



Committing to the future

Field guide

Cooking oil measurement

With practical advice, tips and theory





FOREWORD

As a manufacturer of measuring instruments for a wide range of industrial and commercial applications, TESTO is interested not just in supplying users with a particular device, but also in helping them meet their specific needs, i.e. carrying out their measuring tasks.

The "field guides" that TESTO has been publishing for several years have become useful sources of reference for many users of measuring technology.

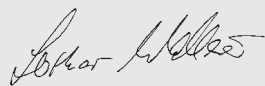
In these seminars, which were constantly expanded, the hope was sometimes expressed that the learning material could be supplemented and condensed into written form and made available as a handbook. We are happy to respond to this request by publishing this guide.

What has not been dealt with intensively enough? We welcome your ideas, amendments and suggestions for how this guide can be improved. They will be considered in the next issue.

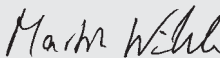
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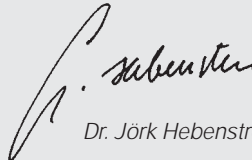
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Cooking oil measurement

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1 Food safety/HACCP concept

1.1 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 objective was and is to overcome trade boundaries in the course of the realization of the 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 Also in February 1997, the HACCP concept was incorporated into the German Food Hygiene Ordinance, which became mandatory for all establishments working with food in August of the same year.

The Food Hygiene Ordinance is based on self-monitoring by the establishments and an obligation to train employees.

1.2 What is HACCP?

HACCP stands for Hazard Analysis and Critical Control Point

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. *Definition of critical control points (CCPs) for monitoring identifiable hazards*

The definition of CCPs is necessary to monitor the identified hazards. They must be used wherever a hazard could occur or can be eliminated or minimised.

The use of 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 allowing an effective control*

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

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 the appropriate action to ensure the safety of the food and thus prevent a health hazard to consumers.

4. *Definition and establishment of a monitoring process for 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 monitored?

Who monitors?

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 case of deviation from the critical limit values*

Corrective measures are implemented at this point if the results of monitoring show that the operation is not under control, i.e. if the CCPs deviate from the limit values.

Any control measures carried out must be recorded!

Food safety/HACCP concept

6. *Setup and completion of documentation of HACCP concept*

By recording any measures introduced and the monitoring values obtained, 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 should extend considerably beyond the best before date of the products being produced.

A detailed and complete document must contain the following:

Product description;

Description of the manufacturing process with specification of the CCPs;

For each CCP: Explanation of measures so that they can be managed;

Monitoring and control measures for 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: Chapter 4.6 protocols, page 52)

7. *Checking the system (verification)*

Verifying: "Confirming the correctness of something by checking".

In terms of the HACCP concept, this means that the functionality of the concept has been checked and confirmed and that proof is being provided that the HACCP program is working effectively and properly.

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

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

1.3 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 calibrating measuring and test equipment at regular intervals. Since temperature is one of the critical control points in HACCP, the thermometers used should 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.

1.4 Application of the HACCP concept to the deep fat fryer

The aim of implementing the HACCP concept is to give the manufacturer and processor of foods 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, with the appropriate measures.

2 The principles 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, the extraction was continually improved in order to maximise the volume of oil extracted.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.



Sunflowers



Olives

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.

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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 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

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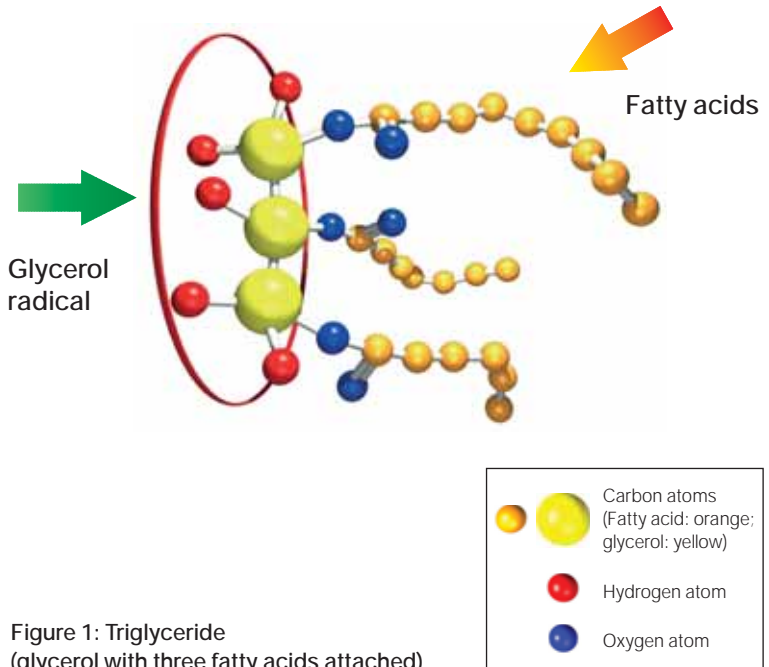
2.2 What are fats and oils in chemical terms?

