# Traditional smoking of meat products, fish and cheese

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**Abstract**

The production of traditional and/or regional products is based on natural raw materials of good quality originating from domestic plant species and animal breeds – the heritage of Polish agriculture. Raw materials originating from Polish domestic breeds are applied in the production of the traditional local products of the highest quality. These products are produced and preserved with the use of traditional methods. All the obtained results demonstrate that these products can be recommended as traditional high-quality foods with a unique taste.

*Fish, cheese, meat products, traditional smoking*

## Introduction

Raw materials originating from Polish domestic animal breeds – Polish Red Cattle and White-backed Cattle; sheep – colour varieties of Polish Mountain Sheep, Heath (wrzosówka) Sheep, Świniarka Sheep, Great Poland Sheep, Olkuska Sheep, Kamieniecka Sheep, Żelaźnieńska Sheep, Uhruska Sheep, Pomeranian Sheep; geese – Zatorska, Kielecka, Biłgorajska, Lubelska, Podkarpacka, Kartuska, Rypińska, Suwalska and Pomorska; ducks – Polish Pekin, Lowered Duck; pigs: Złotnicka Spotted, Złotnicka White, Puławska) – are used in the production of traditional local products of the highest quality. These products are produced and preserved with the use of traditional methods.

Food smoking is one of the oldest food preservation techniques. Since the discovery of fire, this method has been used to preserve meat, fish, cheese and some fruits. Smoking is the process of saturating food products that have been cured or salted and dried with smoke. Saturation with smoke ingredients may take place by means of diffusion from a smoke-air mixture, by the application of a liquid layer on the surface of the product or by the addition of liquid smoke to the product. The following main techniques of smoking are currently used: smoking in an air-and-smoke environment and smoking in smoke solutions (liquid smoke) (Kołakowski 2012). Smoking in an air-and-smoke environment also includes traditional smoking which takes place in traditional smoking chambers in which smoke and heat are generated by burning thick pieces of deciduous tree wood at the proper humidity. Traditional smoking is a process performed in accordance with the artistry and knowledge of local producers, which takes in drying, cold, warm and hot smoking and hot smoking and baking, to achieve a pale, dark, brown, cherry, etc. colour, depending on centuries-old local traditions, conducted in traditional smoke chambers in which the smoke and temperature are generated by burning thick piece of deciduous tree wood at the proper humidity in a fireplace located directly inside the chamber, above which the smoked and processed product is located hanging on smoking sticks at a certain distance.

The regulation issued by the Ministry of Agriculture and Rural Development on 15th December 2014 describes traditional smoking as “smoking without artificial aroma

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smoke compounds". The idea of traditional smoking is the method of heat and smoke production. In traditional smoking, the smoke and heat are the result of wood combusting (fire and smoke). The smoke is composed of a few hundred components that favourably influence the quality of the smoked product, while being harmless to the health of the consumer, as well as components that raise doubts as regards health.

The formaldehyde originating from smoke causes the lowered digestibility of excessively smoked products when acting on meat proteins. Phenols, which are characterized by a specific odour that contributes to the sensory characteristics of smoked products, are important during smoking due to their specific properties. Phenols also display antioxidant activity. Polycyclic aromatic hydrocarbons, which can migrate to food directly and/or indirectly, are important components of smoke. The indirect route is absorption of these components by plants from the soil or absorption of PAHs into plants as air sediments with rain and dust. The direct route is smoking, grain drying in dryers heated with some derivatives of oil, and/or contamination by PAHs in food additives.

Research conducted on the harmfulness of PAHs resulted in the Scientific Committee on Food at the European Commission declaring 15 compounds in the PAH group potentially genotoxic and cancerogenic to people in 2002. The above statement resulted is a set of Commission Regulations (EU) with the objective of limiting the presence of PAHs in food. Ireland, Spain, Croatia, Cyprus, Latvia, Poland, Portugal, Romania, the Slovak Republic, Finland, Sweden and the United Kingdom jointly opted for derogation of Commission Regulation (EC) No. 1881/2006 which caused the European Commission to issue Commission Regulation (EU) No. 1327/2014 on 12$^{th}$ December 2014 changing EC regulation No. 1881/2006 referring to the highest permitted limits of PAHs in traditionally smoked meat, traditionally smoked meat products and traditionally smoked fish and shellfish (European Union Official Journal, L 358/13 issued on 13.12.2014).

