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Benzo(a)pyrene concentrations in smoked fish and shellfish products

by

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Summary

Code words: environmentally harmful substances – PAHs – benzo(a)pyrene – smoke – fish – shellfish

In the Federal Republic of Germany a limit of 1 µg/kg for benzo(a)pyrene (BaP) has been laid down in the meat and cheese regulations for smoked meat products and cheese products. There are no corresponding regulations for smoked fish products. The benzo(a)pyrene (BaP) content was determined in the edible portion of 122 smoked fish and shellfish products. The value of 1 µg/kg was exceeded only in the case of smoked sprats and smoked oysters in oil. The reasons involved here, such as eating habits – e.g. edible portion –, large surface area/weight ratio of the material examined, smoking technologies, environmental contamination of the material examined with polycyclic aromatic hydrocarbons (PAH), are discussed in detail. An amendment to the permitted additives regulations is regarded as necessary for reasons of consumer protection. A limit of 1 µg/kg should be aimed at in these regulations for fish and shellfish products as well, to include any possible environmental contamination.

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Numerous studies and research projects have been carried out on polycyclic aromatic hydrocarbons (PAHs) (Fishbein, 1973). The interest in this group of chemical compounds is due to their widespread occurrence in the environment and the high carcinogenic potential of some of these substances (Fishbein, 1973). Many studies have demonstrated that PAHs, sometimes in substantial concentrations, are present in a wide range of foods (Fishbein, 1973; Howard and Fazio, 1969; Fritz, 1971). In any discussion of PAH levels in foods, it is important to distinguish between two different sources, apart from endogenous formation during food preparation (Fritz, 1971):

a) contamination due to environmental influences,
b) contamination from smoke during processing.

Both forms of contamination can be traced to the incomplete combustion of organic matter such as wood, coal or oil. Processes of this kind are the major source of PAHs that are detected in the environment and in foods (Fishbein, 1973). The contamination of foods with PAHs through environmental pollution alone may take on dimensions that are cause for concern. In the case of various types of vegetables and lettuces, for examples, peak BAP values of up to 24.5 µg/kg have been found (Grimmer and Hildebrand, 1965). In addition to these "unavoidable" forms of contamination, there are technical processes which result in varying PAH contamination levels in the end product that must be accepted by the consumer. Among these is smoking, one of the oldest methods of food preservation (Toth and Blaas, 1972). Smoking also adds flavour to foods, and this flavouring, which is highly prized by the consumer, has gradually come to overshadow the original preservative effect.

In order to protect the health of consumers, legal limits on PAH concentrations in certain types of smoked foods have been set in the Federal Republic of Germany. Because of its particularly high carcinogenity (Fishbein, 1973), BAP (benzo(a)pyrene) has been selected as the index substance. According to Section 1 (2) of the German Meat Regulations, for example, the average BAP concentration in smoked meat, smoked meat products or meat products containing smoked foodstuffs may not exceed 1 µg/kg. Under Annex 3 No. 1 to Section 23 (1) of the German Cheese Regulations, the same limit also applies to smoked cheeses and cheese products containing smoked foodstuffs.

At this time there are no corresponding statutory regulations governing smoked fish products, which constitute a not insignificant product group. The results presented in the following provide an overview of BAP concentrations in samples of smoked fish and shellfish. It is hoped that they will also contribute to the discussions on the establishment of BAP limits for these products, limits which we consider necessary to protect the health of consumers.

Materials and methods

In this study, 122 samples of smoked fish and shellfish were analyzed. The samples were obtained within the framework of the official food inspection service, both as routine samples and, in some cases, on suspicion of contamination, within the area served by the Central Hessian Medicinal, Food

and Veterinary Inspection Office. All samples were obtained from wholesale and retail establishments.

The smoked fish products were divided according to species or special designation into the following categories: herring, mackerel, sprats, rock salmon (salmon substitute), *Schillerlocken* (smoked dogfish strips), trout, and other fish. The smoked shellfish products consisted exclusively of smoked oysters. Further details are shown in Table 1.

Analyses were carried out on the edible portion of the samples. In the case of whole fish, head, innards, bones and in some cases skin were removed, depending on the nature of the product. In the case of sprats, only the head was removed. Prior to analysis, oil was drained off from the fish portion in oil-packed products. In some cases, the BAP content of the oil was also determined.

All samples were processed according to the instructions for Method L 07.00-26 in the Official Collection of Analytical Methods pursuant to Section 35 of the German Law on Foodstuffs and Essential Commodities (LMBG) [see Lit. ref]. This method was incorporated into the Official Collection as a screening method for the "determination of benzo(a)pyrene in (smoked) meat products". Therefore we first had to verify whether this method was also suitable for quantitative determination of BAP concentrations for our purposes. This was confirmed by a series of recovery tests performed within the range of the expected concentrations. The mean recovery rate was 83.6% (range of variation 81.6 to 85.9%). The oil samples were also tested according to the above

instructions. Instead of using 120 ml of the first extract for further clean-up (see instructions), we first determined the volume of the oil/solvent mixture and used 75% of this mixture for the further clean-up.

In the course of processing and thin-layer chromatography (TLC), the following variants (suggested in the instructions) were selected:

- Cyclohexane was used for extraction of the sample material.

