Consortium for Educational Communication

Module

on

Effect Of Cooking On Food

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TEXT

INTRODUCTION

At present, conclusive evidence eludes us as to the origins of cooking. Some researchers believe that cooking was invented over 2.3 million years ago, whilst others argue it is a more recent concept, being invented only 40,000 years ago. Cooking is the process of producing safe and edible food by preparing and combining ingredients, and (in most cases) applying heat. Cooking is a means of processing food, without which many foods would be unfit for human consumption.

Cooking was first used for preservation but it has evolved and now it is a form of entertainment and creativity for many people. Man who is the apex of evolution requires food as one of the important constituent for survival. Food can be taken as raw and in cooked form. Evidently, there are number of advantages, therefore, cooked food is preferred over raw food. Food is essential for the growth of an organism as it contains protein, carbohydrate, fats, vitamins and minerals as nutrients. Cooking affects nutrients present in food in a number of ways. It is important to be aware of the resultant output of the nutrients available in cooked food. This contributes as one of the important aspects for health. During the studies conducted on various food materials, it has been observed that generally there is a decrease in nutrient value in customary cooking methods. The losses of nutrients (protein and vitamins) have been studied, in various food materials and compared for different cooking methods.

Some people are of the opinion that cooking was discovered accidently. Thereafter, food has generally been consumed in the cooked form by man. With advancement in all the fields, man started cooking his food by different methods; as a result, today we use all these different methods to cook our food. Before going into the details of different methods, we should know why we cook food.

Though the main objective is to make the food edible, yet there are other reasons for cooking.

Objectives of Cooking

(i) To make the food attractive and palatable

Cooking makes the food look attractive and also renders it more tasteful than the uncooked food. More sight of a well cooked and pleasant looking food activates our digestive enzymes and makes us feel hungry.

(ii) To make the food digestible

Cooking makes the food soft and tender, thus makes it easy and quick to digest. For example, after cooking carbohydrates present in food become easier to digest to a certain extent. Similarly proteins coagulate (e.g egg protein) on cooking which makes the digestion simple. It is due to these reasons that soft and well cooked food is recommended for people in diseased conditions, as their digestive system is weak. Cooking foods containing starch (e.g., cereals and vegetables), prior to consumption initiates the breakdown of the polysaccharide, thus, aiding the action of amylase and the consequent digestibility of the carbohydrate component of the food.

(iii) To introduce variety in meals

Variety can be brought about in meals easily by using different methods of cooking. For example, one single foodstuff like potato can be cooked by using different methods into a number of dishes and thus add variety to the meals.

(iv) To enhance the availability of some nutrients

For example, cooking destroys trypsin inhibitor present in protein foods. This makes the trypsin freely available to the body. Similarly starch is more easily available after cooking.

(v) To destroy microorganism

Cooking of foods destroy the microorganism present in them to a large extent, thus, making it safe for consumption. Many foodstuffs like milk, meat, fish, can harbour certain disease producing microorganism thus making the person sick on consumption of such foodstuff. Raw milk may have microorganism responsible for causing tuberculosis and typhoid. Meat especially pork, contain eggs of worms (*Trichinella spiralis*) which can cause infestation in the body. Fortunately, these microorganisms are destroyed by usual cooking procedures, hence making the food safe. Most cooking methods if performed properly will heat foods to over 70 °C, so applying such a temperature for a calculated time period will prevent many food borne illnesses that would otherwise manifest if the raw food is eaten. *Campylobacter, Salmonella* and *Listeria monocytogenes* are three of the most common food poisoning bacteria and together are reported to affect over 380,000 European Union (EU) citizens each year. Table 1 lists the foods these bacteria are most likely to be found in and the symptoms they commonly cause.

