Module 32 Animal Food Flavors

1.0 Introduction: According to Merriam Webster dictionary flavour is the the blend of taste and smell sensations evoked by a substance in the mouth. In other words Flavor or flavour means the sensory impression obtained from a food or other substance, and is perceived by the chemical senses of taste and aroma. Thus it is a sum total of the two sensations, in order to perceive flavour the "trigeminal senses", detecting number of substances in mouth and throat are necessary for overall flavor perception. Of the three chemical senses, smell is the main determinant of a food item's flavor. The taste of food is confined to sweet, sour, bitter, salty, umami, the five basic senses. Aroma is considered more important than taste in determining flavor. Flavors possess a variety of chemical groups and structures. They can be heterocyclic, carbocyclic, terpenoid, aromatic, and so on. The overall flavor of foods is due to carbohydrates, lipids, and proteins; however, specific flavours can be elicited by numerous other classes of compounds, such as alcohols, aldehydes, ketones, and various heterocyclic compounds (pyrazines, pyrroles, pyridines etc). Flavours present in nature are versatile. The plant food flavours are distinctively different from the animal food flavours. Animal food flavours can be differentiated into those that are derived from the animal itself i.e. its flesh and the other from the animal products such as dairy flavours. Both vary from each other and are quite unique. The flavour from meat includes two types raw and process induced. Raw meat flavours can be classified as mammal flavours i.e, beef, lamb, goat, pig, Poultry and Seafood flavours like fish. Process induced flavours include flavour originating during smoking, curing, fermentation and frying etc. Dairy flavours include raw and cooked milk flavour, butter or cream flavour and fermented dairy products flavour. This chapter discusses some of these flavours.

1.1 Raw meat flavour:

Meat flavour is thermally derived flavour as raw meat has little or no flavour it has blood like, salty, metallic taste and sweet aroma. But it contain flavour precursors that get converted into meaty aroma during cooking as the result of complex interaction of precursors derived from both the lean and fat meat components generating volatile
flavour compounds that contribute to the ultimate meat flavour. These flavour compounds appear as a result of major reaction mechanisms such as Maillard reaction and lipid oxidation. These reactions may result in generation of more than 1000 volatiles.

1.1.1 Precursors of meat flavour:

The most important precursor of aroma flavor characteristics of cooked meat is the low molecular weight, water soluble compounds and fats in raw meat constituents. The flavor precursor of meat namely, free sugars, free amino acids, peptides, vitamin, sugar phosphate, nucleotide-bound sugars and nucleotides has the ability to either participate in the Maillard reaction or oxidation/ degradation and interaction on heating to generate volatile flavor compounds which develops the final aroma flavor characteristics of cooked meat. These precursor components contribute to the development of meaty flavor, while the adipose tissues and intramuscular fat occupy an important role in development of flavor characteristics of cooked meat and contribute to the characteristic-specific species flavours. This means that the distinct flavor characteristics between the meats from different species are due to the intramuscular fat content and not from water-soluble precursor compounds. Lipids contribute to species flavour as such contain odorous or reactive fat soluble components. Among the amino acids present in meat, cysteine and cystine are two sulfur-containing amino acids, the reaction of these with other sugars lead to formation of many sulfur-containing flavor compounds, while the reaction of other nonsulfur containing amino acids with sugars dominated by the nitrogen-containing products such as pyrazines. The Intact meat proteins have no contribution to meat flavour. Thiamin also acts as a precursor in formation of meat aroma compounds.

However as reported the flavor precursor components are influenced by several factors. These factors are age, diet of animal, chiller storage of meat, fasting and post-mortem ageing factors affect the concentration of flavour volatile precursors. These may affect the reducing sugar content, free amino acid levels, free sugars such as ribose and fatty acid compositions.
1.2 Meat taste: Raw meat contains non volatile components that influence taste. These constituents are changed during processing. There are number of taste components present in raw meat. The sugars i.e. glucose, ribose and fructose contribute to sweet taste, whereas salty taste is due to presence of inorganic salts as well as sodium glutamate and sodium aspartate. Acidic taste is due to lactic and other acids such as: Aspartic acid, glutamic acid, succinic acid etc. Raw meat also contains flavour enhancers which contribute to umami taste these are Ionosine monophosphate and Monosodium glutamate. IMP is formed from adenosine-5'-tri phosphahate (ATP) breakdown during ageing of meat. These components increase the sensory appeal described a meaty, brothy, mouth filling dry and astringent.

1.3 Raw meat Aroma:
Raw meat lacks meat aroma as in cooked meat. The cooked meat aroma is formed during the heating process from the non-volatile precursor compounds. As mentioned earlier the mechanisms responsible for aroma generation in cooked meat are Malliard browning, lipid reactions and thiamine degradation. 90% of flavour volatiles are formed from lipid rections. Thus the remaining 10 % are contributed by Malliard browning and thiamine degradation. Beef differs from other meats by having largest volume of sulphur compounds. Lamb differs by containing more of carboxylic acids and chicken contains more lipid derived volatiles. Chicken meat also contains aldehydes and ketones.

