Aroma Chemicals in Meat Flavors

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Meat flavor has been a focus of attention for the last few years, with the object of developing flavors which will convert proteins from any source into meat-like products. The development of meat flavor that will make *non*-meat protein palatable is perhaps the most challenging problem that the food industry faces today.

Raw meat is almost devoid of any characteristic flavor except that of having a fundamental weak blood-like flavor super-imposed by a flavor distinctive of each species. A report in 1960 indicated that a meaty flavor is believed to originate from the lean portion of meat and the "species flavor" which distinguishes different species is derived from fat tissue.* However, this is only partially accepted today.

The potential for flavor development resides in the water soluble extract. The characteristic "sulphuraceous" note of meat flavor is formed due to heat treatment, but the nature of the flavor depends on the mode of cooking and the extent of water present in the environment.

The chemistry of the substances responsible for the flavor of cooked meat and the mechanism of flavor formation have received considerable attention in recent years. Meat flavors originate due to heat-induced reactions between free amino acids and monosaccaharides which are present in the aqueous extract of raw meat. During the cooking process, amines, acids, sulfur compounds and phenols are released.

Research on meat flavors began as early as 1950. The initial work was mostly concerned with the identification of the non-volatile precursors of meat flavor. However, it did not give a definite answer to the origination of meat flavor which is chemically more complex. It is implied that a chemical reaction between reducing sugars and the sulfur-containing amino acid cystein is involved which indirectly indicates the role of sulfur-containing volatile chemicals and their contribution to meat flavors. With the development of more sophisticated instrumentation and modern techniques, identification of volatile meat chemicals has received more attention in recent years.

Research studies have disclosed the presence of aroma compounds in meat flavors which have been classified into the following major classes.[1,2]

Aldehydes, Ketones, Furans, Aliphatic Sulfur Compounds, Heterocyclic Sulfur Compounds, Pyrazines, Pyroles, Pyridines, Hydrocarbons, Alcohols, Esters, Acids, and Lactones. However, of these only the first six classes of aroma chemicals play a significant role in development of meat-like character in food.

Elaborate review of the literature on all the aroma compounds in meat flavors is only of academic interest and beyond the scope of this article. However, it is our objective to review briefly those aroma compounds which have been found or reported to play a significant role in the development of meat flavors. This review should be of some help to flavor chemists by having at their disposal information concerning chemicals responsible for the basic meat flavor which they are attempting to duplicate.

Allphatic Sulfur Compounds

Sulfur compounds are important in the development of meat flavors. Examination of roasted meat revealed the presence of 2,4,5-trimethylhexathianes and 4,6-dimethyl-2,3,5,7-

*Hornstein and Crowe, Agric. Fd. Chem., **8**, 494, 1960

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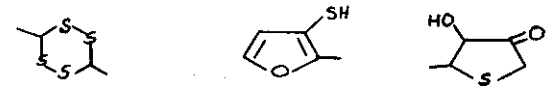
tetrathiooctane.[3,4] 3,6-Dimethyl-1,2,4,5-tetrathian (I) was found in mutton volatiles.[5] 3-Methyl-1,2,4-trithiane has been used to increase meat flavor characteristic of broths.[6]

A German patent claims a range of 3-thiaalkane-1,4-dione and sulfur compounds for roast meat flavor in meat products.[7] Use of 2,5-dimethyl-2,5-dihydroxy-1,4-dithiane in chicken flavor is also reported.

Heterocyclic Compounds

Furan Derivatives

A few sulfur derivatives of furan are recommended in flavor formulation for meaty-roasted aroma. Isolation of flavor concentrate of processed meat flavor on analysis revealed the presence of bis-(2-methyl-3-furyl) disulfide and 2-methyl-3-furanthiol.[8]

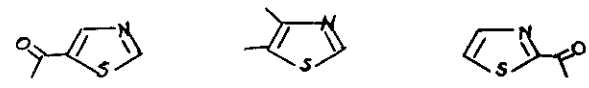


I II III

2-Methyl-3-furanthiol (II) has a roast beef aroma. One of the U.S. patents indicated that a mixture of 2-methyl-3-furanthiol and 4-terpineol-propionate also has a roast beef aroma.[8b] It was stated that 4-hydroxy-5-methyl-3(2H) furanone and its related thiophenone (III) when reacted with hydrogen sulfide produced compounds having the aroma of roasted meat.[9]

Thiazoles and Pyrazines

In recent years, thiazoles and pyrazines have been receiving increasing attention because of their natural occurrence in various foods and because of their organoleptic properties.[10] A few compounds having roast meat flavor are 5-acetylthiazole (IV), 2,4-dimethyl-5-acetylthiazole, 4,5-dimethylthiazole (V), and 2,4,5-trimethylthiazole.



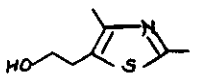
IV V VI

Occurrence of thiazoles in natural flavors related to beef and chicken have been reported.[11] 2-Acetylthiazole (VI) was found in ground beef and canned beef.[11,12] 5-Beta-hydroxyethyl-2,4-dimethylthiazole (VII), also known as sulfurol, has been found in meat flavors.[11]

Thiazoles are formed in food flavors by thermal degradation of reducing sugars in the presence of

hydrogen sulfide and ammonia. More frequently degradation of cysteine and cystine either alone or in the presence of sugar or alpha-diketones leads to the formation of thiazoles.

