THE DISTRIBUTION OF N-NITROSOPYRROLIDINE BETWEEN LEAN, FAT AND VAPOUR IN FRYING BACON

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When bacon rashers were fried after separation into lean, fat and rind components N-nitrosopyrrolidine was found almost exclusively in the residual fatty tissue and cooked out fat. The nitrosamine in the residual fried material and cooked out fat only represented a small part of the total nitrosamine produced. The cooking vapours were found to contain 70-80% of the total N-nitrosopyrrolidine formed during frying. The total N-nitrosopyrrolidine yield from the fat was at least fifteen times higher than that from the lean.

LA PRESENCE DE N-NITROSOPYRROLIDINE ENTRE LE MAIGRE, LE GRAS ET LES VAPEURS DANS LE BACON QUI FRIT

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Quand des tranches de bacon ont été frites après leur séparation en maigre, gras et couenne, du N-nitrosopyrrolidine a été découvert presque exclusivement dans le tissu gras résiduaire et le gras qui sort pendant la cuisson. La nitrosamine dans la matière frite résiduaire et le gras qui sort pendant la cuisson ne représentait qu'une petite partie de toute la nitrosamine produite. On a trouvé que les vapeurs produites au cours de la cuisson contenaient de 70 à 80% de tout le N-nitrosopyrrolidine produit au cours de la cuisson. La production totale de N-nitrosophyrrolidine du gras a été au moins quinze fois plus élevée que celle du maigre.

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DAS VORKOMMEN VON N-NITROSOPYRROLIDIN ZWISCHEN MAGEREM FLEISCH, FETT UND KOCHDUNST BEIM BRATEN VON SCHWEINESPECK

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Als Speckschnitten nach Trennung in mageres Fleisch, Fett und Rinde gebraten wurden, kam N-Nitrosopyrrolidin fast ausschließlich im zurückbleibenden Fettgewebe und im ausgekochten Fett vor. Das Nitrosamin im zurückbleibenden gebratenen Material und im ausgekochten Fett bildete nur einen kleinen Anteil des insgesamt erzeugten Nitrosamins. Der Kochdunst erhielt, wie es sich herausstellte, 70-80% des gesamten N-Nitrosopyrrolidins, das beim Braten entstand. Die Gesamt-N-Nitrosopyrrolodinabgabe des Fetts war mindestens fünfzehnmal höher als die des Magerfleisches.

ПРИСУТСВИЕ N - НИТРОСОПИРРОЛИДИНА МЕЖДУ ПОСТНЫМ И ЖИРНЫМ МЯСОМ И ИСПАРЕНИЕМ ПРИ ЖАРЕНЬИ БЕКОНА

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При жарень кусков шпика посте разделения на постные кусочки, жирные кусочки и корку N-нитросопирролидин был обнаружен почти исключительно в оставшейся жирной ткани и выжаренном жиру. В оставшихся жареных кусках и выжаренном жиру нитросамин составлял только маленькую часть всего произведённого нитросамина. В выделившихся парах обнаружено было 70-80% всего N-нитросопирролидина, образованного при жарень. Количество N-нитросопирролидина, образованного при жарень жирных кусков было по крайней мере на пятнадцать раз выше, чем при жарень постных кусков.

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INTRODUCTION

The occurrence of N-nitrosamines in cured meat products has been the subject of much research during recent years. Nitrosamines have only been found sporadically in cured meats with the exception of fried bacon where N-nitrosopyrrolidine (NPYR) has been found consistently, generally at concentrations in the range 5-20μg/kg but occasionally at levels in excess of 100μg/kg[1-5]. It has been suggested that NPYR is formed from proline by combined decarboxylation and nitrosation, although other amino acids and diamines such as spermidine and putrescine have been shown to produce NPYR on heating with nitrite[6].

NPYR formation in bacon is temperature dependent; cooking below 100°C produced no NPYR whereas concentrations were found to increase with increasing cooking temperature[3]. Bacon containing a high proportion of fat appears to produce more NPYR than leaner cuts and the fat exuded during cooking appears to contain at least as much NPYR as the bacon itself. When bacon was separated into lean and fat and fried, Fiddler et al[4] found that NPYR was formed in the fat but not in the lean.

In recent work[5], we examined the formation of NPYR in the lean, fat and rind components of bacon (Table 1).

TABLE 1. N-Nitrosopyrrolidine (μg/kg) in the lean, fat and rind components of fried bacon. Residual sodium nitrite concentrations (mg/kg) before cooking shown in parenthesis.

	Lean	Fat	Rind	Exuded Fat
Components separated before frying [a]	ND (76)	13 (42)	1 (407)	7 (-)
Rashers fried whole [b]	2 (113)	3 (36)	3 (437)	6 (-)

ND = Not Detected a = mean of 4 determinations b = mean of 6 determinations

Where rashers were fried whole similar levels of NPYR were found in the three components and in the exuded fat, but when the lean, fat and rind were fried separately, NPYR was found almost exclusively in the residual fatty tissue and the exuded fat. Rind from Wiltshire-cured bacon was known to contain very high nitrite levels, arising from immersion of the sides in cover brine during curing, but this did not result in high NPYR concentrations in the rind, nor did it appear to influence the yields in the adjacent fat.

