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Meat flavor precursors and factors influencing flavor precursors— A systematic review

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ABSTRACT

Flavor is the sensory impression sensed by taste and smell buds and is a leading factor determining the meat quality and purchasing decision of the consumer. Meat flavor is characteristic of volatiles produced as a result of reactions of non-volatile components that are induced thermally. The water soluble compounds having low molecular weight and meat lipids are important precursors of cooked meat flavor. The Maillard reaction, lipid oxidation, and vitamin degradation are leading reactions during cooking which develop meat flavor from uncooked meat with little aroma and bloody taste. The pre-slaughter and postmortem factors like animal breed, sex, age, feed, aging and cooking conditions contribute to flavor development of cooked meat. The objective of this review is to highlight the flavor chemistry, meat flavor precursors and factors affecting meat flavor precursors.

Contents

1. Introduction

The meat purchasing decision of consumers is influenced by quality characteristics of meat and they prefer tender meat and meat products with natural taste and flavor (Reicks et al., 2012). Flavor is the sensory impression of a food sensed by taste and smells buds. Flavor after tenderness is one of the principle factors involved in a consumer's meat purchasing decision (Sitz, Calkins, Feuz, Umberger, & Eskridge, 2005). Meat flavor is a combination of taste and odor; however mouth feel and juiciness of meat also affect the individual flavor perception (Farmer, 1992; Robbins et al., 2003). Fats and low molecular weight water-soluble compounds constitute the most important precursors of cooked meat flavor (Resconi, Escudero, & Campo, 2013). The taste of cooked meat is due to the non-volatile constituents of fresh meat that are essential flavor precursors and taste contributors (Chen & Ho, 1998). The reaction between reducing sugars and amino acids acts

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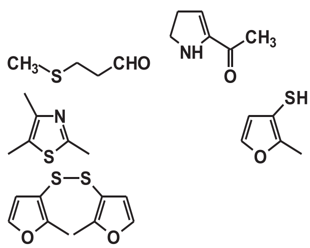
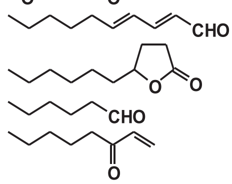
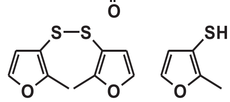
Table 1
Flavor forming precursors, reaction and flavoring compounds.
Source: Framer (1999).

Flavor precursor	Thermal reactions	Flavoring compounds
Sugars, nucleotides, free amino acids, peptides	Maillard's reaction	
Lipids, fatty acids	Oxidation	
Thiamine	Degradation	

as the principal pathway in the formation of cooked meat aroma compounds (Farmer & Mottram, 1990; Mottram & Nobrega, 2002). Cysteine and methionine are considered the largest contributors to meat flavor development (Werkhoff et al., 1990). Vitamin degradation during cooking, lipid oxidation, interaction of lipid-oxidized products with the products of Maillard's reaction and the reactions that are induced thermally as a result of heating during Maillard's reaction produce the volatile flavor components responsible for the characteristic aroma and flavor of cooked meats (MacLeod, 1994). The volatile flavor components are organic in nature (pyrazines, aldehydes, acids, ketones, hydrocarbons, esters, alcohols, nitrogen and sulfur-containing compounds) and they have low molecular weight (Landy, Courthaudon, Dubois, & Voilley, 1996). The volatility of these compounds varied based on variation in their chemical structures. Generally lipids influence the production of aromatic flavor compounds, greatly among all food constituent as they reduce the vapor pressure of most flavor compounds (Rabe, Krings, & Berger, 2003) but most aroma compounds are also lipophilic in nature (Kinsella, 1990) so fats reduce their volatility. Pre- and post-harvest factors influencing meat flavor are animal breed, sex, diets, chiller aging, meat pH, meat composition and cooking conditions (Ames, Guy, & Kipping, 2001; Domínguez, Gómez, Fonseca, & Lorenzo, 2014a, 2014b). So meat flavor is the result of thermally induced chemical reactions of non-volatiles toward the formation of volatile compounds.

