[...]POSITION OF THE VOLATILES OF COOKED PORK, BEEF, AND CHICKEN, AND OF "CURED-MEAT"

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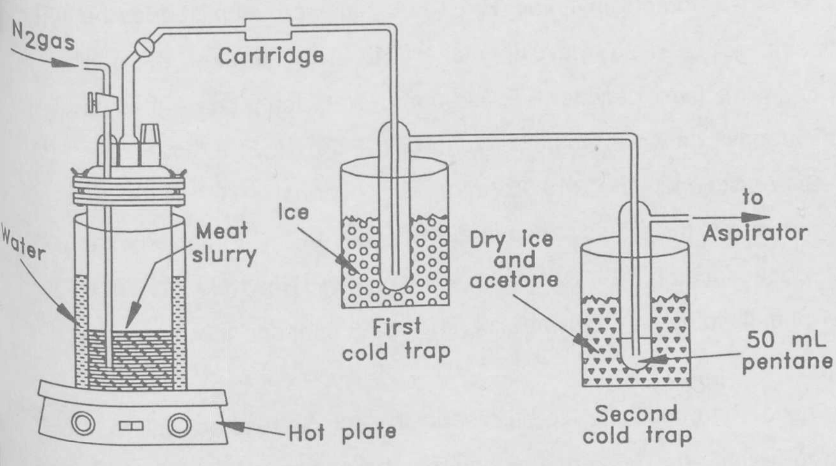
Volatile components from uncured and cured meat of the three species - pork, beef, and chicken - were trapped onto a solid adsorbent (Florisil [...]idge) and in an organic solvent (pentane) using the nitrogen purge-and-trap (NPT) technique. A total of 45 compounds not previously reported in [...]eat-flavour literature were identified. It was also evident that the meat-flavour concentrates prepared by the NPT method showed the presence [...]erocyclic and phenolic constituents not detected in the aroma concentrates previously prepared by us using continuous steam-distillation-extraction. [...]hydro-2,4-dimethylfuran, 3-propyl,1H-1,2,4-triazole, and 2,4,6-trimethylpyridine may be responsible for the species-specific flavour notes in pork, while [...]-dodecanediol, 2,6-bis(1,1-dimethylethyl)-4-methylphenol, 2-butylphenol, and 2,4-diphenyl-1H-pyrrole have been uniquely identified in chicken. The [...]t-like" aroma perhaps includes α-pinene, D-limonene, camphene, methyl 14-hydroxy-5-tetradecenoate, and 2,4-dihydroxybenzaldehyde. 2,2,4-[...]ethylhexane, 2-butyl-2-octenal, and 2-methylcyclopentanol could be contributing either directly as individual components or indirectly as synergists [...]e formation of cured-meat aroma.

[...]RODUCTION.

It is a well-established fact that raw meat, which has very little odour, attains a desirable "meaty-aroma" on cooking. A [...]iety of reactions such as oxidation of polyunsaturated fatty acids of meat lipids, further breakdown, condensation, and [...]lization of the primary oxidation products, and non-enzymatic amino-carbonyl reactions contribute to the formation of a [...]mplex spectrum of meat-flavour volatiles comprising of carbonyls, hydrocarbons, alcohols, phenols, lactones, esters, and [...]erocyclic compounds. A number of reviews have been published in the past decade giving comprehensive accounts of the [...]atile components that have been identified in the aroma concentrates of pork, beef, poultry, and lamb (Gray et al., 1981; [...]cLeod and Seyyedain-Ardebili, 1981; Ramaswamy and Richards, 1982; Moody, 1983; Baines and Mlotkiewicz, 1984; Shahidi [...]al., 1986). Odour descriptions of some of the important class of compounds that may be contributing to the meat aroma has [...]o been provided (Shahidi et al., 1986).

In our previous attempts, we have provided quantitative information on the carbonyls and hydrocarbons present in the [...]oma concentrates of uncured and nitrite-cured pork isolated by the conventional steam-distillation and continuous steam-[...]istillation-extraction (SDE) methods (Ramarathnam et al., 1991a). Using the SDE technique, we have also isolated, identified, [...]d quantitated volatiles from uncured and nitrite-cured beef and chicken, and provided a summary of those carbonyl [...]mponents that may be responsible for the species differences (Ramarathnam et al., 1991b). In continuation of our attempts [...] identifying the key-components that are responsible for the "cured-meat" aroma or the basic "meaty-aroma" of cooked meat, [...]e have isolated the volatiles from cured and uncured pork, beef, and chicken using the nitrogen purge-and-trap (NPT) method, [...]ich is a milder technique than the ones used by us previously.