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 glycerine (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 glyceride 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.



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

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

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 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.

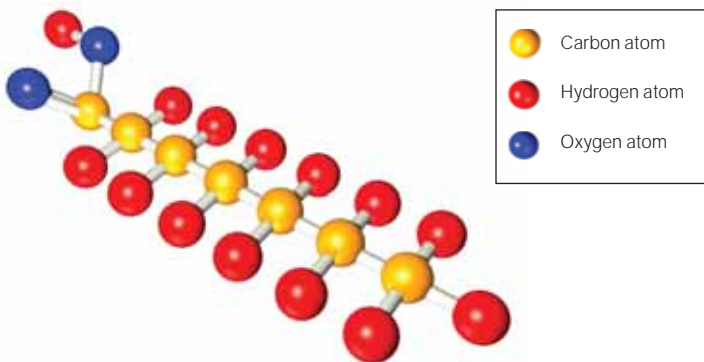


Figure 2: Saturated fatty acids

The single bonds between two carbon atoms (C-C) can rotate freely. The fatty acid molecule is therefore extremely mobile and 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.

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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, what is 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.

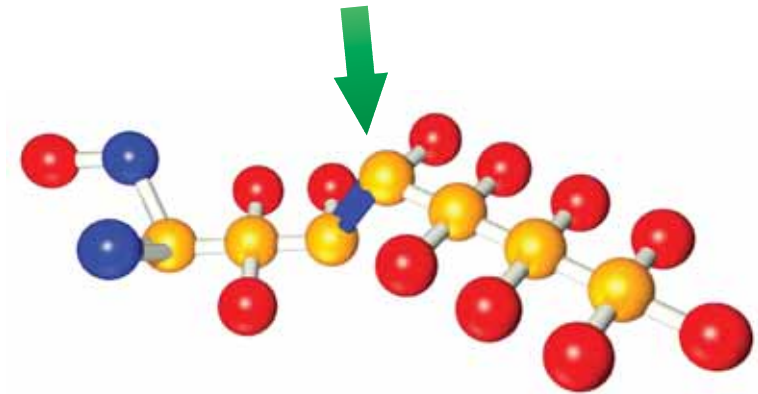


Figure 3: Monounsaturated fatty acids

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.

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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.

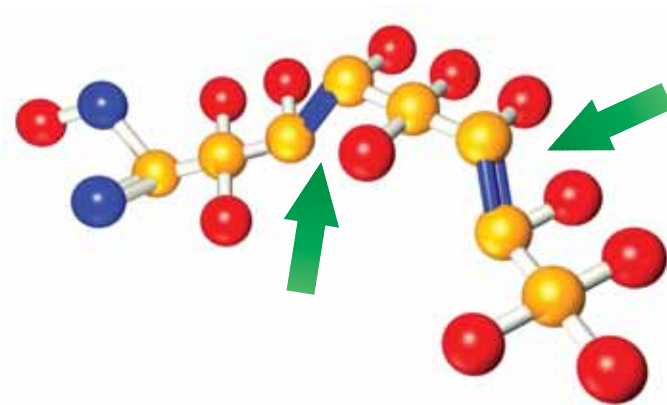


Figure 4: Polyunsaturated fatty acids

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}

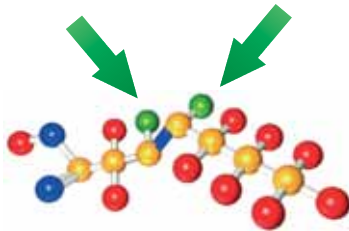
Fats with a higher proportion of monounsaturated and polyunsaturated fatty acids are more prone to fat ageing than saturated fatty acids and are therefore not suitable for deep fat frying. From a health point of view, however, it is advisable to use cooking fat with the maximum possible proportion of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

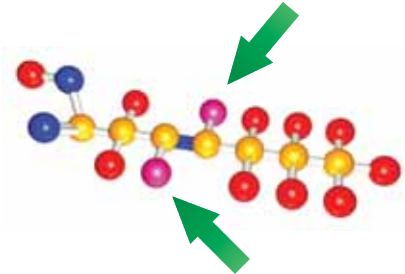
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Trans fatty acids

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).



 Hydrogen atom in Cis position




 Hydrogen atom in trans position

Figure 5: Cis fatty acid

Figure 6: Trans fatty acid

In 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 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.