1.4 Cooked Meat flavour:
1.4.1 Volatile flavor compounds generation Pathways:
1.4.1.1 Maillard reaction
Maillard reaction is a non-enzymatic browning reaction which plays an important role in generation of volatile flavor compounds and appearances of the cooked foods. The precursors in raw meat participate in this reaction and lead to formation of volatiles. Majority of these volatile aroma components are heterocyclic compounds with
characteristic aroma accompanied by low sensory threshold. Heterocyclic compounds formed include furans, furanones, pyrans, pyrazenes, thiopenes thiazoles, oxazolines and heterocyclic polysulphides. The combination of these volatiles leads to production of basic meaty flavour common to all meat species.

The formation of volatile flavor compounds in the Maillard reaction largely depend on the reactants (e.g., the nature of reducing sugars and amino acids participated) and also the catalytic condition (e.g., heating temperature, moisture, pH). The type of reducing sugars and amino acids determine the kinds of flavor compounds generated for instance, many sulphur-containing flavor compounds are formed from the Maillard reaction between cysteine and ribose whereas, the nitrogen-containing compounds (e.g., pyrazines) dominated in the Maillard reaction containing glucose and lysine.

1.4.1.2 Lipid oxidation and degradation

Lipids and fatty acids are major contributors in generating the volatile flavour compounds of cooked meat. Therefore, the levels of fat and fatty acids constituent of meat are important, these are influenced by several factors like pre-harvest factors such as diets, feed regimes and breeds. The fatty acid profiles significantly vary across the breeds. Fatty acids both saturated and unsaturated get oxidized and degraded to create number of volatile flavor compounds. Lipid degradation derived volatiles found in cooked meat include aliphatic hydrocarbons, aldehydes, ketones, alcohols, carboxylic acids and esters. The Lipid-derived compounds have higher odor detection threshold values than heterocyclic compounds formed from the water-soluble precursors via the Maillard reaction. Therefore, the impact of the aroma profile in of not much significance as compared to that for relatively low concentrations of the heterocyclic compounds.

Aldehydes (saturated and unsaturated) containing 6 to 10 carbons in the structures also constitute major volatile components of all cooked meats contributing to a great extent in meat aroma.

Lipids make their contribution to flavour via thermally induced oxidation reactions. The degrees of heating temperatures also affect lipid oxidation. At high temperature oxidations there is formation of significant proportions of positional hydroperoxide isomers (C8-C14). The generation and simultaneous degradation of these compounds
lead to formation of great range of volatile odourous compounds. 2, 4-decadienals form a large share in high temperature oxidations. These compounds are linked with ‘French fry’ aroma, whereas hexenal formed at low temperature has ‘green or grassy aroma’. Saturated triglyceride at higher temperature undergoes to yield methyl ketones, aldehydes, lactones and hydrocarbons contributing to volatile aroma of meat. Lipid has a considerable role in meat flavour. The removal of intramuscular fats and phospholipids may cause marked differences in flavor compounds and sensory characteristics of beef. Thus the intramuscular fat contents (marbling fats) and membrane lipids are the main source of volatile flavor components and also contributor of species- specific flavors. However, high levels of lipids especially polyunsaturated fatty acid contents (PUFA) lead to undesirable aroma as the PUFA-derived products formed may lower or inhibit the formation of some heterocyclic Maillard products. However, the interaction between the lipid-derived products with Maillard products to form volatile flavor components is also thought as the important pathway for formation of flavor compounds.

1.4.1.3 Thiamin degradation

Thiamin is considered as a source of meat flavor generated on heating. Researchers found that the thermal degradation of thiamin produces some ended and intermediate flavor compounds. It was assumed that thermal degradation of thiamin is a quite complex reaction including various degradation pathways to produce interesting flavor compounds in which most of them contain one or more sulfur and/or nitrogen atoms, and many of them are heterocyclic structures. The thermal degradation of thiamin produces range of flavor compounds. It was reported that the primary products of thermally-degraded thiamin including 4 methyl- 5-(2-hydroxyethyl) thiazole which subsequently lead to formation of thiazoles and other sulphur compounds such as 5-hydroxy-3-mercaptopentan-2-one which then gives some sulfur-containing compounds such as thiophenes and furans. Heating temperature and pH conditions have been showed to affect the degradation products of thiamin. The 2-methyl-3furanthiol and bis (2-methyl-3-furyl) disulfide (meaty aroma) and thiophenes were the dominant aroma volatile compounds. Thiamin thermal degradation products such as 2-methyl-3-
furanthiol and bis (2-methyl-3-furyl) disulfide produce intense meaty aromas. 2-Methyl-3-furanthiol (MFT) has been found to be a key odor compound formed in a number of meats, especially pork and beef, and in Maillard reaction mixes. It is intensely odorous, as is its disulfide, which is reported to have an extremely low odor threshold in water of $2 \times 10^{-6}$ ppb. Some other aroma-active compounds were also found such as 4, 5-dimethylthiazole (skunky, earthy), 3- thiophenethiol (meaty, cooked), 2-methyl-4, 5-dihydro-3(2H)-thiophenone (sour-fruity, musty, green), 2-acethylthiophene (burnt), 2-formyl-5-methylthiophene (meaty), and 2-methyl-3- (methylthiol) furan (meaty).

1.5 Species specific meat flavour:
The basic meaty flavor resides in the water-soluble fraction of the meat but that species-specific flavors lies in the lipid fraction.

