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Full Length Research

The effects of Frying on the thermal behaviour of some vegetable oils

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Five different oils were selected for frying process, thermal behaviour (temperature changes). The data obtained indicates that after one minute of frying time ,the temperature decreased from 180ºc to 140, 150, 160 ,140 and 140ºc for olive, ,corn, blend, sunflower and flaxseed oils respectively . The temperature continued to decrease according to the type of oil and reached the minimal the temperature at 125, 126, 135, 128, and 130ºc for same studied oils respectively. The obtained date from thermal behaviour carves showed that the calculated convection area percentages for olive ,corn, blend, flaxseed and sunflower oils were 27.7, 40.08, 42.8, 14.6 and 37.01 % respectively meanwhile the calculated conduction area percentages for the same oils were 72.2, 59.9, 57.1, 85.3 and 62.9 respectively of total heating area. Where the greater the conduction area percentage was the greater the oil potential for frying and the better the fried food. The results from thermal behaviour carves of the five oils during frying process at 180°c after heating for one hours .showed that the initial time required reaching 180°c increased with increasing the heating time (frying cycles) . This time was stable (7, 8 ,9 minutes) for olive oil ,flaxseed and sunflower oil and did not change as compared to that recorded at zero heating time(control) and it increased to (9.5 and 14 minutes) for corn and blend oils respectively. The data obtained also revealed that the percentages of convection area increased and loss of water from 27.7, 40.0, 42.8, 14.6 and 37 after (one hours) to 33.7, 43.0, 55.8 , 33.3 and 39.0 after 2 hours of heating for olive, flaxseed, sunflower, corn and blend oil respectively . Meanwhile, the percentage of conduction area decreased from 72.2, 59.9, 57.1, 85.3 and 62.9 after frying for 1hr to 66.2,56.9,44.1,66.6 and 60.9 for the same studied oils. Eight Frying time did not change for both flaxseed and sunflower oils and was constant at 10.9 and 9 minutes while at increased to 20 minutes for corn and blend oil.

Keywords : Frying, thermal behaviour, vegetable oils

INTRODUCTION

Deep-fat frying is one of the oldest and popular food preparations. The economy of commercial deep-fat frying has been estimated to be $83 billion in the United States and at least twice the amount for the rest of the world (Ahmed and Okasha, 2016; Pedreschi *et al.,* 2005). Fried foods have desirable flavour, colour, and crispy texture, which make deep-fat fried foods very popular to consumers (Boskou *et al.,* 2006).

Frying is a process of immersing food in hot oil with a contact among oil, air, and food at a high temperature of 150 ◦C to 190 ◦C. The simultaneous heat and mass transfer of oil, food, and air during deep-fat frying produces the desirable and unique quality of fried foods. Frying oil acts as a heat transfer medium and contributes to the texture and flavour of fried food. Frying is one of the most popular culinary processes worldwide, both for industrial and domestic food preparation procedures. Fried products have unique organoleptic and sensorial properties, including flavour, texture, and appearance, which turn them largely enjoyed by consumers. In addition, this procedure considerably reduces cooking time and is regarded as inducing equal or even smaller nutrient losses when compared with other common culinary processes (Fillion and Henry, 1998). Frying can enhance the food nutritive value due to the simultaneous incorporation of important lipid components, namely vitamin E and essential fatty acids, providing that it is consumed under a balanced diet, because the lipid uptake might increase significantly the total daily energy intake.

The high temperatures used during frying, in the presence of oxygen and water, induce important chemical changes of the oils, namely by oxidation, polymerization, cyclization, and hydrolysis (Paul and Mittal, 1997; Saguy and Dana, 2003), inevitably reducing their shelf life and affecting directly the quality of the final fried food (Kochhar, 2001). These chemical reactions are influenced by the type and quality of the oil, the food properties, and the food/oil ratio, among other parameters (Saguy and Dana, 2003), altogether determining the frying oil performance (Andrikopoulos *et al.,* 2002).

Foods fried at the optimum temperature and times have golden brown colour, are properly cooked, and crispy, and have optimal oil absorption (Blumenthal 1991). However, under fried foods at lower temperature or shorter frying time than the optimum have white or slightly brown colour at the edge, and have ungelatinized or partially cooked starch at the centre. The underfried foods do not have desirable deep-fat fried flavour, good colour, and crispy texture. Over fried foods at higher temperature and longer frying time than the optimum frying have darkened and hardened surfaces and a greasy texture due to the excessive oil absorption.

Deep-fat frying produces desirable or undesirable flavour compounds, changes the flavour stability and quality, colour, and texture of fried foods, and nutritional quality of foods. The hydrolysis, oxidation, and polymerization of oil are common chemical reactions in frying oil and produce volatile or non-volatile compounds. Most of volatile compounds evaporate in the atmosphere with steam and the remaining volatile compounds in oil undergo further chemical reaction or are absorbed in fried foods. The non-volatile compounds in the oil change the physical and chemical properties of oil and fried foods. Non-volatile compounds affect flavour stability and quality and texture of fried foods during storage. Deep-fat frying decreases the unsaturated fatty acids of oil and increases foaming, colour, viscosity, density, specific heat, and contents of free fatty acids, polar materials, and polymeric compounds (Choe. and Min. 2007).

Frying temperature and time, frying oil, antioxidants, and the type of fryer affect the hydrolysis, oxidation, and polymerization of the oil during frying. Deep-Frying is a fast and easy method to prepare tasty food; therefore despite the trend to low-fat foods, French Fries and other deep-fried products enjoy increasing popularity. On the other hand consumers judge high-fat foods increasingly more critically. With the rising consumption of deep-fried foods, the interest to use nutrition-physiologically less problematic fats and oils and to minimize or exclude the formation of harmful substances has increased. Fried food has grown in popularity despite the low-fat/no-fat health trend. For example, between 1979 and 1988, the snack food industry in the United States increased by about 88%. Fat or oil used for frying often determines the acceptability of food prepared with them. Although frying oil serves primarily as a heat exchange medium, oil often makes up a significant portion of the final food product, as much as 45% of the total product. Oil varies widely in eating quality, functionality, and rate of deterioration depending on source processing, or formulation. Frying oil can be an expensive part of food processing and any steps the processor can use to reduce loss or wastage of oil can only result in greater business profitability. There is no single method for optimizing oil life but rather it should be addressed comprehensively as many areas influence oil integrity. Some of these areas include the selection of the most suitable oil, effective fryer design, oil meeting established specification, oil storage and handling and effective frying procedures (Choe. and Min. 2007).

The quality of the oil used in deep fat frying contributes to the quality of the fried food. The quality of the frying oil and of the food fried in that oil is intimately related (Blumenthal, 1991). Frying oil quality influences oil absorption and the types of by-products and residues absorbed by food. The type of food being fried influences frying oil life. Like it or not, commercial frying is a fundamental method for preparing popular, inexpensive restaurant food.

There the aim of this study was to study the effects of deep frying on thermal behaviour of some vegetable oils with different omega fatty acid composition.

