

# Effect of frying conditions on the fat content of French fries

## **Final report**

Reference number: OPD 03/336  
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Product Safety Authority (VWA)

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## Abstract

Pre-fried chilled French fries have been deep-fried at several temperatures (140°C, 160°C, 175°C, 180°C and 185°C) and times (2, 3, 4, 5 and 6 minutes), to evaluate whether frying conditions affect the fat content of French fries in relation to quality aspects such as moisture content and colour.

Additional to this study, an indicative investigation of other processing aspects that might have an effect on the fat content of deep-fried French fries has been included. The following four aspects have been investigated: 1. Type of fat used for deep frying (liquid or solid), 2. Frozen or chilled French fries, 3. French fry brand and 4. Thawing time of frozen French fries.

It can be concluded that the moisture content of the French fries decreases with increasing frying time and temperature, while the colour index of the French fries increases (the fries obtain a darker appearance). The fat content calculated on total weight increases with increasing frying time and temperature. However, the fat content calculated on dry matter increases only with increasing frying time, and no effect of frying temperature has been observed.

The application of lower frying temperatures implies that longer frying times are necessary to reach the same moisture content or colour value. In the case that the fries are fried on final moisture content, the effect on the fat content is minor. In the case that the fries are fried on a final colour, the fat content is affected due to great differences in frying time.

The experiments that have been carried out under other processing aspects lead to the following conclusions (indicative!). The use of solid fat instead of liquid results in a higher fat content ( $P < 0.05$ ) in finish-fried French fries. Frozen pre-fried French fries contain a higher fat content after frying than chilled pre-fried French fries ( $P < 0.05$ ). No difference in fat content was found between the two brands that have been studied. No effect of the thawing time of frozen French fries on the fat content was observed.

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## 1 Introduction

Previous research performed on the factors that influence the forming of acrylamide during processing of French fries concluded that the frying temperature is an important parameter (van Gijssel et al., 2003a, 2003b). The frying temperature of 180-185°C as prescribed in The Netherlands leads to a higher acrylamide content as for example a temperature of 175°C, which is going to be discussed in Germany. The application of lower frying temperatures contributes to a lower acrylamide content in French fries. However, in general it is assumed that the application of lower frying temperatures leads to a higher fat content in the fried product. Mehta and Swinburn (2001) support this in their review on factors affecting fat absorption in hot chips (French fries). These findings are confirmed for processing of potato crisps by Haase (2003) by illustrating a higher fat content at lower frying temperatures. Moreira et al. (1999) have studied the deep-fat frying process and indicate an opposite effect for potato crisps. They mention that higher oil temperatures lead to a faster crust formation during the early stages of frying, thus an open structure so that fat will be absorbed easier. This means that a higher oil temperature lead to higher fat content in particular in the early stages of frying.

How the fat content of (pre-fried) French fries develops at different frying times and temperatures is unknown. The higher fat content might be a health risk for the consumer. The effect of several times, temperatures and other frying conditions on fat content at finish frying has not been investigated. The Dutch Food and Consumer Product Safety Authority (VWA) invited Agrotechnology & Food Innovations of Wageningen UR to study the effect of frying conditions on the fat content of French fries in relation to its colour and moisture content.

The goal of this research is to study whether frying temperature and time affect the fat content of French fries in relation to quality aspects such as moisture and colour. The frying conditions have been based on frying principles that are carried out in food service (fast food and catering). In these kind of companies frying is performed in commercial batch fryers. Nowadays, more and more companies apply liquid fat. The French fries used are mainly pre-fried and delivered chilled. However, sometimes frozen French fries are used. Several French fry brands are on the market, which deliver different kinds of French fries. The frying instructions in The Netherlands are 3-4 minutes at 180°C-185°C. In practice, the time of frying is determined on colour development during frying. Using lower frying temperatures will probably lead to longer frying times to reach the same colour.

## 2 Materials and methods

### 2.1 Experimental set-up

The effect of frying temperature and time on the fat content of finish fried product is the main research topic described in this report. Other factors such as liquid or solid fat, frozen or chilled French fries, French fry brand and thawing state of frozen French fries have been studied in less detail. The pre-fried French fries used in this study are described in Table 1. The chilled French fries were purchased at a local wholesaler and the frozen French fries at a local grocery store. All three types of French fries had a recommended frying time of 3-4 minutes at 185°C.

**Table 1:** Types of French fries used in this research

Code	Cut-size	Delivery	Packed
A-chilled	10*10mm	Chilled	2 5kg pouches in 10 kg box
B-chilled	10*10mm	Chilled	2 5kg pouches in 10 kg box
A-frozen	10*10mm	Frozen	1 kg pouch

#### 2.1.1 Time temperature relation.

For the determination of the effect of time and temperature of the frying process, French fries (A-chilled) were fried in liquid palm fat (Rodi) at 140, 160, 175, 180 and 185°C and at 2, 3, 4, 5 and 6 min at each temperature.