The Regulation allows for the release onto the local and state market of traditionally smoked meat and meat products smoked within the territory of the state and prepared for consumption at place which contain PAH levels higher than those given in Annex 6.1.4 if these levels are consistent with their highest permitted levels applied before 1 September 2014 – i.e. 5.0 $\mu g \cdot kg^{-1}$ for benzo(a)pyrene and 30.0 $\mu g \cdot kg^{-1}$ for the sum of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and chrysene. Initially, the Regulation was valid until 31$^{st}$ August 2017, though it was then derogated until the thorough elaboration of the next regulation.

New regulations regarding the maximum limits of polycyclic aromatic hydrocarbons (PAH) have caused a huge dispute among processors and academics, causing confusion among consumers. On the basis of our research and research performed by producers, we can report that the final effect of smoking, i.e. the amount of PAH in the final product, depends on a number of factors, of which the most important are: the raw material (research suggests that raw meat contains 0.0 – 0.9 μg of $BaP \cdot kg^{-1}$), the type of raw material and fat content, the type of meat product – type of sausage, its thickness and composition influenced both the amount of BaP and the total PAH, the spices and food additives, the type of casing, the type of heat treatment, the smoking temperature, the degree of drying, the type and construction of the smokehouse, the smoking wood –type, hardness and humidity, smoke generation techniques – traditional smoking is dependent on atmospheric conditions, the wood-burning temperature, the sample collection method – the methods and techniques of sample collection for PAH analysis are regulated by Commission Regulation No. 836/2011, and the analysis methodology – accredited laboratories that analyse the PAH content in food products of animal origin use different analytical methods: gas chromatography with mass spectrophotometry or HPLC. In the case of traditional smokehouses based on natural air flow or convection, the critical factor in the reduction of PAH in the final product is the experience and skill of the smoker who has to control the conditions of combustion.

The aim of this study was to analyse the content of polycyclic aromatic hydrocarbons in meat products, fish and cheese.

### Materials and Methods

Table 1 shows the content of polycyclic aromatic hydrocarbons was analysed in 100 products.
Taking into account the fact that the European Commission Scientific Committee on Food has declared 15 compounds in the PAH group potentially genotoxic and cancerogenic for humans, these 15 components and the presence and amount of benzo(a)pyrene were checked in our control examinations. The method used was HRGC-HRMS (CZ_SOP_D06_06_180 – except chap. 11.3.3.1–11.3.3.7, 11.3.3.9 l, 11.3.4 (US EPA 429, ISO 11338); PAH16: Determination of polyaromatic hydrocarbons by isotope dilution method using HRGC-HRMS).

Table 1. The content of polycyclic aromatic hydrocarbons

| Products | Number of samples | Number of producers |
|---|---|---|
| Raw pork meats (loin and ham of Zlotnicka Pig) | 2 | 2 |
| Meat products obtained from Pulawska Pig | 10 | 2 |
| Smoked meat products of Zlotnicka White and Zlotnicka Spotted Pig meat | 25 | 5 |
| Smoked meat products of Popielno White Rabbit | 3 | 2 |
| Smoked meat products of lamb and sheep meat | 4 | 3 |
| Smoked beef meat products of Polish Red and Simmental Cattle | 6 | 4 |
| Smoked meat products of horse meat of domestic Polish breeds | 11 | 2 |
| Smoked meat products of duck and goose meat | 8 | 4 |
| Smoked fish products of carp and trout | 5 | 4 |
| Smoked ewe’s milk cheeses | 7 | 4 |
| Smoked cow’s milk cheeses | 13 | 7 |
| Goat’s milk cheeses | 3 | 2 |
| Cow-ewe’s milk mixture cheeses | 3 | 3 |

