Sudan University of Science and Technology
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Physicocheminal Changesof Used Oil CollectedFrom Restaurants in Khartoum Area

التغيرات الفيزيائية والكيميائية للزيوت المستخدمة في المطاعم في منطقة الخرطوم

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مايو ٢٠١٥

Dedication

TO MY FAMILY,

TO MY TEACHERS,

TO MY FRIENDS,

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Abstract

This research was conducted to study the effect of repeated use of frying oil on physicochemical properties of cottonseed oil and sunflower oil as common edible oils used for food frying (tammiya , chips and fish) . Samples were collected randomly from different restaurants in Khartoum state for three days in the morning and evening , then the following tests were carried out (viscosity , refractive index , colour ,smoking point , free fatty acid , polymer content , peroxide value ,iodine value) .

The physical properties of collected cottonseed oil used for frying tammiya and potato chips . Viscosity of oil before frying tammiya and chips were 65.8 and 66.07 respectively, these results were changed significantly after frying to 72.42 ,70.00 respectively .Smoking point changed significantly after frying in collected samples from 217 to 190 °C in tammiya and 217 to 191°C in chips frying , but refractive index insignificantly changed after frying in all collected samples . also physical properties of collected sunflower oil used for frying fish were significantly changed after frying , viscosity of sunflower oil changed significantly after frying fish from 75 to 61.4 , and smoking point changed significantly from 215 to 195 °C . The chemical properties of collected cottonseed oil used for frying in some restaurants in Khartoum area (iodine value , polymer content , peroxide value and free fatty acids) were significantly changed after frying in all collected samples of different foods (tammiya and potato chips) . peroxide value changed significantly in tammiya and chips frying from 8 and 9 before frying to 10 and 11 respectively after frying . Polymer content of cottonseed oil changed significantly in tammiya and chips frying from 0.73 and 0.82 to 6.7 and 5.3 respectively . Iodine value of cottonseed oil changed significantly in tammiya and chips frying from 119 and 120 to 109 and 110 respectively .The chemical properties of collected sunflower oil used for frying fish in some restaurants in Khartoum area , iodine value changed significantly from 117 to 112 , and peroxide value changed significantly from 7 to 12 , polymer content changed significantly from 0.73 to 4.3 . Hence the used fried oil in restaurants should be discarded when peroxide value more than 10 m.Eq/kgand free fatty acids exceed 0.8mg KOH/g .

ملخص الأطروحة

يتضمن هذا البحث دراسة تأثير تكرار استخدام زيوت التحمير على الخواص الفيزيائية والكيميائية لزيت بذرة القطن وزيت زهرة عباد الشمس كأكثر الزيوت المستخدمة في تحمير (الطعمية، السمك، والبطاطس)، تم تجميع العينات عشوائيا من مطاعم مختلفة في الخرطوم لثلاثة أيام متتالية في الصباح والمساء وتم إجراءاختبارات مختلفة عليها مثل (معامل الانكسار، اللزوجة، اللون، نقطة التدخين ، الأحماض الدهنية الحرة ، قيمة اليود ، محتوى البوليمرات و قيمة البيروكسيد). استخدم زيت بذرة القطن لتحمير الطعمية والبطاطس أما زيت زهرة عباد الشمس استخدم لتحمير السمك .

الخواص الفيزيائية (ألون،نقطة التدخين، معامل الانكسار واللزوجة) مثل اللزوجة لعينات بذرة القطن المستخدمة لتحمير البطاطس والطعمية حدث لها فروقات معنوية بعد التحمير حيث تغيرت من ٦٥.٨ و ٦٦.٠٧ الـ ٧٢.٤ و ٧٠ على التوالي أيضا تغيرت نقطة التدخين أثناء تحمير الطعمية والبطاطس من ٢١٧ و٢١٧ درجة مئوية إلى ١٩٠ و ١٩١ درجة مئوية على التوالي وأيضا هنالك فروقات معنوية على اللون بعد التحمير في العينات المجمعة ماعدا معامل الانكسار لم يحدث فيه تغير. أيضاهناك تغيرات واضحة في الخواص الفيزيائية لزيت زهرة عباد الشمس الذي استخدم لتحمير السمك حيث تغيرت اللزوجة من ٥٧ إلى ٦١.٤ بعد التحمير وأيضا تغيرت نقطة التدخين من ٢٢٥ درجة مئوية إلى ١٩٥ درجة مئوية. بالنسبة للخواص الكيميائية للعينات المجمعة من المطاعم المختلفة في الخرطوم وجد حدوث تغيرات معنوية في الخواص الكيميائية (محتوى البوليمرات، قيمة البيروكسيد ، قيمة اليود والأحماض الدهنية الحرة) بعد التحمير مثل التغيرات التي حدثت في محتوى البوليمرات أثناء تحمير الطعمية والبطاطس حيث تغيرت من ٠.٧٣ و٠.٨٢ إلى ٦.٧ و٥.٣ على التوالي في زيت بذرة القطن وكذلك بالنسبة لقيمة البيروكسيد تغيرت أثناء تحمير الطعمية والبطاطس من ٨ و٩ إلى ١٠ و ١١ على التوالي أيضا هناك فروقات معنوية في الخواص الكيميائية للعينات المجمعة من زيت بذرة عباد الشمس الذي استخدم لتحمير السمك حيث تغيرت قيمة اليود من ١١٧ إلى ١١٢ بعد التحمير وكذلك قيمة البيروكسيد من ٧ إلى ١٢ . وهنا يجب التخلص من الزيوت بعد التحمير عندما تصل قيمة البيروكسيد ١٠ وأيضاالأحماض الدهنية الحرة أكثر من ٠.٨% .

