

# Investigation of the species specific flavor of meat

By G.A.M. van den Ouweland, Unilever Research, Vlaardingen/Duiven, Netherlands, and R. L. Swaine, Jr., Knox Ingredients Technology, Allendale, NJ

For ages man has been interested in the nutritional and organoleptic aspects of meat, but the systematic investigation of the biochemical derivation of desirable species specific meat flavor is a rather new endeavor. The first clue to this mystery was probably uncovered by Crocker in 1947.<sup>1</sup> He postulated that the factors responsible for meat flavor are found to a greater extent in the juice than in the fibre. Crocker explained that the majority of the flavor is developed as a result of the thermal degradation of proteins. During the cooking process, amines, acids, sulfur compounds, and phenols are released. Of particular note is his observation that all of the meats (beef, poultry, lamb, and pork) studied exhibited "weak fundamental blood-like flavor when raw." Superimposed on this fundamental flavor was a "flavor distinctive of the species, food, and environment." Also important was the discovery that the flavors developed upon cooking likewise were similar for various meats; again, modified by the species. Furthermore, with prolonged cooking these characteristics were lost. The flavor differences were thought to be more quantitative than qualitative. Since that time the chemistry of meat flavor has been the subject of many scientific papers.

## Origin of meat flavor

The flavor of meat is attributed to the reactions of a complex mixture of compounds, and the differences in flavor from these compounds are due to the reaction conditions (that is, temperature, time, and the amount of water present during the reaction). The range of heating conditions used in the normal cooking of meat varies widely. The center of a fried steak is normally exposed to about 60°C for a few minutes, and the outer surface may in this time reach a temperature of about 120°C. The center of a roast will rise to 75° in 2 hours, and its outer surface may reach 190° in these 2 hours. The beef from which a broth is made will be at 100° for 4 hours. It is obvious that both quantitative and qualitative differences in the flavor patterns in different cases are observed. To date, we have learned the following about the complex phenomenon called "meat flavor." Raw meat while possessing a blood serum-like aroma and a salty

metallic and bloody taste has no "meat aroma." It does, however, contain certain key flavor-generating compounds that upon heating form the chemicals responsible for the aroma of meat. These precursors seem to be similar for all types of meat. They are low molecular weight, water soluble, dialyzable compounds.

## Amino acids

The thermal degradation products of proteins, peptides, and amino acids have been identified as significant flavor precursors. These products may not only possess meaty characteristics in their own right but also may further react with carbohydrates and related products via the Maillard reaction to yield potent meaty aromas. The comparison of amino acid content of beef, chicken, and pork is given in part a of figure 1. It may be seen that amino acids are most abundant in chicken, beef, and pork respectively. In fact, in all cases but histidine, the quantity of individual amino acids is greatest in chicken.

## Vitamins

Other precursors for meat flavor, include vitamins, and the composition of the main vitamins in the 3 meat species is given in part b of figure 1. Of these vitamins thiamine, which is most prevalent in pork, is the most important contributor to meat flavor. It produces such compounds as thiazoles, thiazolines, hydrogen sulfide, acetyl mercaptopropanol, and 3-mercaptopropanol. Another vitamin implicated in the development of meat aroma is vitamin C. The degradation of ascorbic acid leads in the initial steps to the formation of highly reactive dicarboxyl intermediates (as seen in figure 2) which, on further reaction, give rise to potent aroma and aroma-generating compounds. Examples of such compounds are glyoxal, glyceraldehyde, furfural, 3-hydroxyfurfural, 5-methyl-4-hydroxy-3-furanon, 3-hydroxy-2-pyron, and 2-acetylfuran.<sup>5</sup> These may react further in the presence of amino acids.

