THE RELATIONSHIP BETWEEN MUTAGENIC ACTIVITY AND FLAVOUR DEVELOPMENT IN FRIED BEEF STEAK

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INTRODUCTION

It is well-known that brown colour and good flavor are developed in the crust of fried meat. Recent research has shown that several mutagenic compounds can be formed during the frying process. (1) Three of these mutagenic compounds have been shown to be carcinogenic in animal studies (2). Our own research has earlier shown that creatin(in)e is an important precursor and that the Maillard reactions are important for this formation (3, 4, 5). It is also well-known that flavour in meat derives from the water soluble precursors (reducing sugars and free amino acids) which during cooking form hundreds of different types of compounds, e.g. pyrazines and pyridines. No single compound has been identified as being related specifically to meat flavour. Flavour is instead a synergistic effect of many compounds altogether (6). For evaluating flavour a sensory panel is therefore an essential instrument. No study has been published where the mutagenicity and flavour of fried meat have been related.

OBJECTIVE

To find out the frying conditions which would result in both a good flavour and a low mutagenicity of a beef steak.

MATERIAL AND METHODS

Beef steaks, 15 mm thick, from Longissimus dorsi muscle with a fat content of 2% and a weight of 90-200 gram, were used.

Frying was performed on a teflon-coated thermostatic fryer using 3 gram of margarine-fat per beef steak. The temperature of the beef steaks before frying was 15°C. Ten different temperature/time combinations (130-290°C for 1.5 to 9 min/side) were used for the flavour evaluations. Only five of these combinations were used in the mutagenicity test and analysed chemically.

Chemical analyses of cretin(in)e were performed using an enzymatic method and brown colour was measured as absorbance at 375 nm per gram dry matter after perchloric extraction of the crust, as described earlier (4).

The weight of the samples was registered before and 10 min after frying and the weight losses calculated. Internal temperature was registered immediately after frying by using a thermo-element.

Mutagenicity of the crusts was performed using Ames test (Salmonella typhimurium TA 98+S9), as described earlier (4). Mutagenicity was expressed as revertants/100 gram wet weight (gE).

Flavour was evaluated by a sensory panel (6 experts). 1/3 of the fried beef steak was served in metal petri dishes under red light, 5 samples at a time. Double samples were evaluated. 15 different attributes were judged by smell (not taste). A hedonic intensity scale from "1 to 9"; "none-to-much" was used. Large differences were obtained for the flavours burned, fried and charcoal; small differences for the flavours smelling intensity, boiled, smelling impression, bitter and petrol but no differences for the flavours meaty, liver, bloody, pig, sour, burned hair and sweet. Results are only given for the burned, fried and boiled flavours in this paper.

RESULTS AND DISCUSSION

Mutagenicity was found in all five samples, between 200-23 000 revertants per 100 gram wet weight, (Table 1).

Measuring mutagenicity does not reveal any information about the amounts of different mutagenic compounds that can occur in the crust (1, 8), and of which all have different specific mutagenicities (7). However, Knize et al., (8) have shown that, when frying ground beef, the distribution of mutagenic peaks (three identified and three unindentified compounds) was independant of the thickness of the patties as well as the cooking temperature (200 and 300°C). Thus, the conclusions of this paper are based on this fact and on the assumption that it is also relevant for lower frying temperatures.

Creatine was partly converted to creatinine depending on the frying time and temperature. For samples fried at 130°C 6 min/side, 180°C 3 min/side or 220°C 3 min/side was 12-18% of the creatine converted. For samples fried at 290°C 1.5 min/side only 9% was converted to creatinine but for samples fried at 290°C 6 min/side, 45% of the creatine was converted. Values for brown colour of the crusts varied between 0.7-3.0, the highest value was obtained for the sample fried at 290°C 6 min/side (Table 1). Thus the more creatinine that was formed and the browner the crust, the more mutagenic activity was found in the crust of the beef steaks.

Fig. 1a, b and c show the results from the sensory panel for burned, fried and boiled flavours. Higher temperature and longer frying time resulted in a more burned, more fried but less boiled flavour. The largest differences in between samples were obtained for the burned flavour. Thus, average values on the hedonic scale for burned flavour were between 1.3 and 7.6 while fried flavour varied between 3.5 and 7.7 and boiled flavour between 1.2 and 4.4 (Table 1). This table also shows a comparision between different samples related to the reference sample fried at 180°C 3 min/side. The reference sample had a low value for burned flavour (1.3), a relatively high value for fried flavour (4.0) and a moderate value for boiled flavour (3.0). It also had a weight loss of 22% and an internal temperature of 70°C, which is considered as normal. The sample fried at 130°C 6 min/side resulted in the lowest mutagenicity-value. However, this way of frying would result in a too boiled flavour, a too high weight loss (6 min/side gave 30% and 9 min/side 34% weight loss), and takes too long to fry whilst giving too little brown colour. Frying at 290°C 1.5 min/side gives about the same mutagenicity as the reference sample but the fried beef steak was "rare" (internal temperature 58°C) and had a low weight loss, 9.6%.

It is known that the frying process of meat will result in the formation of a crust, due to the high temperature and drying out of the surface. In the crust, brown colour and meat flavour develop as a result of Maillard reactions (9). Data in the present study support these facts. However, the present data also show that during these conditions mutagenic substances could be formed in the crust. Although no identification of the mutagens was performed in the present study, they are probably the highly mutagenic substances imidazoquinoline and isomers of imidazoquinoxalines (1). Moreover, the much weaker mutagenic compound imidazopyridine (PhIP), which is the major beef mutagen (10), would also be present in beef steaks fried under the conditions presented in this study.