1.5.1 Lamb or mutton flavour:
Lamb meat flavour is typically dependent on the fat composition. Any alteration in the dietary fatty acid will influence the flavour profile of lamb meat. There has been identification of species specific flavour in lamb meat. The lamb like flavours is associated with principally compounds such as 4-metyloctanoic and 4-methylnonanoic acids. Several compounds (branched-chain fatty acids, carbonyl compounds, sulfur-containing compounds, lipid oxidation products, phenols, and basic compounds) are believed to impact lamb flavor. Goaty/mutton/sheep aroma notes are associated with fatty acids having branch chains at the 4-position. 4-ethylctanoic acid also is a major contributor in lamb or mutton odours. Alkyl and thiophenols also contribute to mutton flavour, which is more desirable. Branched-chain fatty acids (BCFA), 8 to 10 carbons, to lamb’s characteristic flavour. Combination of two may also yield desirable mutton flavour.

1.5.2 Goaty Flavors
The goaty odour in goats, rams, ewes and lambs have been linked to octanoic,4-methylctanoic and 4-ethylctanoic acids. Branched chain fatty acid are also linked with
goaty flavour. 4-ethyloctanoic acids have been identified in sebaceous glands from male goat.

1.5.3 Odors and flavours in pork:
Porcine adipose tissues are the source of pork specific flavor. The pork flavour may also be due to the low concentrations of compounds responsible for boar flavour. The aroma of cooked pork is different from beef or chicken. The major character is that of sulfury notes. Compounds such as 3-mercaptopropanol, 3-acetyl-3-mercaptopropanol and 4-methyl-5-vinylthiazole are characteristic for pork flavour.

1.5.4 Beef odor:
The species-specific flavour has traditionally been associated with the lipid portion because more than 650 fat-soluble volatiles are released when beef is heated. “Speciesspecific flavor” in beef may result from quantitative differences of the same compounds (3,5-dimethyl-1,2,4,trimthiolane, 2,4,6- trimethylperhydro-1,3,5-dithiazine, mercaptothiophenes or mercaptofurans. The beef-like aroma compound, 12-methyltridecanal, has been identified as an important constituent to species flavor; it occurs only in small amounts in other species. Other anteso-methyl-branched compounds identified are believed to arise from phosphoglycerides. Phospholipids from lean muscle may contribute the majority of important species specific flavor volatiles in beef implying that species flavour may not be based on the neutral fat (triglyceride) portion of meat alone. Species-specific flavor generally decline during refrigerated storage.

1.6 Sensation of meat flavour is affected by many factors like:
Species, age of animal, method of cooking and addition of curing agents and seasonings, amount and kind of fat in raw and cooked product, past slaughter ageing of meat, diet.

The meats from different species are different in composition. Basic meaty notes are same in all species but components of fatty tissues mainly carbonyls are quite different.
Many factors affect meat aroma these are age of animal it has been observed that aged animal have stronger aroma and flavour than young. The young has more mild flavour. Method of cooking also affects meat flavour. Roasting, boiling, frying, stewing, smoking processing methods produce distinct aromas in fish. Effect of seasonings like onion, garlic, ginger, tomato, spices also affect the flavour profile. Microwave cooking may also lead to changes.

Amount and kind of fat also influences meat flavour. Mutten and lamb flavour have more impact of fat on flavour due to species specific flavour. Percentage of fat affects meat flavour. Post slaughter ageing also affects meat flavour. Aged meat is known to have strong flavour often objectionable, thus fresh meat mostly preferred. Aged meat also may develops rancidity. Feeds also affect flavour in animal meat. Alfaalalfa, white clover and rapeseed produce off odor in pork meat. Legumes may also produce off flavours in lamb meat. Lipid supplement containing sunflower seed-casein was criticized for ‘sweet’ aroma. Thus animals must be fed controlled rations to have no aroma problem in the meat.

1.7 Frozen meat flavour:

Meat flavour can be altered during frozen storage. The prime effect is of lipid oxidation, (oxidative rancidity) due to which there is generation of off flavour. This off flavour limits the shelf life by hampering palatability. The oxidative rancidity led to the formation of peroxides. The effect is more pronounced with unsaturated fatty acids. However, the peroxide formation is not the reason for flavor deterioration. It is principally the formation of breakdown products of peroxides that lead to off flavour or rancidity. Thus the reaction is hastened with the breakdown products of peroxides which eventually cause autocatalytic effects. In meat number of factors is responsible for the development of rancidity these include: species, muscle type, amount and type of fat in diet and enzymes. The other factors include light and heat damage caused due to damage to muscle structures caused by freezing.

The damage can be reduced by cutting off the oxygen supply during frozen storage and employing ultra low temperatures of -60°C and use of antioxidants like Vit E.
1.8 Fermented Meat Flavor:

Fermented meat flavour has typical aroma being influenced by no of elements. These include the microbial cultures fermenting. A lactic acid bacterium contributes to lactic acid and acetic acid, ethanol and acetoin. Staphylococci lead to the proteolysis and lipolysis which impact the sensory profile to considerable extent. The volatiles formed via staphylococci are amino acid catabolises, piruvate metabolites and methyl ketones from incomplete B-oxidation of fatty acids. The two major strains used are S xylosus and S carnosus. They principally modulate the aroma by conversion of BCAA into methyl-branched aldehydes, alcohols and acids. On the other hand Lactobacillus species act on the porcine muscle myofibrillar and sarcoplasmic proteins. Organisms like L curvatus and L sakei generates hydrophilic peptide and amino acids.