2. Meat flavor chemistry

Meat cooking results in the formation of characteristic meat aroma through thermally induced reactions as shown in Table 1. Lipid oxidation, Maillard's reaction, interaction of lipid oxidation products with Maillard's reaction products, and vitamin degradation are thermally induced reactions producing volatile flavor components responsible for the characteristic cooked meat aroma (MacLeod, 1994). The volatile flavor components have low molecular weight and are organic in nature (Landy et al., 1996). A variety of chemical structures is observed in volatile flavor compounds that have been identified in thousands of numbers including aldehydes, acids, ketones, hydrocarbons, alcohols, nitrogen and sulfur-containing compounds (Ba, Oliveros, Ryu, & Hwang, 2013; Lorenzo & Domínguez, 2014; Machiels, Istasse, & van Ruth, 2004; Rochat & Chaintreau, 2005). Meat flavor and palatability are influenced by fat content; the fatty flavor of beef preferred by US consumers increases with the increase in intramuscular fat (IMF) content (Miller, Moeller, Goodwin, Lorenzen, & Savell, 2000) and the minimum IMF level for US consumer acceptance and preference is approximately 3% to describe slightly intense fat flavor (Miller, 2001). The volatiles derived from lipid sources are believed to be responsible for species specific flavor, as higher unsaturated fatty acid differences in fatty acid deposition of ruminants and non-ruminants (Calkins & Hodgen, 2007), produce more volatile carbonyls (major lipid degradation products) in these species (Perez-Alvarez, Sendra-Nadal, Sanchez-Zapata, & Viuda-Martos, 2010). Although a small proportion of fatty acids are oxidized, they can be sufficient to alter flavor significantly (Belitz, Grosch, & Schieberle, 2009). The degree of unsaturation in IMF is important as it determines overall concentration of volatiles from lipid oxidation (Specht & Baltes, 1994). Most of the aroma compounds recognized in cooked meat are the result of Maillard's reaction (Bailey et al., 1994). The precursors formed from 1-deoxysones interact with products of the Strecker reaction resulting in numerous aromatic compounds. Thermal degradation of thiamin produces a number of sulfur compounds like thiol, sulfides and disulfides (Grosch, 2001) which themselves smell or contribute to the development of cooked meat aroma (Kerscher & Grosch, 1998). The aromatic phenolic compounds in the meat of ruminants come directly from plants or they are products of rumen microbial fermentation (Ha & Lindsay, 1991) or formed by tyrosine microbial metabolism (Schreurs, Lane, Tavendale, Barry, & McNabb, 2008). Phenols and hydrogen sulfide react to form thiophenols responsible for meat aroma (Ha & Lindsay, 1991).

3. Meat flavor precursors

The flavor precursors contributing to basic tastes (sweet, salty, bitter and sour) of cooked meat are the non-volatile constituents (sugars, peptides, amino acids, inorganic salts and organic acids) of fresh meat (MacLeod, 1994) and flavor enhancers, inosine 5′-monophosphate, guanosine 5′-monophosphate and monosodium glutamate give 'umami' taste (Maga, 1987). Most meat flavor precursors responsible for producing meat flavor are water soluble in nature (Koutsidis et al., 2008). Meat peptides and free amino acids have a role in contributing taste during aging (Spanier et al., 2004) and/or cooking (Spanier, Flores, McMillin, & Bidner, 1997). Dry-cured hams have high amounts of free amino acids and peptides (Toldra, Flores, & Sanz, 1997; Bermúdez, Franco, Carballo, Sentandreu & Lorenzo, 2014) and these compounds are taste-active that strongly influence the final flavor. Lipid oxidation is one of the main causes of meat quality deterioration during storage and processing (Gray, Gomoa, & Buckley, 1996; Morrissey, Sheehy, Galvin, & Kerry, 1998) but is essential for the development of the typical meaty aroma of many meat products (Shahidi, Rubin, & D'Souza, 1986). Glycolysis, proteolysis and lipolysis result in production of a large number of non-volatile compounds which are important in contributing to meat flavor and mostly endogenous enzymes are responsible for such reactions (Toldrá & Flores, 2000). The reducing sugar content of beef is increased significantly when cattle are fed with concentrate feed during aging resulting in increased concentration of free sugar such as ribose (Koutsidis et al., 2008) which reacts with free amino acids to produce flavor through Maillard's reaction. The production of volatile flavor precursors can be enhanced through supplementation of fats in animal diet which directly affects the fatty acid composition of animal fat (Elmore et al., 2005; Elmore, Mottram, Enser, & Wood, 2000). The intramuscular triglycerides and structural phospholipids are the main components of meat lean tissues. Meat with subcutaneous fat, either cooked or uncooked, contain lipid derived volatiles in larger amounts except for the grilled meat where severe conditions give off Maillard-derived volatiles (Mottram, 1985). Lipids play multiple roles in meat flavor development; they act as solvent for volatile compounds produced during processing (Moody, 1983) and products of lipid thermal oxidation give distinct flavors after reacting with components of lean meat tissues (Mottram & Edwards, 1983).