Abundant quantities of different types of pyrazines have been isolated from meat volatiles and identified.[13,14] Pyrazines contribute to the nutty roasted aroma of cooked meat. Individually, however, they do not have a meaty odor or aroma.



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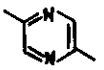
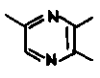
VIII



IX

Several alkyl pyrazines have found application in meat flavors, for example 2,3-dimethyl pyrazine (VIII) in roasted meat, 2,5-dimethyl pyrazine (IX), 2-methyl pyrazine, and 2,3,5-trimethyl pyrazine (X) in beef, chicken broth and grilled meat.



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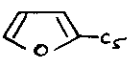

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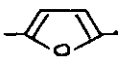


XVI

Pyrazines are formed from the reaction of a sugar or sugar degradation product with an amino acid.[15,16]

Thiazolines and Oxazolines

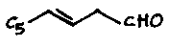
In addition to thiazoles, other sulfur-containing heterocyclic compounds present in cooked meat are thiazolines and oxazolines. Three thiazolines and three oxazolines occur in beef.[14b] These are 2, 4-dimethyl-3-,2,4,5-trimethyl-3-, and 2-acetyl-2-thiazoline. However, only 2,4,5-trimethyl-3-thiazoline has a meaty odor. Among three oxazolines reported are 2,4-dimethyl-3,2,4,5-trimethyl-3-, and 2,4-dimethyl-5-ethyl-3-oxazoline. None of these oxazolines exhibited any meaty odor. Nevertheless they contribute to the overall aroma character.

Non-Sulfur Compounds

Aldehydes, Ketones and Alkenes

The problem of meat flavor is more complex because it is not limited to sulfur compounds. Several non-sulfur organic compounds have been isolated and identified. Gas chromatography analyses of mutton fat volatiles indicated that 4-methyl C_9 and C_{10} carbon atom acids contributed to the mutton aroma.[17-19]

Cis-3-nonenal (XI), 2-trans-dodecenal, 2-trans-5-cis-undecadienal,2,4-dodecadienal (XII), and 2,6-dodecadienal have been identified in cooked chicken.[20]

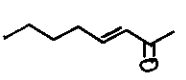


XI

XII

The study of meat and bone meal in pet foods revealed the presence of C_6, C_7 and C_8 aldehydes along with 3-octen-2-one (XIII), 1-octen-3-ol (XIV), 2-(n-pentyl) furan (XV) and others.[21]

A report concerning synthetic meat flavors lists acetyl pyrrolidine, furan, 2,2,5,5-tetramethyl-furan, 2-2-dimethyl-3,4-pentadienal, and 5-methylfurfural (XVI). However, not all of these occur in natural meat flavor.[22]



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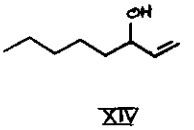

XIV

A recent review by Moody[23] updates some of the important research developments in beef flavors that have occurred in the last two decades and lists some interesting articles.[24,25]

Brennand and Lindsay[26] reported on the sensory discrimination of species related to meat flavors. Another article review by Cramer[27] on chemical compounds found in lamb and mutton flavors would be helpful in understanding those particular meat flavors. However, the chemicals responsible for an unacceptable odor have yet to be identified.

Recently an interesting paper reported on nitrogen-containing heterocyclic compounds identified in the volatile flavor constituents of roasted beef.[28] However, elaborate listing of these compounds is beyond the scope and objectives of the present article.

Conclusion

The complex problem of creating a desired flavor in meat products has been a challenge for chemists. The success of a particular flavor would also depend on the cost of production, marketing and, most of all, on acceptance by the consumer.

Summary

The compound is followed by its FEMA number (if available) and flavor application*

*Most of the chemicals listed here are FEMA substances. However, for further information readers are advised to refer to "Flavor and Fragrance Materials 1981" compiled by The Chemical Sources Association, Washington, D.C., published by Allured Publishing Corporation, Wheaton, Illinois, U.S.A., and references cited therein.

Sulfur Compounds
2-Methyl-3-furanthiol (3188)—Roasted meat flavor
3-Methyl-1,2,4-trithiane—Roasted meat flavor
2,4,5,-Trimethyl hexathiane—Roasted meat flavor
3-Thiaalkane-1,4-dione—Roasted meat flavor
Thioesters of furan (3162, 3347)—Roasted meat flavor
4-Hydroxy-5-methyl-3(2H)thiophenone—Roasted meat flavor
2,5-Dimethyl-2,5-dihydroxy-1,4-dithiane(3450)—Roasted meat flavor
3,6-Dimethyl-1,2,4,5-tetrathiane—Mutton flavor

