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Al-Quds University**



**Formulation and Characterization of Sustainable Oil
Microemulsions and their application in Biofuel.**

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Formulation and Characterization of Sustainable Oil
Microemulsions and their application in Biofuel.

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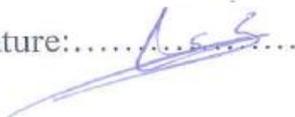
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Dedication:

I would like to dedicate this work to my parents, who gave me confidence from the beginning and gave me the power to continue studying and working efficiently, my family in Jordan, my friends Sana, Ruaa and Riham, my lovely students those who supported me, believed in me and consider me a role model for them, special thanks for salam wadaa'h, who stood by me when things look bleak.

Finally, to all the people in my life who touch my heart.

“Don't ever give up.

Don't ever stop trying”

Noor Hourani

Declaration:

I certify that this thesis submitted for the degree of Master is my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for higher degree to any other university or institution.

Signed:

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Date: 21/5/2016.

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Abstract:

Nowadays there is a great focus on maintaining the environment and thinking in ways to reduce the harmful gases that release daily into the atmosphere, as a result of the petroleum products burning. Also there is a lack of energy sources such as, petroleum and its derivatives. So, we must find alternatives depending on natural products for manufacture renewable energy which does not harm the environment and reduces air pollution.

This study aim to investigate microemulsion formula serves water diesel fuel, using minimum amount of nonionic sugar ester surfactant. The sugar ester in this study is commercial sucrose laurate (C-1216), (C-1205) and (S1570), the oil phase are lemon oil and diesel. Co-surfactant also were used 1-pentanol, 1-Propanol and absolute ethanol.

In this research, we firstly studied the effect of different percentage of surfactant on phase behavior of the systems water/diesel: lemon oil (1:1) /surfactant. We also explored the effect of adding co-surfactant on phase behavior of the systems water/surfactant /diesel: lemon oil (1:1), and water / surfactant /lemon oil.

Water in diesel microemulsions were formulated using 4 wt.% of sugar ester surfactant C1216 , combined with co-surfactant 1-Propanol at 25°C. Also Microemulsion without diesel was formulated using minimum amount of nonionic sugar ester surfactant C1216 values as low as 5wt.% of surfactant at room temperature with 1-Propanol as co-surfactant. At last the reasonable amount of surfactant required to form water in diesel microemulsion provide realistic options in the search for alternative fuel that would reduce the level of both nitrogen oxides and soot in the emission .

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Abbreviations, Symbols and Terminology:

HLB: Hydrophile–Lipophile balance.

CMC: Critical micelle concentration.

L1: Spherical normal micelles.

L2: Reversed micelle.

H1: Normal hexagonal phase.

H2: Reversed hexagonal phase.

L α : Lamellar phase.

I1: Normal micellar cubic liquid crystalline phase.

I2: Reversed micellar cubic liquid crystalline phase.

V1: Normal bicontinuous cubic phase.

V2: Reversed bicontinuous cubic phase.

NO_x: Nitrogen oxides emissions.

nm: Nanometer.

mm: Millimeter.

O/W: Oil in water.

W/O: Water in oil.

ppm : Part per million.

Wt.%: Weight percent.

K: Kelvin.

δ : Co-surfactant concentration.

LM: Lemon oil.

D: Diesel.

Chapter One:

Introduction

1. Introduction:

Nowadays there is a great focus on maintaining the environment and thinking in ways to reduce the harmful gases that release daily into atmosphere, as a result of the petroleum products burning. However, petroleum and natural gas are non-renewable energy sources, since they were originated by geological processes during millions of years, enormously slower than their present consumption rate. Although new oil and gas fields are still being discovered, it is clear that easily accessible reserves will run out in a few decades, and many countries are already facing serious energy shortages. Diesel fuel is known for the excessive production of particulate matter, soot and nitrogen oxide (NO_x) compounds. Reducing the emission from engine using diesel fuel is becoming an urgent priority in many countries worldwide.

Due to the consumer lifestyle of health and sustainability requires bio-based concepts. It is a must to formulate and characterize microemulsions based on biological amphiphiles and different kinds of renewable feedstock oils.

Different vegetable oils have been tested as biodiesel around the world. Each region focused on the most abundant oil available to them, for example palm oil in south east Asia, soybean oil in USA, and rapeseed oil in Europe.

Microemulsification of these fuels with water offers a drastic reduction of soot and nitrogen oxides during combustion in diesel engines [Lif A., 2006].

1.1:Surfactant :

Surface active agent or simply "surfactant", is a general term used to describe molecules that interact with an interface. These consist of two parts, one of which is highly soluble in one of the phases while the other is not [Goodwin, 2004]. Their structures consist of a hydrophobic tail which is usually a hydrocarbon, and polar hydrophilic head group which may be ionic, nonionic, and Zwitterionic.(Fig.1.1.1).

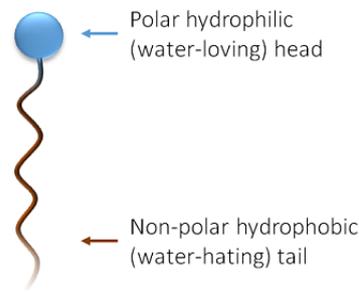


Fig.1.1.1: Schematic illustration of surfactant molecule .

Adsorption of a surfactant at the water/oil interface produces a surface with a significant water low interfacial energies, the formation of this type of low interfacial energy surface is the basis of the stability of most oil and water emulsions and all microemulsions.(Fig.1.1.2).

