

Sensory assessment of stored french fries and crisps fried in sunflower and high oleic sunflower oils

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SUMMARY

Sensory assessment of stored french fries and crisps fried in sunflower and high oleic sunflower oils.

After the elaboration of specific lists of descriptors for crisps and frozen pre-cooked french fries, the sensory profiles allowed to describe these products fried in sunflower, high oleic sunflower and palm/palm based blend oils. The sensory data were analysed by principal component analysis and factorial correspondence analysis.

In the chosen conditions of the trials, the organoleptic quality of four french fries batches is different but stable within the storage period. For the crisps a more or less significant evolution is observed depending on the frying oil type; this modification is mostly described by the fruity and rancid attributes.

KEY-WORDS: *Crisps - French fries - High oleic sunflower oil - Sensory assessment - Storage - Sunflower oil*

1. INTRODUCTION

ITERG has been regularly involved in different research programs on sensory analysis. For the past five years, the first studies using modern methodology assessment have been applied to refined oils (generation of descriptors). Then the panel has been trained to taste margarine and spreads, virgin olive oils (International Olive Oil Council methodology approved by the EC) and animal fats (generation of descriptors).

The skill of ITERG's panel was requested in 1993 for the evaluation of fried products within the context of the European Project AIR1-CT92-0687 «Utilization of Sunflower Oils in Industrial Frying Operations».

Sensory analysis of refined vegetable and frying oils generally deals with oxidation flavors (Raoux, 1992; Raoux and Morin, 1995), frying odors [room-odor test] (Prevot et al., 1990) and quality of the fried products (crisps and french fries).

Published works on sensory analysis of crisps and french fries have related the product taste and texture description to the potato variety (Dreher et al., 1983; True et al., 1983) or to the process (Kintner, 1974; Kintner and Arnold, 1972; Stier, 1970). Other works concerning oil oxidation during frying operations have studied the

stability of soybean and canola oils depending on the number of frying hours, by physico-chemical determinations and overall quality assessment of fried products on a 10-point scale (Warner and Mounts, 1993; Warner et al., 1994). Also physico-chemical characteristics and flavor evolution (five descriptors on 3-point scales) of crisps fried in sunflower, cottonseed and palm oils have been reported (Robertson et al., 1978), results showing that the organoleptic quality degradation is significantly related to an increasing storage time.

The sensory studies of the European Project reported here, have compared Sunflower Oil (SO) and High Oleic Sunflower Oil (HOSO) used in industrial frying operations of crisps and french fries with reference samples prepared in palm olein (PO) or hydrogenated rapeseed/palm oil mixture (RP/REF 1&2). The sensory profile technique was chosen to control the quality of the products during their shelf life. Identification and selection of a list of specific attributes describing precisely the fried products was performed before each storage study. The descriptors were assessed on a continuous scale and data were compared by multivariate analysis.

2. FIRST PART: CRISPS TRIAL

The descriptive quantitative sensory analysis was used to assess the organoleptic quality of the crisps within an eight month period. It is important to state that in France, the shelf life of such products is limited to three months.

This trial had two main objectives: i) to compare the oxidative stability of sunflower oil and high oleic sunflower oil used as frying media. ii) to study the influence of the additive dimethylpolysiloxane (DMPS) on the turn-over of the frying oils. The DMPS is an anti-foaming agent and is also presented as a protective agent of oil baths.

This experiment was based on two productions of crisps: one in 1993 with three groups of products (from May 1993 to January 1994) and the other in 1994/1995 (November 1994 to July 1995).

2.1. Experimental

Operating conditions

a) *Panel*: ITERG's in-house panel composed of ten to twelve members.

b) *Laboratory*: All sessions were performed in ITERG's dedicated sensory laboratory of 10 booths built in agreement with the usual standardized recommendations (ISO 8589, 1988; S.S.H.A., 1990) and equipped with personal terminals («minitel» and sensitive keyboard) connected to a central computer: the answers of the judges are automatically collected, thanks to the French Actis software allowing statistical analysis of data for the usual tests.

Products

a) *Frying oils*: sunflower and high oleic sunflower oils were refined by MEDEOL Cy. The reference, palm oil, was produced by RAISIO Cy.

b) *Crisps*: The industrial production trials were made by RAISIO: **first trial** (1993): Group I, crisps fried in SO and HOSO (oil stability study); Group II, crisps fried in SO and SO with DMPS; Group III, crisps fried in HOSO and HOSO with DMPS (DMPS influence study). In all groups, crisps fried in palm oil (PO) were chosen as a reference. **Second trial** (1994/1995): crisps prepared with SO and PO.

c) *Storage conditions*: as soon as received from RAISIO, the crisps bags were stored in a temperate room (around 20°C), in plastic boxes.

Sensory assessment of crisps

a) *List of descriptors*: ITERG's Documentation Department achieved a rather exhaustive bibliographical study (68 references) in order to draw the inventory of the sensory descriptors generally used for such products [the most significant publications are mentioned at the end of this paper (Bushway et al, 1984; Dreher et al, 1983; Hebash and Fadel, 1994; Kintner, 1974; Kintner and Arnold, 1972; Pokorny, 1989; Robertson et al, 1988; Sevenants and

Krause, 1974; Smith, 1975; Prevot et al, 1990; Stier, 1970; True et al, 1983)]: a list of 20 terms was selected. These terms were proposed to the panelists; the working list of attributes was generated after several sensory sessions and reduced to 11 descriptors describing: **odor**, fruity, rancid; **appearance**, color, greasy aspect; **texture in mouth**, tough, crispy/crusty; **taste**, fruity, rancid, acrid; **after-taste**, salty/burning, oily mouthfeel. For a complete agreement on terminology and methodology, the procedures were repeated until each panelist agreed and could use the different terms easily.

b) *Preparation and monadic presentation of test portions*: five or six selected crisps were presented in individual glass jars covered with a small aluminium sheet. Before evaluation, the jars were kept for one hour in a 50°C regulated oven to help the odor to develop in the headspace; this preparation facilitates the odor perception by the panelists. The sensory analysis of refined oils (Raoux, 1992; Raoux and Morin, 1995) is performed under similar conditions (one hour heated samples at 45°C in «brandy» glasses closed with clock-glass); such a short time of heating has no influence on the quality of the samples. The coded test portions were presented in random order under white light; the temperature of the samples was kept constant during the evaluation, by means of a sample heating device.

c) *Methodology*: the assessment was divided into three steps: 1°) **Odor assessment**: panelists were asked to remove the lid of the sample and take 3 short sniffs. 2°) **Appearance assessment**: after this odor test, they put the crisps into a plate to evaluate the color and greasy aspect. 3°) **Assessment in mouth (texture, taste and after-taste)**: then the judges were asked to place two or three crisps in mouth, to chew them three times and to evaluate the texture, taste and after-taste. Then the judges rinsed their mouth with warm water before testing the following sample. Each attribute intensity was evaluated on a continuous scale from weak to strong.

