

## Frying process in the relation fat/degenerative diseases

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### SUMMARY

#### Frying process in the relation fat/degenerative diseases.

Among the various components of the diet, fat receives very close attention because of its relationship to several chronic degenerative diseases (CDD). Currently most of the available information on these relationships is derived from epidemiologic or experimental studies in which lipid intake is calculated using food composition tables. In most of these tables the quoted lipid content is that of raw food, whereas most foods are usually consumed only after being subjected to several culinary processes. Often there is no indication of the type of fat used in food processing in general or in frying in particular. But as it known, in the course of these processes the lipid content undergoes important qualitative and quantitative changes and not keeping them in mind may be the underlying cause of the difficulties and the confounding results in studies trying to establish the relationship between lipid intake and health.

In the Mediterranean diet, about 50% of total dietary fat is derived not from the food itself but from the cooking fat, of which only a small fraction is eaten raw (as dressings) and the greatest proportion is used in thermal culinary processes, mainly deep-frying.

The scientific study of the process whereby fat penetrates into fried foods has shown the benefits of this cooking method. If the process is correctly carried out, the amount of fat ingested with fried foodstuffs is not greater than when other procedures involving fat are used (for example, sautéing, stewing or canning in oil). Very schematically, deep-frying is a technique that replaces a fraction of the water content of food by cooking fat. Consequently, the fat composition of the fried lean foods will be the same as that cooking fat. The process is more complex with fatty foods, and there are not great changes in the total quantity of fat in the fried food before and after frying. However, there are notable quality changes and these depend on the concentration gradients between frying oil and food.

In deep-frying the cooking fat is usually used more than once, and there comes a moment when one considers subjectively that the oil is no longer suitable for frying and is discarded. This can be of practical significance for the total lipid intake, since a not determined quantity of oil is discarded and is not ingested. Consequently, the theoretical lipid intake has been decreased and, at the same time, some compounds, included saturated fats, are eliminated from diet with the discarded oil. For example, the lipid composition of meats is substantially improved because of the highly favorable monounsaturated fatty acids penetration into them from the frying olive oil.

One of the most important features is the possibility of manipulating fat intake by reducing it and improving the quality of the fat really consumed, this is of special interest in the possible relation to degenerative diseases. These changes in the fatty acids composition of oils and foods are repeatedly seen in laboratory experiments. However, their interpretation is not easy, in part because of the complexity of the deep-frying process used in the test. On the other hand, you would have to see the results obtained in the laboratory coincide with the results at practical level as well in the households as in catering, and, in this sense, some of the first results which we are obtaining in the population of Madrid are presented in the second part of this report.

**KEY-WORDS:** Deep-frying – Degenerative diseases – Fat intake.

Among the various components of the diet, fat receives very close attention because of its relationship to several chronic degenerative diseases (CDD). Currently most of the available information on these relationships is derived from epidemiologic or experimental studies in which lipid intake is calculated using food composition tables. In most of these tables the quoted lipid content is that of raw food, whereas most foods are usually consumed only after being subjected to several culinary processes. Often there is no indication of the type of fat used in food processing in general or in frying in particular. But as it known, in the course of these processes the lipid content undergoes important qualitative and quantitative changes and not keeping them in mind may be the underlying cause of the difficulties and the confounding results in studies trying to establish the relationship between lipid intake and health.

In a recent study, we described how the Mediterranean Diet (MeD) is a good example of how the eating habits of nations can change. Until very recently the eating style of the countries round the Mediterranean did not enjoy much prestige. At a time when body height indicated optimum health, our height was taken to be symptomatic of a poor diet. And certain foods that are basic to our diet such as olive oil did not have a good reputation even though the MeD evolved within the countries that can be considered the cradle of civilisation. Nor were our cooking methods appreciated, especially deep frying which was and is one of the characteristics of the MeD.

In just a short time, the MeD has turned, from being held to be boring and rather less than convenient, into its present status of being considered a dietary panacea protecting against a wide range of common diseases. There are some dangers in this present position, as it is obvious that there is no single diet that is protective against all disease. Indeed, even in the general information given to the public on the diet/health relationship it is clear that many doubts and contradictions remain.

Moreover, it is not easy to define the MeD correctly because, in the first place, it does not tie in strictly with geographic criteria. For example, Portugal is not on the Mediterranean but it is the European country with the most typically Mediterranean diet. And there are clear differences between the eating patterns of the

different countries of Mediterranean Europe as well as very noticeable differences from one region to another.

However, one of the few characteristics that is common to cooking throughout the Mediterranean area, whether in Europe, Asia or Africa, and to the three religions practised within this area –Christian, Muslim and Jewish– is precisely frying.