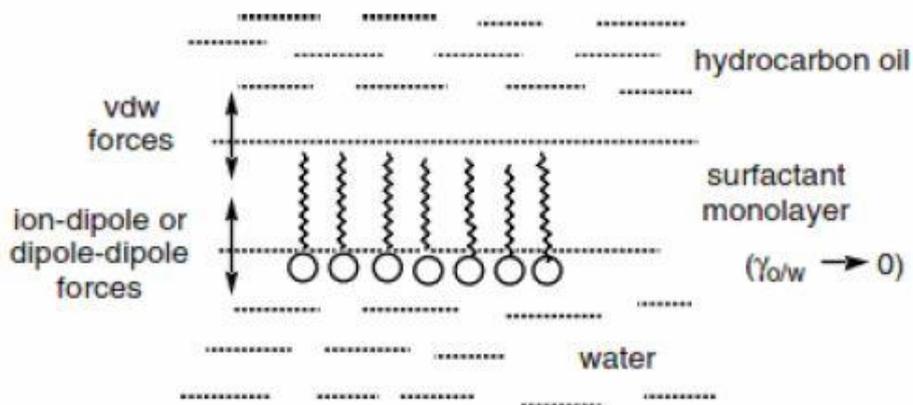


Fig.1.1.2: Illustration of the effect of an adsorbed surfactant layer on the interfacial energy between oil and water. [Richared,et. al. 2004]

The most useful chemical classification of surfactant is based on the nature of the hydrophilic part (head), with subgroups based on the nature of the hydrophobic part (tail). The four basic classes of surfactants are [Myers, 2006] : Anionic in which the hydrophilic part is a negatively charged group such as carboxyl (RCOO^-M^+), Cationic the hydrophilic part is a positive charge for example, the quaternary ammonium halides ($\text{R}_4\text{N}^+\text{X}^-$), nonionic the hydrophilic has no charge, but derives its water solubility from highly polar groups such as R-Polyol groups including sugars and amphoteric (Zwitterionic). The molecule contains, or can potentially contains

both a negative charge and a positive charge, such as the sulfobetaines ($\text{RN}^+(\text{CH}_3)_2\text{CH}_2\text{CH}_2\text{SO}_3^-$). (Fig.1.1.3).

With a wide variety of surfactant structure available, it is not surprising that the selection of a suitable surfactant for a given application can become a significant problem. Thus an empirical numbering system has been developed to enable the correct type of surfactant to become chosen. The system is called the "hydrophile – lipophile balance" (HLB).

- low HLB values soluble/ disperse in oil.
- high HLB value soluble/ disperse in water.

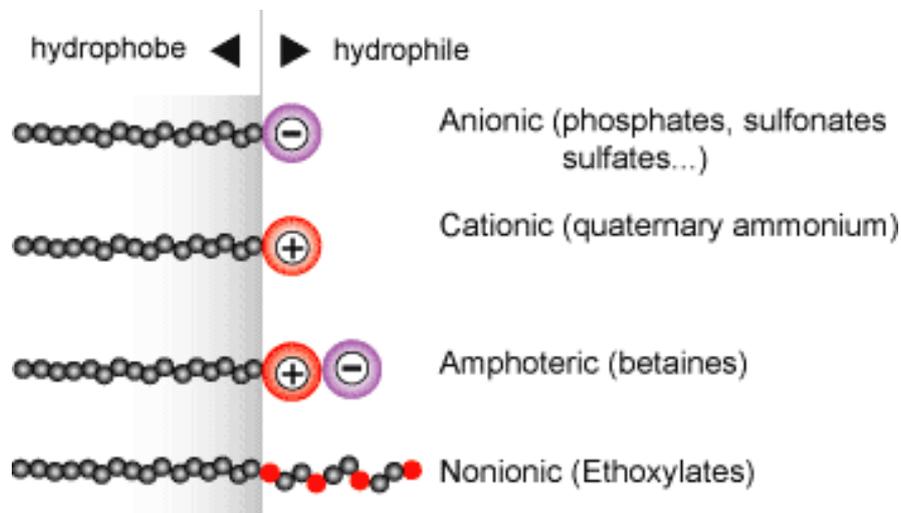


Fig.1.1.3: Scheme classification of surfactants.

1.2: Self-Assembled surfactant structures :

In aqueous solution dilute concentration of surfactant act much as normal electrolytes, but at higher concentration very different behavior results. This behavior is explained in terms of the formation of organized aggregates of large numbers of molecules called micelles (Fig.1.2.1). In which the lipophilic parts of the surfactant associate in the interior of the aggregate leaving hydrophilic parts to face the aqueous medium. Meanwhile, that happens at a specific, higher, surfactant concentration, known as the critical micelle concentration (CMC). Besides, the physic-chemical properties of surfactants vary markedly above and below the CMC value.[Jim W.2004].

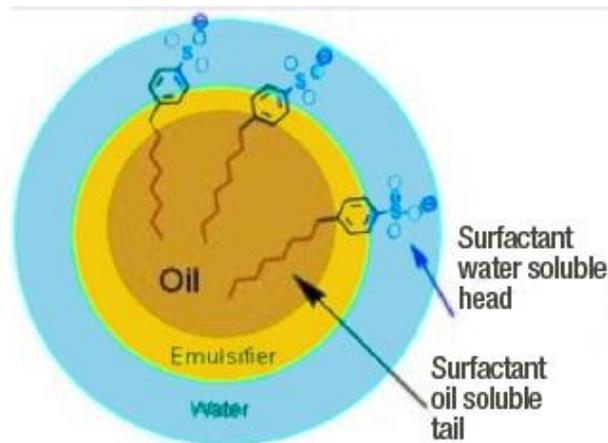


Fig.1.2.1: Schematic diagram of a surfactant micelle.

In addition, acting surfactants at oil/water interface formed a large number of self-assembled structure depending on the type of surfactant [Borne,2002]. Spherical normal micelles (L1) are formed at high water content (oil/water), while reversed micelle (L2) are formed at high water content (water/oil), between these two extremes different isotropic and anisotropic liquid crystalline phases with decreased water content or increased temperature or electrolyte concentration may be formed. The following sequence of anisotropic liquid crystalline phases may take place for the surfactant systems (Fig.1.2.2).

