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IMPACT OF BIOACTIVE COMPOUNDS ON IMPROVING THE OXIDATIVE STABILITY OF GROUNDNUT AND MUSTARD OILS

Rubalya Valantina S.[1*], Phebee Angeline D.R.[2], Mukesh Kumar V.[2]

1 Department of Physics, School of Electrical & Electronics Engineering, SASTRA University, Thanjavur, India-613401;
2 Department of Biotechnology, School of Chemical & Biotechnology, SASTRA University, Thanjavur, India-613401;
SASTRA University, Thanjavur, India-613401;
** rvalantina@gmail.com*

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ABSTRACT
Physical and chemical properties of groundnut oil and mustard oil are studied at different concentrations of two antioxidants Tocopherol and Tert- Butyl Hydro Quinone (TBHQ). Classification of vegetable oils in terms of their usage safety, stability in transport, easy reuse characteristics and overall health benefits is vital to categorize them for quality. Hence, to increase the shelf life of oil in cooking and pipelining, vegetable oils are added with different concentration of antioxidants to improve the permanence. Properties like viscosity, relative density, electrical quality factor and acid value are analyzed with the addition of antioxidants. Variation of viscosity with temperature for different concentration of oil was observed. Empirical equations like Wright's ASTM Equation and Akerlof - Oshry's relating viscosity with temperature are computed and compared and Wright model (R^2= 0.999-0.995) is highly correlated. The experiential value of relative density and acid value show good variation with the addition of tocopherol even below 10 mg/100 mL and random variations with TBHQ. The present study also states that addition of TBHQ to groundnut oil do not produce any synergistic effect with the antioxidant in the oil and also do not impede the oxidation reaction effectively.

1. Introduction

Vegetable oils are also much used in the food industry and are found to have an exponential rise with developing civilizations over the past few decades. Extraction and production of vegetable oil are more in South America and south East Asian countries. They are the suppliers of edible oil to every part of the world (Fasina, 2006). Hence the physical and chemical property of the oil should be maintained for economic transfer. The individualistic properties of oil are pre-determined by their constituent molecules and their behavior at various cooking conditions. With continued exposure to atmosphere at higher heating conditions, the oils achieve a state called rancidity where the double bonds of the unsaturated fatty acids undergo cleavage to release oxidative products (Augustin, 1987). The subsequent effect observed in the oils is highly harmful for consumption. The super-oxides and other free radicals released as the aftermath products of oxidation are capable of eliciting chain reactions within the cell machinery, leading to permanent DNA damage (Augustin, 1987; Williams, 1999).

Lipids, the predominant substrates of oils usually exist in a non-radical singlet state and at times of high exposure to heat; the rate of radical formation is greatly accelerated. When these lipid radicals are formed in the oil, they tend to react with the free oxygen ions in sequential chain reactions, catalyzing auto-oxidation (Soriguer, 2003; Rubalya and Neelamegam, 2015). Thermal oxidation occurs faster than auto-oxidation while the primary oxidation product peroxide gives rise to secondary oxidation products like aldehydes and ketones. These secondary products are the major reason for causing rancidity in oil (Kochhar, 2000).

As an inherent measure of reducing the risk factors, oils contain components called antioxidants that inhibit the process of oxidation, operating at a certain limit (Becker, 2007; Jan Pokorny, 2001). Antioxidants are often extracted from both their natural sources and chemical sources. Tocopherols, Ascorbic acid, Carotene-compounds, phyto-sterol, sterol, oryzanol, etc. are the most commonly occurring antioxidants in oil by nature. There are some synthetic antioxidants like Butylated Hydroxy Anisole (BHA), Butylated Hydroxy Toluene (BHT), Propyl Gallate (PG) and Tert- Butyl Hydro Quinone (TBHQ) added by the distributers to improve the shelf life of the oil (Rubalya and Neelamegam, 2012; Kousuke Hiromori, 2016). Some antioxidants, for example, Tocopherol exists in various forms like α-, β-, γ-, δ-tocopherols (Jan Pokorny, 2001). These antioxidants also play a pivotal role in extending oil's shelf life and keeping it away from rancidity, thereby enabling a manageable extent of oil reuse. Tocopherol and its derivatives are lipophilic antioxidants that are capable of active alkoxyl and peroxyl scavenging. The most important role of tocopherol lies in protecting lipid containing food substances from oxidative stress and damage during prolonged usage and storage (Rubalya and Neelamegam, 2012). TBHQ is a hydro quinone derivative that is extensively used in industries as stabilizers that restrict or stop auto-polymerization of organic peroxides. As a preservative for saturated vegetable oils, TBHQ is found to be fairly inert without causing many changes to the oil it was added. The flavor and odor of the oil remains the same even after TBHQ addition (Kousuke Hiromori, 2016).