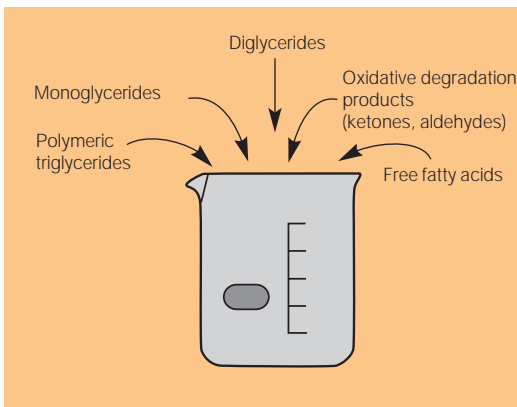


Figure 7: TPM constituents

2.3 What happens when you deep fry with the 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.

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This stabilises the surface of the food, which means that it protects the 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.

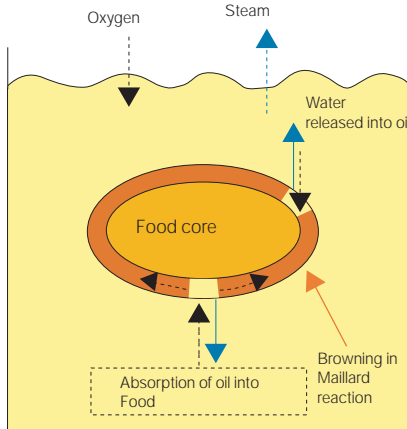


Figure 8: Reactions between product being deep fried and the oil during the deep frying process¹³

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.

	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 fat frying¹⁴

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 causes 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).

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 the 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.

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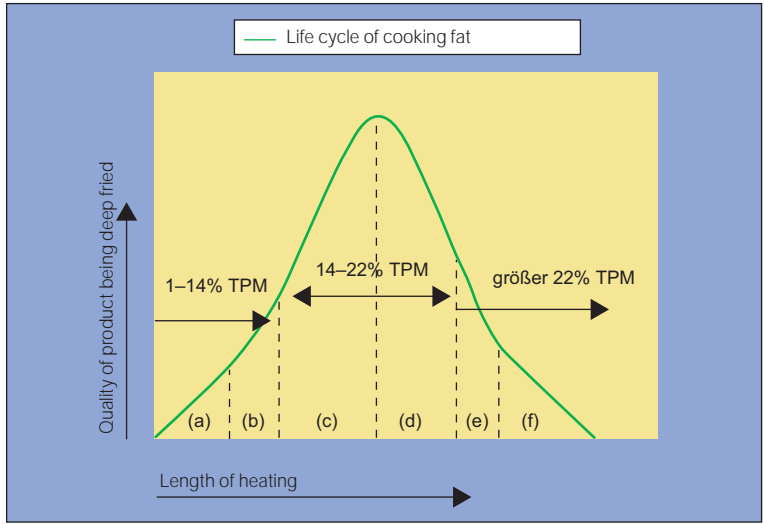


Figure 9: Life cycle of the cooking fat¹⁶

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. Chips, 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*

Oxidation

Oxidation is responsible for the ageing of the fat due to the transfer of oxygen 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 monoglycerides 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 air to form oxygen-bonded radicals (ROO^*).

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

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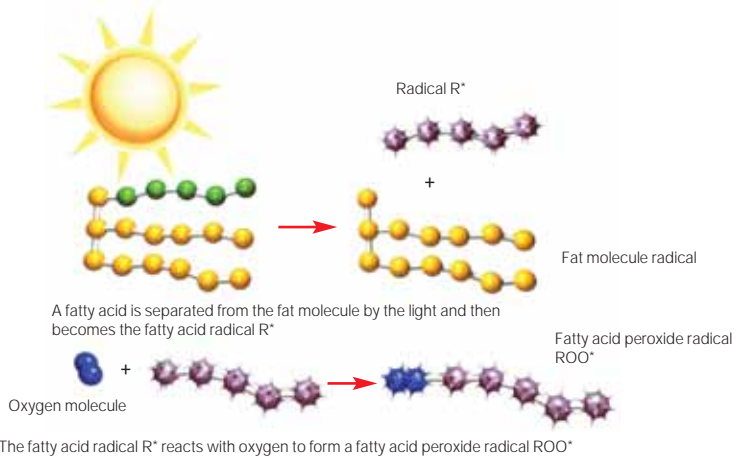


Figure 10: Induction phase

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.

