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Long chain polyunsaturated fatty acids in smoked Atlantic mackerel and Baltic sprats

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Abstract

Atlantic mackerel and Baltic sprats are rich sources of $n-3$ long chain polyunsaturated fatty acids (LC PUFA). Literature data point to an influence of the properties of the raw material, storage conditions, and processing parameters of hot- and cold-smoking on the stability of these acids. The effects of industrial smoking in an automatic smokehouse in controlled, mild conditions at core temperature below 60 °C, as well as of cold storage, on the fatty acids (FA) in mackerel and sprats have been investigated. The FA were determined by gas chromatography (GC) according to the AOCS Ce 1b-89 method, in lipids extracted from the meat of several batches of defrosted and smoked fish early after smoking and during storage at 2 °C for up to 2 weeks. The contents of eicosapentaenoic acid C20:5 $n-3$ (EPA) and docosahexaenoic acid C22:6 $n-3$ (DHA) in different assortments of smoked mackerel meat were from 50 to 55 and from 67 to 100 mg/g of lipids, respectively while, in hot-smoked sprats, they were from 48 to 68 and from 73 to 128 mg/g of lipids. The results show that the variability of the FA composition of the frozen raw material was larger than the changes induced by smoking or by storage within the period of high quality life of the smoked product.

Keywords: Smoked fish; Mackerel; Sprat; Long chain polyunsaturated fatty acids; Eicosapentaenoic acid; Docosahexaenoic acid

1. Introduction

In Europe, particularly in Germany, Poland and the UK, there is a high market demand for smoked fish,such as Bückling, eel, halibut, herring, mackerel, salmon and sprats. According to the FAO (2003), the total world productions of smoked herring and salmon are about 38,000 and 86,000 tons, respectively. The consumer preference for these products resulted not only from their traditionally desirable smoky flavour, but also from their high contents of LC PUFA of the $n-3$ family in fish lipids. These FA decrease the contents of triacylglycerols, cholesterol, and low density lipoproteins in the human serum, and inhibit the aggregation of blood platelets and the damage to blood vessels (Lands, 1986).

Fish oils containing LC PUFA with up to 6 double bonds, such as EPA and DHA, are very susceptible to oxidation. The educated consumer, who in selecting his food takes into consideration also the content of these nutritionally desirable $n-3$ PUFA, should be informed, not so much about their contents in the fresh fish, but rather in the ready-to-eat commodities, e.g. baked, fried, canned or smoked.

The composition of lipids in smoked products depends primarily on their contents and state in the fish used for smoking. The conditions and time of chilling and frozen storage of fish affect the rate of oxidation (Kołakowska, Macur, Pankiewicz, & Szczygielski, 1998). Further factors influencing the state of lipids

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are the preparation of the raw material for smoking, the smoking itself, and storage of the products. Brining, drying, heating, and the reactivity of smoke components may have an impact on the rate of lipid changes by affecting the tissue enzymes involved in oxidation reactions, as well as by generating and changing the stability of radicals. During brining,the fish meat takes up the required quantity of salt, but also some cations present as impurities, that may have prooxidative activity. The reaction rate of peroxidation of FA may also increase due to drying and heating in the initial stages of the process, when the concentrations of phenolic smoke antioxidants in the meat are still low. The extent of loss of moisture and the duration and temperature of heating may also be important. The effects of various factors influencing the oxidation of lipids in fish tissues have been recently reviewed by Kołakowska, Olley, and Dunstan (2002).

The antioxidant effect of smoking has long been recognised, since lipids in smoked fish and meats were known not to undergo rapid oxidation. The role of smoke components in retarding oxidation was investigated by Watts in the early fifties of the last century (Watts & Faulkner, 1954). Later, it was shown that, among the several hundred known wood smoke components certain phenols had the highest antioxidative activity (Kurko, 1969). The phenol fraction of wood smoke is a mixture of about 240 compounds; one third of this number have been positively identified (Tóth & Potthast, 1984). The composition of this fraction, containing mono- di- and trihydroxyphenols, as well as derivatives with additional functional groups in the substituting chains, e.g. hydroxyl, carbonyl, carboxyl groups and ester bonds, depends primarily on the temperature of smoke generation, but also on the kind of wood and the access of air to the smouldering material. Thus, the effectiveness of the antioxidant action of smoking depends much on the composition of the smoke and the chemical character and quantity of phenols deposited on the smoked food. The antioxidant activity of some wood smoke phenols is higher than that of various known commercial antioxidants. The most active are pyrogallol, resorcinol, 4-methylguaiacol, 4-vinylguaiacol, and 4-*trans*-propenylsyringol. Less active as antioxidants are guaiacol, syringol, 4-methylsyringol, and 4-vinylsyringol (Kurko, 1969; Miler & Sikorski, 1990).

Since heating, applied during smoking, may affect the state of fish lipids, data on lipid oxidation in dried fishery products should also be considered. According to Tabara et al. (1998), drying of horse mackerel, frog flounder, Japanese whiting, hard clam, arkshell and scallop, under various conditions, did not induce significant changes in the contents of EPA and DHA in the lipids, regardless of the differences in the fat contents of these commodities. Deep-fat frying of Atlantic mackerel steaks in canola oil at 180 °C for 7 min resulted in about 20% decrease in the concentration of EPA and DHA in the lipids of the fish meat and about 40% in the lipids of the skin. This loss, however, was caused rather by exchange of the lipids between the fried mackerel and the frying medium than by thermal changes in the fatty acids (Sebedio, Ratnayake, Ackman, & Prevost, 1993).

The literature contains contradictory information regarding the stability of PUFA in smoked fish. Most of the earlier publications regarding this subject have been reviewed by Kołakowska et al. (2002).

The aim of this investigation was to determine the effect of industrial smoking in an automatic smokehouse in mild conditions, as well as of refrigerated storage, on the FA, particularly on EPA and DHA, in fish lipids. The results were expected to answer the question, whether smoking, under these conditions, prevents significant oxidation of LC PUFA, and particularly EPA and DHA in these fatty fish during storage within the period of shelf life.

2. Materials and methods

2.1. Smoking and sampling

In the experiments, the effects of hot smoking on the lipids of gutted Atlantic mackerel, fillets of mackerel and whole Baltic sprats were investigated. The experiments were conducted in cooperation with a fish processing plant, PRORYB, Rumia, in Poland.

Whole mackerel (*Scomber scombrus*), frozen on board, imported from Norway, were stored in the plant at −30 °C for 1–4 months. After thawing in a water/steam atmosphere at 21 °C the fish were gutted, brined in a 20% salt solution, 1:1, for 2.5–3 h at 7 °C. In experiment 1, the gutted mackerel was smoked in an automatic kiln according to the procedure presented in Fig. 1. The smoke was produced from a mixture of oak and beech shavings in an external smouldering-type generator. The contents of FA in the meat of thawed fish prior to brining and in the smoked fish were compared. In experiment 2, mackerel fillets were smoked in a similar process. However, the fillets were brined only for 3 min and after spraying, dripping, and surface drying on mesh, they were heated to an internal temperature of 47 °C for 1.5 h and smoked at 45 °C for 1.5 h. In this experiment, one fillet of each pair was left raw for refrigerated storage and analysis, while the other one was smoked and the product was stored at the same temperature as the controls. The results of corresponding fillets in each pair were compared.

In experiment 3, mackerel fillets were cold-smoked by pre-drying at 28 °C for 3–3.5 h and smoking at 26 °C for 1–1.5 h.