MATERIALS AND METHODS

Materials

Vegetable oils

Virgin olive oil: (5kg) was obtained from EL Quorum Company an (Ganadis) Alexandria, Egypt. Olive oil was selected as it is high in oleic acid (18:1) content. Edible corn oil (5 kg) was obtained from Alexandria Oils and Soap Company (AOSCO), Alexandria, Egypt. This corn oil was selected as it is high in linoleic acid (18:2) content. Refined, bleached, and deodorized (RBD) sunflower oil (5 kg) was obtained from SAVOLA, Egypt. Sunflower oil is selected as high in linoleic acid (18:2) content. Edible fresh flaxseed oil (5 kg) was obtained from a private oil company in Tanta, Egypt. Flaxseed oil was selected as high in linolenic acid (18:3) content. Edible blend oil (5 kg) contained (sunflower and soybean oil in the ratio of 7:3), was obtained from SAVOLA Industrial Company, Egypt. This oil was selected as it contained equal saturated and unsaturated fatty acid percentages to those typical of corn and of olive oils. All vegetable oils were of good quality, as indicated by low initial peroxide value, free fatty acid, and low iodine value.

Potatoes

Potatoes (*Solanum Tuberosum*) (18kg) were purchased from a local market.

Experimental procedures

Preparation of potato chips

Potatoes were peeled, cut into 2mm thick slices using a rotary slicer (Edelstahl, Rostfrel, England), washed and dewatered prior to frying.

Determination of frying optimum temperature and time

The optimum temperature and time of frying of potato chips were determined according to (Barbary *et al*., 1999). The optimum temperature and frying time obtained for all oils to produce the best quality of potato chips were 180 ºC and 10 minutes respectively**.**

Thermal behaviour of oils during frying process

Thermal behaviours of oils during deep frying were conducted according to the method performed by Barbary *et al*. (2000**).** Oil (2.5 kg each) was initially heated in an electrical deep-fat fryer (Moulinex, France) until reached 180 ºC. The time required to reach that temperature was recorded during the frying process and assigned as the initial time. Potato chips were (250g) introduced to the heated oil at 180º C and the oil temperatures were recorded using a metal sensor (Hanna instruments, Highland Industrial Park Woonsocket Rl 02895) every minute during frying process. This time was considered as a zero time of frying process. This frying process was repeated on the heated oils every 15 minutes for 8 hours (total of 32 frying cycle) in order to study the effect of heating time on the thermal behaviour of the oil during deep frying of potato chips. The process was reported twice for each oil.

RESULTS AND DISCUSSION

Thermal behaviour of oils during frying process

Frying oils were studied to learn how to control both the process and the resulting quality of the fried food simultaneously. This, unfortunately, has not been the case in the past. Thermal behaviour (Temperature changes) of five types of vegetable oils during deep frying at 180°C (at zero time) were investigated and is shown in Figure (1-5). This thermal behaviour curve could be classified into five stages. (Stage1), represented the time required to heat the oil to reach the required temperature (180°C) and to keep it constant at this temperature. This initial time varied among the five oils used. It was 7, 8, 13, 8 and 9 minutes for olive, corn, blend, sunflower and flaxseed oils, respectively. (Stage2), represented the introducing potato chips at zero time. After only one minute of frying time, the temperature suddenly decreased from 180°C to 140°, 150°, 160°,140° and 140°C for olive, corn, blend, sunflower and flaxseed oils, respectively. The temperature continued to decrease up to 5-6 minutes of frying time according to the type of oil and reached the minimal temperature (stage 3) at 125, 126, 142, 128 and 130 °C for the same oils, respectively. This decrease could be attributed to water evaporation from potato chips. The temperature then started to increase again (Stage 4). It increased to 150, 152, 160, 150 and 155°C for olive, corn, blend, sunflower and flaxseed oils, respectively. However the rate of increment differed according to the type of oil used. Temperature increase is possibly because of the absorption of oil by potato chips and lower water evaporation. Finally, in (stage5), end of frying operation, where potato chips had the optimum sensory quality.

Oil oxidizes faster at higher temperatures. For example, increasing the frying temperature from 163 to 180° C more than doubles the oxidation reaction rate, therefore, frying temperature, even within the normal range, should be selected very carefully. An increase in temperature dramatically raises the rate at which fatty acids react with oxygen, promoting rancidity, and therefore increasing the peroxide value. Increasing the frying oil temperature tends to decrease oil uptake because the product spends less time in the fryer. It might be that this process is aided by the formation of a crust that acts as a barrier to further oil uptake. In addition, it might prevent water from leaving the food to an extent and consequently hinder the ingress of oil. However, it is important to find the optimum frying temperature to prevent a semi-raw and oily product as a result of too low a cooking temperature and a burnt and only partially cooked product from too high a frying temperature (Gertz, 2000).

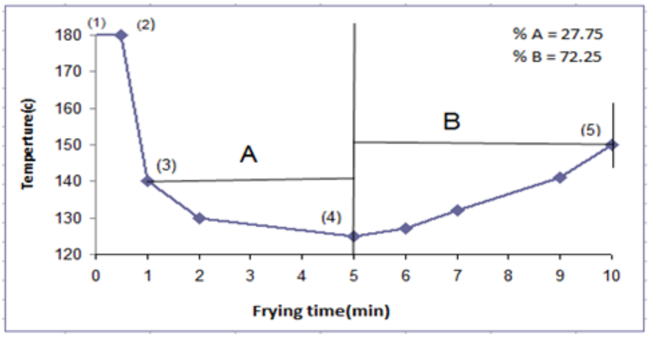

Figure 1: Thermal behaviour of olive oil during deep frying potato chips at 180°C after 1hrs time

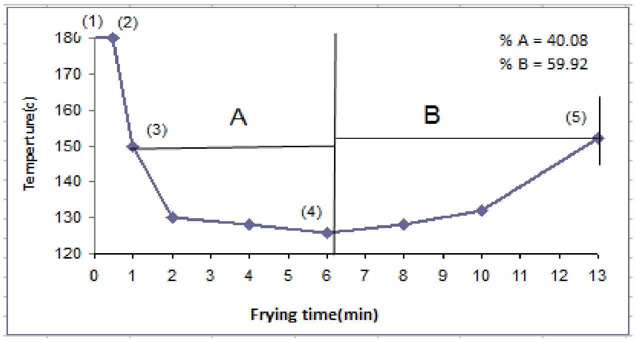

Figure 2: Thermal behaviour of corn oil during deep frying potato chips at 180°C after 1hrs time

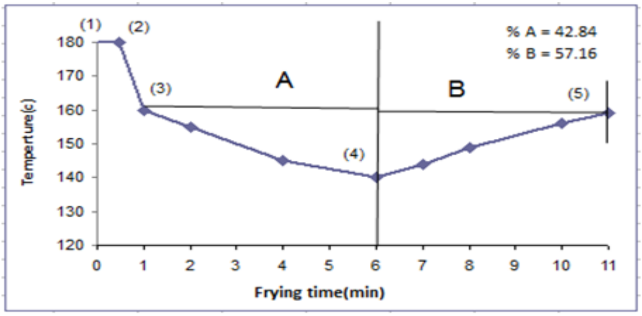

Figure 3: Thermal behaviour of blend oil during deep frying potato chips at 180°C after 1hrs time