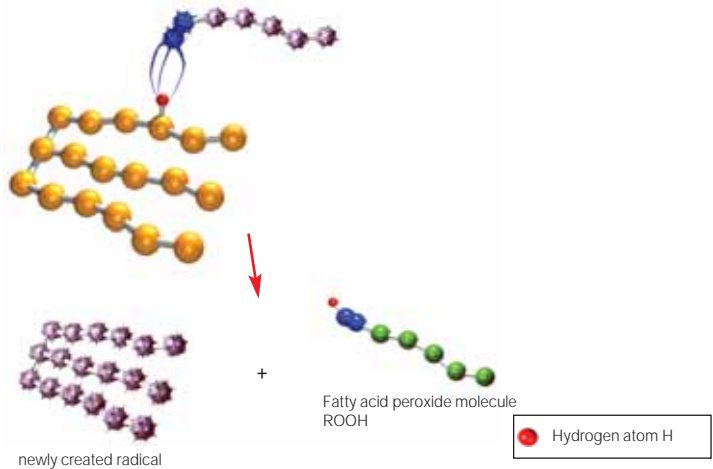


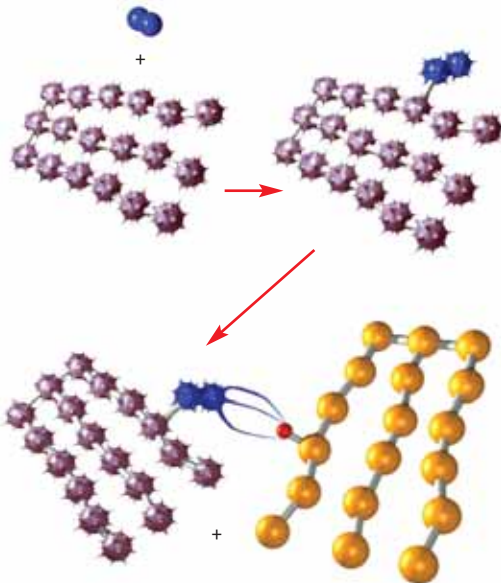
Figure 11: Chain growth phase

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

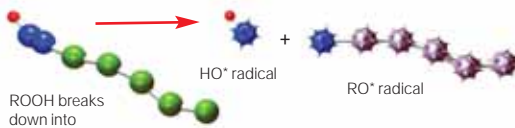
** Hydrogen peroxide (H_2O_2) is a strong oxidant and is used in a heavily diluted form to bleach hair, for example.

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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).



The new oxygen radical catches another hydrogen atom, then becomes a hydrogen peroxide molecule etc. This process continues endlessly until there is a chain termination reaction.

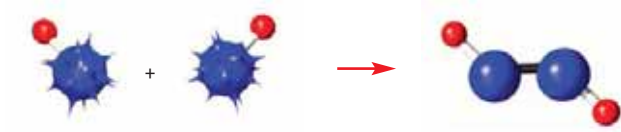


The new radicals HO^* and RO^* react again with surrounding oxygen or fatty acids. Again, the reaction continues endlessly until there is a chain termination reaction.

Figure 12: Chain branching reaction

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 longer catch hydrogen molecules.

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Two radicals react with each other and form a new bond (shown in black in the drawing). The radicals can no longer trap hydrogen in this state.

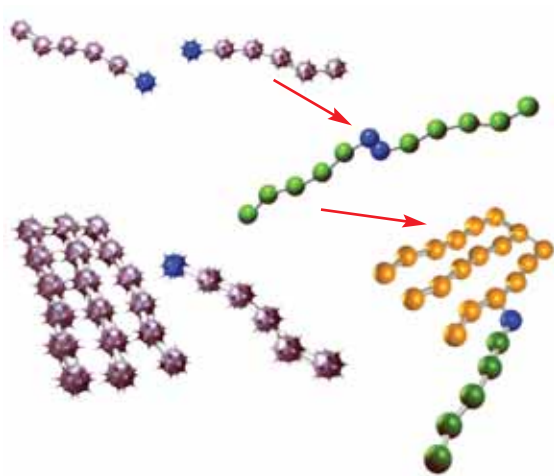


Figure 13: Chain termination reaction

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.

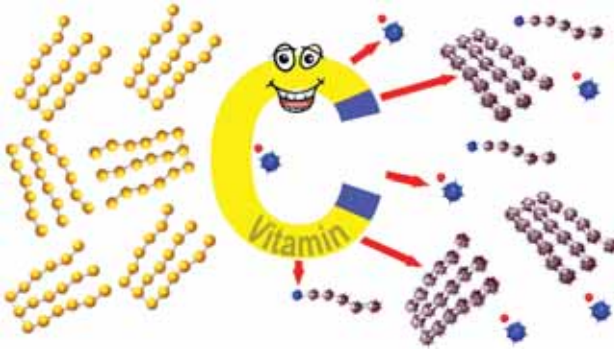


Figure 14: Actions of radical catchers

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.

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.

