PS7.06 **Contribution of aqueous precursors to the odour and flavour of cooked meats** 412.00

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***Abstract*—Studies on the sensory impact of changes in precursor concentrations, whether natural or added, provide evidence for their role in the flavour of cooked meats. In chicken, ribose is important, but in red meats a number of sugars appear to contribute. Some of these effects can be explained by differences in natural precursor concentrations between the main meat species. Variations in meat purchased at retail may contribute to flavour differences.**

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I. INTRODUCTION

Much research has been conducted on the key aroma compounds in cooked meats [1, 2] and on the reaction pathways giving rise to these volatile flavour compounds [3]. Precursors that could be important in meat flavour include reducing sugars and related compounds, nucleosides, amino acids and peptides, thiamine and fatty acids. Although all these precursors may contribute, not all will be rate limiting for flavour formation. Their relative importance will depend on whether changes in precursor concentration occur of sufficient magnitude to cause perceptible changes in odour and flavour.

The aqueous components of muscle react together via the Maillard and other reactions to give, for example, meaty, roasted odours and flavours while the fat soluble components react to give e.g., grassy, fatty and species specific flavours [1, 2]. Many of the aqueous components can also contribute to taste while lipids contribute to the release of flavour. However, this paper considers only aqueous meat components in their role as precursors of odour and flavour compounds.

The relative contribution of the different aqueous precursors to the desirable odour and flavour of meat remains unclear and appears to differ for the different species' meats. This paper examines the evidence for the role of aqueous precursors for cooked flavour of meat in the light of recent data on the concentrations of precursors in commercially available meats.

II. MATERIALS AND METHODS

A. Source of meat and yeast extract

Beef, lamb, pork and chicken were obtained from supermarkets or from meat processing plants. Samples were obtained from a range of sources and on different dates, to ensure that different animals and shelf-lives were sampled.

B. Addition of precursors into meat prior to cooking

Precursors in aqueous solution were mixed with raw minced and homogenized meat in a ratio 1:10 and equilibrated prior to cooking and presentation to consumers for odour analysis as described previously [6].

C. Analysis of nucleotides, nucleosides and bases

IMP and inosine were extracted using perchloric acid and analysed either by reverse phase HPLC [7] or on a HyPurity Aquastar column (5 µm, 150 mm x 4.6 mm i.d; Thermo Electron Corporation, Manchester, UK). Detection was on a variable wavelength UV detector, UV1000 (Thermo-Separation Products, Manchester, UK) with UV detection at 254 nm. The isocratic mobile phase was KH_2PO_4 (50 mM, pH 2.5) with a flow rate 1 ml min^{-1}. Recoveries for these methods ranged from 87 to 104%.

D. Analysis of sugars and sugar phosphates

Reducing and phosphorylated sugars in beef were analysed by ethanol extraction followed by post-column derivatization HPLC, after an enzymatic reaction to convert phosphate sugars to their parent sugars [8]. Analyses of all meats and confirmation of identities was conducted by GC-MS [9], using an Agilent HP-Ultra capillary column (12 m x 0.2 mm x 0.33 µm). Recoveries for these methods ranged from 84 to 98% for sugars and 56 to 85% for sugar phosphates.

III. RESULTS AND DISCUSSION

Research investigating the relative importance of flavour precursors for the ultimate flavour of meat has generally followed one of three approaches:

(a) Known quantities of precursors have been added to raw meat and the impact on sensory quality determined.

(b) Meat showing natural differences in precursor concentrations has been compared by sensory panels.

(c) Production or processing changes have been used to alter the concentrations of precursors and chemical and sensory analyses conducted to relate precursor concentrations and flavour.

In contrast with (a), methods (b) and (c) have the advantage that the precursors are present in their natural cellular environment within the muscle. However, the generation of changes in precursor concentration is difficult and the effect of these changes is often confounded by other physiological differences. Many initial studies have, therefore, been conducted using addition studies (a).