Heterocyclics
2,2,5,5-Tetramethylfuran—Synthetic meat flavor
5-Methyl furfural (2702)—Synthetic meat flavor
Furan—Synthetic meat flavor
2-Methylfuran—Synthetic meat flavor
5-Methylfuran—Synthetic meat flavor
2-n-Pentylfuran (3317)—Bone meal flavor
Acetylfuran (3163)—Smoke flavor
Propionylfuran—Smoke flavor
4-Hydroxy-5-Methyl-3(2H)Furanone—Beef flavor

Thiazoles
5-Acetylthiazole—Roasted meat flavor
2,4-Dimethyl-5-acetylthiazole (3263)—Roasted meat flavor
2,5-Dimethyl-4-acetylthiazole—Roasted meat flavor
4,5-Dimethylthiazole (3274)—Roasted meat flavor
2,4,5-Trimethylthiazole (3325)—Roasted meat flavor
2-Acetylthiazole (3328)—Beef flavor
Sulfurol (3204)—Beef flavor

Thiazolines
2,4,5-trimethyl-3-thiazoline—Beef flavor
2-Acetyl-2-thiazoline—Roasted beef flavor
2,4-Dimethyl-3-thiazoline—Roasted beef flavor

Oxazolines
2,4-Dimethyl-3-oxazoline—Beef flavor
2,4,5-Trimethyl-3-oxazoline—Boiled beef flavor
2,4-Dimethyl-5-ethyl-3-oxazoline—Beef flavor

Pyrazines
2,3-Dimethylpyrazine (3271)—Roasted meat flavor
2,5-Dimethyl pyrazine (3272)—Chicken broth, grilled meat and beef flavor
2,3,5-Trimethylpyrazine (3244)—Chicken broth, grilled meat and beef flavor
2-Methylpyrazine (3309)—Chicken broth, grilled meat and beef flavor

Aldehydes, Ketones and Alkenes
2-Trans-5-cis-undecadienal—Chicken flavor
2-Trans-4-cis-7-cis-decatrienal—Chicken flavor
2,4-dodecadienal—Chicken flavor
2,6-dodecadienal (3637)—Chicken flavor
2-Trans-dodecenal (2402)—Chicken flavor
2,4,7-Tridecatrienal (3638)—Chicken flavor
1-Udecene—Synthetic meat flavor
2,4-Dimethyl undecene—Synthetic meat flavor
2,2,4-Trimethyl heptane—Synthetic meat flavor
2,2-Dimethyl-3,4-pentadienal—Synthetic meat flavor
Hexaldehyde (2557)—Meat flavor
Heptaldehyde (2540)—Meat flavor
Octaldehyde (2797)—Meat flavor
3-Octen-2-one (3416)—Meat flavor
1-Octen-3-ol (2805)—Meat flavor

References

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1. Garbusov, Rehfeld et al., Die Nahrung, **20** (3), 235, 1976
2. Maclead and Coppock, J. Agr. Food Chem., **24,** 102, 1976
3. Dubs and Stuessi, Helv. Chem. Acta., **61,** 2351, 1978
4. Dubs and Joho, ibid, **61,** 2809, 1978
5. Nixon et al., J. Agr. Food Chem., **27,** 355, 1979
6. Flament, Ger. Offen. 2,852,783, June 7, 1979
7. Liberman et al., U.S. Patent 4,139,649, Feb 13, 1979
8. V. Ouwlend and Peet, J. Agr. Food Chem., **23,** 501, 1975
9. Evers et al., U.S. Patent 3,873,732, March 25, 1975
10. Pittet and Klaiber, J. Agr. Food Chem., **22,** 264, 1974
11. Wilson and Hussinan et al., ibid, **21,** 873, 1973
12. Peterson and Izzo et al., J. Food Science, **40,** 948, 1975
13. Maclead and Coppock, J. Agr. Food Chem., **24,** 835, 1976
14. Mussianan and Walradt, J. Food Chem., **22,** 827, 1974
15. Pearson and Von Sydow, J. Food Science, **39,** 406, 1974
16. Tonsbeek and Plancken et al., J. Agr. Food Chem., **16,** 1016, 1968
17. Wong and Nixxon et. al., J. Sci. Food Agr., **25,** 495, 1975
18. Wong and Nixxon et al., Chem. Ind. (London), **1,** 40, 1975
19. Wong and Nixxon et al., Food Technol. N. Z., **10,** 13, 1975
20. Legemain et al., U.S. Patent 3,821,421, June 28, 1974
21. Greenberg, J. Agr. Food Chem., **29,** 875, 1981
22. Hsich and Peerson et al., J. Food Science, **45,** 1078, 1980
23. Moody, Food Technol., **37,** 227, 1983; and references therein
24. McLeod and Seyyedain-Ardebli, CRC, Crit. Rev., Food Sci. Nutr., **14,** 309, 1981
25. Katz, Flavor Research; Recent Advances, Teranishi, ed., Marcel Dekker Inc., New York, 1981
26. Brennand and Lindsay, Leb. Wess. Technol., **15,** 249, 1982
27. Cramer, Food Technol., **37,** 249, 1983; and references therein
28. Chang et al., J. Agri. Food Chem., **31,** 1030, 1983