Table I
Presentation of crisps trials and session schedules

	Crisps	Oils	Session schedules # Weeks of storage from production
1st Trial (May 1993 to January 1994)	Group I Group II Group III	PO, SO, HOSO PO, SO, SO-DMPS PO, HOSO, HOSO-DMPS	3, 7, 11, 17, 22, 27, 35 2, 6, 10, 16, 21, 26, 34 1, 5, 9, 15, 21, 25, 33
2nd Trial (November 1994 to July 1995)		PO, SO	1, 3, 8, 12, 17, 21, 26, 33

d) *Sensory sessions*: the assessments were planned each 5 or 6 weeks during 8 months for the two trials. Table I sums up the session schedules. Depending on the trial and group, the first sensory evaluation began 1,2 or 3 weeks after production. Before each series of sensory tests, the panel was trained once with the crisps under study.

Statistical analysis of data

Multivariate analysis (O'Mahony, 1986; Escofier and Pages, 1990) was used to compare all the sensory data of each trial: **Principal Component Analysis (PCA)** which gives prominence to the correlations between the attributes (first graph: correlation circle) and allows a precise «mapping» of the products (second graph). **Factorial Correspondence Analysis (FCA)** which allows to place the products in relation the others and to the descriptors (one unique mapping graph).

2.2. Results

First trial, crisps of «group I» fried in PO, SO, HOSO

The crisps of this group were tasted on storage weeks 3,7,11,17,22,27 & 35 (from production).

a) *Principal component analysis: Correlation circle of descriptors*: axis 1 describes 44% of total variance. Fruity attributes are opposite to rancid ones (odors and tastes). Axis 2 explains 32% of total variance and is related to the following attributes: color, acrid taste, greasy appearance and tough. **Product «mapping»** (figure 1): sunflower crisps rank on axis 1 according to the storage time and the intensity of rancid attributes (odor and taste). Samples SO3, SO7 and SO11 are fruity, while samples SO17,22,27 and 35 are rancid. High oleic sunflower crisps rank on axis 1 like sunflower products, but with a slower evolution (only samples HOSO27 and HOSO35 are rancid). Palm chips keep a fruity character until 27 storage weeks; beyond, PO35 joins the rancid sunflower samples. On axis 2, high oleic sunflower chips with a slightly darker color, are opposite to lighter sunflower crisps.

b) *Factorial Correspondence Analysis* figure (2): plane 1,2 explains 91% of total variance. Axis 1 (like in PCA test) opposes fruity and rancid attributes (odors and tastes). On axis 2, acrid taste is opposite to the crustiness. The general «mapping» of products is similar to the PCA result. However, FCA reveals that sunflower crisps, SO22, SO27 and SO35 are typically the most oxidized products.

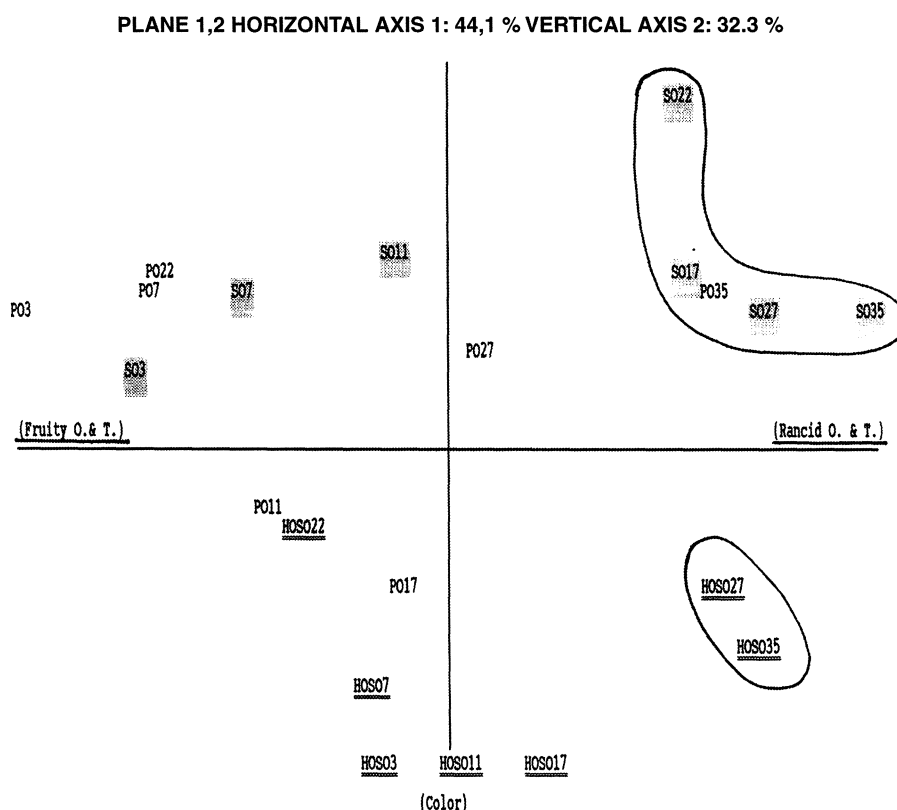


Figure 1

1st Trial, Group I, comparison of relative position of crisps samples during storage-PCA, product «Mapping»

(), explaining attributes for axis «1» and for axis «2»; O, Odor; T, Taste; PO, Frying in palm oil; HOSO, Frying in high oleic sunflower oil; SO, Frying in sunflower oil; 3, 7, 11, 17, 22, 27, 35: # weeks of storage