- Precoated ALOX/CEL-AC-Mix-25 plates (Macherey Nagel) were used for the TLC, since separations obtained with this plate material were definitely superior.

TLC

- Linear application (line length 1 cm; Linomat III, Camag).

- Two-fold development with solvent as per instructions.

Measurement

In each case, the fluorescence position curve of BAP was determined with the aid of a chromatogram spectrophotometer (Zeiss type KM3).

- Excitation wavelength: 297 nm
- Emission wavelength: 436 nm (filter)

Evaluation was based on the peak area within a previously tested linearity range from 0.1 to 10 ng BAP per spot (≙ 0.01 to 1 µg/kg BAP when processed according to instructions and 20 µl applied volume). Concentrations from 0.05 to 0.1 µg/kg could still be quantitatively evaluated with good reproducibility. For lower concentrations (see linearity range), only qualitative evaluations were generally possible. In view of the objective of the study, quantification was not attempted with these measurements. Quantities below 0.1 µg/kg were therefore shown in the results as < 0.1 µg/kg. At least three standards of various concentrations were run along with the sample on each plate. Calculations were based on the standard whose area was closest to that of the sample. In samples with higher BAP concentrations outside the tested linearity range, the extract was diluted as necessary prior to application.

Results

To facilitate comparison of the test results, the results for each category, rounded up to the nearest decimal point, are shown graphically in Figures 1 through 8. Extrapolations based on the recovery rates were not performed.

For herring (Fig. 1), the highest BAP concentration was 0.4 µg/kg. Nine samples contained less than 0.1 µg/kg BAP. There was no clear difference between loose and prepackaged product and oil-packed (canned) product. Overall, the number of samples declined steadily from the lowest to the highest concentrations.

Similarly, in mackerel (Fig. 2), the BAP concentrations did not exceed 0.4 µg/kg. The proportion of samples containing less than 0.1 µg/kg was smaller than in the case of herring. The higher concentrations (0.2 µg/kg and more) occurred exclusively in filets, with the two highest values being found in oil-packed product.

For sprats (Fig. 3), 5 out of 18 samples contained more than 1 µg/kg BAP (concentrations from 1.2 to 2.8 µg/kg). All of these were samples of loose product. The other concentrations were relatively uniformly distributed between < 0.1 and 0.8 µg/kg. Only one sample had less than 0.1 µg/kg. The only relationship that could be discerned between the product form and the BAP concentrations was that the lower concentrations up to 0.4 µg/kg were found mainly in sprats in oil, but concentrations of only 0.3 µg/kg were also found in two samples of loose product. In the somewhat higher concentration range between 0.6 and 0.8 µg/kg all forms of product were represented.

For smoked rock salmon (Fig. 4), the maximum BAP concentration was 0.5 µg/kg. This value, which is something of an outlier in this category, was found in the one sample of "rock salmon slivers" (see Table 1). The remaining samples had BAP concentrations of no more than 0.2 µg/kg. In 9 of 13 samples tested, the concentration was less than 0.1 µ/kg. Figure 4 shows a pronounced gradient from lowest to highest values.

The BAP concentrations in smoked dogfish strips (Fig. 5) were between 0.1 and 0.5 µg/kg. No samples contained less than 0.1 µg/kg. Seven out of the 11

samples tested contained no more than 0.2 µg/kg BAP. All of these samples were canned product packed in oil. The higher concentrations of 0.3 to 0.4 µg/kg were measured in loose and prepackaged product. The highest concentration of 0.5 µg/kg was from a can of smoked dogfish strips in oil.

The maximum value for smoked trout (Fig. 6) was 0.3 µg/kg. The majority of the remaining concentrations were below 0.1 µg/kg. There was no discernible relationship between product form and BAP concentration.

In the remaining samples of various other smoked fish products (Fig. 7), BAP concentrations ranged from < 0.1 to 0.4 µg/kg.; a third of these samples contained less than 0.1 µg/kg. The values < 0.1 µg/kg were measured primarily in pieces from larger fish. The highest concentration of 0.4 µg/kg occurred in a canned product labelled "smoked fish cocktail in oil", which consisted of a mixture of various small pieces such as mackerel filet, herring filet and dogfish strips.

Eight out of 25 samples of oysters (Fig. 8) contained more than 1 µg/kg BAP (from 1.2 to 5.5 µg/kg). The remaining samples were in the < 0.1 to 1 µg/kg range; the minimal concentration was measured in only one sample. Of the samples measuring up to 1 µg/kg, about half were in the 0.5 to 0.6 µg/kg range. All samples were sold as canned, oil-packed product. Despite different outer packages of different suppliers, the material and shape of the cans as well as the largely identical flanges and beading suggested that in all probability all of the products originated from the same company or group of companies in Korea. This observation is of interest for the subsequent

discussion of the relatively wide variation in BAP concentrations in the smoked oyster samples.

In the course of the tests, a surprisingly high BAP concentration was measured in the oil portion of one sample of "smoked oysters in oil". Because of this finding, we proceeded to determine the BAP concentration in the oil portion of one sample per batch in all the subsequent oyster samples.