#### 2.1.2 Other processing parameters.

The additional process factors described in this report have been studied in less detail. Only a few times and temperatures have been analysed to get an indication of the effect of the factor. The factors that have been studied are:

- Type of fat: Difference between the use of liquid palm fat (Rodi) and solid palm fat (Rodi) for frying chilled (A-chilled) French fries (4 min at 185, 175 and 140°C and 3 min at 185°).
- Brand: Difference between A-chilled French fries and B-chilled French fries fried in liquid palm fat (4 min at 185, 175 and 140°C and 3 min at 185°).
- Frozen or chilled: Difference between A-frozen and A-chilled French fries fried in liquid palm fat (4 min at 185, 175 and 140°C and 3 min at 185°).
- Thawing time: Effect of thawing of frozen French fries (A-frozen) fried in liquid palm fat (4 min at 175 and 185°C after 0, 30, 60 and 90 min thawing at room temperature).

#### 2.1.3 Frying of the French fries

The French fries were fried in a commercial batch fryer (ANBO, 35-litre fryer) in batches of 1 kilogram. The temperature was measured with a PT100 temperature probe and kept stable. The colour was measured. In order to carry out further analyses, the samples were frozen. Thus after frying, the French fries were chilled for 30 minutes at 4°C followed by freezing at -30°C for 30 minutes. After freezing, the samples were stored at -20°C. The samples were analysed, including a non fried sample, on fat content and dry matter.

## 2.2 Determination of fat and moisture content

The fat and moisture content of the prepared French fry samples were determined according a standard method. A frozen sample was thawed followed by grinding in a "Hobart" cutter until the particles were smaller than 0.5 cm. From this material 2 samples of approximately 200 ( $\pm 0.01$ ) grams were taken and pre dried for 15 hours at 60°C. After pre-drying the samples were weight and ground in an ultra centrifugal mill. Different samples of the pre-dried ground material were taken for the determination of the moisture and fat content.

### 2.2.1 Determination of fat content

A sample of approximately 4-5 grams ( $\pm 0.0001$ ) from the pre-dried ground French fries was weight. The oil from the sample was extracted with petroleum ether, using a Soxtec Avanti apparatus (2050 Soxtec, Foss Tecotor), and weight. The fat content of the French fries was calculated from the several weights determined in the experiment.

### 2.2.2 Determination of the moisture content

A sample of approximately 3-4 grams ( $\pm 0.0001$ ) from the pre-dried ground French fries was weight. The sample was dried at 105°C for 3 hours followed by weighing the sample. The moisture content of the French fries was calculated from the several weights determined in the experiment.

## 2.3 Colour

The colour of the French fries was determined with the FCT (Ferguson). The FCT is calibrated with the USDA colour card. With the FCT method 20 French fry rods were put on a bleu plate. The colour is determined by computer image analysis of each individual rod and categorised into '000', '00', '0', '1', '2', '3', '4' (or KLI 0-6). The average value of the sample is determined. The higher the USDA or KLI value the darker the colour of the French fries. French fries with an USDA value of more than '2' (or KLI > 3.5) are considered to dark. USDA values of '0' and '1' are normal values for the French fry colour. Table 2 shows the relation between USDA colour and KLI. In practice the USDA colour card is used for determination of colour of the end product. The KLI (kleurindex) is part of a quality control method for raw potato. In our study we prefer to use this KLI, because of its scale between 0 and 6.

