FLAVOR OF MEAT, MEAT PRODUCTS AND SEAFOODS

Second edition

Edited by F. Shahidi

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Preface

Flavor is an important sensory aspect of the overall acceptability of muscle foods. Complex flavor systems of meat, and seafoods in particular, are comprised of both taste- and aroma-active components. While taste-active constituents of muscle foods are generally non-volatile, their aroma-active components are volatile in nature. Whether we accept or reject a food depends primarily on its flavor, in the first instance aroma. Furthermore, threshold values of different flavor active compounds have an important effect on the cumulative sensory properties of all foods.

While meat and meat products, in the raw state, have little aroma and only a blood-like taste, fresh seafoods have a more readily perceivable aroma. The flavors of fresh seafoods are primarily impacted by lipoxygenase-derived lipid-based volatiles and, to a lesser extent, environmentally induced components such as halocompounds and amines. Upon heat processing, many low-molecular-weight aroma-active compounds are formed via lipid oxidation, Strecker degradation and Maillard reaction. Mode of heat processing and presence of other constituents and additives also have a profound effect on the flavor of prepared muscle foods.

The first edition of this book, published in 1994 and reprinted in 1995 and 1997, received overwhelming interest from professionals in the industry, government laboratories and academic institutions. This edition provides an updated presentation of the earlier material, but some have been rewritten completely by different scientists. The monograph has also been expanded in order to include a discussion of flavor attributes of other processed meats and seafoods. The first chapter provides an overview of the field of muscle food flavor research while Chapter 2 discusses its chemistry. Meanwhile, Chapters 3 to 8 present a concise account of the flavor of different species of muscle foods, namely beef, pork, poultry, sheep, fish and shellfish. In Chapters 9 to 15, the role of meat constituents and processing on flavor is described. The final section of the book (Chapters 16 to 18) summarizes analytical methodologies for assessing the flavor quality of meat, meat products and seafoods.

Finally, I wish to extend my sincere thanks to all authors for their cooperative efforts and commendable contributions.

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Contents

1 Flavour of muscle foods – an overview

F. SHAHIDI

1.1 Introduction

Flavour is an important sensory aspect of the overall acceptability of meat and seafood products. The overwhelming effect of flavour volatiles has a tremendous influence on the sensory quality of foods. However, the taste properties of high molecular weight components and contribution of nonvolatile precursors to the flavour of muscle foods should also be considered.

Although raw meat has little aroma and only a blood-like taste, it is a rich reservoir of compounds with taste tactile properties as well as aroma precursors and flavour enhancers (Crocker, 1948; Bender and Ballance, 1961). However, seafoods are somewhat different in that they may carry their own flavour in the raw state. The presence of amines in the gadoid fish and autoxidation in fatty fish such as herring and mackerel is of particular interest. The flavour of both fish and shellfish in the fresh raw state is also impacted by lipoxygenase-derived lipid-based volatiles. Furthermore, shellfish have varied flavour characteristics which arise mainly from existing differences in their nonvolatile taste-active constituents. The nonvolatile precursors of muscle flavour include free amino acids, peptides, reducing sugars, vitamins and nucleotides. The interaction of these components with one another and/or their degradation products via the Strecker degradation and Maillard reaction produces a large number of intermediates and/or volatiles which contribute to the development of desirable aroma of muscle foods during thermal processing. Lipids also play an important role in the overall flavour of meat and seafoods which is distinct and species-dependent (Mottram *et al.*, 1982; Mottram and Edwards, 1983; Shahidi and Cadwallader, 1997).

Dietary regime, metabolic pathway, and species of the animal under investigation may have an effect on the flavour quality of muscle foods. For example, cattle and poultry on a fish meat-supplemented diet are fed a cereal-based finishing feed in order to prevent occurrence of a fish-tainted flavour in their meat. Furthermore, branched fatty acids such as 4-methyloctanoic and 4-methylnonanoic acids are mutton-specific and a swine sex odour is associated with boars (Wong *et al.*, 1975; Gower *et al.*, 1981).

