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PRESENTATION

Physical-chemical aspects of the frying process

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SUMMARY

Physical-chemical aspects of the frying process

Frying is a very elaborate cooking procedure where the heat is distributed to the food by a medium, the oil or fat that intervenes in the process, interacting with the food itself.

The interactions are depending on the quality of the oil or fat, the technology utilized and the nature of the substrate. In effect that last is a mixture of various chemical entities that behave differently toward the heat, between them and with the cooking fat.

One of the most important component of the food is water and the hydration conditions are of great importance in determining the various step of the cooking operation and the type of interactions between the food itself and the oily phase.

Chemical nature of the substrate is important in determining the type of secondary processes that develop during frying and in effect transformations of the lipidic medium are notably influenced.

Main chemical reactions that occur during the frying process are of oxydative nature but their importance must not be overestimated and still frying conditions as well as chemical and physical nature of the food is important in determining the extent at which it occurs.

Hydrolysis is another of the reactions that develop during frying.

Interchange of fats occurs between the substrate and the lipidic phase, sometime bringing to healthier foods, provided a proper choice in the quality of the frying media has been done.

Exchanges of many components, usually minor components occur and are of interest in the repeated frying because they have influence on the behaviour of the cooking operation.

In general terms frying must be evaluated as a beneficial operation directed to enhance the nutritional value of a food, provided that the fundamental rules governing the process are observed.

KEY-WORDS: Frying process – Interactions between food and oil – Physical-chemical aspects.

The cooking of foods presents several alternatives outlined in Figure 1.

Water boiling

The food to be coocked is immersed in boiling water in a steam atmosphere that keeps the temperature in the range of 100° C.

The fat eventually present in the food is partially extracted, the nutritional properties of the food improve as consequence of partial hydrolysis of proteins and starch. Protein are denaturated.

Water boiling decreases the caloric content of a food by subtracting the heat content related to the fat and to the other component that are also extracted and made soluble in the water. In the mean time other minor components soluble or extractable are eliminated in the water phase.

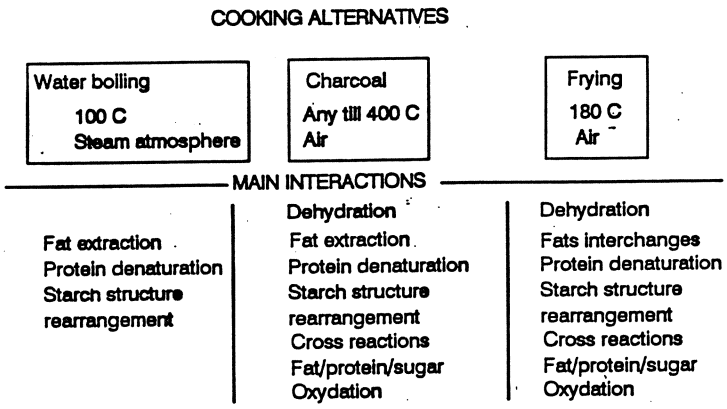

Figure 1

Charcoal cooking

Occurrs in the open atmosphere, the contact with the air is complete, bringing to some autoxydation of the fats eventually present. That last is partially withdrawn from the food. Dehydration is one of the main results of charcoal cooking as the water freely evaporates. Pyrolysis can be a consequence of the strong dehydration and of the temperatures attained that can be very high in the operation (about 400 °C).

Beside fat extraction that decreases the caloric content of the food, proteins are strongly denaturated, starch structures deeply rearranged and cross reactions occur between the fats, the sugars and the proteins.

Maillard reaction are known to bring a strong transformation of the nutritional properties.

Frying

Is known to be one of the most utilized cooking system of the mediterranean diet. Most of the typical dishes of the mediterranean country, producing and consuming olive oil are based on frying.

The operation can be described as a «Mild cooking operation» because the temperature attained is controlled by the cooking medium and by a controlled water evaporation.

Fats eventually present in the food are not lost but interchanged with the cooking medium, proteins are mildly denaturated, starch structures mildly rearranged while cross reactions between the food components are of reduced intensity.

Even oxydation of the fats present in the food or in the cooking medium is not strong because of various reasons that shall be explained later on.