For comparison purposes, we then also determined the BAP concentration of the oil portion in five fish samples. Table 2 shows the BAP concentrations in the fish/oyster portion as compared to the oil portion for all of the samples so tested. As the table shows, the BAP concentrations in the oil portion of the oyster products was considerably higher than those in the fish products. In the case of the oysters, the highest BAP concentration in oil was around 60 µg/kg. It was noted that the highest concentrations in the oil portion corresponded roughly to the highest concentrations in the oyster portion. The same is true of the lowest concentrations. In the intermediate range, the BAP concentrations fluctuated irregularly around 30 µg/kg.

In the fish products, a definite tendency is discernible (bearing in mind the small number of comparative tests): with the exception of the smoked dogfish strips, increasing BAP concentrations in the oil portion corresponded to increasing concentrations in the fish portion. The relationship which was also noted between the size of the fish pieces and the BAP concentrations in the oil may be coincidental, but could also be explained.

Table 1: Smoked fish and oyster products (sample material)

Group	Number	Designation and/or form in which sold (number)
Herring	n = 23	**whole fish:** - smoked herring (4)/*Brado*[1] (1), loose - smoked herring (1)/*Lachshering*[2] (1), prepackaged **pieces:** - smoked herring filet (2)/*Brado* filet (2)/ *Lachshering* filet (1), prepackaged - smoked herring fillet in oil, canned (11)
Mackerel	n = 19	**whole fish:** - loose (1) - prepackaged (4) **pieces:** - filet, loose (2) - *Rollmops*[3], loose (1) - filet, prepackaged (2) - filet in oil, canned (8) - filet in tomato sauce, canned (1)
Sprats	n = 18	- loose (8) - prepackaged (2) - in oil, canned (8)
Rock salmon (salmon substitute)	n = 13	- slivers, in oil, preserve (1) - slivers, in oil, preserve (12)
Schillerlocken[4]	n = 11	- loose (1) - prepackaged (2) - in oil, canned (8)
Trout	n = 5	**whole fish:** - loose (1) **pieces:** - filet, prepackaged (3) - filet in oil, canned (1)
Other fish	n = 8	**pieces only:** - salmon (1), dogfish (1)/black halibut (1), prepackaged - smoked eel (1)/smoked assortment (1)/ smoked cocktail (3) in oil, canned
Oysters	n = 25	- in oil, canned (25)

[1] *Brado* = Dutch cold smoked herring
[2] *Lachshering* = cold-smoked salt herring
[3] *Rollmops* = marinated herring filets
[4] *Schillerlocken* = smoked dogfish strips

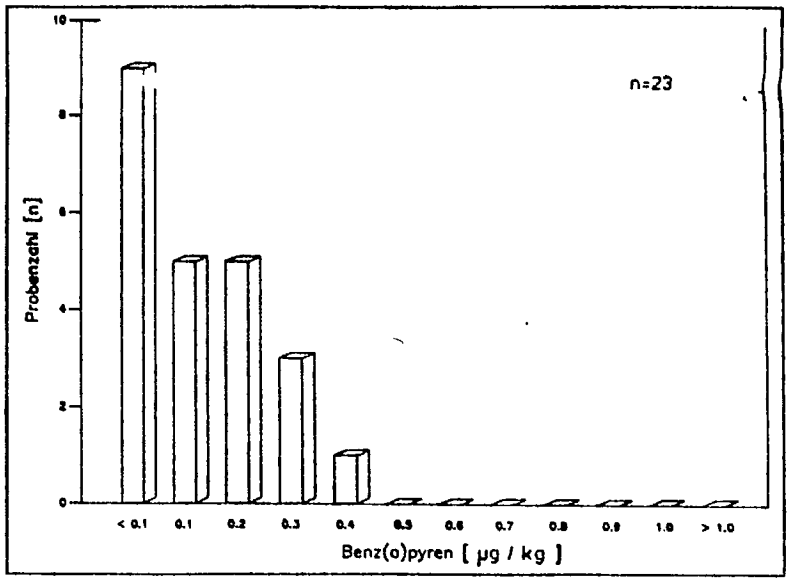

Fig. 1: Benzo(a)pyrene concentrations in smoked herring and herring pieces

X-axis: Benzo(a) pyrene [µg/kg]
Y-axis: Number of samples [n]

