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Analysis of deterioration of frying oil in commercial restaurants in Chapeco city center, Brazil

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Abstract

This study has aimed to analyze the degree of degradation of frying oil in electric frying pans in commercial restaurants in the Brazilian city of Chapecó, in the state of Santa Catarina. This study was done in all commercial restaurants that serve lunch downtown, registered on the Website of the Hotels, Bars, Restaurants and Similar Businesses Union in the city of Chapecó, a total sample of 15 businesses. The instruments for data collection were a semi-structured questionnaire; the 3M® Cooking Oil Monitor; the FOM 310 Food Oil Monitor and an infrared thermometer. These tools have assessed the degree of free fatty acids, of polar compounds and of temperature. Measurement was performed during production, one day in each restaurant, totaling three days of collection. By means of the results it was possible to notice that from the total samples, 66.66% were above the limit for free fatty acids and 13.3% had levels of polar compounds above the recommended ones for oils and fats for frying, therefore ready for disposal. The quick methods can be an alternative for seeking the ideal moment for disposal, avoiding risks to the health of those who consume fried products and even for health surveillance agencies, that can work together with the business owners by using explanatory flyers so that they can obtain information on the correct use of oils.

Keywords: Oils and fats. Fried food. Free fatty acids. Polar compounds.

Introduction

The frying process, characterized by immersing the food product in hot oil, is a fast and convenient method of food preparation, widely used in homes and widely used by commercial establishments.[1,2]

This process develops characteristics of odor, flavor, color and texture that make food more appealing for consumption.[3,4] However, upon heating the oil in the frying process, a complex series of reactions produce a number of degradation compounds.[5] In the course of the reactions, functional, sensory and nutritional qualities are modified and may reach levels where it is no longer possible to produce quality food.[6,7]

The consumption of fried and parfried food has increased in recent years, leading to a higher intake of fats and oils after being subjected to elevated temperatures in the frying process.[2,4] It appears that this fact has been influenced by social, economic and technical reasons, as people have less time to prepare their food and thus the frying process provides an alternative quick preparation, besides attributing pleasant sensory characteristics to fried food. There is also the proliferation of industries producing fried and parfried products, and this fact has led to the development of both industrial and domestic new equipment for frying (deep fryers), in which large quantities of oil are heated for long periods.[8]

The increasing use of edible oils and fats for the preparation of fried products requires an increasingly strict control in order to maintain the quality and safety of the fried foods. Due to the knowledge that the frying process alters the chemical nature of the heated oil and its consumption represents health risks,[9,10] studies on the assessment of the quality of frying oils, which studies are used by the industry of fried products of immediate consumption, have shown the need for measures to reduce the degree of degradation of oils and fats.[11] In this sense, by seeing that it is a public health problem, many countries have adopted regulations, recommendations and legal standards in order to protect consumers by limiting the use of frying oils and fats for human consumption.[11,12]

In their studies, several authors have sought to identify the compounds formed in the frying oil and the biological importance. Among these publications there is an agreement with respect to the new compounds which are formed. The importance of the volatile compounds, partially eliminated during frying, is closely related to the sensory characteristics of oil and fried products,[10] causing deterioration of flavor, aroma and visual appearance, besides the formation of potentially toxic polymeric compounds.[13,14]

The formation of the degradation compounds such as monomers, dimers, polymers and cyclic compounds with different polarities, with or without oxygen, is of great interest under the physiological and nutritional points of view, since such compounds become part of the diet when they remain dissolved.[1]

Apart from the nutritional aspect, there is an analytical interest, since the content of these compounds, accumulated in the oil since the start of frying, is related to its total change. Among the parameters that measure change in oils and fats used in frying is the percentage of total polar compounds, formed from the triacylglycerides.[15]

Laws and regulations to control the quality of frying oil were adopted by some countries, including Belgium, France, Germany, Switzerland, the Netherlands, the United States and Chile. In Brazil, discontinuous frying processes are widely used both in home preparations as in restaurants and cafeterias. The oil is used in a large number of times with minimum replacement, which may result in high levels of change. However, Brazil does not yet have rules for monitoring and disposal of frying oils. These facts demonstrate the importance of studies to get to know the behavior of oil in discontinuous frying processes and their degree of change.[11]

Therefore, this study aimed to analyze the degree of frying oil degradation in commercial restaurants in the Brazilian city of Chapecó, SC.