**Table 2:** Relation between the USDA colour card and the KLI value

USDA	KLI
'000'	0-0.5
'00'	0.5-1.5
'0'	1.5-2.5
'1'	2.5-3.5
'2'	3.5-4.5
'3'	4.5-5.5
'4'	5.5-6

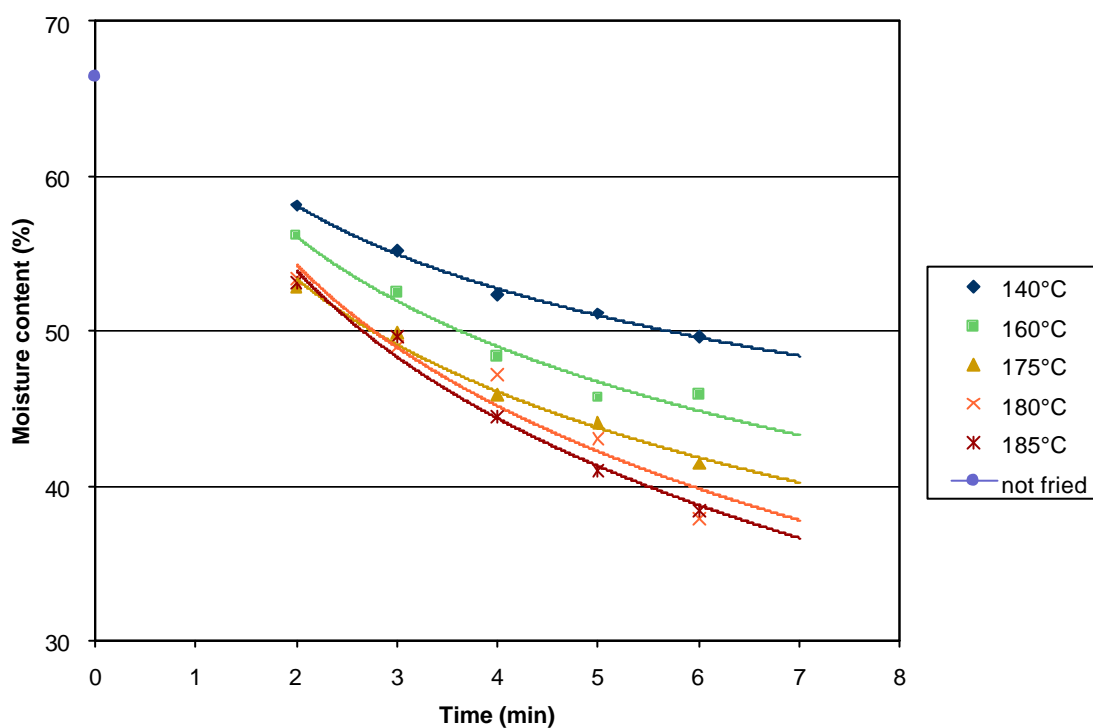
### 3 Results

#### 3.1 Effect of frying time and temperature on French fries.

Pre-fried chilled French fries (A-chilled) were deep-fried at different temperatures for different times. The fat content, moisture content and colour were determined after frying.

##### 3.1.1 Effect of frying time and temperature on the moisture content

Figure 1 demonstrates the effect of frying time and temperature on the moisture content of fried French fries. The general trend reveals that the moisture content decreases with increasing frying time and temperature. However, the effect of time decreases at lower temperatures. This result was expected because higher frying times and temperatures result in more energy available for the evaporation of water out of the French fry rods.

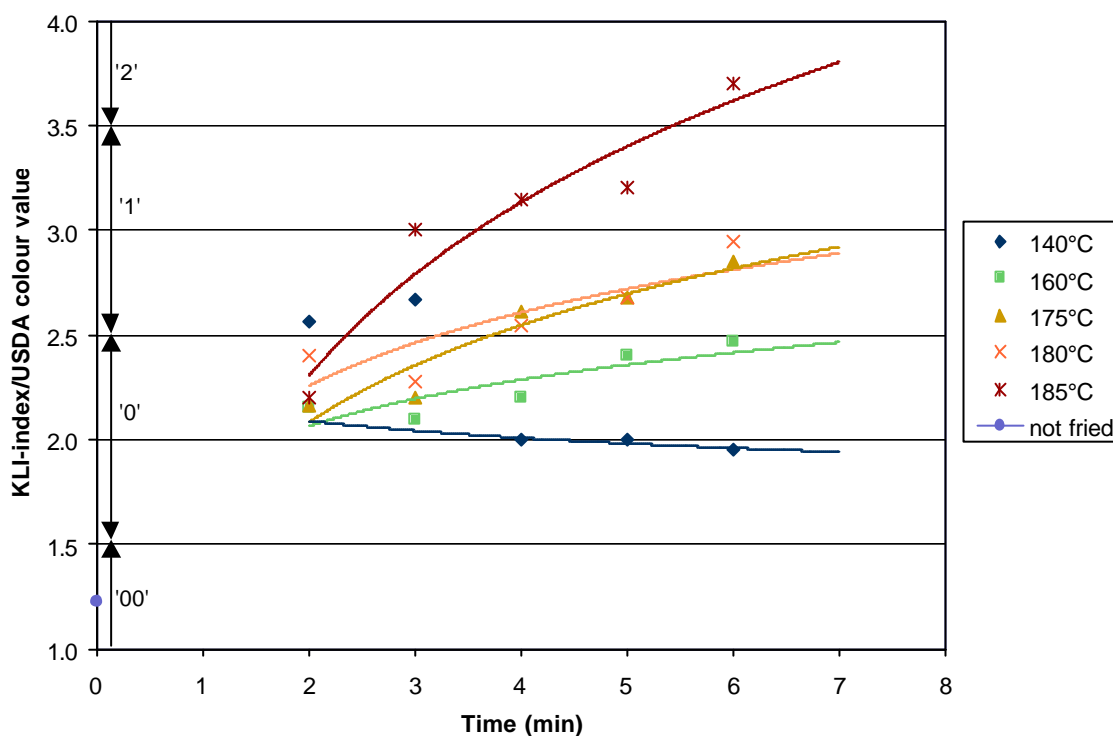


**Figure 1:** Effect of the frying time and temperature on the moisture content of finished-fried French fries (A-chilled).