This paper discusses factors which may be responsible for fat-preferred NPYR formation and reports on the distribution of NPYR between cooking vapours and rasher components during frying of bacon.

EXPERIMENTAL

Materials

Bacon sides, obtained from a local factory were cured by a Wiltshire process with brines containing nitrite and nitrate. The bacon was sliced into rashers, some of which were further separated into fat and lean before frying. The material was fried at 178°C, in a thermostatically controlled electric frying pan equipped with an aluminium lid and fitted with a short chimney terminating in a conical joint machined to accept a B19 ground-glass socket. In this way, the pan was connected to three traps in series, the first cooled with ice/salt and the other two with solid carbon dioxide. The material was fried for 12 mins, during which time it was turned over once; both lean and fat components attained a temperature of 145° ± 5°C. The procedure was repeated until sufficient fried material and trapped vapours had been accumulated for NPYR analysis. Fat exuded during cooking of each batch was poured off, stored and then combined with the appropriate fried material before analysis.

N-Nitrosopyrrolidine Analysis

Extracts were prepared according to published procedures[5] from 250g samples of residual fried material, including exuded fat, and from similar quantities of trapped cooking vapours from the whole rashers and the batches of separated lean and fat. The extracts were analysed for NPYR by the Laboratory of the Government Chemist using gas chromatography-high resolution mass spectrometry[7].

Free Proline Analysis

The free amino acids in 5g samples were extracted by the method described by Zumwalt et al[8] using picric acid to precipitate the protein and Amberlite CG-120 cation-exchange resin to purify the extract. Analysis was then carried out on a Locarte Mk I Bench Model Amino Acid Analyser using 8½% cross-linked sulphonated polystyrene cation-exchange resin (6-8 micron).

RESULTS AND DISCUSSION

A high proportion of the total NPYR formed during cooking was evolved in the cooking vapours (Table 2). The loss in weight of the lean during cooking was approximately 55% and since this was recovered in the form of trapped vapour, it can be calculated that approximately 80% of the total NPYR formed had been volatilised. Similarly, for the fatty tissue, the cooking loss (as vapour) was 14% and thus the proportion of NPYR in the vapour was 78%, while the corresponding values for the whole rasher were 39% and 65% respectively.

TABLE 2. N-Nitrosopyrrolidine (μg/kg) analysed in the tissue residues and cooking vapours of frying bacon.

	Lean fried alone		Fat fried alone		Whole rasher	
	Residue	Vapour	Residue	Vapour	Residue	Vapour
Bacon side 1	2	7	14	198	12	20
Bacon side 2	1	3	8	296	10	43

In a recent report Gough et al[9] also found that the highest proportion of NPYR from frying whole bacon rashers was recovered from the cooking vapours.

The higher water content of the lean results in higher cooking losses, and since NPYR is fat soluble and steam volatile it might be expected that NPYR would accumulate in fatty tissue during cooking, whilst being lost by steam distillation from the lean. However, the much higher quantities of NPYR in the trapped fat vapours do not support this hypothesis. Similarly, differences in temperature of lean and fat during cooking do not provide a tenable explanation of the fat-preferred formation of NPYR. The fat reaches a higher temperature more quickly than does the lean due to its lower water content and low specific heat, but in the experiments described here thermocouple measurements of temperature during cooking showed that the lean attained a temperature similar to that of the fat despite the variable nature of pan frying. It does not seem likely therefore, that small differences in the rate of heating or final temperature could be responsible for the regularly high NPYR levels found in fried bacon fat.

A more promising explanation may lie in differences in the physical and chemical composition of the lean and fat. Adipose tissue comprises 10-15% water, 2-3% structural components, the remainder being lipid. The structural components are over 90% collagen and this must provide the main source of the amine precursor for NPYR. In fact collagen has been shown to yield 0.07 mg NPYR/g when heated with nitrite at 140°C in a simulated frying system[10]. Although fat contains more collagen than lean, the rind comprises 20% collagen (Table 3) and therefore if the concentration of collagen was an important factor the rind, which also has the highest nitrite concentration (Table 1), should have yielded more NPYR than either the fat or the lean.

TABLE 3. Collagen and free proline levels in lean, fat and rind components of bacon.

	Collagen [a]	Free proline [b]	
		Before frying	After frying
Lean	0.3	0.43	0.48
Fat	2.5	0.11	0.21
Rind	20	0.47	0.65

a = mg/100g uncooked material.

b = μmole/g uncooked material, after adjustment for weight losses during frying.

The free proline concentrations in the three components do not differ to an extent which could account for the observed differences in NPYR formation. It is, therefore, necessary to consider the lipid phase of the adipose tissue. Although it is unlikely that it provides the biological precursor for NPYR, it may catalyse nitrosation and decarboxylation by the promotion of mechanisms other than the classical ionic reactions of aqueous systems. Further work is in progress to investigate these possibilities.

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