In addition to proteolysis lipolysis also plays a key role in aroma generation through oxidative degradation of fatty acids into alkanes, alkenes, aldehydes and ketones thus enhancing flavour development. This is brought by the tissue lipases along with the bacterial starter activities.

1.9 Smoked Meat flavour:

Smoky flavour is characteristic for compounds contained in smoke. For smoked meat products the use of smouldered wood smoke generated at 450-550°C is considered ideal for imparting smoky flavour. The smoky flavour is associated with the presence of a mixture of syringol and 4-methylsyringol, in addition 4-allylsyringol, guaiacol, 4-methylguaiacol and trans isoeugenol also contribute to sensory perception. Smoky flavour is the result of the interaction of meat constituents with smoke compounds and the effect of carbonyl compounds in smoke and their interaction products, furans, esters, short chain carboxylic acids, pyrazine and its derivative terpenoids, terpenes and other unidentified constituents.

1.10 Dry Cured ham flavour

Protein and lipid hydrolysis are primarily responsible for aroma generation. Muscle protein degradation leads to generation of peptides and free aminoacids. During the ham production the compounds generated are glutamic acid, glycine, alanine, valine,
proline, histidine and leucine. The more aged taste is linked to lysine and tyrosine whereas the fully ripened ham taste is due to glutamic acid aspartic acid, methonine, phenylalanine, tryptophan, lysine, leucine and isoleucine. Bitterness in some hams is due to excess of typtophan, tyrosine and phenylalanine. Free fatty acids also contribute significantly to flavour as the release FFA are partially oxidized leading to large no of volatiles. About 200 of them are formed and belong to aldehydes, alcohols, hydrocarbons, pyrazines, ketones, esters, lactones, furans, sulphur, chloride compounds, and carboxylic acids. The aroma profile of final Ham is the result of specific aroma and aroma threshold values of the volatile constituents.

1.11 Poultry meat flavour:

Raw poultry meat also like red meat has no significant flavour. The compounds contributing to the taste in chicken occur in raw meat and as such require cooking for their generation. Most taste compounds contributing to taste for poultry flavour are almost similar to red meats like amino acids, peptides, proteins and nucleotides. Cooked chicken have lesser content of IMP than beef. The changes that occur during cooking affect the taste compounds like sugars, amino acids and nucleotides which may lead to changes in aroma as most of these compounds are precursors for volatile formation. In comparison to taste compounds most volatile aromas are generated during the cooking of poultry meat. The aroma of cooked chicken is distinct from that of meat. Decomposition products of chicken fat make significant contribution to chicken aroma. The flavour character of cooked chicken is because of cis-4decenal, trans-2-cis-5-undecadienal and trans-2-cis-4-trans-5-tridecatrienal. It has been reported that about 500 aroma compounds are released in chicken during cooking. As majority of them have high odor thresholds they do not contribute significantly to overall aroma perception. Those that are present in low odor threshold levels contribute significantly to aroma profile. The compounds formed include sulphur compounds and heterocyclic compounds containing oxygen and nitrogen and aldehydes and ketones. The effect of these compounds contribute 'sulphurous', 'meaty', 'toasted', 'roasted', 'fatty', 'tallowy', 'fruity', or 'mushroom' aromas. The characteristic chicken aroma is perhaps the combination of all these flavours. The odour compounds of chicken meat differ from that
of beef that the bis (2-methyl-3-furyl) disulphide, methional and phenyl acetaldehyde are not of much importance, whereas the lipid oxidation products, like trans, trans-2, 4-decadienal, γ-dodecadalactone and trans-undecenal are of greater importance. The probable differences may be due to high linoleic acid content in chicken. n-6 fatty acids were also considered important for cooked chicken flavour. The chicken aroma also differs on the basis of methods of cooking like boiling, roasting, frying etc., Like meat the chicken meat aroma is also generated via several reaction mechanisms such as Maillard reaction, Lipid oxidation and thiamine degradation. However the characteristic flavour of poultry meat develops as a result of the precursor taste compounds in raw meat and volatiles derived via reactions. The concentration and rate of reaction between compounds depend upon the number of parameters pH, temperature etc.

1.12 Flavor of Seafoods:

Seafoods flavor comprised of complex systems of important taste and aroma active components. The taste is generally from non-volatile compounds, such as free amino acids, nucleotides, sugars, mineral salts, etc.,. The importance to seafood flavor is well documented. The aroma characteristics of sea foods may be further subdivided into components contributing to fresh and/or cooked seafood flavor. Fresh seafood flavor has attracted much attention due to the importance of aroma to consumer acceptability of fresh seafood. The flavor of fresh sea foods includes both fish and shellfish. The flavour is primarily influenced by lipoxygenase-derived lipid-based volatiles. Other factors influencing fresh sea food are environmentally-induced flavors as well as amines, primarily trimethylamine. There has been a drastic change in flavour of seafoods upon cooking. Changes in cooked meaty aromas are often species-specific and thermally induced. Development of the meaty aromas of cooked seafoods is due to Maillard and Strecker degradation. Other reactions such as retro-aldol condensation of dienals and lipid oxidation give rise to aroma compounds. The combinations of the above reactions are necessary for the evolution of the character-impact aroma compounds in cooked crustaceans.

