

The effects of addition of antioxidants, pan-frying temperature and microwave heating on formation of heterocyclic aromatic amines in pork products

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Abstract— The objective was, using two pork products, to examine the effects of 1) antioxidants, 2) microwave heating prior to frying and 3) pan-frying temperature regarding the formation of carcinogenic heterocyclic aromatic amines (HCA) and the influence on sensory characteristics.

As antioxidants, apple puree was added to pork patties and garlic marinade was added to boneless pork chops. The meat underwent microwave heating prior to frying (600 W for 0 or 2 min) followed by pan-frying (150°C or 220°C) until 70°C core temperature. A control without antioxidants was subjected to the same heat treatments. The concentration of the HCA, PhIP, was significantly reduced by applying apple puree ($p=0.003$) and garlic marinade ($p=0.04$). In patties, apple puree completely inhibited the formation of PhIP (0.00 ng/g). A pan-frying temperature of 220°C compared with 150°C resulted in an increased formation of PhIP in pork patties ($p=0.02$) and pork chops ($p=0.003$) whereas microwave heating had no effect on the formation of PhIP.

Pork patties with apple puree had a sweeter taste and became more juicy whereas pork chops with garlic had an intense garlic flavour and odour but also more juiciness. For both pork products, a high pan-frying temperature increased the burnt and fried meat odour and flavour. It can be concluded that apple puree and garlic reduce HCA formation in heat-treated pork products. Antioxidants should be selected according to liking and eating quality as the sensory characteristics of pork with antioxidants may be altered.

Keywords— Heterocyclic aromatic amines, antioxidants, pork.

mon HCAs as showed in beef patties fried at 150°C, 190°C and 230°C for 2-10 min [2]. For beef [3] and pork [4], a higher degree of doneness defined by internal temperature, also increased the content of the HCA compounds, MeIQx and PhIP, respectively. Microwave pre-treatment before frying has shown to greatly reduce the HCA content in beef patties possibly due to excretion of the HCA precursor, creatinine [5].

As HCA formation involves free radical intermediates, antioxidants could act as free radical scavengers and thereby reduce the amount of HCAs in heat-treated meat. This has led to investigations of HCA formation in meat to which natural foods containing antioxidants were added, either by being mixed into the meat or used as marinade. So far, the effects of antioxidants have mostly been studied on beef and chicken and it is therefore of interest to study how antioxidants added to pork affect the formation of HCA.

From a health perspective it is of importance to identify and integrate cooking techniques and practices that minimize HCA formation in meat and hereby reduce daily life exposure to HCA. Also, sensory outcomes of a given cooking practice need to be considered as this may influence eating quality and eventually consumer acceptance. The objective of this study was to examine the effects of 1) antioxidants, 2) microwave heating prior to frying and 3) pan-frying temperature on HCA formation and eating quality of pork patties and pork chops. Eating quality was evaluated by descriptive sensory profiling.

I. INTRODUCTION

Heterocyclic aromatic amines (HCA) are suggested to be one of the biological mechanisms to explain the association of red and processed meat with colorectal cancer [1]. Cooking conditions especially time and temperature during frying are important factors in formation of HCA. Increasing the temperature and/or frying time, increases the formation of the most com-

II. MATERIALS AND METHODS

Pork patties (100 g) made from freshly minced pork shoulder and boneless pork chops (2 cm thick) cut from defatted pork loin were examined. Apple puree and garlic marinade were chosen as foods with antioxidative capacity to be added to pork patties and pork chops, respectively. The apple puree was made from grated unpeeled Golden Delicious apples and mixed

into pork patties (10 % w/w). The garlic marinade was made from freshly-squeezed garlic in tap water (3 % w/w) and 60 g of marinade was used for each pork chop. The pork chops were marinated 16-17 hours prior to frying. Both pork products were heated in a microwave prior to frying (600 W for 0 or 2 min) followed by pan-frying (150°C or 220°C) until 70°C core temperature. Controls without antioxidants were subjected to the same heat treatments.

Sensory profiling was performed by a trained panel (1 male and 7 females). The sensory profiling included a training session with plenum discussions for defining the attributes. At the sensory evaluation, the pork products were served in a randomized order and evaluated by each panellist on a 15 cm unstructured line scale ranging from 0 ('no intensity') to 15 ('high intensity'). The 16 different pork products were served in 3 replicates.