The principles of fats and oils

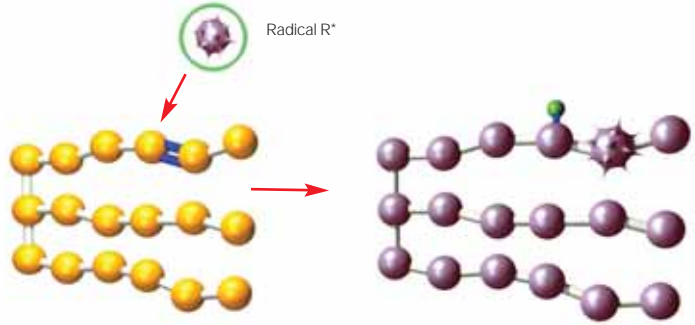


Figure 15: Initial phase of polymerisation

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

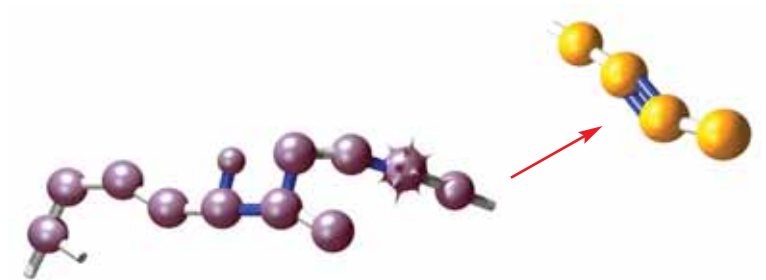


Figure 16: Chain growth

The principles of fats and oils

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.

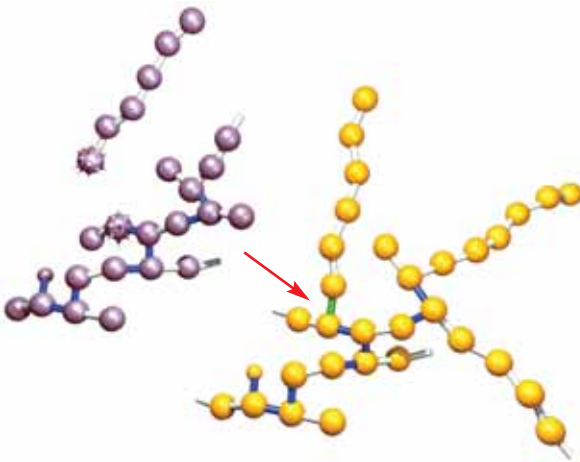


Figure 17: Chain termination reaction

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 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.

The principles of fats and oils

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.

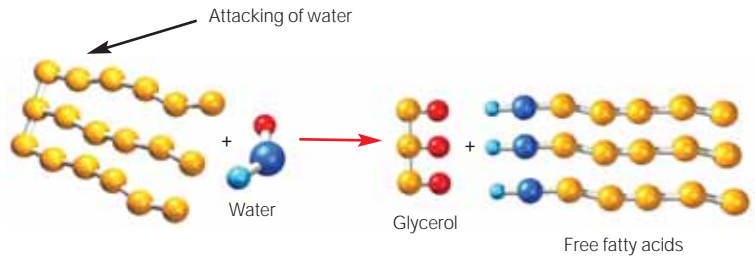


Figure 18: Hydrolysis reaction

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.

3 Technical background knowledge

3.1 Why measure at all?

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 “**Total Polar Materials**”, 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 Chapter 2.3.2 *Life cycle of the cooking 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

Technical background knowledge

range can be maintained by mixing older oil with fresh oil, and the customer receives a uniformly high quality of taste and crispness.

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 O.K.
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

Table 2: Classification of TPM values for fat ageing

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 (Fig. 19).

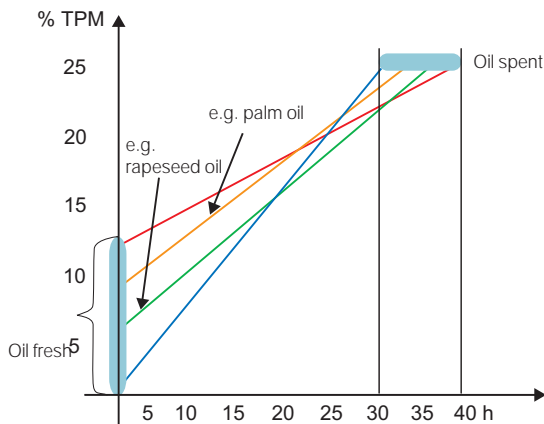


Figure 19: Starting/end values against the operating time

The starting values and operating times given here are only intended as examples for the purposes of illustration.

3.2 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, monoglycerides 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).