The addition of antioxidants is done in significantly low concentrations that are capable of delaying or inhibiting the oxidation of lipid substrates in the oil. It is important that the antioxidants are stable, non-reactive with undesirable substrates, non-toxic and capable of trans-membrane passage. It is also a notable quality of a good antioxidant when the color, flavor, texture and the skeletal physical properties of oil remain the same before and after its addition. Addition of high concentration of antioxidant will alter the behavior of oil leading faster in producing toxic effect in human health (Jun Li, 2014). In addition, antioxidants plays a significant role in donating H+ ions to $RCOO^-$ radical and hence in preserving the quantity of fatty acids that alters the physical and chemical properties of oil. This can be used to enhance the shelf life of oil under storage and also reduce the transportation costs by lowering the viscosity of oil which leads to efficient pumping (Jan Pokorny, 2001). Viscosity of oil plays a major role when oil is transported in bulk across different compartments or through pipes.

Polar molecules (peroxides, ketones, free fatty acids, triglycerides etc.) in the oil can follow the changes in the direction of the electric field, when it is kept in an external field. As the frequency continuously increases, the dipole motion can no longer keep up with the changing field due to its relaxation time (Jun Li, 2014). Quality factor of oil is the ratio of permittivity with imaginary loss in the medium at external electric field. The permittivity of edible oils at room temperature ranges from 3.0 to 1.9 with respect to frequency (Rhet de Guzman, 2009). In the present work, physical and chemical parameters; viscosity, relative density, electrical quality factor and acid value are experimented at different concentration of antioxidants - tocopherol and TBHQ. This study will help understanding the inherent antioxidant property of the oils as well as their behavior in the presence of added natural and synthetic antioxidants. The variation of viscosity with respect to temperature and the concentrations of antioxidant give an understanding of oxidative stability in the oil.

2. Materials and methods

To compare the oxidative stability of Groundnut (*Apios americana*) oil and Mustard oil (*Brasicca compestriss*), the oils fresh samples were purchased from a local supermarket in Trichy, Tamil Nadu. The basic composition of oil was noted down for reference. The various reagents used in physical parameters were purchased from SLR (Standard Laboratory Reagent) grade. TBHQ (tert- butyl hydroquinone) and α-tocopherol antioxidants were procured from Sigma Aldrich Chemicals India Private Ltd. The antioxidants used for this study were both natural and synthetic of origin. Tocopherol was purchased as Vitamin E EVION capsules from a local pharmacy. 16 samples with groundnut and mustard oils along with different concentration of antioxidants were prepared and 2 samples of fresh oil were taken for the study. The maximum concentration used in the studies, as per FDA (Food and Drug Administration) rules, is 0.02%. Thus a gradient of antioxidant concentrations was dissolved in the oil for preparing the samples. Increasing concentration of antioxidants (0mg, 5mg, 10mg, 15mg and 20mg) was added in five 100 mL samples of groundnut and mustard oil. These 20 samples were kept in dark bottles with a paper being wrapped around them to offer protection from external atmospheric conditions and thereby ambient temperature was maintained.

Heating was provided by keeping the oil sample in a copper beaker and placed in a water bath. The whole set up is aided by an electric device. The range of temperatures maintained for the oil samples is 303K, 313K, 323K, 333K, 343K, 353K, 363K and 373K.

A. Physical parameters

a) Measurement of Viscosity: Kinematic viscosity of oil using laminar flow was experimented using redwood viscometer (ASTM D445-American Society for Testing and Materials) manufactured by New Delhi-Associated Instrument Manufacturers, India Private Limited.

b) Measurement of Relative Density: Relative Density of the oil samples was measured using a Pycnometer (ASTM D891-09) calibrated with an accuracy range of ± 0.2 kg m^{-3}.

c) Measurement of Dielectric Constant: Dielectric constant of the oil was measured by the capacitive method (DCK-001,Mittal enterprises, New Delhi, India) at 2MHz. Dielectric constant from 1Hz to 10MHz was measured in accordance with the standard of IEC 61620. All dielectric measurements follow ISO 9001:2000.