1.12.1 Flavor and aroma of Fish:
The aroma of fish has been denoted as an important indicator of quality. Aroma is quite complex due to number of genera of fish. Fish flavour is composed of non-volatile taste active compounds and volatile aroma active compounds. Extractive (taste) compounds play minor role in fish flavour. However there is lot of effect of environment, processing storage, cooking and specifically on the enzymes biogenesis of fish aroma. Flavor characteristics of fresh fish are quite different from stored fish. Thermal reactions occurring during cooking modify fish flavour due to Malliard reactions and from breakdown of lipid derived components.

1.12.1.1 Flavor of Fresh fish:

Fresh fish aroma and flavor are characterized for being pleasant, mild, plant like, melon, green, sweet and depending on the species-specific aroma and flavor characteristics would be encountered. The presence of free amino acids, minerals and fatty acids affects fresh fish. The fish aroma volatiles are influenced by the fatty acid profile. The endogenous enzymes in fish are primarily responsible for fresh fish aroma. The action of enzymes (lipoxygenases) on PUFAs, produces carbonyls, aldehydes and ketones which are responsible for some of the fresh odors of fish. Lipooxygenase catalyzes the synthesis of fatty acid hydroperoxides that upon nonenzymatic or enzymatic degradation leads to formation of low molecular weight odoriferous compounds. Another enzyme hydroperoxidase lyase acts as a catalyst in the hydrolysis of hydroperoxides which lead to formation of Z-aldehydes these undergo isomerisation to yield E-aldehydes. The aldehydes may further be reduced by action of alcohol dehydrogenase to form alcohols. Some of the fresh fish volatile compounds obtained from enzymatic action on PUFAs are: hexanal (green); t2- hexenal (green); 1- octen-3-ol (raw mushrooms); 1, c5-Octadien-3-ol (earthy, mushrooms, green); t2, c6- Nonadienal (cucumber-like); t 2, c6-Nonadienol (cucumber, melon-like). Thus the number of volatile compounds formed will depend upon the fatty acid structure, specificity of fatty acid for lipooxygenase and positional specificity of lipooxygenase. Differences in volatile compounds exist between farmed and wild fish, as well as between freshwater and saltwater species due to diet related differences and
environmental conditions. Several components are responsible for salt water fish. The lipid derived carbonyls which play a major role in fresh water fish flavour have minor role in fresh salt water fish aroma. Trimethylamine has a distinctive fishy amine like odour and is a derivative of Trimethyl oxide abundantly present in salt water fish. Although present at low levels this compound due to low odour threshold may contribute to overall odour profile. Dimethylsulfide gives a canned corn, shellfish, and seashore like aroma to very fresh salt water fish. This compound is formed via hydrolysis of dimethyl-β-propiothetin, which is contained in some microalgae, plankton and seaweeds. Thus it gets accumulated in fish feeding on these plants. This compound will give undesirable aroma to fish. However in contrast to saltwater fish from fresh water do not contain trimethylamine and dimethylsulfide in their aroma notes. Live fresh fish has intense green, plant like and melon like aromatic profile due to number of unsaturated C₆, C₈ and C₉ carbonyls and alcohols.

1.12.1.2 Volatile components in Fish affected by Storage:

Since the freshly harvested fish is perishable this may result in stale and rancid notes upon storage.

In stored fish, aroma compounds arise primarily from the enzymatic action and oxidative processes. From a product quality standpoint of view most aroma changes that occur during storage have negative impact. Off flavours are often formed and encountered during refrigerated and frozen storage of saltwater fish due to development of trimethylamine and dimethylamine via microbial action and endogenous enzyme activity respectively. Of two trimethylamine has very strong intense fishy and ammonical notes and thus is used as an indicator of fish flavour quality. TMA is generated by the action of microorganisms on trimethylamine oxide (TMAO) the reaction is catalyzed by trimethylamine oxidoreductase. TMAO gets degraded to dimethylamine (DMA) in frozen fish by enzymatic action and cause not only off-flavors but toughening of the meat as a result interaction of formaldehyde (by-product of DMA enzymatic reaction) with muscle proteins.
Increased accumulation of taste-active nucleotide degradation products in stored fish also contributes to flavour of fish. Lipid oxidation also plays an equally important role in the development of aromas in stored and cooked fish. The PUFAs of fish lead to autooxidation and the hydroperoxides thus formed are readily broken down during cooking. The lipooxygenase pathway also may participate as an initiator in the development of aroma in stored and cooked fish. The peroxides formed by the action of lipooxygenase on PUFA can serve as a source of free radicals and accelerate the lipid oxidation. The lipid derived compounds either enzymatically or autooxidative pathways derived affect fish flavour during processing and cooking. During storage, fish or fish oils develop strong oxidized odours that have been described as rancid, stale, fishy, and cod liver oil-like. The presence of a complex mixture of mostly unsaturated carbonyl compounds is primarily responsible for oxidized off fish flavours in fish products. The (Z)-4-heptenal contributes to the off flavour of cold-stored cod. Most volatile compounds contributing to the oxidized fishy flavours are formed via autooxidation of the PUFA. These volatiles include hexanal, 2, 4-heptadienal, 3,5-octadien-2-one, 2,4-decadienal, and 2,4,7-decatrienal. Although these compounds are strictly lipid autooxidation products, lipooxygenase may act as an initiator/promoter of lipid autooxidation by its initial formation of fatty acid hydroperoxides. Autooxidation of n-3 fatty acids produces t,c,c-2,4,7-decatrienal (18:3, 20:5 and 22:6 n-3) and t,t,c-2,4,7 decatrienal, which are partly responsible for oxidation off-flavors. Fatty acids of the n-6 family are responsible for the production of hexanal (cut grass, green), (E2)-octenal (lemon), (E)2-nonenal and (E,E)-2,4-decadienal, while oxidation of n-3 fatty acids produce c-4 heptenal (cold-storage flavor, cold boiled potato, cardboardy), pentenylfuran (orange) and (E,Z)-2,6-nonadienal.

