<td>5.03</td>
<td>67</td>
<td>77</td>
<td>217</td>
<td>256</td>
<td>12.6</td>
<td>15.7</td>
<td>2.2</td>
<td>2.4</td>
<td>7.1</td>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>4.89</td>
<td>4.90</td>
<td>78</td>
<td>91</td>
<td>308</td>
<td>344</td>
<td>12.3</td>
<td>12.6</td>
<td>1.0</td>
<td>1.4</td>
<td>7.6</td>
<td>10.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>142</td>
<td>4.90</td>
<td>4.93</td>
<td>98</td>
<td>110</td>
<td>485</td>
<td>580</td>
<td>11.8</td>
<td>13.8</td>
<td>3.2</td>
<td>3.9</td>
<td>7.3</td>
<td>8.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a* Aschehoug (1952). & Packed in cans with spiced sauce without preservatives.

**Table IX**

**Chemical Analyses of Gaffelbitar of Cured Winter Herring from Series 2**

<table>
<thead>
<tr>
<th>Days of storage at 22°C.</th>
<th>pH</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
<th>Herring</th>
<th>Brine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5.03</td>
<td>5.03</td>
<td>69</td>
<td>84</td>
<td>207</td>
<td>245</td>
<td>12.3</td>
<td>17.0</td>
<td>1.9</td>
<td>2.4</td>
<td>7.2</td>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>5.04</td>
<td>5.05</td>
<td>70</td>
<td>90</td>
<td>279</td>
<td>327</td>
<td>11.4</td>
<td>16.0</td>
<td>2.0</td>
<td>2.7</td>
<td>6.4</td>
<td>8.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>142</td>
<td>5.15</td>
<td>5.17</td>
<td>103</td>
<td>122</td>
<td>450</td>
<td>576</td>
<td>11.7</td>
<td>14.7</td>
<td>3.5</td>
<td>4.3</td>
<td>7.4</td>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a* Aschehoug (1952). & Packed in cans with spiced sauce with preservatives.
teria from cured herring, which produce acetylmethylcarbinol on sugar-containing media.

In experiments with antibiotics (chlortetracycline), by treatment of sprats with formaldehyde or through γ-radiation of the packs, an effort was made to establish the true significance of bacteria in the maturing process of anchovies (Alm, 1958). It was shown that the intestinal enzymes are fundamental to proteolysis, the influence of bacteria being seemingly minor. Nevertheless, it is conceivable that bacteria are involved in the formation of aromatic substances, but definite proof has not been obtained. These experiments are being pursued. Truscott and Hoagland (1955) concluded that in vinegar-cured herring the intestinal enzymes are by far the most potent source of proteolytic activity.

A. Microbial Aspects

The real function of the added sugars in these preserved fish products is not fully clarified. In low concentration they may even be germicidal. At high concentration they act unfavorably due to their osmotic effect. These relationships deserve closer study. In some cases a formation of lactic acid can be noted, decreasing the pH (Christiansen, 1962).

In Soviet investigations with sprats the interesting observation was made that sucrose at 0.1% prevented swelling by gas-forming inoculants of the genus *Aerobacter aerogenes*, but not at concentrations of 1–1.5%, but again at 3–5% (Levieva and Ivanova, 1960). Another pertinent finding is the observation that sucrose acts to suppress bacterial growth only at certain stages in the proteolysis of cured sprats in cans, but at a later stage accelerates the formation of lactic acid (Chernogotsev, 1960).

If salt-resistant bacteria are present, which in most cases is true, their growth could be facilitated by the nitrogenous substances becoming available through proteolysis. This is particularly pertinent when the cans are kept at high temperatures, allowing general development of microorganisms. Such growth of haloduric or halophilic strains has been reported in studies on cured sprats in cans (Ivanova, 1958).

V. Fermented Herring (Surströmming)

Fermented herring (*surströmming*) is specific to the northern Baltic coast of Sweden. It is a result of bacterial fermentation. Similar products exist from other fish, such as fermented trout—the Norwegian *rakørret* (Schmidt-Nielsen and Böhmer, 1935)—and also perch and gwyniad.

The raw material is Baltic herring, *Clupea harengus* var. *membras*, caught just prior to spawning from May 1 until the first week of July. The fat content of the herring is rather low at this time. In the autumn
it is too fatty for this purpose. The herring, which must be freshly caught, is first treated in saturated brine for 30–40 hours with continuous stirring for the first 4 hours. After this pretreatment—the brine concentration has been reduced to about 9° Bé—the herring is eviscerated, but roe and milt are retained. The herring is packed in 60-liter barrels: 57 kg. herring and freshly made brine of 17° Bé. A head space of 1.5 inches is allowed in the barrels. After sealing, the barrels are rotated now and then for the first 3 days and then put into storage.