Possibly the most interesting element of the Mediterranean diet when considering the relation between diet and health is fat consumption. The difference between fat intake in our countries and those further to the north lies not just in the composition of the fat but also in the habitual methods of consumption, as shown in Table I. This shows that there are no marked differences in the total quantity of fat ingested in the two areas but that there is a clear difference in the fatty acid content which is much healthier in the MeD. This is of special interest because of the possible link with heart disease and other pathologies.

intake can be considered one of the best and is much better than that in countries far from the Mediterranean basin. With respect to diet cholesterol, average figures and the contribution from the different food groups are similar to those observed in other European countries.

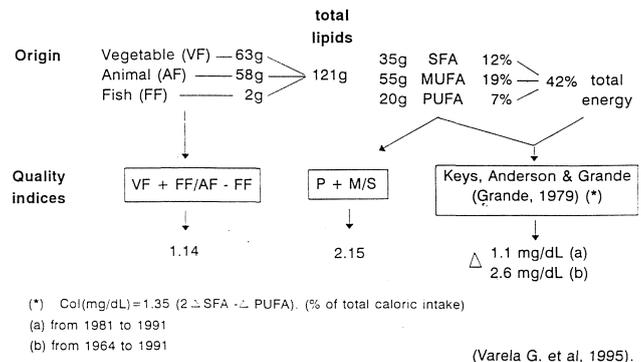


Figure 1  
Quantitative and qualitative aspects of fat intake in Spain

Table I  
Characteristics of fat consumption in the Mediterranean diet

1) Composition	– Quantitative =
	– Qualitative:
	Dietary cholesterol ↓
	SFA ↓
	MUFA ↑
	PUFA n-6 ↑
	n-3 ↑
2) Consumption	a) Low consumption of butter and margarine
	b) High consumption of vegetable oils especially olive oil
	c) 50% of total fat consumption is cooking fat
	d) Most of the cooking fat is used for frying

Note:  
 ↑ Indicates greater consumption in the Mediterranean diet  
 ↓ Indicates lower consumption in the Mediterranean diet  
 The size of the arrows represents quantitative differences

(Varela, 1992)

Figure 1 summarises, by way for example, certain aspects of fat intake in Spain. Total fat intake is high as in other developed countries but the quality of the fat is excellent, especially with respect to the possible links with heart disease. The main contribution to this high quality comes from the high consumption of monounsaturated fatty acids (mostly from olive oil) and the fairly moderate intake of saturated and polyunsaturated fatty acids. These positive aspects, as is to be expected, show up clearly in the various indices used to judge the nutritional- quality of fats which are given at the bottom of the graph. Mediterranean fat

A very interesting feature of fat intake in Spain and in Mediterranean countries in general and which is rarely taken into account is the high percentage of total fats provided by «cooking fat». Fat intake has two basic components - the fat contained in foods and that in the cooking fats with which the food is prepared. In the Mediterranean countries, approximately 50% of total fat intake comes from cooking fat. This is beneficial because it offers great potential for manipulating fat intake which is not possible in other countries where the proportion of cooking fat is much lower.

The question posed is therefore, «How is this cooking fat consumed?». We have devoted a great deal of time to attempting to answer this question. In principle, it should be remembered that only a small fraction of cooking fat is consumed uncooked, mostly to dress foods, and that most is used for deep frying. As already stated, the scientific study of the process whereby fat penetrates into fried foods has shown the benefits of this cooking method, as described below.

## THE FRYING PROCESS

Before discussing frying, certain clarifications need to be made:

1. Firstly, we are referring to Deep Frying (DF), not to sauteing or any other cooking process using fats and oils. This fact is basic to preventing misunderstandings.

2. In DF, unlike other cooking techniques, all the cooking fat is not consumed as in sauteing or stewing. It is drained off before the food is consumed

so that just a small proportion is consumed, precisely that which has penetrated the food during the cooking process, with the rest still being usable for subsequent frying or other cooking uses. Certain very interesting aspects relating to the fats left after frying will be discussed below, not only with respect to the yield of olive oil but also to the energy value of fried foods and to the fact that this cooking method, when carried out correctly, makes it possible to greatly improve the quality and quantity of fat intake, especially in relation to heart disease.