Methodology

On the Union of Hotels, Bars, Restaurants and Similar Businesses Website of the city of Chapecó there are 28 registered restaurants. The inclusion criteria used were: be located downtown, serve lunch and use an electric deep fryer. From the initial total of 28 restaurants, 15 (53.57%) were included, which met the proposed prerequisites.

As instruments for data collection were used: a semi-structured questionnaire with open questions (number of meals a day, number of fryers, type of oil used, amount of oil used at each change, frequency of oil disposal and date of last change); the qualitative method of the 3M® Cooking Oil Monitor, which is a paper strip with four numbered blue bands, changing from blue to yellow as the concentration of free fatty acids increases in the frying medium;[14] FOM 310 Food Oil Monitor of the brand Ebro, determining the level of free polar compounds; and the infrared laser thermometer of the brand Brasiterm®. The latter has a temperature range of -50 to 400 °C and a 0.1 °C error range, and the response time of a second. The measurement was performed between 10:30 and 13 hours during the production of meals and done one day in each restaurant, totaling three days of collection.

The study was descriptive, with a quantitative approach, based on field study. The work was based mainly on the analysis of the frying processes and of the degradation of frying oils in electric deep fryers in commercial restaurants in August 2009.

Measurements were made in triplicate, recorded and tabulated at each step, according to the results seen in the 3M® Cooking Oil Monitor, in the Ebro FOM 310 Food Oil Monitor and in the Brasiterm infrared laser thermometer. Data were analyzed using descriptive statistics and the software SPSS version 16.0. For statistical analysis, the significance level was used for Fisher's exact test of $p < 0.05$.

Results and discussion

The rapid growth of various sectors of oil consumption in recent years is due to changes in dietary habits, the result of a combination of profound social, economic and technological changes associated with the large development of the restaurant industry, collective food systems and immediate consumption food.[13,16]

Given that our country does not have laws that determine the rules for reusing frying oils, some restaurant owners use the same oil for long periods.[17]

The acceptance of processed foods by frying is universal and appreciated by different population groups. This method simply consists in introducing the food in a bath of oil or fat which is at an elevated temperature. However, this cooking technique, which seems so simple, is an extraordinarily complex process, in which several factors are involved.[6]

Some of the factors involved depend on the process itself, such as the type of equipment used, the temperature, time and the cooking method. Others, extrinsic to this, relate to the type of oil used, its composition, surface/volume ratio, physicochemical characteristics, presence of additives, contaminants, etc., as well as the nature of the food, weight/volume, type of preparation: breaded, pre-fried.[18,19]

Table 1 summarizes the characteristics related to the number of meals in restaurants, the number of fryers, the quantity of oil used at every change and/or replacement, frequency of disposal of the oil and when the last oil change has occurred.

Table 1. Sample characterization of commercial restaurants in downtown Chapecó, SC, 2009.