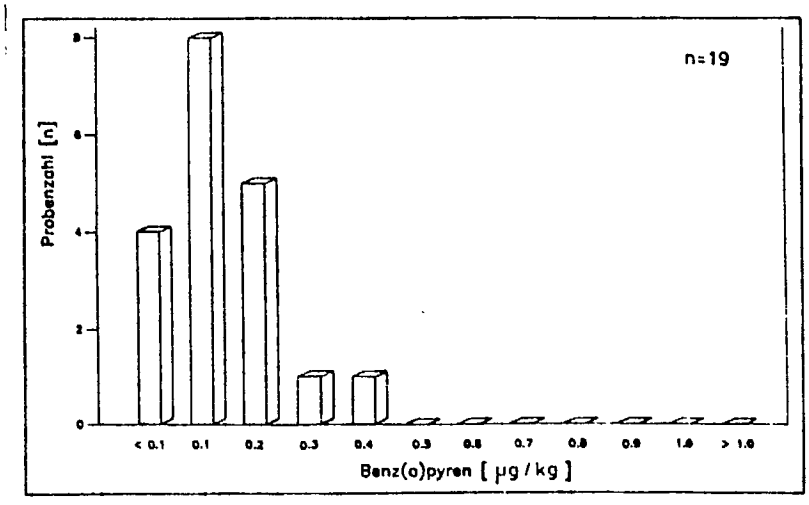

Fig. 2: Benzo(a)pyrene concentrations in smoked mackerel and mackerel pieces

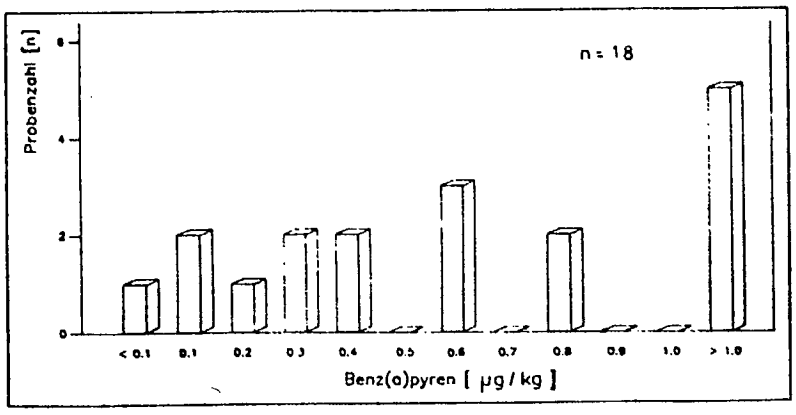

Fig. 3: Benzo(a)pyrene concentrations in smoked sprats

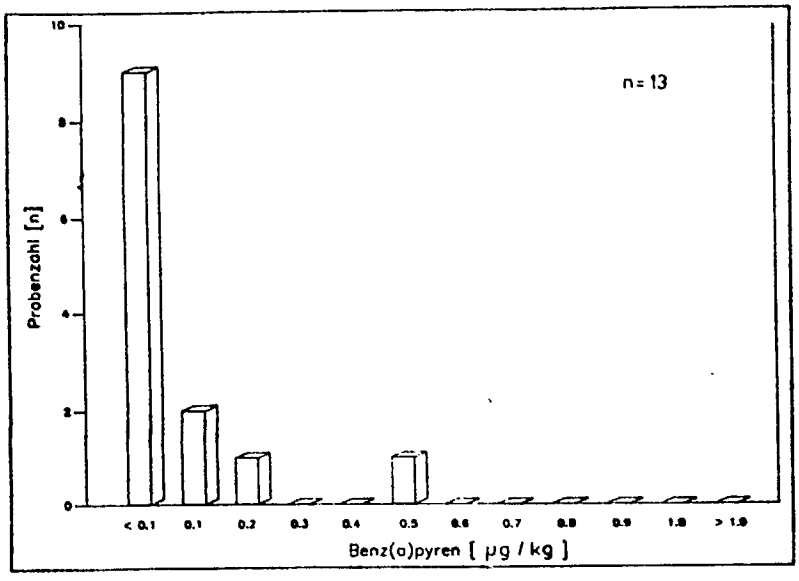

Fig. 4: Benzo(a)pyrene concentrations in rock salmon (salmon substitute)