1.2 Flavour volatiles of muscle foods

Nearly 1000 compounds have so far been identified in the volatile constituents of meat from beef, chicken, pork and mutton (Shahidi, 1992) as well as seafoods (Pan and Kuo, 1994). These volatiles are representative of most classes of organic compounds, such as hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids, esters, lactones, ethers, furans, pyridines, pyrazines, pyrroles, oxazoles, oxazolines, thiazoles, thiazolines, thiophenes, and other sulphur- and halogen-containing compounds. It is believed that the predominant contribution to aroma is made by sulphurous acyclic compounds, heterocyclic compounds containing nitrogen, oxygen and/or sulphur, and carbonyl-containing volatiles (Shahidi, 1989, 1992).

Although the chemical nature of many flavour volatiles of meat from different species is similar qualitatively, there are quantitative differences. For example, it has been reported that mutton aromas contain a higher concentration of 3,5-dimethyl-1,2,4-trithiolane and 2,4,6-trimethylperhydro-1,3,5-dithiazine (thialdine) as compared to those of other species. Other sulphur-containing compounds were also present in high concentration and were attributed to the high content of suphurous amino acids in mutton as compared with those of beef and pork. Similarly a higher concentration of alkyl-substituted heterocyclics was noted in mutton volatiles (Buttery *et al.*, 1977). Mercaptothiophenes and mercaptofurans were significant contributors to beef aroma (Macleod, 1986).

Compared to the total number of volatile compounds identified in meat from different species, only a small fraction of them have been reported to possess meaty aroma characteristics (Shahidi, 1989) and these are mainly sulphur-containing in nature. While most of the sulphurous volatiles of meat exhibit a pleasant meaty aroma at concentrations present in meat, at high levels their odour is objectionable. Therefore, both qualitative and quantitative aspects of volatiles have to be considered when assessing the flavour quality of muscle foods. In addition, possible synergisms between various aroma constituents have to be considered.

Finally, in the evaluation of flavour quality of meat, the contribution to taste by amino acids, peptides and nucleotides must be considered. These compounds not only interact with other components to produce flavour volatiles, they also contribute to sweet, salty, bitter, sour and umami sensation of muscle foods. In the production of soups and gravies, proteins are partially hydrolysed to enhance taste sensation of the molecules. Therefore, studies in this area would allow us to optimize conditions to yield products with a maximum level of acceptability.

1.3 Impact of processing and storage on muscle food flavour

Processing of meat and fish such as curing (Shahidi, 1992) and/or smoking (Maga, 1987) brings about a characteristic flavour in the products. Interaction of nitrite with muscle foods generally retards the formation of off-flavour volatiles which may mask the natural flavour of products. Therefore, process flavours contribute greatly to the desirable characteristics of a wide range of well-loved products.

Cured and salted muscle foods generally retain their flavour, but nitrite curing also modifies the aroma and allows storage of products for a reasonably long period. Progression of oxidation and meat flavour deterioration is dependent primarily on the species of meat and its lipid content. Furthermore, interaction of oxidation products with muscle food components may in turn bring about changes in their colour, texture and nutritional value (Spanier *et al.*, 1992). In gadoid fish, formation of formaldehyde from degradation of trimethylamine oxide leads to toughening of the muscle texture during frozen storage because of cross-linking of protein molecules. Therefore, control of deteriorative processes, including autoxidation, and methods to quantitate them, have received considerable attention over the last few decades.

As analytical methodologies improve, the identification of new flavour-active compounds contributing to aroma at low threshold values becomes possible. Fundamental research has helped the application of important findings to improve the quality of muscle food products and these findings will continue to have an impact in new industrial developments. As more data become available, better understanding of the mechanisms involved in flavour perception and formulation of true-to-nature flavorants may be embraced.

1.4 Methodologies and concerns

The methods used for the analysis of all muscle food flavours are essentially the same (Ho and Manley, 1993; Marsili, 1997). However, identification of characteristic and important aroma compounds in meat has been challenging due to the presence of these compounds at extremely low levels, often at sub parts-per-billion concentrations. Isolation and sampling of volatiles prior to gas chromatographic analysis can be conducted in a number of ways, including equilibrium and dynamic headspace sampling, distillation under atmospheric or vacuum conditions with subsequent solvent extraction, direct solvent extraction or sublimation *in vacuo* and direct sample injection. Each isolation technique has its own advantages and weaknesses and each will give somewhat biased results since it selects for certain groups of compounds over others and some methods are prone to artifact formation.