The methodology used for addition studies has involved equilibration of the precursor with comminuted muscle. This provides an opportunity for enzymic conversions to take place. Meinert *et al.* [10] measured ribose and ribose-5-phosphate 2 hours after addition and found that 70% of the ribose and 98% of the ribose-5-phosphate had disappeared. Studies in our own laboratory concur that these enzymic processes are very active (*Farmer, unpublished data*). Thus, the mechanism for the observed impact of these precursors on sensory quality may be indirect rather than direct.

The results from precursor addition studies vary between different meats and different trials. The results of these studies (published and new data) are summarized on the right side of Table 1. When these studies commenced, little accurate information was available on the concentrations of some potential flavour precursors [11]. Since then, the natural concentrations for potential aqueous precursors have been determined and selected data, from our own and other laboratories, are summarized on the left of Table 1. Mannose, fructose, ribulose and other sugar phosphates were also detected at lower concentrations (not shown).

A. Chicken

Studies comparing chicken meat shown to have natural differences in flavour demonstrated that the resulting differences in odour profile arose from changes in odours described as “meaty” and “chicken-like” [12]. These odours were mainly caused by sulphur-containing compounds such as methional and 2-methyl-3-furanthiol. Such compounds may be derived from the Maillard reaction between flavour precursors such as reducing sugars and S-containing amino acids or proteins or from the breakdown of thiamine [2]. Studies investigating the role of these aqueous precursors in cooked chicken found that ribose was critical for odour and flavour formation [6]. Other substances (other sugars, IMP, cysteine, thiamine) required an addition greatly in excess of their natural concentrations to alter the odour characteristics (Table 1) and are unlikely to be rate limiting for flavour formation. A 2-3 fold increase over the natural concentration of ribose was enough to give a perceptible increase in roast chicken flavour. The fact that such a small increase in ribose can change flavour was confirmed by demonstrating that natural differences in ribose concentration coincided with increased sensory scores for “roast chicken flavour” [6]. Analyses have indicated that such a variation [8] might be expected to occur in chicken from retail sources, both between sources of chickens and between individual samples. Some of these differences may be explained by substantial changes occurring during chilled shelf-life, with an increase in ribose and decrease in IMP (*Aliani et al., unpublished data*).

B. Beef

The key aqueous precursors of the meaty and roasted flavour in beef are less clear than in chicken. Small additions of ribose (of 1 to 8 times the natural concentration) can sometimes increase meaty and roasted odours (Table 1). However, unlike in chicken, small additions of glucose or glucose-6-phosphate can give similar effects. This discrepancy may be explained by the relative concentrations of these compounds (Table 1). While the natural concentrations of ribose are similar in beef and chicken, concentrations of glucose and glucose-6-phosphate are much higher in beef. Therefore, doubling or tripling the concentrations of these compounds would be expected to have more effect on the odour and flavour of beef than chicken. Other five and six carbon sugars and their phosphates, reported at lower concentrations in beef [9], may also contribute to these flavour forming reactions. IMP may also influence meaty and roasted odours, while thiamine had no effect at close to natural concentrations (Table1).

Standard deviations for ribose, glucose and glucose-6-phosphate varied (Table 1), but where beef was sampled from supermarkets rather than forming part of a controlled study the coefficients of variation ranged from 30% for glucose to nearly 70% for ribose and glucose-6-phosphate. This could be sufficient to give flavour differences between the extremes of the distribution. As for chicken, variation in some precursors is explained by changes occurring during ageing [13].

Addition of ribose or ribose-5-phosphate appears to cause changes in odour and flavour through increased concentrations of key flavour compounds such as diand trisulphides of 2-methyl-3-furanthiol, methional and thiazoles [5]. Additions of sugars and IMP to beef has also been shown to decrease the volatile compounds formed by thermal oxidation of lipids in the cooked meat [5]. Thus, changes in sugars may change the balance of odour compounds formed.