Table 2
Factors affecting flavor precursors of meat.

Factors	Impact on flavor precursors	References
Animal breed	Animal breed has impact on intramuscular fat, IMP content, and affects the rate of sensory changes	Brennand and Lindsay (1992), Chen et al. (2002), Campo et al. (1999)
Sex of animal	Subcutaneous and inter-muscular fat vary for different sexes. Female animals have juicier meat and sex of animal also influences flavor related compounds	Ellis, Webster, Merrell and Brown (1970), Seideman, Cross, Oltjen and Schanbacher (1982), Jayasena et al. (2014)
Animal age	Age affects intramuscular collagen solubility, increases flavor intensity. Older animals have higher straight chain fatty acids. Age of animal also influences color, flavor, juiciness, tenderness and overall palatability	Young et al. (1997), Brennand, Ha, and Lindsay (1989), Awan, Khan, Khan, and Khan (2014)
Animal feed	Feed affect carcass composition, degree of fattening, fatty acid profile of meat and formation of short branched-chain fatty acids (BCFAs)	Lewis et al. (2002), Wood et al. (2008), Young et al. (2003)
Chiller aging	Postmortem aging improves tenderness by endogenous enzymes and amount of flavor compounds. Amount of volatile compounds derived from fatty acid degradation also increased during aging	Geesink et al. (2001), Gorraiz, Beriain, Chasco, and Insausti (2002)
Meat cooking	Cooking modifies chemical and nutritional composition, enhances flavor, and improves tenderness of meat. Cooking leads to controlled oxidation of lipids. Cooking also influences amount of free amino acids, carnosine, pyrazines, and hexanol	Brugiapaglia and Destefanis (2012), Byrnea, Brediea, Mottram and Martens (2002), Lorenzen et al. (2005)

4. Factors influencing meat flavor precursors

Meat quality, fat deposition and fatty acid composition are influenced by animal breed, sex, diet, live weight, post slaughter aging and their interactions (DeSmet, Raes, & Demeyer, 2004; Wood et al., 2008). The effect of factors influencing flavor precursors has been summarized in Table 2.

4.1. Breed of animal

Breed of animal should be taken into account while assessing consumer preferences of beef throughout aging (Monson, Sanudo, & Sierra, 2005). The impact of animal breed on total fat, IMF and fatty acid composition has been summarized in Table 3. The major variant for ruminant fatty acid composition is animal species; ruminant meat has more saturated fatty acids due to bio-hydrogenation in the rumen compared to monogastric animals. The fatness level also affects the meat fatty acid composition as with increasing fatness saturated (SFA) and monounsaturated fatty acids (MUFA) increase faster resulting in a decrease in the relative proportion of PUFA and polyunsaturated/saturated fatty acids (P/S) ratio (DeSmet et al., 2004). During aging breed and slaughter weight of the animal affects the rate of sensory changes (Campo, Sanudo, Panea, Albert, & Santolaria, 1999; Candek-Potokar, Zlender, Lefaucheur, & Bonneau, 1998). Campo et al. (1999) stated that aging affects the tenderness and aging evolution of meat depends on breed type. Breed, slaughter live weight and aging influence these attributes significantly. Sanudo et al. (2003) conducted a study in which tenderness, flavor quality and overall acceptability of lamb meat was evaluated by the consumer. The differences among the consumer choices for different breeds were observed and studied, as lambs from different European systems were studied. Gorraiz, Beriain, Chasco, and Insausti (2006) studied the variation in volatile compounds, odor and flavor due to aging time in Pirenaica and Friesian bulls and heifers. Differences in several volatile compounds were observed as the beef of Friesian breed had a stronger fatty flavor and aftertaste than that of Pirenaica, after cooking. Dransfield, Nute, Hogg, and Walters (1990) reported no significant differences between sexes in the intramuscular fat content from Dorset Down breed lambs slaughtered at 20 weeks of age and with an average carcass weight of 17.7 kg. The possible differences in juiciness and flavor intensity of meat between sexes in lambs may be attributed to differences in intramuscular fat as it has a great importance in the development of the aroma and flavor of the meat (Brennand & Lindsay, 1992). Ba, Ryu, Lan, and Hwang (2013) concluded in their study that breed of animal (Hanwoo vs Angus) has great impact on

