RELATIONSHIPS BETWEEN BEEF AROMA COMPOUNDS AND OTHER QUALITY ATTRIBUTES

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The volatile compounds most important for the aroma and flavour of beef are present at very low concentrations and are difficult to detect. Many of these volatile compounds are derived from a small number of very complex pathways. Grilled beef from 14 commercial production regimes was analysed for selected volatile compounds derived from the Maillard reaction, thermal oxidation of lipids or terpene pathways. The results show that some of the more abundant products of these reactions are associated, indicating that grilled beef which is high in Maillard or lipid oxidation products may also be high in other related compounds. These compounds are also linked to sensory attributes.

Key Words – Beef, flavour, aroma, volatiles

I. INTRODUCTION

The compounds contributing to beef flavour [1-4] include water soluble taste compounds and volatile, fat soluble aroma compounds. Many hundreds of these latter have been reported, of which perhaps 20-40 actually contribute to the odour and flavour of the cooked meat. Many of these odour compounds are formed by a small number of very complex reactions, including the Maillard reaction between reducing sugars and amino acids or related compounds, the thermal oxidation of lipids and the breakdown of terpenes from the plant material consumed by the animals [1].

Key odour compounds such as the furanthiols, certain thiazoles and pyrazines have very low odour thresholds and are present at extremely low concentrations. Isotope dilution techniques have been developed for their quantification [5] but they are difficult to detect by routine GC-MS procedures. However, the sharing of common or related pathways within the Maillard or the lipid oxidation reactions may mean that some compounds, although not key odour compounds themselves, show a relationship to flavour quality and to the parameters affecting eating quality. This study aimed to test this hypothesis.

II. MATERIALS AND METHODS

Sample material

Beef animals (28) from 14 different commercial production regimes were sampled as described previously [6, 7]. The groups were chosen to give as wide a variety of eating qualities as possible and included different breeds, sexes, ages of animals, and also different hanging methods and ageing. Some treatment groups were subjected to rapid pH decline such as is characteristic in heat shortening. The two animals in each group were selected to be as alike as possible in all carcase and animal traits. Sirloin (*M. longissimus dorsi*) was frozen as 25mm thick slices prior to analysis.

Sensory and consumer panels

Sensory profiling using a 10 trained panellists assessed samples from all 14 production regimes. From the results, the seven groups which showed the greatest sensory differences were further assessed using consumer panelling with 120 assessors. Sirloin steaks (25mm) were grilled in a clam grill (Silex, Hamburg, Germany) until "well done" by the method described previously [6, 7].

GC-MS analysis

Volatile compounds were collected from steak grilled as described for the sensory panels. The volatiles were collected by placing 20g (+/- 1g) of chopped steak (5-7mm cubes) in a glass flask equipped with a Dreschel head. The sample was held at 65°C and, after equilibration for 5 minutes, the volatiles were swept on to a Tenax

TA tube (Markes International) for 30 minutes at 50ml/min nitrogen. The samples were desorbed on to an Agilent 6890N GC-MS equipped with a 5975B Inert XL MSD and a Unity 1 Markes thermal desorption unit with Ultra 1 autosampler. The samples were analysed on a Zebron ZB5 (60m, ID 0.32mm, DF 0.25 μm) capillary column using gradient elution. The identification of compounds was confirmed by comparison of the mass spectrum and linear retention index with those of authentic compounds or (for methanethiol, dimethyl trisulphide, (E,Z)-2,4-Decadienal and phyt-1-ene) with reported data [8].

Statistics

Residual Maximum Likelihood Analysis (REML) of the sensory profiling data, Analysis of Variance of the instrumental data, Principle Component Analysis (PCA) and External Preference Mapping were conducted using Genstat version 14.1. External preference mapping excluded profiling data where P>0.25.

III. RESULTS AND DISCUSSION

Volatile odour compounds

Table 1 lists the volatile odour compounds analysed in this study. The compounds were selected to be easy to monitor and representative products of the Maillard, lipid oxidation and terpenic breakdown pathways. Analysis of Variance showed that, of the 27 compounds monitored, only seven showed significant differences between groups. Four of these were products of lipid oxidation, two were Maillard products and phyt-1-ene is derived from the terpene breakdown pathways.

Principal Component Analysis

Figure 1 shows the separation of 14 pairs of beef carcases on principal component axes relating to the selected volatile compounds. Principal components 1 and 2 (PC1 and PC2) account for 29 and 22% of the variance. PC1 separates the groups on the basis of total quantities of volatiles, especially lipid oxidation products (shown in green); most of the volatiles are weighted towards the positive side of this axis.