[...]igure 1. Schematic representation of the nitrogen purge-and-trap (NPT) assembly.

MATERIALS AND METHODS

Meat. Fresh pork loin, ground beef (lean meat from shoulder), and chicken breasts (with skin on) were purchased from a local market and used immediately. The skin in chicken and excess fat in chicken and pork were removed. The meat was deboned manually, cut into small pieces, and then ground twice using an Oster meat grinder (0.476-cm grind plate, Model 990-68).

Reagents. Anhydrous sodium sulphate, sodium chloride, and sodium nitrite, all of analytical grade, and sodium ascorbate (USP grade) were purchased from BDH Chemicals. Sodium tripolyphosphate (food grade) was obtained from ERCO Industries, Ltd., while *n*-pentane (spectral grade) was purchased from Caledon Laboratories Ltd.

Cooking. Preparation of the cooked meat of uncured and nitrite-cured pork, beef, and chicken was carried out according to the procedure already published (Ramarathnam et al., 1991a; 1991b).

Nitrogen Purge-and Trap (NPT) Technique. A schematic representation of the NPT technique is illustrated in Figure 1. The cooked meat (250-400g) was homogenized with 500 mL distilled water using a Polytron homogenizer (Brinkmann Instruments, Model PT 10/35) until a free flowing meat slurry was obtained. The slurry was placed in the extraction jar, where it was constantly maintained at 65±5 °C, and stirred with the help of a magnetic hot plate/stirrer. A slow stream of oxygen-free nitrogen gas was passed through the meat slurry so as to purge the volatiles from the headspace. The effluent stream was passed through a Sep-pak Florisil C-18 cartridge (Waters Associates, Massachussetts), which was connected to a cold trap maintained at 4-5 °C with crushed ice, and finally through another trap containing *n*-pentane maintained at -60 °C with the help of an acetone-dry ice mixture. The second cold trap was further connected to an aspirator. This mode of fractionation was designed so as to adsorb some of the less volatile components onto the Florisil cartridge, condense excess water and water soluble components in the 1st cold trap, and absorb the volatile components that were not adsorbed onto the cartridge in *n*-pentane. The volatiles were collected over a 10 h purging period. At the end of the experiment, the cartridge was flushed with *n*-pentane (2X5 mL), the pentane extract dried over anhydrous sodium sulphate, and concentrated by passing a slow stream of oxygen-free nitrogen to a final volume of around 250 µL. Aroma concentrates from the 1st cold trap were prepared in a similar way by extracting the components from the aqueous condensate using *n*-pentane (2X10 mL). The pentane extracts from the 1st cold trap and 2nd cold trap were dried and concentrated as described above.

Gas Chromatography-Mass Spectrometric (GC-MS) Analysis. A Hewlett-Packard Model HP 5880A gas chromatograph equipped with a DB-5 capillary column [0.13 mm (i.d.)X 30 m] and coupled to a Hewlett-Packard Model HP 5987A mass spectrometer was used. Analysis was carried out by using helium as the carrier gas, with the column temperature maintained initially at 30 °C for 2 min and then programmed from 30 to 280 °C at a rate of 10 °C/min, where it was held for 3 min. The source, injector, analyzer, and transfer-line temperatures were 200, 250, 300, and 300 °C, respectively. The ionization voltage applied was 70 eV. Mass spectra obtained were compared with those of known compounds in the NBS (now NIST) library by using an HP 1000E series computer. Tentative identification of the individual constituents was based on the MS data.