B. Chemical parameters

a) Measurement of Total Acid Value (TAN): Acid Value is measured by a simple titrimetric analysis method. Oil samples with varying concentrations of antioxidants are dissolved in solvent system containing ethanol and diethyl ether. Using 0.1N KOH as burette solution and phenolphthalein as indicator, titration is carried out till an end point of pale pink is observed for about 10-15 seconds. The set up follows ASTM D664.

C. Statistical analysis

The independent parameter temperature and dependent parameter viscosity listed in Table 1 were fitted with Akerlof and Oshry's Equation and Wright ASTM using SPSS (version 12). Akerlof and Oshry's Equation relating viscosity to temperature was correlated for 18 oil samples and determination coefficient R^2 was observed between 0.871 and 0.994. Whereas Wright ASTM equation using least square fitting exemplify determination coefficient R^2 ranges between 0.992 – 0.999. Table 2 and 3 explicate the computed values of constant A, B, C, D and R^2 for the oil sample with different concentration of antioxidants with the temperature.

3. Results and discussions

A. Physical Property

a)Variation of viscosity with temperature

Viscosity variation with respect to temperature was determined for pure groundnut and mustard oil also other 16 samples added with natural and synthetic antioxidants. Table 1 illustrates the variation of kinematic viscosity with the change in the concentration and temperature 303 – 373K. It was observed that as temperature increases there's a consequential decrease in the viscosity of the oil. Groundnut oil has larger 34% of polyunsaturated fatty acids (PUFA) and 47% of monounsaturated fatty acids (MUFA) (El-Shami, 1992). With the addition of natural antioxidants the % of variation of viscosity decreases in steps of 52.6%, 46.7%, 42.6%, 42.4% and 41.9%. Viscosity has direct relationship with the chemical composition of oils such as chain length of fatty acids and unsaturated compounds. Viscosity is negatively correlated with unsaturation; hence it decreases with increase in unsaturated fatty acids (Kim, 2010). There is more rapid decrease in viscosity with increase as the % of PUFA is high compared to MUFA. The polyunsaturated fatty acid exists in *cis* form and there is no interaction between the molecules. Hence with increase in temperature due to thermal acceleration the molecule gets agitated in the direction of flow and the viscosity decreases. Addition of TBHQ with groundnut oil was pragmatic that the % of variation of viscosity with increase in concentration and temperature differ in steps of 75%, 78.8%, 82.3% and 73%.

Mustard oil has 12% of oleic acid (C18:1), *Erucic* acid 42% (C22:1), PUFA 21% (Wanasundara and Shahidi, 2005), hence it has more percentage of monounsaturated fatty acids. The % of variation of viscosity with concentration of tocopherol and temperature found to be 63.2%, 56%, 53.8%, 52%, 51.4%. Whereas with the addition of TBHQ, 68%, 71.7%, 74.4% and 73%. Early studies have stated that viscosity is highly correlated with polyunsaturated fatty acids than monounsaturated fatty acids (Choe and Min, 2007; Kim, 2010). Mustard oil has high percent of long chain erucic acid. Hence the % of variation of viscosity in mustard oil is high compared to groundnut oil. The studies also exemplify the synergistic effect of added antioxidant with antioxidants in oil. The maintenance of viscosity would be much useful in the transportation of oil from one part of the world to another which is at different temperature reducing the cost of transportation and pipelining. The behavior of viscosity with the addition of natural antioxidant is more cooperative compared to TBHQ. Hence addition of tocopherol to the oil in retaining the property would be more beneficial.

Variation of viscosity with temperature can be investigated to analyze the correctness of the computed value with the experimental, predict the intermediate value of viscosity at any temperature and quality analysis of the food samples (Hosahalli Ramaswamy, 2015). Empirical modelling equations were employed to understand the viscosity-temperature correlations. The equation was fitted with the experimental values using least square fitting and the constants with the correlation coefficient (r^2) was analyzed using SPSS software and tabulated in Tables 2 and 3.

Table 1. Viscosity of Groundnut and Mustard Oil Varying with Temperature added with antioxidants.