A good approach to account for some of the bias has been to rely on two or more of the above techniques for isolation of volatiles. The subsequent analysis of volatile extract is most often accomplished by gas chromatography (GC) and GC–mass spectrometry (GC–MS). In addition to these, GC–olfactometry (GC–O) has proven useful for the identification of character-impact compounds in meat and seafoods. The use of an electronic aroma sensor for analysis of flavours is a recent development.

References

Bender, A.E. and Ballance, P.E. (1961). A preliminary examination of the flavour of meat extract. *J. Sci. Food Agric.*, **12**, 683–687.

Buttery, R.G., Ling, L.C., Teranishi, R. and Mon, T.R. (1977). Roasted lamb fat: Basic volatile components. *J. Agric. Food Chem.*, **25**, 1227–1229.

Crocker, E.C. (1948). The flavor of meat. *Food Res.*, **13**, 179–183.

Gower, D.E., Hancok, M.R. and Bannister, L.H. (1981). In *Biochemistry of Taste and Olfaction*, eds. R.H. Cagan, and M.R. Kave, Academic Press, New York, pp. 7–31.

Ho, C-T. and Manley, C.H. eds. (1993). *Flavor Measurement.* Marcel Dekker, New York.

MacLeod, G. (1986). The Scientific and Technological Basis of Meat Flavours. In *Development in Food Flavours*, eds. G.G. Birch and M.G. Lindley. Elsevier Applied Science, London. pp. 191–223.

Maga, J.A. (1987). The flavor chemistry of wood smoke. *Food Reviews International* **3**, 139–183.

Marsili, R. ed. (1997). *Techniques for Analyzing Food Aroma*. Marcel Dekker, New York.

Mottram, D.S. and Edwards, R.A. (1983). The role of triglycerides and phospholipids in the aroma of cooked beef. *J. Sci. Food Agric.*, **34**, 517–522.

Mottram, D.S., Edwards, R.A. and MacFie, H.J.H. (1982). A comparison of the flavor volatiles from cooked beef and pork meat systems. *J. Sci. Food Agric.*, **33**, 934–944.

Pan, B.S. and Kuo, J.-M. (1994). Flavour of shellfish and kamaboko flavourants. In *Seafoods: Chemistry, Processing Technology and Quality*, eds. F. Shahidi and J.R. Botta. Blackie Academic & Professional, Glasgow, pp. 85–114.

Shahidi, F. (1989). Flavour of cooked meats. In *Flavour Chemistry: Trends and Developments*, eds. R. Teranishi, R.E. Buttery, and F. Shahidi, ACS Symp, Ser. 388, American Chemical Society, Washington, DC, pp. 188–201.

Shahidi, F. (1992). Prevention of lipid oxidation in muscle foods by nitrite and nitrite-free compositions. In *Lipid Oxidation in Food*, ed. A.J. St. Angelo, ACS Symposium Series 500, American Chemical Society, Washington, DC, pp. 161–182.

Shahidi, F., Rubin, L.J. and D'Souza, L.A. (1986). Meat flavor volatiles: A review of the composition, techniques of analysis, and sensory evaluation. *CRC Crit. Rev. Food Sci. Nutr.*, **24**, 141–243.

Shahidi, F. and Cadwallader, K.R., eds. (1997). *Flavor and Lipid Chemistry of Seafoods.* ACS Symposium Series 674, American Chemical Society, Washington, DC.

Spanier, A.M., Miller, J.A. and Bland, J.M. (1992). Lipid oxidation: Effect on meat proteins. In *Lipid Oxidation in Food*, ed. A.J. St. Angelo, ACS Symposium Series 500, American Chemical Society, Washington, DC, pp. 161–182.

Wong, E., Nixon, L.N. and Johnson, C.B. (1975). Volatile medium chain fatty acids and mutton flavor. *J. Agric. Food Chem.*, **23**, 495–498.