## Minerals

Another important factor is the minerals present in the raw meat. They act especially on the sweet, sour,

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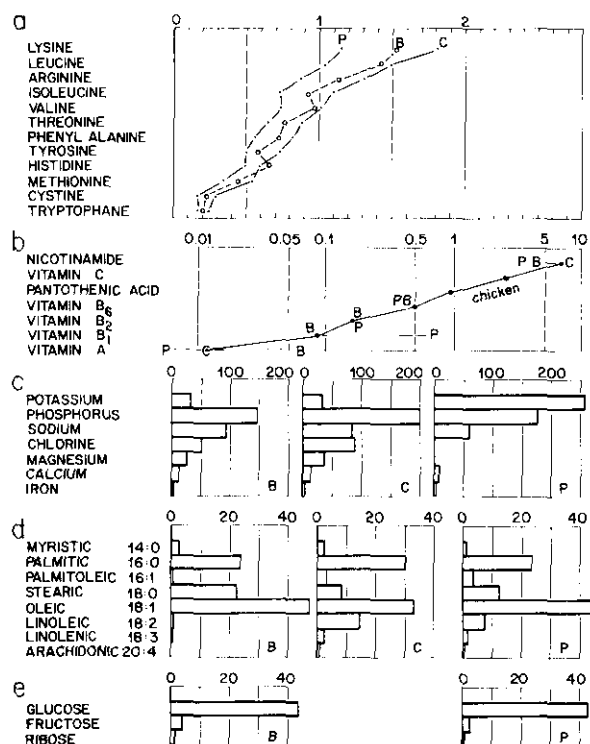


Figure 1. Part a: The amino acid composition of meat species in g/100 gm.<sup>2</sup> Part b: The vitamin composition of meat species (mg per 100 gm).<sup>2</sup> Part c: The composition of minerals in meat species (mg/100 gm).<sup>2</sup> Part d: The percentage of the main fatty acids in the lipid fraction of meat species. Part e: The concentration of carbohydrates in lyophilized diffusate from different meat species (mg/100 gm).<sup>9</sup>

salty, and bitter tastebuds of the tongue. The composition of the various minerals in beef, chicken, and pork is given in part c of figure 1.

## Lipids

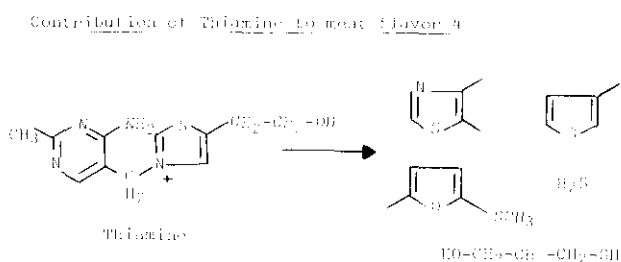
It has been shown by many investigators that the fatty acid composition of animals differs widely between different layers of the depot fat as well as between different types of muscles. It is, therefore, very difficult to tabulate accurately the fatty acid composition of different species, but we may be sure that chicken and pork meat contain higher proportions of polyunsaturated fatty acids than beef meat. In part d of figure 1 an average composition of the main fatty acids in the three species is given. More characteristic flavor compounds are formed from polyunsaturated fatty acids than from saturated and monounsaturated fatty acids.

## Carbohydrates

The final important factor contributing to the meat flavor development reaction is carbohydrates. The amounts of sugars found in raw meat (diffusate) are given in part e of figure 1.

## Resulting meat flavor

There is no single chemical totally responsible for



Contribution of ascorbic acid to meat flavor 5

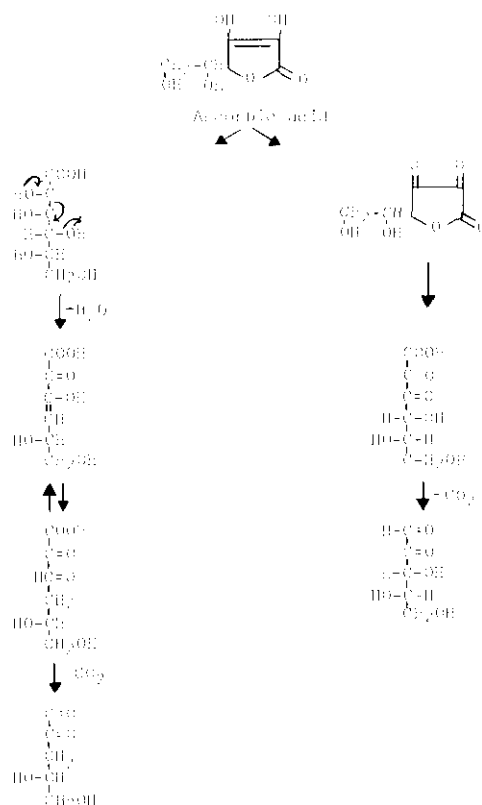


Figure 2. Top: Contribution of thiamine to meat flavor 4. Bottom: Contribution of ascorbic acid to meat flavor 5.

the characteristic flavor of meat. Rather the total flavor profile is a product of the volatile and non-volatile compounds. The taste of meat is developed by the nonvolatile components such as salts, amino acids, peptides, organic acids, monosodium glutamate, pyrrolidone carboxylic acid, and 5'-ribonucleotides. Volatiles implicated as making an important contribution to meat aroma include low molecular weight sulfur compounds, substituted furans, lactones, low molecular weight carbonyls, and heterocyclic compounds (composed of oxygen, sulfur, or nitrogen). These aromatic constituents are the products of the flavor precursors spoken about above.