1.12.1.3 Volatile components in Fish affected by processing and cooking:

Volatile compounds produced by the action of cooking and processing fish products are generally related to the flavors obtained from canned seafood products (canned tuna-like). Lipid derived volatile carbonyls have been reported to be the most important contributors to the flavour of dried and salted fish. These compounds are less important in the flavours of fermented fish, fish sauce and fish hydrolysates. In these products the
predominant volatiles are volatile fatty acids, esters, sulphur-containing compounds, and Malliard and Strecker degradation reaction products. In the pickled fish, only modest levels of volatile carbonyls and alcohols are found due to their extraction into the pickling solution. The mild aroma of pickled fish was primarily due to decline in the volatile constituents initially present in the fresh fish. The small peptides, free amino acids, ammonia and trimethylamine (TMA) contribute to the specific aroma and flavour of fish sauce.

Lipoxygenase derived carbonyls have been found to affect the aromas of cooked fish, but lipid autooxidation products seem to be of greater importance. Occurrence of (Z)-3-hexenal, (Z, Z)-3, 6-nonadienal in the aroma profiles of boiled trout and salmon and cod indicates the initial involvement of lipoxygenase in the formation of site-specific hydroperoxides. However, most aroma active components of these cooked fish were lipid oxidation products and that were found to increase during storage of raw material. The predominance of lipid derived compounds also was reported in the aroma profiles of cooked catfish and sardines. Despite the importance of lipid derived volatiles in the above cooked fish, there are several types of cooked fish in which lipid oxidation products were found to make only a minor contribution. For example, the character impact aroma component of canned tuna is 2-metyl-3-furanthiol, which can be thermally derived from reaction of ribose and cysteine. n-Saturated aldehydes (formaldehyde, acetaldehyde, propanal, butanal, pentanal, hexanal, heptanal, octanal, and nonanal) were formed of heated fish flesh (herring, mackerel, sardine, and squid) were derivatized to their corresponding thiazolidin. Some compounds like. formaldehyde and acetaldehyde generally made up the largest quantities of aldehydes recovered.

1.12.1.4 Fish flavour environmentally derived:
These are volatile compounds produced from the action of the environment. The most common example of environmentally influenced off-flavor is “muddy, musty or blue-green”. The aroma of fresh water fish is influenced by the occurrence of earthy and musty off flavour compounds geosmin and 2-methylisoborneol. Both geosmin and 2-methylisoborneol are of environmental origin and have low odor threshold values. These are produced by cyanobacteria, actinomycetes, and algae. In the catfish industry the
presence of muddy flavor accounts for 80% of the rejections due to off-flavor in the meat. Farmers must contend with the production of off-flavors most commonly identified as: muddy, musty, sewage, rotten plants, stale, metallic, lagoon, which most of the time are produced by algae; other common farmed fish off-flavors are “hatchery” (soybean oil) and “fishy” (fish (menhaden oil) / (TMA)).

1.13 Dairy product flavours:

The flavor of dairy products is quite distinctive. The study of dairy flavours involves two main categories of products i.e. fresh and fermented. The Fresh milk products include milk, butter, ice-cream etc., whereas fermented includes cheese and yoghurt.

1.13.1 Milk flavour: Raw and heat-treated milk flavor

Fresh, milk has a characteristic but bland taste. It has a slight sweet/salty taste that is caused by lactose and milk salts. Apart from this a delicate flavour due to many odorous compounds. Although at least 400 volatile compounds (carbonyl compounds, alkanols, free fatty acids, sulphur compounds, etc.) most of them are present in very low concentrations. Their conclusions were that, although the concentrations of many of these volatiles were of a sub-threshold level, the delicate, weak flavour of milk is the result of a specific ratio between these volatiles. Some volatiles like ethyl butanoate, ethyl hexanoate and dimethyl sulphone have a relatively large impact on the total milk flavour. The lipid (fat) fraction of milk also affects milk's flavour to great extent. It is also the precursor of range of chemical compounds of importance in majority dairy flavors. Milk has unique and complex fatty acid composition among foods. More than 60 fatty acids have been reported in cow's milk. Butyric acid, caproic, caprilic, decanoic (fatty acids with 6, 8, and 10 carbon atoms) acids are unique to milk and of great importance in the development of flavors in products based on milk. These lipids upon oxidation gives rise to some key flavour components.

