Paper No : 02

Paper: ***Principles of the Food processing and Preservation***

Module No: 20

Module Title: ***Roasting and Smoking of Foods***

20.1 Introduction

Food processing techniques dates back to the prehistoric ages. Cooking is evolved as one of the widely practiced food preservation method. Cooking is a type of heating process in which the primary objective is to produce a more palatable food. During cooking heat is transferred to the food either by conduction, convection, radiation or by the energy of microwaves-electronic heat transfer. In general, cooking takes place either by moist or dry heat as mentioned in the following table 20.1. Water or steam and air or fat or combinations of these are used as cooking media. Moist heating (cooking) involves water and steam. Air or fat are most commonly used in dry heat.

The word cooking is a broad term embodying at least six forms of heating, including baking, broiling, roasting, boiling, frying, and stewing. The method of applying heat energy and the duration differs somewhat for each of these processes. Baking, broiling, and roasting usually require dry heat at relatively high temperatures (greater than 100°C), boiling and stewing are done by placing the product in boiling water, and frying involves cooking oil and temperatures much greater than 100°C.

20.2 What is Roasting

Until the late 19th century, roasting by dry heat in an oven was called baking; and it is one of the oldest forms of cooking known. Roasting was originally meant turning meat or a bird on a spit in front of a fire. Traditionally recognized roasting methods consist only of baking and cooking over or near an open fire. Grilling is normally not technically a roast, since a grill (gridiron) is used. Barbecuing and Smoking differ from roasting because of the lower temperature and controlled smoke application.

Roasting is generally defined as a dry heat treatment of foods with the intention to generate roast aroma compounds, to develop color, and often to create a crispy texture. These intentional product alterations make the explicit difference between roasting and simple drying. Roasting can enhance flavor through caramelization and Maillard browning on the surface of the food. Roasting is a cooking method that uses indirect, diffused heat (as in an oven) or dry heat, whether in an open flame, oven, or by the application of other heat source. Roasting is applied to a number of foodstuffs. In general any type of food products that has been cooked in this fashion is called a roasted.

Table 20.1 Different types of Cooking Techniques

Type/mode of Cooking		List of Cooking Techniques
Dry	Conduction	Dry Roasting, Hot Salt frying, Searting
	Convection	Baking, Roasting (modern), Smoking
	Radiation	Grilling, Roasting (Traditional), Toasting, Rotiserie
Wet	High heat	Blanching, Boiling, Decoction, Parboiling, Shocking
	Low heat	Codding, Infusion, Poaching, Simmering, Steeping, Steawing
	Indirect Heat	Double boiling, Steaming
Fat-based	High heat	Blackening, Deep frying, Pan frying, Shallow frying
	Low heat	Sweating, Gentle frying
Mixed medium	Barbecuing, Braising, Stir frying, Gridding, Indirect grilling	
Device-based	Clay-pot cooking, Earth oven, Masonry oven (Tandoor), Micro oven, Pressure cooker, Pressure frying, Solar oven	
Non-heat	Curing, Fermentation, Pickling, Souring	

20.3 Mechanisms of Roasting

Roasting can be used to cook a variety of foodstuffs such as beans, nuts, oilseeds, cereal grains, pulses and most root and bulb vegetables, poultry, meat, fish and seafood. Roasting is a time-temperature controlled process that usually involves dehydration, reaction of free amino acids and short-chained peptides with free mono- and disaccharides during nonenzymatic browning, protein denaturation and subsequent changes in texture. Roasting is normally carried out under atmospheric conditions with hot combustion gases and excess air as the primary heating agent though heat may also be provided by contact with hot metal surfaces, solely in more primitive methods, but more generally as a supplement to convection from the hot gases. Some heat may also be supplied by radiation and in some designs even as the primary source by radiative heating of various kinds. Baking and roasting are essentially the same unit operation: they both use heated air to alter the eating quality of foods. The terminology differs in common usage; baking is usually applied to flour-based foods or fruits, and roasting to beans, coffee beans, oil seeds and nuts, meats, nuts and vegetables.

In general, the roasting technique illustrated in this teaching module is with reference to the roasting of coffee bean, being it is one of the most and widely roasted foodstuff. The roasting process can be roughly divided into a drying phase, a roasting phase, where a number of complex chemical reactions take place, and a final cooling phase. In roasting the initial stage of chemical reactions are endothermic, whereas a number of authors state an exothermic final roasting stage. On the basis of calorimetric measurements, the net result of reactions in coffee to become exothermic.