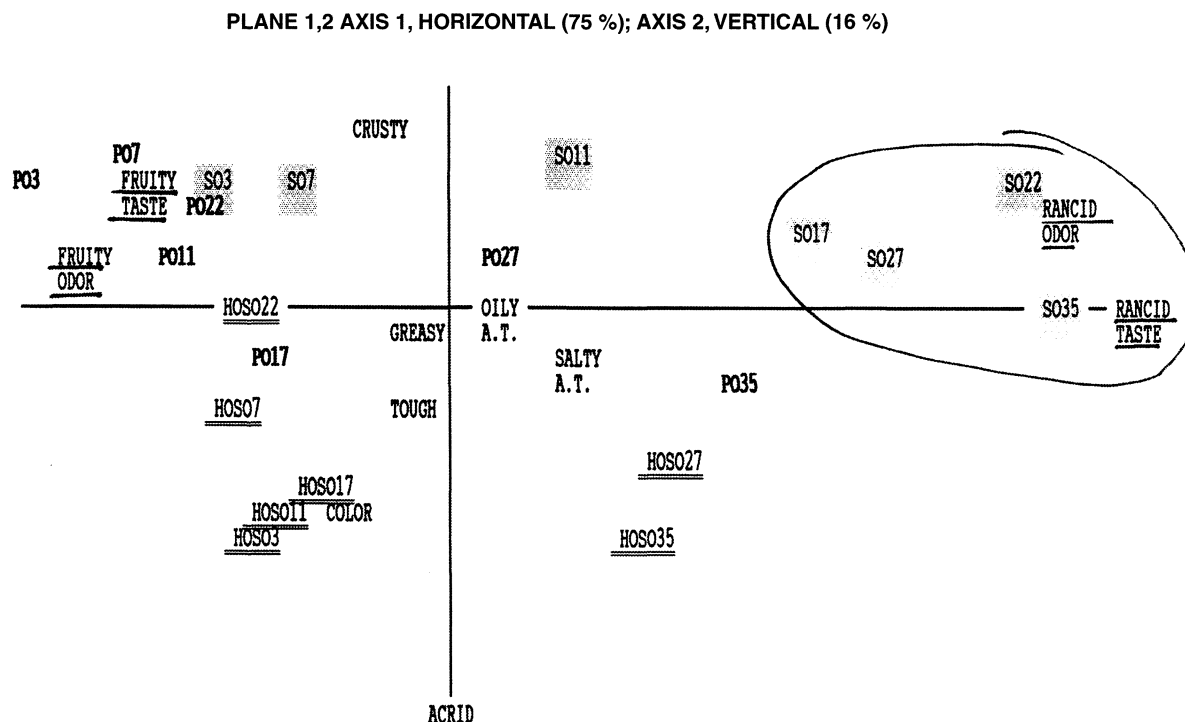


Figure 2

1st Trial, Group I, factorial correspondence analysis on sensory data from production to 35 weeks of storage

PO, Frying in palm oil; HOSO, Frying in high oleic sunflower oil; SO, Frying in sunflower oil; 3, 7, 11, 17, 22, 27, 35, # weeks of storage

Table II sums up the evolution of the fruity and rancid attributes for the three batches of group I. The fruity attributes decrease as the storage time increases; progressively, the rancid taste become predominant, but more or less fast depending on the nature of the frying oil. High oleic sunflower and palm crisps have similar shelf lives: they are still judged fruity by the panel until weeks 22 and 27 respectively. Sunflower crisps are rancid from week 17, with an increasing intensity throughout the storage. At the end of the storage period, they are more rancid than all the other batches (palm and high oleic sunflower products).

First trial, crisps of group II (PO, SO, SODMPS) and III (PO, HOSO, HOSODMPS)

Group II crisps were tasted on storage weeks 2,6,10,16,21,26 & 34 and group III samples on weeks 1,5,9,15,21,25 & 31 (from production). As in group I, the sensory data have been compared by PCA and FCA.

As in group I, a significant evolution for fruity and rancid attributes is observed (table II).

a) *Group II*: the sunflower with DMPS crisps tend to oxidise faster than the batches of sunflower without DMPS; thus the addition of DMPS in the oil baths seems to have a rather negative effect on the crisps quality. Palm chips show a similar behaviour in group I and II. However it may be noted that the group II sunflower products resist better to oxidation than those of group I (group II, rancid from week 26; group I, rancid from week

17). These differences may be correlated to the potato quality: RAISIO stated that the germinative process had begun before the crisps production. The different salt contents of the batches could also explain these differences; group I and II PCA show the redundancy of the rancid taste and salty after-taste.

b) *Group III*: The global evolution of high oleic sunflower crisps without DMPS (group I) or with the additive (group III) is similar. However, within group III, samples without DMPS become rancid slightly faster: HOSO 15,21,25 and 33 are judged rancid, when HOSODMPS 15 and 21 are still fruity. Palm chips behave as in groups I and II, only PO33 is weakly rancid.

The effect of DMPS does not appear very clearly; only two trials do not allow to conclude on this matter.

Second trial

MEDEOL and RAISIO have asked for a second trial in order to confirm the sunflower crisps results previously described: sunflower chips became rancid from week 17 in group I, and only from week 26 in group II. It has to be noted that palm products behave similarly in all groups. In order to clarify this difference between the two groups for sunflower samples, another trial was set up at the end of 1994. As high oleic sunflower oil was no more available, it was decided to compare sunflower crisps and palm crisps. The assessments were planned on 8 different storage times: 1,3,8,12,17,21,26 and 33 weeks from production.

Table II
Organoleptic quality of crisps samples during storage from PCA & FCA.