## Results and Discussion

The data obtained pointed to differences in PAH levels in dependence on the smoking method used. Higher levels of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and chrysene were measured in products smoked in hot smoke (the south of Poland) in comparison with smoking in warm and/or cold smoke (the Greater Poland and Kujawy regions). Lower levels of naphthalene, acenaphthylene, acenaphthene, fluorene and phenanthrene were measured in smoked meat products in comparison with some small smoked cheeses (especially those smoked at shepherd huts) in which the content of naphthalene and/or acenaphthylene reached as much as 1200 $\mu g \cdot kg^{-1}$ and the content of phenanthrene as much as 790 $\mu g \cdot kg^{-1}$) – Table 2.

The smoking of cheeses is based on a process conducted in cold and/or warm smoke, so there is no threat of the formation of large amounts of PAHs. Nevertheless, taking into account the high solubility of PAHs in fat and the high amounts of fat present in cheeses, such pollutants can be accumulated in the product during smoking (Guillen and Sopelana 2004). The high levels of benzo(a)pyrene and the sum of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and chrysene in smoked cheeses concern just a single type of cheese – smoked ritta – a ricotta-type goat cheese produced from whey and smoked in hot cherry-wood smoke to obtain the typical bonfire-like taste and aroma. Thin sausages, i.e. kabanos and sausages in natural pork casings (from pork guts; Ø 32 mm), and thin smoked meats prepared from whole muscle and/or parts of muscle, i.e.

Table 2. Content of polycyclic aromatic hydrocarbons in meat products, fish and cheese

| Polycyclic aromatic hydrocarbons | Raw meat and meat products | Fish products | Cheeses |
|---|---|---|---|
| | | from – to [µg·kg-1] | |
| Naphthalene | < 3.30 – 300 ± 90.0 | 30.0 ± 9.0 – 140 ± 42.0 | 20.0 ± 6.0 – 1200 ± 360 |
| Acenaphthylene | < 0.98 – 270 ± 81.0 | 28.0 ± 8.4 – 240 ± 72.0 | 18.0 ± 5.4 – 1200 ± 360 |
| Acenaphthene | < 0.59 – 7.90 ± 2.37 | 1.90 ± 0.57 – 13.0 ± 3.90 | 1.60 ± 0.48 – 57.0 ± 17.1 |
| Fluorene | < 1.8 – 64.0 ± 19.20 | 11.0 ± 3.30 – 77.0 ± 23.1 | 9.1 ± 2.73 – 400 ± 120 |
| Phenanthrene | < 4.3 – 470 ± 141 | 31.0 ± 9.30 – 190 ± 57.0 | 15.0 ± 4.50 – 790 ± 237 |
| Anthracene | < 0.39 – 95.0 ± 28.50 | 4.1 ± 1.23 – 44.0 ± 13.2 | 3.2 ± 0.96 – 190 ± 57.0 |
| Fluoranthene | < 1.20 – 250 ± 75.00 | 6.30 ± 1.89 – 50.0 ± 15.0 | 2.7 ± 0.81 – 94.0 ± 28.2 |
| Pyrene | < 1.40 – 220 ± 66.00 | 5.70 ± 1.71– 39.0 ± 11.7 | 1.80 ± 0.54 – 150 ± 45.0 |
| Benzo(a)anthracene | < 0.39 – 34.0 ± 10.20 | < 0.70 – 3.90 ± 0.52 | < 0.61 – 67.0 ± 21.2 |
| Chrysene | < 0.39 – 36.0 ± 10.80 | < 0.70 – 3.30 ± 0.99 | < 0.61 – 7.30 ± 2.19 |
| Benzo(b)fluoranthene | < 0.39 – 11.0 ± 3.30 | < 0.47 – 2.40 ± 0.72 | < 0.34 – 4.50 ± 1.35 |
| Benzo(k)fluoranthene | < 0.20 – 5.90 ± 1.77 | < 0.46 – 1.40 ± 0.42 | < 0.34 – 2.10 ± 0.63 |
| Benzo(a)pyrene | < 0.39 – 12.0 ± 2.60 | < 0.47 – 2.70 ± 0.81 | < 0.34 – 4.50 ± 1.35 |
| Indeno(1,2,3-cd)pyrene | < 0.20 – 5.10 ± 1.53 | < 0.47 – 1.30 ± 0.39 | < 0.18 – 2.30 ± 0.69 |
| Dibenzo(a,h)anthracene | < 0.041 – 0.86 ± 0.258 | < 0.21 – < 0.83 | < 0.049 – < 0.61 |
| Benzo(g,h,i)perylene | < 0.59 – 5.50 ± 1.65 | < 0.47 – 3.80 ± 1.14 | < 0.4 – 1.90 ± 0.57 |