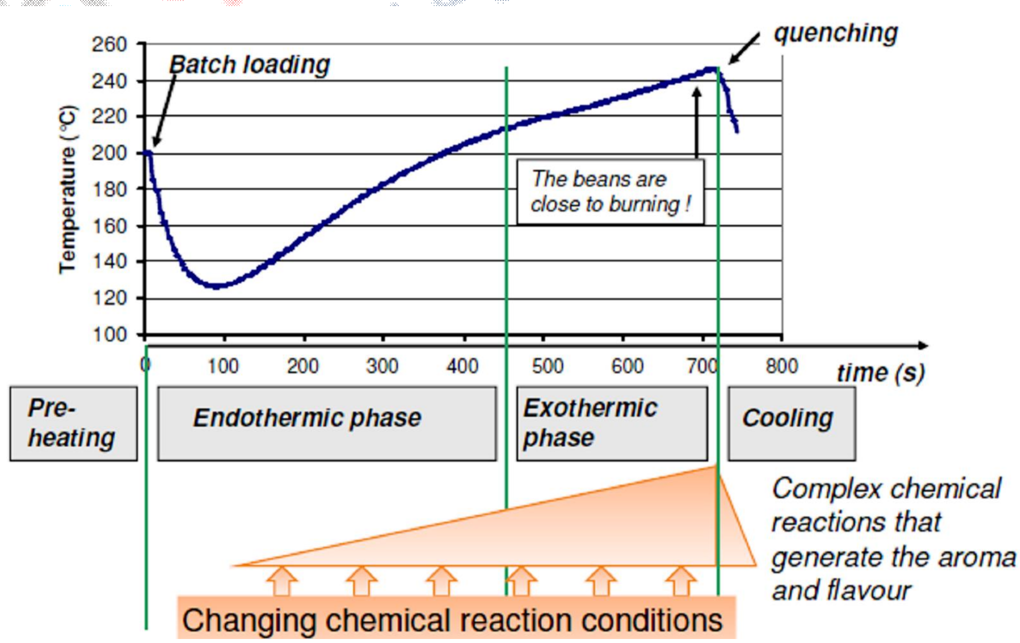


Fig. 20.1: Mechanism of roasting process

20.4 Methods of Roasting

Roasting method differs according to type of food matrix. For those foods which are meant for immediate consumption (meats and fish products) roasting method differs than that of other foods (coffee beans, oil seeds and nuts). There are several plans for roasting: low-temperature roasting, high-temperature roasting, and a combination of both. Each method can be suitable, depending on the food and the tastes of the people. For roasting, the food may be placed on a rack or in a roasting pan to ensure even application of heat, may be rotated on a spit or rotisserie. If a pan is used, the juice can be retained for use in gravy. During oven roasting, hot air circulates around the food, cooking all sides evenly.