A brief scrutiny of the data describing chemical composition of meat, especially with regard to amino acids and sugars, reveals the relatively similar concentrations of the significant flavor precursors. The notable exception to this, however, is the lipid-related

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fraction. When one realizes the similarities of the biochemical functions and constituents of skeletal muscles, it is not surprising to find the basic meaty flavor produced by thermal reaction is also similar even between species.

As early as 1960, Hornstein and Crowe found evidence that volatiles isolated after thermal treatment of lyophilized cold water extracts of beef and pork gave odor responses that were remarkably similar.<sup>9</sup> Batzer and coworkers similarly examined the flavor that could be generated from raw ground beef muscle.<sup>10</sup> It was observed that of the various fractions studied only the dializable extract produced a desirable meaty flavor. This portion was again dialized and further separated. The various fractions were cooked, and it was found that the fraction containing amino acids and low molecular weight sugars (especially the hexose glucose and phosphorous-containing compounds) produced a good meat aroma. While this fraction seemed to contain the same chemical constituents necessary for the basic meat odor, the addition of other fractions (carbohydrate and protein) produced a more complete cooked meat aroma. This procedure was repeated using chicken and pork and yielded similar results. This one fraction gave identical meat flavor no matter if it came from chicken, pork, or beef. Thus a general meaty flavor is produced while the species identity is lost.

To determine the specific species flavor, we must now turn to the lipids found in meat. For it is this meat fraction that produces the volatiles that are responsible for a species flavor. This should not come as a surprise when we realize that for some time now gourmets have believed that meat with a high content of intramuscular fat produces the best flavor. Returning once again to the work of Hornstein and Crowe, we see that it was the free fatty acids and carbonyls liberated upon heating to which they attributed specific flavor.<sup>9</sup> Meat lipids may be classified into two groups—the intermuscular (depot) lipids and the intramuscular (tissue) lipids. Located mainly in the connective tissue, depot lipids serve as solvents to trap, dissolve, and retain aroma volatiles generated from regions outside this fat. The marbling or intramuscular lipids is distributed throughout the muscle tissue. It varies substantially from the depot fat existing in close association with protein and containing a large portion of phospholipids and free fatty acids. It is this fraction that generates volatiles that give rise to aromas specific to the species.

As previously mentioned, lipids may be potent flavor precursors, at times yielding desirable flavors yet also capable of producing off odors. Flavor moieties may be generated oxidatively at temperatures as low as 60°C and in the presence of a few free radicals. This is at least in part due to the phospholipids and their high concentration of polyunsaturated fatty acids (most notably arachidonic and linoleic acids). It is the oxidative products of arachidonic acid from the phospholipid fraction in chicken, the monounsaturated *cis*-4-decenal, and the polyunsaturated *trans*-2-*cis*-5-undecadienal and

Table I. Aldehydes identified in heated beef fat, chicken fat, and pork fat

Aldehyde	Beef <sup>12</sup>	Chicken <sup>11</sup>	Pork <sup>16</sup>
C5	+	-	-
C6	+	+	+
C7	+	+	-
C7 2t	+	+	+
C7 2t 4C	-	+	+
C8	+	-	+
C8 2t	+	+	+
C9	+	+	+
C9 2t	+	+	+
C9 2t 4C	-	+	+
C10	-	+	+
C10 2t	+	+	+
C10 4C	-	+	-
C10 2t 4C	+	+	+
C10 2t 4C 7C	-	+	-
C11	-	-	+
C11 2t	+	+	+
C11 2t 5C	-	+	-
C12 2t	-	+	-
C12 2t 6C	-	+	-
C12 2t 6t	-	+	-
C13	-	+	-
C13 2t	-	+	-
C13 2t 4C	-	+	-
C13 2t 4C 7C	-	+	-