rabbit rump, are particularly susceptible to high PAH levels. Attempts to replace casings of natural origin (gut) with collagen casings have resulted in the lowering of PAH levels, though a significant proportion of consumers questioned was dissatisfied with sausages in collagen casing. Analyses of casings has shown a content of PAHs several times higher in casings in comparison with the core sausage meat. Sausage producers should inform the customer (on labels) that the casing should be removed before consumption (this does not concern kabanos for which this is impossible).

PAHs were present at amounts below the detection levels of the method used in the analysed smoked meats (raw loin and ham).

Only 3 products (kabanos and smoked rabbit rumps) were doubtful because of PAH content as Regulations (EC) No. 1881/2006 and (EU) No. 1327/2014 demanded limits. After modification of the smoking method (short smoking in warm smoke and roasting), subsequent batches of these products met the standards concerning the content of PAHs. The specific order of technological steps should be observed to obtain satisfactory smoking results:

- fish: partial drying – thermal treatment (salting) – smoking
- meat products: partial drying – smoking – thermal treatment
- meat products: partial drying – smoking and thermal treatment (hot smoking with roasting)
- ripening cheeses: smoking
- fruit (plums): partial drying – smoking

On the basis of our research and research performed by producers, we can report that the final effect of smoking, and the amount of PAH in the final product, depend on a number of factors, of which the most important are:

- The raw material – research suggests that raw meat contains 0.0 – 0.9 µg of BaP·kg$^{-1}$ This may be the result of contamination of soil, water and air and accumulation of PAH in the plants that constitute animal fodder (Kuna 2011)

