

POLYCYCLIC HYDROCARBONS IN SINGED FOOD IN ICELAND

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The contents of polycyclic hydrocarbons, including the carcinogen 3:4 benzpyrene, in singed food depends on the fuel used. Evidence was found that the polycyclic hydrocarbons were not produced by the action of the heat on the singed material but rather that they were taken up as intermediary products of incomplete combustion of the fuel. When combustion of fuel is nearly complete, as in the flame of propane or acetylene-oxygen, only negligible amounts of polycyclic hydrocarbons are found in the singed material whereas they are taken up in considerable quantities when fuel of lower rate of combustion as coal or diesel oil is used. Sheep heads singed over slow-burning fuels such as peat or coal have been a common dietary source of the carcinogen 3:4 benzpyrene and other polycyclic hydrocarbons in Iceland and the same applies to singed birds in some locations.

THAT CONSUMPTION OF SMOKED FOOD MIGHT be at least partly responsible for the unusually high mortality from gastric cancer in Iceland has been suggested.² Polycyclic hydrocarbons—including 3:4 benzpyrene in the range of 1 to 2 $\mu\text{g}/\text{kg}$ —were found in commercially smoked Icelandic mutton³ and subsequent analysis has revealed much higher contents, in particular of 3:4 benzpyrene in home-smoked mutton (unpublished results).

Considering that polycyclic hydrocarbons have been reported in charcoal-broiled meat,⁴ we thought that singed food might be another source of substance of that nature in the Icelandic diet. Therefore, we examined singed sheep heads, the most common of singed food articles, and singed sea birds for the presence of polycyclic hydrocarbons and studied the effect of different methods of singeing.

In Iceland it is customary to singe practically all sheep heads available for consumption over open fire after the wool at the neck has been shorn. Formerly the fuel most used was peat, dry sheep manure, scrap wood or coal but in recent years diesel oil, propane or acetylene-oxygen gas has come into use, at

least for commercial singeing. After singeing, whereby the skin becomes superficially carbonized, the heads are cut sagittally, immersed in water, washed and scraped and then cooked by boiling in water to be eaten fresh or preserved in fermented whey. Salting is less common and refrigeration is becoming the most common method of preservation.

The practice of singeing seabirds was particularly common in the district Skagafjardarsýsla in the northern part of Iceland where enormous numbers of birds are caught in springtime every year. This district ranks among the highest in mortality from gastric cancer.⁵

After the bulk of the feathers was removed by hand, the birds were singed in the same way as sheep heads, irrespective of the method of preparation to follow, i.e. whether they were to be cooked and eaten fresh, smoked or preserved in other ways.

MATERIAL AND METHODS

Sheep heads for the analysis were obtained from a slaughter-house or freezing plant and singed in the traditional way over coal fire or in a flame from acetylene-oxygen or propane gas. Heads singed commercially by diesel oil flame were procured from a food store in Reykjavík.

Seabirds (guillemots and puffins) were obtained from the district Skagafjardarsýsla and singed as was customary there, using coal or

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wood and dried sheep manure as fuel; in one exception the singeing was done over propane gas flame.

Analyses were made of both raw and cooked material and after preservation in various ways. The edible portion of heads and birds, respectively, was minced in a meat mincer and extracted in soxhlet apparatus, first with acetone and then with benzene. The polycyclic component was extracted from the acetone-benzene soluble fraction after solvents and water were removed by vacuum distillation under nitrogen according to the method of Lijinsky and Shubic.⁴ Then the polycyclic hydrocarbons were separated on alumina column and assayed according to the method of Commins¹ using Beckman spectrophotometer.

Ten polycyclic compounds were estimated: pyrene, acenaphthalene, anthracene, 1:2 benzpyrene, 3:4 benzpyrene, 1:12 benzperylene fluoranthene, 1:2 benzanthracene, fluorene and phenanthrene.

RESULTS

The results are shown in Tables 1 and 2. There is a striking difference in the amounts of polycyclic hydrocarbons according to the fuel used for singeing.

Singeing by propane—or acetylene-oxygen flame produced only negligible amounts of these substances while relatively high values were obtained when the fuel was coal, wood and dried sheep manure or diesel oil. This might be of practical importance considering the carcinogenic properties of 3:4 benzpyrene

and the possibility of some of the other polycyclic hydrocarbons being capable of acting as cocarcinogens.

The amount of 3:4 benzpyrene in raw coal singed sheep heads is on level with that found in home smoked mutton (unpublished) and much higher than in commercially smoked meat.³ Coal-singed seabirds, however, contained about five times more of 3:4 benzpyrene than the sheep heads and also considerably more of most of the other hydrocarbons.

Much lower values were found for cooked than for raw sheep heads singed over coal fire or diesel oil flame whereas the raw and cooked values for coal-singed seabirds showed no clear differences. Coal-singed and salted seabirds, however, gave higher results when cooked than when raw.

When singed birds subsequently were smoked, polycyclic hydrocarbons increased considerably except for 1:2 and 3:4 benzpyrene. Preservation by salting or in fermented whey, on the other hand, resulted in over-all reduction although less marked for salted birds when cooked.