Normal hexagonal phase (H1) → lamellar phase ($L\alpha$) → reversed hexagonal phase (H2). Isotropic discrete reversed micellar cubic liquid crystalline phase (I2) and normal (I1) can appear between the micellar and the hexagonal phases of both the reversed and normal types. The normal bicontinuous cubic phase (V1) and reversed (V2) occur on each side of lamellar phase. [Borne, 2002]

The variation and complexity of these structures has led to much research on potential industrial applications. However, microemulsion is the most important structures in which single low viscous isotropic phases formed in L1 and L2 regions of the phase diagram.

The critical packing parameter can be used as a guide to the aggregate Architecture for a given surfactant. Represented by eq.(1). Where \mathbf{A} the cross sectional area of head group for surfactant , $\mathbf{l_c}$ extended chain length and \mathbf{v} a hydrocarbon volume.

$$R = v|alc| \dots \text{eq(1)}$$

$V/alc < 1/3$ Spherical micelles.

$1/3 < V/alc < 1/2$ poly-dispersed cylindrical micelles.

$1/2 < V/alc < 1$ Vesicles, oblate micelles or bilayers.

$V/alc > 1$ inverted structures.

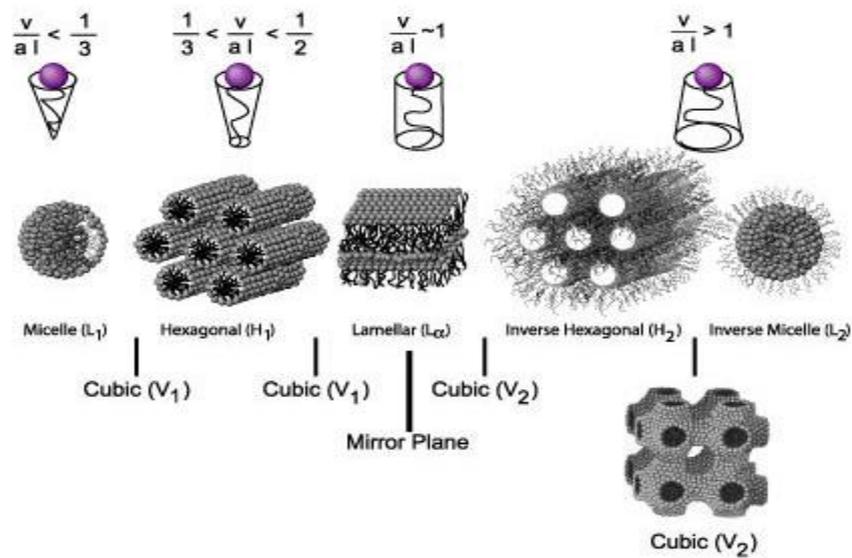


Fig.1.2.2: Scheme show typical values and their corresponding aggregate structures of surfactants [Richared, et al. 2004]

1.3: Sugar-Base Surfactant.

Sugar-based surfactants are surface active agents with sugar group in their structure. The kind of sugar group in the molecule of surfactant depends on the type of raw material used for its production. The number of natural products is large but only some of them can be transformed into surfactants [Piispanen, S. 2002]. These starting materials are generally plentiful, inexpensive, reproducible and biocompatible [Shinoda, K. 1996], and their type determines not only the construction of final sugar surface active agent but also it impacts on physicochemical and ecological properties of the obtained compound.

Sugar-based surfactants can be derived from the sugar raw materials occurring in the form of monomeric (such as glucose, fructose, sorbitol), dimeric (such as sucrose, lactose) or polymeric (such as starch, cellulose, pectin, chitin, polysaccharides, dextrans) compounds as well as from sugars which remain as post-production wastes [Piispanen ,S.2002], [Kjellin, K. 2010]. At the same time, these materials may constitute the hydrophilic head in the molecule of obtained surface active agent which is linked glycosidically with the alkyl moiety of the fatty alcohol or which is linked with the rest of the fatty acid by the ester, amine or amide bond [Stubenrauch, C. 2001].

The type of chemical bond existing between the hydrophilic and hydrophobic parts of the surfactant molecule has an effect on its properties. The presence of amide group in the molecule reduces the solubility of the surfactant in water and gives a stable connection between the head and tail of the surfactant characterizing high resistance to acidic and basic hydrolysis. Moreover, the amide bond is easily degraded because living organisms have enzymes capable of breaking it down. The Ether groups form a strong bond not easily degraded in nature in contrast to the ester groups which form a weaker bond, useful and flexible which can be easily hydrolyzed [Piispanen ,S. 2002]. The hydrophilic group could consist of many the same or different sugar units and the hydrophobic part could consist of one, two and even more alkyl chains with the same or different lengths [Stubenrauch, C. 2001].

A wide group of sugar-based surfactants can be includes among others, alkyl glycosides, alkyl thio-glycosides, alkyl maltosides and their homologues or derivatives, betaines (Zwitterionic surfactants), Gemini (compounds with two monomeric surfactant molecules linked by a spacer chain) and bolas (compounds with two polar groups linked to both ends of a long alkyl tail) surfactants. Among them those based on glucosides, especially alkyl polyglucosides (APGs), are often used [Ruiz, C. 2008 & Garcia, I. et. al. 1997] . As mentioned at the beginning, surfactants derived from natural products are non-toxic and have a high rate of biodegradation because they can be composed of a variety of ingredients commonly occurring in the environment. These compounds have high surface activity because even at low concentration they are very effective in diminishing the surface tension of water and the water/oil interface tension [Ruiz, C. 2008] . A large number of sugar-based

surfactants are also characterized by high values of CMC. In comparison to chemical surfactants these with sugars as a polar head are more stable and sustainable.