	Number of samples	Average value	Median	Minimum value	Maximum value	Standard deviation
Number of meals (day)	15	91.13	90.00	12	160	41.092
Number of electric deep fryers	15	1.07	1.00	1	2	0.258
Oil quantity (liters) used at each change	15	21.25	18.00	4	60	15.407
Disposal frequency (days)	15	11.47	10.00	7	20	4.406
Last change (days)	15	5.80	5.00	3	14	2.757

According to this table, it as possible to see, by means of the semi-structured questionnaire, that the average number of meals from the restaurants analyzed was 91.13 meals/day, where 93.3% (n = 14) had only one fryer. Regarding the type of fat or oil used for frying, 93.3% (n = 14) have reported soybean oil as the most used, and 6.7% (n = 1) the hydrogenated vegetable fat specific for frying. In 73.3% (n = 11) of the fryers there was the addition of water and salt as for guidance from a specific manufacturer. As for the amount of oil used in each change and/or replacement, it was found that the average was 21.2 liters. It was also possible to observe the discard rate of this oil, in which 40% (n = 6) reported disposing the oil at 15 days of use; 40% (n = 6) in seven days; 13.3% (n = 2) in ten days; and 6.7% (n = 1) in 20 days. The last oil change was 53.3% (n = 8) in five days or less, and 46.7% (n = 7) in more than five days.

Changes in (animal and plant) oils and fats and products that contain them are due mainly to chemical and/or enzymatic processes, and such changes can be sensorially detected or perceived already in early stages. Biochemical processes depend on humidity, enzymatic activity and the presence of micro-organisms, while chemical processes, called autoxidation and photo-oxidation, occur by means of oxygen intervention.[20]

Assessing the change and identifying the compounds formed during frying food are of great value, not only for researchers but also for consumers, the food industry and health inspection services.[10,21] The paths used to determine when an oil has reached the point of disposal are not simple. Many different foods are fried in different types of oil, in various types of fryers and operating scenarios. The combination of all these variables is what determines the rate at which degradation reactions occur.[7]

Table 2 shows the different results of measurements taken with each of the instruments used to analyze the oil quality.

Table 2. Index of polar compounds, free fatty acids and temperatures of frying oils in commercial restaurants in downtown Chapecó, SC, 2009.

Restaurant	3M® Cooking Oil Monitor		Laser thermometer	FOM 310 Food Oil Monitor	
	A.G.L.* (%)	Number of bands****	Temperature (°C)	CP** (%)	Temperature (°C)
1	3.5	2	129.76	12	149.46
2	5.5	3	155.6	17	175.4
3	3.5	2	185.0	10.83	172.46
4	5.5	3	180.13	25.83	172.9
5	2.0	1	156.56	14.16	147.53
6	3.5	2	176.7	19	197.76
7	5.5	3	182.48	27.33	176.63
8	2.0	1	160.06	8.66	150.7
9	2.0	1	117.56	11	109.76
10	3.5	2	187.2	19.5	187.63
11	3.5	2	150.0	13	180.83
12	2.0	1	152.1	14.66	172.13
13	3.5	2	160.7	14	150.3
14	5.5	3	147.4	8.16	148.53
15***	0	0	165.13	0	156.13

* Free fatty acids; ** Polar compounds; *** Only one that has used special vegetable fat for frying; ****Caption: 3M® Cooking Oil Monitor:

– 1 yellow band (2%) – Fat began to break;

– 2 yellow bands (3.5%) – The fat is discarded if the quality (color/flavor/texture) of the fried food is not acceptable;

– 3 yellow bands (5.5%) – The fat is discarded if the quality (color/flavor/texture) of the fried food is not acceptable;

– 4 yellow bands (7%) – Fat disposal is recommended.

Among the methods for analyzing the breakdown percentage of fats used in food preparation, one is the 3M® Cooking Oil Monitor, which analyzes according to the number of reagent bands.[14]

It was possible to see, by means of this tool that measures the level of degradation of fat in electric deep fryer, that from the assessed restaurants, 6.6% (n = 1) had no saturation, that is, no band was observed indicating some level of degradation. In 26.7% (n = 4), fat had begun to decompose, generating a yellow band. At the highest level found, with 40% (n = 6), the fat should be discarded if the quality (color/flavor/texture) of the fried food (chicken, fish, etc.) were not acceptable, which corresponds to two yellow bands. It could also be seen that in 26.7% (n = 4), fat should be discarded if the quality (color/flavor/texture) of the fried food (chicken, fish, etc.) were not acceptable, corresponding to three yellow bands. Regarding the recommendation for disposal of the fat from all the food products, which would be assessed by four yellow bands, this was not seen in any assessment. It is evident that this recommendation refers to what the manufacturer recommends, according to its manual.