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

Table 3: Recommended TPM standards of various countries

Technical background knowledge

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 bottom.

As the sample moves through the column, the polar materials present are retained by the weighting agent of the column, so that only 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 deducted from the total weight, the polar materials of the sample are obtained.

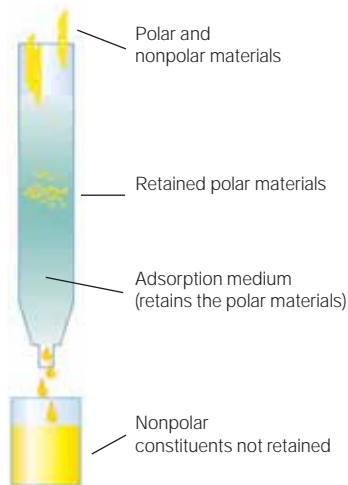


Figure 20: Column chromatography

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 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. Cooking oil contains a mixture of polar materials, from the relatively non-polar 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.

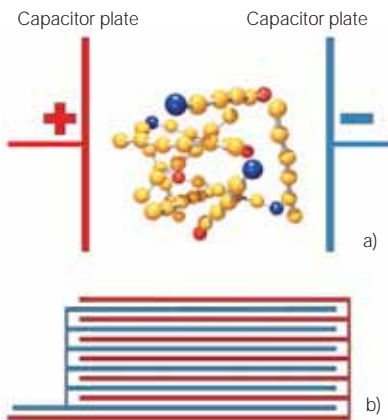


Figure 21: a) Schematic representation of a capacitor,
b) Technical design of the oil sensor

To this end, a voltage is connected to both plates of the capacitor (shown in red and blue in the illustration). The capacitor plates are charged until a certain 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.

Technical background knowledge

Once the capacitor is charged, it has a certain capacity. 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 (free fatty acids, FFA)*

The 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. However, 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.

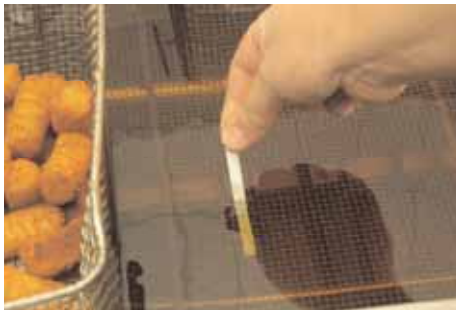


Figure 22: Measuring free fatty acids using a test rod

By then comparing the test strip against an appropriate colour scale, the content of free fatty acids can be determined.

Caution!

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.

3.2.4 Colour check of oils

In the field, 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.

Caution!

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 as 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 Identification of 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 of 1991, 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.

Technical background knowledge

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.

Caution!

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.

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.

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.

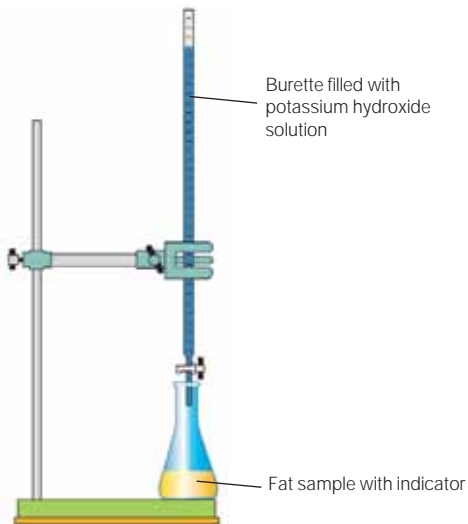


Figure 23: Titration apparatus

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.

Technical background knowledge

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 The testo 270 cooking oil tester

First, the testo 270 enables the user to provide its customers with perfectly deep fried foods with a full taste and secondly to ensure compliance with statutory recommendations.

3.3.1 "Total polar materials" variable

As already indicated, the TPM can be determined by means of either column chromatography or a capacitive measurement. The deep-frying 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.

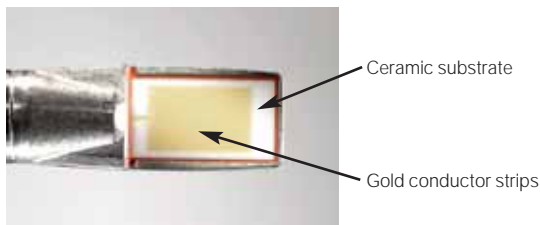


Figure 24: Fat measuring sensor

3.3.2 Temperature variable

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, is attached to the ceramic plate by means of a special process.

3.3.3 A general overview of the testo 270 cooking oil tester

The testo 270 cooking oil tester is a handy measuring instrument for quickly testing the freshness of cooking fats.