Moreover, they are no-irritating and mild for skin, mucous membranes and eyes. Therefore, they are very attractive for personal care products, especially for facial skin care and those used for the delicate skin of children [Garcia, I. et. al. 1997 & Forster, T. 1995]. Besides, depending on the structure surfactants have characteristic features. For instance, alkyl polyglucosides are stable at high pH and sensitive to low pH in which they hydrolyze. They do not exhibit clear relationship between solubility and temperature as for most typical nonionic compounds including poly(ethylene oxide) surfactants [Holmberg, K. 2001].

The International Journal “ Pharmacy and Pharmaceutical Sciences” study noted that compared to other similar chemicals, it can be used in smaller amounts and has no toxicity concerns. It is also relatively free of color, smell and taste and quickly biodegrades after it is used, making it relatively environmentally friendly.

1.3.1: Sucrose laurate (C1216).

Sucrose Laurate is a mixture of sucrose esters of Lauric acid consisting primarily of the monoester. Used as skin conditioning agent, emollient, surfactant emulsifying agent(fig.1.3.1)

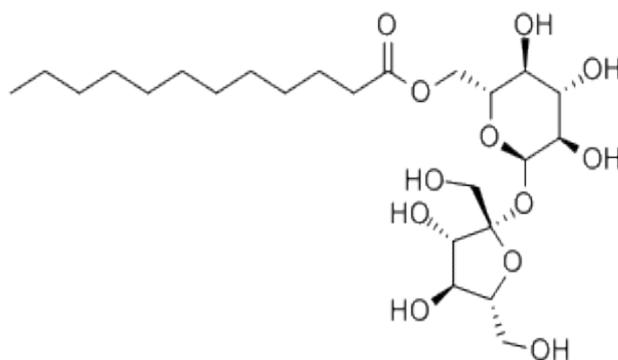


Fig.1.3.1: Illustration the structures of Sucrose laurate (C1216) .

1.3.2: Sucrose dilaurate (C1205).

Sucrose Dilaurate is a diester of lauric acid and sucrose, and it is classified as surfactant skin conditioning emulsifying emollient.

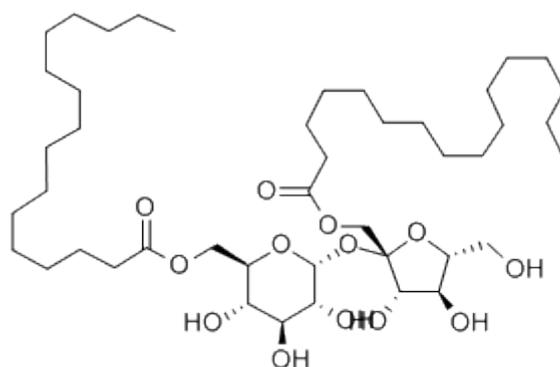


Fig.1.3.2 : Illustration the structures of Sucrose dilaurate (C1205) .

1.3.3: Sucrose Stearate (S1570).

Sucrose stearate is a monoester of stearic acid and sucrose. Used as skin-conditioning agent, emollient, surfactant, emulsifying agent, skin conditioning

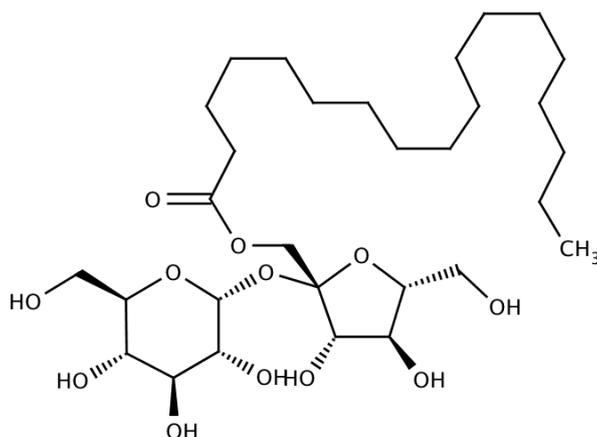


Fig.1.3.3 : Illustration the structures of Sucrose Stearate (S1570) .

Sucrose stearate can form liquid crystal phase at much lower concentration and lower temperature by adding oleyl polyoxyethylene(20) surfactant (Brij98). Inducing isopropyl myristate (IPM), the liquid crystal phase was formed by Brij98/S1570 system transformed from hexagonal liquid crystal to lamellar liquid crystal. [Zhen Li, 2011].

1.4: Microemulsion.

The term of microemulsion applies to a mixture with at least three components; an oily phase, an aqueous phase and a surface active species, so called surfactants. Sometimes the fourth component i.e., co-surfactant can/must be present [Saito & Shinoda, 1967. Saito & Shinoda, 1970]. Depending on the ratios between the components, in the two extremes the microstructure of the microemulsions vary from a very tiny water droplets dispersed in oil phase (w/o microemulsion) to an oil droplets dispersed in water phase (o/w microemulsion). The microstructure of the mixture changes continuously from one to another extreme, namely, from a spherical to cylindrical, tubular and interconnected continuous oil and water phases separated with a very thin layer of surfactant molecules, in the middle, which is defined as bicontinuous microemulsion [Scriven, 1976]. The microemulsions of each kind are thermodynamically stable and transparent solutions. There are main differences between emulsions and microemulsions in terms of structure and stability. In contrast to the microemulsions, the emulsions are unstable systems and without agitation, phase separation will occur in them. The other difference is that the size of droplets in emulsions are in the range of micrometers, while in microemulsions the size of micelles are in the range of 3-50 nm, depending on the some parameters such as surfactant type and concentration, the extent of dispersed phase [Prince 1977, Hou et al., 1988, Maitra, 1984]. Hence, sometimes the microemulsion term is misleading, because it doesn't reflect the size of dispersed phase droplets in the system which, are in the nanometer range. (Fig.1.4).