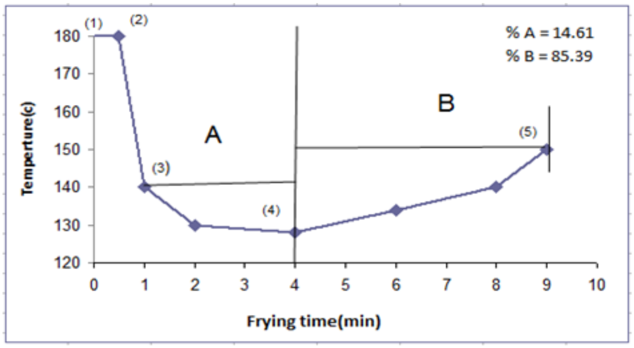

Figure 4: Thermal behaviour of Flaxseed oil during deep frying potato chips at 180°C after 1hrs time

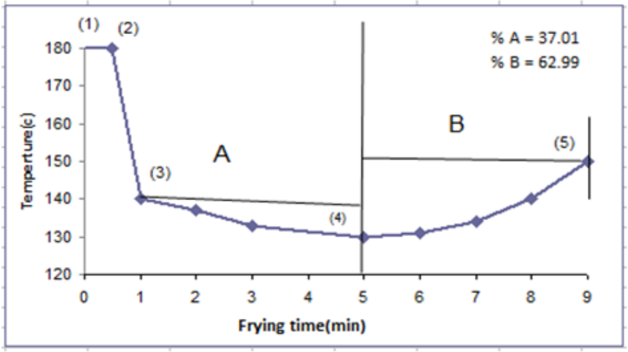

Figure 5: Thermal behaviour of sunflower oil during deep frying potato chips at 180°C after 1hrs time

Frying involves heat and mass transfer as well as interaction between the food and the frying medium. Only few studies offer some partial explanation of the mechanism (s) of oil uptake during frying (Saguy and Pinthus, 1995). During immersion frying of foods, there are two distinct modes of heat transfer, conduction and convection. Convective heat transfer occurs between a solid food and the surrounding oil. The surface interactions between the oil and the food material are complicated because of the vigorous movement of water vapour bubbles escaping from the food into the oil. Conductive heat transfer, however, occurs within a solid food. The rate of heat transfer is influenced by the thermal properties of the food, including thermal diffusivity, thermal conductivity, specific heat, and density (Singh, 1995). The magnitude of these properties changes during the frying process.

Two distinctive areas under the curve could be observed Fig. (1-5). Convection area (Area A) representing the area of water loss and oil uptake, while the conduction area (Area B) represented the frying area. The mode of heat transfer between the oil and potato chips in first minute of frying was neglected because no vaporization of water occurs from the surface of the food and no oil picked up by the food (Blumenthal, 1991). The calculated convection area percentages for olive, corn, blend, flaxseed and sunflower oils were 27.7, 40.08, 42.8, 14.6 and 37.01%, respectively. Meanwhile the calculated conduction area percentages for the same oils were 72.2, 59.9, 57.1, 85.3 and 62.9%, respectively, of the total heating area. The conduction area was the area, which signifies the quality of fried food, since several physicochemical changes, such as starch gelatinization and cooking take place in the internal core region (Singh, 1995). The greater the conduction area percentage, the greater the oil potential for frying was and the better the fried potato chips. This explains the best quality of potato chips obtained during frying in flaxseed oil followed by olive oil, sunflower oil, corn oil and finally the blend oil. In case of blend oil, the convection area percentage was dominant on account of conduction area percentage, hence lowered the potato chips quality. In case of flaxseed oil, the conduction area percentage was the dominant on account of the convection area percentage, hence gave the best potato chips quality. For olive oil, both areas were approximately equal.

Figure (6-10) shows the thermal behaviour of the five oils during deep frying process at 180°C after heating for 2 hour. Data showed that the initial time required reaching 180°C increased with increasing the heating time. This time was stable (7, 8, 9 minutes) for olive oil, flaxseed oil, sunflower oil and did not change as compared to that recorded at 1 heating time (Barbary, 2000). However, it increased to 9.5 and 14 minutes for corn and blend oils, respectively. On introducing potato chips to the heated oil at 180°C, the temperature dropped to 140, 165, 158, 140 and 142°C with falling rates of 35, 25 and 22°C/m for olive, corn, blend, flaxseed and sunflower, respectively. The temperature decreased in blend oil and increased in corn oil. The percentages of convection area (area A) increased from 27.7, 40.0, 42.8, 14.6 and 37.0% (after one hour) to 33.7, 43.0, 55.8, 33.3 and 39.0% after 2 hours of heating. Meanwhile, the percentage of conduction area (area B) decreased from 72.2, 59.9, 57.1, 85.3 and 62.9% (after frying for 1 hr) to 66.2, 56.9, 44.1, 66.6 and 60.9% for the same oils, respectively. No changes in frying time were observed for all oils and were (10 minutes).

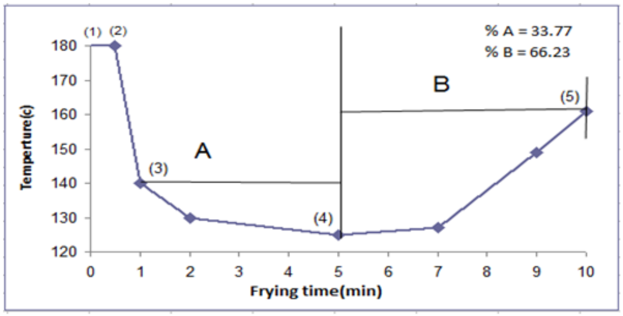

Figure 1: Thermal behaviour of Olive oil during deep frying potato chips at 180°C after 2 hour

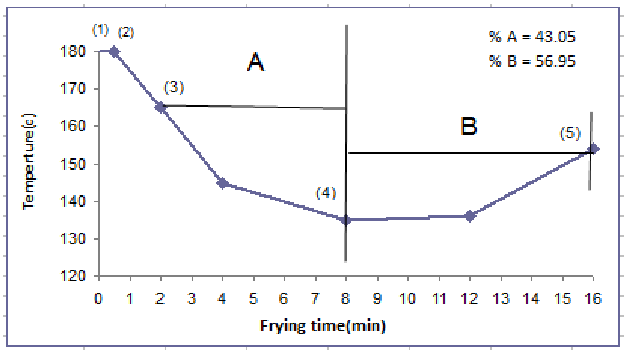

Figure 2: Thermal behaviour of Corn oil during deep frying potato chips at 180°C after 2 hour

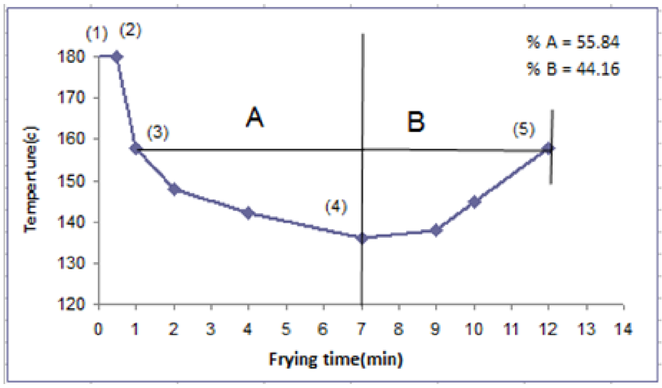

Figure 3: Thermal behaviour of blend oil during deep frying potato chips at 180°C after 2 hour