The sensor is entirely integrated into the meter which uses batteries to operate and is completely portable...no cables getting in the way. The freshness of the oil can be measured quickly and easily without long waiting times especially since the sensor doesn't have to cool between measuring samples.

We only recommend that the sensor is wiped carefully with a kitchen towel (caution: risk of catching fire!) to avoid residues.

Both the % TPM value and the oil temperature are shown in the two line digital display. Due to the larger display and the optional backlighting, the values can be quickly and easily read, even in dark surroundings.



Figure 25: Visual and Audible alarm if a given limit is exceeded

Easily set the quality limit values for the polar materials using the two function keys on the front of the testo 270. The lower and upper limits can be set independently from each other, but the two values must differ by at least 1%. The limit values are safe against accidentally erasing or changing them after they've been set.

If a TPM value exceeds the upper set limit value, the word "ALARM" appears in the display.



Figure 26: testo 270 cooking oil measuring instrument

A three-color alarm bar is an additional air function.

The bar changes color according to the polar material content. Below the lower limit value, the bar above the display is green and the fat is still OK.

In the range between the two set limit values, the bar 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.

When the upper limit value has been exceeded, the bar is red. The fat is now so spent that it can no longer be improved by replacing it in part. The oil must now be replaced.

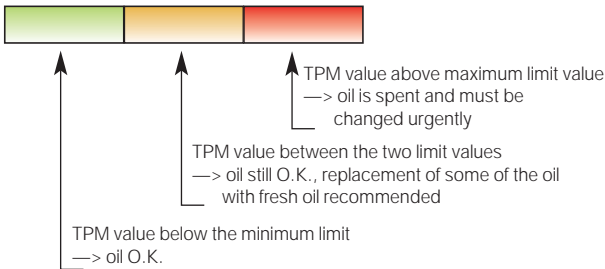


Figure 27: LED display

The temperature of the cooking fat being tested must be at least +104°F. If it is less than 104°F, the display flashes 104 °F and it's no longer possible to carry out the test as the discrepancy in accuracy is too great. The same applies if the maximum oil temperature is +410 °F or above. In this case, 410 °F flashes in the display and you must wait until the temperature falls below 410°F before proceeding with the measurement.



Figure 28: Aluminium case for the transport and storage of the testo 270

The cooking oil tester's sensor is extremely compact making it possible to use for testing in low oil levels.

The sensor is also equipped with a protective layer which makes it relatively insensitive to mechanical strain and since it's also embedded in metal it is additionally solid and unbreakable.

Technical background knowledge

The 270 itself is protected by a TopSafe. It protects the device against soiling from the oil, but also against dust and other impurities. The TopSafe can be removed and is dishwasher safe

Looking after the device is just as easy as looking after the TopSafe. 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 relative cost of ownership of a 270 is the initial expense. Apart from the annual calibration and the changes of batteries, there are no further costs. In fact the money the 270 can save you in cooking oil means it pays for itself in no time.



Figure 29: Removable protective cap (TopSafe) and hand strap for testo 270, provides optimum protection

4 Practical application – handling tips

4.1 Tips and advice

The 270 is extremely easy to use. However, there are still a few safety factors 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 bean, 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. 30) However, a correct measurement is still possible. Coconut oil and palm seed oil are usually used to make margarine and rarely for deep fat frying.

Under what circumstances may the measurement be incorrect?

The measurement of the testo 270 may be incorrect if

- ... the sensor is scratched (there are also scratches invisible to the 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 kitchen paper 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 302 °F), the oil residues do not need to be removed. Above this temperature, the oil residue from the last

Practical application – handling tips

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. If it is not entirely certain when measuring if 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?

The 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 skeining in deep fat fryers with calorifiers

Using calorifiers as a heat source can cause what is known as "temperature skeining". 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 to be deep fried is in the oil, as the water will significantly increase the measurement results.



Figure 30: Correct measurement results only possible if measurement is taken without the product being deep fried!

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. The deep frying basket should be removed from the deep fat fryer before any measurement is taken in order to avoid contact. Contact with the edge of the deep fat fryer should also be avoided by immersing the cooking oil tester somewhere 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} time, e.g. T_{90} time. This is the length of time until 90% of the change in reading is indicated. The testo 270 has a response time of less than 20s if it is moved briefly in the oil when immersed.

The cooking oil tester testo 270 has an Auto hold function: When the measurement has reached a stable value, the user is given an audible signal to indicate this. The measured value is shown on the display

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!

Practical application – handling tips

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 filtering 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 and die TPMS cannot be compared mathematically. They are two completely different methods of measuring the quality of the fat.

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. The TPM should therefore be measured to obtain a representative indication of the decomposition. With fats that are still fresh, the rate of ageing can be determined using the FFA value.