Table 3
Impact of breed on fat, IMF and fatty acid composition of different species.

Animal Species	Varying Components	References
Cattle	Fat content in cattle breeds varied from 8.92% (Holstein-Friesian) to 13.61% (Belgium blue)	Čepin, Žgur, and Čepon (1998)
Cattle	Higher level of dimethyl sulfide was observed in Pirenaica breed while Australian breed has lower sulfur compounds in cooked meat	Insausti, Goni, Petri, Gorraiz, and Beriain (2005)
Cattle	The IMF content in different breeds of cattle varied from 0.99% (Australian valley) to 2.72% (Pyrenees)	Piedrafitaa et al. (2003)
Goat	Fat content in goat breeds varied from 1.98% (Jamunapari goat) to 12.6% (Ethiopian goat)	Solomon, Girma, and Kassahun (2007), Stankov, Todorov, Mitev, and Miteva (2002), Das and Rajkumar (2010), Ivanovic et al. (2014)
Sheep	Breed affects fifty-four flavoring compounds of which 75% were Maillard's reaction products. Soay breed has over 40 flavor compounds at higher levels than Suffolk breed	Elmore et al. (2000)
Goat & sheep	Goat and sheep breeds have varying fatty acid composition as boar goats have more saturated while Damara sheep have more unsaturated fatty acids	Tshabalala, Strydom, Webb, and de Kock (2003)

meat physicochemical quality, sensory characteristics and the content of volatile flavor compounds.

4.2. Sex of animal

The sex of the animal has apparent impact on the flavor variations in meat as Crouse, Busboom, Field, and Ferrell (1981) observed in their study that meat from rams had more intense flavor than that of wethers. Gorraiz et al. (2006) studied variation in volatile compounds, odor and flavor due to aging time in Pirenaica and Friesian bulls and heifers. After cooking, bloody flavor that was related to higher 2-propanone content and stronger liver-like odor and flavor were observed in bull beef while beef from heifers had stronger characteristic flavor. Lough, Solomon, Rumsey, Kahl, and Slyter (1993) and Ellis, Webster, Merrell, and Brown (1997) observed that carcasses from female lambs compared to male showed thicker subcutaneous fat and greater intermuscular fat. These differences explain why male lambs presented better quality (flavor) of meat than females (Cosentino, Girolatni, Pelosi, & Matassino, 1980). Lorenzo, Sarriés, and Franco (2013) observed a vibrant influence of sex on the fatty acid profile of longissimus dorsi but observed no effect on color parameters, textural properties, carcass measurements, and amino acid. Horcada, Beriain, Purroy, Lizaso, and Chasco (1998) observed the larger infiltration fat content in females. They suggested that the meat of females should be juicier than the meat of males. The rib roasts from steers were described as tenderer, juicier, and more flavorful, and received higher overall palatability scores than roasts from bulls (Forrest, 1975). In contrast Franco et al. (2011) observed no significant differences of meat quality between the sexes and the slaughter age whereas the livestock production system significantly affects intramuscular fat content and meat tenderness.