Therefore, it is observed that in 33.33% (n = 5) of the restaurants, up to a yellow band was found, corresponding to 2% saturation, and in 66.66% (n = 10), up to three yellow bands, indicating 5.5% saturation.

It is important to note that the 3M® Cooking Oil Monitor associates fat degradation to the concentration of free fatty acids. Often, low concentrations of free fatty acids may mean that the oil is in an advanced state of degradation and that fatty acids that may have formed at an early stage of fat breakdown by hydrolysis may have already been oxidized in later stages, with oil reuse.[22]

It is known that, with increases in the number of fried foods, the hydrolysis of oil can increase, due to high temperature and moisture exchange from the food to the frying medium, with consequent increase in the content of the free fatty acids.[22]

Lopes et. al.[1] report that some countries set maximum percentage limits of free fatty acids, which are around 1-2.5%, for levels above 2.5% generally provide low quality products. Taking into account these ceilings, it may be seen by this study that of the 15 restaurants assessed, 66.66% (n = 10) were at levels above the recommended for free fatty acids, and 33.33% (n = 5) had not exceeded the limits, confirming the results obtained by the manufacturer's recommendation.

Lopes & Jorge compare rapid tests used to assess the quality of oils and fat in fryers and, of the 58 samples examined, 15.5% had free fatty acids in amounts exceeding the limits established by international laws – lower values than those found in this study. They have also found that 75.9% of the tests using the 3M® Cooking Oil Monitorpresented correct results.[16]

In a study carried out in the Brazilian state of Rio Grande do Sul with 62 restaurants, only five were using the indicative strip to determine when to discard oil; most would determine based only on sensory characteristics.[23]

In the study by Masson *et al*.,[24] a wide variation in levels of degradation compounds found in the samples was observed, especially their heterogeneousness and the randomness with which they were collected, therefore differing in many variables of the process, more specifically by the variety of fried products and the time of use of the oils. In their studies, they have associated the low degradation found to the amount of oil incorporated into the product during frying, which has led to a higher fresh oil replenishment rate which, in turn, has helped to reduce oil degradation. Del Ré and associates add that the oil quality is improved only momentarily.[25]

Jorge and Soares[2] mention that the free fatty acids, during their degradation, can form volatile compounds and be lost by means of vaporization. Furthermore, this analysis depends on the type of oil used and the form of frying. However, the assessment of free fatty acids is very important to understand the degradation of cooking oil.

For the assessment of the deterioration by means of the Ebro FOM 310 Food Oil Monitor, the percentage of polar compounds that indicate their degradation is observed. Percentages between 0% and 18.5% are not noticeable in the device, indicating no need for oil change; from 19% to 24%, the oil is in the critical measure of its use, and percentages above 24% require the oil disposal (data suggested by the manufacturer).

The determination of total polar compounds has been reported by many authors as one of the best methods for classifying the state of change of the frying oil. This method, in most cases, is what provides the most reliable measure in the decay process.[26] The content of the polar compounds constitutes the most significant determination in analyses of frying oils and fats, as it indicates the total amount of alteration products originated as a result of the process, representing the base of the existing legal restrictions in many countries, established in around 25%. [27,28]

From this, it was observed that 73.33% (n = 11) of the restaurants were using oil without any visible change to the device; 13.33% (n = 2) were using it in the critical measure of its use; and 13.33% (n = 2) were using oils that exceeded 25% of free polar compounds.

Cella *et al*.[29] have studied the behavior of refined soybean oil during frying of vegetables at temperatures of 170 to 180 °C with periodic addition of fresh oil. The maximum values of total polar compounds remained between 18 and 21% for more than 30 hours. As for the study by Tavares *et al*.,[30] from a total of 50 samples analyzed, 20 (40%) had exceeded the maximum limit of 25%.