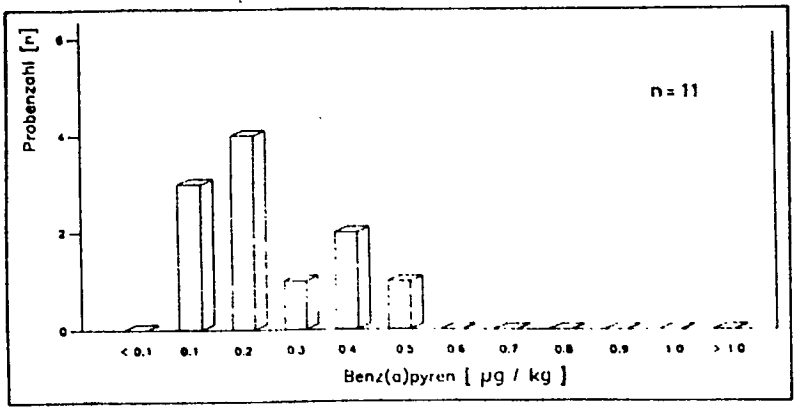

Fig. 5: Benzo(a)pyrene concentrations in smoked dogfish strips

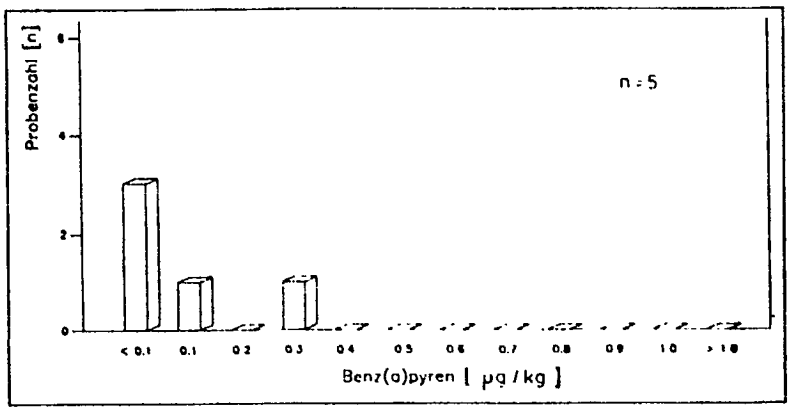

Fig. 6: Benzo(a)pyrene concentrations in smoked trout and trout pieces

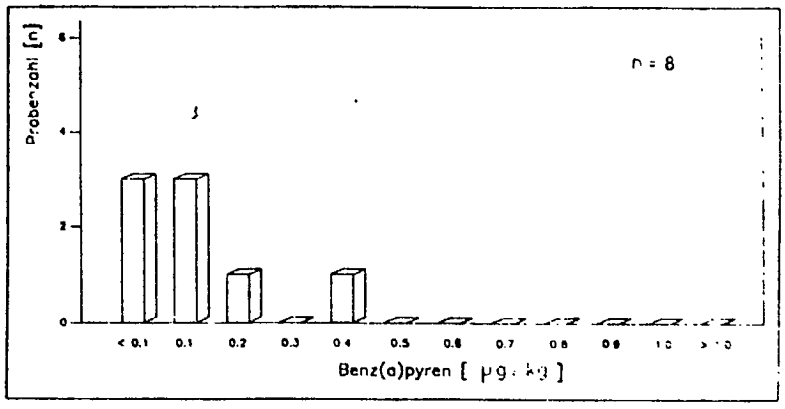

Fig. 7: Benzo(a)pyrene concentrations in miscellaneous smoked fish pieces

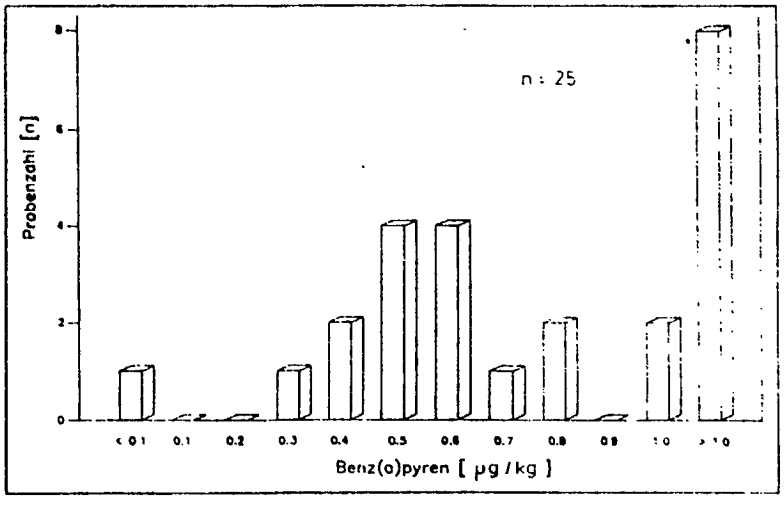

Fig. 8: Benzo(a)pyrene concentrations in smoked oysters

Table 2: Smoked oysters and fish in oil (canned); comparison between oysters/fish and oil portion (benzo(a)pyrene µg/kg)

Product	Benzo(a)pyrene (µg/kg)	
	Oyster/fish portion	Oil portion
Smoked oysters in oil (canned)	<0.1	2.1
	0.4	11.3
	0.4	23.3
	0.5	32.0
	0.5	39.0
	0.6	29.5
	0.6	37.2
	0.6	39.9
	0.8	23.8
	0.8	30.1
	1.0	27.8
	1.0	57.0
	2.2	34.6
	2.3	59.3
Smoked mackerel filets in oil and own juice	0.1	0.6
Smoked herring filets in oil and own juice	0.1	1.0
Rock salmon slices in oil	0.1	2.1
Smoked dogfish strips in oil and own juice	0.2	1.4
Smoked sprats in oil and own juice	0.6	5.8

Discussion

Since in the Federal Republic of Germany statutory limits for BAP have been established only for smoked meat, smoked cheese, and products made from them, but not for other smoked food, it seems reasonable to begin by applying the maximum of 1 µg/kg in interpreting our own results for smoked fish and shellfish. Steinig (1976) and Larsson (1982) also used this standard in discussing their results. The question of whether such a limit is even practicable in the case of smoked fish and shellfish products will be discussed later.

In 13 of the 122 fish and oyster products tested, the BAP concentration in the edible portion was over 1 µg/kg. These higher concentrations occurred only in sprats and oysters. Extrapolation based on the recovery rate (increase by approx. 20%) would not significantly change the overall picture. Only in the case of the oysters would two additional samples come in at just over 1 µg/kg, so that even if the recovery rate were taken into account the higher values would still be limited to sprats and oysters. Of all the products tested, the smoked oysters in oil are probably the least important commercially. If we eliminate these, then, we find that only about 5% of all the other samples - all of them sprats - are over 1 µg/kg.