4.3. Feed of animals

One of the major costs in animal production is animal feed and resources define the establishment of feeding in different types of production systems. Feed also affects the carcass conformation, physicochemical and organoleptic parameters of meat quality like proximate composition, fatty acid profile, meat tenderness and color (Franco, Crecente, Vázquez, Gómez, & Lorenzo, 2013; Li, Zhu, Wang, He, & Cao, 2014; Ramírez-Retamal & Morales, 2014). The composition of carcass and the degree of fattening are affected by the feeding system of the animals (Lewis, Emmans, & Simm, 2002). Consumer acceptability increases for animals fed through grazing as they present lower fat levels (Sanudo et al., 2000), and grass-fed animals have yellower fat (Priolo, Micol, Agabriel, Prache, & Dransfield, 2002). The types of feed mainly affect the fatty acid profile of meat (Wood et al., 2008) and grass-fed animals' meat is recognized as healthier. Young, Berdagué, Viallon, Rousset-Akrim, and Theriez (1997) derived terpenes and diterpenoids from feed as these volatile compounds (terpenes and diterpenoids) are commonly present in cooked meat of pasture-fed sheep. Priolo et al. (2004) have also authenticated this observation, whereas Sivadier, Ratel, and Engel (2010) have suggested that 2, 3-octanedione would be a suitable biomarker for authentication of a pasture diet. Use of grain feeding regimens for sheep produces higher concentrations of γ-lactones in the cooked meat (Shorland, Czochanska, Moy, Barton, & Rae, 1970). Free fatty acids available in the grain are likely to be the precursors for these compounds as a mechanism for the biosynthesis of γ-dodecalactone from oleic acid. Pasture-finished animals have high δ-lactones in meat (Bailey, Suzuki, Fernando, Swartz, & Purchas, 1994). ‘Mutton’ aroma in cooked sheep meat is because of the formation of short branched-chain fatty acids (BCFAs) as an implication of diet. Animals fed with grain-based finishing diet showed higher concentrations of BCFA compounds (Young, Lane, Priolo, & Fraser, 2003). Grain-based diets have greater carbohydrate availability than pasture based (Young & Braggins, 1998).

4.4. Chiller aging

Post-mortem aging of meat leads to meat tenderization and flavor enhancement by the action of endogenous enzymes during a complex set of reactions (Geesink, Taylor, Bekhit, & Bickerstaffe, 2001; Hopkins & Thompson, 2001). A significant alteration in various chemical constituent like sugars, organic acids, peptide, free amino acids and adenine nucleotides is observed during post mortem period of meat aging (Spanier et al., 1997). Lipid oxidation, Maillard's and Strecker reactions are considered to be potentially responsible for flavoring compounds occurring in meat (Resconi et al., 2013). Formation of peptides during the postmortem process leads to the development of flavor precursors (Etherington, 1987) and the concentration of these flavor precursors increases during aging which react with other degradation products for the formation of volatiles responsible for meat aroma (Imafidon & Spanier, 1994). The free amino acid and beef flavor precursors increase due to higher degree of proteolysis with longer aging time responsible for umami and butter fried taste (Koutsidis et al., 2008). Daszkiewicz, Wadja, and Matusevicius (2003) observed the better taste in beef samples of M. longissimus lumborum conditioned at 0–2 °C stored for longer periods (10 to 14 days) than those conditioned for 3 to 7 days which proved the positive effect of aging on the organoleptic properties (flavor, tenderness, and juiciness). (Miller et al., 1997). Jeremiah and Gibson (2003) observed flavor intensity and desirability of beef ribs and short loins aged for a period of four weeks. The beef aged for 7 days showed an increased aftertaste and characteristic flavor (Gorraiz et al., 2006) and the amount of volatile compounds derived from fatty acid degradation increased in the products produced as a result of lipolytic enzyme activity. The oxidized fatty acids contributed to increase the flavor intensity of meat through lipid oxidation products like aldehydes, ketones and hydrocarbons (Belitz et al., 2009). The degree of polyunsaturation is important as it determines the overall concentration of volatiles derived from lipid oxidation (Elmore, Mottram, Enser, & Wood, 1999).

