Effect of Heating Processes on Red Meat

Subjects: Others

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The heating process is a crucial step that can lead to the formation of several harmful chemical compounds in red meat such as heterocyclic aromatic amines, N-Nitrosamines, polycyclic aromatic hydrocarbons and acrylamide. Meat has high nutritional value, providing essential amino acids, bioactive compounds and several important micronutrients which can also be affected by heating processes.

acrylamide heated red meat heterocyclic aromatic amines nitrosamines nutritional value polycyclic aromatic hydrocarbons

1. Introduction

Meat heating processes could result in a number of harmful chemical compounds, so the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) of the United Nations discourage high consumption of meat, especially red meat. This suggestion is due to some toxic effects on humans, such as cardiovascular diseases and cancer risks that these molecules may exercise, especially after heating processes. In particular, the International Agency for Research on Cancer (IARC) Working Group classified processed meat as “carcinogenic to humans” (Group 1), on the basis of sufficient evidence for colorectal cancer, and red meat as “probably carcinogenic to humans” (Group 2A), based on substantial evidence of a positive association between consumption and colorectal cancer, other than strong mechanistic evidence [1]. Despite these aspects, meat consumption is increasing worldwide, particularly in developing countries [2].

On the other hand, meat has high nutritional value, providing essential amino acids, bioactive compounds and several important micronutrients such as iron, zinc and vitamins B3 and B12 [3]. The heating process is a key phase for meat, since it makes foods microbiologically safe to consume and palatable; however, heating processes affect the nutritional value of meat due to changes in some components [4]. It is an extremely complex subject that includes many variables often related to each other.

Several chemical compounds have been listed as possible toxic contaminants of meat. These compounds may be present at low levels in raw meat, but the concentration may increase after heating processes and if preservative agents, such as nitrite/nitrate, have been added to the product [5]. The Heterocyclic Aromatic Amines (HAAs), N-Nitrosamines (NAs), Polycyclic Aromatic Hydrocarbons (PAHs) and Acrylamide have been indicated in the scientific literature as groups of chemicals of concern in meat [6]. Most of these compounds are listed among “processing contaminants” since their levels in the product depend on the specific heating treatment [7] and/or on other food

processing. The occurrence of these classes of compounds in meat has been investigated during the last few years, especially for PAHs [8]. However, many aspects of food safety are still worthy of research. Among these aspects, the evaluation of the contemporary presence of different toxic compounds, also at very low levels, the so-called “cocktail effect”, represents a new frontier in food safety knowledge. In 2019, the European Food Safety Authority (EFSA) released a scientific report focused on understanding chemical mixtures in food, highlighting that the consumer’s level of concern from being exposed to the combined effects of chemicals in food is high [9]. It is worthy of mentioning that there are many gaps in knowledge and, taking into account the significant toxic effects of HAAs, NAs, PAHs and acrylamide described above, and their possible simultaneous presence in meat, further insights are needed.

Another important aspect of food safety, related to meat consumption, is the high variability of toxic compound levels due to the specific product composition and heating processes. Indeed, the differences in meat composition, especially between fresh and processed meat, and relating to the specific lipid/protein profile of meat from different species, influence the formation of HAAs, NAs, PAHs and acrylamide significantly. Previous studies [10][11][12] on the effects of product type/heat treatment type highlighted a correlation with toxic compound composition; this finding is crucial for food safety and it is useful for improving meat product formulations and for correct heat treatment management.

To date, the available literature has discussed the effects of cooking on meat from different animal species such as cattle, chicken or pig (e.g., [13][14][15]), but on the basis of researchers' knowledge, the effect of thermal processing on red meat from different animal species such as sheep, goat and horse, focusing on toxic compounds production and nutritional parameters changes, has not been reviewed.

2. Effect of Heating Processes on Meat Safety

The most significant effects of heating processes on the formation of different contaminants in meat from different animal species have been reported in **Table 1**.

Table 1. Effect of heating processes on the production of processing contaminants in red meat from different animal species.

