

FLAVOUR OF BEEF AND WHALE MEAT

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AS a result of a series of investigations of beef, pork and lamb¹⁻³, we concluded that an identical basic meaty aroma is associated with the lean portion of these red meats and that species flavour differences reside in the fat. To check the validity of the conclusion, that lean meats contribute an identical meaty aroma, we have now compared the volatiles, both chemically and organoleptically, of lean whale and lean beef. If differences in the basic meaty flavour derived from lean meats of different species of animals do exist, one might expect to find them in a mammal that lives in an environment and subsists on a diet so completely alien to that of its terrestrial relatives.

Approximately 20 lb. of lean whale meat were obtained from a 49-ft. sei whale, *Balaenoptera borealis*⁴, less than 20 h after it was killed. The sample was frozen, packed in dry ice and flown to the laboratory where it was kept at dry-ice temperature until needed.

For flavour evaluations, steaks 1 in. thick were cut from the sample, heated to an internal temperature of 150° F and tasted by the laboratory personnel. The results were uniformly unfavourable; all tasters said the steaks were 'fishy', and descriptive terms such as 'metallic', 'oily', and 'rancid' were also used by the panel. The procedures used to concentrate the flavour precursors in lean meats¹⁻³ were applied to the lean whale meat. The following operations were carried out at 0°-4° C. Whale meat (1 kg) was ground and homogenized with 1,500 ml. of water. The slurry was centrifuged, filtered and the extract lyophilized to yield 50 g (5 per cent of starting weight) of a water-soluble red-brown powder. 100 ml. of a 5 per cent solution of the powder (pH 5.2) were refluxed. This solution gave a strong 'fishy' aroma that soon disappeared and was replaced by a typical meaty aroma indistinguishable from the cooked meat aroma obtained from similar solutions prepared from beef, pork or lamb powders. The whale 'broth' by odour evaluation was

gated excellent and described as 'meaty' but without any species identity being attached to the 'meaty' aroma.

Chemical comparisons of lean beef and whale volatiles were made on freeze-dried extracts of the lean meats; 30 g of powder were vacuum pyrolysed at 100° C and 10⁻⁵ mm mercury. Total volatiles were condensed in a trap surrounded by liquid nitrogen. The total volatiles were in turn fractionated at 10⁻⁵ mm mercury by allowing the trap containing the total volatiles to come to room temperature and collecting fractions at liquid nitrogen temperature and at dry ice-acetone temperature. A small amount of residue remained in the total condensate trap. The techniques and apparatus were previously described^{1,3}. The aroma of the fractions from whale were identical to their counterpart fractions from beef. Of particular interest was the residue in the total condensate trap, which in both whale and beef consisted of a very small amount of a colourless, viscous, water-soluble liquid of a pleasant, fruity odour that, on exposure to air, slowly darkened and assumed a 'meaty' aroma. The volatiles were analysed for acidic and basic compounds by conversion to their salts and their subsequent analyses¹; for carbonyl compounds, by conversion to 2,4-dinitrophenylhydrazones¹, and by separation of these derivatives on paper^{5,6}; for hydrogen sulphide, by conversion to methylene blue by a modified procedure of Marbach and Doty⁷; and for lactic acid, by the colorimetric method of Hullin and Noble⁸.

Compounds positively identified in the volatiles from whale, other than water and carbon dioxide, included ammonia, methylamine and trimethylamine, hydrogen sulphide and methyl mercaptan, formaldehyde, acetone and acetaldehyde, and lactic acid and its ammonium salt. Of these compounds, only trimethylamine was absent in the beef volatiles.

In a separate set of experiments, 5 g of whale powder were heated for 45 min at 100° C with nitrogen flowing over the sample, at a rate of approximately 30 ml./min. The volatiles were trapped on a collection coil⁹ and separated by gas chromatography. The column was an 8 ft. × $\frac{1}{8}$ in. outer diameter, stainless steel coil; the liquid phase was 20 per cent castorwax on acid-washed 'Chromosorb P'. The column was temperature programmed, and a flame ionization detector was used¹⁰. 5 g of beef powder were treated in identical fashion. The gas chromatographic patterns are shown in Fig. 1. The qualitative agreement between the two traces is excellent. Only one peak is not common to both, and that is the trimethylamine peak present in whale. The gas stream was split after emergence from the column, part going to the flame detector and the rest to the nostrils of an