Table 1: Common food poisoning bacteria and their likely food sources and symptoms

Bacteria	Food sources	Symptoms
Campylobacter	Raw poultry and meat, unpasteurised milk	Fever, headache, diarrhoea
Salmonella	Raw meat, poultry and eggs, raw unwashed vegetables, unpasteurised milk and dairy products	Fever, diarrhoea, vomiting, abdominal pain
Listeria monocytogenes	Raw milk, meat, poultry, cheeses (particularly soft, mould-ripened varieties), salad vegetables	Flu-like symptoms, meningitis, septicemia and abortion, miscarriage

(vi) Increasing consumption of food/ Edibility

The desire to eat is primarily driven by the body's need for nutrition, with the intake of essential nutrients being indispensable for life. This fundamental reason to eat is challenged by the psychological needs of enjoyment and pleasure. Cooking can cause changes in the colour, flavour and texture of foods that allow us to create foods that we derive pleasure from eating. For example, roasting potatoes initiates a series of changes that makes them edible, as well as attractive in colour and taste by generating a golden brown colour, invoking a natural sweetness and producing a crisp shell and a soft internal texture.

(vii) Concentrate nutrients

This may be due to removal of moisture or using combination of foods or due to cooking procedures, e.g. sweets. Thus cooking of food is very important, as it increases digestibility, appeals to palate and destroys microorganisms.

Main types of cooking

The fundamental types of cooking from which cooking methods stem across Europe and indeed, the world, are listed below.

(i) **Frying**

Frying is the cooking of food in oil or fat. Usually, fried foods have a characteristic crisp texture. This is because oils and fats can reach higher cooking temperatures than water. Common types of foods that are fried include; battered or breaded fish or vegetables, crisps, chips and doughnuts.

Frying types

- Stir-frying – a frying pan is used to cook foods at a very high temperature, in a thin layer of fat. The food is fried very quickly and stirred continuously to prevent the food from burning.
- Deep-frying – a large deep pan, or deep-fat fryer is half-filled with fat and heated. Food is immersed in the fat for a few minutes and then removed.
- Shallow-frying – a large, shallow pan is filled with a layer of fat deep enough to cover about one third of each piece of food. As with deep-frying, the fat is heated prior to the food being added to the pan. After a few minutes, the food is removed from the pan and drained.

(ii) **Baking**

Baking is the process of cooking foods in the dry heat of an oven. During baking, moisture within the food is converted to steam, which combines with the dry heat of the oven to cook the food. Common types of foods that are baked include; bread, cakes, jacket potatoes, and pastries.

(iii) Boiling

Boiling is the cooking of foods in a liquid (e.g., water, milk), which is at boiling point. Common types of foods that are boiled include; vegetables, rice, pasta rice, eggs, dals, potatoes, meat, sago and beetroot. Blanching is a very similar cooking technique to boiling and involves immersing food into a boiling liquid for a very short period of time, before being removed and plunged into ice water to stop the cooking process. Common types of food that are blanched include; vegetables and fruits.

(iv) Simmering

Simmering is also similar to boiling, except that the food is cooked in liquid, which is held below boiling point. The simmering point of most liquids is between 85-95 ^{o}C, and compared to boiling, is a gentle and slowe method of cooking. Common types of foods that are simmered include; vegetables, soups and sauces. Poaching is a comparable cooking technique to simmering, except that the temperature of the liquid in which food is cooked is slightly lower than simmering point (around 70-85 ^{o}C). This makes poaching an ideal method of cooking fragile foods such as eggs and fish.

(v) Grilling

Grilling is the cooking of food using a direct and dry heat. There are several sources of dry heat that may be used for grilling including; charcoal, wood, gas or electric heated grills. Common types of food that are grilled include; fish, meat, vegetables and bread.

(vi) Steaming

Steaming is the cooking of foods by steam. Steam is generated by boiling water, which evaporates and carries the heat to the food. Steaming is done in two ways i.e. direct steaming and indirect steaming.

Direct Steaming – In this method, the food comes in direct contact with the steam. Direct steaming can be done in an ordinary steamer or in an improvised steamer. For example, steaming of cut vegetables, or sprouted pulses, fish, idly, Dhokla etc.

Indirect Steaming– In this method, the food does not come in direct contact with the steam, but is cooked by the heat of the steam surrounding the container containing the food material. Examples of indirect steaming are steaming of puddings like custards etc.

(vii) Roasting

Roasting is the cooking of food using dry heat. This may include cooking in an oven, or over an open flame. Normally, the food is placed in a roasting pan, or rotated on a spit to ensure an even application of heat. Typical foods that are cooked by roasting include meat and vegetables.