A factor influencing these results, according to some authors, is the high replenishment of fresh oil, i.e., frequent turnover of new oil added due to the oil absorption by fried foods, preventing the level of 25% polar compounds to be reached.[2,17] This was observed in all the restaurants studied.

A study carried out by Corsini et al.[10] has shown an average value of 15.17% of total polar compounds for cottonseed oil. Similar results were found by Del Ré & Jorge[31] when studying the behavior of polyunsaturated vegetable oils in discontinuous frying of frozen pre-fried products, in which they have observed increased values of polar compounds over the frying time.

Similar results were also found by Damy and Jorge[32] when studying the behavior of soybean oil and hydrogenated vegetable oil during the discontinuous frying process of potato chips. They have observed increased amounts of polar compounds over the frying time. They have also observed that soybean oil has shown higher changes when comparing to hydrogenated vegetable fat. This result is similar to the one in the present study, in which it is possible to see on Table 2 that restaurant No. 15 was the only one that was using the special hydrogenated vegetable fat for frying and presented less formation of polar compounds and free fatty acids. Therefore, it is fat with greater oxidative stability, being more suitable for this type of cooking. It should be noted that the frequent incorporation of new oil (15% to 25%) to the frying oil decreases the formation of polar materials and can increase the time of use; however, the addition of oil to hydrogenated vegetable fat causes further degradation.[17]

Jorge *et al*.,[33] when studying changes in sunflower, corn and soybean frying oils, have also noticed increased values of total polar compounds over the frying time.

Table 3 expresses the descriptive analysis for the temperature and degradation values.

Table 3. Descriptive study for the values of polar compounds, free fatty acids and temperatures of frying oils in commercial restaurants in downtown Chapecó, SC, 2009.

	Number of samples	Average value	Median	Minimum value	Maximum value	Standard deviation
Temperature (laser thermometer)	15	160.36 ºC	159.90	117.56 ºC	187.2 ºC	2.001
Temperature (FOM 310)	15	163.21 ºC	171.50	109.76 ºC	197.76 ºC	2.166
Degradation (3M® strip)	15	3.4	3.50	0	5.5	1.792
Degradation (FOM 310)	15	14.34	13.00	0	27.33	6.883

By analyzing the temperature collected in the restaurants with the infrared laser thermometer, it was noted that the minimum value was 117.56 °C, and the maximum value was 187.2 °C. The average was 160.36 °C. Analyzing these values with what is provided by Resolution RDC-216 of ANVISA (Agência Nacional de Vigilância Sanitária; National Health Surveillance Agency), which cites in its Annex, in item 4.8.11, that used oils and fats must be heated to temperatures no higher than 180 °C, and replaced whenever there is any obvious change of physicochemical or sensory characteristics such as aroma and taste, and intense foaming and smoke.[34] It is observed that 73.33% of the restaurants (n = 11) have not exceeded the limits, while 26.66% (n = 4) have obtained values above what is recommended.

By the assessment performed by means of the Ebro FOM 310 Food Oil Monitor, the apparatus used to assess two requisites of this study, it was observed that in 20% (n = 3) of the samples, the oil was temperature greater than 180 °C, thus surpassing the limits established for this cooking process. In other samples, 80% (n = 12) have shown temperature lower than 180 °C. The results have revealed an average temperature of 163.21 °C, and the minimum was 109.76 °C and the maximum was 197.76 °C.