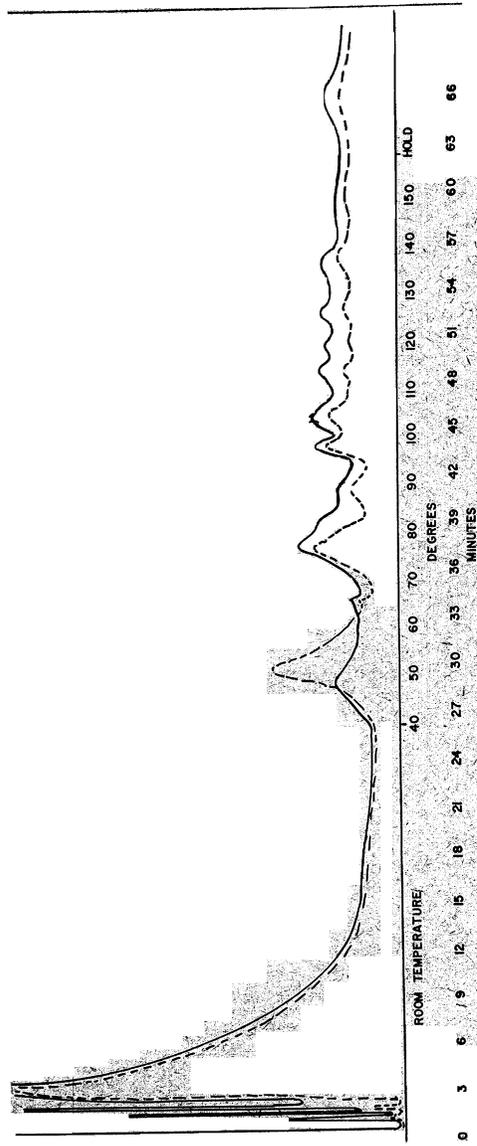


Fig. 1. Comparison of the chromatographic patterns obtained from lean beef and lean whale volatiles. The third peak on whale pattern is absent in beef and represents trimethylamine. Thick line, whale volatiles; dashed line, beef volatiles.

Table 1. FATTY ACID COMPOSITION OF LIPID FRACTIONS (% OF TOTAL FATTY ACIDS) OBTAINED FROM LEAN BEEF AND WHALE. SUPERSCRIPTS REFER TO NUMBER OF DOUBLE BONDS IN ACID. THE DASH SIGNIFIES THAT THE ACID WAS ABSENT

Acid	Triglycerides		Cephalins		Lecithins and Sphingomyelins	
	Beef	Whale	Beef	Whale	Beef	Whale
C ₁₆ ⁰	5.15	7.96	2.28	9.60	4.25	9.91
C ₁₆ ¹	1.73	1.60	1.17	4.95	1.63	7.29
C ₁₆ ²	1.78	—	1.52	—	1.08	—
C ₁₈ ⁰	33.15	13.62	6.63	11.57	18.25	23.80
C ₁₈ ¹	5.10	11.69	2.06	6.17	3.38	10.56
C ₁₈ ²	16.43	5.65	23.91	25.95	7.01	6.54
C ₁₈ ³	31.09	16.35	13.47	20.41	27.57	17.50
C ₁₈ ⁴	4.31	6.19	11.96	4.68	23.05	—
C ₁₈ ⁵	1.31	—	2.92	—	1.36	—
C ₂₀ ⁰	—	3.18	—	2.55	—	0.93
C ₂₀ ¹	—	2.52	—	—	—	—
C ₂₀ ²	—	—	4.11	—	2.71	—
C ₂₀ ³	—	—	22.72	6.84	6.07	4.62
C ₂₀ ⁴	—	14.50	1.81	7.28	0.96	16.64
C ₂₀ ⁵	—	3.47	—	—	0.28	—
C ₂₂ ⁰	—	—	1.43	—	0.92	—
C ₂₂ ¹	—	3.91	3.68	—	2.07	—
C ₂₂ ²	—	9.36	0.33	—	—	2.21

observer. The path-lengths, after emergence from the column, were so adjusted that the odour could be noted as the peak was being recorded. No one compound could be assigned the designation of 'meaty'; however, the collective fractions above 70° C were much more characteristic of meat than were the collective fractions below 70° C. These chromatograms were obtained at high sensitivity, and the peaks at the higher temperatures correspond to microgram amounts of material.