Fermentation starts in the middle of July and terminates after 2 weeks. This process is accompanied by vigorous formation of gases which escape from between the barrel staves. When the fermentation is ended, the herring is transferred to cans together with brine from the fermentation barrels.

Mörner (1895) has investigated this fermentation. The gases formed are carbon dioxide and hydrogen sulfide, the latter giving a very sharp odor when the cans are opened. This disappears, however, rather soon after opening. The characteristic odor of this herring comes from methyl mercaptan, which of course has a very strange odor but not as unpleasant as hydrogen sulfide. Neither indole, skatole, putrescine, nor cadaverine is formed.

Some people consider fermented herring a delicacy, others find it repulsive.

VI. Overripeness and Fermentation

As pointed out earlier, the maturing process in anchovies and tidbits is of a continuing nature and is not suppressed at any one point. In mature anchovy the brine has a rather strong protein-decomposing activity. The rate of degradation is influenced by temperature and it is possible to slow down this process through refrigeration. Higher temperatures may occasionally bring about complete dissolution of the herring flesh, leaving only a liquid. This liquefaction proceeds very rapidly, in particular at temperatures above 30°C.

Refrigeration is also necessary for other reasons. The finished products easily undergo fermentation by bacteria, even if preservatives are added. The bacteria in question are halophiles of a lactic acid-forming type. They form gas, and swelling of the cans does not necessarily mean that the products are less wholesome. Some experts even claim that an “anchovy” pack does not reach its full flavor until fermentation has started in the can. Fermentation is, however, not desirable from the point of view of food hygiene, and these products therefore have to be kept under refrigeration to prevent overripeness and fermentation.
Another type of bacterial attack on these products gives rise to the so-called ropy brine. This often appears in the barrels during the maturing process. The brine becomes quite thick and slimy. This phenomenon appears sporadically in certain years, but the conditions under which it occurs are not well understood. Its appearance is therefore rather unpredictable.

The sliminess is caused by certain bacteria (Lindeberg, 1954, 1957). *Achromobacter* strains isolated from this type of slime were cultivated on sucrose-containing media. They formed levan from the fructose (levulose) of the sucrose. The slime-forming substance in herring brine is also levan. This compound could be synthesized by these bacteria only from sucrose (and raffinose). Strangely enough these bacteria do not use sugars for growth, while amino acids and pyruvic acid together with other intermediates of the Krebs cycle are readily oxidized (Lindeberg, 1957).

This ropy brine inflicts large losses on the herring packing industry. Hjort-Hansen (1954) has been successful in preventing ropy brine by adding mustard to the barrels. Lindeberg (1957) suggested other methods which appeared feasible in order to check slime formation. He proved that sugars other than sucrose have an inhibiting effect on the bacterial formation of levan. A comparatively small addition of lactose suppressed the slime formation on laboratory media. A drastic method is, of course, to use dextrose as a substitute for sucrose and in this way make levan formation impossible. Dextrose is, however, more expensive, at least in dry form. The use of these methods does not appear to be economically feasible.

VII. Discolorations

Herring products have a strong corrosive action on tin plate owing to their content of TMAO (trimethylamine oxide), which is reduced by the metal to TMA thereby dissolving the tin and iron. This results in black discoloration through formation of iron sulfides, and in off-flavors. With the use of lacquered tin plate in cans and boxes, these risks have been removed.

A more difficult problem is the appearance of white precipitates on products of this kind. Wille (1931) showed these white coatings to consist of tyrosine. This was confirmed independently by Cultrera (1934). The amino acid is released during and after the ripening process. Being a less soluble substance, it forms white specks or patches on the surface of anchovies and tidbits. This phenomenon obviously constitutes no hazard but the product loses its finish and becomes less appetizing.
to the uninitiated. There seem to be no dependable methods known for
preventing this, except cold storage of the product and early removal
of the active viscera in the gutting and washing in order to reduce the
rate of proteolysis (Truscott and Hoagland, 1955). Such white precipi-
tates of tyrosine, so-called "flecking," are also described in aging hams
(Hunt et al., 1939).

VIII. Nutritive Aspects

Anchovies and tidbits do not belong to the basic foods. They are not
consumed in large quantities. Fermented herring formerly made a cer-
tain contribution to the foods of the northern part of Sweden, but this
is no longer so. The inclusion of these products in the menu as hors
d'oeuvres appears to be well justified. They not only have an appetizing
effect, but are readily digested. Their abundant content of free amino
acids makes them an effective amino acid supplement to a cereal diet.

ACKNOWLEDGMENT

The author is indebted to Mr. Henry Jarmell, Lysekil, Sweden, for valuable
information as to details in the manufacture of anchovies and herring tidbits.

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