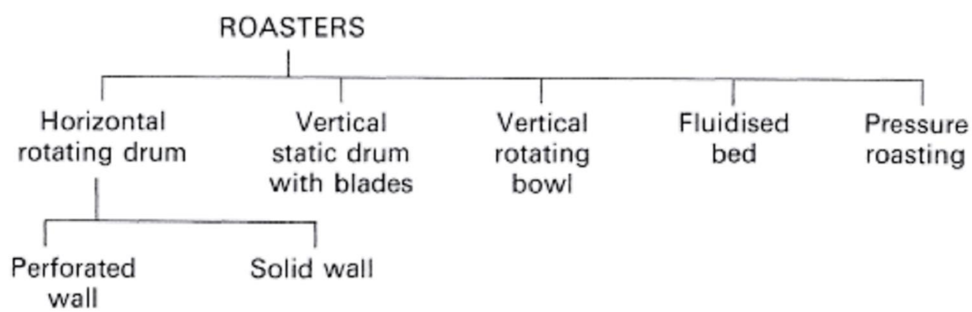


Fig. 20.2: Different types of roasters

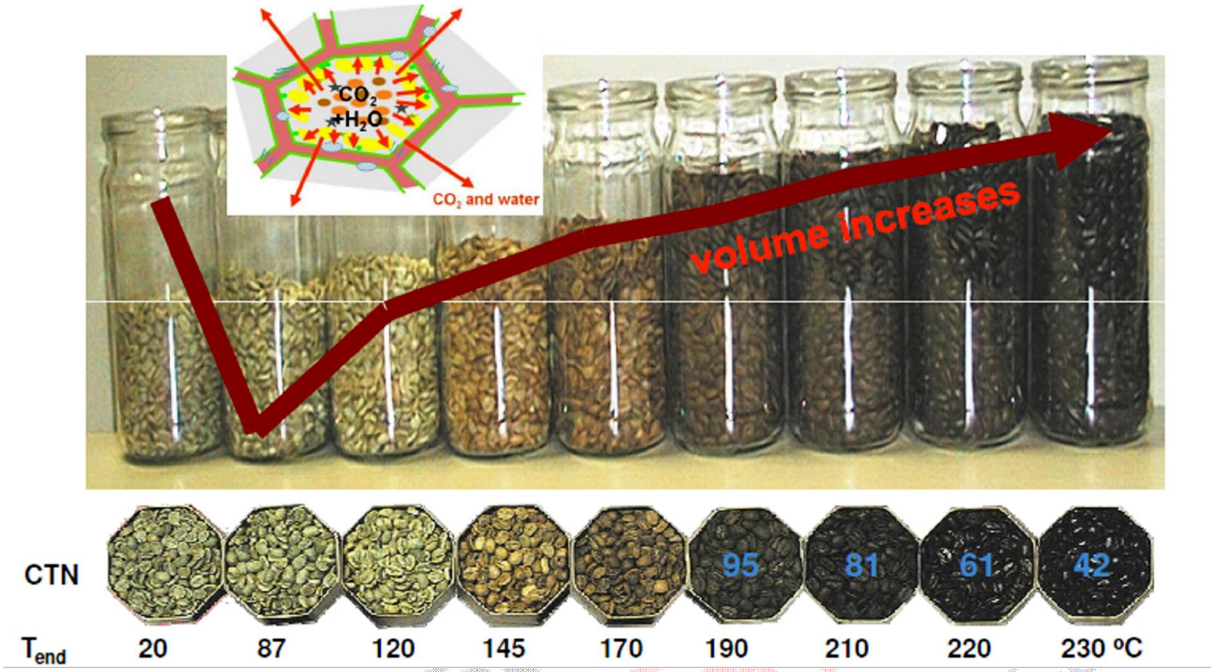
The horizontal rotating drum has been the most usual method of providing contact of hot air in a tumbling coffee bed, but roasters have been designed and are available based on other mechanical principles. Horizontal rotating drums may provide either batch or continuous roasting whereas the vertical drum and bowl are usually batch. Fluidisedbed roasters generally operate in the batch mode, but the latest designs are often continuous.

20.5 Physico-Chemical Changes in Roasted Foodstuff

Two important preservative changes occur in food as a result of roasting: destruction or reduction of microorganisms and inactivation of undesirable enzymes. Other desirable changes that may occur during cooking include (1) destruction of potentially hazardous toxins present naturally or through microorganisms; (2) alteration of color, flavor, and texture; and (3) improved digestibility of food components. Undesirable changes also may occur, such as degradation of nutritive components and sensory attributes.

During roasting the beans looses weight, generally between 14 and 20%, depending on the green bean quality, the process conditions and the target degree of roast. A major part of this weight loss is due to dehydration, whereas another substantial part (some 5 to 8% for a medium degree of roast) is caused by a loss of dry matter, primarily as CO_2. The chemical reactions that convert organic matter into gaseous products also result in the formation of a considerable amount of water that is then again lost as water vapor.

Some of the more extensive and complex chemical reactions during roasting affect the carbohydrates of green beans and include Maillard reaction, Strecker degradation, pyrolysis, caramelization, mainly resulting in aroma, flavor and color compounds. Roasting leads to protein denaturation and degradation. Free amino acids, peptides and proteins with free amino groups react with reducing sugars to form glycosylamines and/or aminoaldoses and/or amino-ketones by condensation. Amino acids react with a-dicarbonyls during Strecker degradation and form amino-ketones. On roasting there is a reduction in the amount of citric and malic acid and an increase of many of the other acids, in particular quinic acid and volatile acids. Chlorogenic acids are strongly degraded. The loss is about proportional to the degree of roast and can reach 80% in dark roasted



Note: CTN= Colour Test Neuhaus scale, reflectance colorimetric unit that is used to determine the final roasting point.