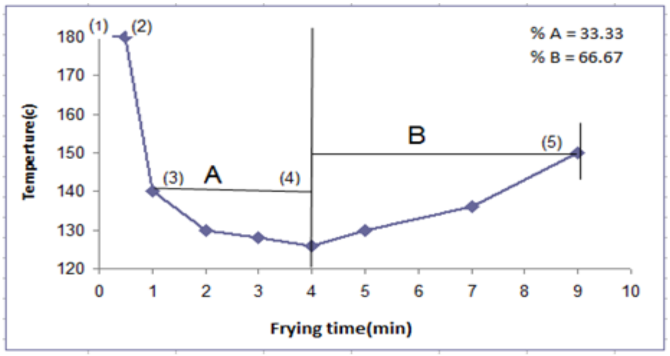

Figure 4: Thermal behaviour of Flaxseed oil during deep frying potato chips at 180°C after 2 hour

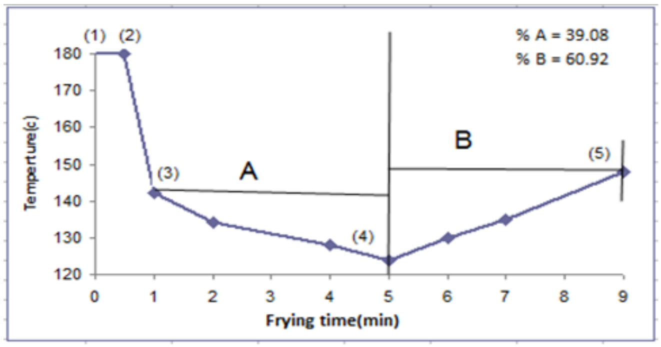

Figure 5: Thermal behaviour of Sunflower oil during deep frying potato chips at 180°C after 2 hours

After 3 hours of heating (Fig. 11-15), the initial heating time slightly increased in olive oil, flaxseed oil, sunflower oil, to 7, 8, 9 to 7.5, 9, and 10 minutes, respectively, while it was higher for corn and blend oil. It increased from 9.5 and 14 minutes (after 2 hours) to 11 and 16 minutes, respectively, after 3 hours of heating. On introducing potato chips, the temperature decreased to 138, 145, 150, 147 and 150°C with falling rate of 31, 16 and 23°C/m for olive, corn, blend, flaxseed and sunflower oil, respectively due to the increasing in viscosity of oils.

The percentage of convection area (area A) increased to 36.1 , 51.0 ,58.9 ,40.4 and 41.2% for olive, corn, blend, flaxseed and sunflower oils, respectively, on account of the conduction area (area B) which correspondingly decreased to 63.8, 48.9, 41.0, 59.6 and 58.7% for the same oils, respectively. The frying time did not change for both olive, flaxseed and sunflower oils and was constant at 10, 9, and 9 minutes, while it increased to 20 minutes in case of the corn, blend oil.

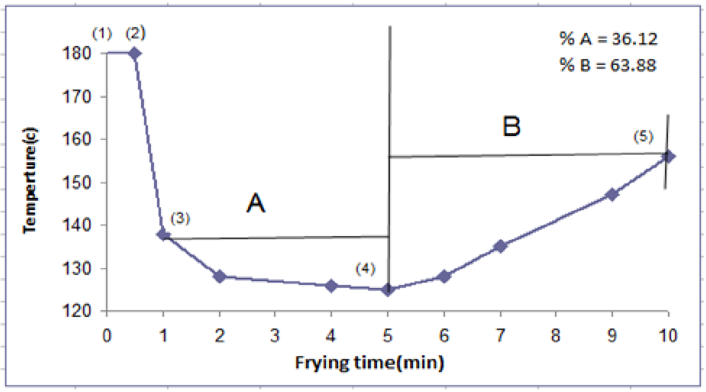

Figure 6: Thermal behaviour of olive oil during deep frying potato chips at 180°C after 3 hours

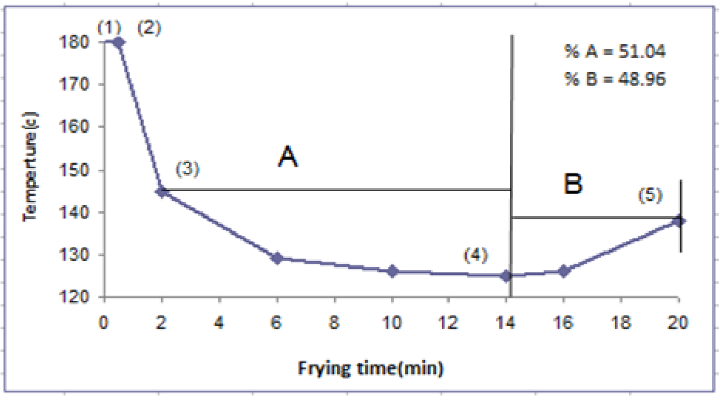

Figure 7: Thermal behaviour of corn oil during deep frying potato chips at 180°C after 3 hour.

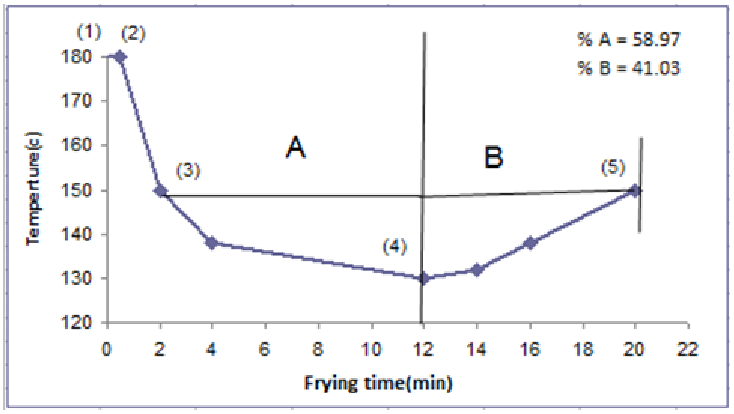

Figure 8: Thermal behaviour of bland oil during deep frying potato chips at 180°C after 3 hours

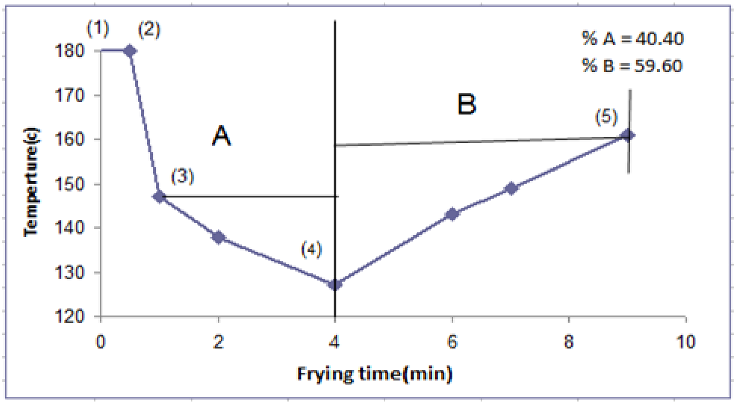

Figure 9: Thermal behaviour of flaxseed oil during deep frying potato chips at 180°C after 3 hours