Type Of Oil	Anti – Oxidants	Concentration mg/100 mL	Viscosity x 10^{-6} (m^2/s)							
			303 K	313 K	323 K	333 K	343 K	353 K	363 K	373 K
Groundnut Oil	α Tocopherol	0	56.45	44.9	36.32	22.02	20.21	17.36	14.31	11.26
		5	46.93	36.9	29.7	22.6	19.04	16.32	13.63	10.99
		10	43.92	34.76	27.28	21.5	18.24	15.72	13.17	10.68
		15	42.64	33.26	26.14	20.77	17.39	14.78	12.42	10.13
		20	42.2	32.74	25.27	19.99	16.16	13.26	11.07	8.95
	TBHQ	0	56.45	44.9	36.32	22.02	20.21	17.36	14.31	11.26
		5	75.81	42.56	28.38	21.41	18.62	12.39	14.74	7.94
		10	78.92	43.07	28.59	21.69	18.5	14.53	12.56	8.05
		15	82.46	48.74	32.28	23.61	21.59	17.27	13.3	8.36
		20	73.32	43.64	29.36	22.66	19.83	15.95	13.38	8.69
Mustard Oil	α Tocopherol	0	63.38	46.91	34.49	25.72	20.69	17.13	13.84	10.47
		5	56.39	42.88	32.56	25.11	20.43	16.96	13.97	11
		10	54.1	41.06	31.29	24.42	19.61	16.02	12.86	10.57
		15	52.21	39.76	30.33	23.62	19.11	15.74	12.57	10.36
		20	52.61	39.50	28.77	21.55	17.33	14.32	10.9	8.81
	TBHQ	0	63.38	46.91	34.49	25.72	20.69	17.13	13.84	10.47
		5	68.32	51.81	39.95	31.3	24.88	20.02	16.33	13.46
		10	72.04	59.74	49.93	42.03	35.63	30.4	22.54	20.1
		15	74.53	49.48	34.06	24.22	17.72	13.29	10.2	7.99
		20	73.24	49.22	34.23	24.54	18.08	13.64	10.53	8.28

Table 2. Akerlof and Oshry's Modelling Equation relating viscosity and Temperature.

Type Of Oil	Values	$\eta = A/T + B + C*T + D*T^2$								
		Pure	0.05 g/L Toco	0.10 g/L Toco	0.15 g/L Toco	0.20 g/L Toco	0.05 g/L tbhq	0.10 g/L tbhq	0.15 g/L tbhq	0.20 g/L tbhq
Groundnut Oil	r^2	0.989	0.986	0.994	0.994	0.985	0.873	0.871	0.893	0.893
	A $x10^4$	3.2	2.8	2.59	2.52	2.60	4.60	4.80	5.13	4.46
	B	486.4	395.1	369.1	365.1	377.7	1111	1155	1121	982.5
	C	-3.02	-2.45	-2.29	-2.26	-2.35	-6.86	-7.14	-6.95	-6.08
	D x 10^{-3}	4.06	3.30	3.05	3.02	3.14	9.56	9.95	9.62	8.40
Mustard Oil	r^2	0.972	0.963	0.971	0.971	0.965	0.972	0.983	0.982	0.985
	A $x10^4$	4.06	3.51	3.39	3.26	3.40	4.29	4.17	5.03	4.96
	B	673.3	541.8	514.3	493.3	553.4	640.6	372.8	993.0	953.1
	C	-4.19	-3.37	-3.20	-3.07	-3.45	-3.99	-2.34	-6.18	-5.94
	D x 10^{-3}	5.68	4.50	4.30	4.12	4.66	5.35	2.92	8.50	8.10

Table 3. Wright's ASTM Modelling Equation relating viscosity and Temperature.

Type Of Oil	Values	Ln Ln(η) = A + B*Ln T								
		Pure	0.05 g/L Toco	0.10 g/L Toco	0.15 g/L Toco	0.20 g/L Toco	0.05 g/L TBHQ	0.10 g/L TBHQ	0.15 g/L TBHQ	0.20 g/L TBHQ
Groundnut Oil	r^2	0.996	0.997	0.997	0.998	0.998	0.998	0.990	0.996	0.999
	A	6.625	6.079	5.993	6.174	6.805	8.391	8.544	8.266	7.909
	B	-2.283	-2.213	-2.182	-2.256	-2.510	-3.130	-3.190	-3.074	-2.936
Mustard Oil	r^2	0.997	0.998	0.998	0.998	0.996	0.990	0.995	0.992	0.992
	A	7.124	6.611	6.679	6.755	7.568	6.355	4.809	9.160	8.921
	B	-2.621	-2.419	-2.484	-2.480	-2.807	-2.308	-1.681	-3.434	-3.338

Table 4. Dependence of Relative Density, Acid Value and Dielectric Constant of Groundnut and Mustard oil with the concentration of antioxidants.