A comparison of our results with those of Steinig (1976) is possible only with certain qualifications. Whereas for our samples no information about the smoking techniques used was available, the above author was able to differentiate between the various smoking methods and discuss these

differences. Based on the edible portion and 100% recovery, Steinig found BAP concentrations of more than 1 µg/kg in one out of five mackerel samples, all three samples of smoked dogfish and one of three smoked herring samples. All of the samples were loose product. The higher values, which were significantly higher than 1 µg/kg, generally occurred only in product that had been smoked using traditional methods. In our own study, we did not find any levels exceeding 1 µg/kg in mackerel, smoked dogfish or smoked herring. Overall, Steinig's results (1976) are higher than ours. The samples of loose sprats, which were all smoked in "Altona ovens"[1], all contained levels over 1 µg/kg. Taking into account that the skin was tested separately and contained substantially higher concentrations than the remaining "edible portion", we find here too a tendency towards higher concentrations than in our own results, which were based on tests of samples with skin.

The above-mentioned tendency towards higher values is also seen in Steinig's results (Steinig 1976) for canned smoked fish, particularly sprats and mackerel in oil, for both the fish and the oil portions. In products of this kind, we did not find any concentrations over 1 µg/kg in the fish portion. The article by Larsson (Larsson 1982) also shows a definite tendency towards higher BAP values in loose as well as canned product. It should be borne in mind, however, that most of the samples of loose product were smoked in traditional facilities.

[1]After the city of Altona, now part of Hamburg. - Translator

Overall we find that the magnitude of the BAP values determined here is in relatively good agreement with the results reported in the two articles cited above. The lower values measured in our study, however, are more likely to lend support to efforts to have the limit for benzo(a)pyrene in fish products also set at 1 µg/kg. The reason for the discrepancy could be that the situation has improved over the last few years. Steinig's results date from 1976. Advances in smoking technology since then may well have already resulted in a slight reduction of BAP levels in smoked products within the last 12 years. Further improvements and modifications in smoking technology are surely possible and, above all, are certainly necessary.

To better understand the differences in BAP concentrations, even within product groups, a number of factors which influence BAP levels in the edible portion, both singly and in combination, must be considered. Chief among these is the method of smoking. It is undisputed that with the use of modern smoking methods - in special plants with external smoke production - it is possible to produce fish products containing less than 1 µg/kg of BAP. In these smoking plants parameters such as smoke concentrations, temperature and others can be controlled so that PAH concentrations in the product are held to reasonable levels. However, the old-fashioned smoking ovens, primarily the so-called "Altona ovens", in which the smoke is produced in the smoking chamber directly below the material to be smoked, are still frequently used in the fish industry. In these ovens the smoking process can generally be controlled only by regulating the air intake. The use of these ovens - as the study by Steinig (1976), among others, has shown - leads to substantially higher levels of contamination with PAHs and, consequently, with BAP, than is

the case with modern technology. It must be assumed that the simpler, i.e. the more uncontrolled, the smoking process, the higher will be the PAH levels in the smoked products.

The dimensions of the product to be smoked also play a rather significant role in determining contamination levels. As a rule, the larger the ratio of surface area to weight or volume, the higher will be the BAP levels, even under identical smoking conditions. Thus for example one would expect to find higher concentrations in filets than in whole fish of the same type.

One must also consider that fish products are not always consumed in the form in which they were exposed to the smoke; in other words, the concept of "edible portion" is an important one. In many products the skin is removed prior to eating; in others, such as sprats, it is not. Steinig's results (1976) show very clearly that the BAP contamination in the skin is frequently several times higher than in the muscle tissue, in other words that the outer layers contain several times more BAP than do the inner, edible ones.

While so far we have discussed only factors related directly or indirectly to smoking, contamination of untreated fish and shellfish as a result of environmental pollution cannot be ignored. Unfortunately, no figures are available for fish. For oysters harvested in oil-polluted waters, BAP levels of up to 6 µg/kg have been measured (Howard and Fazio, 1969). It has also been demonstrated that oysters absorb BAP relatively quickly, but then excrete it slowly (Sims et al., 1983).

As Table 2 shows, considerable BAP concentrations were found in the oil in which the product was packed, particularly in the case of smoked oysters. Similarly, the oil from a number of fish samples contained concentrations that were significantly higher than 1 µg/kg. Vegetable oils too may be contaminated with PAHs due to environmental pollution (Gerts, 1988; Speer and Montag, 1988). The effect of smoke during processing is also a possible source of contamination (Speer and Montag, 1988). In recent studies of native plant oils, BAP levels of up to 4.1 µg/kg were measured (Speer and Montag, 1988). One soya oil used for canned fish contained 3.5 µg/kg of BAP. However, the in some cases very high BAP levels found in oil in the present study are probably not attributable to contamination of the oil prior to its use for packing the fish products. We are not familiar with any reports of such high levels of BAP in oil. Since benzo(a)pyrene is highly soluble in oil, it is much more likely that the substance originally appeared in the fish as a result of smoking and was then distributed throughout the finished product.

The factors presented thus far admit of a number of possible variations. Thus for example the addition of oil containing relatively high levels of BAP to smoked fish containing less than 1 µg/kg could result in a final product containing more than 1 µg/kg. Conversely, the BAP content of a smoked fish may be considerably reduced by packing it in virtually uncontaminated oil. The question of how to assess the food product if consumption of the oil cannot be ruled out will be treated in the discussion of potential legislation.