CHAPTER ONE

INTRODUCTION

Frying is one of the oldest and most popular cooking methods in existence. Deep-fat frying is a method to produce fried food where an edible fat heated above the boiling point of water serves as the heat transfer medium, fat also migrates into the food providing nutrients and flavour (Fan *et al.,* 2005). These conditions lead to high heat transfer rates, rapid cooking, browning, texture, and flavour development. Therefore, deep-fat frying is often selected as a method for creating unique flavours, colours, and textures in processed foods . However, surface darkening and many adverse reactions take place during deep-fat frying because of high temperature . Due to the pressure lowering , the boiling points both of the fat and moisture in the foods are lowered .Depending upon temperature and the duration of the deep-frying process, the heating of fats and oils will change the composition of the medium and eventually lead to the degradation of the fat . On the other hand fat degradation is not reversible, the processing must aim at obtaining and maintaining optimal conditions for the production of tasty food for as long time as possible . Frying process has many problems due to , various reactions such as oxidation ,polymerization and hydrolysis occur in the cooking oil (Fritsch,1981) . As these reactions proceed ,the functional ,sensory and nutritional quality of the fat changes and may eventually reach a point where it is no longer possible to prepare high quality fried products and the frying fat will have to be discarded .The rate of formation of decomposition products , and indeed the product themselves ,vary with the food being fried, the fat being used ,the fryer design and the nature of operating conditions . Cooking oils have been known to have different characteristics in physical appearance from those of frying fats . In other words , the cooking oils should remain clear and transparent at room temperature and for sometimes even at or below 0.0̊C during low temperature storage .Health impact of consuming deteriorated cooking oils causes loss of nutritive value due to essential fatty acids, (linoleic acid) and vitamins (A,D and E) destruction., Health effects from toxic substances and some polymers (carcinogens) formation . Consumers have concept that the fried food in restaurants pose a potential hazard to human health and nutrition ,as result of repeating use of oil in frying . Nowadays there are many claims about fried foods such as check pea tammiya, fish and potato chips ..etc in restaurants . The frying cost and scarcity of good vegetable oil raised the doubt about the type and quality of continuous use of frying oil for such popular fried foods .Oil and fats constitue one of the major classes of food constituents besides proteins and carbohydrates , deep-fat frying is one of the most popular procedures for food preparation ,since it is rapid and desirable flavour and texture are developed .

Objective from this study is:

- To determine the physicochemical changes of such used oil .

CHAPTER TWO

LITERATURE REVIEW

2.1 Edible oils in human diets

Edible oils are major dietary component and plays important nutritional role as concentrated source of energy and carrier of fat –soluble vitamins .They also impart flavour and taste to foods , provide essential fatty acids and fats are required for normal functions of the body (Frezzotte*et al.*, 1956).

2.2 The use of edible oils for frying purposes

Recommendations by the German Society for Fat Science that the heating of foods (rich in starch and poor in water content) by baking, roasting, grilling, frying and deep-frying may cause the formation of acryl amide in the presence of protein components like asparagines and reducing sugars like glucose. The formation of acryl amide can clearly be minimized through a short deep-frying process with temperatures not exceeding 165 – 175°C and by the selection of food with a suitable volume/surface ratio. Vacuum frying is an alternative technique to improve the quality of dehydrated food (Song *et al.,* 2007). Fats/oils may be obtained from plants, animals, marine animals, or microorganisms. Fats and oils represent lipids that are saponifiable (react with alkali to form soap). Natural fats and oil predominantly glycerol esters of fatty acids. Crude fat/oil as obtained by normal extraction processes contain not only true fat but also other minor constituents like waxes, phospholipids , fat-soluble vitamins (e.g., vitamin A, D, E and K) , sterols , pigments (chlorophyll, carotenoids, etc.) and antioxidants (ferulic acid, sesamol, etc.) (Basuny*et al.,*2009).

2-3 Types of oil used in restaurants for frying process

2-3- 1 Sunflower oil

Sunflower (*Heliantusannuusl .)* is one of the most ancient oil seeds .The genus *Helianthus* comprises 68 known species. An ashen, the seed of sunflower, is pointed at the base and rounded at the top. Seed size ranges between 10 and 15 mm in length and between 4 and 12 mm in width, appearing to be four-sided in cross-section. The outer layer, the per cap or hull, represents 18–45% of the total weight. Physicochemical properties of fats and oils are often used to identify them. The oil extracted from sunflower seeds is 40% and 50% .The sunflower oil is interesting by its content in linoleic acid .It is considered equal to olive oil or almond oil for table use .Sunflower oil uses in food industry (dressing , seasoning ,frying and other preparations) and cosmetic industry .NCPA (2006) showed that the refractive index of raw sunflower oil is 1.4663-1.4684 , and yellow colour is 1-2 but red colour 0.1-0.3 .Iodine number for raw sunflower oil is 125 -136 , peroxide value is 3.2-4.5 . Increased interest in high oleic sunflower oil has been spurred by dietary recommendation favouring high mono saturates and stable alternatives to hydrogenated oil . Functional applications for this oil include use as dairy substitute , spray oil for fruits and cereal ,salad or frying oil and use in the manufacture of confectionery items (Sakurai and Pokorny, 2003). Sunflower in the Sudan has been tried at the first time in Gezira research station in 1932, however more experiments were carried out during fifties, sixties, seventies , and the production on commercial basis only started in the mid – eighties of the twentieths century by the private sector (Khidir ,2003). The fatty acids composition of sunflower oil has been reported by a number of scientists to vary with planting date , genotype , location , and with climatic condition during the growing season .Many workers reported that varietals different had a marked effect of the fatty acids composition of sunflower especially oleic and linoleic acid content . Parvthi*et al.,(*1976) stated that , fatty acid composition of sunflower oil produced at Hyderabad in India and sunflower obtained from Canada were particularly of large difference in oleic : 50.3% and linoleic 40.9 ,74.8 %, respectively .

2-3-2 Cottonseed oil

Cotton (*Gossypiumhirsutumand*) is both used for food (cottonseed oil) and fiber (cotton lint) crop. For each 100 kg of cotton fiber produced, the plant also produces about 150 kg of cottonseed. It is grown primarily for the fiber or lints but the seeds bearing oil are highly important. Cottonseed is about15–20% of the value of the cotton crop ,. Cottonseed oil is classified as vegetables oil , it is lower in cholesterol (liu*et.al*., 2002) . Kitchen test showed cottonseed oil withstand high temperature (Wiki books website , 2007) . Cottonseed gives fried food a high flavour and food achieves a similar colour and texture .Potato chips and snacks fried in cottonseed oil may maintain a longer shelf life due to antioxidants qualities of the oil (NCPA ,2002) . A long with each of these properties , cottonseed oil also low costs . NCPA (2006) showed that the refractive index of raw cottonseed oil was 1.467 -1.4679, and yellow colour was 15 and red1.5 . Iodine value for raw cottonseed was (95-108) and peroxide value was 1 . Cottonseed oil meets the governments highest food quality standards , in part because it can be cleaned and processed to the highest purity without losing its nutritional value . The fatty acids composition of cottonseed is variable. A typical composition of the oil is: oleic acid 22%, linoleic acid 52%, linolenic acid 1%, palmitic acid 24%, and stearic acid 1%. Two fatty acids, viz., sterculic and malvalic acid, are unique to cottonseed oil. These acids are collectively called cyclopropenoid acid. Presence of these acids in other oil is an indication of adulteration. The test for the qualitative determination of cyclopropenoids is called halphen test. Another unique constituent of cottonseed is the gossypol, a pigment compound. (Munro , 1987) .