FIRST CRISPS TRIAL, GROUP I			
	PALM OIL (PO)	SUNFLOWER OIL (SO)	HIGH OLEIC SUNFLOWER OIL (HOSO)
Fruity Samples	PO3, PO7, PO11, PO17 PO22, PO27	SO3, SO7, SO11	HOSO3, HOSO7, HOSO11, HOSO17, HOSO22
Rancid Samples	PO35	SO17, SO22, SO27, SO35	HOSO27, HOSO35
FIRST CRISPS TRIAL, GROUP II			
	PALM OIL (PO)	SUNFLOWER OIL (SO)	SUNFLOWER OIL WITH DMPS (SO-DMPS)
Fruity Samples	PO2, PO6, PO10, PO16, PO21, PO26	SO2, SO6, SO10, SO16 SO21	SO-DMPS2, SO-DMPS6, SO-DMPS10
Rancid Samples	PO34	SO26, SO34	SO-DMPS16, SO-DMPS21, SO-DMPS26, SO-DMPS34
FIRST CRISPS TRIAL, GROUP III			
	PALM OIL (PO)	HIGH OLEIC SUNFLOWER OIL (HOSO)	HIGH OLEIC SUNFLOWER OIL WITH DMPS (HOSO-DMPS)
Fruity Samples	PO1, PO5, PO9, PO15, PO21, PO25	HOSO1, HOSO5, HOSO9,	HOSO-DMPS1, HOSO-DMPS5, HOSO-DMPS9, HOSO-DMPS15, HOSO-DMPS21,
Rancid Samples	PO33	HOSO15, HOSO21, HOSO25, HOSO33	HOSO-DMPS25, HOSO-DMPS33
SECOND CRISPS TRIAL			
	PALM OIL (PO)	SUNFLOWER OIL (SO)	
Fruity Samples	PO1, PO3, PO8, PO12, PO17, PO21, PO26	SO1, SO3, SO8, SO12,	
Rancid Samples	PO33	SO17, SO21, SO26, SO33	

[Numbers stand for weeks of storage]

PCA (figure 3) and FCA (figure 4) results are close to those of the first trial. During the storage, the palm crisps part from the sunflower samples, in keeping a fruity flavor until a 33 week period. The oxidation of the sunflower crisps begins, as in the first trial/group I, at week 17; yet, the intensity of the corresponding rancid attribute is weaker within the 17th and the 26th week, and then reaches a similar level. **This second trial**

confirms a minimum 4 month shelf life for sunflower crisps.

2.3. Conclusion

For the two trials and all crisps samples the results obtained from PCA and FCA are complementary and lead to the following conclusions:

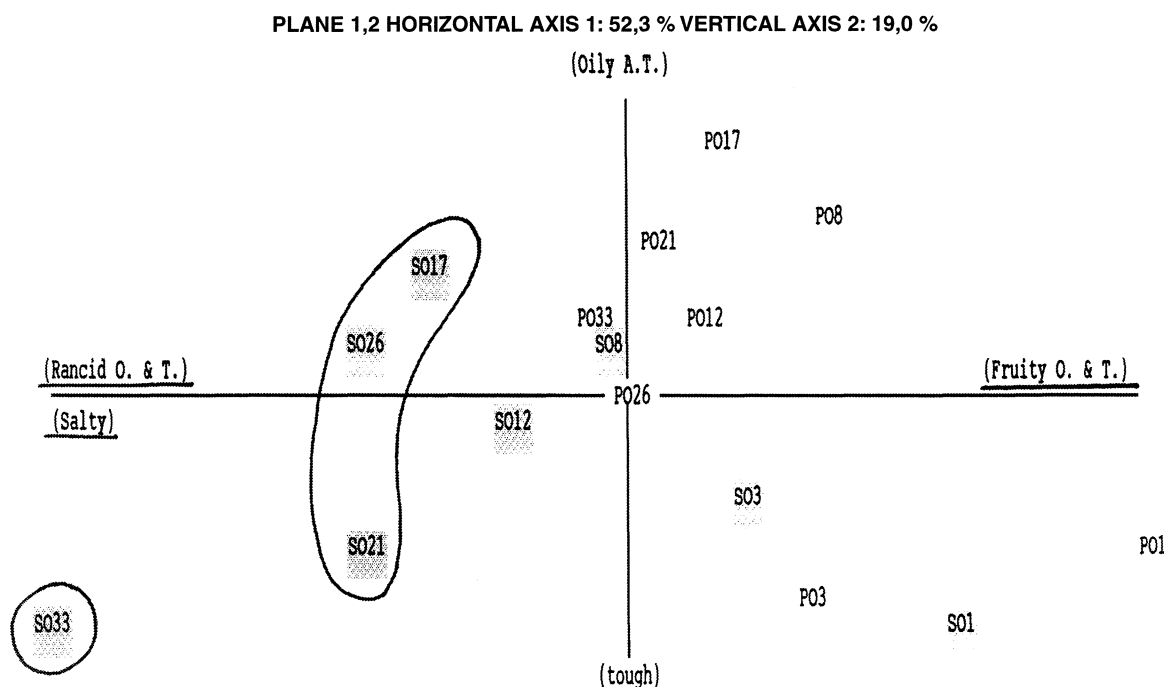


Figure 3

2nd Trial, comparison of relative position of crisps samples during storage - PCA, product «Mapping»
 (), explaining attributes for axis «1» and for axis «2»; O, odor; G, taste; AT, after-taste; PO, Frying in palm oil; SO, Frying in sunflower oil; 1, 3, 8, 12, 17, 21, 26, 33; # weeks of storage

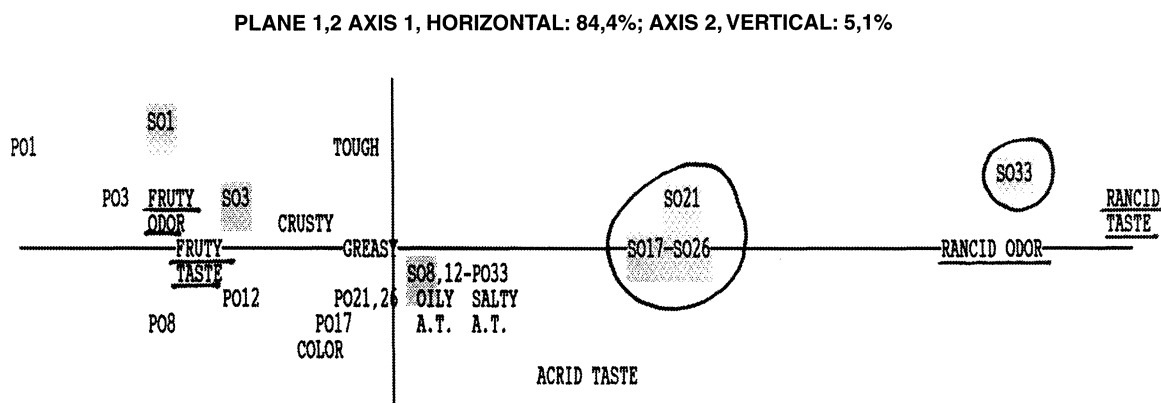


Figure 4

2nd trial, factorial correspondence analysis on sensory data from production to 33 weeks of storage

SO Sunflower oil; PO, Palm oil; 1, 3, 8, 12, 17, 21, 26, 33; # weeks of storage from production

1°) Among the 11 selected terms, the «fruity» and «rancid» characters are the best descriptors of the crisps evolution within the considered storage period (8 months). As the storage time goes on, the fruity odor and taste decrease when the rancid attributes (odor and taste) increase.