The above remarks show that only in a few cases does one of the factors alone have a decisive influence on the BAP content of the final product. Since often a number of different factors are involved, the values obtained within the various product groups cannot always be definitively interpreted. Nevertheless, the observed tendencies can be satisfactorily explained. The main reason that no concentrations over 1 µg/kg were found in herring, mackerel, trout and various other fish, is probably because in these cases the fish was tested without the skin - i.e. edible portion only. Higher levels were measured in mackerel filets than in whole mackerel. The less favourable surface-to-weight ratio of filets no doubt is a factor here. This factor is probably also the reason why the highest concentration in the salmon substitute samples was measured in the single sample of rock salmon slivers, since the surface of the slivers is substantially larger than that of slices. In the smoked dogfish strips a tendency towards higher values was observed in loose and prepackaged product. With one exception the oil-packed products were lower. This could be due to the solubility of BAP in oil. The exception - the highest concentration among the group of dogfish strips in oil - may be attributable to an old-fashioned smoking method.

Concentrations over 1 µg/kg were determined in only two groups: sprats and oysters. In both groups a number of unfavourable factors come together, and if one of these factors consists in an outdated smoking method the overall effect will be particularly noticeable. A major factor in both cases is the large surface-to-weight ratio, which is even more unfavourable in oysters than in sprats. For sprats there is also the fact that the skin, which generally contains particularly high levels of contamination, is also consumed. In the

case of oysters, relatively high levels of contamination in the starting material due to environmental influences cannot be ruled out (Howard and Fazio, 1969). All of these points indicate why these products were identified in our tests as "problem groups".

The influence of the oil in which the smoked product is packed becomes especially clear in these two groups. Levels of 1 µg/kg were exceeded only in sprats which were marketed in the unpackaged (loose) form, while the lower concentrations occurred primarily in oil-packed product. It seems unlikely that this would be due solely to differences in smoking methods. Rather, it seems that a considerable amount of BAP goes into the oil. In oysters this transfer is particularly pronounced, because of the relatively large smoked surface area (see Table 2). It is highly improbable that the very high levels of BAP in the oil were already present before the oil was added to the oysters.

In view of the justified suspicion that all of the oyster samples originated from a single source in Korea, the range of variation in the BAP concentrations in the oyster portion is surprisingly large. Apart from differences in size (surface area) and in the initial contamination of the fresh oysters, the only explanation is that either different Korean supplier companies use different smoking methods, or that one supplier smokes the product by empirical, but not controllable methods.

Although the smoked sprats and oysters occupy a special position among the products tested because of their higher BAP levels, the tests also show that

it is possible to produced smoked sprats in all forms as well as smoked oysters in oil in which the BAP content in the fish/oyster portion is below 1 µg/kg. This finding is of particular significance for the following discussion of the food legislation aspects.

At this time, no statutory limit has yet been established for BAP levels in smoked fish and shellfish and products made from them. Thus these products can only be assessed under the general food regulations (German Law on Foodstuffs and Essential Commodities [LMBG]). Opinions regarding the BAP levels at which a product becomes unacceptable differ widely. Correspondence relating to preliminary inquiries [concerning the establishment of statutory limits - Tr.], for example, expresses the viewpoint that smoked fish products with BAP concentrations of 2 and 3 µg/kg are still commercially acceptable, as long as the consumer is made aware of the BAP levels. Only at extremely high levels, according to this view, would the product be considered unfit for consumption pursuant to Section 17 (1) 1 of the LMBG. Others feel that products containing more than 5 µg/kg BAP, including contamination of the raw material, should no longer be considered fit for human consumption.

Our own view is that the situation must always be considered from the point of view of the consumer, since it is the consumer whom the statutory regulations are primarily there to protect. From this point of view, then, three factors are important:

1. An increased intake of polycyclic aromatic hydrocarbons - particularly BAP - can cause damage to health.

2. Because of this, a limit of 1 µg/kg of BAP, as an index substance, has already been established for two groups of smoked foods, namely meat/meat products and cheese/cheese products.

3. As the present study, among others, indicates, it is indeed possible to prepare smoked fish and shellfish and products made from them that contain less than 1 µg/kg BAP.

We feel that if the consumer is aware of these facts, he will refuse to buy products containing BAP levels over 1 µg/kg, even if the levels are indicated on the product. Thus it seems reasonable that such products should be assessed in accordance with Section 17 (1) 1 of the LMBG.

Experts also disagree on whether the oil in oil-packed products is generally consumed or not. The very high BAP concentrations found in some samples of oil (see oysters in Table 2) suggest that this is indeed a problem to be taken seriously. Even in products containing concentrations of less than 1 µg/kg in the edible fish or oyster portion, the oil is often highly contaminated. We do not share the view of some experts that consumption of the oil should be reagrded as exceptional. In canned products of the kind tested here, it is by no means unlikely that the oil will be consumed along with the rest of the product. The larger the surface area of the smoked product, the more likely this is to be true. In products of this kind, including sprats and particularly oysters, the consumer will not wait until the oil has almost completely drained off the product, as is done in laboratory tests. Consequently he will be exposed to further PAH contamination. Similarly, it

cannot be completely ruled out that the oil will be used for other purposes, e.g. in salads, because of its aromatic qualities. In this context we point out that even in the existing legislation, the oil added to a product is not treated as a "low-value" additive. In oil-packed products, there is no requirement to indicate the drained weight of the product. Oil is not one of the "low-value" packing liquids listed in Section 11 (1) of the Packaged Food Regulations. Only in the case of such liquids is it safe to assume that they will not be consumed with the product. Moreover, producers not infrequently use expressions such as "packed in finest vegetable oil" on their labels, which in themselves fairly invite consumption.