- The type of raw material and fat content – poultry meat products contained lower amounts of BaP (0.9 μg·kg$^{-1}$) than pork meat products. Waszkiewicz-Robak et al. (2014) concluded that the overall amount of PAH formed during the smoking of a product increases when the raw material contains more fat. Moreover, they also reported that the amount of "heavy" PAH formed during smoking depends on the fatty acid composition of the raw material and is positively correlated with a higher content of unsaturated fatty acids. The addition of oils to animal fodder (such as fish or flaxseed oil) influenced changes in the fatty acid composition, which in turn increased PAH formation during smoking, especially that of heavy PAHs such as BaP. This could also be caused by the contamination of vegetable oils with PAHs (Ciecierska & Obiedziński 2006). It is necessary to determine PAH levels in individual food products, since the EU reports published in 2004 and 2008 lacked the PAH level in smoked food products and environmental samples from Poland.
- The type of meat product – the type of sausage, its thickness and composition influenced both the amount of BaP and the total PAH. The most problematic sausage is the kabanos sausage – a long, thin dry Polish sausage. Large surface and low mass and thin profile cause large fluctuations in PAH content: the BaP content ranged from 0.9 μg·kg$^{-1}$ (poultry kabanos) to 9.1 μg·kg$^{-1}$, while the sum of 4 PAH reached 45.0 μg·kg$^{-1}$. Only short smoking followed by baking enabled a reduction to the amount of these compounds.
- Spices and food additives – the quality of spices, the drying method and the quality of added soy protein or fibre affect the quality of the final product. According to Kubiak (2013), the more common use of smoking additives to improve the quality and sensory properties of the product has become a significant source of PAH in meat products.
- The type of casing – natural casings are not a barrier to PAH during smoking. Moreover, during analysis the sausage is ground together with the casing which is treated as an edible part of the sausage. The use of collagen protein casings in the same sausage significantly reduced the amount of PAH inside the product. Moreover, the use of collagen protein casings with thick overprint reduced the BaP in the sausage to 0.9 μg·kg$^{-1}$ and the sum of 4 PAH to 8 μg·kg$^{-1}$. During the analysis, the sausage is ground without the casing, while the overprint acts as a barrier to PAH. In order to reduce the PAH content in meat products, processors should use artificial casings which stop the PAH on the surface and decrease their migration into the inner layers of the product. The cellulose casing stops the smoke compounds from migrating within the product to a much greater degree. However, traditional products may not be accepted by the consumer in an artificial casing.
- The type of heat treatment – this parameter is connected with the smoking temperature. Fast smoking, known as "smoke peck", followed by baking at 85 °C reduces the amount of PAH so that the product does not exceed the new limits. This method is particularly recommended for smoked meat products with a high fat content such as bacon or sausage.
- The smoking temperature – generally, the higher the smoking temperature, the more PAH in the final product. A decreased BaP content was reported (approx. 1.7 μg·kg$^{-1}$) during cold and warm smoking. Pale smoking, however, resulted in a loss of attractiveness to consumers. Consumers in Lesser Poland and Subcarpathia are used to meat products with dark, brown or cherry smoking, depending on the local tradition, while pale smoked products are treated as not fully smoked or unfinished.
- The degree of drying – our research performed on smoked meat products and sausages whose surface was not dried before smoking showed that they accumulated more PAH (up to 10 μg·kg$^{-1}$ of BaP and 85 μg·kg$^{-1}$ of the sum of four PAH). When the same products were first surface-dried at a temperature of 80 °C for around 90 minutes, they showed a much lower PAH content (1.8 μg·kg$^{-1}$ of BaP and 21 μg·kg$^{-1}$ of the sum of four PAH). The wet surface of the casing accumulates more smoke ingredients, especially what is known as thick smoke.

- The type and construction of the smokehouse – the object of new smokehouse construction, which includes moving the fireplace out of the smoking chamber and using alternative smoking methods, often recommended by various experts, is an attempt to destroy local tradition and eliminate the traditionally smoked products in the area. This is in direct contrast to the idea of "Small Homelands" and the preservation of local tradition and heritage promoted by the European Union. These ideas aim to preserve traditionally smoked products. Moving the fireplace out of the smoking chamber is the favouritism of cold and warm smoking. Suggesting that meat products from Lesser Poland and Subcarpathia are dripping with tar and burned fat is an expression of ill will. Almost no smokers or meat processors will allow fat to drip from the product, as such a product would lose its succulence and taste – its basic sensory attributes, and will be unacceptable to the consumer. Intense drying of the product at 60 – 80 °C followed by smoking and baking at 75 – 80 °C leads to "closing" of the product and prevents fat loss.
- The smoking wood – its type, hardness and humidity. The best smoking effect is achieved with wood from fruit trees which is acquired by chopping down old trees or the yearly undercutting of fruiting trees, especially plum, cherry, gean, apricot and apple trees as the wood of these trees is rich in hemicellulose. The highest hemicellulose content is present in apricot (approx. 40%), apple (37%) and pear (32%) trees, while the hemicellulose content of non-horticultural trees is usually 25 – 30%. Walnut trees should be avoided due to the intense bitter taste of the final product. The type of wood also influences the colour of the final product. Smoke from beech, maple, ash and linden trees gives the product a specific golden-brown or golden-yellow colour, while smoke from pear and apple trees gives a red to dark brown colour. Oak wood smoke gives a dark-gold to brown colour. In Poland, the tree that is most commonly used for smoking is alder which gives a specific colour from lemon to brown depending on the smoke concentration. However, when the humidity of alder is not appropriate, it has a tendency to tar the product. Alder is a cheap and efficient wood which also contains low levels of tannins (3 – 5%) which results in the low bitterness of the final product. The recommendation of using hard wood for smoking has its justification, because the formation of BaP is 1.5 – 4.5 times lower during the pyrolysis of hard wood as compared to soft woods (pine, fir) (Kowalski & Pyrcz 2006). Hard wood, with its tight structure, burns more slowly, and the volatiles formed during this process are less prone to oxidation into carbon dioxide, as happens when burning soft wood. The wood for smoking should have a hardness of > 40 MPa and a volumetric mass density of 0.500 $g \cdot cm^{-3}$. Such parameters are met by various deciduous trees such as ash, beech, hornbeam, maple, oak, elm, acacia and pear, because an increase in wood hardness is also accompanied by an increase in the efficiency of acquired smoke compounds. The oak tree seems controversial due to the high tannin content of 4 – 10% in the wood, 5 – 17% in the bark and 20 – 45% in the leaves (Surmiński 2000). Not every consumer, especially in Lesser Poland, tolerates the bitter "oakish" taste of the meat products. The wood used in smoking should be dry, which means its humidity should range between 15 and 20%. The use of wet (humidity above 30%) and dry (humidity less than 10%) wood should be avoided. The use of mouldy wood, wood with putrefaction, etc. should also be prohibited. Wood from the dismantling of old houses should also be avoided.
- The smoke generation techniques – traditional smoking is dependent on the atmospheric conditions. Humidity, temperature and the movement of air outside the smokehouse will affect the final result of the process, because they affect the temperature of wood combustion. The use of modern industrial smoking chambers with smoke generators eliminates the problem of ensuring the proper combustion temperature, while in traditional smoking this process has to be regulated by the skill and experience of the smoker.