Fig. 20.3: Changes in colour and volume during roasting stage with respect to degree of roasting

As presented in figure, the volume increase is the most obvious macroscopic change of the bean structure during roasting. Bean expansion occurs progressively, but including a "popping phase", leading to considerable decrease of density. It is not quite clear from this statement whether the term "popping phase" applies only to sounds accompanying the expansion, or a phase of instantaneous expansion. Volume increase and density decrease is a function of the degree of roast, but also of the speed of roasting. When the resulting bean volume is correlated with the final roasting temperature; bean expansion is caused by a very rapid pressure build-up, due to rapid formation of water vapor and gas within the bean. A steady and continuous volume increase is positively correlated to weight loss. Extent of darkness is also positively correlated with the degree of roasting.

The roasted whole beans are characterized by the roasting process to which they have been subjected; their so-called degree of roast is reflected in their external colour, the flavour developed, the dry mass loss that has occurred, and the chemical changes in selected components. In simple terms, roast coffee can be described as having a 'light', 'medium' or 'dark' roast. Degree of roast plays a major part in determining the flavour characteristics of extracts subsequently brewed from roasted coffee.

20.6 Roasting of Meat and Meat Products

Tenderness of meat changes during roasting due to the transformations in connective tissue and myofibrilar proteins. When heated in the presence of water, collagen dissolves, which results in crushing of meat, while myofibrilar proteins denature, which causes the meat increased hardness and shrinkage both crosswise and along muscle fibres and connective tissue. During heat treatment, meat loses 20-40% of its total initial weight due to fluid leakage with the increasing temperature. Cooking loss is strongly associated with fibres shrinkage and thereby impacts the overall process efficiency and general consumer acceptance of the product. Proper roasting methods and setting of temperature-time-humidity parameters, adequate to these processes, are important in improving tenderness in roasted food.

There is a loss of dry matter, primarily as gaseous carbon dioxide and water (over and above that moisture already present), and other volatile products of the pyrolysis. During roasting, meats and vegetables are frequently basted on the surface with butter or oil to reduce the loss of moisture by evaporation. In recent times, plastic oven bags have become popular for roasts. These cut cooking times and reduce the loss of moisture during roasting, but reduce flavor development from Maillard browning, somewhat more like (boiled or steamed) stew or pot roast. They are particularly popular for turkeys. In general, in either case, the meat is removed from heat before it has finished cooking and left to sit for a few minutes, while the inside cooks further from the residual heat content, a phenomenon known as carry over cooking, also known as "resting" the meat. Following are the three types of roasting employed in meat and meat products.

a) A low-temperature oven, 95°C to 160°C (200°F to 325°F), is best when cooking with large cuts of meat, turkey and whole chickens. This is not technically roasting temperature, but it is called slow-roasting. The benefit of slow-roasting an item is less moisture loss and a tenderer product. More of the collagen that makes meat tough is dissolved in slow cooking. At true roasting temperatures, 200°C or more, the water inside the muscle is lost at a high rate.

b) Cooking at high temperatures is beneficial if the cut is tender enough as in filet mignon or strip loin to be finished cooking before the juices escape. A reason for high temperature roasting is to brown the outside of the food, similar to browning food in a pan before pot roasting or stewing it. Fast cooking gives more variety of flavor, because the outside is brown while the center is much less done.

c) The combination method uses high heat just at either the beginning or the end of the cooking process, with most of the cooking at a low temperature. This method produces the golden-brown texture and crust, but maintains more of the moisture than simply cooking at a high temperature, although the product will not be as moist as low-temperature cooking the whole time. Searing and then turning down to low is also beneficial when a dark crust and caramelized flavor is desired for the finished product. Note that searing in no way "locks in" moisture: moisture loss is simply a function of heat and time.