Studies of whale depot fat have shown this to be highly unsaturated¹¹⁻¹³. If the intramuscular lipid fraction was similarly unsaturated, oxidation could account for the observed off-flavour of the whale steaks. The fatty composition of the lipid fractions extractable from lean whale and lean beef were therefore compared. 100 g of diced meat were extracted according to the procedure of Folch *et al.*¹⁴ with 2 : 1 chloroform-methanol. The lipid fraction, after clean-up and solvent removal, was dissolved in a minimum of 20 : 1 chloroform-methanol and chromatographed on silicic acid. Chloroform containing increasing amounts of methanol was used to successively elute two triglyceride fractions, a cephalin fraction, and a mixed lecithin-sphingomyelin fraction¹⁵. The fatty acid composition of the combined triglyceride fraction and

Table 2. FATTY ACID COMPOSITION OF LIPID FRACTIONS (% OF TOTAL FATTY ACIDS) OF LEAN BEEF AND WHALE IN TERMS OF UNSATURATION

Acid type	Triglycerides		Cephalins		Lecithins and sphingomyelins	
	Beef	Whale	Beef	Whale	Beef	Whale
Saturated acids	54.73	33.88	32.82	49.67	29.79	41.18
Mono unsaturated acids	37.92	32.16	16.70	31.53	32.53	35.35
Dienoic acids	6.04	6.19	13.48	4.68	24.18	—
Tetraenoic acids	1.31	—	8.46	—	4.99	—
Tetraenoic acids and greater unsaturation	—	27.77	28.54	14.12	9.10	23.42
Wt. of fraction (g)	4.438	3.767	0.432	0.312	0.443	0.390

each of the other fractions was determined by hydrolysis of an appropriate aliquot, followed by conversion of the fatty acids to their methyl esters and their subsequent separation by gas chromatography^{15,16}.

Retention volume data were obtained on both a non-polar 'Apiezon' substrate and on a polar diethyleneglycol succinate ('DEGS') substrate. Packed columns, 20 per cent substrate on acid-washed 'Chromosorb P', 7 ft. \times $\frac{1}{8}$ in. outer diameter stainless steel, were used. Columns were operated isothermally at 202° C with the 'Apiezon' column and at 192° C with the 'DEGS' column²⁰. Identification of the acids was in the main based on both a comparison of the retention volumes of the methyl esters with knowns and on plots of log of retention volume versus chain length for both liquid phases¹⁵. In Table 1, the fatty acid composition is given for the combined triglyceride fractions, the cephalin fraction, and the combined lecithin-sphingomyelin fraction in whale and beef. The profound difference in the fatty acid composition of the triglyceride fractions is particularly striking. Beef triglycerides contain no fatty acids above C₁₈; whale triglycerides contain approximately 37 per cent C₂₀ and C₂₂ fatty acids, and about 75 per cent of these contain four or more double bonds. The differences in terms of unsaturation in the fatty acid composition of whale and beef liquids are summarized in Table 2.

In a comparison of the phospholipids in lean pork and beef, we noted that the isolated, highly unsaturated, phospholipid fractions quickly assumed fishy, unpleasant off-flavours, while in the total lipid extract, which contained large amounts of the relatively saturated triglycerides, this development of off-flavour was retarded¹⁸. The whale triglyceride fraction, on the other hand, is actually more unsaturated than the phospholipid fraction and, rather than retarding the development of oxidative off-flavours, probably enhances their development. This high degree of unsaturation of the lipid fraction triglycerides, in combination with the trimethylamine presumably formed by the reduction of the trimethylamine oxide present in the whale's food supply, could well account for the poor flavour of the whale meat. The organoleptic and chemical evaluation of the water-extractable portion of the lean whale meat confirms the supposition that a basic meat flavour originates in the lean portions of meats. A corollary can be added; the lean meat, which is in essence an aqueous phase, can act as a reservoir for extraneous, water-soluble materials, in this case, for trimethylamine oxide, that may also affect flavour.

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