- The wood burning temperature – detectable amounts of PAH are reported at temperatures above 400 °C. However, BaP appears clearly only after a temperature of 500 °C is reached (McGrath 2003), with the peak of formation at 800 – 900 °C. Products smoked in smoke generated at a high temperature may be hazardous to the consumer's health, since they contain larger amounts of PAH, while the product is also less aromatic. The maximum temperature of wood combustion should not exceed 425 – 450 °C (Kowalski & Pyrcz 2006). Furthermore, smoke acquired with a small air inlet has a lower BaP content than smoke generated with a full air inlet. Due to this it is important to install air flow regulating latches in the smokehouse. The speed of evacuation of volatiles from the combustion area also influences the amount of PAH in the final product. Smoke generated at a low combustion (pyrolysis) temperature contains a larger amount of acids and a lower amount of phenolic compounds. Meat products smoked in such a way are characterized by an acidic aroma and a loose, less preferable, texture of the meat.
- The sample collection method – samples collected for analysis should be uniform and representative. Samples of meat products that are closer to the smoking stick (sausages hanging on the stick) had a lower PAH content than samples of the sausage collected further from the stick. This is particularly important in sausages, because the fat settles on the lowest parts of the product. The methods and techniques of sample collection for PAH analysis are regulated by Commission Regulation No. 836/2011.
- The analysis methodology – accredited laboratories that analyse the PAH content in food products of animal origin use different analytical methods: gas chromatography with mass spectrophotometry or HPLC. Despite validation, these methods are not comparable.
- Cleaning (washing) of the smoking chamber, removal of smoking sediments (smoking sludge) and clearing of tunnels carrying smoke (with removed furnace item) and the chimney is the basis of smoking safety (eliminating the threat of self-ignition of smoking sediments). In addition, heated sediments release harmful components (including PAHs). The smoking, cleaning in-situ, chambers should be washed with dedicated washing-up liquids, while the plaster should be scraped and replaced with a new clay plaster layer in chambers with a smooth clay surface (clay plaster).
- In the case of traditional smokehouses based on natural air flow or convection, the critical factor in the reduction of PAH in the final product is the experience and skill of the smoker who has to control the conditions of combustion. Expert advice is valuable, but should be based on their own experience. Traditional smokehouses and traditional smoking are not the same as a modern computerized industrial smoking chamber.

## Conclusions

All analysed products were subjected to chemical, physicochemical and microbiological analyses at the Animal Products Processing Dept., Food Technology Faculty, University of Agriculture in Krakow, Poland.