Oil	Antioxidant	Concentration mg/100 mL	Acid Value mg (KOH / g)	Dielectric Constant	Relative Density (g/L) at 25 °C
Groundnut Oil	α – Tocopherol	0	3.402±0.001	3.59±0.06	0.926±0.002
		5	3.235±0.07	3.25±0.03	0.914±0.003
		10	3.107±0.01	3.14±0.05	0.918±0.009
		15	2.224±0.04	3.25±0.03	0.919±0.007
		20	1.910±0.001	3.31±0.08	0.916±0.006
	TBHQ	0	3.446±0.01	3.59±0.06	0.926±0.002
		5	3.328±0.02	3.59±0.04	0.919±0.004
		10	3.305±0.08	2.98±0.05	0.923±0.006
		15	2.562±0.05	2.89±0.01	0.920±0.004
		20	2.210±0.001	2.99±0.02	0.924±0.001
Mustard Oil	α – Tocopherol	0	5.213±0.003	2.98±0.02	0.904±0.006
		5	4.202±0.002	3.09±0.0	0.921±0.005
		10	4.190±0.01	3.31±0.07	0.913±0.008
		15	3.202±0.001	3.33±0.05	0.920±0.002
		20	2.524±0.04	3.23±0.03	0.924±0.005
	TBHQ	0	5.516±0.02	2.98±0.02	0.904±0.006
		5	4.473±0.04	3.23±0.07	0.926±0.005
		10	4.370±0.003	3.21±0.05	0.929±0.007
		15	3.617±0.002	3.26±0.01	0.915±0.009
		20	2.724±0.04	3.14±0.04	0.908±0.006

Values are expressed by mean ± SD of three independent observations, with significance p-value<0.001

i. Akerlof and Oshry's Equation

Temperature and Viscosity dependent models are a key analytic tool to determine oil quality and antioxidant capacity. Using appropriate viscosity measurements at set temperatures, one can qualitatively assess the activity of the antioxidant added and also the nature of the oil at that state. Antioxidants increase the stability of oil by preventing rapid proliferation of free radicals which lead to primary oxidized products like peroxides, ketones, aldehyde, esters etc. This leads to a decrease in overall viscosity of sample. Thus, compared to pure oil the viscosity of oils with antioxidants must have a lesser viscosity at any temperature.

$$\eta = A/T + B + C\cdot T + D\cdot T^2 \quad (1)$$

Behavior of oxidative stability and flow characteristics of ground nut oil and mustard oil with temperature. The r^2 value lies in the range of 0.871 to 0.994 for the groundnut oil added with tocopherol and TBHQ. It is observed from the table the variation of viscosity with additional natural antioxidant is much correlated with temperature and has accuracy of 2-3%. The r^2 value for TBHQ is less and has deviation of viscosity from experimental to computed value of 7-9%. Which show TBHQ is not synergistic with the antioxidants in the oil. The constant A and B values are computed and tabulated in Table 2.

In mustard oil, the r^2 value lies in the range of 0.963 to 0.985 for the oil added with tocopherol and TBHQ. It is observed from the table the variation of viscosity with additional natural antioxidant and TBHQ is much correlated with temperature and has variation in accuracy of 3-5%. The data show that both the antioxidants are synergistic with the antioxidants in mustard oil. The constant A and B values are computed and tabulated in Table 2.

ii.Wright's ASTM Equation

$$\text{Ln Ln } \eta = A + B\cdot \text{Ln } T \quad (2)$$

This equation relates the behavior of unsaturation nature and flow characteristics of ground nut oil and mustard oil with temperature ([a]Rubalya, 2015). The r^2 value lies in the range of 0.996 to 0.999 for the groundnut oil added with tocopherol and TBHQ. It is observed from the table the variation of viscosity with additional natural antioxidant and TBHQ is much correlated with temperature and has deviation of viscosity from calculation less than 1%. The % of accuracy is less for TBHQ compared to tocopherol hence it is experiential to have less synergistic with the antioxidants in the oil. The constant A and B values are computed and tabulated in Table 3. These constants could be used in predicting the viscosity at any desired temperature within the range. In mustard oil, the r^2 value lies in the range of 0.992 to 0.998 for the oil added with tocopherol and TBHQ. It is observed from the table the variation of viscosity with additional natural antioxidant and TBHQ is much correlated with temperature and has deviation less than 1%. The % of accuracy is less for TBHQ compared to tocopherol hence it is comparatively less synergistic with the antioxidants in the oil. The constant A and B values are computed and tabulated in Table 3.