### 3.1.2 Effect of frying time and temperature on the colour

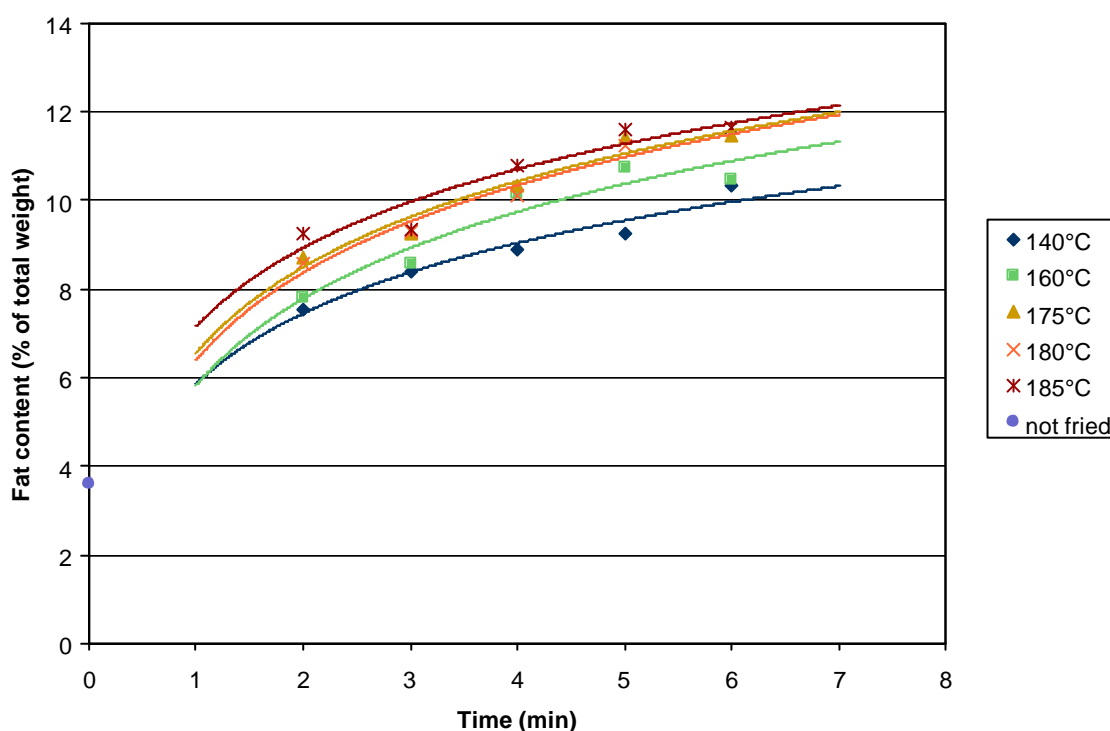
Figure 2 demonstrates the effect of frying time and temperature on the colour of fried French fries. The left side of the Y-axis presents the KLI value and the right side (corresponding with the coloured areas) the USDA French fry colour values. The use of longer frying times and higher frying temperatures leads to a higher KLI index and USDA colour, indicating a darker colour. However, the differences are small. An USDA value of '2' or KLI value above 3.5 is too dark. This occurs after 6 minutes frying at 185°C. The colour values of 140°C at 2 and 3 minutes frying are not in line with the data of further frying. This can be caused by an inhomogeneity of these two samples compared to the other samples. It is also possible that the light in the FCT in combination with the potato tissue colour in these samples result in a higher value.