Up-to-date examination results have revealed that traditional smoked products are of high quality and safety, especially as regards the content of PAHs (fulfilling the demands of EU Regulation No. 1327/2014) which can originate in large amounts during smoking using traditional methods.

All the results obtained indicate that these products can be recommended as traditional high-quality foods with a unique taste.

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Commission Regulation (EC) No. 1881/2006 of 19th December 2006 setting maximum levels for certain contaminants in foodstuffs (Text with EEA relevance)

Commission Regulation (EU) No. 835/2011 of 19th August 2011 amending Regulation (EC) No. 1881/2006 as regards maximum levels for polycyclic aromatic hydrocarbons in foodstuffs (Text with EEA relevance)

Commission Regulation (EU) No. 836/2011 of 19th August 2011 amending Regulation (EC) No. 333/2007 laying down the methods of sampling and analysis for the official control of the levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benzo(a)pyrene in foodstuffs (Text with EEA relevance)

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Fig. 1. The HPLC chromatogram of PAHs in kabanos sausage

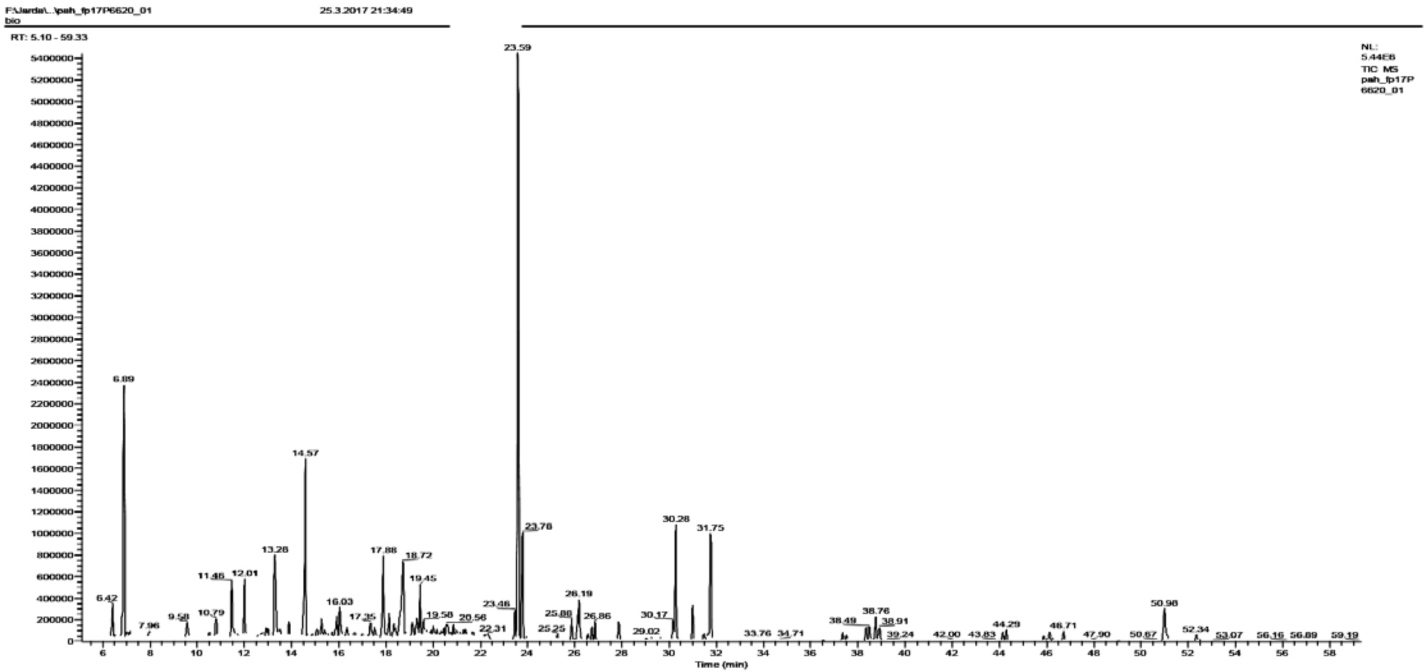

Fig. 2. The HPLC chromatogram of PAHs in oscypek cheese

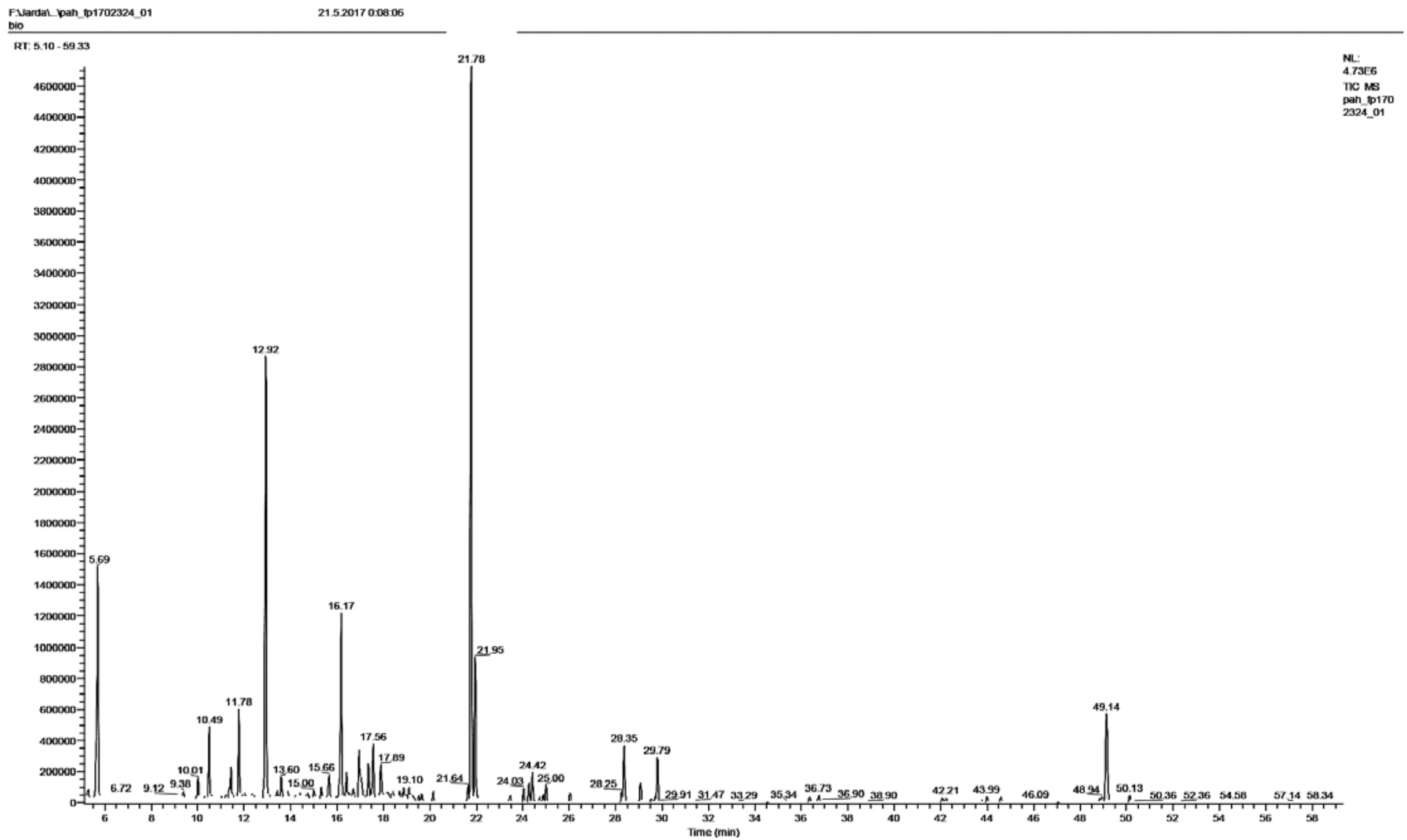

Fig. 3. The HPLC chromatogram of PAHs in smoked trout