2-4 Types of fried food

2-4-1 Potato chips

Fried foods play a very important role in the diet of the modern consumer. Potato chips have been a popular salty snacks for 150 years and retail sales in many countries are about 6 billions/year, representing 33% of the total sales on the market (Garayo and Moreira 2002) . However, potato chips have an oil content that ranges from 35 to 45g/100g (wet basis), which is a major factor affecting consumer acceptance for oil-fried products today (Dueik and Bouchon, 2011). Due to consumer health concerns, fat content of potato chips is an important parameter to be controlled during processing.

2-4-2 Fish

Indicators are available to measure most biological aspects of the state of wild marine fish stock ,e.g .abundance ,rates of mortality ,length and age compositions ,annual recruitment, growth ,bodily condition ,and sexual maturity .Such indicators are termed "population indicators" when they apply to a population or stock of one species ,the alternative being "community indicators'' ,when they apply to more than one species (Rochet*et.al.*,2005) . Physiological indicators such as liver weight orlipid content which have direct relevance to energy usage, reproductionand so on (Anonymous ,2003). Since chemical composition can vary widely, not only from fish to fish of the same species, but also within an individual fish, precision is impossible. The processor, the nutritionist, the cook and the consumer all have a direct interest in the composition of fish. While the consumer is interested mainly in the edible part of the fish, that is the flesh or muscle, the fish meal manufacturer is concerned with the composition of the whole fish, and the processor of fish oils wants to know what is in the liver (Murray and Burt,2001) .

2-4-3 Tammiya

It is traditionally Arab food also called falafel means pepper ,these fried vegetation fritters are often served along with hummus and tahini sauce . Tammiya is a great source of protein for people who have cut meat out of their diet . It is relatively low in fat and has no cholesterol if you fry it in heart –healthy grape seed oil . It is delicious fast food that is much higher and better for heart than burgers and fries . Tammiya made from check pea soaked in water ,ground by specialized miller and thin, and its ingredients are check pea , water, salt and baking powder . (Wiki Books Website 2007) .

2-5 Frying process

Deep-frying is a cooking process, with which water containing food stuff is immersed into edible oils or fats at temperatures between 140 – 180 °C. In the first phase, within a few seconds , a thin crust forms, whose structure crucially affects the deep-frying process and the quality of the food with regards to fat absorption and crispness. Fats and oil have a high heat capacity, thereby enabling heat transfer at temperatures far above that of the boiling point of water. Due to the evaporation in the boundary zone between food and oil, the water bound in the food is gradually transported from the inside to the boundary layer into the surrounding oil (mass transfer). The speed of transfer depends more or less on the structure of the outer crust. As soon as the transfer of water ends, the temperature inside the food starts to rise above 100 °C. At this point the typical deep-frying aromas and flavours as well as the gold-yellow colour begin to develop. A viable data on reactions taking place during frying indicate that they are probably different from those produced by heating the oil in the presence of air , still it has been found that the content of oxidation products was somewhat higher in case of potato frying , fish or the tammiya (Sonia and Badereldeen, 1983). Fritish (1981) reported some of major changes which occur during frying ,the fat exposed continuously or repeatly to elevated temperature in the presence of air and moisture. Number of chemical reactions , including oxidation , and hydrolysis , occur during this time as do changes due to thermal decomposition. As these reactions proceed , the functional , sensory and nutritional quality of the fat changes and may eventually reach a point where it is no longer possible to prepare high quality fried products and the frying fat will have to be discarded .

2.6 Physical characteristics

2.6.1 Refractive index (RI)

Ecey and Lawrence (1954) defined refractive index as the ratio of the velocity of light in vacuum to the velocity of light in the medium being measured.Schultz*et al.,* (1962), noticed that, the RIof oils and fats were closely related to oxidation products and development of rancidity . It is useful for identification purpose and for establishing purity , and also for observing the progress of reactions, such as catalytic , hydrogenation and isomerization . Mondal and Nadi (1984) reported that, the R I of fats and oils decrease in most condition controlled or normal ,with concomitant increase in fatty acids. According to Sarojini*et al* (1985) alkali refining causes slight difference in R I between crude and refined oils . Increasing in temperature of oil and fats causes the R I to decrease along with decrease in density , (Ecky and Lawrence 1954) . Increase in unsaturation cause increase of refractive index and conjugated unsaturation cause a higher refractive index . Balla (2001) reported from the work of other investigators (Ecky and Lawrence ,1954) that ,the variation in R I could be due to specific gravity, molecular weight ,increase in saturation and linearly autoxidation stage . Jar elnabi (2001) reported the R I of crude oilof sunflower as 1.47300 to 1.4706 , and cottonseed is 1.4680

(Kabashi2000) .Richard (1986) reported that the R I of crude sunflower oil at 25̊C as 1.2700 .

2.6.2 Viscosity

Eugene *et al* (1991) defined the viscosity as the measure of resistance to flow . Viscosity is the measure of the internal fraction in the oil and is the important index of the study of oil and their intermolecular forces and its useful criterion for degradation or depolymeraization such as that occur in initial stage of hydrolysis of fat and oil during storage (Joslyn,1970).

The viscosity of an oil decrease with the rise of temperature and increase with saturated and large molecules such as long –chain fatty acids . Prasad and Butt (1989) found that the viscosity to be influenced by change in temperature and decreased exponentially with increase in temperature . Russel (1972) studied various sunflower seeds oil and cottonseed oil heated at 182̊C and observed a small change in the viscosity of cottonseed oil compared to that of sunflower oil which increased after 60 hours of heating , such increase in viscosity was probably due to polymer formation . Richard (1986) reported the normal value of viscosity for crude sunflower oil at 20̊C to be 50 centipoises(cp).Jar Elnabi (2001) reported that, the viscosity of both refined and crude sunflower seed oil was 21.4 and 24.3 (cp) , respectivelyand cottonseed is 29.7 cps (Kabashi2000). Jar alnabi (2001) reported that the viscosity of sunflower oil is 3.14 (cp) . Mohammed (1998) reported that the relative viscosity of Sudanese refined sunflower seeds oil was 31(cp) measured at 30̊C .