Table 1. Volatile compounds monitored in grilled sirloin, showing likely mechanism of formation and significant differences between production regimes

Compound	Abbrev.[a]	Mech.[b]	Sig[c]
methanethiol	me-thiol	Mld	ns
2,3 butandione	bu-dione	Mld	ns
3-methylbutanal	3mebut	Mld	ns
2-methylbutanal	2mebut	Mld	ns
hexanal	hexanal	Lox	ns
heptanal	heptanal	Lox	ns
methional	methional	Lox	ns
pinene	pinene	Ter	ns
dimethyl trisulphide	DMTS	Mld	ns
1-octen-3-one	1octen3one	Lox	ns
1-octen-3-ol	1octen3ol	Lox	*
2-pentylfuran	2pefuran	Lox	*
octanal	octanal	Lox	ns
limonene	limonene	Ter	ns
phenylacetaldehyde	pheacet	Mld	*
Nonanal	nonanal	Lox	ns
decanone	decanone	Lox	**
decanal	decanal	Lox	ns
Benzothiazole	benzotz	Mld	*
2-decenal	2decenal	Lox	ns
(E,Z)-2,4-Decadienal	Ezdecad-al	Lox	ns
Undecanal	Undecanal	Lox	***
(E,E)-2,4-Decadienal	Eedecad-al	Lox	ns
2-Undecenal	2undecenal	Lox	ns
tridecanone	tridecanone	Lox	ns
phyt-1-ene	phyt1ene	Ter	**
phytane	phytane	Ter	ns

a Abbreviated chemical name used in PCA Figures 1 and 2
b Formation pathway: Mld = Maillard, Lox = lipid oxidation, Ter = terpene breakdown
c Significance: REML on 2 carcases from 14 groups, duplicate analyses ; ns, *, **, *** = not significant, significant at P<0.05, P<0.01, P<0.001 levels.

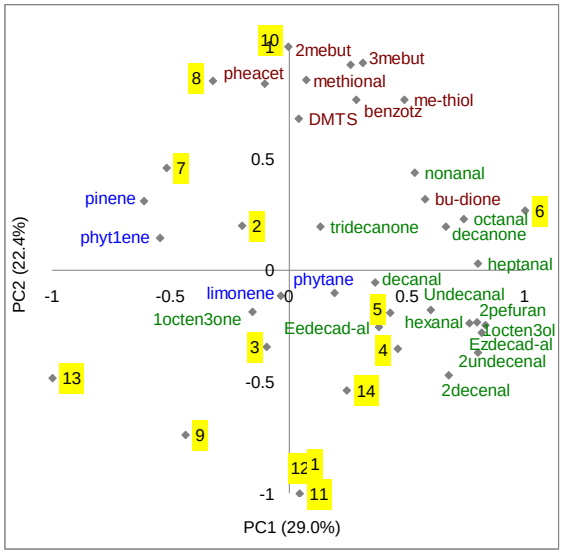

Figure 1. PCA of PC1 versus PC2 for the volatile aroma compounds from grilled sirloin

This could be due either to greater flavour formation in the groups to the right side of the plot, or greater flavour release due to reduced fat content. The groups to the negative side of PC1 included the two most highly marbled groups (7 and 8, US marbling scores 710, 550) with the lowest marbling scores (325, 330) from treatment groups 12 (centre) and 6 (positive side). Thus, PC1 appears to differentiate partly due to the impact of fat content on flavour release but other factors are also involved.

PC2 differentiates groups on the basis of the quantities of Maillard products detected (Figure 1, shown in brown). The beef groups on the positive side of PC2 are Groups 2, 6-8 and 10, all of which were aged for 21 days. The remaining groups were aged for 4-9 days. Thus, the formation of these Maillard products is clearly associated with the extent of ageing.

Amongst the Maillard products monitored, methional, 2-methylbutanal, 3-methylbutanal, phenylacetaldehyde are formed by the Strecker degradation of the amino acids, methionine, isoleucine, leucine and phenylalanine in the presence of dicarbonyl compounds [1]. Dimethyldisulphide and methanethiol are further products of the Strecker degradation of methionine. The dicarbonyl compound, 2,3-butanedione is a product of the Amadori rearrangement and 2,3-enolisation pathways. It is evident from Figure 1 that 2,3-butanedione is located separately from the Strecker-derived Maillard products, which are closely associated.