20.7 Roasting of Coffee Beans

Coffee and cocoa has received much attention because of the high demand for the typical caramalized flavors. After harvesting, cocoa beans are fermented under controlled conditions. The beans are then roasted; that darkens the color and yields a typical characteristics flavor. The fermentation hydrolyzes sucrose to reducing sugars, frees amino acids, and oxidizes some polyphenols. During roasting, many pyrazines and other heterocyclics are formed, but the unique flavor of cocoa is derived from an interaction between aldehydes from the Strecker degradation reaction in roasting stage.

Green coffee beans provide neither the characteristic aroma nor flavour of brewed coffee until they are roasted. Moreover, the roasting process increases the value of coffee beans, by 100-300% of the raw material. Roasting of coffee beans typically takes place at 200-240°C for different times depending on the desired characteristics of the final product. Events that take place during roasting are complex, resulting in the destruction of some compounds initially present in green beans and the formation of volatile compounds that are important contributors to the characteristic of coffeeǒs aroma.

Briefly, as temperature increases to about 100°C, green coffee beans undergo moisture loss from 8-12% in green coffee beans to about 5% in the roasted coffee beans. The smell of the beans changes from herb-like green bean aroma to bread-like, the color turns from green to yellowish, and the structure changes from strength and toughness to more crumbly and brittle. When the internal temperature of beans reaches 100°C, the color darkened slightly for about 20-60 s due to the vaporization of water. At 160-170°C, the beans become lighter in color for about 60-100 s. As roasting continues at this temperature, beans begin to turn brown and the caffeol, or oil, locked inside the beans begins to emerge. This process, called pyrolysis, is at the heart of roasting. It is what produces the flavor and aroma of the coffee. Maillard reactions also start to take place, resulting in gradually darkening of the beans. The buildup of water pressure, along with the large amount of gases generated causes the cellulose cell wall to crack, giving rise to the so called ñfirst crackò. As heating continues at the roasting temperature (160-170°C), the coffee becomes darker and more rapid popping of coffee bean occurs (ñsecond crackò) as the carbon dioxide (CO_2) buildup exceeds the strength of the cellulosic walls of the bean. Finally, after roasting, the fresh roasted coffee beans are quickly cooled to stop roasting.

The final quality of roasted coffee is influenced by the design of the roasters and time-temperature profiles used. Although heat transfers during roasting can involve conduction, convection, and radiation, convection by far is the most important mode of heat transfer that determines the rate and uniformity of roasting.

20.8 Smoking

Smoking is one of the oldest method of food preservation, probably having arisen shortly after the development of cooking with fire. Smoking is the process of cooking, flavoring, or preserving the food by exposing it to the smoke from burning or smoldering plant materials, most often wood.

From the engineering point of view there is no such process as smoking. Smoke is an antimicrobial and antioxidant, used as a condiment and claimed as a preservative, but smoke alone does not give us the so called smoked food products. The basic food process called drying, combined with the effects of salt and smoke particulates results in smoked products. Smoking is defined as the process of penetration of volatiles resulting from thermal destruction of wood into the surface of food products.

Meat, chicken and fish are the most common smoked foods. Cheeses, nuts and seeds, hard-boiled eggs, berries, vegetables, and ingredients used to make beverages such as whisky, Rauchbier, and lapsang souchong tea are also smoked. However, amateurs using ordinary smoke ovens or adapting barbecue grills to the purpose have successfully used the smoking technique to flavour and preserve not only meat, variety meats parts including heart, tongue, and liver. Pork and beef hams, bacon bellies, and sausages are the most common commercially smoked meats.

20.9 Types of Smoking

a) **Cold smoking:** Cold smoking can be used as a flavor enhancer for items such as chicken breasts, beef, pork chops, salmon, etc. The item is hung first to develop a pellicle, and then can be cold smoked for just long enough to give some flavor. Some cold smoked foods are baked, grilled, steamed, roasted, or sauted before eating. Smokehouse temperatures for cold smoking are typically done between 20 to 30°C. In this temperature range, foods take on a smoked flavor, but remain relatively moist. Cold smoking does not cook foods.

b) **Hot smoking**: Hot smoking exposes the foods to smoke and heat in a controlled environment. Like cold smoking, the item is hung first to develop a pellicle, and then smoked. Although foods that have been hot smoked are often reheated or cooked, they are typically safe to eat without further cooking. Hams and ham hocks are fully cooked once they are properly smoked. Hot smoking occurs within the range of 52 to 80°C. Within this temperature range, foods are fully cooked, moist, and flavorful.

c) **Smoke-roasting"** or **"Smoke-baking:** Smoke roasting or smoke baking refers to any process that has the attributes of smoking combined with either roasting or baking. This smoking method is sometimes referred to as "barbecuing", "pit baking", or "pit roasting". It may be done in a smoke roaster, closed wood-fired masonry oven or barbecue pit, any smoker that can reach above 121°C, or in a conventional oven by placing a pan filled with hardwood chips on the floor of the oven so the chips smolder and produce a smoke bath. However, this should only be done in a well-ventilated area to prevent carbon monoxide poisoning.