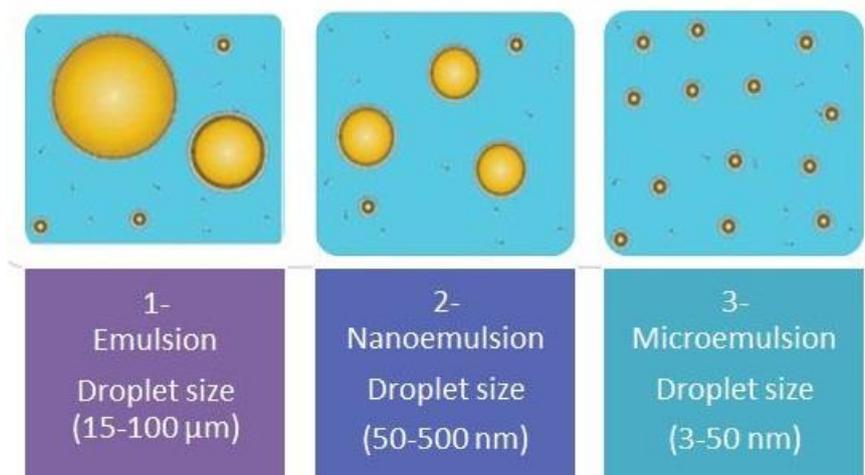


Fig.1.4: Emulsion classifications according to droplet size. [Piorkowski & McClements, 2013].

1.5: Effect of alcohol in the formulation of microemulsion.

Three effects of an alcohol additive in the formulation of microemulsion have been mentioned so far [Cosima, 2009]. First, it contributes to the general formulation as a co-surfactant, slightly hydrophilic contribution for methanol and ethanol; lipophilic contribution for n-butanol and longer linear alcohols. Secondly, as a co-solvent. The alcohol co-adsorbs with the surfactant at the interface and thus changes the overall interaction of the amphiphilic film with the adjacent solvents. The longer the alcohol chain length, the lower its tendency to act as co-surfactant, because it is rather solubilized in the oil phase. Consequently, the co-surfactant effect may be said to fade away. As the alcohol mostly partitions into water or oil phase it behaves either as a co-solvent. When such alcohol co-solvents are present in small proportion, they might not mix uniformly in the bulk of the oil or water phase and they could exhibit a third effect so-called lipophilic linker. (Fig.1.5).

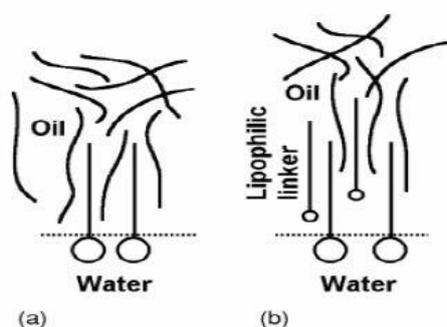


Fig.1.5:solubilization improvement of a conventional surfactant (a) by a lipophilic linker (b) [Cosima, 2009].

Alcohol can also reduce the time needed for equilibration to be reached in multi-phase systems.[kayali, et al. 2012].However, for application like water-diesel fuel, alcohol may be desirable to be used at low percent, because of their volatility, flammability.

Fanun reported the effect of ethanol in formulation of mixed nonionic surfactant microemulsion . The systems were water/sucrose laurate/ ethoxylated mono-di-glyceride/oleic phase [Fanun,2008]. The oleic phase was R(+)-limonene,

isopropylmyristate, and caprylic-capric triglyceride; these oils were mixed with ethanol at different mixing ratios (w/w). The total area of the monophasic microemulsion increases with the increase in the ethanol/oil mixing ratio (w/w). [Wadaa'h S. , 2012].

1.6: Application of microemulsion .

Microemulsions play a great role in the everyday life of human being. There are many final products which, in principle based on the microemulsions and/or they are somehow in very close relation with the microemulsions. Sometimes the microemulsion formation is the important process that, occur at the final stage of the application. However, in every case the formation of the microemulsion results in the solubilization of the chemicals which may be the active agent or the unwanted compound that its removal is the first task of the process. Or in some cases this solubilization helps to deliver the active agents to the required sites. Any formulation which intended to be used in industrial scale should be economical. Various types of cleaning process are one of the main areas that relates to the application of the microemulsions in big scales. Some of the other areas include: agrochemicals formulations [Mulqueen 2003, Chen et al., 2000](solubilizing organic agrochemicals in water), preparation of the vaccine adjuvants to improve the effectiveness of the active compounds [O'Hagan et al., 1997, Hariharan & Hanna, 1998], micro and - emulsion polymerization [Xu & Gan, 2005, Capek 2001], floatation process in the pulp and paper industry, concrete and asphalt, petroleum industry (for example in enhanced oil recovery, natural gas dehydration and etc.) [Santanna et al., 2009, Austad & Taugbøl 1995], firefighting foams, defogging agents, decontamination of the media from chemical and biological agents and many more other application [Solans & Kunieda, 1997].

Also, formulation of the cosmetics [Valenta & Schultz, 2004], medicals and food additives are the other important areas that require very exact control and analysis. According to the statistics, in 2003 about 2 million of surfactants, made from fatty alcohols has been consumed [Brackmann & Hager, 2004].

The water molecules solubilized in the interior of the water pool have different properties from those of bulk water. This makes reverse microemulsion applicable to many fields such as water –diesel fuels [Ding, et al.2007].

1.6.1: Biofuel .

During the past several decades, there has been a considerable increase in research and development in areas of environmentally acceptable alternative fuels. Synthetic fuels were of prime interest in the 1970s, due to a sudden shortage of petroleum supply kindled by an oil embargo in 1973, as well as public concern about Dwindling petroleum reserves. Although synthetic fuels seemed to be a most promising solution to the conservation of petroleum resources or at least, frugal use of the resources and the development of additional sources for conventional liquid fuels [Lee, et al. 2007]. The Concerns of global warming via greenhouse gases have further intensified the issue of environmental acceptance of fuel consumption. Hence, efforts have been made to reduce emissions of air pollutants associated with combustion processes whose sources include electric power generation and vehicular transportation.