2°) **Oxidative stability of the oils:** the crisps fried in high oleic sunflower and palm oils have a rather similar shelf life: the fruity characters (odor and taste) are predominant until weeks 22 and 27 in the first trial

and longer in the second trial (palm oil). Sunflower crisps are distinctly rancid from week 17 (4 months) **that is beyond the 3 month legal shelf life of such products in France**. Because of this rancidity, it is possible to conclude that, at the end of the storage time, these chips are the most oxidised products.

3°) **Effect of DMPS addition:** if negative for sunflower crisps (group II), it appears positive for high oleic sunflower crisps (group III). From these observed opposite effects, the DMPS action seems uncertain.

Table III
French fries cooking method

Preheating of ovens at 180°C, 30 min			
OVEN A 1 st sample to be tasted	OVEN B 2 nd sample to be tasted	OVEN C 3 rd sample to be tasted	OVEN D 4 th sample to be tasted
Beginning of cooking : 9h50		Beginning of cooking : 9h55	
1 st Turn over (*) : 9h56			
2 nd Turn over (*) : 9h59			
3 rd Turn over (*) : 10h02		1 st Turn over (*) : 10h01	
End of cooking : 10h06 (**)		2 nd Turn over (*) : 10h04	
Assessment of 1 st sample : 10h07		3 rd Turn over (*) : 10h07	
Assessment of 2 nd sample: 10h11		End of cooking : 10h11(**)	
		Assessment of 3 rd sample: 10h15	
		Assessment of 4 th sample: 10h19	

(*) The french fries are turned over three times in the oven for an homogeneous cooking

(**) Open oven «A» for cooling, settle the thermostat on 100°C and keep french fries in oven until the assessment

3. SECOND PART: FRENCH FRIES TRIAL

This trial refers to the second part of the European Program. The aim of the study was the stability control of frozen pre-cooked french fries in relation to storage time and nature of frying oils. The whole experiment lasted 19 months to comply with the shelf life of the commercial products, which is two years in France.

3. 1. Experimental

Operating conditions

Same as for the crisps trial.

Products

a) *Frying oils and batches of french fries*: it was decided to manufacture four batches (one a week): two reference batches (REF1 & REF2) in a blend of hydrogenated rapeseed oil and palm oil, and in between, the batches in sunflower (SO) and high oleic sunflower (HOSO) oils. As RAISIO needed one week to produce one batch, the total production was made in four weeks. In order to verify if this delay would have any influence on the stability and on the sensory tests,

reference REF1 was first manufactured and reference REF2 was produced at the end of the series.

b) *Potatoes*: the «RECORD» variety was used for REF1, but the other batches were made with the «SABINA» variety.

c) *Quality on delivery*: the products were sent by plane from Finland to ITERG - Bordeaux, France. For different reasons (48 hour non-refrigerated transport, opening of the parcels by the Customs, packing with a too small quantity of dry ice – 2 kg for 100 kg of product –) they arrived totally defrosted. The data interpretation in the long-term will have to take this parameter into account.

Sensory assessment

a) *Specific list of descriptors*: Before assessing the french fries of the Program, the panel needed to elaborate a specific list of descriptors applying for these products (Barthelemy, 1990; ISO 11035, 1995; ISO/CD 13299, 1994).

The main steps of this work are summarized below:

First ten batches of french fries were selected in order to detect all qualitative differences and to generate as many terms as possible to describe the product: i) Two batches manufactured by RAISIO 7

and 18 months before and cooked in a blend of hydrogenated rapeseed oil and palm oil (storage at -18°C). ii) Eight different products available on the French market: depending on the brand, the precooking oil was either sunflower or hydrogenated palm or hydrogenated rapeseed or a blend of these two hydrogenated oils.

Remark: The shelf life of frozen pre-cooked french fries being 2 years in France, it is very difficult to find on the market some samples with such a long storage time or even around one year of age. Moreover, it is of course impossible to accelerate artificially the aging of frozen products.

In the second step, the assessors were asked to generate the maximum number of terms to describe these products. The 10 products were presented to the panel in three group sessions. The judges identified 67 terms to describe odor, texture by touch, consistency in mouth, taste and after-taste.

In the third step, two successive reductions of the number of descriptors were made for each group of terms. In the first reduction all the list was submitted to the panel. Hedonistic intensity and intrinsic describing terms were rejected, as for the terms proposed by only one judge and not confirmed by the others. The judges and panel organizer experience allowed some synonymous terms to be grouped.

A reduced list of 21 terms was established:

- ODOR: Global intensity, potato fruity, frying and bakery (pastry, bread).
- APPEARANCE: Heterogeneous color, surface appearance (matt, shiny), yellow color (pale, dark).
- TEXTURE BY TOUCH: Greasy.
- CONSISTENCY IN MOUTH: Hardness, elasticity, mealy.
- TASTE: Potato fruity, sweet, bakery, bitter, green potato, over burnt, greasy, rancid, old product.
- AFTER-TASTE: Acid, irritant.

A 21 terms list is still too long for an efficient and precise use by judges who have to taste four products in one session. A second reduction multivariate analysis (PCA) was used to group synonymous descriptors or to eliminate descriptors which hardly contributed to differentiate the french fries:

– **PCA applied to odor descriptors** (4 terms).

Data analysis shows that most information is given by 3 attributes: bakery, potato fruity, frying. The total intensity odor term was cleared out.