Nature of the food

Foods are not pure chemical products, they are a mixture of chemically defined components, basically classificable in the following cathegories:

Lipids
Proteins
Sugars (starch)
Minor components ascribable to various chemical classes

Water is sometime a dominant component and in general it is present in high concentrations (Figure 2).

The variability of the components of each class gives rise to many alternatives that can be of importance in the frying process.

For instance lipids vary in saturation, physical characters, chemical behaviour and they are the solubilizer of many minor components.

Proteins vary in the physical and chemical characters because of their constituents aminoacids; they can show free reacting groups, originally present or better created during the cooking process.

Starch have an high degree of active centres, usually OH, CH and even NH.

Their physical and chemical characteristics vary strongly as a function of the polymerization degree that vary also during the cooking operations (Figure 3).

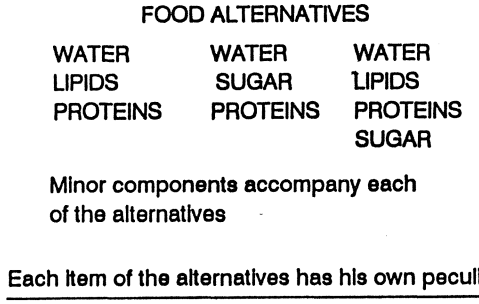

Figure 2

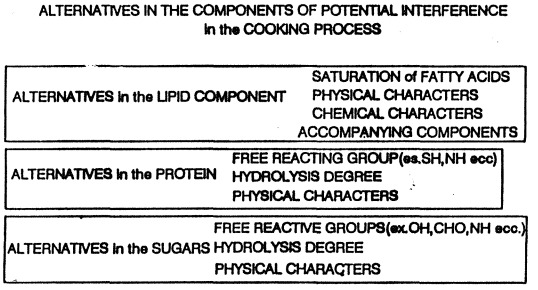

Figure 3

The frying operation

A typical frying arrangement is shown in Figure 4: the heat is exchanged between the source and the medium trough a wall, usually metal.

The cooking medium, the oil is heated trought the wall, heats the food, causing water evaporation from it.

The oil layer is in contact with the air that surrounds the frying device.

The loss of heat in the system that helps to make frying a mild operation, are:

— the losses of the system itself, function of the device.
— the heat necessary to bring the food at the proper temperature, mostly lost when the food is withdrawn from the operation.

That last loss is depending on the type of food, considering its specific heat only and not its water content.

- the water is the most important controller of the process because it distills after being transformed in steam, together with other volatiles eventually present.
- some of the heat is also spent in the various reactions occurring in the frying system and that exchange is a function of the food and of the oil, used to cook.

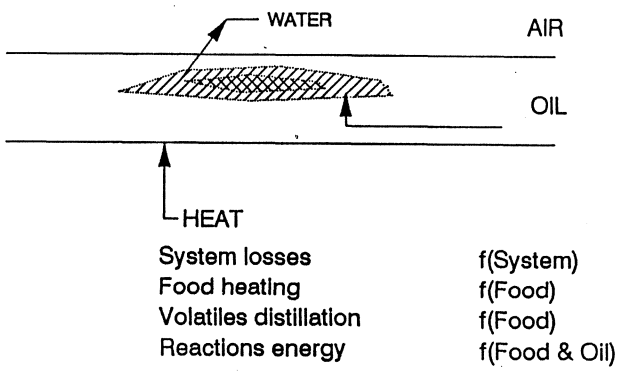

Figure 4

One of the major aspects in the frying of concern to the nutritional properties of the cooked food is the partial substitution of the original fat present in the food.

Figure 5 is describing a theoric situation of a mixture protein/fat: part of the fat present in the food is dissolved in the cooking medium and replaced by the new fat mixture formed.

As the situation presented is similar to that occurring in frying meat Figure 6 is describing the results of the substitution taking into account that the values are very close to the real situation.