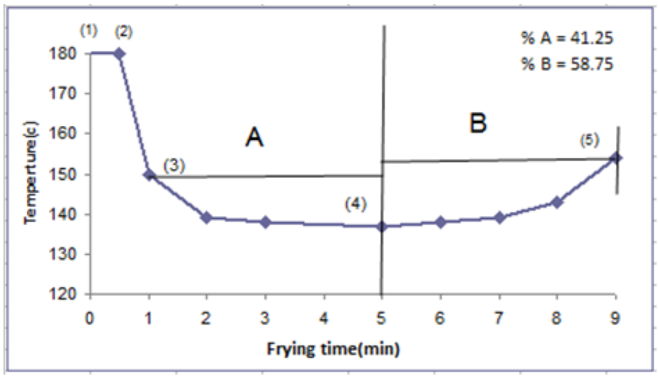

Figure 10: Thermal behaviour of sunflower oil during deep frying potato chips at 180°C after 3 hours

Figure (16-20) shows the thermal behaviour of the same oils after heating for 4 hours at 180°C. Results showed that the initial time continued to increase and reached to 8, 12, 17 and 12 min for olive, corn, blend, and sunflower oils.

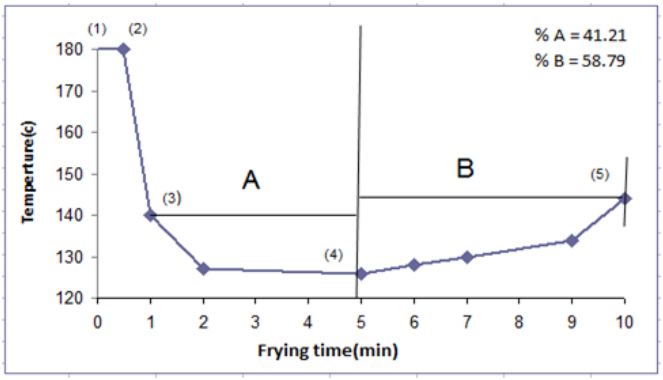

Figure 11: Thermal behaviour of olive oil during deep frying potato chips at 180°C after 4 hours

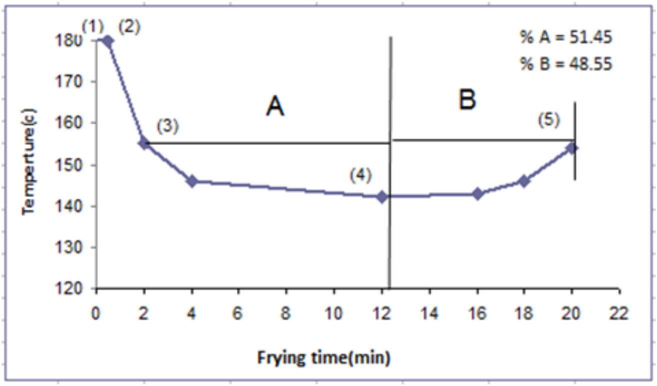

Figure 12: Thermal behaviour of corn oil during deep frying potato chips at 180°C after 4 hours

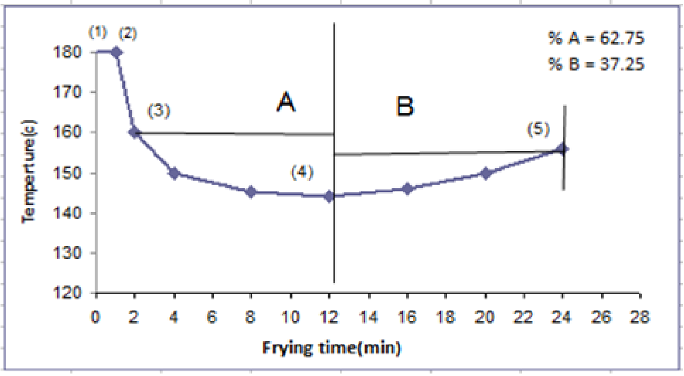

Figure 13: Thermal behaviour of blend oil during deep frying potato chips at 180°C after 4 hours

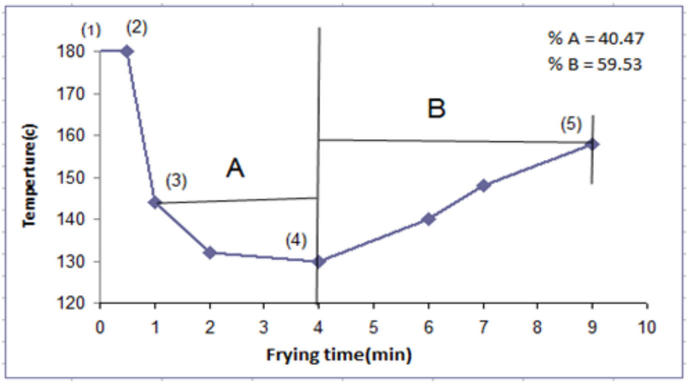

Figure 14: Thermal behaviour of flaxseed oil during deep frying potato chips at 180°C after 4 hours

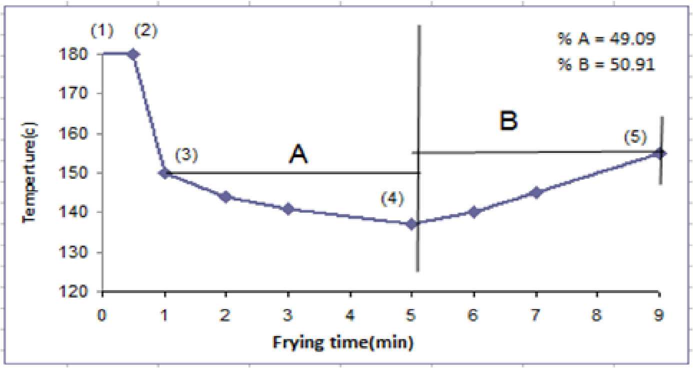

Figure 15: Thermal behaviour of sunflower oil during deep frying potato chips at 180°C after 4 hours

The conduction area after 4 hours was 41.2, 51.4, 62.7, 40.4 and 49.0% of the total heating area for olive, corn, blend, flaxseed and sunflower oil, respectively. The frying time increased also to 20 and 24 minutes for corn and bland oil, respectively.

Figure (21-25) shows the thermal behaviour of the five oils during frying process at 180°C after heating for 5 hours. The percentages of convection area (area A) increased from 59.9, 55.2, 66.0, 50.4 and 50.7% for olive, corn, blend, flaxseed and sunflower oil, respectively. And correspondingly the conduction areas (area B) decreased 40.02, 44.7, 33.95, 49.5, and 49.2% for olive, corn, blend, flaxseed and sunflower oil, respectively and increased in frying time for olive and sunflower oil to 12 and 12 minutes respectively.