2.6.3 Colour

Oils generally coloured ,as they contain in true or colloidal solution varying quantities of different lipodolube pigments originated from oleiferous tissues ,or artifacts caused by degradation ,most usually thermal , during processing –treatments. Standards show that the colour of oil will be creamy white to yellow . Colour is important quality factor ,and in order to maintain a bright colour in the final product,chemical treatment and additives are often used in place of bleaching by heat to inactivate enzymes (Luh*et al* .,1986). Niewiadom,*et al*.(1965) stated that ,the natural colour in vegetables oils and fats is due to presence of the natural pigments or of their decomposition and their a compounded substances e.g . Xanthophylls and other colour substances related to them . Soheil (1979) reported that, decline in colour of oil was closely correlated with increasing amount of carbonyls compounds. Cocks and Van Rede (1972) pointed out that, the determination of colour of oil was based on visual composition with standard by using LovibondTinometer . Colour of crude oilof sunflower as 1.0 yellow tint and 1.0 red tint, or 2.0 yellow tint and 3.0 red tint .and cottonseed yellow 35 , red 1.2.(Kabashi , 2000) . also stated that , the colour of three sunflower oil cultivars grown in Sudan ranged between 4.7 - 4.4 yellow tint , 0.61 -0.58 red tint . Jar alnabi (2001) reported that the yellow colour of sunflower oil is 25 and red colour is 0.1-0.7 tint .

2.6.4 Smoking, flash, and fire points:

The smoking point is the temperature at which a fat or oil gives off a thin bluish smoke. It is measured by a standard method in an open dish specified by ASTM (American Society for Testing Materials) so that the evolution of smoke can be readily seen and reproduced. The flash point is the temperature at which the mixtures of vapor with air will ignite; the fire point is the temperature at which the substance will sustain continued combustion (Basuny 2009) For a given sample of oil or fat, the temperature is progressively higher for the smoke point, flash point, and fire point. The flash point decreases with increase in free fatty acid content in oil and a decrease in chain length. The test is useful in connection with fats used for any kind of frying.

2.7 Chemical characteristics

2.7.1 Iodine number

Iodine number (I N) is the number of milligrams of iodine absorbed by one-gram fat . It is a measure of proportion of unsaturated constituents present in fat . Hence ,it is the halogen addition double bonds of the unsaturated fatty acids and the quantity of halogen take up expressed in terms of iodine as iodine number (Hartley,1967).The iodine number gives an indication of the number double bonds in any particular oil or fat it, however also indicates the total amount of unsaturation. The standard value of iodine number of sunflower oil is 110-143 as reported by (Pearson,1988). Jar alnabi (2001) reported that, the iodine number 129.4 and 126.9 for crude and refined sunflower oil, respectively and INof cottonseed 109.0 . Robertson*et,.al* (1972) reported the iodine number of sunflower oil is 130and 138 for sunflower grown in Northern U.S.A and Canada . The standard value of iodine number of sunflower oil is 110-143 as reported by Pearson (1988) .

2.7.2 Acid value

The acid value (AV) of an oil and fat is defined as the number of milligrams of potassium hydroxide required to neutralize the free fatty acids in one gram of the sample.Standards showed that the acid value: not more than 0.8 mg KOH/g.The AV is measure of the extent to which the glycerides in the oil have been decomposed by lipase action .During frying, fats and oils are oxidized to form hydro peroxides that can decompose further to yield the secondary oxidation products, such as alcohols, ketones, aldehydes and acids. In deep-fat frying, however, acids are also produced by hydrolysis the reaction of fat with water to form free fatty acids (Amany*et al.,* 2012) . Humeid*et al.*(1987) reported that ,the breakdown of the fat to fatty acids was promoted by the presence of water , higher temperature and by the growth of microorganisms in presence of water and increased by molds . Acid value of crude sunflower oil was 0.25-1.75(Huesalope 1974) , and cottonseed as oleic acid was 0.22 , and sunflower oil was 0.34 mg KOH\g (Kabashi 2000) .The development of free fatty acids in oil is usually considered to be one of the main parameters to use in evaluating the quality of oil specially the state of storage and heat . Jar alnabi (2001) reported that , the free fatty acids for refined and crude sunflower oil were 0.5 and 2 % ,respectively , Yousuf*et al.,* (1979) reported a value of 1.8 % free fatty acids for crude sunflower oil . It was determined earlier that , the free fatty acids of crude sunflower oil was 1.0 % (Richard 1986) . Mohammed (1998) reported that free fatty acids of 0.3% for Sudanese refined sunflower oil .

2.7.3 Peroxide value (PV)

Hydroperoxides are the primary products of lipid oxidation; therefore, determination of peroxide value can be used as an oxidation index for the early stages of lipid oxidation (Amany*et al.,* 2012) . Mohammed *et al*.,(2013) noted that peroxides are formed as a result of oxidation ,under normal conditions ,these peroxides can break down in to secondary oxidation products usually containing carbonyl group . Oxidation of lipid to hydroxide , referred to as the peroxide value. The change of PV of oils and fats during storage under controlled condition is an important parameter for detecting their quality .Standards show that the PV of oil not more than 10 milliequivalents of peroxide. Morrison (1981) reported that , sunflower was strong – flavoured at PV 8 m.Eq /Kg or was off-flavoured at P.V of 13m.Eq/Kg . The change of PV of oil and fats during storage under normal and controlled condition is an important parameter for detecting their quality (Hoffmann ,1962) . Kabashi (2000) reported that the PV of cottonseed oil was 8.9 and Jar alnabi (2001) reported that the peroxide number for sunflower oil was 1.07 m.Eq/Kg .

2.7.4 Polymer content (P C)

Polymers are substances made of recurring structural units ,each of which can be regarded as derived from a specific compound called monomer .The properties of a polymer ,both physical and chemical are in many ways as sensitive to changes in the structure of the monomer as are the properties of the monomer itself .Polymers can be classified in several different ways according to their structure ,the types of reactions by which they are prepared, their physical properties or their technological uses . Pokorny*et al,.* (1957)concluded that PC increase with increasing storage period of the oil , oxidative polymerization occurs by the interaction of double bonds and oxygen to form peroxides conjugation of double bonds occurs to stabilize hydroxides . A free radical chain reaction is initiated as hydroxides decompose and the subsequent chain – growth , polymerization reaction gives high molecular weight , cross linked product , the rates of oxidative polymerization increase with extent of conjugation and unsaturation . kabashi (2000) reported that polymer content of crude cottonseed oil was 0.02 and Jar elnabi (2001) reported that the PC for sunflower oil was 1.00% .