(viii) Canning

Heating of foods in hermetically sealed containers is known as canning. Nicolas Appert, a French confectioner was the first to demonstrate canning of foods. Canning requires a medium for heat transfer e.g oil or water. Time and temperature combination during canning is of prime importance. More severe heat treatment or heating for prolonged time may have negative impact on product quality.

Changes during cooking

Heating causes a complex series of physical and chemical changes in the food to be cooked. These changes vary depending on the type of food being cooked and the cooking method. The changes may be advantageous e.g., improving the flavour, texture and colour of the food, or they may be disadvantageous e.g., reducing the nutritive value of the food, or the generation of undesirable compounds. In addition changes occur due to various inorganic, mineral components and a number of pigments, flavour components, vitamins, acids, enzymes etc. The main physical and chemical changes that occur during the cooking of foods are discussed below.

(i) Changes in flavour

Flavours of the food during the cooking are produced by the caramelisation process. This type of process is characteristic of many food products such as dark beer, coffee, confectionery and peanuts. The caramelisation reaction occurs when foods containing a high concentration of carbohydrates are cooked at high temperatures using a dry-heat e.g., roasting peanuts, setting-off a chain of chemical reactions:

- As the food is heated, the sucrose in the food melts decomposes into glucose and fructose. The temperature at which this occurs is known as the caramelisation temperature, which (depending on the types of carbohydrates present in the food), is generally between 110°C – 180°C.
- A further series of complex chemical reactions take place between the molecules, which, ultimately results in the generation of flavour compounds.

In actual fact, caramelisation generates hundreds of flavour compounds. One of the most important flavour compounds produced is diacetyl. Diacetyl is generated during the initial stages of caramelisation and has a butterscotch flavour, which provides one of the characteristic flavours of caramelised foods. Other important flavour compounds produced during the caramelisation reaction include the furans hydroxymethylfurfural and hydroxyacetylfuran, and maltol from disaccharides and hydroxymaltol from monosaccharides, which together contribute to give the sweet, slightly burnt flavour of the caramelisation reaction.

Any foods that contain high concentrations of carbohydrates e.g., beer, coffee, peanuts and confectionery under goes caramelisation during roasting, grilling, baking, frying. Table 2 describes the variation in flavour during the caramelisation of sucrose.

Table 2: Flavour variation during caramelisation

Caramel description	Temperature (°C)	Caramel Flavour	Caramel colour
Light caramel	180	Intense, very sweet flavour	Pale amber to golden brown
Medium caramel	180-188	Intense sweet flavour	Golden brown to chestnut brown
Dark caramel	188-204	Bitter, non-sweet flavour	Very dark brown

Black	210	Burnt, bitter flavour	Very dark brown/ black

(iii) **Maillard reaction**

Along with caramelisation, the Maillard reaction is another most important browning process in foods. The Maillard Reaction is essentially a chemical reaction between an amino acid and a sugar such as glucose, fructose or lactose. Usually, heat is required to start the reaction that causes a cascade of chemical changes, which, ultimately, result in the formation of a range of flavour and colour compounds. The complex pathways of chemical reactions, not only generate important flavour compounds, but they also produce brown colour compounds known as melanoidins. Melanoidins give many foods their characteristic colouring e.g., coffee, bread and meat. Maillard Reaction is responsible for producing many sulphur containing compounds, which contribute to the savoury, meaty, flavour characteristics of cooked meat. Any food that contains both protein and carbohydrate can undergo Maillard reaction e.g., meat, biscuits, bread, coffee and nuts. Cooking methods that may result in the Maillard reaction are frying, baking, grilling and roasting

(iv) **Starch degradation**

The polysaccharide starch is present in all plant seeds, tubers, and their processed products like pasta, rice, bread, potatoes and oats. It is a common form of carbohydrate, composed of several thousand glucose units, linked together by glycosidic bonds. When foods containing starch are cooked, the heat can break the glycosidic bonds linking the glucose units together and effectively break-up the polysaccharides to release the glucose monosaccharides. This imparts a natural sweetness to the cooked food.