When oils and fats exceed the temperature of 180 °C, there is the emission of smoke and the onset of the oxidative processes. It should be emphasized that the quality of food in the frying process is dependent not only on the temperature but also on the amount, size and shape of the food and initial oil content.[17]

By comparing soybean oil to hydrogenated vegetable fat, this one has shown a minor change and a minor tendency to polymerization, regardless of the temperatures and frying times.[35]

In a study performed by Tavares *et. al.*,[30] it can be seen that the temperature at the time of frying was the test with the highest number of unsatisfactory results, i.e., 82% of the samples (n = 41) had values above 180 °C. This was not observed in this study, where only 26.66% of the samples have shown temperatures above what is recommended by the laws.

Repeated heating of oils and fats, particularly polyunsaturated ones, such as soybean oils, results in accumulation of decomposition products, which not only affect the quality of the food subjected to frying, but also the sensory attributes (appearance, odor and taste).[30]

When relating the temperature parameters (infrared laser thermometer) to degradation (3M® Cooking Oil Monitor), it can be seen that in the 15 restaurants assessed, 26.66% (n = 4), changes were evident regarding the temperature and free fatty acids, not meeting the established compliance; nevertheless, there was no significance when applying the Fisher's exact test (p = 0.231).

Even in the item temperature versus degradation, relating the verified temperature by means of the Ebro FOM 310 Food Oil Monitor to the 3M® Cooking Oil Monitor, it was observed that the entire sample (n = 15), 20% (n = 3) has shown temperature changes and oil degradation, respectively. By applying the Fisher's exact test (p = 0.505), no statistical difference was found.

Therefore it can be noticed, by the crossing accomplished, that all restaurants that had had temperature changes had also evidenced oil degradation. However, there was no significance to the applied test.

When crossing the the infrared laser thermometer temperature values with the degradation observed by the FOM 310 Food Oil Monitor, it was observed that 26.66% (n = 4) of the restaurants had had changes in temperature; of these, 50% (n = 2) had also shown changes regarding the polar compounds. In these parameters, statistical analysis applied by the Fisher's exact test (p = 0.476) has shown no statistical difference.

In the temperature versus degradation ratio, seen by means of the FOM 310 Food Oil Monitor, it is possible to see that 20% (n = 3) of the total sample had had temperature changes, but none of these had shown degradation regarding the polar compounds. By applying the Fisher's exact test ($p = 0.629$), there was no significant evidence.

When comparing the results obtained by the two analytical methods, it was noticed that in the 3M® Cooking Oil Monitor, 66.66% (n = 10) of the restaurants there was degraded oil, while in the FOM 310 Food Oil Monitor, only 13.33% (n = 2) had exceeded the recommended values. This fact can be justified due to the reduced tolerance of the 3M® Cooking Oil Monitor when comparing to the FOM 310 Food Oil Monitor, since the compounds sensitive to this one are formed the higher the frying time.

Several studies have employed the surface/volume ratio (S/V) as an oil change factor, since the oxidation rate depends on the surface area of the oil exposed to contact with oxygen in the air. However, in this study this aspect was not taken into account.

Conclusion

Considering the discard limit for frying oils of up to 25% of polar compounds, the average values of this chemical indicator in the assessed oils were within the ones recommended by the literature. However, 13.33% of the businesses had above recommended values.

As for the level of free fatty acids, 66.66% of the samples were above the limit stipulated by the law, therefore, in disposal conditions.

The quick methods can be an alternative for seeking the ideal moment for disposal, avoiding risks to the health of those who consume fried products and even for health surveillance agencies, that can work together with the business owners by using explanatory flyers so that they can obtain information on the correct use of oils.

Specific laws on the subject are also lacking in order to provide means for the health surveillance agencies to be able to act more rigorously, both in supervisory and in guidance aspects.

Thus, it is advisable to monitor the frying conditions, such as the nature of the fried food (food type, quantity of water), temperature (below 180 °C), preventing the addition of new oil to the used one. It is expected, therefore, that it is possible to achieve better control of frying and hence better quality fried food, maintaining the health of the population.

Therefore, it is noticed that knowing the procedures used in the frying processes and determining when the oils and fats should be discarded are issues that have an economic impact and may incur in an eventual reduction of costs and food quality control. The importance of this study is thus highlighted for knowing the quality of oil according to its degree of degradation, as it is part of the daily diet of the population.