RESULTS AND DISCUSSION

The components identified in the aroma concentrates of pork, beef, and chicken, prepared by the NPT method, are listed in Table 1. In all 75 compounds were identified in the different fractions of the aroma concentrates. Of these, 33 components were hydrocarbons, 18 carbonyls, 5 alcohols, 6 phenols, 5 esters, and 8 heterocyclics. Organoleptic evaluation of the contents of the 1st cold trap strongly indicated the presence of the components responsible for the desirable "meaty aroma" of cooked meat. Mass-spectrometric analysis of the aroma concentrates showed that the aroma fraction trapped in the 1st cold trap was richer in the heterocyclic constituents (data not shown). Forty-five compounds not previously reported in the literature have been identified in the present investigation. Of the various heterocyclic components identified, tetrahydro-2,4-dimethylfuran (RT, 8.60 min), 3-propyl,1H-1,2,4-triazole (RT, 11.32 min), and 2,4,6-trimethylpyridine (RT, 19.08 min) were identified for the first time in the aroma concentrates of pork. Hydrocarbons such as 1,1-dimethylcyclopentane (RT, 11.74 min) and the newly identified compounds 2-methylundecane (RT, 11.94 min) and 4-methyl-1-decene (RT, 13.00 min) were found to be present uniquely in the pork aroma concentrates. In addition, certain carbonyls such as 2-methylhexanal (RT, 6.50), (*E,E*)-2,4-nonadienal (RT, 8.41 min), (*E*)-2-heptenal (RT, 12.93 min), (*E,E*)-2,4-decadienal (RT, 13.76 min), 2-undecenal (RT, 14.40 min), and 4-pentylbenzaldehyde (RT, 15.79 min) were also found only in the aroma concentrates of pork. 4-Ethyl-2-methylhexane (RT, 5.50 min), 4-ethylbenzaldehyde (RT, 11.46 min), 1,12-dodecanediol (RT, 18.89 min), 2,4-diphenyl-1H-pyrrole (RT, 19.61 min), and certain phenolic components such as 2,6-bis(1,1-dimethylethyl)-4-methylphenol (RT, 16.49 min) and 2-butylphenol (RT, 19.54 min) were uniquely identified in chicken.

Though several heterocyclic components have been implicated to be responsible for the roasted, grilled, and smoked flavour of beef, the present investigation failed to identify the presence of heterocyclic components in cooked beef. The components uniquely identified in beef aroma concentrates were mainly terpene hydrocarbons such as D-limonene (RT, 9.12 min), and the newly identified α-pinene (RT, 7.40 min) and camphene (RT, 11.85 min). Other components that were present only in the volatile mixtures of beef aroma were 1,3,5-trimethylbenzene (RT, 8.50 min), decane (RT, 8.61 min), 4-ethyl-1,2-

able 1. Compounds identified in the aroma concentrates of pork, beef, and chicken, isolated by the nitrogen purge-and-trap ethod.

compound	pork		beef		chicken	
	uncured	cured	uncured	cured	uncured	cured
3-methylhexane	+	+	+	+	-	+
2-methyl-3-hexanone**	+	+	+	+	+	+
2,4-dimethylhexane	-	-	+	+	+	+
methylbenzene	+	+	+	+	+	+
2,2,4-trimethylhexane	-	+	-	+	-	+
hexanal	+	-	+	-	+	-
2,3,5-trimethylhexane	+	+	+	+	+	+
4-ethyl-1-methylhexane**	+	+	+	+	-	-
4-ethyl-2-methylhexane**	-	-	-	-	+	+
1,1,3-trimethylcyclohexane**	-	-	+	+	-	-
1,1,3,3-tetramethylcyclopentane**	-	-	+	+	+	+
2,2,5,5-tetramethylhexane**	+	+	+	+	-	-
2,2,4-trimethylheptane	+	+	+	+	+	+
2-methylhexanal**	+	-	-	-	-	-
heptanal	+	+	+	+	+	+
3,3-diethylpentane**	-	-	+	+	-	-
α-pinene**	-	-	+	-	-	-
7-octen-4-ol**	+	+	+	+	+	-
(E,E)-2,4-nonadienal	+	-	-	-	-	-
1,3,5-trimethylbenzene	-	-	+	-	-	-
tetrahydro-cis-2,4-dimethylfuran**	+	-	-	-	-	-
decane	-	-	+	-	-	-
1,4-dichlorobenzene	-	-	+	+	+	-
D-limonene	-	-	+	+	-	-
(E)-2-octenal	+	-	+	-	+	-
2,2,4,6,6-pentamethylheptane**	-	-	+	-	+	-
octanol	+	+	+	+	+	+
4-ethyl-1,2-dimethylbenzene**	-	-	+	-	-	-
1,2-dimethylcyclopentane**	+	+	+	+	+	-
3-propyl,1H-1,2,4-triazole**	+	-	-	-	-	-
4-ethylbenzaldehyde	-	-	-	-	+	-
1,1-dimethylcyclopentane	+	-	-	-	-	-
camphene**	-	-	+	-	-	-
3,6-dimethylundecane**	-	-	-	+	-	-
2-methylundecane**	+	+	-	-	-	-
2-methylcyclopentanol**	-	+	-	+	-	+
decanal	+	-	+	-	+	-
(E)-2-heptenal	+	-	-	-	-	-
4-methyl-1-decene**	+	-	-	-	-	-
nonylcyclopropane**	+	-	+	-	+	-
1-nonen-3-ol	+	-	-	-	-	-
5-propyldecane**	-	-	+	-	+	-
(E,E)-2,4-decadienal	+	-	-	-	-	-
1,3-dimethoxybenzene**	+	-	+	+	-	-
2,4-dihydroxybenzaldehyde**	-	-	+	-	-	-
2-undecenal	+	-	-	-	-	-
2-butyl-2-octenal**	-	+	-	+	-	+
1,2-dibutylcyclopentane**	-	-	-	-	-	+
2,3,5-trimethyldecane**	+	+	+	+	+	+
dodecanal	+	-	+	-	+	-
4-pentylbenzaldehyde	+	-	-	-	-	-
(1,1-dimethylethyl)-4-methoxyphenol**	-	-	+	-	+	+
pentadecane	+	-	+	-	+	+