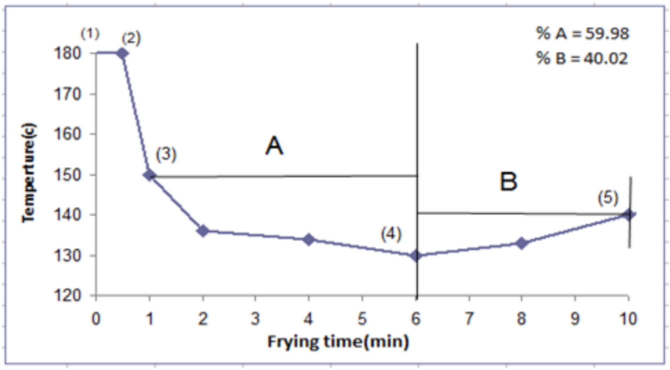

Figure 16: Thermal behaviour of olive oil during deep frying potato chips at 180°C after 5 hours

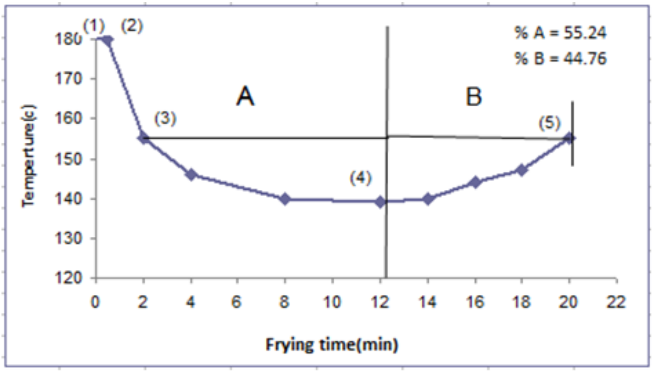

Figure 17: Thermal behaviour of corn oil during deep frying potato chips at 180°C after 5 hours

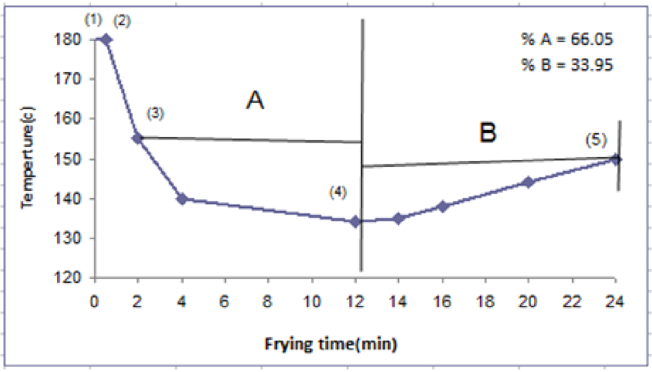

Figure 18: Thermal behaviour of blend oil during deep frying potato chips at 180°C after 5 hours

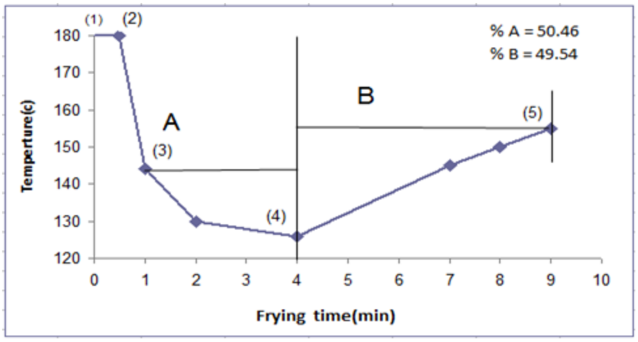

Figure 19: Thermal behaviour of flaxseed oil during deep frying potato chips at 180°C after 5 hours

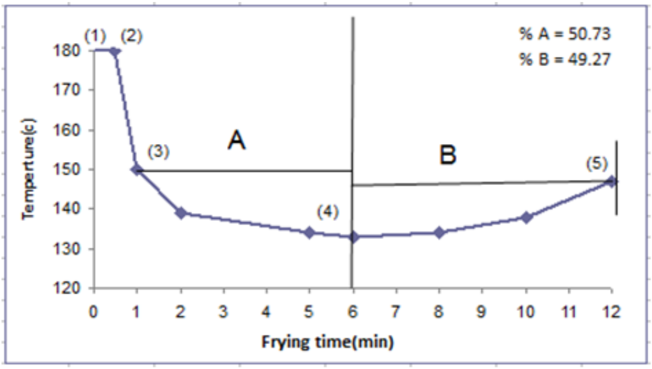

Figure 20: Thermal behaviour of sunflower oil during deep frying potato chips at 180°C after 5 hours

Figure (26-30) shows the thermal behaviour of the same oils after heating for 6 hours at 180°C. The frying time increased in all oils 24,22,28,11and13 for olive, corn, blend, flaxseed and sunflower oil, respectively and increased in percentages of convection area (area A) correspondingly decreased in conduction (area B) depending on the quality of each oil.

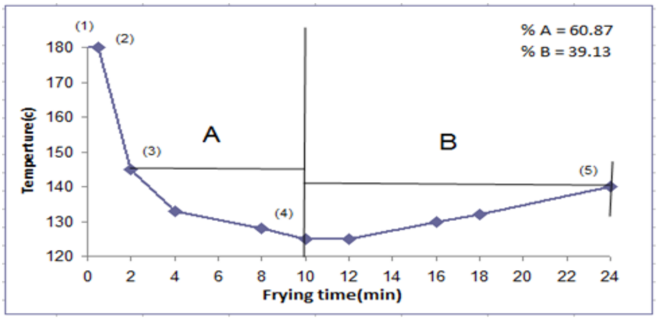

Figure 21: Thermal behaviour of olive oil during deep frying potato chips at 180°C after 6 hours

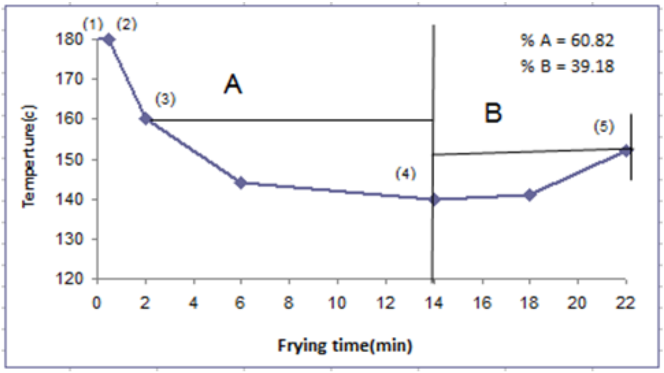

Figure 22: Thermal behaviour of corn oil during deep frying potato chips at 180°C after 6 hours

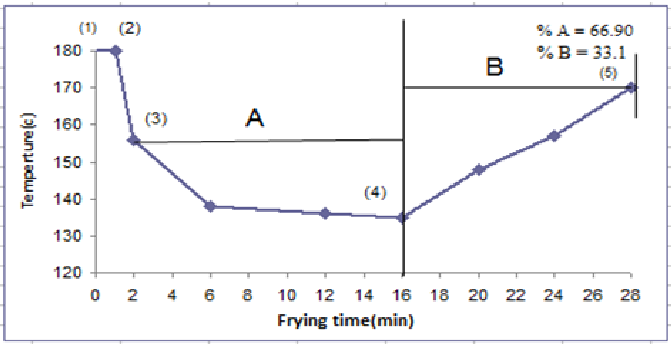

Figure 23: Thermal behaviour of blend oil during deep frying potato chips at 180°C after 6 hours