The crust (1 mm) from one of each pork product from each replicate (n=3) was collected for HCA analysis. The content of six common HCAs (PhIP, DiMeIQx, AαC, MeAαC, harman and norharman) was analysed and quantified on Liquid Chromatography-Mass Spectrometry (LCMS).

Analysis of variance (ANOVA) was used for analysis of the sensory profiling data and the chemical data on HCAs (SAS, version 9). The panellist performance was analysed in Panel Check (www.panelcheck.com).

III. RESULTS

A. Heterocyclic aromatic amine (HCA) formation

In this study, the heat treated pork patties and pork chops only contained detectable levels of PhIP of all the HCAs measured. The addition of antioxidants, either as apple puree to pork patties or garlic marinade to pork chops, reduced the PhIP content (Table 1). Pork patties with apple puree did not contain detectable levels of PhIP (Table 1). The content of PhIP increased with pan-frying temperature for each pork product with/without antioxidants except for pork patties with apple puree that had undetectable levels of PhIP (Table 1).

For pork patties and pork chops, significant effects of antioxidants ($p=0.003$ and $p=0.04$, respectively) and pan-frying temperature ($p=0.02$ and $p=0.003$, respec-

tively) on PhIP formation were observed. Moreover, significant interactions between antioxidants*pan-frying temperature were found for pork patties ($p=0.02$) as a larger reduction was seen at 220°C, at which temperature the content of PhIP was largest, compared with 150°C (Table 1).

Microwave heating prior to frying had no effect on PhIP content in neither pork patties ($p=0.57$) nor pork chops ($p=0.27$).

Table 1 PhIP content of pork patties and pork chops with or without antioxidants cooked at two different pan-frying temperatures.

Pan-frying temperature		PhIP content (ng/g meat)		
		150°C	220°C	Stderr
Pork patties	+ apple	0.00	0.00	0.17
	- apple	0.13	1.00	0.17
Pork chops	+ garlic	0.10	0.44	0.14
	- garlic	0.25	0.92	0.14

B. Sensory profiling

The sensory profiling of pork patties and pork chops was influenced by the addition of antioxidants, pan-frying temperature and microwave heating. The mean intensity scores of the sensory attributes are shown in Table 2. The addition of apple puree to pork patties resulted in a sweeter taste and more juiciness while the surface was perceived browner. For pork chops with garlic marinade, the flavour and odour of garlic were pronounced and the garlic marinade moreover reduced the piggy odour and flavour. Whether apple puree or garlic was used in the pork products the odour and flavour of fried meat were less intense.

Microwave pre-treatment decreased the juiciness of both pork products. Moreover, the surface of pork patties was perceived less brown.

Increasing the pan-frying temperature to 220°C, increased the fried meat odour and flavour as well as the burnt odour and flavour in both pork products as expected. The surface of both pork products was moreover perceived as browner.

Table 2 Mean intensity scores (scale 0-15, continuous) of the sensory attributes for pork patties and pork chops dependent on antioxidants, microwave pre-treatment and pan-frying temperature.