The flavour in milk is related to the metabolic activity of the cow and diet. The market milk flavour is generally due to thermally induced flavour compounds. Flavor changes occurring during the heat treatment may be formed from three distinct chemical mechanisms: Degradation of thermally labile precursor found in milk.; Reaction between
the sugars and proteins (Maillard reactions) and the release or formation of sulphur-containing components. Heat treatments to milk at varying degrees affect and the resulting flavour profiles. Mild pasteurization leads to a weak cooked flavour caused by traces of H$_2$S. More pronounced and distinct cooked flavour is produced at higher heat treatments. Sterilised milk is characterized mainly by a strong cooked flavour, UHT/ketone type and caramelisation/sterilisation flavours. Key aroma compounds in such milk are respectively 2-pentanone, 2-heptanone, 2-nonanone, 2-undecanone, 2,6-dimethylpyrazine, 2-ethylpyrazine, 2-ethyl-3-methylpyrazine, methional, pentanoic acid, benzothiazole, vanillin 2-nonanone, hexanal, benzothiazole. Besides this many sulphur-containing volatiles such as H$_2$S, methanethiol, dimethylsulphide and carboxyl sulphide, are associated mainly with the cooked flavour, arise during heat-induced denaturation of serum or whey proteins with accelerated production at high temperatures. For the flavour of heated milk, the Maillard reaction is important because it results in the production of volatile flavours such as aldehydes, ketones, maltol, isomaltol, pyrazines, furanones and methanethiol and H$_2$S (when methionine and cysteine take part as the amino acids respectively). The exact type of Maillard flavours that are formed in each product depends on the ingredients and reaction conditions. UHT treatment at a high temperature (140–150°C) lead to ‘cooked’ (sometimes also called ‘sulphur’ or ‘cabbage’), ‘sterile’ (sometimes also called ‘Maillard’, ‘caramel’ or even ‘gluey’) and ‘oxidation’ (sometimes also called ‘stale’ or ‘ketone’) flavour. Intrinsic UHT flavour that seems to be a combination of ‘ketone’, ‘oxidation’ and ‘rich’ attributes. The cooked flavour in UHT milk is caused by sulphur-containing flavours (e.g. H$_2$S, methanethiol, dimethylsulphide and carboxylsulphide) that are produced due to the denaturation of serum proteins. In general, the cooked flavour attributes increases with increasing process temperatures. However, exceptions are reported in which an increase of heat treatment leads to a lower cooked flavour. This is thought to be due to oxidation of the free sulphur groups into disulphides or a participation of the free sulphur groups in the Maillard reaction.

1.13. 2 Butter:
Butter is a fat concentrate prepared from milk fat by mechanical separation. It is water in oil emulsion that has a mild characteristic flavor. The flavour compounds of butter reside both in aqueous and fat phase. Lactic acid is principally present in aqueous phase. The perception of flavour is affected by media in which it is present. Generally flavour is perceived more in aqueous phase than fatty phase. The flavour perception of butter is affected by complex combination of properties of butter fat. The important class of compounds contributing to butter flavour is carbonyls: aldehydes, ketones and diketones. The best and important among them is diacetyl along with acetaldehyde which are formed during cream ripening stage of butter manufacture. However both these compounds play a little role in sweet cream butter. In sweet cream butter the flavour note is imparted by the deca and dodecanoic acids and methyl ketones. Lactones have also been considered to be a major flavor contributor in butter and cream. They are generated from the small amount of J-hydroxy acids occurring in milk fat. These compounds upon hydrolysis get converted to J-lactones. The r-lactones also may be formed from unsaturated CIS fatty acids via hydration and oxidation. The amount of lactones formed is related to the type of feed, the season, the type of breed, and the stage of lactation of the animal. Fatty acids also play a key role in butter flavour. They act as precursors of other compounds. Butter when heated yield ghee, which has a characteristically different flavour. This may be due to the Malliard reaction in aqueous phase leading to furfural and other conjugated furans. Also the level of volatiles increases in fat phase leading to increase in lactones. Thus heated butter has stronger flavour profile.

1.13.3 Yoghurt

Yoghurt is fermented milk product prepared by action of two types of bacteria, namely Streptococcus thermophilus and Lactobacillus bulgaricus. The flavour of yoghurt is a unique mixture of volatiles synthesized during initial stages of fermentation. There are about more than 90 different volatiles being identified in yoghurt these include carbohydrates, alcohols, aldehydes, ketones, acids, esters, lactones, sulphur-containing compounds, pyrazines and furan derivatives. However primarily a combination of
ethanol, acetaldehyde, diacetyl, acetone, acetoin, butanone, formic acid, acetic acid and dimethylsulphide are been reported quantitatively. Among all these compounds, acetaldehyde is the predominant yoghurt flavour. Diacetyl is also considered important for the ‘roundness’ of the yoghurt flavour. The balance between the acetaldehyde and diacetyl ratio is quite important as too much acetaldehyde compared to diacetyl would generate a ‘green’ off-flavour. A ratio 1:1 between acetaldehyde and diacetyl of 1:1 contribute towards optimal yoghurt taste. The key aroma components for yoghurt are acetaldehyde, diacetyl, 2, 3-pentanedione, methional, 2- methylytetrahydrothiophene-3-one, (2E)-nonanal, 3-methylbutyric acid, guiacol, benzothiazole and two unidentified compounds. Six volatiles known to have a high impact on the yoghurt flavour are: acetaldehyde, dimethylsulphide, diacetyl, 2, 3-pentanedione, L-limonene and undecanal. However, the main ingredients (fat, proteins and carbohydrates) in dairy products have a major impact regarding release of these volatiles. In addition to this the flavour perception of yoghurt is also been influenced by the acidity of the product. Less acidic yoghurts although popular have less flavour intensity. This may be due to the decrease in acetaldehyde concentration and an increase in diacetyl and 2,3-pentanedione concentrations in mild yoghurts compared with more acidic products. The key aroma components of yoghurt are produced during fermentation. Therefore, the production routes towards these components are mainly catalysed by complex series of enzymatic reactions.