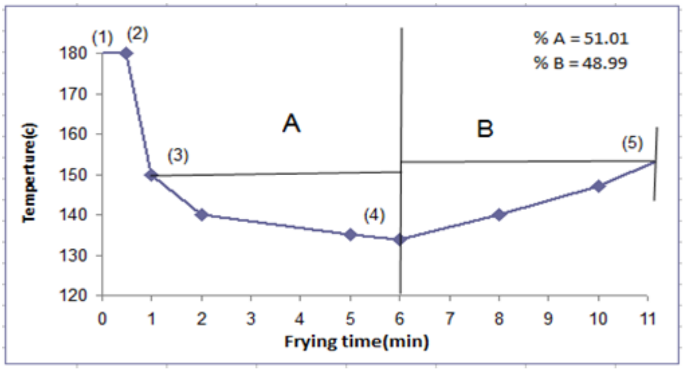

Figure 24: Thermal behaviour of flaxseed oil during deep frying potato chips at 180°C after 6 hours

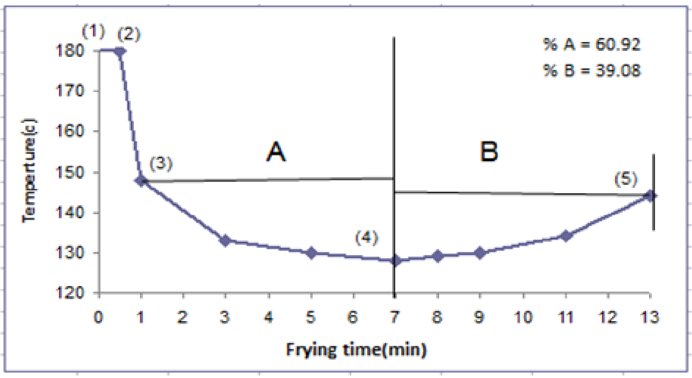

Figure 25: Thermal behaviour of sunflower oil during deep frying potato chips at 180°C after 6 hours

Figure (31-35) and (36-40) show increased initial time at 180°C after 7 and 8 hours to 9, 13, 15, 10,and 12 to 9,16,15,10, and21 for olive, corn, blend, flaxseed and sunflower oil respectively. Also increased in frying time in olive corn, bland, flaxseed and sunflower oils to 24, 24, 38, 24, 28, respectively and convection area (A) Depending on the quality of each oil and decreased in conduction. These increases observed in both initial time required to reach 180°C and frying time as the heating continued up to 8 hours could be attributed to many factors:

(1) As the high heat capacity of oils is diminished by the prolonged heating, the oil would loss its functional properties as a heat transfer medium ((Blumenthal, 1991) and as a result the time required to achieve the best frying will increase.

(2) Formation of soap and soap-like materials will cause excessive foaming in oil forming a soapy layer on the surface of potato chips preventing the oil to reach potato surface hence increasing the frying time (Gil and Handel, 1995).

(3) As saturation increases during frying, viscosity and melting points of oils will increase causing oil to need longer time reaching there required, temperature, (Hemandez, 1989.; and Tyagi Vasishtha, 1996).

(4) Frying process causes the formation of fatty acids with trans configuration (Hu et al., 1997; Tyagi and Vasishtha, 1996), which have higher melting points than cis configuration fatty acids (i.e., C18:I cis melts at 14°C while C18 : 1 trans melts at 51 °C) (Nawar, 1996).

These trans fatty acids will increase viscosity and melting points. At the same time, variation differences existed in both initial heating time and frying time observed in the three oils could be due to the deterioration rate for oleic: linoleic : linolenic acids, which is 1: 10 : 20-30 (Warner, 1995). The blend oil which contains linoleic as a dominant fatty acid and linolenic acid, therefore, deteriorated faster than corn oil which contains only linoleic acid in high quantity. Olive oil containing oleic acid, as a major constituent, was the least deteriorated among the oils because it has not yet been possible to find an easy, reliable, practical analytical solution to predict when to discard the oil (Chang *et al.,* 1978; Fritsch, 1981; Wu and Nawar, 1986; Firestone *et al.,* 1991). The time required to reach 180°C and the frying time as well as the conduction area percentage can, therefore, be used as good indicators for oil quality and when it should be discarded.

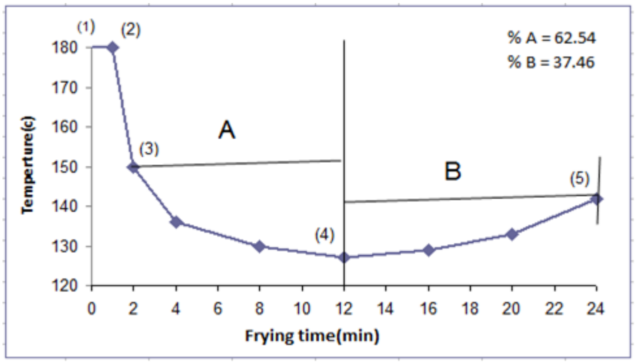

Figure 26: Thermal behaviour of olive oil during deep frying potato chips at 180°C after 7 hours.

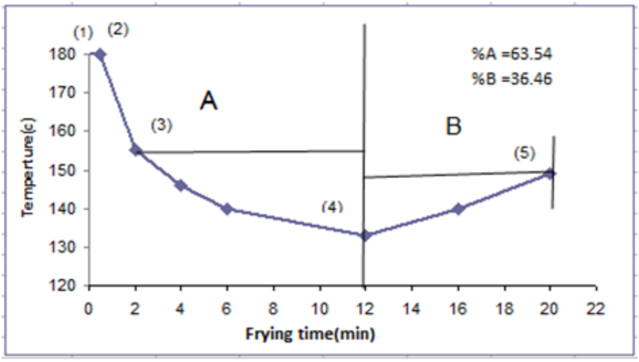

Figure 27: Thermal behaviour of corn oil during deep frying potato chips at 180°C after 7 hours

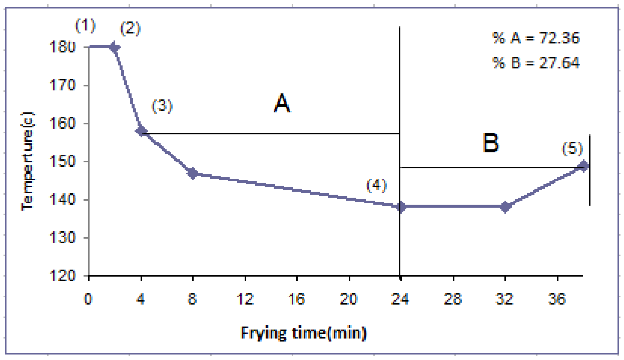

Figure 28: Thermal behaviour of blend oil during deep frying potato chips at 180°C after 7 hours.