*trans*-2-*cis*-4-*trans*-7-tridecatrinal that are responsible for the characteristic flavor of chicken.<sup>11</sup> Table I reveals the presence of aldehydes formed from

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polyunsaturated fatty acids (such as arachidonic) in heated chicken fat. It is also common to observe thermal degradation of tissue lipids at temperatures of 200° to 300°C. Thermal oxidative volatiles such as lactones, aldehydes, and ketones are formed. Gamma or delta hydroxy fatty acids present in the lipid fraction are also known to be precursors to a group of potent aroma compounds. Gamma and delta, C<sub>5</sub>-C<sub>15</sub>, lactones have been identified in beef fat while gamma C<sub>5</sub>-gamma C<sub>12</sub> and gamma C<sub>9</sub> lactones have been reported in pork.<sup>13</sup> Long chain unsaturated aliphatic monocarbonyl compounds, alpha dicarbonyls, and

free fatty acids all have been implicated as lipid-originating moieties possessing beef aroma.<sup>14</sup> Many carbonyls important to beef flavor are formed from the degradation of triglycerides and/or free fatty acids. While it appears that the species flavor is due to carbonyl compounds derived from lipids, one must not attribute all carbonyls to a lipid origin. It must be remembered that in a heterogeneous system such as meat lipid degradation products may further react with other compounds to give carbonyls. It is also possible that aldehydes may be formed via the Strecker degradation of amino acids and diketones.

### Industrial use of meat flavor development

The flavor industry has originated, over the years, methods of developing meat flavors by processing the precursors discussed above. Work started in the late 1950s when May and Akroyd disclosed the preparation of meat flavor by heating hydrolysed vegetable protein fortified with the essential amino acid, cysteine, and a monosaccharide, preferably ribose.<sup>15</sup> This led to a flood of patents by flavor houses all based on these general principles, with the high point of meat flavor inventions being the years from 1966 to 1972. It is however, not too speculative to assume that in the future more patent applications will still be filed, but in a reduced number.

The basis for the formation of meat-like flavor having the species characteristic is a careful selection of the starting materials. Protein hydrolysates are in most cases prime ingredients. The type of flavor produced can be controlled by the reaction conditions: the presence or absence of water and the temperature/time relationship. From these processings, in which the Maillard reaction is undoubtedly the principal reaction, flavor materials with an aroma and a taste resembling that of cooked, roasted, or grilled meat result.

### References

1. E. C. Crocker, *Food Research*, **13**, 179 (1948)
2. *The Composition of Food*, S. W. Souci and V. Hamann, eds., Scientific Publishing Co., Stuttgart (1969)
3. K. Hofmann, *Die Fleischwirtschaft*, **10**, 1818 (1977)
4. L. Schutte, Symposium, ACS, Washington, DC (1976)
5. K. Mikova and J. Davidek, *Chemicke Listy*, **68**, 715 (1974)
6. U. Stoll, *Ernaehr-Umsch*, **7**, 157 (1973)
7. R. W. Seerley, J. P. Briscoe, and H. C. McCampbell, *J. Animal Science*, **46**, 1018 (1978)
8. R. L. Macy, D. H. Naumann, and M. E. Bailey, *J. Food Science*, **29**, 142 (1964)
9. I. Hornstein and P. F. Crowe, *J. Agricultural and Food Chemistry*, **8**, 494 (1960)
10. O. F. Batzer, A. T. Santoro, M. C. Tan, W. A. Landmann, and B. S. Schweight, *J. Agricultural and Food Chemistry*, **8**, 498 (1960)
11. P. D. Harkes and W. J. Begemann, *J. American Oil Chemist Society*, **51**, 356 (1974)
12. K. Watanabe and Y. Sato, *Agr. Biol. Chem.*, **35**, 756 (1971)
13. A. E. Wasserman, *J. Agricultural and Food Chemistry*, **20**, 737 (1972)
14. T. Yamato, T. Kurato, H. Kato, and M. Fujimaki, *Agr. Biol. Chem.*, **34**, 88 (1970)
15. C. G. May and P. Akroyd, U.S. Patent 2,918,376 (1959)
16. D. A. Lillard and J. C. Ayres, *Food Technology*, **23**, 251 (1969)