Three types of heterocyclic amines, found in fried beef, have been shown to be carcinogenic in mice and rats and may be involved in human cancer. To assess the actual carcinogenic risk of these compounds and other hetero-cyclic amines to humans it will be necessary to investigate the factors modulating their mutagenicity and carcinogenicity and to determine their intake by humans (2). In spite of the

absence of risk analysis and exposure data, it is prudent to minimize the amounts of these substances in fried meat products. At the same time it is desirable to obtain sufficient fried flavour so that the product is palatable. Frying beef steak at a pan temperature of about 180°C (or probably down to 160°C) for only some minutes on each side seems to be a fairly good way of achieving these demands. This way of pan frying is, in fact, close to the practical advice recommended to Swedish consumers by "Köttinformation" (Meat Information, see reference 11).

CONCLUSIONS

A sensory panel can, when smelling fried beef steks, judge statistical differences in e.g. burned, fried and boiled flavour which are all related to the conditions for frying time and temperature. The conditions for Maillard reactions seem to be important for the amounts of creatinine converted from creatine, for the development of brown colour as well as good (fried) and bad (burned) flavour in the crust. Frying under normal conditions (180°C 3 min/side) will result in low mutagenicity, a good flavour and also in a low weight loss, which is important for the tenderness and juiciness of a beef steak.

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Table 1. Data for evaluation for flavour, mutagenicity and coloration of crust of beef steaks, fried at different conditions. Data for sensory panel: Mean values (n=6) for fried, burned and boiled flavour on a hedonic scale "1 to 9"; "none-to-much"). Comparison is made with the reference beef steak, fried at 180°C 3 min/side with an internal temperature of 70°C and a weight loss of 22%.

Evaluation of flavour	Pan temp/ time °C/ min per side	Burned flavour	Fried flavour	Boiled flavour	Mutagenicity rev/100 gE	Coloration absorbance/ gdm
Too burned	290/6	7.6***	7.7***	1.5**	23 000	3.0
"-	290/3	5.5***	7.2***	1.2***		
"-	220/6	5.2***	7.2***	1.4***		
"-	220/3	4.6***	7.1***	1.2***	2 000	1.1
"-	180/6	5.1***	7.1***	1.2***		
"-	290/1.5	2.7*	6.0*	1.8*	800	0.7
Equal	130/9	2.2ns	6.2*	2.0*		
"-	130/6	1.4ns	5.3ns	2.1ns	200	0.8
"-	180/3	1.3	4.0	3.0	500	1.1
Too boiled	130/3	1.3ns	3.5ns	4.4**		

The differences when samples are compared to the reference:
***P<0.001; P<0.001, **P<0.01; P<0.05; ns = not significant.
rev/100 gE = revertants/100 gram wet weight; gdm = gram dry matter

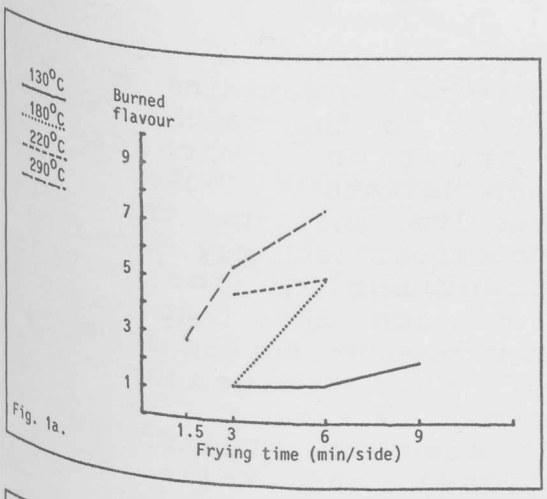

Fig. 1a.

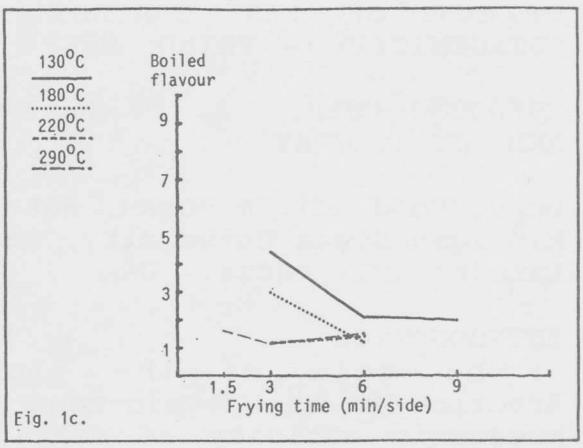

Fig. 1c.

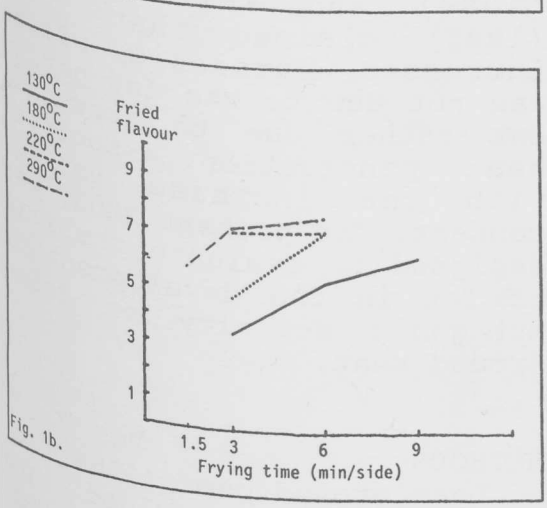

Fig. 1b.

Figure 1a, b and c. Sensory evaluation of beef steaks, fried at different temperatures (130-290°C). Relationships between burned, fried or boiled flavours and frying time. Flavours were evaluated by smell on a hedonic intensity scale from 1 to 9; none-to-much, (n=6).