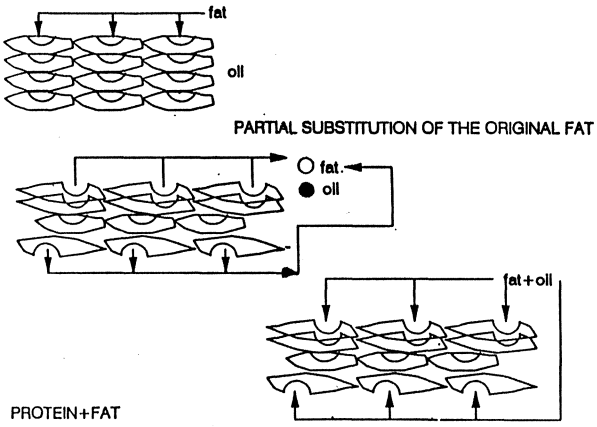

Figure 5

BEEF S M P
48.0 50.0 2.0

% SUBST.	SOYA			OLIVE			OL.SUNFLOWER			LARD		
	S	M	P	S	M	P	S	M	P	S	M	P
10	44.4	48.3	7.3	44.4	52.5	3.1	44.4	53.0	2.6	47.4	50.0	2.6
20	40.8	46.6	12.6	40.8	55.0	4.2	40.8	56.0	3.2	46.8	50.0	3.2
30	37.2	44.9	17.9	37.2	57.5	5.3	37.2	59.0	3.8	46.2	50.0	3.8

IMPROVEMENT in the RATIOS	P/S RATIO(SOYA)	M/S RATIO(OLIVE)
0	0.04	1.04
10%	0.16	1.18
20%	0.31	1.35
30%	0.48	1.54

Figure 6

Soyabean oil for instance is introducing a notable quantity of PUFA(P), Olive oil, beside of enhancing the PUFA content is introducing the MUFA(monounsaturated fatty acids) and strongly decreasing the content of the saturated(S).

High oleic sunflower oil is doing more or less the same as olive oil.

An animal fat as pork fat is changing very little the situation.

The improvements in the P/S and M/S are shown in the table and they are impressive taking into account that to them are bound the risk factors of the coronary heart deseases.

Frying of starch in presence of water (potatoes are a similar mixture) offers the possibility of speculating on the effect of water evaporation on the process.

The distillation of water is subtracting 200 kcal/kg of material, explaining the temperature excursions during frying of potatoes or of other food with a high/medium content of water (Figure 7).

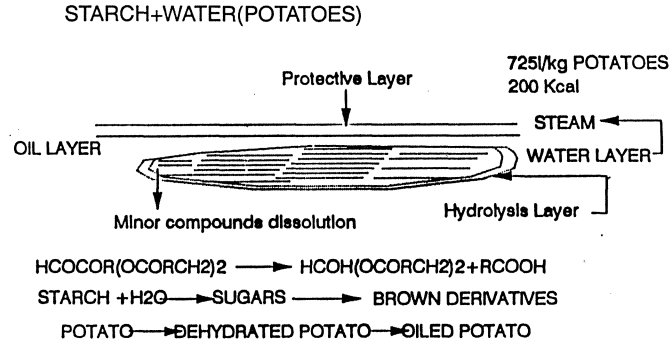

Figure 7

A strong volume of steam is also generated in the operation, corresponding to 725 liters/kg of potatoes.

That figures explain why hydrolysis is a major reaction in frying while autoxydation is not being the contact with air strongly diminished by the steam evolution.

The finding is not confined to the present case because evolution of steam is a general fact in frying.

Water is hydrolizing the starch to lower molecular weight compounds, enhancing the digestibility of the finished product.

That last becomes more energetic because of the substitutio, in the holes created by the water evaporation with the oil utilized as a frying medium (Figure 8).

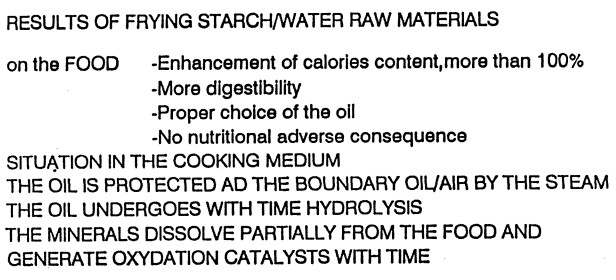

Figure 8

That last can be choosen at will to improve the capability of the fried product and also to take into account the nutritional properties of the added fat or oil.