Biofuel that are based on renewable resources has become more and more desirable in the past years due to several reasons. First of all, the use of sustainable vegetable oils represents an ideal alternative to fossil resources, that are constantly diminishing with time, while the demand is increasing worldwide. Secondly, the environment benefits due to the use of biofuels are obvious when comparing to fossil fuels. Reduction in emissions of greenhouse gases is an important factor in this regard [Shay,1993].

There are two distinct types of plant oils: (a) fixed oils such as coconut and castor oils, which do not readily evaporate on exposure to air; and (b) essential oils such as citronella and cinnamon oils, and lemon oil, which readily evaporate or volatilize on exposure. Fixed oils are usually extracted by crushing and pressure, by boiling, or by chemical solvents. On the other hand, essential oils are almost always extracted by distillation, many of them from flowers such as ilang-ilang oil, sampaguita oil and lemon oil . Some fixed oils that are liquid at relatively high temperature become solid in ambient and lower temperatures. These fixed oils from

plants are the oils of interest as possible replacement for diesel fuel or as diesel fuel extenders while essential oils are of interest as components in the production of perfumes and other cosmetics and pharmaceuticals. Soybean oil, coconut oil and palm oil are the most widely used plant oils, followed by rapeseed oil, sunflower seed oil, peanut or groundnut oil, cottonseed oil, and olive oil. [Shay,1993].

The viscosity of the bio-based energy carriers like rapeseed oil and palm oil is not suitable for proper atomization in engines designed to burn diesel. Diluting the vegetable oils with a low molecular weight solvent can reduce viscosity, thus making them compatible with diesel engines. In addition, trans-esterification with various alcohols reduces the high viscosity of oils and fats, making them more applicable as alternative fuels than neat vegetable oils. Fatty acid methyl ester is the most popular ester among others considering the lower price of methanol compared to other alcohols [Freedman B. 1989 , Reed T. 1991].

Currently, I am investigating the phase behavior of biocontinuous and water in diesel microemulsions using nonionic surfactants combined with hydrophobic alcohol ethoxylates. The nonionic surfactant used here contains only carbon, hydrogen, and oxygen atoms. This is crucial in formulating microemulsion fuel systems. The surfactant should burn readily without forming smoke and should not contain sulfur or nitrogen.

1.6.2: Microemulsions as fuels

The advantageous effects of water on the combustion of diesel- fuel have been repeatedly studied over the past thirty years. Unfortunately, emulsions do not exhibit long-term stability as they separate into an aqueous and an oily phase after a certain time. However, the thermodynamic instability of emulsions has remained an unsolved problem. Thus, the best way to produce a homogeneous mixture of two immiscible liquids as water and fuel is a microemulsion [Bemert, et al. 2009].

Microemulsion-based fuel formulations date back to 1976 when Gillberg and Friberg published a paper on the use of water in-diesel microemulsions as fuel [Lif, et al.2006]. The main advantage with the microemulsion concept is the thermodynamic stability which means that there should be no risk of phase separation on storage as

long as the temperature is under control [Lif, et al.2010]. Only the chemical stability of the single components could be a limiting factor [Bemert, et al.2009] .

Fortunately incorporating water into the fuel as microemulsion provides opportunity to use water-in-diesel fuels in diesel engine vehicles with no major modifications of the engines [Ochoterena, et al.2010].

One of the direct advantages of microemulsion-based fuels is the presence of water in a stable microemulsion and they are successfully used to reduce soot formation. One way to add water to air–fuel mixtures is to use water-in diesel Fuels. These fuels are generated by mixing vigorously the two main components and stabilizing them by adding relatively small amounts of emulsifiers, i.e. surfactants and polymers. The two main components are blend into a system consisting of fine, or ultra-fine, water drops dispersed in diesel forming either an emulsion or a microemulsion [Ochoterena, et al. 2010]. The amount of water dispersed in diesel within the range of 5–15% for an emulsion or a microemulsion water-diesel fuel [Lif, et al. 2010].

In diesel fuels (a typical diesel hydrocarbon Equivalent to dodecane), many problems are overcome due to the high combustion temperatures (160–325°C) [Bidyut, et al.2001]. Hence, water incorporated in fuel as microemulsion vaporizes during combustion and acts as a heat sink. In the case of combustion of fuel in an internal combustion engine; water is also expected to assist in fuel atomization due to micro explosions phenomenon, which occurs during the evaporation of the water inside droplets of fuel gives a membrane of oil (Fig.1.6.2). This lowers the peak combustion temperatures, which results in a drastic reduction in nitrogen oxides (NO_x) emissions, reduces the particulate soot formation and improves the combustion efficiency [Ding, et al.2007].

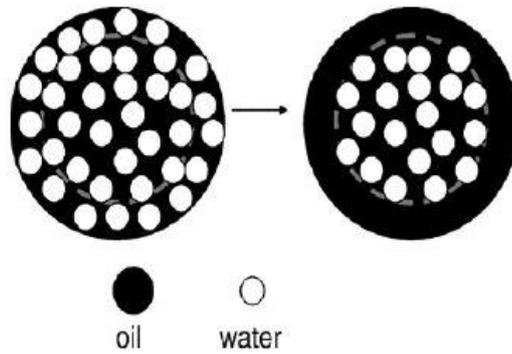
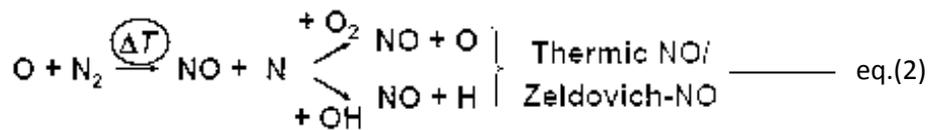


Fig.1.6.2: Formation of the oil membrane in the atomization process after fuel inject in the cylinder . Evaporation of water microdroplets in the periphery gives a membrane of oil [Lif, et al. 2006].