(v) **Changes in colour**

Caramelisation

The color of cooked food has great impact on its acceptance. Different physicochemical reactions occurring during the cooking of food are responsible for the generation of typical color. Besides this various factors like temperature of cooking, time of cooking, ingredients used, intrinsic and extrinsic factors of the food play a vital role in development of color. However the main processes responsible for the generation of color in most of the foods are discussed here. During the caramelisation reaction, molecules known as caramels (Caramelans, Caramelens and Caramelins) are generated and it is these compounds that are responsible for the characteristic brown colour of caramelised foods. As with flavour generation during the caramelisation reaction, the colour of caramel also varies depending on the type of carbohydrate undergoing the reaction. However, for all caramelisation reactions, the colour becomes darker as the temperature is increased. Any foods that contain high concentrations of carbohydrates e.g., beer, coffee, peanuts and confectionery undergo caramelisation. Cooking methods that may result in caramelisation are roasting, grilling, baking and frying

(vi) Loss of pigments

The main foods containing pigments and therefore likely to be prone to losing pigmentation during cooking, are fruits and vegetables. Chlorophyll is a fat-soluble pigment and thus, may leach from fruit and vegetables if they are cooked in a medium containing fat e.g., stir-frying. However, as cooking continues, acids in the cells of the fruit or vegetable are released and cause a chain reaction resulting in the conversion of chlorophyll to pheophytin-a (a grey-green coloured pigment), or pheophytin-b (an olive-green coloured pigment).

Similar to chlorophyll, carotenoids are also fat-soluble colorants, which mean cooking methods involving the use of fats may also cause leaching of the pigment. Cooking methods, which expose fruits and vegetables containing carotenoids to the atmosphere for long periods of time e.g., boiling without a lid, will therefore cause the depletion of the pigment, resulting in paler coloured food.

Both anthocyanins and anthoxanthins are water-soluble pigments and thus may leach into cooking water during soaking or prolonged heating. Cooking methods avoiding water such as stir-frying will thus minimise the loss of these flavonoids during heating. Food types that may undergo pigment loss are fruits and vegetables. The cooking methods that may result in pigment loss are boiling, frying, grilling, steaming and roasting.

(vii) Changes in texture

Protein denaturation

Many foods contain proteins, such as meat, fish, eggs, vegetables, nuts and pulses. Proteins are large molecules, composed of strands of amino acids, which are linked together in specific sequences by the formation of peptide bonds. Proteins form different 3-dimensional structures, by the folding and subsequent bonding of the amino acid strands. Generally, the bonds which link the folded amino acid strands together (mostly hydrogen bonds), are much weaker than the strong peptide bonds forming the strands. During cooking, the heat causes the proteins to vibrate violently, which results in the breakage of the weak hydrogen bonds holding the amino acid strands in place. Ultimately, the protein unravels to re-take its initial form of amino acid strands. The denaturation of protein molecules in foods usually causes a substantial change to the texture of the product. For example, egg white is composed of two key proteins; ovotransferrin and ovalbumin. As the egg white is heated, ovotransferrin begins to denature first, entangling and forming new bonds with the ovalbumin. As the temperature increases, ovalbumin then starts to denature, unravelling and forming new bonds with the ovotransferrin, until denaturation and rearrangement of the protein molecules are complete. In this case, the rearrangement of the protein molecules results in the change of a runny, fluid texture to a rigid, firm texture.

Conversely, protein denaturisation can also cause the formation of softer textures. For example, the protein collagen, which is the major component of the connective tissue in meat, has a tough, chewy texture. However, during cooking, the weak hydrogen bonds are broken and the protein begins to decompose and react with water molecules to form gelatine. This tenderises the meat, giving it a softer, more palatable texture. Food types that may undergo protein denaturation include meat, fish, eggs, pulses. The cooking methods that may result in protein denaturation are boiling, frying, grilling, roasting, steaming and baking

(viii) Polysaccharide gelatinisation

Foods containing the polysaccharide starch, such as corn flour and rice flour, are often used to create and/or thicken sauces. This is because the cooking of these foods causes a process known as starch gelatinisation. The starch granule is made up of two polysaccharide components, known as amylose and amylopectin. Amylose has a linear chain of glucose units, whilst amylopectin has a branched structure of glucose units. When cooked in water, the starch granules absorb water and swell. At the same time, amylose leaches out of the granules and bonds to form organised lattice structures, which trap the water molecules causing the thickening of the mixture. **Food types that may undergo starch gelatinisation include** potatoes, wheat, rice, pasta. The cooking method that may result in starch gelatinisation is boiling.