2.8 Effect of frying on physical characteristics

2.8.1 Effect of frying on colour

Oil are always more or less coloured, as they contain true or colloidal in solution varying quantities of different liposoluble pigments . This may be lipochromes originated from oleiferous tissues , or artifacts caused by degradation , most usually thermal, during processing –treatments . Most vegetable pigments ,products of their decomposition and their accompanying substances , and xanthophylls and other colour substances related to them. .The oil colour of sunflower variety increased sharply after 48 hrs of heating , and , it has also been found that the change in colour of cottonseed oil upon deep frying at 180̊ C was deeper than that of heated oil (Sonia and Bader eldeen ,1983). Moreover ,the colour of oil was deeper in case of fish or tammiya frying than in potato frying .It has been reported edible oils becomes darker by heating . Kabashi (2000) reported that changes in color of cottonseed oil during frying as yellow 35 and red 1.2 .Hamed*et al.,* (2010) reported that the colour of cottonseed oil yellow was 10 and red 1.08 . Mohammed and Hassan (2013) reported that the red colour was 25.3333 and yellow 70.6666 .Jar alnabi (2001) reported that the colour of sunflower oil yellow is 25 and red 4.8 .

2.8.2 The effect of frying on the refractive index

Increase in temperature of oils and fat causes the R I to decrease , along with decrease in density . Also , the changes for most fatty oils uses found to be between 0.00035 and 0.0004 per degree (Eckey and Lawrence , 1954). The data on physiochemical changes of hydrogenated cottonseed oil during deep frying and continuous heating reported that RI increased in case of frying from 1.4603 to 1.4609 and in case of heating to 1.4620. this indicated that chemical reactions which take place during deep frying were different from those due to continuous heating (Rollier,1977). Kabashi (2000) reported that the RI of cottonseed oil changed from 1.4680 to 1.4700. Shakak (2007) reported that the RI was 1.459 . Jar alnabi (2001) reported that the refractive index of sunflower oil is 1.47243 .

2.8.3 The effect of frying on viscosity

Various studies carried out on sunflower seed oil varieties and cottonseed oils heated at 180̊C indicated that there are small change in viscosity of cottonseed compared to that of sunflower seed which increased rapidly after 60 hours of heating (Robertson and Morrison ,1973).

In the case of continuation of the heat treatment to 48 hours a very marked increase in viscosity has been observed .In addition ,it has been found that changes in the oil during the initial hours of heating may effectively produce material which will slowly polymerize after 12 hours of heating (Johnson and Kummerous ,1957). Kabashi (2000) reported that viscosity of cottonseed oil changes from 29.7 to 32.1 during frying . Ping Tan (2010) reported that the viscosity of frying oil was 50 .Shakak (2007) reported that viscosity was 25.25 centipioses . But Mohammed and Hassan (2013) reported that viscosity was 28.19715 .Jar alnabi (2001) reported that the viscosity of sunflower oil is 3.5952-4.000 .

2.8.4 The effect of frying on smoking point

During frying, decomposition of low-molecular-weight compounds such as free fatty acids and volatile compounds in the oils contributes to the formation of smokes (Azmil andlin 2008). Smoke point is defined as the lowest temperature of a heated oil or fat at which smoke continuously and visibly develops on the surface. It is an important characteristic in deciding when to change the frying oil. Palm olein oil showed the lowest initial smoke point of 208̊C.This observation could be due to the presence of high amount of polyunsaturated fatty acid in oil. The greater the degree of unsaturation, the more rapid the oil tend to be oxidized particularly during deep fat frying (Azmil and Lin 2008). Throughout the frying period of 5 days, the smoke point values obtained were still above typical frying temperature of 180°C and were higher than the dicard point of 170°C.According to (Berger ,2005) the maximum difference of smoke point between fresh and used oil should be within 50°C.

2.9 Effect of frying on chemical characteristics

2.9.1 The effect of frying on iodine value

Various reports on cottonseed , sesame and groundnut oils evaluate that the initial IV were 106.7 , 103.5 and 97.5 (mg/iodine /100g fat) , respectively . When these oils were subjected to temperature of 195̊C , the iodine values decrease gradually in case of cottonseed and groundnut oils but rather sharply in case of sesame oil particularly after 2 hrs of exposure (Khattab*et al* .,1974).It has been concluded that ,the IV of cottonseed and sunflower oils decrease when these oils are subjected to heat (Rrobertson*et,.al*,1972). It has been found that the content of oxidation products was some what higher in case of potato frying than in frying of fish or the leguminous Tammiya paste (Sonia and Badereldeen ,1983) .Kabashi (2000) reported that the IV of cottonseed change during frying from 102.0 to 109.0 . Shakak (2007) showed that iodine value of oil after frying was 63 .Augastin*et al,.(1989)* reported that the IV of sunflower oil was 96.2 in 72 hours at 170 ̊C . Jar alnabi (2001) reported that the IV of sunflower oil was 103. .

2.9.2 The effect of frying on acid value

From frying practices with sunflower seed oils ,it has been reported that after running 75 batches of potato chips an observable increase in acid values has been recorded after the first 30 runs (Fauziah,2000). Kabashi (2000) reported that acid value of cotton seed oil changes during frying from .22 to .37% as oleic acid . Jar alnabi (2001) reported that the acid value of sunflower oil ranged from 0.7093-0.9206 % .

2.9.3 The effect of frying on peroxide value

Gray (1978) pointed out , lipids become rancid because of oxidation , and this oxidative rancidity was a major cause of food deterioration , and rate of oxidation of fatty acids increase in relation to their degree of unsaturation . The same pattern changes were reported in a previous deep-fat frying study (Che Man *et al.,*2005) .This observation could be explained by the fact that peroxides are unstable compounds and will break down to carbonyle compounds during deep-fat frying in the presence of high temperature , air and light . The change of P V of oils and fats during storage under controlled condition is an important parameter for detecting their quality PV of sunflower oil range between 2.29 to 8.54 m.Eq/kg depending on variety and cottonseed oil . Serjouie*et,.al* (2010) reported that the P V after frying is 8 mg\kg. The P V of oil reflects the quality of the raw material used in the extraction of the oil . Kabashi (2000) reported that PV change during frying in cottonseed oil from 8.9 to 21.8 mg\kg .Shakak (2007) reported that PV was 12 . Jar alnabi (2001) reported that the peroxide value of sunflower oil ranged from 1.2-1.6.