Changes to the salt concentrations may also change the balance of odour forming reactions. Injection of an "enhancement solution" containing salts and polyphosphates (pH7.2), intensified beef flavour and reduced rancidity and livery off-flavour [14]. These changes were reported to be due to changes in taste and possibly suppression of lipid oxidation products. Elevated phosphate concentrations are also known to enhance several flavour-forming reactions. Koutsidis *et al.* [13] have reported that free phosphates increase by more than 30% during ageing from 1 to 21 days. Whether this increase is sufficient to increase flavour formation requires further experimentation.

C. Pork

The natural concentration of glucose in pork is as high as in beef but glucose-6-phosphate is 10-fold lower, similar to that in chicken. Ribose and IMP concentrations were similar to the other meats. The relatively high concentration of glucose in pork, together with considerable variation, may suggest that glucose could be important for flavour differences in pork. However, the evidence for the role of glucose and other sugars is unclear. Early studies [4, 15] showed that ribose and IMP increased meaty, roasted and/or grilled odours, while glucose and glucose-6-phosphate gave mixed results (Table 1). However, analyses (Table 1) show that, while the glucose additions in these studies were comparable to natural concentrations, additions of ribose and glucose-6-phosphate were considerably in excess. Addition studies using glucose, mannose and glucose-6-phosphate (added at 28, 1.2 and 0.5 mmol kg^{-1}, respectively) gave some increases in the volatile compounds formed but ribose (8 mmol kg^{-1}) had no effect [10]. The authors suggested that this may have been due to enzymic loss of ribose.

The analysis of precursors in pork from pigs from different breeds, aged for different periods found no relationship between ribose and flavour [16, 17]. However, pork from one breed was found to have more glucose and glucose-6-phosphate than the other and this corresponded to increased sensory profiling scores for burnt caramel, sweet and sour odours and flavours [16]. However, whether this effect was linked to precursor concentrations, differences in ultimate pH or other factors is uncertain.

In order to give different natural precursor concentrations, pork has been produced under different conditions of feeding, fasting, slaughter weight, gender and ageing [18]. Concentrations of ribose were very low in all treatments (0.1-0.2 mmol kg^{-1}) but mean concentrations of glucose, glucose-6-phosphate (Table 1) and mannose varied. Nevertheless, the sensory differences were small and did not relate to precursor concentrations. Piggy odour was related to weight at slaughter, which also correlated with thiamine concentration, but the mechanism of any causative link is unclear.

D. Lamb

Early studies [19] showed that adding xylose into lamb gave increases in flavour. The few analyses conducted on flavour precursors in lamb indicate that concentrations of glucose were similar to those in beef and pork (Table 1). Ribose concentrations were low but this could relate to the extent of ageing. Further studies would be needed to determine the effect of changes in sugar concentrations on lamb flavour.

IV. CONCLUSION

Studies of the sensory impact of small changes in precursor concentrations, whether natural or added, have shown that increases in reducing sugars can increase meaty and roasted aromas in most species meats. In chicken, ribose is important, but in red meats a range of reducing sugars may contribute. Some of these observed differences can be explained by substantial differences in natural precursor concentrations between the main meat species. The variation between different samples of meat purchased at retail may explain observed differences in the flavour intensity in cooked meats. While the natural concentrations of thiamine and cysteine are too low for these compounds to be limiting for flavour, further studies are required to clarify the role of changes in IMP and free phosphates.

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Table 1. Concentrations of selected aqueous precursors in meats and effects of their addition into meat on sensory quality