b) Variation of viscosity with concentration

Table 1 illustrates that addition of antioxidant decreases the viscosity of oil by inhibiting the formation of peroxide which initiate rancidity in oil. Concentrations of antioxidant play an important role in increasing the shelf life of the oil ([b]Rubalya, 2015). From Table 1 it is observed viscosity decreases with the increase in the concentration of tocopherol but random variation is observed with TBHQ. The behavior is neither linear nor non- linear hence attempt in correlating with empirical equations could not be done using the concentration of antioxidants. For tocopherol, the behavior of viscosity with increase in concentration up to 20 mg/100 mL has good correlation coefficients but with TBHQ there was poor correlation coefficient. The study indicates that the addition of natural antioxidants more synergistic compared to TBHQ.

c) Relative density

The ratio of the density of groundnut and mustard oil to the density of water was practical to be 0.926 for groundnut oil and 0.904 for mustard oil. The specific gravity value for mustard oil is low due to the high content of erucic acid. It was supported by the early research that oil which contains more % of monounsaturated fatty acids has less specific gravity value compared to the oil that has higher % of polyunsaturated fatty acids. Throughout the experiment, the overall stability of the oil is maintained with the addition of antioxidants. Table 4 show that relative density of groundnut oil decreases with increase in the concentration of antioxidants. With the addition of Tocopherol the specific gravity values get reduced by 1.29% and maintain the same with increase in concentration. Addition of TBHQ reduces the relative density value by 0.53% and retains the change. Mustard oil added with tocopherol increases the relative density value by 2.1% whereas the specific gravity value with the addition of TBHQ increases by 2.7%. The relative density of groundnut oil decreases with the addition of antioxidants whereas mustard oil the parameter increased. The increase is observed to be more with TBHQ may be due to the synergistic effect between the natural antioxidant present in the oil with the synthetic TBHQ. But it was observed with the presence of antioxidants, the relative density of the oil is fairly maintained as a constant, thus extending the original property of the oil for a longer shelf life.

B. Chemical Properties

a)Total Acid Value (TAN)

Acid value corresponds to the degree of acidity existing in the oil sample. Oils are known to contain inherent quantities of fats, which when heated beyond a range are converted into acid products. For examples, triglycerides are converted into glycerol and fatty acids. This increase in acid products is an accurate measure of oil quality and helps determining the state where oil reaches rancidity. To study the TAN value the oil sample was added with antioxidants, stir thoroughly until it becomes homogeneous. The sample was left for a couple of days and the variations of TAN with the concentration of antioxidants are illustrated in Table 4. It was experimental that acid values ranges from 3.402 to 1.91 mg KOH/g with the addition of tocopherol with groundnut and 5.213 to 2.524 for mustard oil. The addition of TBHQ to the groundnut oil, the TAN values varies from 3.446 to 2.213 mg KOH/g. Mustard oil added with TBHQ show slight increase in the acid value 5.516 to 2.724 mg KOH /g. Any how the antioxidants maintain fairly a constant rate of TAN value index to maintain the quality of oil.

b) Electrical property

Electrical quality factor was measured at frequency ranges from 1-10^7 Hz as shown in Figure 1. The ratio of the dielectric constant and the loss from the capacitance and the resistance is termed as Quality factor (Q) represented below:

$$Q = 1/\tan ø = \varepsilon' / \varepsilon'' = Rp \cdot Cp \quad (3)$$

where the dielectric constant is represented as ε', capacitance of the parallel plate capacitive cell represented as $C_{p,}$ resistance of the sample is denoted as Rp and ø is the impedance phase angle. Dielectric constant depends on the polarization effect in the oil (Dilip Kumar, 2013). The variation of dielectric constant with respect to frequency ranges from 1-10^7Hz is highly due to study the polarization of orientation, ionic and electronic variation of dipoles. The increase in passage of current induces furthermore dissipation of electromagnetic energy and thus results in a higher dielectric loss.