The lipid oxidation products (Figure 1, green) included saturated aldehydes (C6 to C11) and ketones (C10 and 13) together with a range of unsaturated aldehydes, ketones and alcohols. The unsaturated compounds are loaded towards the negative end of PC2, while the saturated compounds are clustered between these unsaturated compounds and the Maillard products. The unsaturated lipid oxidation products are formed from the thermal oxidation of the more unsaturated fatty acids [1, 4]. For instance, E,E-2,4-decadienal, E,Z-2,4-decadienal, 1-octen-3-ol and 2-pentylfuran are formed from the oxidation of n-6 fatty acids such as linoleic and arachidonic acids, while 2-undecenal is a product of the oxidation of oleic acid [9]. These compounds appear more abundant in beef that has not been aged for 21 days. It is possible that the increased formation of Maillard products in aged beef includes the formation of antioxidative compounds [10, 11], which may inhibit lipid oxidation.

The terpene compounds detected (Figure 1, blue) are likely to be dietary in origin. Phytane and phyt-1-ene have been reported to occur in beef and lamb as a result of microbial breakdown of chlorophyll in the digestive system of ruminants [1]. Elmore *et al*. [12] have reported that phyt-1-ene is elevated in the volatiles from silage-fed beef. The treatment groups analysed in this experiment were obtained commercially and only groups 9, 10 and 14 were reported to have been fed on "grass" or "grass with concentrates". There appears to be no relationship in this experiment between these groups and phyt-1-ene. However, the animals were commercially produced by a number of farmers and it is possible that some of the remaining groups, purported to have been fed on "concentrates", also received some silage.

External Preference Mapping

This investigation formed part of a larger study which included the sensory profiling and consumer evaluation of the beef [6, 7]. Figure 2 shows the external preference map for seven of the 14 beef groups for the sensory profiling attributes for aroma, flavour and aftertaste only. The average scores for acceptability of aroma and flavour and the volatile compounds are correlated on to the same axes. PC1 separates the samples mainly on the intensity of roast beef flavour, beef aroma, liver aroma and lactic aftertaste versus fatty flavour and aftertaste. Most of the aroma and flavour attributes are more intense to the positive side of PC1 and this correlates with lower total fat content in these samples (not shown). Thus, these sensory attributes and the higher quantities of aroma volatiles associated are likely to be explained by increased flavour release.

PC2 separates the groups on the basis of bitter flavour versus sweet flavour, with acceptability

of aroma associated with the latter. The products of the Maillard reaction (brown) are located towards the negative side of PC2 and tend to be associated with sweet flavour, while the lipid oxidation products (green) are more associated with bitter flavour and liver aftertaste. While these compounds may not themselves be responsible for these flavour characteristics, further research may determine whether these associations are helpful in identifying the potential of beef for desirable aroma and flavour.

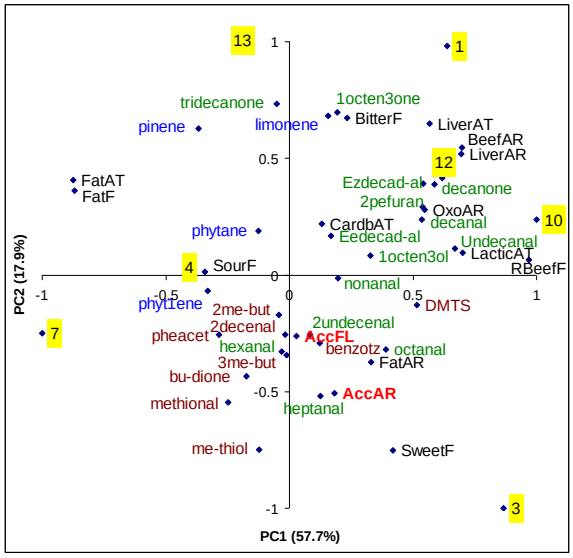

Figure 2. External preference map for aroma, flavour and aftertaste attributes of grilled sirloin, showing correlations with headspace volatiles (Acc, AR, AT, F/FL = acceptability, aroma, aftertaste, flavour)

IV. CONCLUSION

Analysis of selected aroma compounds from grilled sirloin from a range of commercial production regimes suggests that compounds from the same overall formation pathway are associated, indicating that beef which is high in Maillard or lipid oxidation products may be high in other related compounds. These compound classes are also associated with sensory attributes.

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