4.5. Meat cooking

The acceptance and preference of meat by the consumer is influenced by the characteristic aroma and flavor of cooked meat (Van Ba, Hwang, Jeong, & Touseef, 2012). The cooking of meat is essential to achieve palatable and safe products (Tornberg, 2005) and it results in the development of meat aroma through Maillard's reaction, lipid oxidation, and thermal degradation of thiamine and these pathway products' interaction by utilizing non-volatile flavor precursors such as free amino acids, peptides, reducing sugars, vitamins, unsaturated fatty acids and nucleotides (Mottram, 1998). The cooking methods and cooking conditions (heating rate, cooking time and temperature) modify the chemical composition and subsequently the nutritional value of meat (Brugiapaglia & Destefanis, 2012; Kosulwat, Greenfiel, & Buckle, 2003). Lipid oxidation depends on the nature of triglyceride (Carrapiso, 2007), antioxidant, and metal ion composition (Ma, Ledward, Zamri, Frazier, & Zhou, 2009). The thermal treatment conditions (temperature and time) are the important factors leading to controlled oxidation of lipids (Byrnea, Brediea, Mottram & Martens, 2002). The roasting of meat results in increased oxidation compared to other cooking methods due to the use of high temperature for a longer time period (Domínguez et al., 2014a, 2014b). Cooking temperature and the increase in volatiles with increased cooking temperature influence the flavor development through Maillard's reaction and lipid oxidation (Ames et al., 2001). A strong relationship has been observed by Lorenzen, Davuluri, Adhikari, and Grün (2005) between cooking temperature, amount of free amino acids, carnosine, pyrazines, hexanol and intensity of roasted, burnt and beefy flavor. The cooking of beef reduces the sulfur containing compounds which generate important nitrogen containing compounds (pyrazines and thiazoles) as urea is generated during cooking. Cooking temperature, time, pH and moisture content are important for the formation of pyrazines in meat (Bailey et al., 1994). Pyrazines also vary with cooking methods (Mottram, 1985) and in grilled meat pyrazines contribute 80% of the volatile compounds. Glutathione is a principal source of hydrogen sulfide in the early stages of cooking which is replaced by cysteine in the later stages (MacLeod, 1994). Hydrogen sulfide potentially reacts with phenols to form thiophenol that contributes to sheep meat aroma (Ha & Lindsay, 1991). Meats having a nutty and roasty flavor have pyrazines on the surface. However, having low temperature and shorter time of cooking, and microwave treatment also result in increased lipid oxidation (Rodríguez-Estrada, Penazzi, Caboni, Bertacco, & Lercker, 1997). Frying, one of the oldest cooking methods, improves sensory quality of the formation of aroma compounds, attractive color, crust and texture (Bognar, 1998), but oil used for frying can change the fatty acid composition resulting in increased oxidation (Broncano, Petrón, Parra, & Timón, 2009).

The flavoring compounds in meat are produced through lipid oxidation, Maillard's reaction, vitamin degradation, and interaction between their degradation products. Breed, sex, and feed of animal significantly influences the quantity and quality of fats in their carcasses. Amount of fats and degree of fatty acid unsaturation affect the amount and types of flavoring components. Chiller aging is responsible for protein degradation and as a result of proteolysis peptides and amino acids are produced. These peptides and amino acids contribute to meat flavor development through Strecker degradation and Maillard's reaction. Meat cooking methods and conditions are important for thermally induced reactions responsible for flavor development. Vitamin degradation results in formation of certain flavor precursors which contribute to meat flavor themselves or interact with other precursors for production of cooked meat flavor.