2.9.4 The effect of frying on polymer content

In a comparatively elaborate study on changes in cottonseed oil during frying of foods , it has been revealed that amount of polymeric and oxidized glycerides increased by increasing the frying or heating time (Sonia and Badereldeen ,1983). In the Netherland , frying fats can be rejected for consumption on the basis of sensory evaluation as well as when levels of polymeric and diametric triglycerides exceed 10% or diametric triglycerides exceed 6% (Robertson*et,.al*,1984) .The increase in PC due to formation of higher molecuear weight substances by polymerization occurring at elevated frying temperature proceeds . The oil containing higher percentage of polyunsaturated fatty shows the greater tendency to form polymeric compound rather than higher saturated fatty acids containing oil .Kabashi (2000) reported that polymer content in cottonseed oil changes during frying from 0.02 to 3.5% .Mirhosseini (2010) reported that the P C of frying oil was 2.02 % . Shakak (2007) reported that polymer content of frying oil was 4% .Jaralnabi (2001) reported that the polymer content of sunflower oil ranged from 3.133-4.166 .

CHAPTER THREE

MATERIALS AND MATHODS

3.1 Materials

3.1.1 Food materials

Both refined , bleached and deodorized cottonseed oil and sunflower seed oil were used in frying . potatoe chips , tammiya and fish these samples were collected randomly from local restaurants in Khartoum .

3.1.2 Collection of samples

Three samples of 100 volume of frying oil were collected two times a day (morning and evening) before and after frying potato chips , tammiya and fish from three different local restaurants in Khartoum . These oils as the restaurant's owner mentioned they don't repeat the same oil in frying , but they discarded it ., and use new oil for each batch in frying. The collected samples were kept in refrigerator and checked for physicochemical properties .

3.1.3 Chemicals and reagents

Chemicals and reagents used in this study were all of technical grade (BDH) brought from the Industrial Research Center Kartoum, and the stores of the College of Agricultural Studies, Sudan University of Science and Technology .

3.2 Methods

3.2.1 Oil determination

3.2.1.1 Refractive index

The refractive index (RI) was determined by Abbe 60 Refractometer as described by the AOAC (2005). A double prism was opened by means of screw head and few drops of oil were placed on the prism . The prism closed firmly by tightening the screw head. The instrument was then left to stand for minutes before reading in order to equilibrate the sample temperatures with that of the instrument (32°C) . The prism was cleaned between reading by wiping of the oil with soft cloth , then with cotton moistened with petroleum ether and left to dry .

3.2.1.2 Colour

The colour intensity of oils was recorded using LovibondTintometer as units of red , yellow and blue according to the (AOCS 2005). Samples of oils were filtered through filter paper immediately before testing . An appropriate cell (2” cell) was filled with oil and placed in the tintometer near-by window for light .The instrument was switched on and looked through the eye piece . The yellow colour was adjusted to 35, then slides were adjusted until a colour match was obtained from combination of red and blue . The values obtained by matching were recorded as red , yellow and blue .

3.2.1.3 Viscosity

The viscosity of the oil samples was recorded using an Ostwald –U- tube viscometer according to Cocks and Van Rede (1966) . The viscometer was suspended in constant temperature bath (32°C) so that the capillary was vertical . The instrument was filled to the mark at the top of the lower reservoir with the oil by means of pipette into the side arm , so that the tube wall above the mark is not wetted . The instrument was then left to stand for few minute before reading in order to equilibrate the sample temperature with that of the instrument (32 °C). By means of the pressure on the respective arm of the tube , the oil moved into the other arm so that the meniscus is 1cm above the mark at the top upper reservoir . The liquid was then allowed to flow freely through the tube and the time required for the meniscus to pass from the mark above the upper reservoir to that at the bottom of the upper reservoir was recorded by centipoises (cp) .

Calculation :

Relative viscosity of the oil = T-To/To

Where :

T: Flow – time of the oil

To : Flow – time of distilled water .

3.2.1.4 Iodine value

The iodine value (I V) of the oils which quantifies their unsaturation level was determined according to the (British Standard Institute Method 1985). Approximately ,0.2 grammes of oil was accurately weighed and placed in a dry and clean flask specially offered for the test .A 10 ml of chloroform was used for dissolving the oil . A 25 ml of pyridine sulphate dibromide solutions was added and finally 20 ml of KI (0.1 N) were added to the contents of the flask was then stoppered and the mixture was allowed to stand for 10 minutes in a dark place . The stopper and the side of the flask were rinsed with enough amount of distilled water , the contents of the flask was then stoppered and the mixture was allowed to stand for 10 minutes in a dark place .The stopper and the side of the flask were then shaken and titrated against 0.1N sodium thiosulphate solution using starch liquid as indicator . A blank determination was carried out simultaneously .

Calculation:

Iodine value (IV)= (b-a) x 0.01269 x 100 / S

Where :

b; Volume (ml) of sodium thiosulphate in blank solution

a; Volume (ml)of sodium thiosulphate in test active solution

S: Weight (gm) of the oil sample

0.01269 Iodine factor

3.2.1.5 Peroxide value (P V)

Peroxide value (P V) of oils indicates not only the extent of overall oxidation but also resistance of oil to rancidity . The PV of the oil samples was determined according to the AOAC method (2005) . One gramme of the oil was accurately weighed into 250 ml conical flask .Thirty ml of a mixture of glacial acetic acid and chloroform (3 : 2) were added and solution was swirlled gently to dissolve the oil . A 0.5 ml of 0.1N KI was added to the flask and then the contents of the flask were left to stand for one minute before adding 30 ml of distilled water .After a while ,the contents of flask were titrated with 0.01 N sodium thiosulfate until the yellow colour almost disappeared .A 0.5 ml of 1% starch solution was added ,and the titration continued with vigorous shaking until the blue colour completely disappeared . The number of ml of 0.01N sodium thiosulphate required (a) were recorded . The same process was repeated for blanks . The number of ml of 0.01N sodium thiosulphate required by the blank (B) recorded by mg of O2 .

Calculation :

Peroxide value (PV) of the oil = (b-a)X N x 100 /s

Where ;

b; Reading of blank (ml)

a: Reading of oil sample (ml)

S : Original weight of oil sample (gm).

3.2.1.6 Free fatty acids

Free fatty acids content was carried out according to the (British Standard Institute Method 1958) . About five grammes of the oil was weighed accurately into 250 ml conical flask. Fifty ml mixture of 95% alcohol and ether solvent (1:1) were added. The solution was neutralized after addition of one ml of phenolphthalein indicator . The contents of the flask were then heated with caution until the oil was completely dissolved .The contents of the flask were then titrated with 0.01N KOH with constant shaking until a pink colour persisted for 15 seconds .The number of ml of 0.1 N KOH recorded as % .