3. The changes occurring in fats as a result of frying, because of the process of penetration to be discussed below, are very different to those occurring when the fats are overheated. The literature on this subjects shows that such conditions can give rise to a number of potentially toxic compounds. Obviously, however, the extreme situation of overheating is incompatible with frying. If foods are submitted to such conditions, they would be inedible or blackened and, clearly, when we fry it is so that we can consume the fried foods. This is a very important fact but the study of what happens in overheated fats is of interest even though its results cannot be tied in with frying. It could be said that foods to some extent protect themselves against any extreme conditions they are submitted to and deep frying is a good example of this.

4. Studies have been made by Morton, amongst others, into foods fried with or without coatings. Clearly, if fish is fried coated with flour, the end result is very different to when it has a very thick coating such as that of the fish fingers popular in some non-Mediterranean countries. In such cases, this is cooking rather than frying because the fat does not penetrate the food and remains in the coating.

5. Although home cooking bears much resemblance to industrial cooking, the greatest difference is that in home cooking the food is prepared just before consumption and this is impossible in collective cooking. In the latter, food has to be pre-cooked, conserved, reheated and then kept hot until collected by the consumer from the different distribution systems. This period during which food is kept warm is when the greatest losses of thermolabile substances occur. We therefore consider that frying is especially suitable for such cases because, as is shown below, the preparation time is very short, as is the time during which the hot fat acts on the food.

A particularly interesting possibility is the use of a continuous frying line in which the real time during which the hot fat acts on the food is very short and the speed of the «belt» is adjusted according to the number of people waiting for the fried product (Figure 2).

The frying process itself is extraordinarily complex and involves a large number of factors which make it difficult to analyse. It should therefore be no surprise that an expert such as M. Dagerskog should say «the frying process is the most important yet difficult

operation in the industrial or institutional preparation of food». His opinion was shared by K. Paulus, a member of the Working Group on Industrial Frying which was part of the European Community's COST - 91 Project. The factors can be divided into three categories: those involved in the frying process itself, those involved in the type of fat used, and those involved in the characteristics of the food to be fried.

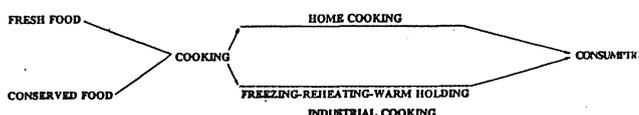


Figure 2  
Basic differences between home and industrial cooking

Figure 3 gives a very simplified version of the process. Deep Frying can be said to be a technique in which a fraction of the water within the food is replaced by frying fat. This exchange takes place in two phases. Firstly, a large proportion of the water in the food has to evaporate and it is known that during this phase the temperature inside the food is practically 100° C. This is a very important fact and gives rise to the following comments:

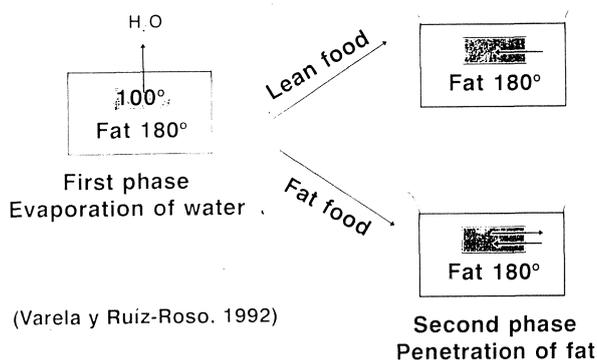


Figure 3  
Diagram showing fat penetration during frying of lean and fat foods

a. One of the advantages of home frying is the short cooking period, just a few minutes. Much of this time corresponds to the first phase of evaporation of the water. When frying potatoes, for example, evaporation can be assumed to last approximately 2/3 of the total

frying time during which the temperature inside the food does not exceed 100°C, and the action of the hot oil only lasts 2 minutes. This is very important when considering thermal aggression on the thermolabile nutritional components of the food.

b. There is practically total absence of oxygen during the process.

c. Once the water has evaporated, the second phase begins during which the hot oil penetrates the food. The consequences of this penetration, when frying is carried out correctly, are very beneficial, as explained below.

c.1) Deep Frying is less aggressive for the thermolabile components of food than other cooking methods. For example, much less vitamin C is lost during the deep frying process than in other cooking methods as can be seen in Table II which compares

deep frying with sauteing or stewing. It should be remembered that it is precisely the coefficient for vitamin C retention that is normally used to indicate the aggression of the industrial or cooking process on nutritional value. Table I shows that the retention coefficient is similar, around 70%, for both potatoes with a low vitamin C content and pimientos with a high content. In both cases only 30% is lost whereas in sautéing or stewing vitamin C loss reaches about 75%. This shows that, under the conditions applied during our tests, whatever the level of vitamin C, the frying process preserves the nutritional value of foods much better than other cooking techniques. This fact can be explained because of the short period of action of the hot fat on the food and the absence of oxygen.

Table II  
Effect of certain cooking processes using olive oil on Vitamin C content in certain foods

	UNCOOKED		FRIED	SAUTEED/STEWED	
	mg/100 g	mg/100g of uncooked food	RC %	mg/100g of uncooked food	RC %
POTATOES	19,1 ± 1.2	13.3 ± 0.1	70	4.5 ± 0.1	24
PIMIENTOS	112.3 ± 2.5	82.7 ± 2.2	74	29.6 ± 0.2	26

R.C. Retention coefficient, in relation to content before cooking.

(Moreiras, O., Ruiz-Roso, B., Belmonte, S., Pérez, M., 1990)

c.2) The exchange of water for fat and especially the formation of the outside crust considerably increases the palatability of fried foods.

c.3) When frying is carried out correctly, the quantity of oil ingested is no greater than with other cooking procedures using fats and oils. This is a well known fact in the Mediterranean countries in which it is considered that if food is properly fried and drained, the paper in which it is wrapped should remain completely dry with no grease marks.

c.4) As already stated, the frying process produces important qualitative and quantitative changes in the fat composition of foods so that the intake of fats and oils through fried foods is of improved quality.

As explained in a recent report of ours published as a special article in «Nutrition Review», this aspect offers great potential because of the possible relation with cardiovascular disease and other degenerative diseases related to dietary fats. Through proper frying, especially if olive oil is used, it is possible to control the quality and quantity of fat intake. The last section of this paper covers this aspect more fully.

#### POTENTIAL FOR IMPROVING THE QUALITY AND QUANTITY OF FAT INTAKE THROUGH FRYING

It is interesting to note the different behaviour of lean and fat foods when fried. Figure 3 attempts to show the process of penetration of cooking fat in the two types of food. In both cases, as already stated, it is necessary for a large proportion of water to evaporate from the food before the fat can penetrate. During this time the temperature inside the food remains practically constant at 100°C.

After the water has evaporated, the fat starts to penetrate the food but to very different extents, depending on whether the foods are lean or fat. With the former, the frying oil penetrates the food, the fat content of which is enriched and, obviously, the fat composition of the fried food will be practically the same as that of the cooking oil. For example, when potatoes are fried in olive oil, the fat composition is very rich in monounsaturated fatty acids (MUFA) coming from the olive oil (Table III).

Table III  
Changes in the fat composition of potato chips  
fried in olive oil

	Raw	Fried in OO
Total fat	0.16	16.5*
SFA	23.1	13.2*
MUFA	3.1	78.2*
PUFA (total)	73.1	8.4*

Total fat expressed as g/100 g of food and fatty acid families as g/100 g of fat

OO = Olive oil

\* Significant

(G. Varela y B. Ruiz-Roso, 1992)

The process is much more complex with fatty foods. From the quantitative point of view, the quantity of fat passing from the food to the frying oil and vice versa is practically the same and there are therefore no great changes in the total quantity of fat in the fried food before and after frying.

However, there are notable changes from the point of view of quality and these depend to a great extent on the concentration gradients of the different fatty acids in the cooking oil and in the food. Generally speaking and without going into too many

technical details, when the concentration of a component in the cooking oil differs from that of the same component in the food, there is a tendency for it to balance out. This means that the composition of fatty acids changes both in the cooking oil which is enriched with the fatty acids passing into it from the food and viceversa: the food is enriched with those fatty acids which penetrate it from the frying oil.

This can be seen in practice when meat is fried in olive oil. The changes in the lipid composition, as stated above, are very different both quantitatively and qualitatively depending on whether the meat is fat or lean. Table IV shows on the left what happens with lean meat when fried in olive oil, OO. The olive oil composition is shown in the first column. As is to be expected, the total quantity of fats in the lean meat increases. With respect to quality, the proportion of saturated fatty acids (SFA) shows a marked drop. These pass into the frying oil while the monounsaturated fatty acids (MUFA) increase and the polyunsaturated fatty acids (PUFA) decrease. The final result is that the quality of the meat improves with frying. In the case of the fatty meat, the quantitative changes are not significant because practically the same amount of fat enters as leaves and the changes in the fatty acid families are in line with the concentration gradients: The SFA decrease and the MUFA increase while there is practically no variation in the PUFA because the concentration of this family in the meat and in the oil are very similar. In summary, deep frying in olive oil improves the quality of the fats in both lean and fat meat.

Table IV  
Changes in the fat composition of lean and fat beef fried in olive oil

	MEAT				
	OO	LEAN		FAT	
		UNCOOKED	RAW	FRIED	RAW
Total fat (g/100 g of food)	100	3.1	6.4*	41.0	40.8
SFA	15.7	41.2	28.6*	43.8	42.0*
MUFA	74.4	43.2	61.5*	49.5	52.0*
PUFA (g/100 g of total fat)	9.7	15.6	9.6*	2.3	2.0*

Total fat expressed as g/100 g of food and fatty acid families as g/100 g of fat

OO = Olive oil

\* Significant against raw ( $P < 0.05$ ).

(G. Varela y B. Ruiz-Roso, 1992)

Having established this much, it should be considered whether the effect of the fat would be the same ingested inside or outside the meat. However, it must be remembered that the oil used for frying is not generally used just once but

several times. The subject of repeated frying is of great interest and is closely linked to the so-called «useful life» of the different cooking fats. It is a question of finding out how often these can be used for frying.

This is not at all easy to determine because many factors are involved, especially the fat composition of the food and the type of oil used. It is well known that olive oil, because of its high MUFA and low PUFA content, is much more stable than other PUFA-rich oils.

There is a practical fact that is often forgotten and which can influence the quantity and quality of real fat intake as shown in Figure 4. The oil used for frying eventually becomes unusable and has to be discarded and, obviously, is therefore not ingested. The quantity of oil discarded may be large depending, amongst other factors, on the fat composition of the food and the stability of the cooking fat used. It is difficult to calculate the quantity of oil discarded but our experience shows it is at least 20% of the theoretical amount consumed.

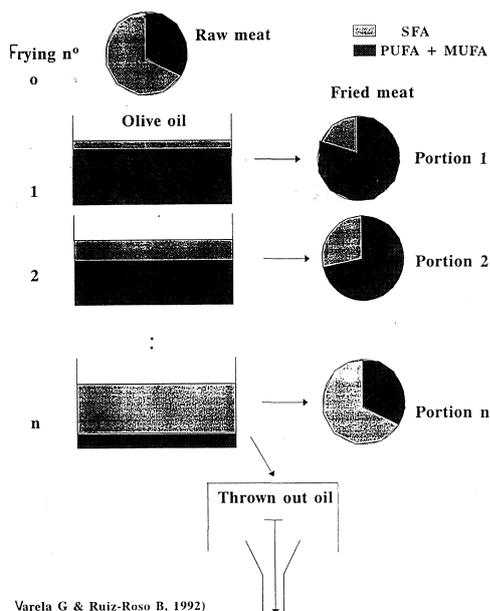


Figure 4

Quantity and quality of the fat really ingested in the repeated frying of the meat (G. Varela & B. Ruiz-Roso, 1992)

However, the oil discarded does not have the same composition as fresh oil. In the case of meat, for example, the frying oil is enriched with saturated fatty acids and in practical terms this means that by discarding it we reduce the total fat intake and, at the same time, we also discard negative compounds such as SFA which can be damaging in the case of cardiovascular diseases. In addition, meat substantially improves its fat composition because of the fatty acids that penetrate it which, in the case of olive oil, are monounsaturated fatty acids (MUFA).

## CONCLUSIONS

We have tried to explain the scientific reasons that justify current interest in deep frying and in the use of olive oil as the frying medium. Its special behaviour during the process of penetration of the food being fried and in the formation of the crust leads to the following conclusions:

1) The time during which the hot fat acts on the food is extremely short and, if the process is correctly carried out, only affects the outside of the food.

2) The process takes place in the absence of-oxygen.

3) The crisp outside crust is a quality factor in fried foods which increases palatability.

4) For the above reasons, the deep frying process is less damaging to the nutritional value of fried foods than other cooking processes.

5) For the same reasons, the quantity of fat consumed and its calory value is also less than in other cooking processes.

6) Also for the same reasons and, where a continuous frying process is possible, the losses occurring during the «keeping warm» period when cooking for large numbers can be reduced or avoided altogether. Losses of nutritional value in foods can be substantial during this period.

7) One of the most important features of frying in olive oil is the possibility of manipulating fat intake by reducing it and improving the quality of the fat really consumed. This is of special interest in relation to cardiovascular diseases.

These changes in the fatty acids composition of oils and foods are repeatedly seen in laboratory experiments. However, their interpretation is not easy, in part because of the complexity of the deep-frying process used in the test. On the other hand, you would have to see the results obtained in the laboratory coincide with the results at practical level as well in the house holds as in catering, and, in this sense, some of the first results which we are obtaining in the population of Madrid are presented in the second part of this report.

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