For the reasons just given, we felt that smoked oysters in oil were unacceptable if the BAP content in the overall product (oysters and oil) was greater than 1 µg/kg, even if that of the oysters along was lower. This situation occurred almost exclusively in the product group "oysters", due to the high levels measured in the oil.

Efforts are currently under way to extend the existing limits for meat, cheese and their corresponding products to smoked foods in general. Since from the point of view of food legislation, smoke is considered an additive, this would be done by an amendment to the Additive Certification Regulations. Limits would then also apply to fish and shellfish products. Much of the debate concerning new limits centres on the question of whether limits of 1 µg/kg can be complied with in these products.

The fish industry, as well as certain experts, both free-lance consultants and government officials, feel that an overall limit of 1 µg/kg for fish and shellfish products is too low. Various arguments along these lines have been presented in reports prepared as part of the preliminary inquiry into the matter.

One of the arguments is that meat and fish are usually smoked for different reasons: whereas in the case of meat the purpose is primarily to add flavour, the primary purpose of smoking fish is to preserve it. Moreover, because of the special properties of fish, it must be smoked faster and therefore higher temperatures must also be used (hot smoking). The proponents of this view also point to the "Altona ovens" still used in many parts of the fish industry. They do admit, however, directly or indirectly, that lower BAP levels can be achieved with modern smoking facilities. An argument frequently advanced is that the average consumption of smoked fish per person per year (about 12 kg of fish in total, of which about 5% is smoked) is much lower than that of smoked meat products. It is also emphasized that in many plant foods, such as salads and vegetables, significant PAH levels may be present, but that there are no statutory regulations governing this situation, nor are any planned.

In our opinion, none of these arguments is sufficiently demonstrates why the relatively low limits which have been proposed for smoked fish should not be enacted. One cannot compare a product in which the PAH levels are caused by a technical process (smoking) with foods in which the contamination is due to environmental pollution. For this reason the last of these arguments is the

least convincing. Moreover, limits on environmentally-caused PAH contamination could only be set by appropriate provisions in the Regulations concerning Limits on Toxic Emissions. The argument that smoking of fish is carried out primarily to preserve it does not hold water. This would mean that a consumer who wants to buy fish that will keep would automatically have to buy smoked fish. Modern methods of extending shelf life, such as thermal processing, chilling and freezing, make this argument very questionable. Furthermore, only a fraction of all smoked fish products are sold in loose form, in which smoking actually serves its original purpose of preserving the product. All other products, i.e. those which are packaged in some way, are preserved by other methods. Overall we believe - and this view is shared by others - that over the years flavouring has clearly come to outweigh preservation as a reason for smoking both meat and fish. We do not disagree with the statement that different smoking techniques are needed for fish than for meat because of the specific properties of the former. However, it is equally clear that with the help of modern facilities, fish can be smoked in such a way that the resulting products are of good quality and contain low levels of PAH contamination. The reference to the many "Altona ovens" still in operation would at most serve as an argument for a transitional regulation, which would eventually be dropped in favour of lower limits once newer technology had been adopted on a broad basis. The relatively low consumption of smoked fish (per year and per person) is also not a convincing argument for substantially higher limits than for meat and cheese. This becomes clear if one considers the annual per capita consumption of smoked cheese and cheese products containing some smoked foods. The average amount consumed is of the same order of magnitude as for smoked fish, and according to reliable

estimates is probably even lower. Since a legal limit of 1 µg/kg has been established for these products, the amount consumed evidently was not considered a major factor.

The arguments against a 1 µg/kg limit should be taken into account however, inasmuch as any legislation should provide for transitional periods: the changeover from the old "Altona ovens" to modern smoking plants will take some time, even if the problem itself is not a new one.

The transitional periods should make allowance for the technical problems faced by industry, but should also be acceptable to the consumer.

In establishing the limit values, it must be made clear that they apply to the edible portion. The question of what may be considered the edible portion in individual cases should then be established, at least in the official justification for the law. It should also be decided whether contamination due to environmental factors should be included in the limits or whether they should be specified in the Regulations concerning Limits on Toxic Emissions and added on to the limits for smoked fish products. Since meat and milk are not contaminated with relevant amounts of PAH from the environment, such questions did not to our knowledge arise to any significant extent at the time the limits for BAP in meat and cheese were established. At that time meat and cheese products in oil also did not play any significant role, so that potential effects of the oil were not discussed. The results of our tests show that it is possible to comply with an overall limit of 1 µg/kg, and that a breakdown into environmental and smoking-related components does not appear

necessary. For practical reasons, among others, we recommend that no such distinctions be made. Only in the case of smoked oysters in oil should another solution be found, due to the overall potentially higher levels of environmental contamination.

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