(ix) Polysaccharide degradation

Many plant foods, in particular vegetables, maintain their rigidity by the incorporation of polysaccharides such as cellulose and pectin in the plant walls. During degradation of starch, cellulose and pectin can also be broken down into their monosaccharide constituents by cooking, resulting in the substantial softening of foods containing these polysaccharide**.** Any foods containing polysaccharides such as cellulose and pectin e.g., vegetables undergo this degradation. The cooking methods that may result in polysaccharide degradation are boiling, frying, grilling, roasting and baking.

(x) Nutritional Composition

(a) Minerals

As with vitamins, minerals are also essential nutrients, without which the body cannot function correctly. There is no loss of minerals in normal cooking procedures. If cooking water is discarded (a small fraction) water soluble minerals may be lost. Heating itself does not affect mineral levels but are usually leached if cooked in boiling water. Minerals tend to have higher heat stability and are less affected by cooking methods which involve heating foods for longer periods of time.

(b) Vitamins

Vitamins are essential nutrients, without which the body cannot function properly. There are two main types of vitamins; water-soluble and fat-soluble (Table 4).

Table 3: List of water-soluble and fat-soluble vitamins

Water-Soluble		**Fat-Soluble**	
Vitamin	Scientific Name	Vitamin	Scientific Name
B1	Thiamine	A	Retinol
B2	Riboflavin	D	-
B3	Niacin	E	Tocopherol
B5	Pantothenic acid	K	-
B6	Pyridoxine		
B7	Biotin		
B12	Cobalamin		
C	Ascorbic acid		

As the name suggests, water-soluble vitamins are highly soluble in water and tend to be found in foods that have high water contents such as fruits and vegetables. Similarly, fat-soluble vitamins are highly soluble in fat and tend to be found in foods that have high fat contents such as dairy products, vegetable oils and oily fish.

The differences in vitamin solubility mean that the method by which foods are cooked has a substantial influence on the final vitamin content. Due to their tendency to disperse in water, water-soluble vitamins in particular are heavily affected by cooking processes that involve immersing food in water for long periods of time e.g., boiling. In contrast, fat-soluble vitamins tend to be lost during cooking processes where foods are cooked in fat e.g., frying, or when fat is lost from the product e.g., grilling.

Cooking medium and the length of heating can also affect the vitamin content of foods. Both fat-soluble and water-soluble vitamins are susceptible to heat, with the latter being particularly sensitive. Short cooking methods such as stir-frying and blanching help to reduce the heat degradation of vitamins, compared to longer cooking methods such as roasting.

Thiamin and Vitamin C are two vitamins, which are most affected by cooking. The losses may occur due to dissolved nutrients being discarded or destruction due to exposure of heat in cooking. The amount lost depends on the combination of these factors. Discarding the cooking water accounts for a loss of nearly 20-25 per cent of thiamin depending on the quantity of water used in cooking. If sodium bicarbonate is added to pulses during cooking, most of the thiamine is destroyed. Similarly, the cooking of vegetables for prolonged periods of time can result in a loss of over half of their vitamin C content. If vegetables are heated, canned and reheated, almost 2/3rd of the original vitamin C content may be lost.

Vitamin C in the cooking water which is later discarded amounts to a loss of 10% to 60% depending on the vegetables cooked and the method of cooking used. Loss of riboflavin during cooking occur in four ways (i) exposure of the food during cooking to strong light, (ii) loss of riboflavin due to heat (iii) loss of riboflavin due to leaching by discarding excess of cooking water and (iv) loss of riboflavin due to addition of cooking soda during cooking of dal and vegetables. Foods containing vitamin e.g., fruit and vegetables suffer loses during cooking. The cooking methods that may result in the loss of vitamins are frying, boiling, grilling, steaming and roasting.