	Antioxidant ¹		Microwave ²		Panfrying temp	
	+	-	+	-	150°C	220°C
Pork patties						
<i>Brown surface</i>	8.4	6.8**	7.1	8.1*	5.2	10.0**
<i>Burnt odour</i>	3.7	5.3*	4.2	4.8	1.7	7.3**
<i>Fried meat odour</i>	3.5	4.2*	3.9	3.7	3.5	4.2*
<i>Sweet odour</i> ³	4.3	3.1*	3.6	3.9	3.7	3.6
<i>Piggy odour</i> ⁴	3.3	3.9	3.6	3.6	4.2	3.0*
<i>Burnt flavour</i>	2.3	2.3	2.4	2.1	0.9	3.6**
<i>Fried meat flavour</i>	3.3	4.8**	4.4	4.1	3.6	4.6**
<i>Sweet taste</i>	8.4	4.1**	6.3	6.2	6.3	6.3
<i>Piggy flavour</i>	2.5	3.6*	2.9	3.2	3.7	2.5**
<i>Bitter taste</i>	2.1	2.5	2.3	2.2	1.9	2.6*
<i>Juiciness</i>	8.0	6.8**	7.0	7.8*	7.2	7.6
<i>Coherent</i>	5.3	5.6	5.9	4.9*	5.6	5.3
Pork chops						
<i>Brown surface</i>	7.5	8.3*	8.1	7.7	6.3	9.5**
<i>Burnt odour</i>	0.8	2.0**	1.7	1.1	0.6	2.3**
<i>Fried meat odour</i>	4.6	5.3*	4.8	5.1	4.4	5.5**
<i>Garlic odour</i>	7.8	0.0	4.0	3.9	3.8	4.0
<i>Piggy odour</i>	1.6	2.7**	2.1	2.3	2.3	2.1
<i>Burnt flavour</i>	0.7	1.0	1.0	0.7	0.5	1.1*
<i>Fried meat flavour</i>	4.1	5.9**	4.9	5.1	4.4	5.5**
<i>Garlic flavour</i>	8.9	0.0***	4.7	4.2	4.4	4.5
<i>Piggy flavour</i>	1.2	2.2**	1.7	1.7	1.8	1.6
<i>Juiciness</i>	6.8	6.2*	6.2	6.9*	6.3	6.8

Significant differences between the products in each column are designated with *p<0.05, **p<0.001, ***p<0.0001

¹ apple puree to pork patties or garlic marinade to pork chops

² Microwave heating (600 watt, 2 min) prior to frying

³ Odour of the surface of the pork patty

⁴ Odour of the interior of the pork patty

IV. DISCUSSION

The present study showed that the addition of apple puree and garlic to pork products effectively reduced the formation of PhIP which accounts for most of the general HCA exposure [6]. This effect could be owed to the antioxidative capacity of polyphenols in apples and phytochemicals in garlic.

The carcinogenicity of HCAs has been found in animal models and under experimental conditions but the effect in humans has not been clearly established. Thus, no official threshold for maximum intake of HCAs has been set. A food database of several potential carcinogenic compounds including HCAs has been compiled and published [7]. According to this, pork chops predominantly contain the HCA, MeIQx, which was not quantified in this study. However, PhIP and DiMeIQx are also found in pork chops in the ranges 0.00-4.90 ng/g and 0.00-1.10 ng/g, respectively. A study of the HCA content in restaurant-cooked meat showed that in pork ribs only PhIP was detectable of the HCAs being measured in the range 0.5-7.4 ng/g [8]. In the present study of pork patties and pork chops, the levels of PhIP were low compared with the above-mentioned levels.

The sensory characteristics of pork patties and pork chops were affected by the addition of antioxidants, pan-frying temperature and microwave pre-treatment. Therefore, in the attempt to reduce carcinogenic compounds in meat during cooking, the eating and sensory quality ought to be taken into account as well. The use of antioxidants as marinade to meat should confer good taste and appealing appearance and should not reduce eating quality.

In the present study, microwave pre-treatment of pork patties and pork chops did not reduce the HCA content and resulted on the other hand in less juicy meat. This can be explained by 1-3.3% liquid loss during microwave heating (data not shown). Microwave pre-treatment of meat prior to cooking may therefore not be suggested from a health and good eating quality perspective. The antioxidative effect on HCA reduction was most pronounced at high pan-frying temperature (220°C). The use of apple or garlic as marinade in meat could therefore be beneficial to reduce carcinogenic compounds during grilling or other high-temperature cooking practices.

The present study only analysed for 6 of the common HCAs of which MeIQx was not included. As MeIQx has been found in substantial amounts in other studies [7], it can therefore not be excluded that MeIQx may be present as well in the current heat-treated pork products.

V. CONCLUSIONS

To conclude, the present study showed that apple puree and garlic can be used as antioxidants to reduce the formation of HCA in pork patties and pork chops, respectively. In fact, apple puree completely inhibited the formation of the HCA, PhIP. Moreover, the HCA content increased with increasing pan-frying temperature whereas microwave heating prior to frying had no effect on the HCA content. The examined cooking practices altered the sensory characteristics which are important to consider in order to address eating quality.

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