Excess heat vaporizes water, this lowers combustion temperature, and less thermal energy for this initial step available so a decrease of 30% of nitrogen oxides produced according to Zeldovich eq. (2) [Aljabarin, 2010]:



On the other hand, the formation of hydroxyl radicals by water dissociation, enhancing the oxidation of soot [Ochoterena, et al.2010]. Hence, high combustion temperature splits water into radicals; this accelerates the degradation of fuel molecules to form short chain alcohol, and hydrocarbons eq. (3) [Pascal, et al.2009]:



The presence of water is also supposed to cause improved fuel atomization, minimization of particulate emission and sooting, and improved fuel economy in terms of price and miles/volume of the fuel.

There are many reports about microemulsion fuel systems containing anionic, cationic and nonionic surfactant. [Neuma de Castro Dantas et al. 2001] in his work showed that it was possible to obtain new microemulsions with diesel and vegetable oils, through a simple methodology and, low cost. System of (diesel oil – soy oil, water, Isopentyl alcohol/ comperlan = 0.5) indicates that it is possible to obtain

microemulsion areas of diesel-soy oil in a wide composition domain. This system presented the best microemulsion areas and the best physical-chemical properties when compared to the diesel. It was possible to add certain amounts of water and active matter to the diesel, obtaining a good microemulsion area. It takes an economy of diesel of up to 25%.

Depending on M. Klossek, D. Touraud and W. Kunz ,2012 there is a possibility of replacing classical n-alkanes as the oil phase in common microemulsions by green renewable feedstock oils (RFOs) whether RFOs are “pure” or a mixture of RFOs of different origins. Limonene and cuphea biodiesel can replace short-chain alkanes whereas TBK- and fatty methyl ester (FAME)-rapeseed biodiesel can substitute long-chain ones. From the chemical structure of the oils, it appears that not only the polarity of the oil plays an important role but also does the absolute size of the oil molecules.

Kayali et al. investigated biocontinuous and water in diesel microemulsion were formulated at co-surfactant concentration $\delta = 0.10$, using single nonionic alkylpoly glycol ethers combined with hydrophilic alcohol ethoxylates [Kayali, et al.2012], This work shows that the addition of hydrophilic alcohol ethoxylates as a co-surfactant was necessary to initiate the formation of both continuous and w/diesel microemulsions in the formula of water, diesel and the nonionic surfactant CiEj. Varying the mass fraction of co-surfactant in the surfactant/co-surfactant mixture, δ , between 0.05 to 0.16 gave approximately similar surfactant efficiency.

In 2014 Kayali, found that water-in-diesel microemulsions were formulated using single nonionic alkyl poly glycol ethers combined with hydrophilic alcohol ethoxylates. The emissions of NO_x, soot, and CO₂ were reduced substantially compared to neat diesel, while for the CO the reduction occurs just at low load.

Kanan in 2015 found that, Increasing the chain length of co-surfactant from 4 carbons in the case of 1-butanol to 5 carbons for 1-pentanol increases the area of the one-phase region (microemulsions and liquid crystals).

Newly phase behavior of water, diesel, limonene, and ethanol was investigated at ambient temperature using single nonionic alkyl polyglycol ethers (C14E3) [Kayali et al.2016]. Visual inspection as well as cross polarizers was used to detect

transparency and anisotropy. Ternary phase diagrams were determined. Combustion experiments using a four-cylinder diesel engine were carried out. Isotropic water in diesel microemulsion region (L2) and anisotropic liquid crystalline region (LC) were found with all combinations.

Increasing the ratio of limonene to diesel reduced the microemulsion region while the presence of ethanol increased it on the expense of the LC region. Combustion tests performed on a selected formulation from the ternary phase diagram of water, diesel, ethanol, and C14E3 revealed substantial reduction of soot, NO_x, and CO₂ emissions compared to neat diesel.

1.7:lemon oil.

The name is derived from the Arabic 'laimun' or the Persian 'limun'. The tree was brought to Europe by the Crusaders in the Middle Ages and the fruit has a good content of vitamins A, B and C - an ounce a day was given to sailors in the Royal Navy to alleviate scurvy and other vitamin deficiencies.

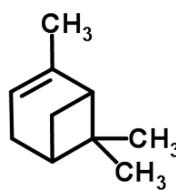
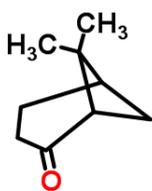
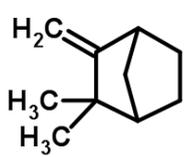
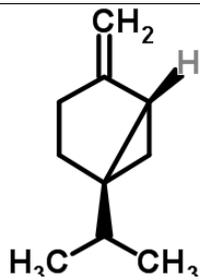
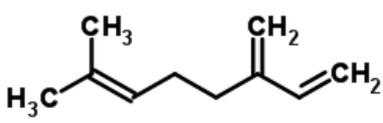
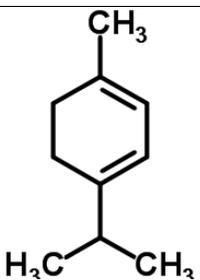
Lemon essential oil is extracted from the fresh fruit peel, the *Citrus limonum* (also known as *Citrus Limon*), of the Rutaceae family and is also known as cedro oil (which refers to terpeneless oil).

Table 1.7 :Physical-Chemical Properties of Lemon Oil.[Secondi, O. ,1990].