Prec-ursor[a]	Meat	Natural concentration in meat[b]				Impact of added precursors to aroma and flavour		
		Conc. (mmol kg^{-1})	SD	n	Ref./ foot-note	Added conc. (mmol kg^{-1})	Impact	Ref.
GLU	Chicken	2.2	1.0	24	[8]	4.4	No effect on aroma	[6]
		1.5	1.1	6	e	5.6	No effect on flavour	[6]
	Pork	46	24	24	[16], c	7.8	No effect on aroma	[4]
		10	5	24	[16], d	16	More “meaty” aroma	[4]
		18	6.1	5	e	50	No effect on aroma	[15]
		4.5 - 12	up to 4	80	[18]			
	Beef	8.2	0.3	8	[9], f	4.1, 7.8	No effect on aroma	[4]
		9.2	0.4	16	[13], g	16	More “roasted” aroma	[4]
		11, 12	3, 3	15, 6	e			
	Lamb	7.9	1.7	6	e			
G6P	Chicken	0.56	0.44	24	[8]	3.3	No effect on aroma	[6]
	Pork	0.6	0.2	24	[16], c	9.8	No effect on aroma	[4]
		0.2	0.1	24	[16], d	20	More “roasted” aroma	d
		1.4 – 5.3	up to 1.4	80	[18]	25	No effect on aroma	[15]
	Beef	6.3	0.3	8	[9], f	3.1	No effect on aroma	e
		7.1	0.5	16	[13], g	9.2-9.9	Intermittent effect	[4]
		6.3	3.9	11	e	19.7	More “meaty” and “roasted” aromas	[4]
RIB	Chicken	1.7	0.6	24	[8]	3.3-6.7	More “chicken”, “meaty” and “roasted” aromas	[6]
		0.14	0.03	6	e	6.7	More “roasted” flavour	[6]
	Pork	1.5	0.9	24	[16], c	40, 80	More “meaty” and “roasted” aromas	[4]
		1.4	0.6	24	[16], d	50	More “grilled” and “caramel” aromas	[15]
		0.14	0.02	5	e			
		0 – 0.2	-	80	[18]			
	Beef	0.67	0.02	8	[9], f	40, 80	More “meaty” and “roasted” aromas	[4]
		1.3	0.06	16	[13], g	0.9, 1.5, 2.5, 8.5	Intermittent effect. Sometimes more “meaty” aroma	e
		1.6, 1.0	1.1, 0.3	15, 6	e			
	Lamb	0.12	0.02	5	e			
R5P	Chicken	0.44	0.22	24	[8]	1.8, 3.3	No effect on aroma	[6]
	Beef	0.04	0.003	16	[13], g	0.45, 1.4	No effect on aroma	e
		0.35	0.38	9	e			
	Pork					25	No effect on aroma	[15]
CYS	Chicken	0.002	0.004	6	[7]	4.1	No effect on aroma	[6]
	Beef	0.12	0.01	8	[9], f			
		0.12	0.02	16	[13], g			
IMP	Chicken	2.4	1.07	30	[7]	2.2, 4.3	More “off” odour	[6]
						5.5	No effect on flavour	[6]
	Pork	2.4	0.2	4	[17]	4.9, 9.8	More “meaty” and “roasted” aromas	[4]
	Beef	3.5	0.2	8	[9], f	4.9	No effect on aroma	[4]
		3.7	0.1	16	[13], g	9.8	More “meaty” and “roasted” aromas	[4]
		1.2	1.2	3	e			

Precursor[a]	Meat	Natural concentration in meat[b]				Impact of added precursors to aroma and flavour		
		Conc. (mmol kg^{-1})	SD	n	Ref./ foot-note	Added conc. (mmol kg^{-1})	Impact	Ref.
INO	Chicken	1.4	0.4	30	[7]			
	Pork	3.3	0.2	4	[17]			
	Beef	1.8	0.1	8	[9], f			
		1.9	0.1	16	[13], g			
		1.7	2.4	3	e			
THI	Chicken	0.006	0.002	6	[7]	0.027	No effect on aroma	[6]
						3.0	More "meaty" aroma	[6]
	Beef	0.004			[11]	0.015	No effect on aroma	[11]

a GLU = glucose, G6P = glucose-6-phosphate, RIB = ribose, R5P = ribose-5-phosphate, CYS = cysteine, IMP = inosine 5'-monophosphate, INO = inosine, THI = thiamine. b The natural concentrations are reported do not correspond to the addition studies, unless the reference is common. c, d Pork from Hampshire, Landrace, Yorkshire cross or Duroc, Landrace, Yorkshire crosses, respectively. e Analyses conducted in our laboratory; where two values, these were by HPLC and GC-MS, respectively. f, g Beef from Aberdeen Angus steers, on silage, aged for 10d or from Charolais steers, aged 14d, respectively.