– **PCA applied to appearance, texture and consistency in mouth** (7 terms); yellow color, greasy texture by touch, mealy consistency and hardness were the most discriminating terms; all the other terms were thus eliminated.

– **PCA applied to taste and after taste** (10 terms). In spite of the lack of information given by rancid and «old product» attributes, they were maintained and grouped as synonymous terms (as in the crisps study). As previously explained, it is difficult to get some frozen french fries close to the end of their shelf life which could develop these attributes.

– **PCA applied to all attributes** (21 terms). This test correlates bakery odor and taste. The judges preferred to maintain the bakery odor, easier to assess than the bakery taste. Greasy in mouth and greasy by touch are synonymous terms; as for «bakery», the greasy touch was preferred to the impression in mouth.

14 terms constitute the final list of descriptors, dedicated to the frozen pre-cooked french fries: **odor**, potato fruity, bakery, frying; **appearance**, yellow color; **texture by touch**, greasy; **consistency in mouth**, hardness, mealy; **taste**, fruity taste of potato, sweet, bitter, green potato, over burnt, rancid/old product; **after-taste**, acid/irritant.

b) *Training of the panel to the assessment of 4 products:* it began with two test portions, then with four in order to prepare the panel to the real study. Descriptor intensities were at first evaluated on a scale divided into 10 successive values. The judges were then asked to use a continuous scale, more precise for the evaluation of slight differences. The whole training was performed in ten sessions.

c) *French fries cooking method:* As the study refers to the oxidative stability of the pre-cooking fats in the products, it was excluded to add any oil or fat for the cooking. For this reason, an oven cooking mode was chosen; this cooking mode does not induce any modification of the oil concentration or nature; moreover, it gives the products an appearance and texture similar to those obtained by deep-frying. Four household ovens were used on grill position following a precise cooking protocol presented in table III. The frozen french fries were put in one layer on greaseproof paper placed on the oven plate. The conditions were as follows: oven temperature 180°C (precisely measured by temperature captor), cooking time 16 minutes. The fries were turned over three times every 3 minutes, after 6 minute cooking time: this allows products of an homogeneous yellow color to be obtained; however, some fries may be slightly over burnt on the edges. Before 6 minutes of cooking, the fries are too soft and may be mashed when turned over. The cooking method was established in order to present all the test portions in the same conditions to the panel.

d) *Presentation of test portions:* five french fries were presented on aluminium plates; each judge was asked to taste each fry and to assess the whole. A larger sampling number of fries would be too much for one session (4 samplings \times 5 = 20 fries), producing the well known saturation effect in sensory analysis. A less important test portion would not significantly represent the batch.

Table IV
Sensory session schedules for french fries

Storage times	# weeks of storage for reference 1 & 2 (*)		
• Production of french fries (April 1994)	04 (REF1)	00 (REF2) weeks	
• Time 1	11	08	"
• Time 2	17	14	"
• Time 3	26	23	"
• Time 4	34	31	"
• Time 5	43	40	"
• Time 6	51	48	"
• Time 7	60	57	"
• Time 8	77	74	"
• Time 9	83	80	"

(*) Storage times since the production for REF 1 & REF 2 (in between week zero and four, production of HOSO and SO french fries)

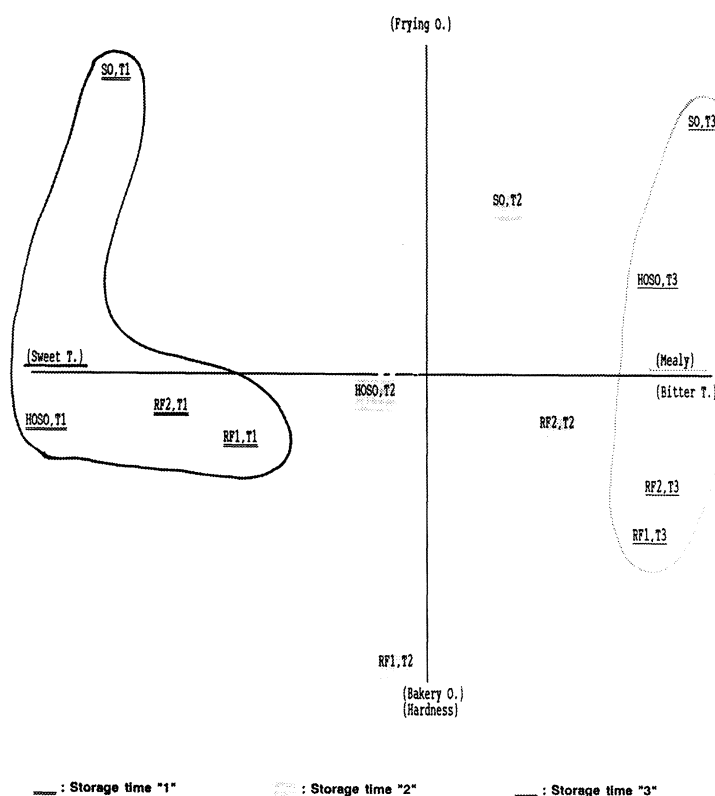


Figure 5

PCA-comparison of relative position of french fries samples from production to 5.5 months of storage (T1, T2, T3)
SO, Sunflower Oil; HOSO, High Oleic Sunflower Oil; RF1 & RF2, Palm oil/hydrogenated rapeseed oil; (), explaining attributes for axis «1» and for axis «2»; O, Odor; T, Taste; AT, After-taste

e) *Sensory sessions*: from May 1994 to December 1995, sensory assessments were set up every 7 or 8 weeks, corresponding to 9 different storage times on a 19 month period. Table IV indicates the storage times for REF1 and REF2, due to their different production

dates. The first assessment was made two months after production.