Calculation :

Free fatty acid as (% oleic acid) = a (ml) x N x 56.1 /S

Where:

a; Reading with sample (ml)

N : Normality of KOH

S : Original weight of sample.

3.2.1.7 Polymer content

It was determined according to Peled*et al.,* (1975) as the portion of the oil which after methanolysis remained insoluble in methanol at 25 ̊C (polymer) to a 500 ml conical flask , were added 250 ml methanol which contained 1% sulphuric acid and 2 g of heated oil .The conical flask was placed on hot plate with a magnetic stirrer inside , the methanol oil mixture was boiled under reflux condenser for 2 hrs and cooled to 25 ̊C .The methanolicmicella was thoroughly decanted off and methanol insoluble were washed with three volumes of 15 ml portion of methanol , also , at 25 ̊C .The insolubles were dissolve in 40 ml petroleum ether (B p 60 -80 ̊C) and transferred to pre – weighed flask .The solvent was evaporated first in a vacuum oven at 60 ̊C and then by placing the flask for 2 hours in an air oven (103 ̊ C) the weight of the polymers was then recorded as follows ;

% polymer content = a x100/S

Where

a = weight of polymer (gm)

S = Orginal weight of sample (gm)

CHAPTER FOUR

RESULTS AND DISCUSSION

4 .1 Physical properties of the used cotton seed oil for frying (tammiya and potato chips) in the restaurants

Table 1. shows that the collected samples of the used cottonseed oil in frying tammiya and chips were significantly different ($P < 0.05$) in viscosity . The results after frying tammiya was 73.4 and after frying chips was 71.3 which were higher than (Kabashi2000) , (Ping Tan 2010) and Mohammed and Hassan (2013) who obtained 29.7to 32.1 ,50 and 28.19715 , respectively .The. refractive index for the collected samples of the used cottonseed oil in frying tammiyaand chips were significantly different ($P < 0.05$) in oil , was 1.4950 after frying tammiya , after frying chips was 1.4780. were no difference compared to (Shakak,2007)and (Kabashi,2000) were 1.459 and 1.4680 to 1.4700 , respectively. Changes in smoking points forthe collected samples of the used cottonseed oil in frying tammiya and chips were significantly decrease in smoking point ($P < 0.05$) , the results were changed in frying tammiya from 217 in the morning to 190̊C in the evening , in frying chips changed from 216 in the morning to 191̊C in the evening . Changes incolour for collected sample of used cottonseed oil after frying tammiya red was 5.33 and yellow was 23 , in frying chips red was 1.4 and yellow was 22 .The colour increase significantly ($P<0.05$) in redness and yellow in case of tammiya frying which were higher than (Mohammed ,2013) , (Kabashi, 2000) and (Hamed,2010) were 25.333 ,35 and 1.8 , respectively . Yellow colour 70.6666 ,35 and 10 , respectively.

Table 1: Physical properties of the used cottonseed oil for frying of tammiya and potato chips in restaurants.

Sample	Viscosity		Refractive index		Smoking point		Colour R		Colour Y	
	Frying									
	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening
Tammiya	65.63[c] ±1.06	73.43[a] ±1.05	1.474[d] ±0.0	1.479[a] ±0.0	217.00[a] ±1.00	191.30[b] ±1.53	1.400[b] ±0.10	5.33[a] ±0.31	29.67[a] ±1.53	23.00[b] ±2.65
Chips	67.07[a] ±1.00	71.00[b] ±1.00	1.475[c] ±0.0	1.478[b] ±0.0	216.00[a] ±1.00	191.00[b] ±1.00	1.40[b] ±0.10	1.367[b] ±0.06	28.67[a] ±1.53	22.00[b] ±2.65
$Lsd_{0.05}$	1.936*		0.0005954*		2.174*		0.3206*		4.068*	

Values are mean±SD.

Any two mean value(s) sharing same superscript(s) are not significantly different (P >0.05)

Where:

* = Significantly different

**= High Significantly

n . s = no Significantly

4.2Physical properties of the used sunflower oil for frying (fish) in restaurants

Table 2. shows that the collected samples of the used sunflower oil in frying fish in morning compared to evening were significantly different ($P < 0.05$) in viscosity . The viscosity changed from 56.77in the morning to 62.50 in the evening ,these results were highcompared to (Jar alnabi,2001) , (Ping Tan ,2010) and (Mohammed and Hassan ,2013) who found 4.685 , 50 and 28.19715 ,respectively . Changes inrefractive index for collected samples of used sunflower oil after frying fish insignificantly different ($P < 0.05$) was 1.4850 , no difference when compared to (Shakak,2007) , (Jar alnabi2001) were 1.459 and 1.47243 ,respectively.Smoking point for collected samples of used sunflower oil after frying fish high significantly decreased ($P < 0.05$) in oil ,changed from 224̊C in the morning to 195̊C in the evening . The colour increase significantly ($P<0.05$) in case of fish frying the result after frying fish red was 7.00 and yellow was 29.00 . there were high significantly different in redness but insignificantly different in yellow colour , these results were high than(Hamed,2010) and(Jar alnabi,2001) were 10 and 25 in yellow and 1.08 and5.7 in red colour, respectively .

Table 2: Physical properties of the used sunflower oil for frying of fish in restaurants

Sample	Viscosity		Refractive index		Smoking point		Colour			
							R		Y	
	Frying									
	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening
Fish	56.77 ±1.00	62.50 ±1.21	1.4866 ±0.001	1.48743 ±0.001	224.00 ±1.00	196.00 ±1.00	2.13 ±0.15	7.43 ±0.38	31.73 ±2.83	29.00 ±1.00
P-value	0.042^{*}		$0.4661^{n.s}$		0.0017^{**}		0.0019^{**}		$0.2518^{n.s}$	

Values are mean±SD.