Quality factor Q is the important property in the excellence analysis of the oil which reflects the characteristics of polar compound with the change in the dielectric constant. The ratio of loss factor and dielectric constant (ε''/ ε') decides the quality factor of the oils (Fritsch, 1981). Figure 1 illustrates the observed Q-factor for pure groundnut oil in the presence of alternating electric field with the addition of tocopherol and TBHQ at different concentrations.

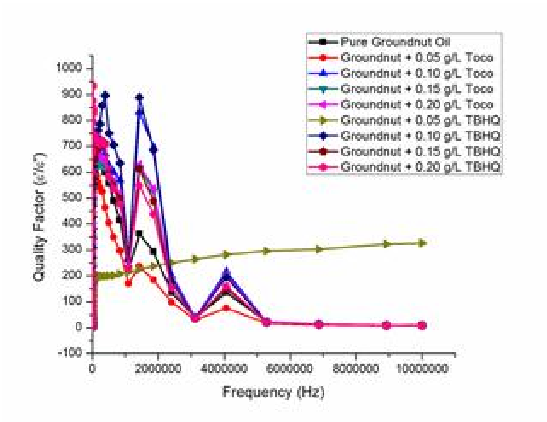

Figure 1. Dependence of quality factor of groundnut oil added with antioxidants at different concentration to the change in frequency

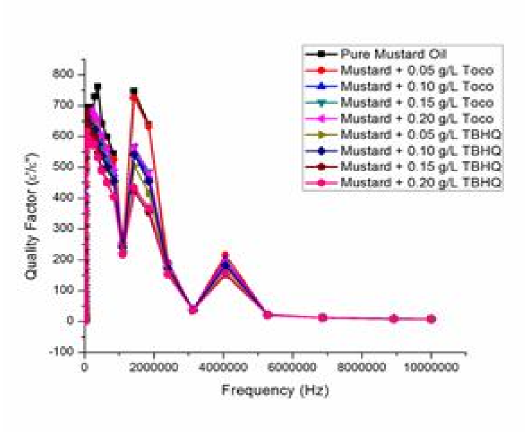

Figure 2. Dependence of quality factor of mustard oil added with antioxidants at different concentration to the change in frequency

The quality factor is less for groundnut oil added with TBHQ. Similar characteristic behavior is observed in Figure 2 for mustard oil where the quality factor of TBHQ is less. The quality peak is observed from low frequency region up to 5 MHz.

Dielectric constant is the measure of the ability of a substance to concentrate electric flux. With the release of oxidized compounds, the number of double bonds decreases in the oil (Pace, 1968; Dilip Kumar, 2013, Tjaša Prevc, 2013).

Table 4 shows the variation of dielectric constant with change in concentration at 2 MHz frequency. The experiments emphasize that addition of antioxidants at low concentration (10 mg/100 mL) shows better effect than higher concentration. One of the noninvasive methods used in the estimation of quality of the fats on frying is the dielectric constant, which is reliant on the sum of total polar compounds (Hamparsun Hampikyan, 2011). Decrease in dielectric constant with the addition of antioxidant inhibits the oxidation and increases the shelf life of the oil. The study also exemplifies the synergistic effect of added antioxidant with the antioxidant in oils. Best interaction is observed in the addition of tocopherol to the oil, increasing the stability of both oils. But addition of TBHQ does not maintain the stability in oils. It was exemplified by Becker, (2007) that tocopherol regenerates myricetin during auto-oxidation.

4. Conclusions

Groundnut and Mustard oils were mixed with antioxidants like tocopherol and TBHQ to test their ability to resist secondary product formation by oxidation. Various physico-chemical properties like viscosity, density and acid value along with electrical properties. Significant deviations in the parameters were noticed on addition of antioxidants indicating the synergistic effect. Akerlof and Oshry's model and Wright's ASTM model were used to relate the variability of viscosity with temperature. It was observed that Wright's model has high determination coefficient (R^2= 0.999). Oil added with TBHQ exhibited less co-relation compared to Tocopherol. Acid value of the oil is controlled with the addition of antioxidants; support the retarding degradation effect in the oil. The quality analysis elucidates the quantity of polar compound in oil. Assessing the impact of antioxidants on the physical and chemical properties of oil gives us an idea about designing the storage conditions of oil with respect to the environment. Antioxidant addition can be used to retain the quality level of the oil during transportation by conserving the viscosity across a wide range of temperatures.

5. References

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