**Figure 2:** Effect of the frying time and temperature on the colour fried pre-fried chilled French fries.

### 3.1.3 Effect of frying time and temperature on the fat content

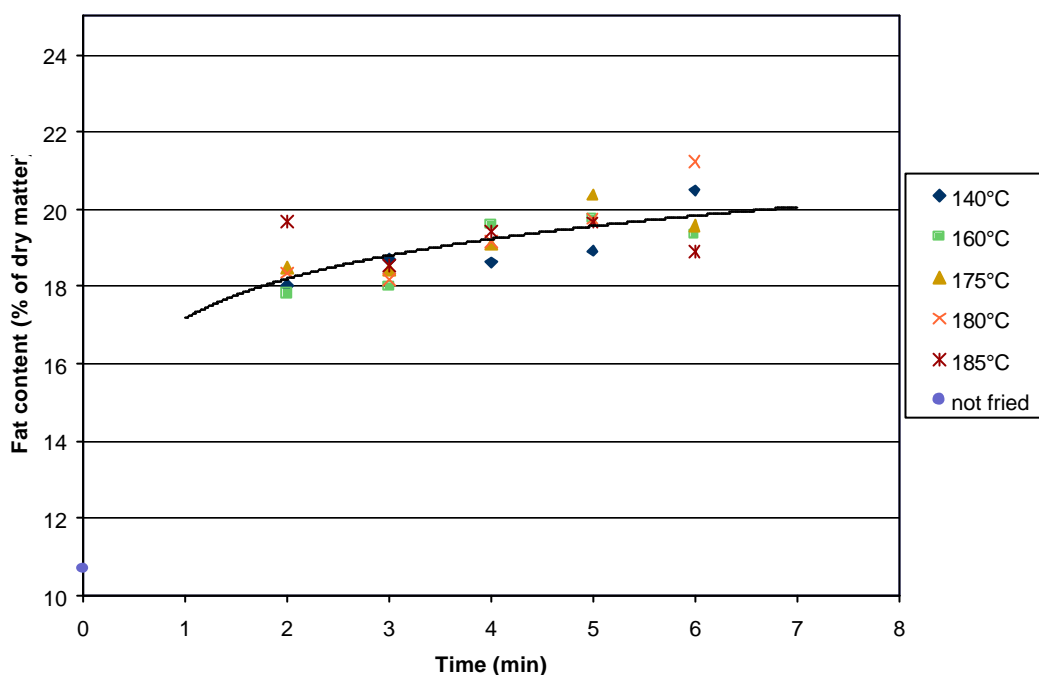
Figure 3 presents the fat content calculated on the total weight of the sample against frying time at varying temperatures. Longer frying times results in higher fat content. Also differences can be observed between the frying temperatures and the fat uptake. Higher temperatures result in higher fat content. However, there is no strong effect observed in fat uptake for the temperatures 175°C, 180°C and 185°C. A temperature of 140°C and the same frying time clearly results in a lower fat content. These results are in line with the findings of Moreira et al. (1999). They described crust formation and its effect on fat content. It could be that the crust formation during pre-frying is not completed and continued during finish-frying. The finish-frying, as studied in this chapter, shows a higher fat content at higher frying temperatures. This could be explained by more crust formation at higher frying temperatures leading to an open structure and thus higher fat absorption.



**Figure 3:** Effect of the frying time and temperature on the fat content calculated on the total weight of fried pre-fried chilled French fries.

Fat content based on the total weight of the French fry does not take into account the difference in weight loss caused by water evaporation during frying. This weight loss results in different moisture contents when using different times and temperatures as presented in Figure 1. To correct for this weight loss due to water evaporation the fat content should be calculated as a percentage of the dry matter base of the French fries. This also results in a better understanding of the amount of fat per rod.

Figure 4 presents the fat content calculated on the dry matter against the frying time at different temperatures. There is a slight increase in fat content when using longer frying time. There is no relation between frying temperature and fat content calculated on the dry matter of the French fries. Application of all the investigated frying temperatures reveal more or less the same behaviour against frying time. This indicates that the moisture content determines the fat content. The fat content calculated on the dry matter is only determined by the frying time. In food service and at domestic cooking, it is common practice that frying time is mainly determined by evaluation of colour development in the sample. A sample that will be fried at 140°C has to be fried for a longer time than frying at 185°C. The effect of frying conditions on the fat content in relation to moisture content and colour will be discussed in 3.1.4.



**Figure 4.** Effect of the frying time and temperature on the fat content calculated on the dry matter of fried pre-fried chilled French fries.