For each storage time, two training sessions were organized, followed by the four batches evaluation, in two sessions. Profile tests were double because the

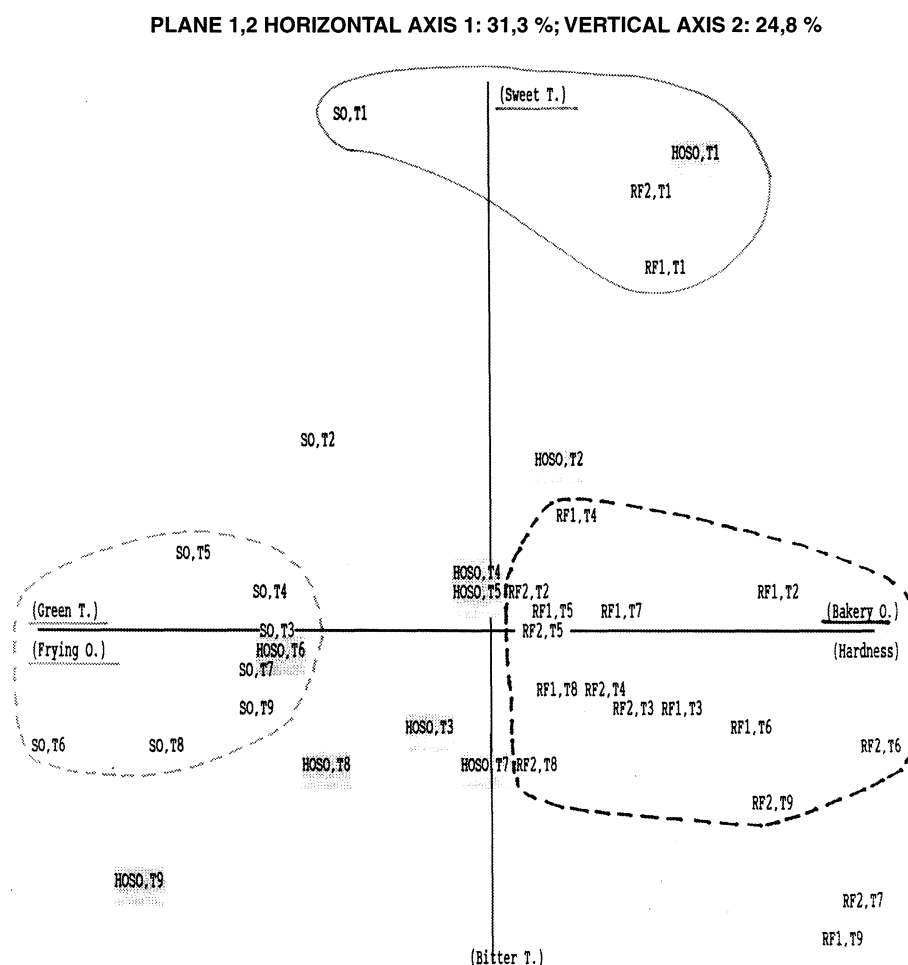


Figure 6

PCA-comparison of relative position of french fries samples from production to 19 months of storage (T1 to T9)

SO, Sunflower Oil; HOSO, High Oleic Sunflower Oil; RF1 & RF2, Palm oil/hydrogenated rapeseed oil; (REF 1&2); () explaining attributes for axis «1» and for axis «2»; O: Odor; T: Taste

french fries are heterogeneous products. During a session, all the judges received the test portions in the same order, but in random order from one session to the other.

Statistical analysis of data

We chose to comment, here, the product «mappings» after the third storage time (5.5 months) and at the end of the storage period, because they show the specific evolutions of the french fries.

3. 2. Results

a) *Sensory evolution of french fries from production to 5.5 month storage period.*

PCA and FCA point out: i) the evolution of two attributes related to the potato, for all samples: a decreasing sweet taste and a growing mealy texture in

mouth (figure 5). ii) An opposition between reference 1 & 2, characterized by a typical «bakery» odor, and the sunflower french fries, recognized by a weak «frying» odor. Figure 5 also shows that high oleic sunflower french fries are close to reference 2 (see the point on potato varieties above).

At this point of the study, no pre-frying oil related sensory difference can be observed between the samples. The detectable differences are only due to the potato quality.

b) Sensory evolution of french fries from production to 19 month storage period.

PCA applied to storage times 1 to 9 (T1 to T9) – **Correlation circle:** the three first axes explain 71.4% of the total variance (axis 1, 31.3%; axis 2, 24.8%; axis 3, 15.3%). i) Axis 1 is negatively correlated to «green potato» taste and «frying» odor; it is positively correlated to «bakery» odor and «hard» texture. ii) Axis 2 opposes «sweet» and «bitter» tastes. iii) Axis 3

stands for color, «over burnt» taste, «frying» odor (negative correlations to the axis) and «mealy» texture (positive correlation).— **Product «mapping»** (figure 6): the batches assessed on storage time 1 (RF1, RF2, HOSO1, SO1) are distinct from all others (T2 to T9), and characterized by an intense «sweet» taste (axis 2) that decreases as early as storage time 2. On axis 1, references (RF1 & RF2, T2 to T9) are opposite to the sunflower samples; in between are located the high oleic sunflower products. The «bakery» odor of references (RF1 & RF2) grouped on axis 1, allows to identify these products apart from the others (HOSO & SO); but this attribute cannot be correlated with product aging.

Sunflower french fries are characterized by «green potato» taste and «frying» odor; but as bakery odor and sweet taste, these descriptors do not evolve during the storage period.

High oleic sunflower samples at storage times 6,8 & 9, are close to the sunflower sample group. For the other HOSO batches (T2, T3, T4, T5 & T7), «bakery» odor, «green potato» taste and «frying» odor are not pertinent attributes.

Axis 3 represents «color» and «over burnt» taste. The apparent differences between samples for these attributes are due to the more or less homogeneous cooking. The position of the products on this axis brings no complementary information on the pre-frying oil related sensory evolution.

It seems quite clear that the different batches have reached a relatively stable position. Thus, it was decided to stop the assessments after 19 months of storage.

FCA results are similar to those of PCA and lead to identical conclusions for the different batches.

3.3. Conclusion

Before sensory assessment, the frozen french fries were cooked in household ovens. In spite of a very precise cooking protocol, an homogeneous cooking is difficult to achieve. This variability inevitably influences the profile tests (color, over burnt and bitter tastes) and consequently the statistical results, particularly the product «mapping». Likewise, such parameters as, potato variety and the cooling chain interruption, may have slightly modified the results of this experimentation.

In spite of these imposed conditions, the sensory data processing by PCA and FCA allows to draw the following conclusions:

I) Parallel to the potato sweet taste decreasing after 3 months of storage, a growing mealy texture in mouth is observed.