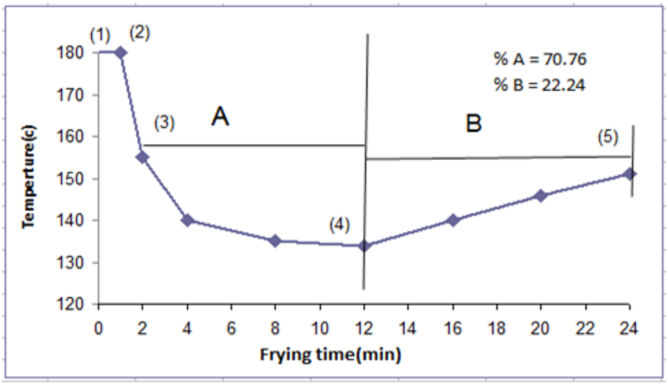

Figure 29: Thermal behaviour of flaxseed oil during deep frying potato chips at 180°C after 7 hours.

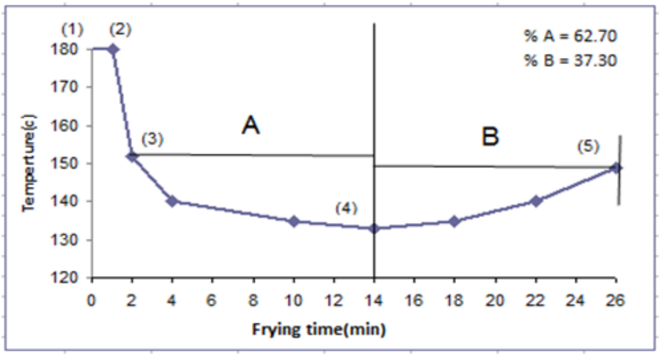

Figure 30: Thermal behaviour of sunflower oil during deep frying potato chips at 180°C after 7 hours.

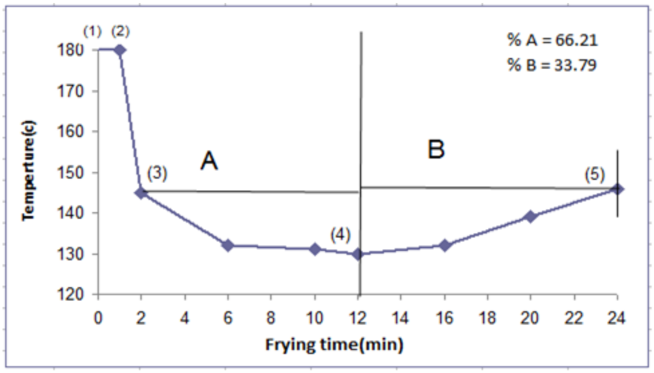

Figure 31: Thermal behaviour of olive oil during deep frying potato chips at 180°C after 8 hours.

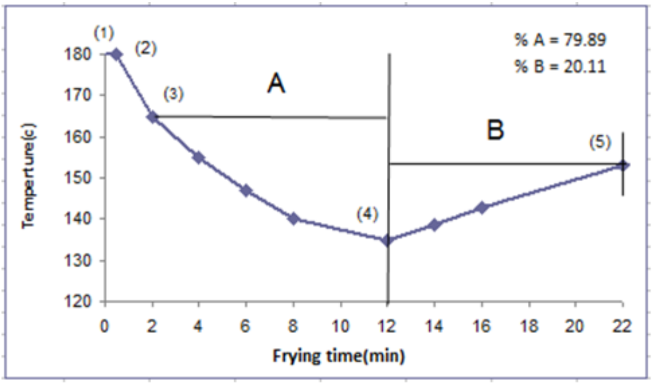

Figure 32: Thermal behaviour of corn oil during deep frying potato chips at 180°C after 8 hours.

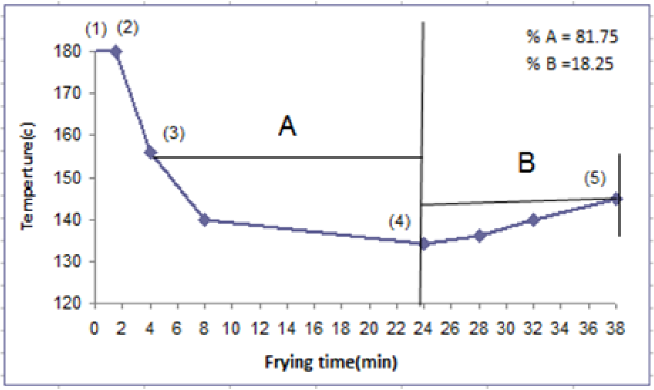

Figure 33: Thermal behaviour of blend oil during deep frying potato chips at 180°C after 8 hours.

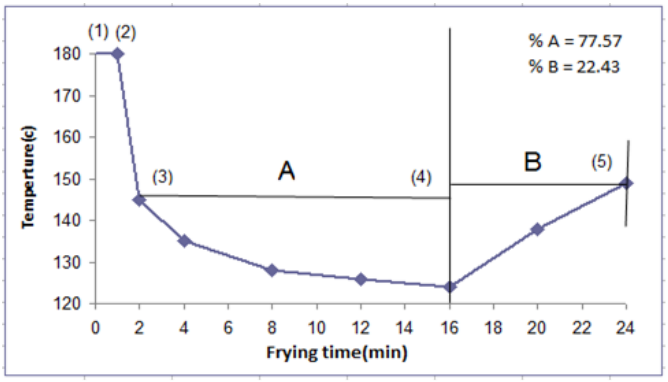

Figure 34: Thermal behaviour of flaxseed oil during deep frying potato chips at 180°C after 8 hours.

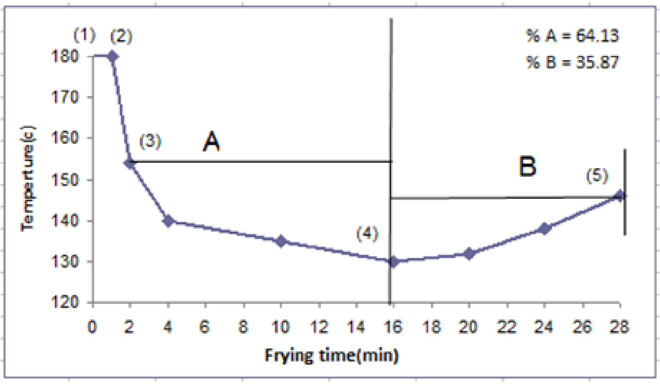

Figure 35: Thermal behaviour of sunflower oil during deep frying potato chips at 180°C after 8 hours

CONCLUSION

The time need for oil to reach the optimum temperature of 180ºC for frying increased with the number of frying process for vegetables oil of different omega fatty acids. The great increase happen in sunflower oil of omega 6 after 8 hours when compared with olive oil and flaxseed oil which made it less efficiency than them during frying process.

The area of heat transfer by convection which represented by (A) increased by the number of frying process. This explain the reduction of oil capacity in heat transfer to the food material due to the changes which occur in the oil during the frying process. The area of thermal conductive decreased which representing by (B) when the number of frying process increased due to reduce in rate of in moisture lost from food material which increase in frying time and this explain by reduce of absorbance rate of food material to oil. The flaxseed oil (omega 3) recorded high value of thermal conduction area after one hour when comparison with olive oil and sunflower oil. Break in point is the point which the curve of heat convection area percentage (A) crossed by the curve of thermal conduction area percentage (B) which represented the start of break in point of oil. The flaxseed oil recorded high value of oxidative stability point equal six hours due to its content of natural antioxidants and lignan which gave high efficacy in frying process.

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