References

1. Lopes MRV, Aued-Pimentel S, Caruso MSF, Jorge N, Ruvier V. Composição de ácidos graxos em óleos e gorduras de fritura. Rev. Inst. Adolfo Lutz 2004; 63(2):168-76.
2. Jorge N, Soares BBP. Comportamento do óleo de milho em frituras. Rev. Inst. Adolfo Lutz 2004; 63(1):63-69.
3. Jorge N, Janieri C. Avaliação do óleo de soja submetido ao processo de fritura de alimentos diversos. Ciênc. Agrotec 2005; 29(5):1001-1007.
4. Sanibal EAA, Rodas MAB, Della Torre JCM, Mancini Filho J. Avaliação da qualidade sensorial de batata frita, óleo de soja e gordura parcialmente hidrogenada de soja em tempos de fritura variáveis. Rev. Inst. Adolfo Lutz 2004; 63(1):80-86.
5. Vergara P, Wally AP, Pestana VR, Bastos C, Zambiazi RC. Estudo do comportamento de óleo de soja e de arroz reutilizados em frituras sucessivas de batata. B.CEPPA 2006; 24(1):207-220.
6. Freire PCM, Mancini-Filho J, Ferreira TAPC. Principais alterações físico-químicas em óleos e gorduras submetidos ao processo de fritura por imersão: regulamentação e efeitos na saúde. Rev. Nutr. 2013; 26(3):353-358.
7. Osawa CC, Gonçalves LAG. Changes in breaded chicken and oil degradation during discontinuous frying with cottonseed oil. Food Science and Technology. 2012; 32(4):692-700.
8. Jorge N, Janieri C. Avaliação do óleo de soja utilizado no restaurante universitário do IBILCE/UNESP. Alim. Nutr 2004; 15(1):11-16.
9. Yen PL, Chen BH, Yang FL, Lu YE. Effects of deep-fryingboil on blood pressure and oxidative stress in spontaneously hypertensive and normotensive rats. Nutrition 2010; 26(3):331-6.
10. Corsini MS, Jorge N, Miguel AMRO, Vicente E. Perfil de ácidos graxos e avaliação da alteração em óleos de fritura. Quim. Nova 2008; 31(5):956-961.
11. Jorge N, Lopes MRV. Avaliação de óleos e gorduras de frituras coletados no comércio de São José do Rio Preto – SP. Alim. Nutr 2003; 14(2):149-156.
12. Lima FEL, Menezes TN, Tavares MP, Szarfarc SC, Fisberg RM. Ácidos graxos e doenças cardiovasculares: uma revisão. Rev. Nutr 2000; 13(2):73-80.

13. Del-Ré PV, Jorge N. Comportamento dos óleos de girassol, soja e milho em frituras de produto cárneo empanado pré-frito congelado. Ciênc. Agrotec 2007; 31(6):1774-1779.

14. Marques AC, Valente TB, Rosa CS. Formação de toxinas durante o processamento de alimentos e as possíveis conseqüências para o organismo humano. Rev. Nutr 2009; 22(2):283-293.

15. Sanibal EAA, Mancini-Filho J. Alterações físicas, químicas e nutricionais de óleos submetidos ao processo de fritura. Food Ingredients South America 2002; 1(3):64-71.

16. Lopes MRV, Jorge N. Testes rápidos utilizados na avaliação da qualidade de óleos e gorduras de fritadeira. Rev. Inst. Adolfo Lutz 2004; 63(1):73-79.

17. Almeida DT, Araújo MPN, Furtunato DMN, Souza JC, Moraes TM. Revisão de literatura: aspectos gerais do processo de fritura de imersão. Hig. Alimentar 2006; 20(138):42-7.