	Heating Processes					
	Grilled	Roasted/Oven-Broiled	Boiled	Microwaved	Fried	Sous Vide
Cattle	Heterocyclic amines increase in meat [16][17]	Heterocyclic amines increase [18][19]			Heterocyclic amines increase in meat [20]	Heterocyclic amines increase [21]

	Heating Processes					
	Grilled	Roasted/Oven-Broiled	Boiled	Microwaved	Fried	Sous Vide
	Nitrosamines increase in beef preparations [22] and meat [23]			No increase of nitrosamines in beef preparations [22]	Nitrosamines increase in beef preparations [22]	
	Polycyclic aromatic hydrocarbon increase [24][25][26][27][28]	Polycyclic aromatic hydrocarbon increase [29]	Polycyclic aromatic hydrocarbon increase [27]		Acrylamide increase in burger [30]	
	Heterocyclic amines increase in meat [16]				Heterocyclic amines increase in lamb meat [31]	
Sheep and Goat	Nitrosamines increase in meat [32]				Nitrosamines increase in meat [23]	
	Polycyclic aromatic hydrocarbon increase [25][33]					
Pig	Heterocyclic amines increase in meat [16][34]	Heterocyclic amines increase in meat [34]	Heterocyclic amines (MeIQx)	Heterocyclic amines increase in bacon [35]	Heterocyclic amines increase in bacon [35]	

	Heating Processes					
	Grilled	Roasted/Oven-Broiled	Boiled	Microwaved	Fried	Sous Vide
			increase in meat [34]			
	Nitrosamines increase in meat [23]				Nitrosamines increase in meat [23]	
	Polycyclic aromatic hydrocarbon increase [27]	Polycyclic aromatic hydrocarbon increase [27] [36]	Polycyclic aromatic hydrocarbon increase [27]			
Horse	Heterocyclic amines increase in meat [16]					

2. Food

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3. Effect of Heating Processes on Meat Nutritional Value

Generally, the heating process contributes to the loss of water-holding capacity, resulting in the different concentrations of proteins, fat and ash compared to raw meat [37][38]. **Table 2** summarizes the effect of the heating process on the nutritional value (fatty acids, proteins, vitamins, and minerals) of meat from different animal species.

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Table 2. Effect of heating processes on nutritive value of red meat from different animal species.

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	Grilled	Roasted/Oven Broiled	Boiled	Microwaved	Fried	Sous vide
Cattle	Total lipids,		Total lipids, SFA and MUFA	Total lipids, SFA and MUFA	Total lipid increase, SFA increase [40]	Total lipids increase in

	Grilled	Roasted/Oven Broiled	Boiled	Microwaved	Fried	Sous vide
	SFA and MUFA increase, PUFA decrease [39]		increase, PUFA decrease [39]	increase, PUFA decrease [39]		Limousin calves [41]
	Protein digestibility decrease [42] Leucine, glutamic and aspartic acid increase [43]	Protein digestibility increase [42]		Leucine, glutamic and aspartic acid increase [43]	Protein digestibility increase [42]	
	Vitamin E decrease [41] No effect on vitamin B12 [44]	No effect on vitamin B12 [44]	Vitamin B1 and vitamin D decrease [45]		Vitamin D decrease; vitamin B12 decrease [44]	Vitamin E decreases [41]
	Ash increase from 1 to 1.3% [38] Na, K, P, Ca and Mg decrease Fe and Zn increase [45]		Na, K, P, Ca and Mg decrease, while Fe and Zn increase [45]	Fe, Mg and K decrease [46] Ca, Cu, Fe, K, Mg decrease in bovine liver [47]		Ca, Cu, Fe, K, Mg stability in bovine liver [47]
Sheep and	SFA, MUFA and PUFA		Ash increase [49]			SFA, MUFA and PUFA

produced by frying beef, pork and a soy-based food. Food Chem. Toxicol. 1995, 33, 821–828.

	Grilled	Roasted/Oven Broiled	Boiled	Microwaved	Fried	Sous vide
Goat	increase [48]					increase [48]
	Ash increase [49] No differences in total amino acids and in essential amino acids [49]		No differences in total amino acids and in essential amino acids [49]			
	Total lipids and ash increase [47]		Total amino acids content decrease [50] Tryptophan decrease [51]			Protein digestibility increase [52]
Pig	Vitamin B1 strong decrease [45]		Protein digestibility increase [53]			
	Ash increase [38]; Na, K, P, Ca and Mg decrease, while Fe and Zn increase [45]		Na, K, P, Ca and Mg decrease, while Fe and Zn increase [45]			
Horse	Total lipids, MUFA and	Total lipids, MUFA and		Total lipids, MUFA and	Total lipids, MUFA and	

nitrosamines in grilled lamb and vegetables using comprehensive gas chromatography—Nitrogen chemiluminescence detection. Food Chem. 2012, 135, 2215–2220.

	Grilled	Roasted/Oven Broiled	Boiled	Microwaved	Fried	Sous vide
	PUFA content increase; SFA content decrease [54]	PUFA content increase; SFA content decrease [54]		PUFA content increase; SFA content decrease [54]	PUFA content increase; SFA content decrease [54]	

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