16.37	tridecanal	+	-	+	-	+	-
16.49	2,6-bis(1,1-dimethylethyl)-4-methylphenol[**]	-	-	-	-	-	+
17.47	diethylphthalate	+	+	+	+	+	+
17.49	hexadecane	+	+	+	+	+	+
17.64	tetradecanal	+	-	+	-	+	-
18.86	4-(2,2,3,3-tetramethylbutyl)phenol[**]	+	+	+	+	-	-
18.89	1,12-dodecanediol[**]	-	-	-	-	+	+
18.95	4-nonylphenol[**]	+	+	-	-	+	+
19.03	1,3-dihydro-2H-imidazo(4,5-b)pyridin-2-one[**]	+	+	+	+	+	+
19.08	2,4,6-trimethylpyridine[**]	+	+	-	-	-	-
19.14	4-(1-methyl-propyl)phenol[**]	-	-	+	+	+	+
19.24	3-amino-5,6-dimethyltriazolo (4,3-a)pyrazine[**]	+	-	-	-	+	+
19.30	3-methyl-1,2-benzisothiazole[**]	+	+	-	-	+	+
19.40	4-ethyl-2,6-dimethylpyridine[**]	+	+	-	-	+	+
19.54	2-butylphenol[**]	-	-	-	-	+	+
19.61	2,4-diphenyl-1H-pyrrole[**]	-	-	-	-	+	+
20.04	hexadecanal	+	+	+	+	+	+
20.69	(*E*)-5-octadecene[**]	+	+	+	-	-	-
21.62	bis(2-methoxyethyl)phthalate[**]	+	+	+	+	+	+
22.87	methyl 11,14-eicosadienoate[**]	+	+	+	+	+	+
22.98	methyl 14-hydroxy-5-tetradecenoate[**]	-	-	+	-	-	-
26.90	bis(2-ethylhexyl)phthalate[**]	+	-	-	-	+	+

[**]newly identified; +, detected; -, not detected

dimethylbenzene (RT, 10.13 min), 3,6-dimethyl-undecane (RT, 11.91 min), 2,4-dihydroxybenzaldehyde (RT, 14.21 min), and the ester methyl 14-hydroxy-5-tetradecenoate (RT, 22.98 min). Hexanal (RT, 4.80 min), (*E*)-2-octenal (RT, 9.58 min), decanal (RT, 12.20 min), nonylcyclopropane (RT, 13.11 min), dodecanal (RT, 15.01 min), tridecanal (RT, 16.37 min), and tetradecanal (RT, 17.64 min) have been found in the aroma concentrates of all uncured meat samples, while 2,2,4-trimethylhexane (RT, 4.4 min), 2-methylcyclopentanol (RT, 12.02 min), and 2-butyl-2-octenal (RT, 14.58 min) seem to be unique components of the cured meat aroma.

CONCLUSIONS

The objective of the present work was to identify the components responsible for the "basic-meaty" aroma or the "cured meat" aroma and also to reveal more about the identity of the species-specific compounds. Using the nitrogen purge-and-trap technique we have identified many new compounds not known so far. However, how many of these newly identified components actually contribute to the "meaty-aroma" and "species-specific" flavour notes is not understood as yet. A detailed sensory evaluation of the newly identified components is being planned and work is currently in progress in that direction.

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