The skin of the birds, together with the subcutaneous fat, was in some instances analyzed separately. It was about 30% of the entire edible portion by weight but contained about 50% of the total acetone-benzene soluble fraction.

From 81 to 98% of the total amount of 3:4 benzpyrene in freshly singed birds was found in the skin and adjoining fat but after 4 months preservation in fermented whey the percentage had dropped to 43 (Table 3).

TABLE 1. Polycyclic Hydrocarbons in Singed Sheep Heads

Fuel used	Preparation	No. of heads	Polycyclic hydrocarbons ($\mu\text{g}/\text{kg}$ wet weight of edible portion)									
			Py	Ac	A	1:12-BP	1:2-BP	3:4-BP	Fla	1:2-BA	Fle	Phe
Coal	Raw	2	38	2	7	10	5	21	33	15	20	31
Coal	Cooked	3	15	1	2	3	2	9	11	5	11	10
Coal	Cooked	2	7	—	2	2	1	6	7	2	5	5
Coal	Preserved (fermented whey)	3	8	2	9	2	1	8	9	3	6	8
Diesel oil	Raw	3	68	5	9	23	8	28	44	17	42	68
Diesel oil	Cooked	4	24	2	6	4	2	10	29	4	12	25
Acetylene oxygen	Raw	2	3	tr	tr	—	tr	1	3	tr	6	5
Acetylene oxygen	Cooked	3	3	tr	tr	—	tr	tr	3	tr	5	5
Propane	Raw	3	1	—	—	—	—	tr	—	—	3	2
Propane	Singed frozen	4	1	—	—	—	—	—	1	—	1	1

Abbreviations: Py, pyrene; Ac, acenaphthalene; A, anthracene; 1:12-BP, 1:2 benzperylene; 1:2-BP, 1:2 benzpyrene; 3:4-BP, 3:4 benzpyrene; Fla, fluoranthene; 1:2-BA, 1:2 benzanthracene; Fle, fluorene; Phe, phenanthrene; tr, trace; —not measurable by method used.

TABLE 2. Polycyclic Hydrocarbons in Singed Seabirds

Fuel used	Preparation	No. of birds	Polycyclic hydrocarbons ($\mu\text{g}/\text{kg}$ wet weight of edible portion)									
			Py	Ac	A	1:12-BP	1:2-BP	3:4-BP	Fla	1:2-BA	Fle	Phe
Coal	Raw	5	75	2	9	19	16	99	67	69	60	25
Coal	Cooked	6	72	1	10	24	19	96	79	50	57	28
Coal	Smoked, raw	5	91	30	54	9	10	54	101	54	341	148
Coal	Smoked, cooked	6	138	31	98	37	15	88	165	79	434	227
Coal	Salted, raw	5	22	1	4	4	4	26	25	19	21	11
Coal	Salted, cooked	6	40	—	4	9	10	50	52	30	31	16
Coal	Cooked, whey-preserved	11	37	1	6	5	6	34	29	28	22	27
Wood/dried manure	Raw	3	52	6	7	3	6	35	47	28	58	21
Propane	Raw	4	4	0	0	0	0	0	5	0	12	7

Abbreviations: Py, pyrene; Ac, acenaphtalene; A, antracene; 1:12-BP, 1:12 benzpyrene; 1:2-BP, 1:2 benzpyrene; 3:4-BP, 3:4 benzpyrene; Fla, fluoranthene; 1:2-BA, 1:2 benzantracene; Fle, fluorene; Phe, phenanthrene; tr, trace;—not measurable by the method used.

DISCUSSION

When sheep heads and seabirds were singed over coal and dried manure fire, the temperature at the surface of the skin reached only 620 to 660° C. In singeing by propane gas and especially by acetylene-oxygene flame the surface would have been exposed to much higher temperatures; nevertheless, after preparation by this method negligible amounts of polycyclic hydrocarbons were found in the singed material.

It appears, therefore, that the bulk of the polycyclic hydrocarbons found in singed food represents an uptake of such product formed during incomplete combustion of the fuel

used. Thus, as the combustion in the propane- and acetylene-oxygene flame is almost complete, only minimal amounts of polycyclic hydrocarbons gain access to the material singed by that kind of flame.

As shown for coal-singed birds, the hydrocarbons are concentrated in the superficial structure although some diffusion occurs to the deeper lying parts, presumably mainly through fat, such diffusion being augmented when stored in liquid medium as fermented whey (Table 3).

The superficial accumulation might be partly responsible for the conspicuously higher values found for coal-singed seabirds than for sheep heads since the exposed surface is relatively bigger in the former. It is also possible that the hydrocarbons are more readily taken up by the fat which is of lower melting point in the birds and tends to penetrate out of the skin under the singeing.

When the sheep heads are cooked, considerable amounts of fat from the cut surface of the fat depot of the neck exudes into the cooking waters. This might go far in explaining the considerable loss in polycyclic hydrocarbons observed for coal-singed sheep heads.

TABLE 3. Proportional Amounts of 3:4 Benzpyrene in Skin and Subcutaneous Fat of Singed Seabirds

Fuel used	Preparation	%3:4-benzpyrene
Coal	Raw	91
Coal	Cooked	98
Coal	Smoked and cooked	80
Wood/manure	Raw	81
Coal	Cooked and preserved in whey	43

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