II) When considering only the pre-frying oil, the sensory quality of REF1, REF2 and sunflower french fries does not evolve significantly within 19 months. However, these products characterized by specific attributes, form distinct groups: french fries prepared in a blend of hydrogenated rapeseed and palm oils (REF1 & REF2), with their bakery odor, part from the sunflower products, recognized by their slight frying odor and green potato taste.

III) The high oleic sunflower french fries do not develop typical flavors during approximately one year of storage; afterwards, they tend to be close to the sunflower products.

In France, these products have a 2 year shelf life. After a 19 month storage period, no pre-frying oil related sensory evolution can be observed. The detectable differences seem mainly due to the oil type or to the potato quality.

4. GENERAL CONCLUSION

This study on crisps and frozen pre-cooked french fries fried in sunflower, high oleic sunflower and palm/palm-based blend oils, shows a different behaviour of these two fried products during their shelf life:

– For the french fries, the organoleptic quality is fairly stable whatever the pre-frying oils may be. However, some specific descriptors allow to discriminate the products according to the oil type.

– For the crisps, the sensory quality evolves significantly: fruity at the beginning, they become rancid as the storage time goes on. This evolution is all the more rapid and intense since the batches are fried in sunflower oil. The shelf lives of crisps prepared in high oleic sunflower and palm oils are very close, and twice as long as the products fried in sunflower oil which is four month long (recall: the legal shelf life of these products in France is 3 months).

– Furthermore, from the point of view of sensory analysis, the addition of dimethylpolysiloxane in the frying oil bath has no determining effect on the crisps quality.

REFERENCES

- Barthelemy, J. (1990).— «Evaluation d'une grandeur sensorielle complexe: description quantifiée; Evaluation sensorielle, manuel méthodologique».— Tec. & Doc. Lavoisier, Paris 144–158.
- Bushway, A.A., True, R.H., Work, T.M. and Bushway, R.J. (1984).— «A comparison of chemical and physical methods for treating french fries to produce an acceptable microwaved product».— *American Potato Journal* **61** (1) 31–40.
- Dreher, M., Johansen, R., Orr, P., Farnsworth, B., Berglund, P. and Jahner, D. (1983).— «Sensory evaluation of french fries

- rom advanced selections at North Dakota State University».- North Dakota Farm Research **41** (3) 20-22.
- Escofier, B. and Pages, J. (1990).- «Analyses factorielles simples et multiples - objectifs, méthodes et interprétation».- 2^{ème} éd. Dunod, 1990 p. 274.
- Hebhash, K.A. and Fadel, H.H.M. (1994).- «Changes in oils and potato chips during frying».- Die Nahrung **58**, 278-282.
- ISO 11035 (1995).- «Identification and selection of descriptors for establishing a sensory profile by multidimensional approach».
- ISO 8589. (1988).- «Guidelines for the design of the facilities for sensory analysis».
- ISO/CD 13299 (1994).- «General guidance for establishing a sensory profile».
- Kintner, J.A. and Arnold, R.G. (1972).- «Some comparative aspects of the flavour of fabricated and traditional potato chips».- American Chemical Society **164** AGFD 20.
- Kintner, J.A.B. (1974).- «Flavor characteristics of conventional and fabricated potato chips».- Dissertation Abstracts International, B **34** (7) 3291.
- O'Mahony, M. (1986).- «Sensory evaluation of food. Statistical methods and procedures».- Marcel Dekker, Inc., New York 487 p.
- Pokorny, J. (1989).- «Flavor chemistry of deep fat frying in oil» In «Flavor chemistry of lipid foods».- Min, D.B. and Smouse, T.H. (Ed.).- American Oil Chemists'Society, Champaign, Illinois p. 113-155.
- Prevot, A., Perrin, J.L., Laclaverie, G., Auge, P. and Coustille, J.L. (1990).- «A new variety of low linolenic rapeseed oil; characteristics and room-odor tests».- Journal of American Oil Chemists'Society **67** (3) 161-164.
- Raoux, R. and Morin, O. (1995).- «Sensory assessment of oils and fats» In «New trend in lipid and lipoprotein analysis».- Sebedio, J.L. and Perkins, E.G. (Ed.).- American Oil Chemical Society, Champaign, Illinois p. 265-276.
- Raoux, R. (1992).- «Analysis sensorielle des huiles raffinées: manuel des corps gras».- A. Karleskind 1419-1427, Tec. & Doc. Lavoisier, Paris.
- Robertson, J.A., Lyon, B.G., Morrison, W.H. and Miller, J.F. (1988).- «Sensory and chemical evaluation of stored oil-roasted, high oleic nonoil sunflower kernels».- Journal of American Oil Chemists'Society **65** (6) 985-989.
- Robertson, J.A., Morrison, W.H., Lyon, B.J. and Shaw, R.L. (1978).- «Flavor and chemical evaluation of potato chips fried in sunflower, cottonseed and palm oils».- J. Food Sci. **43**, 420- 424.
- S.S.H.A. (1990).- «Evaluation sensorielle manuel méthodologique».- 328 p., Technique & Documentation Lavoisier, Paris.
- Sevenants, M.R. and Krause, C.C. (1974).- «Flavor analysis of formulated potato chips».- American Chemical Society **168** AGFD 3.
- Smith, O. (1975).- «Potato chips» In «Potato processing».- Talburt, W.F. and Smith, O. (Ed.).- Avi Publishing Company Westport, Connecticut p. 305-402.
- Stier, E.F. (1970).- «Texture panel evaluation of potato chips».- Food Technology **24** (1) 46.
- True, R.H., Work, T.M., Bushway, R.J. and Bushway, A.A. (1983).- «Sensory quality of french fries prepared from BelRus and Russet Burbank potatoes».- American Potato Journal **60** (12 Part 1) 933- 937.
- Warner, K., Orr, P., Parrott, L. and Glym, M. (1994).- «Effect of frying oil composition on potato chip stability».- J. Am. Oil Chemists'Soc. **71**, 1117-1125.
- Warner, K. and Mounts, T.L. (1993).- «Frying stability of soybean and canola oils with modified fatty acids compositions».- J. Am. Oil Chemists'Soc. **70**, 983-986.