Olive oil is in both respect very useful because it conferes stability to the food and in the mean time offers the inserction of valuable fatty acids such as the monounsaturated.

In any case pure oils or mixtures offer the possibility of large nutritional variations.

Autoxydation in frying is mostly a secondary negative aspect caused more than by the process itself, by the minerals and catalytic products accumulating in the frying system if the frying operation is prolonged or repeated frequently.

Oils reutilized after frying and kept in contact with air are prone to show deep oxydation phenomena because of the combined action of the oxygen and of the accumulated autoxydation catalysts.

Figure 9 shows a mixture formed up with Protein/fat/water that represent the most frequent case in the frying operation.

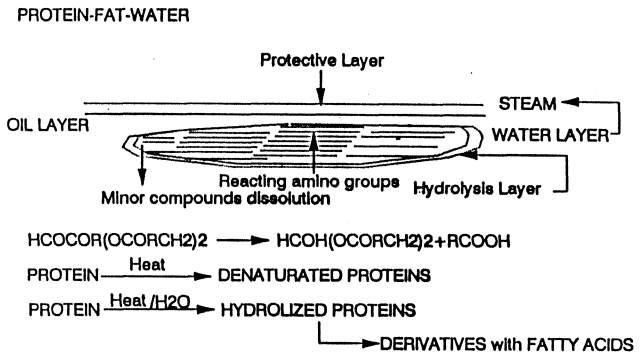

Figure 9

The presence of protein and mostly of sulfurated aminoacids has been proven to strongly prevent the oxydation of the food, while hydrolysis, formation of Maillard compounds are the most important of the occurring reactions.

Proteins, starch (or derived sugars) have been shown to react with fatty acids present in the frying process but till now the real nature of the products formed has not been clarified.

Artifacts from autoxydation and further reaction with the food component have also been shown as formed but just in prolonged frying operations (Figure 10).

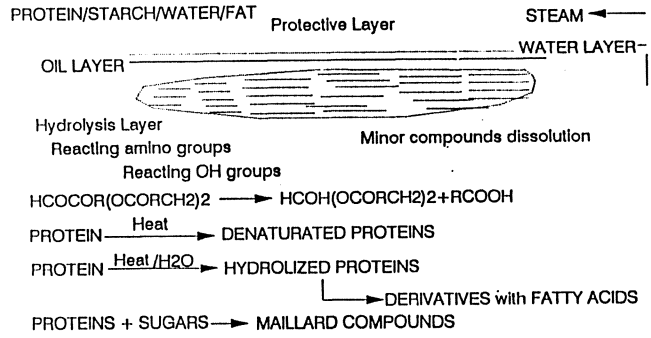

Figure 10

In conclusion (Figure 11):

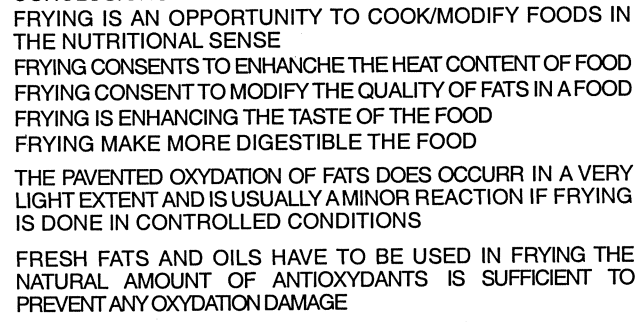

Figure 11

Frying is an opportunity to cook and in the mean time improve the quality of the food in the nutritional sense improving the caloric content the quality of the fat present, the digestibility.

Palatability of the food can be greatly enhanced as well.

Autoxydation considered a deterrent to utilization of frying do not occurs at a great extent with fresh oils even if they are deeply unsaturated; of course a monounsaturated fat is more apt to the operation because of its capability and that of the final product.

The presence of natural antioxydants is of importance in the operation but mostly to the keepability of the fried product if it is to be stored for some time.

Autoxydation occurs more in the preserved cooked product than during the process.