1.13.4 Cheese:

Cheese is a fermented product obtained from milk by starter cultures and rennet coagulation. Many different, flavors, tastes, and textures of cheese exist in world. The use of microorganisms (yeast, bacteria, and mold) together with the basic milk source (typically cow's, goat's or sheep's milk) and controlled fermentation has resulted in variety of cheese. Raw cheese as such has no significant flavour but it is during the maturation the typical aroma of cheese develops.

1.13.4.1 Chemistry of flavour development: The basic chemistry or biochemistry of cheese-making involves slow degradation of the macromolecules (protein and lipid material) to simpler components of flavor (aroma and taste) value. Cheese flavour is
basically enzymatically derived. Proteolysis during cheese ripening and aging leads to peptide formation. The Peptides formed have varied taste characteristics based on their polarity. The basic taste sensations of sour/sweet and salt/bitter and the umami are all taste attributes of peptides and amino acids. It has been observed that the acid- (sour), hydrophobic- (bitter), and glutamic/aspartic-rich (umami) peptides are the key taste peptides and amino acids found in aged cheese. The hydrophilic (sweet) and salt-based peptides contribute very little to the flavour profile. The sweetness is from lactose and the saltiness due to the salt (sodium chloride) added to all cheese to produce a selective environment and the chemistry needed to develop the specific cheese character play a more significant flavor role than do the peptides that have salty or sweet taste character. The volatile chemicals formed from the amino acid, peptides, lipids, and sugar. Fat in cheese is broken down by lipolysis to yield number of flavour compounds from different fatty acids. These are amides, ketones, aldehydes, lactones, alcohols and esters. Sugar upon fermentation and citrate cycle generates acetic acid, diacetyl, acetaldehyde, ethanol, propionic acid and lactic acid. Protein via proteolysis gives peptides, aminoacids and finally amines sulphur compounds and fatty acids. The Interaction product of all the three processes generate further compounds e.g., Thioesters.

1.13.4.2 Flavor Attributes of different Cheeses: Cheeses with lesser flavour notes are those which have undergone least amount of ripening: fresh, soft, low-fat, higher fat cream/Neufchatel, and the whey/ricotta type. The flavors of such cheeses are primarily due to the components contributing to milk, cream, and butter flavor. They are low in flavor intensity and they may be considered to have a flavor defect. Cheddar cheese is by far the most popular type of cheese in world. It is produced by a unique process, cheddaring. It has a very complex flavour profile. The basic taste of cheddar is due to the peptide fraction and, in particular, to the umami and bitter components. The development of acetic acid during ripening contributes to the sharpness of aged cheddar. The medium chain fatty acids released during the ripening process also contributes in cheddar cheese flavor character. A correct level of acidity is desired in the finished cheese for the release of sulphur-containing compounds. Compound, in
particular, methyl mercaptan, results in a cheese with good cheddar character. Methanethiol has also been shown to be a significant factor in aged cheddar. Acetylpyrazine and 2-methoxy-3-ethylpyrazine are important in aged cheddar. The overall flavor of good cheddar is a balance between the free fatty acids and the other flavor components. Cheddar has a typical creamy, acidic and sulphurous character. Some of the important volatiles contributing to cheese flavour are methanethiol, hydrogen sulphide, diacetyl, butanone, pentan-2-one, dimethyl sulphide, acetone and ethanol. However, the whole aroma profile is quite complex which lead to difficulties in manufacture of realistic imitation cheddar flavourings.

The blue cheese contains 13 to 37 times the amount of free fatty acids occurring in cheddar. Lipolysis of the fat by the Upases generated from the use of the mold *Penicillium roqueforti* is the prime reason. Since Roquefort is made from sheep milk it does not have the high levels of free fatty acids seen in the blue cheese made from cow’s milk. Part of the flavor difference between the two is due to the lower concentration of propionic acid (4:0) in Roquefort and the relative larger amount of C8:0 and C 10:0 free fatty acids. The characteristic aroma character of the blue cheeses is combination of methyl ketones and short chain fatty acids. Methyl ketones are responsible for fruity character of this type of cheese. Secondary alcohol may be produced from the methyl ketones.

Brie and camembert are the French soft cheeses. The characteristic flavour is due to white mold growth on cheese surface. Brie has creamy, slightly acidic and nutty flavour. It also has mushroom like overtones. Camembert has strongly aromatic aroma volatiles like methanethiol. The mushroom like note present in both cheese is due to 1-octen-3-ol. In Swiss cheese peptides play an important role in flavour. Interaction of small peptides with calcium and magnesium gives the cheese a sweet flavor, with the small free peptides and amino acid contributing a slight brothy nutty flavor. An important reaction in Swiss cheese is the conversion of pyruvic acid to propionic acid by propionibacterium. Propionic acid is found in Swiss cheese at levels forms the basis of the sweet taste of that cheese. Limburger cheese is a semisoft cheese from Belgium. Flavour formation is due to the microflora. The major flavour compounds are phenol (tyrosine fermentation by microbes) dimethyl disulfide and indole. Mozzeralla cheese
has a mild, slightly acidic and buttery flavour. Quarg cheese has bland and acidic flavour. In most unripened cheese the principal flavour is diacetyl/lactic.

References:


