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Version 2.0

Practical guide Frying oil measurement

Practical advice, tips and tricks.

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Testo SE & Co. KGaA, in December 2023

Foreword

Dear Reader

As a manufacturer of measuring instruments for a wide range of industrial and commercial applications, Testo SE & Co. KGaA aims to offer its customers a lot more than just measuring technology. It is our wish to help those who use our instruments to fulfil their specific requirements, i.e. their measuring tasks.

During many further and advanced training program seminars at the Testo Academy, the hope was frequently expressed that the learning material could be condensed into written form and made available as a handbook. We are pleased to be able to fulfil this request by publishing this Field Guide.

We hope that you find some helpful tips and tricks in this guide, which

you can put to use when carrying out your day-to-day tasks. If you find that an issue has not been dealt with in sufficient detail, then we would be happy to receive your proposals, amendments or suggestions for improvement.

Have fun browsing through!

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1. Food safety/HACCP concept

1.1 What is HACCP?

HACCP stands for **Hazard Analysis and Critical Control Points**

The HACCP concept is based on seven principles:

1 Risk analysis and definition of risk groups
(identification and assessment of hazards)

Systematic assessment of a food and its raw materials and ingredients to determine the risks from biological, chemical and physical hazards. This area covers everything from growth and harvesting through to consumption of the products. It is a kind of diagnosis and therefore forms the basis for the HACCP concept.

2 Identification of (critical) control points for monitoring identified hazards

CPs and CCPs must be defined in order to monitor the identified hazards. They must be used wherever a hazard could occur or can be eliminated or minimised. The use of CPs and CCPs at points where there is no exposure to hazards is not appropriate.

Their use would create unnecessary work and reduce the transparency of the safety concept.

3 Definition of critical limit values facilitating effective control

Limit values for temperature, total polar materials or pH value, for example, are defined as monitoring parameters which must be observed.

These limit values are based on statutory regulations, general hygiene guidelines or scientific studies. If the values measured deviate from these, the relevant employees must take appropriate action to ensure the safety of the food and thus prevent a health hazard for the consumer.

4 Definition and establishment of a monitoring process for CPs and CCPs

This aspect is crucial to the success of the system.

To ensure effective monitoring of the system, the following six questions should be answered:

What is being monitored?

Who is doing the monitoring?

What form of monitoring is used?

Where does monitoring take place?

When does monitoring take place?

What limit values must be observed?

In general, the physical parameters are monitored or product and raw material samples are examined.

5 Definition of corrective measures in the event of deviation from the critical limit values

Corrective measures are implemented at this point if the results of monitoring show that CPs or CCPs deviate from the limit values.

Any control measures carried out must be recorded!

6 Setup and completion of documentation of the HACCP concept

Logging any measures introduced and the monitoring values obtained means that there is a written record for a given time, which can be checked.

This written record is not required by law, but the burden of proof lies with a company in the event of a complaint in accordance with §7 of the Product Liability Act. For the company, this means proving that the product did not have any faults at the time it was handed over to the customer. With the help of careful documentation, on the basis of the HACCP concept, the company can thus be released from any liability.

To this end, all HACCP steps must be documented. The recommended period of time for keeping the HACCP documents is one year past the best before date of the processed products.

A detailed and complete document must contain the following:

Product description;

Description of the manufacturing process with specification of the CPs/CCPs;

For each CP/CCP: Explanation of measures so that they can be managed; monitoring and control measures for CPs and CCPs with specification of the limit values for the corresponding monitoring parameters

and planned corrective measures in the event of a loss of control; Checking measures (for more information, see also: Section 4.6 Logging, page 53)

7 Checking the system (verification)

Verification means confirming the correctness of something by checking. This also applies when checking a HACCP system: the effectiveness of the developed concept is checked and confirmed. This provides proof that the HACCP program is working effectively and properly.

It is recommended that this is verified at least once a year or whenever a process or composition has been changed.

To implement the HACCP principles, depending on the size of the company an HACCP team or HACCP officer should be appointed and assigned responsibility for implementing the above points.

1.2 HACCP and ISO 9000

ISO 9000 (EN 29000) is a quality assurance standard which originated

in industry. A company operating in accordance with the concept of ISO 9000 defines operations, monitors the result, makes changes in the case of inappropriate action and documents the results. HACCP and ISO 9000 are very similar in this respect. A core feature of ISO 9000 is the calibration of measuring and test equipment at regular intervals. Since temperature is one of the critical control points in HACCP, the thermometers used must also be calibrated at regular intervals. Because HACCP and ISO 9000 are not mutually exclusive but on the contrary complement each other perfectly, a combined concept is implemented in the USA. This is known as HACCP 9000.

1.3 Applying the HACCP concept to the deep fat fryer

The aim of implementing the HACCP concept is to assist the food manufacturer to produce safe food. When HACCP is applied, it can also give the manufacturer and processor of food the possibility of optimising work processes with appropriate documentation, thereby saving costs and supplying the customer with the best quality. Applied to the deep fat fryer, this would mean using cooking oil whose quality is documented with relevant verifications of the manufacturing process and storage. In terms of the use of the cooking oil, it can be used efficiently, i.e. not too little and not too long, by means of the appropriate measurements.



History of the HACCP

The National Astronautics and Space Agency (NASA) developed a safety system to ensure the provision of supplies to its astronauts which allows end products to be traced back through all processing stages to growing or cultivation. Production errors can thus be identified at an early stage and food poisoning of the astronauts in space can be prevented. This safety system prevents the early termination of space missions and in turn the loss of millions.

The risk system was adopted by some companies in the automotive and pharmaceuticals industry to monitor the production process. In February 1997, the European Union incorporated the HACCP concept into European law.¹ The aim of this was and is to break down trade barriers in the context of realising a common market. The intention is to create a standard legal basis which will ensure the same competitive conditions and a standard level of protection for consumers across all member states.² Apart from this, the HACCP concept is prescribed in the EC Guideline 852/2004 since the 1st of January 2006, and is obligatory for all companies which are involved with the distribution or processing of foodstuffs.

2. Basics of fats and oils

2.1 Manufacture and purification of oil

There is an extremely long tradition of extracting oil. Even in ancient times, plant oils were used as a base product in various areas such as nutrition, cosmetics, medicine and fuels. In earlier times, oil was extracted in an extremely simple form. Over time, however, it was continually improved to achieve the maximum possible oil yield.³

Oil is extracted from oil seeds (e.g. sunflower seeds or linseeds) or oil fruits (e.g. olives).

A distinction is generally made between two different processes for extracting oil: pressing and extraction. In many cases, both processes are used in tandem in order to get the most out of the base product.

The extraction of oil starts with cleaning and, where necessary, shelling the oil seeds. The oil seeds and fruit are then crushed by breaking and grinding. This ensures the maximum possible yield from the subsequent pressing.

Prior to pressing, the ground raw products are heated to a temperature of approximately 38 °C. Regular

stirring during this process will prevent scorching. The benefit of heating is that the oil content becomes more fluid and can consequently be expressed more easily and effectively.

The heated mass is added to a worm extruder and compacted more and more tightly by the rotary motion.

The freshly pressed oil is then slowly released as a result of the increasing pressure.

Not all of the oil is extracted from the oil seeds by pressing, so there is a subsequent "extraction" after the pressing. Using a solvent (usually hexane), the walls of the seed cells are opened at low temperatures and the remaining oil is released.

At the same time, all useful liposoluble contents such as vitamin E are also extracted from the cells.

After the extraction, the solvent is completely removed from the oil by means of evaporation.

The last step in the production of oil is the "refinement" (purification) of the oil. Undesirable flavourings and escort substances are then removed from the oil in various phases and at temperatures no higher than 200 °C. By removing substances harmful to



Sunflowers



Olives

the environment, fibrils and colourings which have entered the oil and by diluting extremely intense inherent flavourings, the oil is made more durable and the appearance is improved. In some cases, oils are not edible until they have been refined. This is the case with soya bean oil, for example. This would not be fit for consumption without refinement, as it contains a

number of bitter compounds.

However, useful ingredients such as unsaturated fatty acids or vitamin E are not impaired by this step and remain in the oil.

There are, however, exceptions which prohibit the refinement of certain oils.

This is the case with cold-pressed olive oil, for example, which cannot be refined according to EU directives.⁴

These oils are described in retail as cold-pressed or cold-crushed; this means that "no external heat was applied during pressing".

This method consists of an extremely gentle pressing, but the oil yield is not particularly big. Cold-pressed oils are then only washed, dried, filtered and steamed slightly. Residues which are transferred from the oil fruit to the oil are not removed from the oil as a result of this process. It is therefore particularly important for cold-pressed oils to select the oil fruits carefully so that all health risks can be excluded.

Unrefined oils are described as "virgin oils".⁵

2.2 What are fats and oils in chemical terms?

Fats and fatty oils* (also called lipids) are water-insoluble substances with a liquid or solid consistency. Fats which are still liquid at temperatures below 20 °C are generally referred to as oils.

2.2.1 Triglycerides

All fats, whether animal, plant, liquid or solid, have the same structure. The fat molecule always consists of a glycerol molecule (alcohol). This forms the backbone of the fat molecule. The three fatty acids (hydrocarbon chains) are attached to the glycerol molecule. The chemical term for fats is therefore triglyceride. The “tri” represents the

three attached fatty acids, the “glyceride” the glycerol molecule to which they are attached.⁶

All natural fats usually have different fatty acids attached to the glycerol. They are also referred to as mixed triglycerides (see Fig. 1).

2.2.2 Fatty acids

Fatty acids consist of a chain of carbon atoms (C) strung together, to which the hydrogen atoms (H) are attached. Natural fatty acids usually have an even number of carbon atoms (C), as the chains are compiled from C-C units. The fatty acids are classified according to their chain length (short-, medium- or long-chain), their

* For the purposes of simplification, the term "fat" will hereafter be used as a generic term.

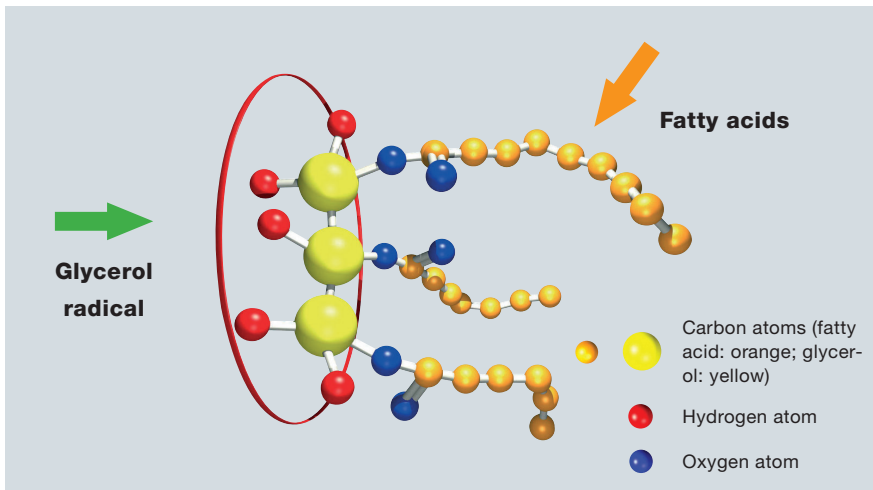


Figure 1: Triglyceride (glycerol with three fatty acids attached)

degree of saturation (saturated or unsaturated) and the position of the double bonds (e.g. between the 9th and 10th carbon atom).

Saturated fatty acids⁷

If the maximum number of hydrogen atoms which the carbon chains can carry are bonded to the chain, the chains are described as "saturated" (Fig. 2).

In these chains, all four valences (the "arms" of the carbon atoms) are "neutralised".

Saturated fatty acids are "saturated and inert" and therefore stable. In terms of their use, this means that they can withstand high temperatures and can be stored for a long time.⁸ An

extremely common saturated fatty acid is stearic acid with 18 carbon atoms (see Fig. 2).

The single bonds between two carbon atoms (C-C) can rotate freely. The fatty acid molecule is therefore extremely mobile, the carbon chains of the fatty acids can arrange themselves in straight lines and take up less space. For this reason, fats with a large number of saturated fatty acids are solid at room temperature. Due to their inert reactivity, fats with a high share of saturated fatty acids are preferred for deep fat frying.

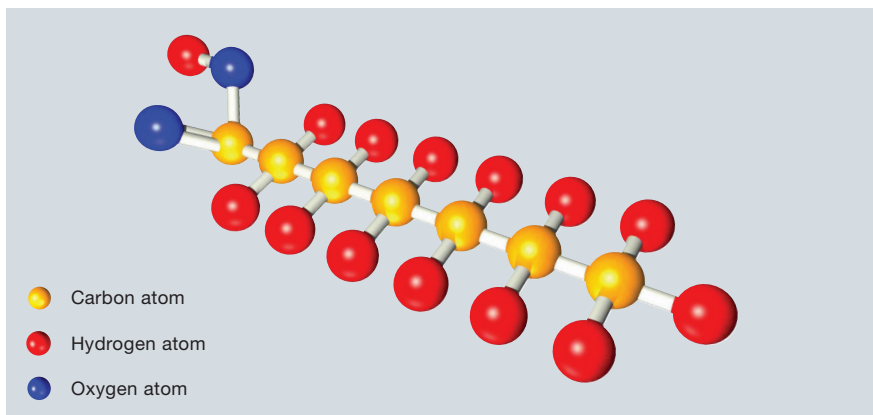


Figure 2: Saturated fatty acids

Unsaturated fatty acids⁹

Unsaturated fatty acids are divided into monounsaturated and polyunsaturated fatty acids.

Monounsaturated fatty acids are missing two hydrogen atoms, which means that the two free arms bond and form a second bond, referred to as a "double bond", between two carbon atoms. The most common monounsaturated fatty acid is oleic acid. It is derived from stearic acid and also has 18 carbon atoms (see Fig. 3).

Polyunsaturated fatty acids are missing several pairs of hydrogen atoms.

An example of a polyunsaturated fatty acid is linoleic acid with 18 carbon atoms and two double bonds.

The more double bonds there are, the more unsaturated and reactive the fatty acids are.

Unsaturated fatty acids have a special role in nutritional physiology. Polyunsaturated fatty acids (e.g. linoleic and linolenic acid) cannot be produced by the body itself, but the body needs them for building cells, for example. For the same reason, animal fats have relatively few of these "essential" fatty acids. Plant oils such as sunflower oil, on the other hand, contain a large number of unsaturated fatty acids (see Fig. 4).

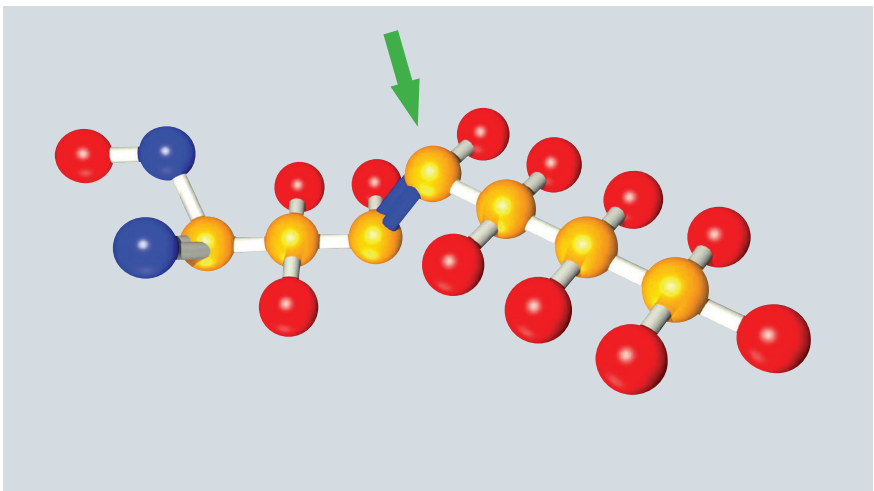


Figure 3: Monounsaturated fatty acids

Fats consisting largely of monounsaturated and polyunsaturated fatty acids have a lower melting range than fats with a large number of saturated fatty acids, i.e. they are liquid at room temperature.

As a general rule, the longer the chain and the more double bonds there are, the lower the temperature at which the fats become liquid.^{10,11,12}

Fats with a higher proportion of monounsaturated and polyunsaturated fatty acids are more prone to fat ageing than saturated fatty acids and are therefore not suitable for deep fat frying. From a health point of view, however, it is advisable to use cooking fat with the maximum possible proportion of unsaturated fatty acids.

Modern cooking fats have a high proportion of the beneficial fatty acids and have been modified so that they remain stable at high temperatures.

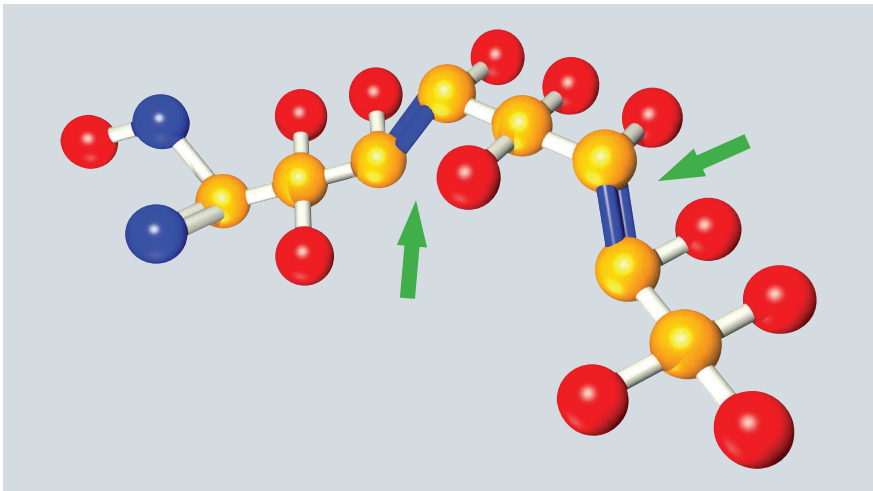


Figure 4: Polyunsaturated fatty acids

Trans fatty acids

Another form of unsaturated fatty acids are the trans fatty acids. Their double bonds have a special spatial structure described in the chemistry field as the trans form (Fig. 6), as opposed to the cis form (Fig. 5).

In the cis fatty acid the two hydrogens (shown in green in the illustration) are on the same side, in this case the top side.

In the trans fatty acid on the other hand, the two hydrogen atoms (shown in pink in the illustration) are opposite each other.

Trans fatty acids are mainly found in nutritional fats from animal sources. They are produced, for example, as a result of the conversion of natural cis fatty acids by microorganisms in the digestive tract of ruminant animals and are passed from there into their milk or meat.

In plant fats, trans fatty acids are

primarily produced in the intermediate stage during hardening. In the so-called partially hardened fats, the proportion of trans fatty acids is considerably higher than in fully hardened fats.

In terms of nutritional physiology, the trans fatty acids are on a par with saturated fatty acids. The feature common to both types of fatty acids is that they increase the cholesterol level in the blood and are suspected of increasing the risk of cardiovascular diseases.

Cis fatty acids, on the other hand, reduce the cholesterol level and therefore have a positive impact on health. During deep fat frying, the aforementioned fatty acids are separated from

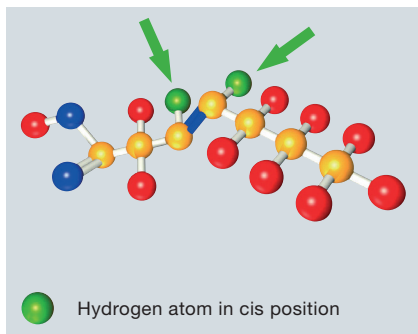


Figure 5: Cis fatty acid

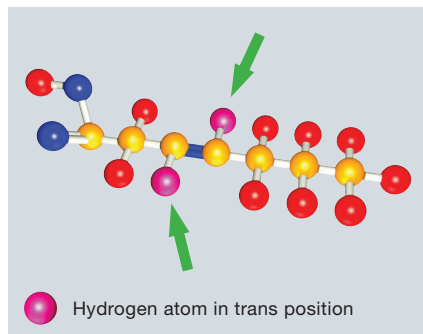


Figure 6: Trans fatty acid

the glycerol radical as a result of various reactions, and in addition to the free fatty acids monoglycerides and diglycerides, polymeric triglycerides or oxidative degradation products such as aldehydes and ketones are some of the substances produced. They are grouped under the term total polar materials, TPM for short, and used as a benchmark for measuring the rate of decomposition of the fat (see Fig. 7).

2.3 What happens when you deep fry with oil?

2.3.1 The deep frying process

Deep fat frying is primarily a dehydration process, which means that water

and water-soluble substances are extracted from the product being deep fried and transferred to the cooking fat. At the same time, the product being deep fried absorbs surrounding fat. If the product to be deep fried is placed in hot fat, the water on the surface evaporates and water moves from the inside of the product being deep fried to the outer layer, to compensate for the loss of water at the surface. As the water released does not readily move from the hydrophilic surface of the food to the hydrophobic cooking fat, a thin layer of steam forms between the fat and product being deep fried. This stabilises the surface of the food, which means that it protects the

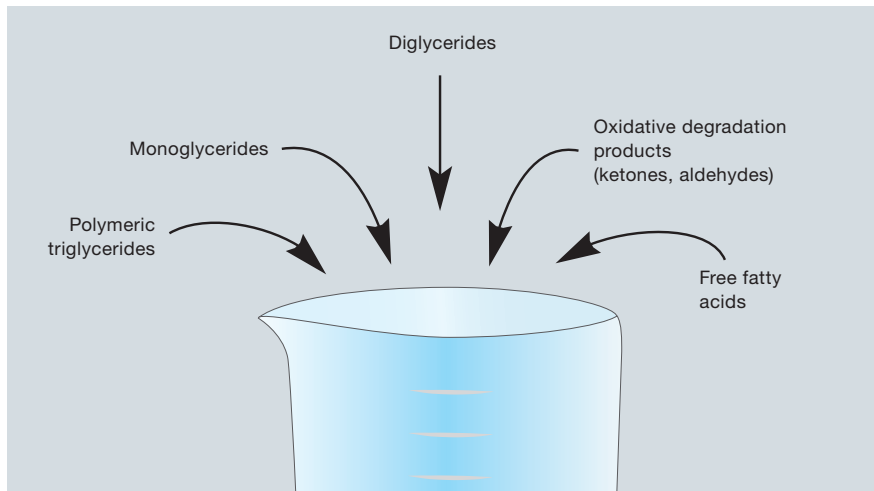


Figure 7: TPM constituents

surface against the permeation of the fat until the water has evaporated from the food. At the same time, the layer of steam stops the food scorching and burning (see Fig. 8).

Protected by the steam, a crust with a large number of pores and cavities forms on the surface of the product being deep fried.

Once the majority of the water has evaporated, the product being deep fried sucks the fat into the vacated cavities and the inside is cooked.

The cooling effect at the surface of the food gradually diminishes. The rising

temperature resulting from this causes what is known as the "Maillard reaction". The protein constituents (amino acids) react with the sugar present and cause browning. This gives the food a pleasant aroma.¹⁵

2.3.2 The life cycle of the fat

Due to its composition and the various external influences, the cooking fat is constantly exposed to chemical reactions during a deep frying cycle (from adding fresh fat through to throwing away the aged fat).

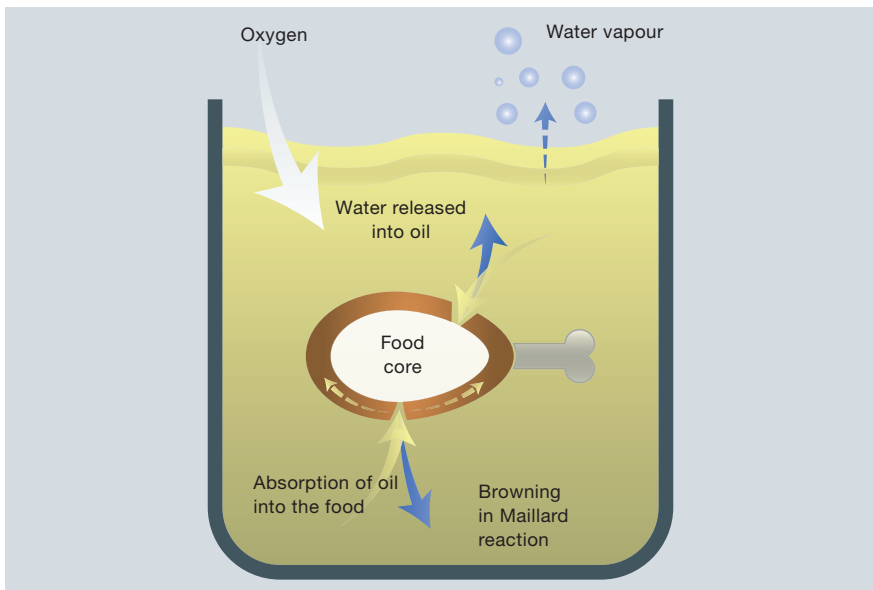


Figure 8: Reactions between product being deep fried and the oil during the deep frying process¹³

	Fat content in %	
	Raw product	Deep fried food
Chicken (skinless)	3,9	9,9
Crisps	0,1	39,8
Chips	0,1	13,2
Doughnuts	5,2	21,9

Table 1: Fat absorption of various foods during deep frying¹⁴

The condition of the cooking fat can be divided into various phases which are followed through during a cycle (see Fig. 9).

The first phase (a) starts with the unused, fresh cooking oil. The fat has not yet been heated and has also not yet come into contact with the product being deep fried. In its fresh state, therefore, there are no deep frying aromas or polar materials as yet. These are not produced until the ageing of the fat increases. The water only evaporates extremely slowly and remains on the surface of the product being deep fried for a long time. The product is overcooked and becomes slushy, but without hardly colouring.

In phase (b) the proportion of polar materials increases. As a result of the fat coming into contact with the oxygen in the air and being heated, decomposition produces a number of desired bonds which are responsible for the large majority of the typical and

pleasant deep fat frying aromas. The flavourings and aromatics typically associated with deep fat frying are responsible for bringing the fat further into the optimum deep fat frying range (c). Here the ideal volume of water is extracted, without too much water escaping. At the same time, the Maillard reaction is set in motion as a result of the improved extraction of water. The fat now has contact for a sufficient length of time to brown the product perfectly and give it the typical, desired taste.

In the course of the life cycle, the curve falls sharply back towards the optimum. Bonds are produced in the fat which result in a deterioration of the condition of the oil (phase [d]). At the same time this means a deterioration of the product being deep fried in the oil.

As the decomposition progresses, the colour of the fat becomes increasingly

darker and the taste more rancid and abrasive. The product being deep fried absorbs an increasing volume of fat during this phase, as the water is quickly extracted due to the extremely high proportion of polar materials. French fries, for example, become hollow inside. The more quickly the water leaves the fat, the more prolonged the contact between the fat and the product being deep fried, increasing the volume of fat which permeates the product being deep fried.

In the last phase (e), the cooking fat is no longer fit for consumption and should therefore be replaced or freshened with fresh oil.¹⁷

The curve profile described is attributable to various reactions triggered,

among other things, by the effects of oxygen in the air, light or heat.

The unsaturated fatty acids play an important role in these reactions, as the double bonds can react extremely quickly.

There are essentially three main reactions which are described in greater detail below.

2.3.3 The reactions of the fat

It is important to know the three chemical reactions which fat is often exposed to, since they have an effect on the quality of fats.

Oxidation

Oxidation is responsible for the ageing of the fat due to the transfer of oxygen

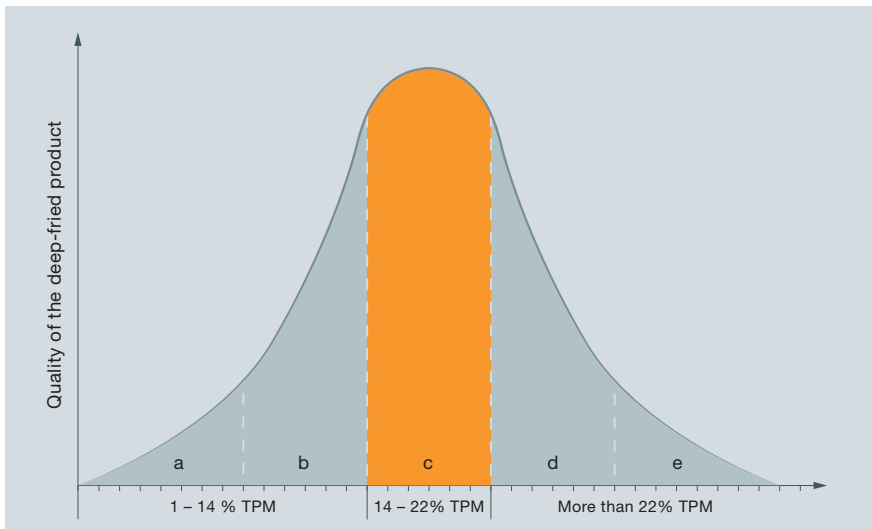


Figure 9: Life cycle of the cooking fat¹⁶

from the air.

It is already happening before the cooking fat is heated. For every 10 °C increase in temperature, the rate of oxidation is doubled.* For example, if two radicals are formed at room temperature (25 °C), there will be 16 radicals at 55 °C and 16,384 radicals at a temperature of 155 °C. For the fat, this means that the more radicals that are present, the faster the fat is broken down into its individual parts, in other words the faster it ages. Apart from temperature, light also has a considerable impact on decomposition. Light consists among other things of ultraviolet (UV) rays which create favourable conditions for triggering oxidation. Fats are organic substances which can oxidise, and in fact all the more easily the more double bonds are contained in the fatty acids of the fat. Cold-pressed olive oil, for example, has a shelf life of approximately just six months at room temperature due to its large number of unsaturated fatty acids.

In addition to degradation products with an intense taste such as fatty acids, oxidation also produces mono-glycerides and diglycerides. During the deep frying process, the

water evaporates from the product being deep fried and a crust is formed. This stops the fat permeating the product too deeply. After a certain time, the majority of the water is evaporated and the cooling effect at the crust stops. The desired browning of the product being deep fried now begins as a result of the high temperature.

As the proportion of polar materials in the fat increases, the water can evaporate through the fat more easily and quickly. The formation of the crust progresses more slowly in relation to the evaporation, but at the same time the rate of browning is quicker as the outer layer of the product is no longer being cooled so effectively. In the case of chips, this means that they become hollow inside. In the case of fats with a higher proportion of polar materials, more fat can permeate the product due to the faster evaporation.

The decomposing process in oxidation is divided into several phases. The "induction phase" triggers the oxidation. The products of oxidation as a result of effects such as heat, light or heavy metals (Cu, Fe) include free radicals (R^* , R = fatty acid radical) which react with oxygen (O_2) in the

* This is only an assumption. The rate may differ from this figure in reality.

Basics of fats and oils

air to form oxygen-bonded radicals (ROO*) (see Fig. 10).

In the chain growth phase, the fatty acid peroxide radical ROO* gains a hydrogen atom H from another fatty acid

and becomes a fatty acid peroxide molecule** (ROOH). The attacked fatty acid thus becomes a new radical and in turn reacts with the oxygen present (see Fig. 11).

* Note: Radicals are identified by means of an asterisk *.

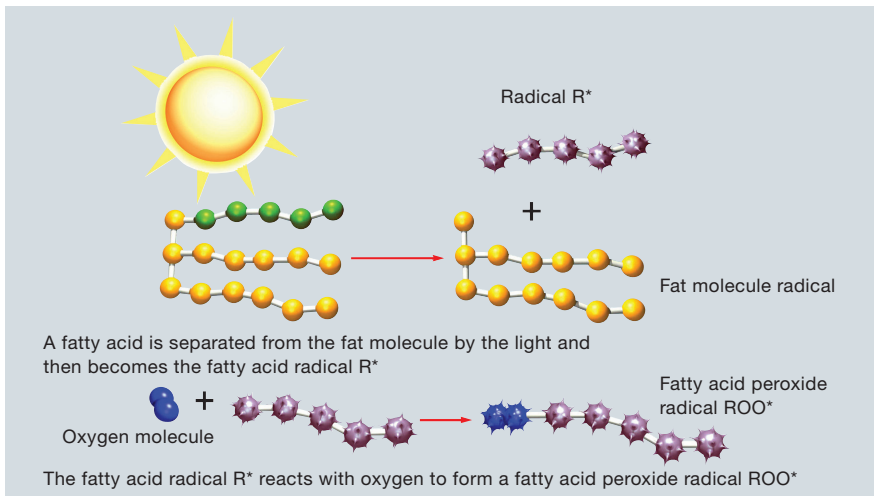


Figure 10: Induction phase

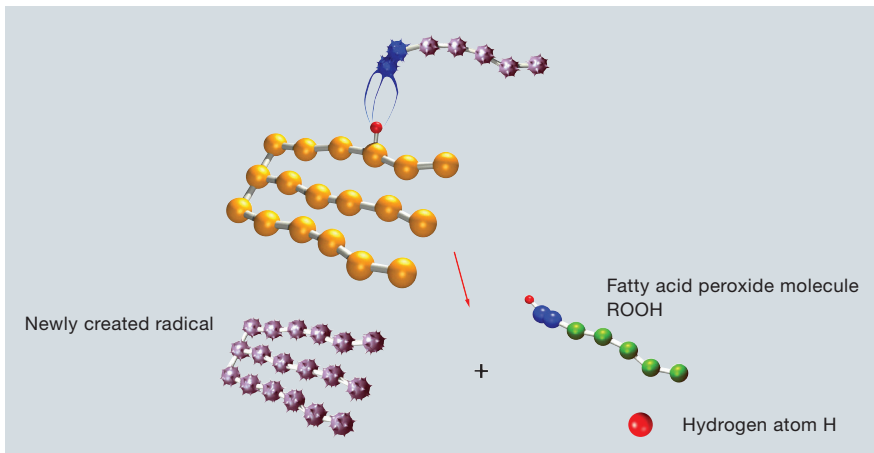


Figure 11: Chain growth phase

The unstable fatty acid peroxide molecule (ROOH) is largely broken down into various radical products (RO* and *OH) and reacts with the oxygen present or with the surrounding bonded fatty acids (chain branching reaction) (see Fig. 12).

The more radicals that are formed, the

greater the probability that the radicals will collide. When radicals collide, the two free radicals form a bond and there is a chain termination reaction.

The radicals are "trapped" and can no

** Hydrogen peroxide (H_2O_2) is a strong oxidant and is used in heavily diluted form to bleach hair, for example.

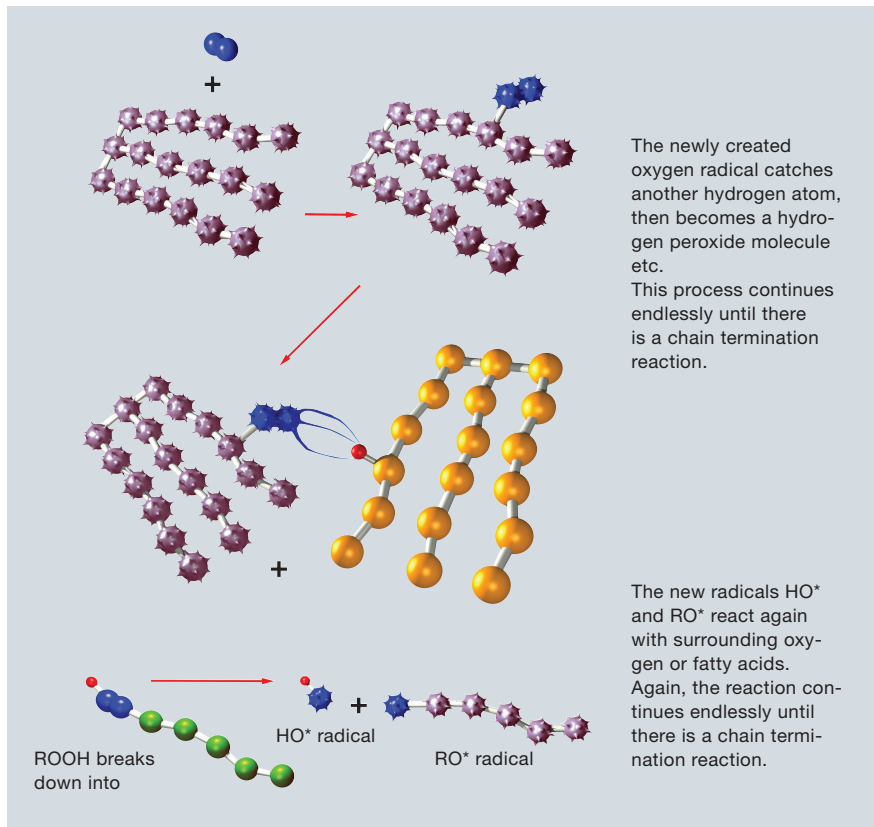


Figure 12: Chain branching reaction

longer catch hydrogen molecules (see Fig. 13).

Radical catchers (antioxidants) such as Vitamin E or C make use of this mechanism. They attract the radicals like "magnets" and prevent or delay the chain reaction by catching radicals. The antioxidant is used itself when the radicals are caught.

Polymerisation

This is a chemical reaction in which the unsaturated fatty acids present in the cooking fat, under the influence of heat, light or metals (Cu, Fe) and by breaking down the multiple bond, react to form first dimers (two connected fat molecules) and then polymeric (large number of connected molecules) triglycerides.

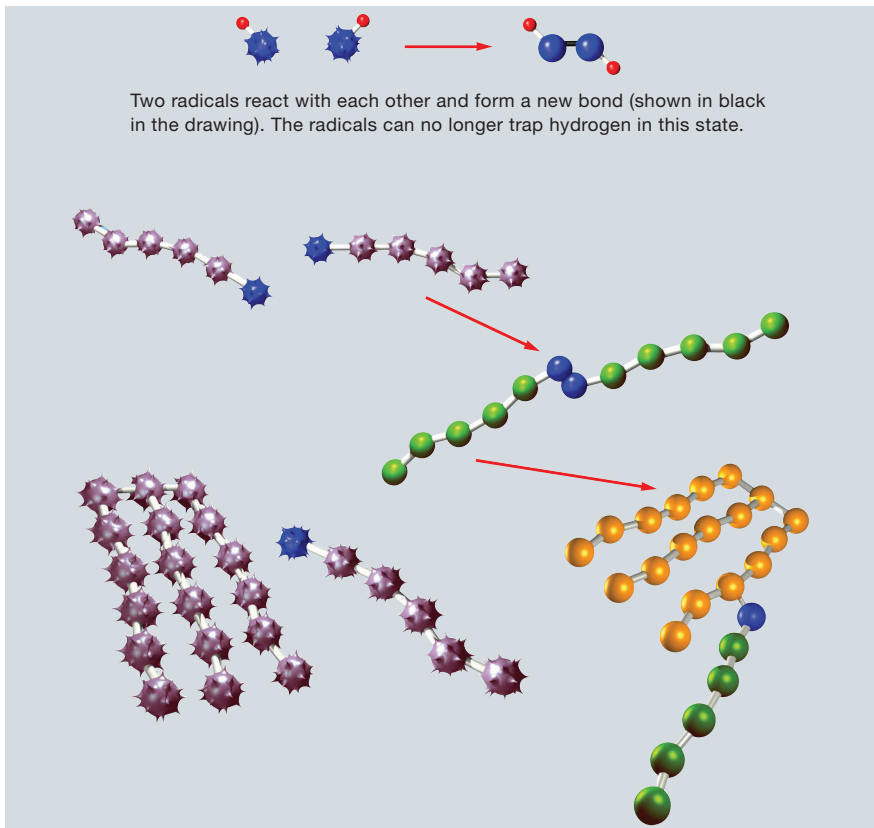


Figure 13: Chain termination reaction

The oil becomes more viscous as a result of the chain formation of the molecules. As a result, it is harder for the water to evaporate from the oil, which means that, as with fresh fat, the heat cannot get to the food properly, no browning reaction can take place and the food becomes dried out and shrivelled. At the same time, the fat has a greater tendency to stick to the food when it is removed from the deep fat fryer, which in turn results in greater fat loss in the deep fat fryer than with fresh fat.

Following polymerisation, the quantity of volatile substances across the fat is reduced. Smoke formation is therefore lower in very old fats.

Apart from the change in colour,

cooking fats with a high proportion of polymers are characterised by a high degree of fine-pored foaming.

As with oxidation, the first step is induction. A radical (R^*) is produced as a result of the effect of light, heat or heavy metals (Cu, Fe). However, instead of now reacting with oxygen, the radical attacks the double bond of a fatty acid which constitutes part of the fat molecule. After the reaction, the entire fat molecule has become a radical (see Fig. 15).

If the fat molecule radical attacks another fat molecule with a double bond, the double bond breaks down and the fat molecule radical attaches itself. In this first step, chains of two fat molecules are produced which can

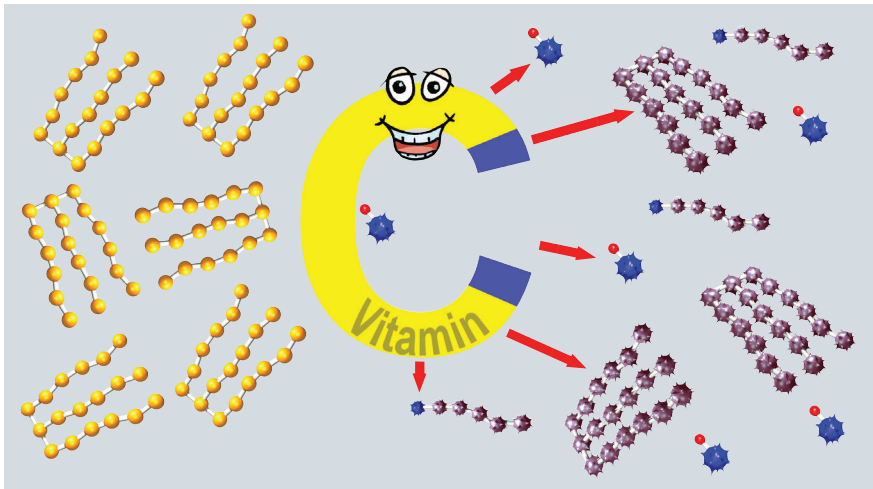


Figure 14: Actions of radical catchers

grow during polymerisation to form a chain of many hundreds of fat molecules (polymers) (see Fig. 16).

If two of these fat molecule radicals collide, the chain is terminated. The two radicals bond (green) and do not attack any further fat molecules (see Fig. 17).

It can sometimes happen that a fat

radical attacks the double bond of one of its own fatty acids. This causes a ring closure within the molecule. The product of such a reaction is called a "cyclic bond".

Hydrolysis

Hydrolysis is primarily triggered by the permeation of water from the product

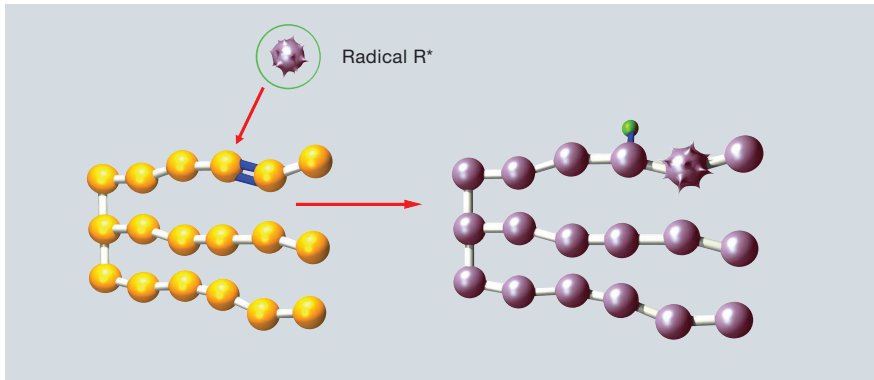


Figure 15: Initial phase of polymerisation

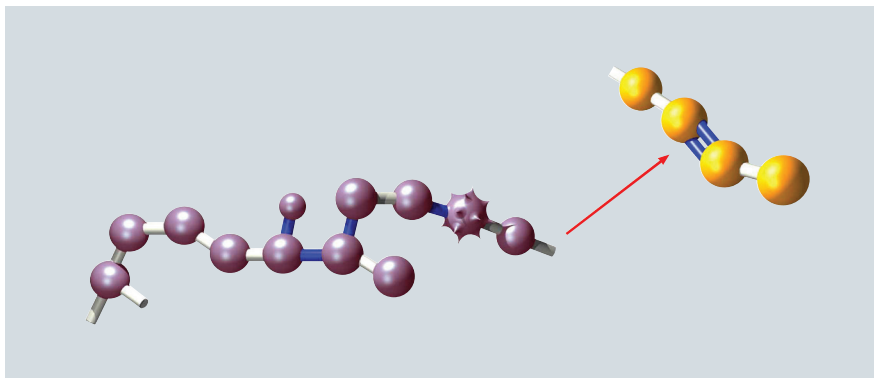


Figure 16: Chain growth

being deep fried and is encouraged by certain substances such as baking powder.

Hydrolysis is a controversial subject of discussion in specialist literature. Opinions of researchers differ with regard to whether the permeation of water does not also have positive effects on the fat. It is known, for example, that the evaporating water extracts volatile degradation products such as short-chain fatty acids or alcohols together with fat and thus helps

to purify and stabilise the fat.

The water (H_2O) content is evaporated across the cooking fat and leaves behind monoglycerides and diglycerides and free fatty acids.

In hydrolysis, the water attacks the bond between the glycerol and fatty acid and is then itself split into two parts. The one part (an H atom, red) attaches itself to the glycerol radical and the second part (OH radical, blue/turquoise) remains attached to the fatty acid radical (see Fig. 18).

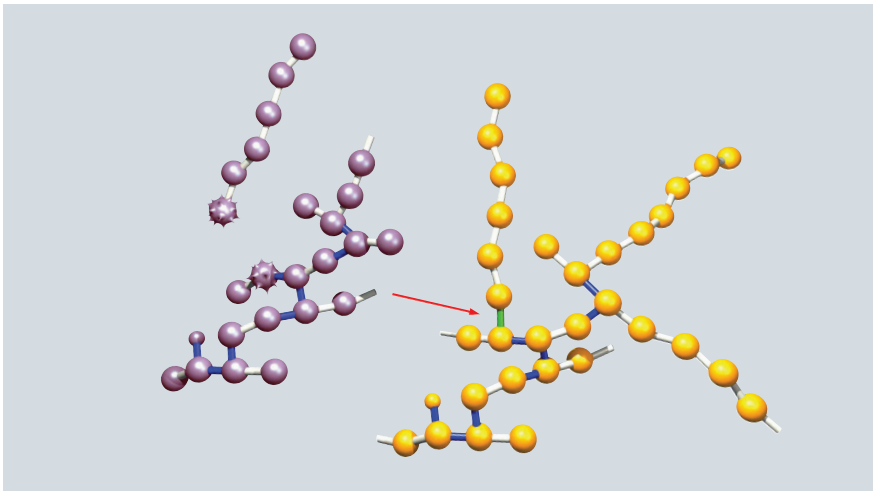


Figure 17: Chain termination reaction

Basics of fats and oils

The smoke point of the fat is lowered as a result of the decomposition of the fat molecule and the fat takes on a different taste due to the changed molecules.

If baking powder (alkaline) is added to the fat via the product being deep fried, soap is produced from the fatty acids. This is why hydrolysis is also known as "saponification". One ingredient of baking powder is sodium. If the baking powder reacts with the

fatty acid, very small amounts of curd soap are produced.

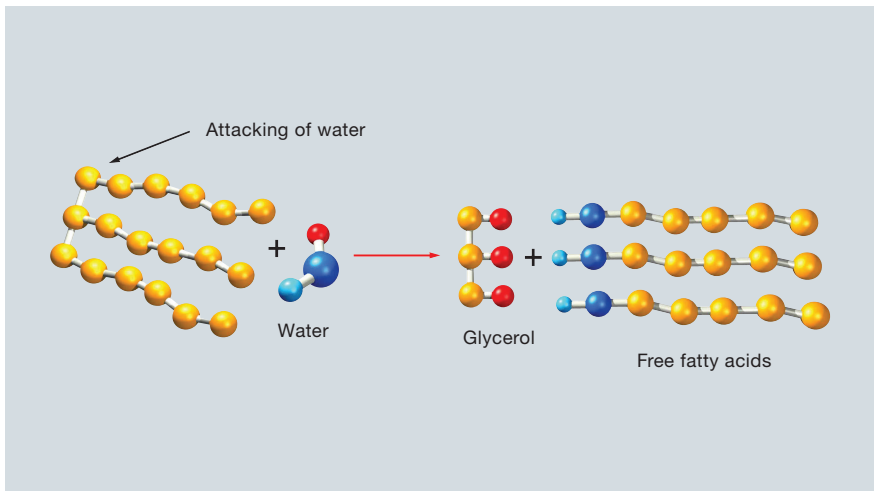


Figure 18: Hydrolysis reaction



3. Technical background knowledge

3.1 Why measure at all?

In this chapter, the three main reasons for measuring the frying oil quality with the testo 270 are highlighted: Frying oil and fried food quality, cost savings and compliance/effectiveness.

3.1.1 Ensuring the quality of the frying oil and fried food (quality)

Various degradation substances are produced in the fat as a result of the reactions described above. They are referred to under the collective term "total polar materials". Total polar materials is a generic term for the free fatty acids, monoglycerides and diglycerides and a number of oxidation products (aldehydes or ketones).

The "**T**otal **P**olar **M**aterials", TPM for short, affect not only the consistency, taste and appearance of the fat, but also its deep frying quality. A product which is deep fried in spent oil very quickly forms a dark crust but at the same time sucks in a large quantity of fat. In fats with a high proportion of polar materials, the water can escape more quickly via the fat and the product dries out more quickly. French fries, for example, become hollow inside. As a result of the rapid loss of water, the steam protection cover also

disappears, which means that the fat comes into contact with the surface of the food for a longer period of time. The consequence of this is that more fat permeates into the inside of the product being deep fried, but also that the surface is exposed to a higher temperature for a longer period of time and there is therefore more opportunity for browning.

Examinations have shown that decomposed fat causes severe stomach ache and digestive complaints, among other things.¹⁸

Nearly all food laws prohibit the sale of any foods not fit for consumption. This includes any foods in a condition unacceptable to consumers or which are likely to cause nausea. According to an opinion of the Working Group of Food Chemistry Experts (ALS, German



Federal Health Gazette 2/91), cooking fat with more than 24 % TPM is regarded (in Germany) as spent. Any violation of this will be liable for fines.¹⁹

Another positive aspect of measuring TPM is the possibility that this offers of adjusting the fat to the optimum deep frying range. As already described in Section 2.3.2 The life cycle of the fat, the fat changes over the course of its usage period. When the fat is first used, it does not yet contain any flavourings or aromatics. When the fat is first heated, these aromatics are released noticeably and the fat moves closer to its optimum deep frying range. This is where the best result for crispness and taste is achieved. As the heating continues, the fat breaks down more and more and becomes inedible. The proportion of polar materials for the optimum deep frying range is approximately between 14 % and 20 %. By measuring regularly, this optimum range can be maintained by

mixing older oil with fresh oil, and the customer receives consistently high quality taste and crispness.

At this point it should be pointed out that the TPM value for fresh fats can vary from one sort to another. Palm oil has a higher TPM value at the start than rapeseed oil, for example. This is due to the fatty acid composition. However, this does not mean that rapeseed oil is a poorer cooking fat. On the contrary, rapeseed oil in fact has a longer shelf life than oils with lower starting values (see Fig. 19).

Percentage of polar materials	Classification of fat ageing
Less than	1 – 14 % TPM Fresh cooking fat
14 – 18 % TPM	Slightly used
18 – 22 % TPM	Used, but still OK
22 – 24 % TPM	Heavily used, change the fat
More than 24 %*	Spent cooking fat
*This value is determined by respective national regulations. It varies between 24 % and 30 % TPM depending on the country (see overview on page 33).	

Table 2: Classification of TPM values for fat ageing

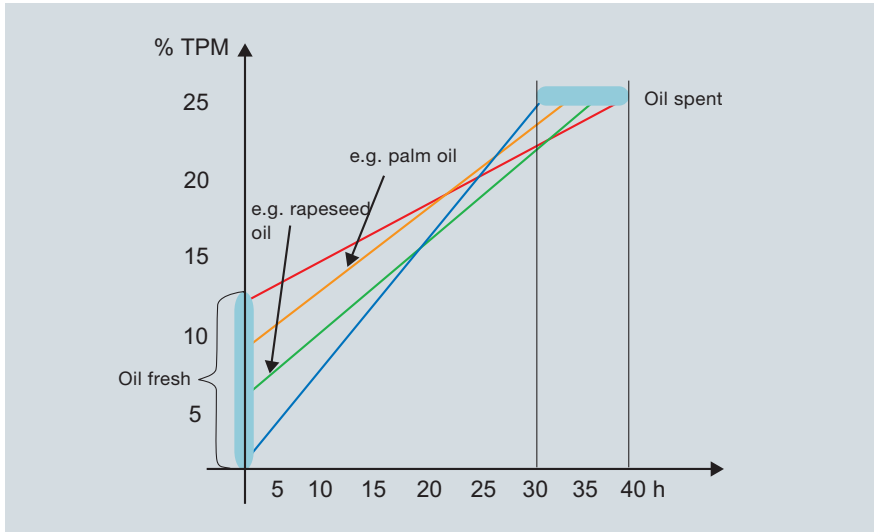


Figure 19: Starting/end values against the operating time
 The starting values and operating times given here are only intended as examples for the purposes of illustration.

3.1.2 Compliance with regulations

Nearly all food laws prohibit the sale of any foods not fit for consumption. This includes any foods in a condition unacceptable to consumers or which are likely to cause nausea. According to legal rulings in Germany, deep-frying fat is considered a foodstuff (OLG Düsseldorf 1990) and deep-frying fat that has been used for too long is considered "not suitable for consumption" (within the meaning of § 17(1) No.1 LMBG, KG Berlin 1987). In more and more regions, companies that produce or market food are therefore legally obliged to regularly check the

quality of their frying oil. There are often clear limit values that must be adhered to. According to an opinion of the Working Group of Food Chemistry Experts (ALS, German Federal Health Gazette 2/91), frying fat with more than 24 % TPM is in Germany considered to be spent. Any violation of this will be liable for fines. This is where the testo 270 can help you in a simple way: The integrated traffic light system of the testo 270 shows you limit value violations or warnings immediately and clearly. A meaningful measurement can be carried out within seconds and the legal or internal requirements

Country	TPM value in %
Germany	24
Switzerland	27
Austria	27
Belgium	25
Spain	25
France	25
Italy	25
Turkey	25
China	27

Table 3: Recommended TPM values of various countries

can be checked. With the testo 270, it is therefore very easy to carry out a compliance-relevant, presentable and reproducible measurement on the frying oil and thus ensure the highest quality of the fried products.

The testo 270 is therefore the ideal choice for companies looking for a quick and precise way to check their frying oil, not only to ensure lasting quality, but also to cover the relevant legal requirements.

3.1.3 Cost savings

Prices for vegetable oils rose sharply in 2021. According to a report by the Food and Agriculture Organization of the United Nations (FAO), the price index rose to around 224% in May 2021 compared to the previous year. ^{20,21}

This has had a major impact on costs in many sectors, particularly in the food service industry, where deep

fryers are essential for frying food.

To reduce costs, there are various ways to optimize the frying oil. One approach is to change the type of oil, using a higher-quality type of oil that lasts longer and oxidizes less quickly. The addition of antioxidants can also help to make the oil last longer. Another option is the use of automated deep fryers, which enable more precise temperature control and thus protect the frying oil. Suitable filtration of the frying oil can also help to extend the shelf life of the oil.

3.2 Various measuring methods

In addition to the column chromatography and capacitive methods for determining the TPM value, methods for determining the free fatty acids, FFA for short, are also outlined below. In many countries, they are the official methods for ageing the fat, although this is only possible with a limited degree of certainty.

3.2.1 Column chromatography for determining the polar materials

Column chromatography measures the polar materials (free fatty acids, mono-glycerides and diglycerides) in the fat. They are a measure of the thermooxidative decomposition of a fat and

are used as an official unit of measurement in chemical testing in the laboratory. In many countries, column chromatography is the official method for measuring the polar materials. The content of the total polar materials is specified as % TPM or in some cases TPC ("total polar compounds or components"). The threshold value in Germany for decomposition was set at 24 % TPM. The threshold value can vary from country to country, however (see Table 3).

How it works

A sample of a defined weight is placed on the weighting agent of the column. The sample moves slowly through the column and is collected again at the

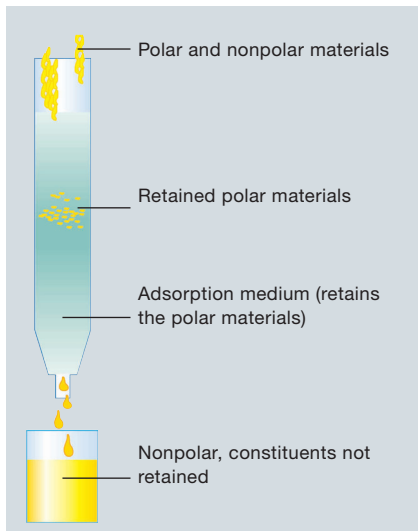


Figure 20: Column chromatography

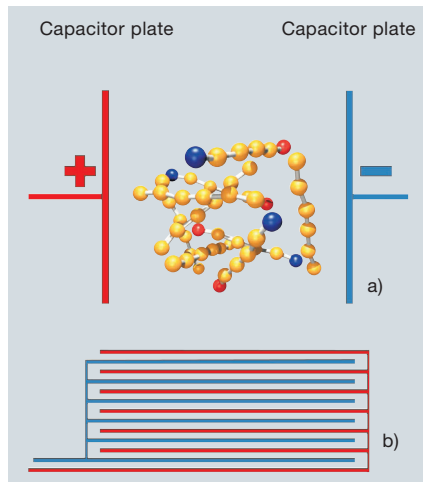


Figure 21:
a) Schematic representation of a capacitor,
b) Technical design of the oil sensor

bottom.

As the sample moves through the column, the polar materials present are retained by the weighting agent of the column, so that the collector will only contain the nonpolar parts of the fat. Once the entire sample has gone through the column, the residual fat can be weighed and the nonpolar materials of the fat can thus be determined. If this sum is detracted from the total weight, the polar materials of the sample are obtained (see Fig. 20).

in many countries, column chromatography is prescribed as the statutory method for measuring the TPM. It is therefore used as the reference method for all instruments which measure the TPM content.

A major disadvantage of column



Figure 22:
Measuring free fatty acids using a test rod

chromatography lies in its execution, however, in respect of handling hazardous chemicals and the complexity of the measuring procedure. Expert knowledge is absolutely essential, so it can therefore not be performed by laypersons.

Another disadvantage of column chromatography is the poor reproducibility of the result in some cases when using different pack types for the weighting agent.

Chromatography separates according to polarity. As already mentioned, nonpolar droplets move through the column while polar particles are retained. Frying oil contains a mixture of polar materials, from the relatively nonpolar through to the heavily polar. The extremely different proportions of polar and nonpolar components mean that an examination of the same fat sample in different laboratories may produce differing results.

3.2.2 Capacitive measurement of "total polar materials"

In addition to column chromatography, the capacitive measurement is another way of measuring the total polar materials. It is based on a measurement of the dielectric constant.

To this end, a voltage is connected to both plates of the capacitor (shown in red and blue in Figure 21). This means



Measuring the free fatty acids is only viable if the fat has not yet been heated. If the fat is hot, evaporated water removes volatile degradation products from the fat. The free fatty acids are part of this volatile group and therefore vary greatly in content. It is therefore inadvisable to only use the measurement of the free fatty acids to determine the rate of decomposition of the fat already heated.

the capacitor plates are charged until a specific quantity of electrical charge is reached. As the charge increases, the polar materials of the fat progressively align themselves. The red, positive ends of the materials point towards the blue, negative plate, the blue, negative ends towards the red, positive plate. Once the capacitor is charged, it has a specific capacitance. This is dependent on the dielectric, in this case the oil. The more polar materials are contained in the cooking oil, the greater the capacity of the capacitor.

This change in capacity is converted and then appears on the display of the testo 270 cooking oil tester as a percentage TPM content, for example.

3.2.3 Test rod for measuring free fatty acids (FFA)

Free fatty acids are a measure of the change in a fat at room temperature with exposure to oxygen in the air (rancidity) or as a result of hydrolysis. It is therefore appropriate to determine the ageing of unused, i.e. unheated fat, via the free fatty acid content. There are countries in which free fatty acids are used as an official method for determining the ageing of fats. This is only correct with certain provisos, as the fatty acid content can change constantly during deep fat frying, making it impossible to obtain a reproducible reading.

How it works

Free fatty acids in a fat not yet heated can be measured using a test rod, for example.

A dye is applied to the test rod which changes colour according to the content of free fatty acids (see Fig. 22).

By then comparing the test strip

against an appropriate colour scale, the content of free fatty acids can be determined.

3.2.4 Colour check of oils

In practice, the colour of an oil is a quality feature for freshness. It can vary from one oil to another. If the colour of the fresh oil is darker than expected, further tests are required such as a measurement of the free fatty acids.

In the case of cooking oil, the colour is changed firstly by the various degradation products of the oil and secondly by the ingredients which can enter the oil from the product being deep fried. If breaded meat is fried, for example, the oil darkens much more quickly than if mainly potatoes are fried. This effect is attributable to the so-called "Maillard reaction" (after its discoverer Luis Maillard). With strong heating, protein constituents (the amino acids) in the meat react with sugar (carbohydrates). This produces aroma and flavour enhancing substances on the one hand, and browning substances (melanoides) which result in an intense colouring of the product being deep fried and the oil.

The Maillard reaction also takes place

in chips, but not quite as strongly since potatoes do not contain as much protein.

The darkening of the oil does not therefore mean that the oil can no longer be used. A colour check should therefore not be used to measure the rate of decomposition.

3.2.5 Identifying the smoke point

The smoke point is the lowest temperature of a heated oil or fat at which smoke visibly develops on the surface. According to the opinion of the Working Group of Regional Food Chemistry Experts and the German Federal Public Health Department, the smoke point of a cooking oil must be at least 170 °C and must not differ from the temperature of the fresh fat by more than 50 °C so that the fat can still be classified as usable.

The smoke point is reduced by the various decomposition reactions which take place in the oil before and during deep frying, so the oil starts smoking at lower temperatures.

The smoke point should always be checked using an external thermometer in order to obtain the most accurate information possible about the smoke point temperature.

3.2.6 Acid number (AN)

The acid number indicates how much potassium hydroxide (KOH) in milligrams is required to neutralise the free fatty acids contained in one gram of fat.

i The lower the smoke point falls, the greater the risk of a fat fire. In addition to the above methods, there are a range of other means of determining the quality of the fat, although these are only intended for use in laboratories. As there are frequent references to these processes in literature, a selection of the most well known is given below.

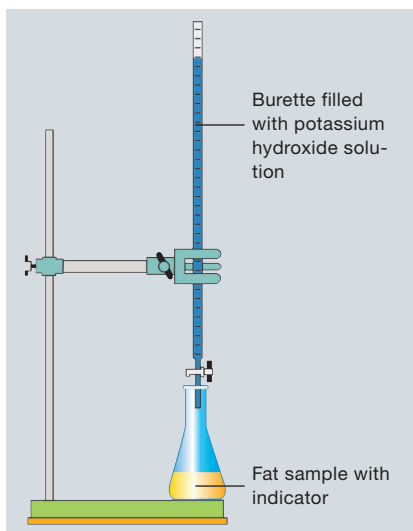


Figure 23: Titration apparatus

How it works

To determine the acid number, potassium hydroxide solution is added to the fat sample until a colour change can be seen on the indicator placed in the fat. The acid number is not at all suitable as a sole indicator for assessing cooking oil.

3.2.7 Iodine number (IN)

The iodine number indicates how many of grams of iodine are absorbed by the fat. The greater the quantity of iodine consumed, the greater the number of double bonds and therefore the greater the freshness of the tested oil. The iodine number is determined by means of titration analogously to the acid number.

3.2.8 Peroxide number (PN)

The calculation of the peroxide number is the classic test for measuring oxidation in fresh oil. However, it does not give any direct information about the rate of decomposition of the fat, as the number can fluctuate greatly. As with the two previous measurements, the PN is determined by means of titration. The oil must be cold for the calculation, as the test is extremely sensitive to heat.

3.3 "Total polar materials" measurement parameter

As already indicated, the TPM can be determined by means of either column chromatography or a capacitive measurement. The cooking oil tester uses the principle of capacitive measurement.

A plate capacitor is used. Due to its large surface area, it has the advantage of being able to measure as many polar materials as possible at once. A ceramic material is used as the carrier material for the plate capacitor, to which the gold strip conductors have been attached using a special process.

3.3.1 Temperature measurement parameter

The dielectric constant varies according to the temperature, so a temperature sensor is located on the back of the ceramic plate. It is made of metal and, like the gold conductor strips, has been attached to the ceramic plate by means of a special process.

4. Testo solutions

4.1 Which Testo solution is right for your application?

Testo offers two solutions! Testo offers high-quality classical measuring instruments for individual outlets or outlets with independent quality management.

The best-selling measuring instrument for determining the quality of frying oil is the popular testo 270 (see Chapter 4.2)

For customers with an extended branch network and centralized quality management, Testo Solution offers a complete solution comprising measuring instrument, service and software. The multifunctional handle is offered here for frying oil management (see chapter 4.3)



Figure 25: testo 270 cooking oil tester

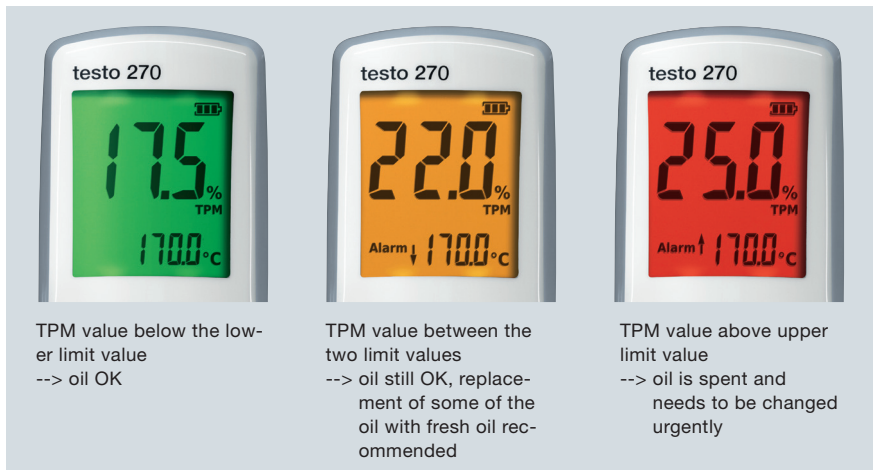
4.2 The testo 270 frying oil tester – simple frying oil measurement with interpretation (traffic light) directly on the instrument

The testo 270 enables the user firstly to provide its customers with full-tasting, perfectly deep fried foods, and secondly to ensure compliance with statutory recommendations. The result also has an economical aspect, because with the testo 270, the expenditure for cooking oil can be reduced by up to 20%.

The testo 270 cooking oil tester is a robust measuring instrument for quickly testing the decomposition of



Figure 26: Visual alarm if a given limit value is exceeded



TPM value below the lower limit value
--> oil OK

TPM value between the two limit values
--> oil still OK, replacement of some of the oil with fresh oil recommended

TPM value above upper limit value
--> oil is spent and needs to be changed urgently

Figure 27: LED display



Figure 28: The cooking oil tester fulfils the protective class IP65, and can be rinsed under running water after the measurement.

cooking fats.

As the power is supplied by batteries and the built-in sensor, the device is portable and there are no cables getting in the way. The ageing of the fat can thus be measured quickly and easily without long waiting times. If there are several deep fat fryers whose contents are to be checked for their TPM value, this can be done without the having to leave the sensor to cool first. We only recommend that the sensor is wiped carefully with a kitchen towel (caution: risk of catching fire!) to avoid residues.

The % TPM measured and the tem-

perature are shown in the two-digit digital display. The temperature can therefore be determined in addition to the ageing of the fat. Due to the larger display, the values can be quickly and easily read, even in dark surroundings (see Fig. 26).

The instrument can be set to the required quality limit values for the polar materials using the two function keys on the front of the testo 270. The upper and lower limit values are set in the configuration mode, and must deviate from each other by 1 %. As the set TPM limit values are, like all other configurations, secured by a PIN, an inadvertent alteration is eliminated. With three traffic light colours, the display's backlighting simplifies the interpretation of the measured TPM value. The colour of the display changes depending on the polar substance content. As long as the lower limit value has not been exceeded, the LED is green and the fat is still O.K. In the range between the two set limit values, the display is orange. The ageing of the fat is already advanced and the fat may require improving by replacing some of the fat with fresh fat.

If the upper limit value has been exceeded, the display lights up in red. The fat is now so spent that it can no longer be improved by replacing it in part. The oil now needs to be urgently replaced (see Fig. 27).

In addition to the unmistakable alarm provided by the display colour, there are two further indicators of limit value violation.

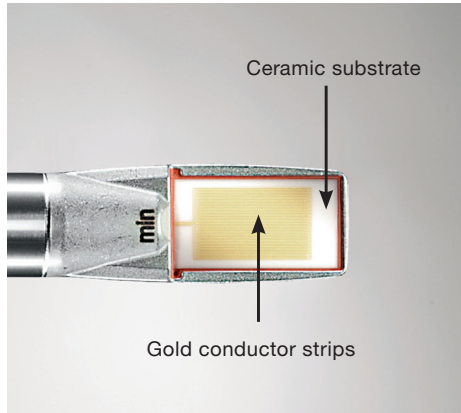


Figure 24: Fat measuring sensor



Figure 29: Case for the transport and storage of the testo 270

For one, the word "Alarm" appears, and for another, a violation of the lower limit value is shown by a small arrow pointing down, and for one of the upper limit value, a small arrow pointing up.

The user is further supported by the display colour flashing during the measurement. The final measurement is reached when the display colour as well as the TPM value stop flashing. The temperature of the cooking fat to be measured must be at least 40 °C. If this value is undershot, the display flashes ↓ 40 °C. It is no longer possible to carry out the measurement below this temperature, as the discrepancy in accuracy is too great. The same applies if the maximum measuring temperature of 200 °C is overshoot. In this case, ↑ 200 °C flashes in the display and you must wait until the temperature has fallen below the maximum measurable temperature again before proceeding with the measurement. The cooking oil tester's sensor is compact in design. This makes it possible to use the testo 270 to measure even in low oil levels.

Thanks to the protective layer, the

sensor is relatively insensitive to mechanical strain. It is embedded in metal, making it additionally solid and unbreakable..

The instrument is ideal for use in kitchen surroundings. The properties of the material make it easy to remove dirt, particularly oil. In addition to this, it fulfils the protection class IP65, and can simply be cleaned under running water after the measurement.

The care of the instrument is very easy. No special cleaning agents are required to clean the sensor. A mild household cleaning agent or standard household flushing agent are fully adequate for cleaning. When cleaning, it must be ensured that the sensor is not cleaned with sharp-edged objects, abrasive cleaners or a coarse sponge. It is sufficient to rinse it in hot water after use and then wipe it down with a kitchen towel. It is important to ensure that no fat residues remain on the sensor, so that the sensor does not stick, thereby resulting in inaccurate measurements.

The purchase of a cooking oil tester only binds the buyer to a one-off payment. Apart from the annual calibration



and the changes of batteries, there are no further costs.

A crucial advantage of the testo 270 is the more efficient use of the oil: regular measurement prevents you from changing your cooking oil too early or too late. This can reduce your cooking oil costs by up to 20 %. Thanks to the testo 270, the deep fried products that you serve up will always be of impeccable quality, guaranteeing the satisfaction of your guests.

4.3 The complete solution: Frying oil management with testo Saveris 3 Food Solution

Frying oil management and quality control using TPM measurement is also part of the testo Saveris 3 Food Solution digital quality management system. With it, Testo Solutions GmbH offers an automated quality management system that reliably meets all compliance requirements, increases quality through process and data security and noticeably reduces operating costs for companies in the chain gastronomy and retail sectors with several branches or spatially separated operations. The testo Saveris 3 Food Solution relies on the three-part harmony of robust measuring

instruments, innovative software and close support from the Testo Solutions GmbH service team.

The hardware: robust, flexible and automatic measurement technology from the world market leader

In contrast to the individual frying oil measurement with the testo 270, the testo Saveris 3 Food Solution uses the multifunction handle. As the name suggests, the multifunction handle enables many different measurements thanks to its interchangeable probes. The sensors are screwed onto the front of the handle and are immediately ready for use. In addition to the frying oil measurement, penetration probes for measuring the core temperature in a fine and robust design, sensors for surface and air temperature and a TC adapter for validating the equipment are also available. As with the testo 270 measuring instrument, the testo Saveris multifunctional handle measures the TPM value and the temperature of your frying oil. You can find more information on the measurement method in Chapter 3. Using the testo Saveris multifunction handle is very simple. The probe is first screwed onto the multifunction handle and the instrument is then



i testo Saveris 3 Food Solution: Typical areas of application for the multifunction handle

- Fast food restaurants
- Central production units
- Business and industry
- Communal catering in the healthcare and education sector
- Leisure /events
- Food retail
- Consumer markets/convenience stores



switched on. When the Bluetooth connection to the Control Unit is established, this is indicated by an illuminated symbol. The measurement can be started immediately. As soon as the measurement value is stable, the handle vibrates. The measurement values are transmitted wirelessly and securely by Bluetooth from the testo Saveris 3 multi-function handle to the Control Unit and the software.

The software: more than a digital quality handbook

The software is the heart of the testo Saveris 3 Food Solution. It is used to digitalize the quality handbooks. This means that they can be rolled out globally at the touch of a button, updated on an ongoing basis or adapted to individual local conditions. Above all, however, the software documents all quality-relevant measuring points and processes and enables both the analysis and control of all relevant quality parameters. In the of limit value violations, those responsible can, thanks to alarms, immediately intervene with correction measures.

The multifunctional handle also makes

it easy to check several fryers in larger operations. This can be done without a cooling phase between measurements. The measuring probe should only be carefully dabbed with some kitchen paper to prevent possible measurement deviations due to carry-over. Final cleaning of the multifunction handle is uncomplicated and only requires water, a mild detergent and a soft paper towel. The multifunction handle and the measuring probes are always within easy reach and yet safely stored thanks to a case and the wall bracket supplied.

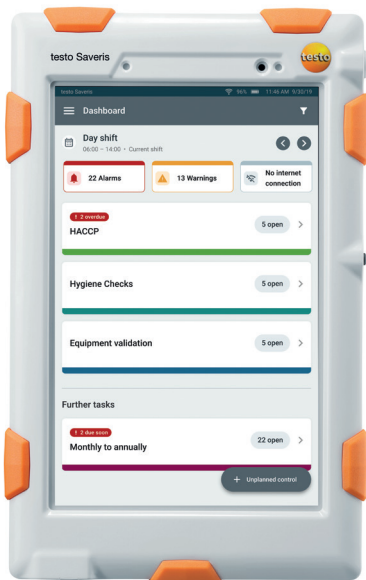
The multifunction handle measures the frying oil in a temperature range between +40 and +200 °C and the

Technical data frying oil probe	
Temperature sensor	PTC
TPM sensor	Capacitive sensor
Measuring range	Temperature: +40 to +200 °C TPM: 0 to 40 %
Accuracy	Temperature: ±1.5 °C TPM: ±2 % (+40 to +190 °C)
Solution	Temperature: 0.1 °C TPM: 0.1 %
Operating temperature	0 to +50 °C
Ambient humidity	0 to 90 %RH
Storage temperature	-20 to +70 °C
Response time t90	Approx. 30 s
Dimensions	305 x 60 x 32 mm
Weight	123 g
Protection class	IP65

TPM value in a range from 0 to 40 %. The accuracy is ± 1.5 °C for the temperature and ± 2 % in the range from +40 to +190 °C for the TPM value. The resolution is 0.1 °C for the temperature and 0.1 % for the TPM value. The instrument operates in a temperature range of 0 to +50 °C and can be used in environments with a humidity of 0 to 90 %. Weighing just 123 grams, it is easy to handle. Thanks to the IP65 standard, the multifunction handle is well protected and resistant to external influences.

Testo Solutions offers hardware, software and services from one supplier

To ensure that digital quality management with the testo Saveris 3 Food Solution is implemented in the best possible way and supports the user in their daily work, Testo Solutions GmbH has specially trained service staff available for all process steps. From planning via commissioning to servicing – the compliance, quality and cost requirements are in focus. Even when the system is installed and running, we're still just a phone call away.



5. Practical application – handling tips

5.1 Tips and tricks

Operation of the instrument is extremely easy for the user.

The instrument lies securely in your hand during measurement, thanks to the ergonomic design. However, there are still a few points which should be observed when measuring oil.

Which oils/cooking fats can be measured with the testo 270?

In principle, all oils and fats intended for deep fat frying can be used. This includes, for example, rapeseed, soya, sesame, palm, olive, cotton seed or groundnut oil. Fats from animal sources can also be measured. The starting values may be higher for pure coconut oil (from the core flesh of the coconut) and palm seed oil (not to be confused with palm oil), see Fig. 19., p. 32). However, a correct measurement is still possible. Coconut oil and palm seed oil are mainly used to make margarine and rarely for deep fat frying.

Under what circumstances may the measurement be incorrect?

The testo 270 measurement may be incorrect if

- the sensor is scratched (some scratches are invisible to the naked eye);
- there is still water in the oil;
- additives are used;
- an induction deep fat fryer was not switched off during the measurement.

A more exact check of the instrument can be made using the reference oil.

How can errors be circumvented or prevented?

Cleaning the sensor

In order to protect the sensor, it should only be cleaned using a household washing-up liquid, detergent or soap solution, and dried with a kitchen towel.

When cleaning, ensure that there is no more fat residue on the sensor, as otherwise the sensor will stick and the

accuracy of the measurement is no longer guaranteed.

If the measurement takes place in hot oil (above 150 °C), the oil residues do not need to be removed. Above this temperature, the oil residue from the last measurement is automatically dissolved. In this case, however, a second measurement is required, as the first measurement serves only to clean the sensor.

Effect of water on the measurement result

If there is still water in the oil, this will significantly augment the display values. If bubbles are still coming out of the fat, water is still present. When measuring, if you are not entirely certain whether water is still present, we recommend repeating the measurement after one minute. If the second reading is lower than the first, there is still water in the oil, and further measurements should be taken at five minute intervals until the reading is constant.

What effect do additives have on the measurement result?

This testo 270 is designed for the use of pure fats/oils. When using additives and filter aids, particularly extremely aqueous ones, discrepancies may arise due to the substances contained in these agents.

Using an induction deep fat fryer

The induction deep fat fryer has an electromagnetic field for generating heat.

The sensor acts like an antenna when immersed in the electromagnetic field. The electronics are disrupted by the electromagnetic rays and the readings obtained are incorrect. It is therefore imperative that the induction deep fat fryer is switched off during the measurement or a sample is taken, in order to get an accurate measurement result.

Temperature skening in deep fat fryers with calorifiers

Using calorifiers as a heat source can cause what is known as "temperature skening". This results in temperature differences in the fat and therefore in different measurement results. To avoid these differences, we recommend first of all moving the instrument in the deep fat fryer until the temperature has equalised but then keeping the instrument still for the measurement itself.

Effect of product being deep fried on the measurement results

No measurements should be taken while the product being deep fried is in the oil, as the water will significantly increase the measurement results (see Fig. 30).

Which minimum fat level is required for measuring?

For the best measurement results, the cooking oil tester must be immersed into the fat at least as far as the "min" marking, but no further than the "max" marking. The deep fat fryer should be filled with fat according to the manufacturer's specifications. Maintain a minimum distance of 1 cm from metallic parts. Contact with the edge of the deep fat fryer should also be avoided



Figure 30: Wrong – measurement with product being deep fried

by immersing the cooking oil tester in the middle of the deep fat fryer.

When is the measurement complete?

The sensor takes a certain time to equalise the temperature. In practice, the response times are specified as T_{xy} times, e.g. T_{90} time. This is the time that elapses until 90 % of the change in reading is indicated. The testo 270 has a response time of about 30s if it is moved in the oil when immersed. This movement in the oil is essential for correct use of the measuring instrument.

The testo 270 cooking oil tester has an Auto hold function:

Once the measurement has reached a stable value, the measurement value and the the alarm backlighting stop

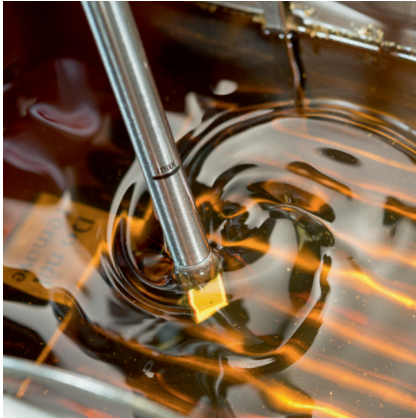


Figure 31: Right – measurement without product being deep fried

flashing, and the are frozen in the display with the corresponding backlighting colour.

Can measurements be taken immediately after each other with the cooking oil tester?

Several measurements can be taken immediately after each other with the testo 270. In between the individual measurements, we recommend wiping the sensor with a kitchen cloth before changing to the new basin, in order to avoid residues. When cleaning, do not touch the metal pipe, protective cap or sensor with unprotected hands. Risk of burns!

Does the TPM value of a cooking fat already exposed to heat change if it is heated again?

Yes, the TPM value changes again by a few percent. The reason for this is the fatty acid peroxides already formed. They are not thermally very stable and decompose as soon as they are reheated. This produces new polar materials which cause a further increase in the TPM value by a few percent.

Does the TPM vary between filtered and unfiltered oil? What causes the increased TPM value and why does it fall after prolonged heating?

The older the oil, the better able it is to bond and transport water. Like the degradation products of the fat, a water molecule is also polar and is included in the measurement. With increasing age, the water takes increasingly longer to evaporate from the fat even at high temperatures of 175 °C. Consequently, the TPM may be significantly increased as the fat is being heated and fall again in a repeat measurement in hot fat.

By filtering the cooking fat, some of the decomposition constituents and residues of the product being deep fried are filtered out of the fat. Water which is bonded to these constituents is thus also removed from the fat. The water content is therefore lower in freshly filtered fat than in unfiltered fat. In order to determine whether there is still water in the fat, we recommend taking several measurements at five-minute intervals without frying in between. If the value falls after each measurement, water is still present. The measurements should be repeated until two consecutive measurements show the same value or only a discrepancy of 2 % TPM or less.

Can free fatty acids (FFA) and % TPM be compared?

FFA (Free Fatty Acids) and TPM (Total Polar Materials, often also: TPC - Total Polar Components) are two completely different measurement methods for determining the quality of frying oil. There is no correlation between the TPM value and the FFA value. The term "free fatty acids" is a misleading term for measuring the acidity of used frying oils. In fats already heated, the FFA value is not a measure

of ageing, as the free fatty acids are removed from the fat together with the evaporating water and their content fluctuates heavily. Only the oxidation and polymerization products are relevant for the measurement quality of used frying oils. The TPM value (along with the DPTG value) is therefore the most suitable value for assessing the quality of frying oils.

In contrast to the FFA value, the TPM value is a reliable indicator of the degree of decomposition of the fat and provides an exact statement of how heavily the fat is already contaminated. For this reason, the measurement of the TPM value is recommended in order to obtain a reliable assessment of the frying oil quality.

Studies from 2023 indicate that an FFA value in deep-frying fat of over 0.5% can even significantly reduce the carcinogenic substance acrylamide, which in turn contradicts the practice of using increasing FFA values as a measure of the rancidity of the oil.²³

What temperature is the best control point, 45 – 50 °C or 175 – 185 °C?

We recommend measuring in hot oil, as the measurement is quicker due to the fluidity of the fat and the sensor is easier to clean after the measurement. Only carry out measurements after deep frying once there are no longer any bubbles rising. Only then can you be sure there is no more water in the oil. If you are unsure, simply repeat the measurement after a few minutes, until the reading is virtually constant ($\pm 2\%$ TPM).

What happens if the tester is kept too deep in the deep fat fryer and the "max" marking is exceeded? Will this damage the sensor?

No. However the sensor should not be immersed more than five centimetres below "max". The housing must on no account be immersed in the fat, as it is not heat-resistant.

Is it possible to install the cooking oil tester so that it is permanently measuring in hot oil? Is there a specified maximum length of time for which the tester can be in the oil?

The cooking oil tester is not designed to be permanently in hot oil. It is designed for short measurements of between 30 seconds and five minutes.

What has to be taken into account to get the best results for deep fat frying?

Here are a few tips for achieving optimum frying results and as long a duration of use of the cooking oil as possible. The frying temperature should not exceed 175 °C, as the formation of acrolein intensifies considerably above this temperature. The testo 270 helps the user in that it warns of too high temperatures (from 200 °C) by an optical alarm.

- Set the "optimum frying point" of the fat using the testo 270 in order to obtain the optimum quality of the product being deep fried.
- The quantity of product being fried should be measured so that the temperature does not fall too sharply during deep frying, thereby having a negative impact on the frying result.
- Turn down the temperature of the deep fat fryer when out of use for prolonged periods of time in order to prevent unnecessary exposure to

Practical application – handling tips

heat and therefore premature ageing of the fat.

- The frying oil should be filtered at the end of frying in order to remove from the oil any residues of the product and parts of the degradation products of the oil, and water bonded to these.

5.2 Areas of application

5.2.1 Large-scale catering establishments, canteens, large catering companies

The cooking fat can be used most effectively if the TPM value is measured. The fat can remain in use until the national recommended guideline has been exceeded or it can be reset to the optimum deep frying range by replacing some of the fat with fresh fat, thus ensuring that the deep fried food is of consistently high quality. Regular measurements can also preclude health risks and fines due to a failure to keep within the limit values.



Figure 32: Regular measurement guarantees that the food is of consistently high quality

5.2.2 Food monitoring

Food monitoring is quicker and more efficient thanks to on-site monitoring. In the event where you are not certain as to whether oils have already exceeded the guideline, these can be tested using the testo 270. Food inspector costs can thus be reduced, because not all fats have to be sent to the laboratory now, only those which are actually above the statutory guideline and require closer examination.

5.2.3 Food manufacturers

(e.g. of deep fried products, snacks etc.)

By setting the optimum TPM value in the fat, the food manufacturer can supply its customers with perfect taste and quality.

At the same time, costs can be saved in fat consumption.

Companies which as a precaution change their oil regularly in order to prevent the guideline being exceeded are able to save costs with the testo 270, as they can determine the right point at which the fat is decomposed using the cooking oil tester and thus use the oil for longer.

5.2.4 Large restaurants, fast food chains

Particularly in catering, the requirement for maximum quality is especially important. A meal in a restaurant can determine whether a guest comes back or recommends the restaurant to others. If a guest suffers health complaints after visiting a restaurant due to spoiled food, firstly the guest will not come back and secondly the restaurant may find itself liable for a fine. If the TPM value of the fat is checked

regularly and the fat is replaced at the appropriate time, disagreeable health risks and fines can be prevented.

Furthermore, the TPM value can also be set to the optimum value, which benefits the customer in terms of improved taste.

5.3 Calibration of measurement parameters

Calibration means measuring an oil with a known TPM value, for example, and comparing the value displayed on the testo 270 with the known value.

The discrepancies are recorded on a calibration certificate. Anyone wishing to carry out measurements in accordance with HACCP/the Food Hygiene Ordinance [LMHV] needs a calibrated instrument. Calibrations may be performed by all authorized calibration centres.



Figure 33: Calibration seal

5.4 What is meant by measuring range, accuracy and resolution?

Measuring range

The measuring range indicates the range in which the sensor measures with a specified accuracy. The cooking oil tester, for example, has a temperature measuring range of 40 to 200 °C with a margin of ± 1.5 °C from the actual temperature. Below the specified range the results may be inaccurate, as solid fat does not start to melt until at just below 40°C room temperature and is still extremely viscous. The upper limit is extremely generous at 200 °C. For health and safety reasons, a temperature of 175 °C should not be exceeded during deep fat frying. As soon as the temperature falls below or above the measuring range, the arrow in the display of the cooking oil tester lights up and the upper or lower measuring limit flashes.

Accuracy

The accuracy describes the largest possible deviation of the measured value from the actual value. If, for example, a deep fat fryer has an actual temperature of 190 °C and the sensor is measuring a temperature of 191.5 °C, it has a margin of +1.5 °C.

There are several possible ways of showing the accuracy:

- Relative deviation from the reading
- Relative deviation, referring to the final value of measuring range
- Absolute specification in Vol% or ppm (parts per million), for example

Solution

Resolution refers to the smallest subdivision of the unit of measurement. The accuracy is always poorer than the resolution.

Example

Display: 150.5 °C

Resolution: 0.5 °C

Display: 150.53 °C

Resolution: 0.01 °C

Display: 150,531 °C

Resolution: 0,001 °C

There are specific errors on digital measuring instruments, the so-called **digital unit**, referred to as digit for short. A digit denotes the last digit of a digital display. It can jump by ± 1 unit. The poorer the resolution of a measuring instrument, the greater the effect of a jump in digit on the accuracy of the measurement result.

Example

Display:	150 °C	150.5 °C
Display +1 digit:	151 °C	150.6 °C
Display -1 digit:	149 °C	150.4 °C

5.5 Calibration and adjustment for the testo 270

The user can check the accuracy of the cooking oil tester himself, by carrying out a comparative measurement using Testo reference oil (calibration). If there is too great a difference between the reading and the reference value, future device readings can be adjusted in line with the reference value (adjustment).

Please refer to the instruction manual for a detailed description of how to carry out the calibration/adjustment.



Figure 34: Testo reference oil

For a simple inspection of the instrument

When commissioning the new instrument, carry out measurements in unused cooking oil and note the measured TPM start value (mean value from measurement conducted several times). The reference value thus obtained serves as a comparative value for subsequent instrument testing.

5.6 Logging

Each measurement includes the documentation of the results and where applicable the evaluation of the measurement data. Documentation is not a mandatory regulation, but it is customary for authorities to view records as part of the official food controls. In these cases, complete and clear documentation is used for verification purposes. Documentation is strongly advised, on the basis that:

“What is not documented does not exist!”

Depending on the scope and purpose of the measurement, all or at least the first six of the following pieces of data should be noted. An example record can be found in this section and in the appendix.

Date and time

Absolutely necessary entries to allow traceability of documents and products.

Processor

If there are any queries, the designated contact person must be identifiable. Initials will suffice in small companies.

Measuring location

It must be possible to retrospectively match the readings to the place at which they were taken. In some circumstances, a sketch of the site or an exact description in relation to permanent fixtures, such as the entrance door, can be enclosed.

Measuring device

The measuring instrument used must be specified. This is the only way to ensure that the accuracy of the measurement can be assessed retrospectively and be compared with subsequent measurements.

Comments

Any unusual effects which could alter the reading are noted here. This may include superheating of the cooking oil, for example.

Actual value

The reading(s) taken.

Nominal value

The required temperature or upper limit value for the TPM value (24 % TPM), for example.

Discrepancies between nominal value and actual value

If discrepancies between the actual value and the nominal value are recorded in a log, appropriate corrective action must be taken. For this, the person logging the values must have the authorisation to perform independent corrections on the equipment concerned (the employee must be familiar with the instrument and know how to operate it) or know where to turn if he cannot perform the measures himself.



A discrepancy always requires corrective action, and corrective action requires a check to ascertain whether the corrective action was successful. The check can only be performed by employees with the appropriate expertise and authority. User-friendliness or the self-declaration is a decision-making criterion in using logs.

6. Technical data for testo 270

6.1 Measuring range and accuracy

Measurement type	Measuring range	Accuracy	Resolution
Temperature	+40 to +200 °C	±1.5 °C	0.1 °C
TPM (Total Polar Materials)	0.0 to 40.0 %TPM	0.5 %TPM (+40 to +190 °C)	(+40 to +190 °C)

6.2 Other instrument data

Power supply/Battery type	Battery: 2 AAA batteries
Battery life at 20 °C	Approx. 25 hr continuous operation equals approx. 500 measurements
Sensor	
Temperature	PTC
TPM	Capacitive sensor (Testo)
Storage/transportation temperature	-20 to +70 °C
Operating temperature	0 to +50 °C
Operational frying oil temperature	+40 to +200 °C
Display	LCD, 2-line, backlit
Weight of instrument with TopSafe, batteries and wrist strap	255 g
Dimensions	50 x 70 x 130 mm
Housing materials	ABS / ABS-PC fibre glass 10%
Response time	approx. 30 sec
Protection class IP65	
Warranty	2 years

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9. Valuable practical knowledge on food safety

Whether you're involved with production, transport or processing: in whatever capacity you work with food – you can always rely on Testo. Reliable measurement solutions and useful know-how will help you monitor limit values and ensure quality throughout the entire process chain.



Video: Measuring cooking oil quality using the testo 270

Watch a short video to see how Chef David Rothe measures the quality of cooking oil quickly and reliably using the testo 270 cooking oil tester:

[To the video](#)

Cooking Oil Measurement online training module

You can also find a condensed version of this Field Guide on our website in the form of a free online training module. This can be used either to refresh your knowledge or to train employees and colleagues: [To the training](#)

How-to videos testo 270

These videos illustrate the easy and convenient operation of the testo 270 step by step. [To the videos](#)

Pocket Guide Food Safety

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