20.10 Mechanism of Smoking

Application of smoke to foodstuffs essentially is a physical process, which is based on such phenomena as diffusion, absorption, dissolution and deposition in force fields. It is accompanied by chemical process where in smoke compounds interact with food components. Te basic fact pertaining to the smoke formation and application is the products of oxidative thermo-destruction of raw materials used for the developing the smoke.

Whether done on a commercial or a home scale, the smoking technique involves hanging the food products or placing it on racks in a chamber designed to contain the smoke. Commercial smokehouses, usually several stories high, often use steam pipes to supplement the heat of a natural sawdust fire. Generally, smokehouse temperatures may go up to 71° C, and smoking periods vary from as short as a few hours to as long as several days, depending on the type of food and its moisture content. In order to shorten the production process, commercial meats are sometimes artificially ñsmokedò by dipping them in a solution of preservative chemicals or by painting them with such a solution. But because this procedure involves no natural drying action, it has practically no preservative effect.

a) **Dry Smoking**: Dry smoking uses indirect cooking with a low, smoldering wood fire to slowly cook foods while infusing smoke flavor.

b) **Wet Smoking**: Wet smoking, or water smoking, is more commonly employed and uses a pan of water to maintain moisture and tenderness.

20.11 Preservation Effect in Smoking

Smoke is an antimicrobial and antioxidant, but smoke alone is insufficient for preserving food in practice, unless combined with another preservation method. The brown color that develops at the surface of protein-based foods during smoking is primarily caused by nonenzymatic browning reactions involving amino groups on food proteins and carbonyl compounds in the smoke. Phenol as one of smoke components act as antioxidant agent, while other components are organic acids, alcohol, carbonyl, hydrocarbon and nitrogen compounds such as nitrooxide, whilst the compounds found at the surface which possibly also penetrate into smoked food are aldehydes, ketones, ester and ether also impart preservative effect.

Hot-smoked chum salmon   Smoked Gruyère cheese

Fig 20.4: Smoked salmon and cheese

20.12 Desirable Effects of Smoking on Food

The desirable effects of smoking on foods are flavouring, preservation and coloring, contributed by the smoke material. Wood, the material most widely used for smoke production, consists of many groups of polymers which are the cellulose, lignin and hemicelluloses. The composition of wood smoke is very complex and is known to contain acids, carbonyls, alcohols, phenolics, and other neutral compounds. Many of the fat-soluble compounds present in wood smoke are absorbed into the food surface during natural smoking, and presumably the same is true for water-soluble components such as acids. The typical aroma of smoked food seems to be due mainly to the effect of phenols, carbonyls and acids. The smoke phenols contribute essentially to the typical flavour of smoked food.

20.13 Undesirable Effects of Smoking on Food

Undesirable effects are contamination with toxic components of smoke and some destruction of essential amino acids of food proteins which are attributed to certain class of components of smoke and liquid smoke. The main problem is the smoke compounds adhere only to the outer surfaces of the food; smoke does not actually penetrate far into meat or fish. Surface dehydration often occurs in foods that are subjected to natural vaporous smoking. Loss of moisture during smoking should cause soluble constituents to become more concentrated within the water phase of the food material in direct relation to moisture loss. If the smoker is allowed to get hotter than 85°C, the foods will shrink excessively, buckle, or even split. Smoking at high temperatures also reduces yield, as both moisture and fat are "cooked" away.

20.14 Health implications of Smoked and roasted foods

Eating a diet high in smoked, cured, or salted meats has been shown to be a risk factor in stomach cancer. In addition to sugar and salt exposure, smoking can directly create compounds known to have long-term health consequences, namely polycyclic aromatic hydrocarbons, or PAHs, many of which are known or suspected carcinogens.