18. Corsini MS, Jorge N. Estabilidade oxidativa de óleos vegetais utilizados em frituras de mandioca palito congelada. Ciênc. Tecnol. Aliment. 2006; 26(1):27-32.

19. Freitas LR, Rocha HG, Souza AS, Alvez SB. Caracterização físico-química e toxicológica do óleo de soja, do óleo composto (soja + algodão). Cientec 2009; 1(1):25-37.

20. Antoniassi R. Métodos de avaliação de estabilidade oxidativa de óleos e gorduras. B. CEPPA 2001; 19(2):353-380.

21. Mendonça MA, Borgo LA, Araújo WMC, Novaes MRCG. Avaliações físico-químicas em óleos de soja submetidos ao processo de fritura em unidades de produção de refeição no Distrito Federal. Comun. Ciências Saúde 2008; 19(2):115-122.

22. Reda SY, Carneiro PIB. Óleos e gorduras: aplicações e implicações. Revista Analytica 2007; 8(27):60-66.

23. Martins DMS, Broilo MC, Zani VT. Óleos e gorduras utilizados em restaurantes. Rev. Soc. Bras. Alim. Nutr. 2014; 39(1):25-39.

24. Masson L, Robert P, Romero N, Izaurieta M, Valenzuela S, Ortiz J et al. Comportamiento de aceites poliinsaturados en la preparación de patatas fritas para consumo inmediato: formación de nuevos compuestos y comparación de métodos analíticos. Grasas y Aceites 1997; 48(5):273-381.

25. Del Ré PV, Coltro AL, Manente JCPP, Marti GE, Jorge N. Influência da relação superfície/volume em frituras de batata palito. Rev. Inst. Adolfo Lutz 2003; 62(3):213-9.

26. Costa-Singh T, Sanches PMA. Avaliação da qualidade de óleos vegetais submetidos ao aquecimento. Nutrição Brasil 2014; 13(3):110-117.

27. Jorge N, Lopes MRV. Determinação de compostos polares em óleos e gorduras de frituras. Hig. Aliment. 2005; 19(134):46-50.

28. Malacrida CR, Jorge N. Influência da relação superfície/volume e do tempo de fritura sobre as alterações da mistura azeite de dendê-óleo de soja. Ciênc. Agrotec 2006; 30(4):724-730.

29. Cella RCF, Regitano-D'arce MAB, Spoto MHF. Comportamento do óleo de soja refinado utilizado em fritura por imersão com alimentos de origem vegetal. Ciênc. Tecnol. Aliment. 2002; 22(2):111-116.

30. Tavares M, Gonzalez E, Silva MLP, Barsotti RCF, Kumagai EE, Caruso MSF et al. Avaliação da qualidade de óleos e gorduras utilizados para fritura no comércio da região metropolitana da Baixada Santista, estado de São Paulo. Rev. Inst. Adolfo Lutz 2007; 66(1):40-44.

31. Del-Ré PV, Jorge N. Comportamento de óleos vegetais em frituras descontínuas de produtos pré-fritos congelados. Ciênc. Tecnol. Aliment. 2006; 26(1):56-63.

32. Damy PC, Jorge N. Determinações físico-químicas do óleo de soja e da gordura vegetal hidrogenada durante o processo de fritura descontínua. Braz. J. Food Technol. 2003; 6(2):251-257.

33. Jorge N, Soares BBP, Lunardi VM, Malacrida CR. Alterações físico-químicas dos óleos de girassol, milho e soja em frituras. Quim. Nova 2005; 28(6):947-951.

34. Brasil. Resolução n° 216, de 15 de setembro de 2004. Dispõe sobre Regulamente Técnico de Boas Práticas para Serviços de Alimentação. Diário Oficial da União 16 set. 2004.

35. Uriarte PS, Guillén MD. Formation of toxic alkylbenzenes in edible oils submitted to frying temperatura influence of oil composition in main components and heating time. Food Res. Inter. 2010; 43(8):2161-70.

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