What temperature is the best control point, 113–122 °F or 347–365 °F?

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.

If measuring after deep frying, do not forget the water test.

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 practical tips for achieving the optimum deep fat frying result and the longest possible usage time for the cooking fat:

- The deep frying temperature should not exceed 347 °F, as the acrolein formation increases significantly above this temperature. The testo 270 helps the user: It warns of too high temperatures (from 356 °F) by sounding an audible 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 to be deep fried should be measured so that the temperature does not fall too sharply during deep frying, thereby having a negative impact on the deep 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 heat and therefore premature ageing of the fat.
- The cooking oil should be filtered at the end of deep fat frying in order to remove residues of the product being deep fried and parts of the degradation products of the fat and water bonded to these from the fat.

Practical application – handling tips

4.2 Areas of application

4.2.1 *Large-scale catering establishments, kitchens, large catering companies (large-scale catering establishment)*

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 a uniform quality of the deep fried food. However, regular measurements can also preclude health risks and fines due to a failure to keep within the limit values.



Figure 31: Regular measuring ensures uniform quality of food

4.2.2 *Food monitoring*

Food monitoring is quicker and more efficient due to on-site monitoring. Oils for which it is not certain whether they have already exceeded the guideline can be tested using the testo 270. Official 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.

4.2.3 *Food manufacturers (e.g. from deep fried products, snacks etc...)*

By setting the optimum TPM value in the fat, the food manufacturer can supply its customers the 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.

4.2.4 *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.

4.3 Calibration of 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. A calibrated instrument is required for performing measurements in accordance with HACCP/the Food Hygiene Ordinance. Calibrations may be performed by all authorized calibration centers.

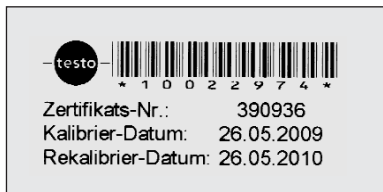


Figure 32: Calibration seal

4.4 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 +104 to + 410 °F with a margin of ± 1.5 °F from the actual temperature. Below the specified range the results may be inaccurate, as at room temperature solid fat does not start to melt until just below 104 °F and is still extremely viscous. The upper limit is extremely generous at 410 °F. For health and safety reasons, a temperature of 347 °F 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 374 °F and the sensor is measuring a temperature of 376.7 °F, 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

Resolution:

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

Example:

Display:	302.9 °C	303 °F	302.9 °C
Resolution:	0.5 °F	0.01 °F	0.001 °F

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

4.5 Calibration and adjustment for testo 270

In order to test the instrument accuracy, the testo 270 is calibrated in Testo reference oil.

The adjustment can then be made manually from a reference value at 77–140 °F.

4.6 Recording

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 urgently 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 chapter and in the appendix.

Date and time

Mandatory entries to allow traceability of documents and products.

Contact person

If there are any queries, the designated contact person must be accounted - . Initials will suffice in “small” companies.

Location

It must be possible to match the readings to the location 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 equipment

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

Comments

Any unusual effects which could alter the reading are noted here. This may include overheating 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 recording the values must have the authorization 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 it cannot perform the measures itself.

Caution!

A discrepancy always means corrective action, then a follow-up 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.

5 Technical data of testo 270

5.1 Measuring range and accuracy

Measurement type	Measuring range	Accuracy	Resolution
temperature	+104 to +392 °F	± 1.5 °C	± 0,5 °F
TPM (Total Polar Materials):	0.5 to 40 %TPM:	±2,0 %TPM (at +104 to +374 °F)	±0.5 %TPM

5.2 Other instrument data

Power supply/Battery type	Battery: 2 x AAA
Battery life at 68 °F	Approx. 30 hrs continuous operation Corresponds to 600 measurements

Sensor	
temperature	PTC
TPM	Capacitive sensor (Testo)

Storage/transport temperature	-4 to +158 °F
Operating temperature	32 to +122 °F
Operational cooking oil temperature	+104 to +392 °F
Display	LCD, 2-line, backlit
Weight instrument with TopSafe and batteries	approx. 5.5 oz
Dimensions instrument incl. TopSafe	approx. 14" x 2" x 1.2" (L x W x H)
Housing material	ABS (white)
Dimensions housing	approx. 6" x 2"
Response time	< 30s
Protection class	IP 65 with TopSafe
Warranty	2 years
EC Directive	VO (EG) 1935/2004

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8 Reference to other publications

"Measuring technology in the food industry"



testo

Messtechnik im Lebensmittelbereich

Einführung in die Messwertfassung im Rahmen des HACCP-Konzeptes

°C

pH

%rF

%TPM

3. überarbeitete Auflage

9 General

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