LECTURE 8: REACTIONS INVOLVED DURING DEEP FRYING OF FOOD

8.1 Introduction

Deep frying is one of the methods of food preparation used both in the home and in industry. Several food products like potato chips, meat, fish, etc prepared by frying it into fat/oil heated to about 180 °C. After some time of frying process, the food article is sufficiently cooked to be consumed. Due to prolonged heating at very high temperature, substantial changes take place in chemical and physical properties fat or oil. The changes taking place in fat/oil during frying affects the quality of fat/oil being used and quality of finished foods.

When period of frying is short, the changes are mostly desirable as there is improvement in the organoleptic quality of product, due to production of desirable flavour and aroma. During such short periods characteristics and concentration of undesirable compounds originating due to heating do not cause any problem. In continuous deep fat frying, large quantities of fat are absorbed by food. This has to be replenished by fresh frying oil. This replenishment results in a steady state condition wherein it is unlikely that the oil deteriorates beyond a certain point. In intermittent frying, fats remain hot for long periods and undergo many heating and cooling cycles before they are used up by subsequent frying operations. This results in more rapid destruction of fat probably due to increase in hydroperoxides upon cooling, followed by their decomposition when fat is reheated.

8.2 Behaviour of Frying Oil

Different classes of compounds produced from oil during deep fat frying. These compounds are given below:

8.2.1 Volatiles

- Oxidative reactions involving formation and decomposition of hydroperoxides lead to production of Saturated and unsaturated aldehydes, ketones, hydrocarbons, lactones, alcohols, acids and esters
- The amounts of volatiles produced vary widely depending on type of oil, type of food and extent of heat treatment
- Generally reaches plateau values because balance achieved between formation of volatiles and their loss due to evaporation and/or decomposition

8.2.2 Nonpolymeric polar compounds of moderate volatility

e.g. hydroxyl and epoxy acids produced through oxidative pathways

8.2.3 Dimeric and polymeric acids and glycerides

Occur from thermal and oxidative free radicals through polymerization of the radicals which results in a substantial increase in viscosity of the frying oil

8.2.4 Free fatty acids

Arise from hydrolysis of triacylglycerol in presence of heat and water. These reactions are responsible for various physical and chemical changes in the frying oil.

- Increase in viscosity and foaming tendency
- Changes in colour (dark) and flavor
- Decrease in iodine value and surface tension
- Changes in refractive indices

8.2.5 Behaviour of food during frying (Event occur during frying of food)

- Water is continuously released from the food into hot oil. This produces a steam distillation effect, sweeping volatile oxidative products from the oil. The released moisture agitates the oil and hastens hydrolysis. Blanket of steam formed above the surface of the oil tends to reduce the amount of oxygen available for oxidation
- Volatiles may develop in food itself and/or from the interactions between food and oil.
- Food absorbs varying amounts of oil during deep fat frying. Sizable amounts of oil/fat are carried with the food – 5 to 40% by weight, e.g. potato chips have a final fat content of about 35% resulting in need for addition of fresh oil
- Food itself can release some of its endogenous lipids into frying oil/fat
    - e.g. fat from chicken
    - consequently oxidative stability of new mixture may be different from that of the original frying oil/fat
- Presence of food causes the oil/fat to darken at an accelerated rate.

8.3 Changes in Frying Medium

Hydrolysis, oxidation and polymerization are due to the chemical reactions that take place during deep fat frying.

Factors influencing the proportions of breakdown components in vegetable oils are:

1. Temperature
2. Presence of O_2

3. Heating time
4. Frying capacity
5. Method of heat transfer
6. Metals in contact with oil
7. Turnover
8. Nature of food being fried

The various chemical changes commonly observed are:

8.4 Oxidation and Decomposition

Release of moisture, high temperature and exposure to atmospheric O_2 during frying of fats favours the oxidation of frying medium. As food enters oil, oxygen is introduced into the oil leading to oxidative changes. After an initial induction period, the peroxide content of food begins to increase and finally decreases. The major reactions occurring during the autoxidation include degradation reactions resulting in the formation of volatile compounds. Autoxidation of unsaturated fatty acids leads to the formation of conjugated hydroperoxides and peroxides, which decompose to form volatile aldehydes, ketones, acids, alcohols and hydrocarbons.

8.5 Thermal Oxidation

The process of thermal oxidation also occurs when oil is heated at high temperature in the presence of O_2. Thermal oxidation results in:

- Formation of free fatty acids due to cleavage and oxidation of double bonds
- Formation of hydroperoxides which may undergo-
- Fission to form alcohol, aldehydes and acids, which contribute to darkening of frying medium and flavour changes.
- Dehydration to form ketones
- Formation of free radicals followed by their combination to form dimers, trimers, epoxides, alcohols and hydrocarbons, all of which contribute to increase in the viscosity of the oil.
- During deep fat frying, thermal and oxidative decomposition of oil produces volatile and non-volatile products.

8.5.1 Volatile decomposition products

Most of them are removed by steam generated during frying. They contribute to flavour of deep fried products, e.g. unsaturated lactones.

8.5.2 Non volatile decomposition products

These are formed largely due to thermal oxidation and polymerization of unsaturated fatty acids present in frying medium. These products include polymeric triglycerides, cyclic acids,

fatty acids and other oxidative products. The accumulation of these products is responsible for changes viz. increase in FFA content, carbonyl value, -OH content and saponification value and decrease in unsaturation with resultant decrease in Iodine value. Such changes are also accompanied by increase in viscosity and refractive index.

8.6 Polymerization

The oxidation and thermal alteration products undergo polymerization forming gums and residues. Reactions between fatty acids of same/different triglycerides form cyclic and non-cyclic dimers and other polymeric compounds involving C-C linkages and oxygen bonding. Thermal polymerization of unsaturated fatty acids also yields cyclic monomers, dimers, trimers and higher polymers. The rate of polymerization increases with increase in unsaturation of triglycerides and frying time. This results on changes in molecular weight, viscosity, heat transfer rate, foaming, darkening of colour and gum accumulation. Polymerization also causes increased absorption of fat by food making it unpalatable and greasy.

8.7 Hydrolysis

Moisture that is continuously released from the food during frying brings about hydrolysis of fat causing an increase in acidity, due to the initial formation of FFAs, mono and diglycerides and glycerols; Soaps of some fatty acids are also formed which accelerate the deterioration of frying medium. Accumulation of alkaline material decreases the interfacial tension between the product and frying medium and decreases the food quality. Liberation of the FFAs causes a decrease in smoke point of oil. Viscosity, colour and iodine value of hydrogenated oils changes more rapidly at FFA levels of ~1.5%.