4.3 Chemical properties of used cottonseed oil for frying (Tammiya and potato chips) in restaurants

Table .3 shows that the collected samples of the used cottonseed oil used in frying potato chips and tammiya . The free fatty acids as oleic significantly increased ($P < 0.05$) in frying tammiya, in the morning was 0.24 and in the evening was 0.73 ,but in case of frying chips in the morning was 0.17 and in the evening was 0.145342 . These results were less than (Mohammed 2013) and(Kabashi2000) were 0.299767 and from 0.22 to 0.37 , respectively.Changes in free fatty acids as palmatic of cottonseed oil used in frying potato chips and tammiya was significantly increased ($P < 0.05$) in used oil . Changes in polymer content (P C) for collected samples of used cottonseed oil used in frying of tammiya and chips significantly increased ($P < 0.05$) in cottonseed oil with high percentage of polymers after frying tammiya changed from 0.73 in the morning to 6.7 % in the evening , in chips frying changed from 0.82 in the morning to 5.3%in the evening , compared these results were similar to (Shakak,2007),(Kabashi,2000) And (Mirhosseini,2010) were 1% to 4% , 0.02 to 3.5% and 2.02 % , respectively . Changes inperoxide value (P V) for collected samples of used cottonseed oil were significantly increased ($P < 0.05$)in oil by frying of tammiya and chips. (Kabashi,2000) was noted that the rate of formation of peroxides was faster in cottonseed oil compared with other vegetables oil .The results were changed in frying tammiya from 7 in the morning to 10 in the evening and in frying chips was 9 in the morning to 11 in the evening ,these results weresame when comparedto(Serjouie,2010) , (Kabashi,2000) and (Shakake,2007) who found that the (P.V) after frying is 8 mg\kg , 8.9 to 21.8 mg\kg and 12 mg\kg ,respectively .The PV of oil reflects the quality of the raw material used in the extraction of the oil . Changes iniodine value (I V) for collected samples of used cottonseed oil used in frying tammiya and chips were significantly decreased ($P < 0.05$) in oil by frying , in frying tammiyathe results changed from119 in the morning to 108 in the evening ,and after frying chips changed from 121 in the morning to 110 in the evening . These results were the same as (Kabashi 2000) and (Shakak2007) were 102.0 to 109.0 and 63 , respectively. Decrease in IV of oil by frying was reported by (Khattaab*et al.,*1974) in groundnut ,cotton seed and sesame oil.

Table 3: Chemical properties of the used cottonseed oil for frying of tammiya and potato chips in restaurants .

Sample	F.F.A as oleic %		F.F.A as palmatic %		Iodine value (mg/kg)		Peroxide value (mEq/kg)		Polymer content (%)	
Frying	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening
Tammiya	0.24^{b} ±0.01	0.74^{a} ±0.01	0.23^{d} ±0.01	0.68^{c} ±0.01	119.00^{b} ±1.00	108.00^{d} ±1.00	7.00^{c} ±1.00	10.00^{ab} ±1.00	0.71^{c} ±0.05	6.50^{a} ±0.20
Chips	0.17^{c} ±0.01	0.15^{d} ±0.01	1.14^{a} ±0.01	1.04^{b} ±0.01	121.60^{a} ±0.95	110.00^{c} ±1.00	9.00^{b} ±1.00	11.00^{a} ±1.00	0.83^{c} ±0.02	4.23^{b} ±0.12
$Lsd_{0.05}$	0.0005954^{*}		0.0005954^{*}		1.86^{**}		1.883^{*}		0.2228^{*}	

Values are mean±SD.

Any two mean value(s) sharing same superscript(s) are not differ significantly (P≤0.05).

4.4 Chemical properties of the used sunflower oil after frying fish in the restaurant:

Table .4 shows that the collected samples of the used sunflower oil in frying fish were significantly increase ($P < 0.05$) in free fatty acids as oleic changed from 0.45 in the morning to 1.26% in the evening .These results were high compared to (Jar alnabi, 2001) ,(Mohammed 2013) and (Kabashi2000) were 0.92 ,0.2997 and 0.22to0.37 % , respectively . Changes in free fatty acids as palmatic for collected samples of used sunflower oil in frying fish changed from 0.36 in the morning to 1.15 % in the evening .The free fatty acids as palmatic significantly increased ($P < 0.05$) in oil . Changes in polymer content for collected samples of used sunflower oil in frying fish significantly increased ($P < 0.05$) in oil with higher percentage of polymers , results changed from 0.74 in the morning to 4.45 in the evening and no difference when compared to (Jar alnabi 2001) and (Mirhosseini2010) who found 3 to 4 % and 2.02 , respectively . Changes inperoxide value for collected samples of used sunflower oil used in frying fish insignificantly increased ($P < 0.05$) in oil by frying of fish.The results were changed from 8 in the morning to 12 in the evening ,there is large difference in results compared to (Serjouie 2010) and (Jaralnabi2001) who reported 8 mg\kg and 1.60 ,respectively . Changes iniodine valuefor the collected samples of the used sunflower oil in frying fish , insignificantly decreased ($P < 0.05$) in oil . The results were changed from 116.5 in the morning to 113 in the evening , which were high compared to(Jar alnabi2001) were 106 to 101.0 .Decrease in IV of oil by frying was reported by (Khattaab*et al.,*1974) in groundnut ,cotton seed and sesame oil .

Table 4: Chemical properties of the used sunflower oil for frying of fish in restaurants.

Sample	F.F.A as oleic %		F.F.A as palmatic %		Iodine value (mg/kg)		Peroxide value (mEq/kg)		Polymer content (%)	
	Frying									
	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening	In the morning	In the evening
Fish	0.45 ±0.01	1.26 ±0.01	0.36 ±0.015	1.15 ±0.01	116.50 ±1.10	113.00 ±1.00	8.00 ±1.00	12.00 ±1.00	0.74 ±0.01	4.45 ±0.13
P-value	0.0002**		0.0002**		0.102 n.s		0.0572 n.s		0.0004**	

Values are mean±SD.

Any two mean value(s) sharing same superscript(s) are not differ significantly ($P \leq 0.05$)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- The use of edible oil for frying purpose affects their physicochemical attributes through increase in viscosity ,colour ,free fatty acids ,peroxide value (PV) polymer content (PC) and decrease in smoking point and iodine value (IV) .
- Edible oils differ in their thermal susceptibilities to frying .
- Type of product used in frying affect on physicochemical properties of oil such as (PV),(PC)and (IV).
- Potato product induce less change in physicochemical properties of oil than tyammiya and fish.
- The oils collected from different restaurants were deteriorated .

2.5 Recommendations

1. Sudan is considered potentially rich source for different types of oil seed crops, more wise polices are need to secure the production and lowering cost .
2. Using other alternative ways for frying process e.g vacuum frying to minimize the adverse changes of physicochemical properties of oil .
3. More samples of used oil in different fried products are need to be collected and analyze.
4. The used fried oil in restaurants should be discarded .

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