### 3.1.4 Fat content in relation to the quality of French fries

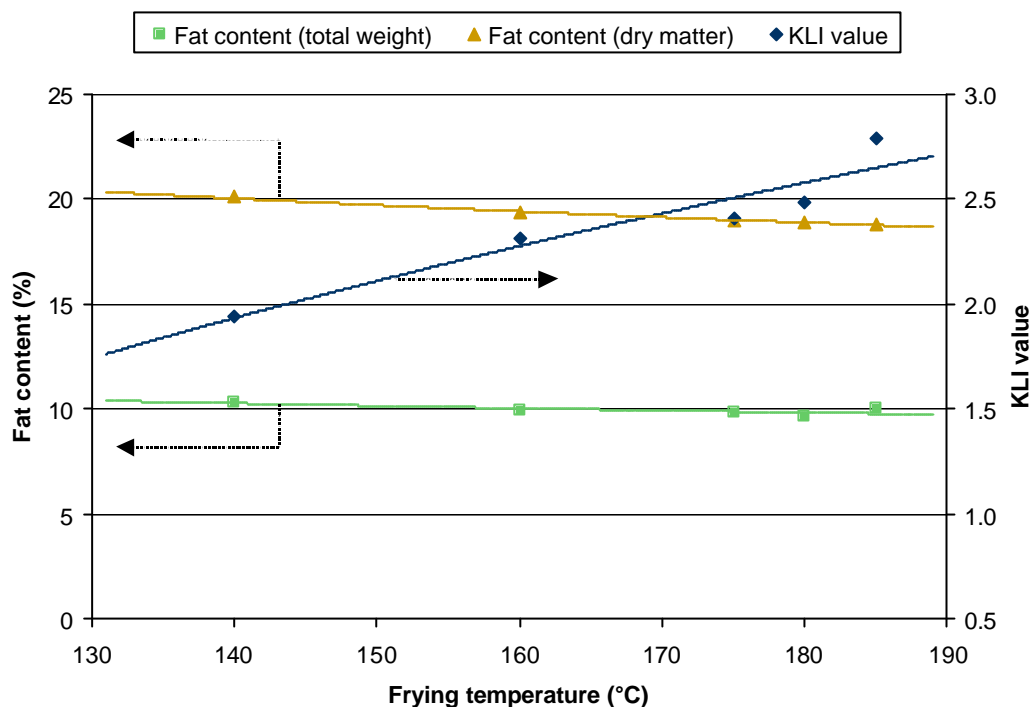
For a good comparison, the fat content of French fries should be related to the quality or appearance of the fries. Therefore, the colour and moisture content should be the same in every sample. To obtain the same moisture content at lower frying temperatures, the frying time has to be increased (according to Figure 1). Evaluating the colour Figure 2 demonstrates that the frying time needed to produce fries of the same colour increases when the temperature decreases. To present the reader a better understanding, the fitted curves of Figures 1 to 4 have been used to estimate the effect of keeping a constant moisture content or colour value on the other properties of the French fries. Frying at 185°C for 3 minutes was taken as a standard. Table 3 presents the frying times needed at different temperatures to get either the same moisture content or the same colour value. These times were used to calculate the fat content, moisture content and colour value.

**Table 3:** Frying times needed for a standard moisture content (48.3%) and colour value (2.8) at different frying temperatures

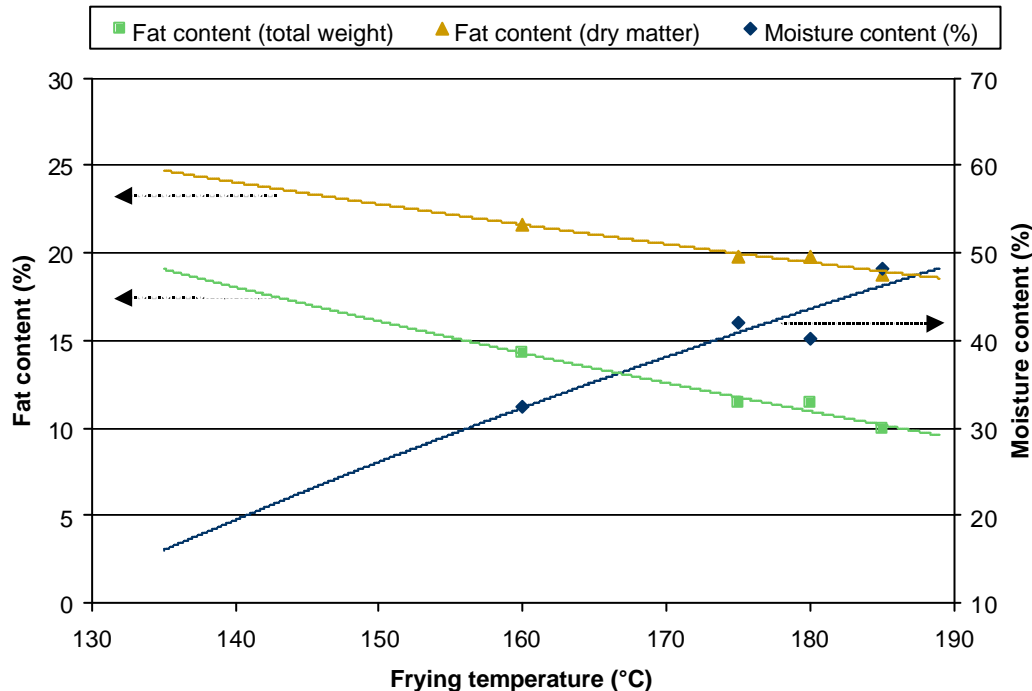
Temp (°C)	Frying time for constant moisture content of 48.3% (min)	Frying time for constant colour value of 2.8 (min)
185	3	3
180	3.14	5.85
175	3.24	5.83
160	4.28	20
140	7	-

The results are presented in Figure 5 and 6. Figure 5 demonstrates the situation for *fixed moisture content* of 48.3%. The frying temperature has a strong influence on the colour; higher temperature leads to darker French fries. The fat content, however, is hardly affected (140°C -> 10.3 % fat ; 185°C -> 9.7% fat).