(c) Fats & Oils

Ordinary cooking has no effect on fat, but prolonged heating, as in the case of frying for long periods thickens and darkens the fat. A part of essential fatty acids present in fat are destroyed and toxic polymerized products are formed. These changes are accompanied by changes in flavour also, which may not be acceptable. Fats and oils, become rancid by action of air (oxidized) water (hydrolysis) and enzymes. These changes must be minimized, so that the food in which fat is used remains acceptable. Food types that may result in the loss of minerals include meat and vegetables. The cooking method that may result in the loss of minerals is boiling.

Generation of Undesirable and Desirable Compounds

(i) **Undesirable compounds**

Over recent years, it has become evident that cooking foods can lead to the generation of undesirable compounds. The generation of potential carcinogenic compounds has received particular attention due to the serious nature of their possible consequences.

Perhaps the most well known of these compounds are nitrosamines. During cooking, nitrosamines are produced from nitrites and secondary amines. They are found in some smoked, grilled or fried foods, such as charred meat, and they can also be found in tobacco. Several other compounds are considered as carcinogenic, such as acrylamide and heterocyclic amines, which are both formed as a result of the Maillard Reaction, as well as furan, polycyclic aromatic hydrocarbons and chloropropanols/ esters. Furan, formed by several pathways, is a volatile chemical that tends to evaporate quickly. However, when it cannot escape for some reason (e.g. in sealed cans or jars), it remains present in the food for some time. Polycyclic Aromatic Hydrocarbons (PAHs) are produced when any incomplete combustion occurs, from grilling roasting and frying, but also smoking and drying (dependant on fat content). Most PAHs are not carcinogenic, although a few are (such as pyrene and benzo(a) pyrene). Chloropropanols/esters have also been linked with the thermal treatment of processed food products. Nevertheless, most food processing contaminants can be reduced by modifying cooking times/temperatures or by the inclusion of certain additives, while not cooking food can lead to higher health risks, due to microbial contamination for example.

Foods containing starch and protein e.g., meats, biscuits, bread, potatoes produce undesirable compounds. The cooking methods that may result in the generation of these compounds are frying, baking, grilling, smoking and roasting.

(ii) Desirable compounds

Despite the fact that cooking can cause the generation of undesirable compounds, research has shown that cooking can also increase the formation of favourable molecules and the bio-availability of some antioxidants, such as lycopene. Unlike heterocyclic amines and acrylamide, antioxidants are known to be beneficial to human health. Antioxidants are molecules that can slow down or prevent other molecules from undergoing reactions that can cause damage to human cells. Antioxidants are also generated during the Maillard Reaction. Food types that may generate desirable compounds when cooked are starchy foods e.g., meats, biscuits, bread, potatoes. The cooking methods that may result in the generation of desirable compounds are frying, baking, grilling and roasting.

Now the question arises, then, why the food should be cooked?

Of course, there is loss of some of the nutrients partially during cooking e.g. the nutrients in beans and legumes leach into cooking water when they are boiled. Does this mean one should not cook the food and use it as raw? No, this is also not always true as some of the foods (182) should be cooked and never eaten raw such as grains, dried beans (red kidney beans and white kidney beans) and eggs. In addition to this, certain nutrients are released in cooking that would otherwise be unavailable. For example phytic acid is a naturally occurring chemical in grains that can partially block the availability of the grain minerals, including iron and zinc. The processing and cooking of grains lowers their phytic acid content, often by more than 50%. The sprouting of raw grains also lowers their phytic acid content. To minimize the mineral-blocking effect of phytic acid and maximize the mineral availability, grains should be sprouted or cooked rather than eaten raw. In raw forms beans contains excessively high amount of potentially toxic chemical called phytohemagglutinin. This is a lactic glycoprotein, and in sufficiently high amounts, it has been shown to disrupt cellular metabolism. It has also been observed by the researchers that optimal cooking time and temperature decreases hemagglutinin and other potentially toxic substances. In case of eggs two types of proteins are present (i) conalbumin protein can bind together with iron and blocks its availability, and (ii) Avidin protein which can bind together with biotin (B- vitamin) making it unavailable. The cooking of eggs helps denature both of these proteins, and can increase the availability of both iron and biotin from eggs.

Thus cooking also involves health safety. Cooking therefore has a substantial impact on the final sensory (organoleptic), nutritious and health properties of many different foods.