5. Estimation of flavoring compounds in meat

Estimation of the sensory contribution of single odor active compounds in a range of volatile mixtures largely relies on the screening technique. Volatile flavor components in cooked meat can be assessed by gas chromatography and flame ionizing detector (GC/FID) or mass spectrometry (GC/MS) combined with a variety of techniques. Volatile compounds from cooked meat are extracted by simultaneous steam distillation–extraction (SDE), dynamic head-space and solid-phase microextraction (SPME) (Elmore, 2008; Madruga, Elmore, Dodson & Mottram, 2009; Moon, Cliff, & Li-Chan, 2006; Oliveros, Ryu, & Hwang, 2010). In addition, there are many factors that affect SPME fiber performance, such as the choice of stationary phase and extraction conditions (Lorenzo, 2014). Solid phase extraction is a process that utilize a small amount of solvents, stripped out volatile compounds and recovered many compounds qualitatively (Madruga, Elmore, Dodson & Mottram, 2009). Dynamic head-space is widely used in studies for the estimation of flavor compounds in cooked meat since the 1980s. Solid phase micro extraction is widely used as an alternative for extracting the volatile compounds of cooked meat. These techniques are tentatively used by researchers to determine the volatile compounds but could not find the aroma or flavor of the sample. The combination of two or more techniques for the analysis of meat samples such as gas chromatography-olfactrometry (GC/O) will be more advantageous as it measures the human response to odorants separated by gas chromatography. Intensity of aroma (odor) and characteristics of volatile compounds in cooked meat has become easy to determine in recent years by the use of GC-O (Machiels, Van Ruth, Posthumus, & Istasse, 2003; Rochat & Chaintreau, 2005; Xie, Sun, & Wang, 2008). Different GC-O sensing methods have been proposed, and classified into several categories including dilution analysis such as combined hedonic response measurement (Acree, Barnard, & Cunningham, 1984) and aroma extraction dilution analysis (AEDA) (Grosch, 1994), time-intensity methods such as Osme (Miranda-Lopez, Libbey, Watson, & Mcdaniel, 1992), finger span cross modality (FSCM) (Etiévant, Callement, Langlois, Issanchou, & Coquibus, 1999; Qian, Burbank, & Wang, 2007) and detection frequency (DF) methods such as surface of nasal impact frequency (SNIF) or nasal impact frequency (NIF) (Pollien, Fay, & Baumgartner, 1999; Pollien et al., 1997). Various separation approaches prior to GC-O screening are utilized to simplify analysis of aroma potency in the complex mixture (Qian et al., 2007). New multi-dimensional gas chromatography technology increased consistency for compound identification and provides an accurate aroma perception in ways of improving separation from its dominant background. Integrated MDGC with simultaneous MS and olfactometry detection (MDGC-O/MS) has been introduced and widely used since the last decade for the investigation of aroma and flavor of food and beverage products (Begnaud, Starkenmann, Vande Waal, & Chaintreau, 2006; Eaton, Nielsen, & Wright, 2007). Several case studies of malodor were investigated by applying MDGC-O/MS like precursor oxidation in bottled drinking water, flavor defect in a plastic-wrapped cracker product and defective flavoring in powdered smoked meat flavor concentrate (Eaton et al., 2007). Maikhunthod, Morrison, Small, and Marriott (2010) developed switchable GC system that allows targeted MDGC and GC–GC analysis to be performed in a single run. In addition full mapping of all compounds as a contour plot produced using GC–GC separation and desired co-eluted regions from the D column can be selected to permit targeted MDGC separation on a longer D column than that employed for GC–GC operation. Specht and Baltes (1994) investigated the key-odor compounds of shallow pan-fried beef by means of GC-O and aroma extract dilution analysis (AEDA). According to the attained FD factors, AEDA revealed 16 compounds as responsible for the overall stewed beef juice flavor; six (acetic acid, methional, butyric acid, 12-methyltridecanal, 4-hydroxy-2,5-dimethyl-3(2H)-furanone, and 3-hydroxy-4,5-dimethyl-2(5H)-furanone) present in the highest FD values (Campo, Cacho, & Ferreira, 2006). These extraction and analysis techniques can be used effectively for determination of flavoring compounds responsible for characteristic meat flavor.

6. Conclusions

The non-volatile constituents of fresh meat are essential flavor precursors and contribute to the taste of cooked meat as a function of thermally induced reactions. The pre-slaughter parameters like breed, sex and feed of animal have correlation with these flavor precursors. The aging of meat leads to enzymatic degradation of certain constituents and has a positive impact on the flavor precursors. Meat cooking methods and conditions are critical to flavor development as most volatiles are produced as a result of thermally induced reactions.

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