In Figure 6, the French fry properties have been plotted at *fixed colour value*. It is very clear that the frying temperature affects the fat content when fried until a colour value of 2.8 (160°C -> 14.3 % fat ; 185°C -> 9.7% fat). This is caused by the application of long frying times that are needed to reach this colour value. The times required demonstrate an exponential growth with decreasing frying temperature. Based on this result, it can be concluded that when the French fries are prepared aiming at a specific final colour the application of lower frying temperatures will lead to higher fat content.



**Figure 5:** Calculated fat content and KLI value of French fries at a fixed moisture content of 48.3% fried at different time-temperature combinations.



**Figure 6:** Calculated fat content and moisture content of French fries at a fixed colour value of 2.8 fried at different time-temperature combinations.

### 3.2 Effect of other frying properties on French fries

Other frying related properties and conditions that can influence the fat content of French fries have been investigated in less detail. The properties that have been studied are:

- Liquid or solid fat used for frying
- Chilled or frozen pre-fried French fries
- Brand of French fries
- Effect of thawing time of frozen pre-fried French fries

A couple of frying times and temperatures have been investigated to indicate its effect on the fat content over the whole range. To conclude whether there is a significant difference between the parameters that have been tested a T-test was performed on the data ( $P < 0.05$ ).

#### 3.2.1 Effect of using liquid or solid fat

Both types of fat used were palm fat. One was liquid and the other solid at room temperature. Table 4 presents the results of the experiments done with the two kinds of fat. The fat content calculated on the total weight is significantly higher ( $P < 0.05$ ) when using solid fat for frying instead of liquid fat. The fat content calculated on the dry matter shows the same result. No significant differences can be found in moisture content and colour.

**Table 4:** Properties of chilled French fries (A-chilled) fried in liquid palm fat and solid palm fat

Temp (°C)	Time (min)	A-chilled fried in liquid palm fat				A-chilled fried in solid palm fat			
		Fat (% total)	Fat (% dm)	Moisture (% total)	Colour (KLI)	Fat (% total)	Fat (% dm)	Moisture (% total)	Colour (KLI)
0	0	3.6	10.7	66.4	1.2	3.6	10.7	66.4	1.2
140	4	8.9	18.6	52.3	2.0	9.5	20.3	53.2	2.1
175	4	10.3	19.1	45.9	2.6	10.6	20.0	47.0	2.3
185	4	10.8	19.4	44.5	3.2	11.0	19.6	43.8	3.1
185	3	9.3	18.5	49.6	3.0	9.6	18.9	49.1	2.7

#### 3.2.2 Effect of using chilled or frozen French fries

For this experiment, chilled and frozen French fries of the same brand and cut-size have been used to demonstrate a possible difference between the use of chilled and frozen French fries. Table 5 presents that the frozen French fries contain a significantly higher ( $P < 0.05$ ) fat content than the chilled fried French fries. Complementary, the moisture content of frozen French fries is significantly higher ( $P < 0.05$ ) and the KLI value lower. This implies that longer frying times or higher temperatures are needed to obtain similar moisture content or colour as for chilled French fries. Consequently, the fat uptake increases even more. The initial fat content of pre fried frozen French fries is higher as for the chilled fries. The pre frying of frozen French fries is generally a high temperature short time process (e.g. 180°C; 1 min). Pre frying of chilled French fries however is done at low temperature and for longer time (e.g. 140°C; 4 min). These differences in pre frying conditions correspond with a quicker crust formation and initial higher fat content at higher oil temperatures as described by Moreira et al. (1999).

**Table 5:** Properties of A-chilled and A-frozen French fries fried in liquid palm fat

Temp (°C)	Time (min)	A-chilled fried in liquid palm fat				A-frozen fried in liquid palm fat			
		Fat (% total)	Fat (% dm)	Moisture (% total)	Colour (KLI)	Fat (% total)	Fat (% dm)	Moisture (% total)	Colour (KLI)
0	0	3.6	10.7	66.4	1.2	4.3	14.7	70.6	0.8
140	4	8.9	18.6	52.3	2.0	10.3	24.2	57.5	2.0
175	4	10.3	19.1	45.9	2.6	12.9	25.7	50.0	2.4
185	4	10.8	19.4	44.5	3.2	11.8	23.5	49.9	2.4
185	3	9.3	18.5	49.6	3.0	10.4	22.7	53.9	2.1

### 3.2.3 Effect of brand of French fry

Two brands of pre-fried chilled French fries were finish fried in liquid palm fat. The cut-size was the same for both brands. Table 6 presents the properties of both brands. No significant ( $P < 0.05$ ) difference was found between the fat content calculated on the total weight of the two brands. The fat content calculated on the dry matter however was significantly higher ( $P < 0.05$ ) of the B-chilled French fries. The moisture content of the A-chilled French fries is lower and the colour index shows no difference. If the B-chilled properties are adjusted to the A-chilled French fries longer frying times are necessary. This implies that the fat content of the B-chilled will be higher at equal moisture content and colour index. Differences in process conditions and potato kind can explain the observed differences between the properties of the French fries.

**Table 6:** Properties of chilled French fries of brand A and B fried in liquid palm fat

Temp (°C)	Time (min)	A-chilled fried in liquid palm fat				B-chilled fried in liquid palm fat			
		Fat (% total)	Fat (% dm)	Moisture (% total)	Colour (KLI)	Fat (% total)	Fat (% dm)	Moisture (% total)	Colour (KLI)
0	0	3.6	10.7	66.4	1.2	4.3	13.3	67.7	1.3
140	4	8.9	18.6	52.3	2.0	9.0	20.4	55.7	2.0
175	4	10.3	19.1	45.9	2.6	10.1	19.9	46.6	2.4
185	4	10.8	19.4	44.5	3.2	10.3	19.6	47.4	2.6
185	3	9.3	18.5	49.6	3.0	9.5	19.8	52.1	2.4

### 3.2.4 Effect of thawing time of frozen French fries

To investigate the effect of thawing of deep frozen pre-fried French fries the following procedure was used. The frozen fries have been put as a thin layer in an open box at room temperature. After 0-30-60-90 minutes a 1-kg sample was taken and fried. Table 7 presents the properties of the thawed and fried French fries. The fries fried at 175°C do not demonstrate a change in fat content. The samples fried at 185°C reveal an increasing fat content (total weight) with increasing thawing time. However, this relation is not found if the fat content is calculated on dry matter basis. These results indicate that there is no effect of thawing of the French fries.

**Table 7:** Properties of frozen French fries (A-frozen) after different thawing times

Thawing time (min)	Temp (°C)	Time (min)	A-frozen fried in liquid palm fat			
			Fat (% total)	Fat (% dm)	Moisture (% total)	Colour (KLI)
0	175	4	12.9	25.7	50.0	2.6
30	175	4	12.5	25.2	50.6	2.2
60	175	4	13.2	26.8	50.8	2.2
90	175	4	12.7	25.9	51.0	2.3
0	185	4	11.8	23.5	49.9	3.2
30	185	4	13.0	25.4	49.0	2.4
60	185	4	13.2	25.9	49.2	3.1
90	185	4	13.8	25.5	46.0	2.5



## 4 Conclusions

The frying time and temperature have an effect on the moisture content, colour and fat content of finish fried chilled pre-fried French fries. The experiments that have been carried out lead to the following conclusions:

- The moisture content of the French fries decreases with increasing frying time and temperature.
- The colour index of the French fries increases (the fries become darker) with increasing frying time and temperature.
- The fat content calculated on total weight increases with increasing frying time and temperature.
- The fat content calculated on dry matter increases with increasing frying time, no effect of frying temperature has been found.

Out of the presented results it can be concluded that at constant frying time the fat content is determined by the moisture content. When lower frying temperatures are used longer frying times are necessary to reach the same moisture content or colour value.

- When the fries are fried on final moisture content the effect on the fat content is minor.
- When the fries are fried on a final colour the fat content is largely affected due to great differences in frying time.

It is indicated by basic experiments that other factors in the frying process affect the fat content of French fries. The conclusions presented are only an indication. The experiments that have been carried out lead to the following conclusions (indicative):

- The use of solid fat instead of liquid results in a higher fat content in finish-fried French fries.
- Frozen pre-fried French fries contain a higher fat content after frying than chilled pre-fried French fries. This effect is emphasised by the fact that the quality expressed as the colour and moisture implies that longer frying times are necessary.
- No difference in fat content was found between A-chilled and B-chilled. However, the quality of B-chilled indicated that longer frying times were needed. This will increase the fat content of B-chilled above the fat content of A-chilled.
- No effect of the thawing time of frozen French fries on the fat content was found.

## 5 Recommendations

It is expected that consumers and employees at food service define the frying time by colour development during frying. The results of this study demonstrate that long frying times are required to reach a similar colour at low frying temperature as is the case at higher frying temperature. It has been demonstrated that this will increase the fat content. It is therefore recommended to define a 'French fry colour' at a set frying temperature that corresponds with acceptable values for aspects such as fat content. In this case a better understanding of the relation between colour and the aspects that are of concern is required.

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