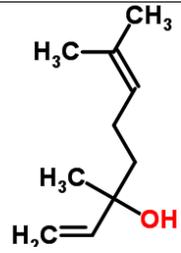
Property	Lemon oil
Color	Pale to deep yellow or greenish yellow
Odor	Fresh citrus, intense
Refractive Index	1.474-1.467
Boiling point	176°C
Density	0.853 g/mL at 25 °C
Stability	Air/light sensitive
Flash point	54.4 °C

The main chemical components of lemon oil are α -Pinene, camphene, b-Pinene, Sabinene, Myrcene, α -Terpinene, linalool, b-bisabolene, limonene, trans- α -bergamotene, Nerol and Neral. [AZAR et al. ,2011]. shown in fig. 1.7.

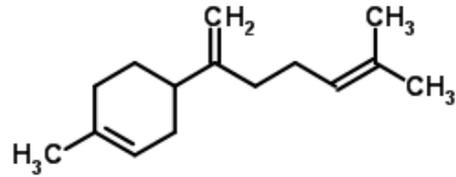
Fig.1.7:Structures of chemical components of lemon oil .

α -Pinene	
β -Pinene	
Camphene	
Sabinene	
Myrcene	
α -Terpinene	

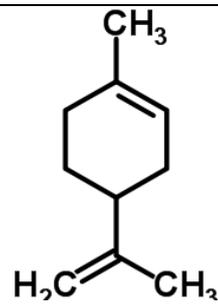
linalool



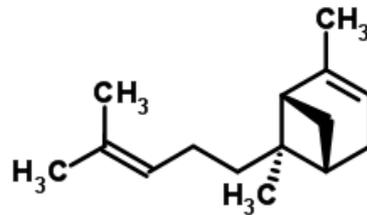
β -bisabolene



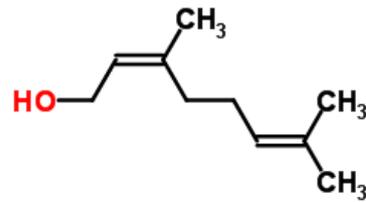
limonene



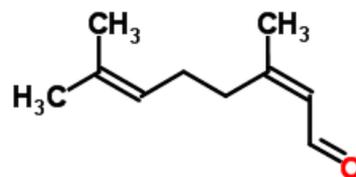
trans- α -bergamotene



Nerol



Neral



1.8 :Problem :

Nowadays there is a great focus on maintaining the environment and thinking in ways to reduce the harmful gases that release daily into the atmosphere, as a result of the petroleum products burning. The problem is incomplete combustion, the long-chain hydrocarbons used as diesel fuel do not burn as easily as the lighter ones found in petrol. Some of the carbon therefore ends up as soot, rather than carbon dioxide, and oxygen that should be combining with carbon combines with nitrogen from the air instead. So, we must find alternatives depending on natural products for manufacture renewable energy which does not harm the environment and reduces air pollution.

One possibility for the simultaneous improvement of combustion efficiency and reduction of emission of noxious substances is the use of special fuels; especially fuels which consist of a mixture of aqueous and non-aqueous phases, such fuels allow an efficient combustion process in spite of comparatively low combustion temperatures.

1.9 : Objectives:

The main objective of this study is the preparation of suitable, stable and applicable microemulsion formula serves water-Diesel fuel and biofuel without diesel using nonionic surfactants to obtain this formula.

There are specific objectives needed to be achieved:

- To estimate phase diagram of the best components concentration for microemulsion preparation.
- The ingredients should be very cheap so that the price is comparable with current petrol-based fuel.
- A good biofuel should contain as all other diesel-alternatives between 5 and 15 % of water.
- The oil should be based on renewable resources, but it should not come from resources in competition with food. Best would be to use natural waste.
- The composition should be optimized for optimum combustion.

Chapter two :
Methods and Experiments

2. Methods and Experiments.

2.1 Materials :

Sucrose laurate(α -D-Glucopyranoside , β -D-fructofuranosyl, dodecanoate) (C1216), Formula Weight 524.6 g/mol, Assay(mono, di, tri-esters) 80% , with HLB value 16, Sucrose dilaurate (α -D-Glucopyranoside, . β -D-fructofuranosyl, didodecanoate) (C1205), formula weight 706.90144 g/mol, Assay(mono, di, tri-esters) 80%, with HLB value 5, and sucrose stearate(**3-O-Stearoyl- β -D-fructofuranosyl α -D-glucopyranoside**) (S1570), Formula Weight 608.76 g/mol Mono-ester content 70% with HLB value 15. All of them was obtained from Mitsubishi-Kasei Food Corp., (Mie, Japan).

Lemon oil was purchased from Ziv Chemicals, 1-pentanol 99% was purchased from Sigma-Aldrich, 1-propanol 99.8% was purchased from CS-Chemicals, Ethanol 99% was purchased from CS-Chemicals, Diesel was obtained from a local gas station in Bethlehem, Palestine. Aqueous solutions were prepared using deionized water supplied by a Milli-Q water purification system (Milli pore system, Al-Quds University). All components were used as supplied without further purification.

2.2 Instruments and Equipment:

Analytical Balance, Vortex, Cross Polarizers, Test tubes, a thermostated water baths.

2.3 Procedures (Constructing of Phase Diagram):

The phase behavior of the systems consisting of water, oil (Diesel and lemon oil with co-surfactant), surfactant may be described on a phase tetrahedron whose apexes respectively represent the pure components.

1g of a mixture consisting of oil, surfactant at different weight ratios - as it is shown in the table(2.3.1) - were prepared in culture tubes sealed with Viton lined screw caps and stirred at high temperature(45°C) by vortex until clear solution was obtained.

Titration of these samples with MQ water which was added -as shown in table (2.3.2)- until its solubilization limit was reached. Vigorous stirring followed all of the aqueous phase additions on a vortex mixer. The time for equilibration between each addition was typically, from a few minutes up to 24 h.

Phase diagram was investigated at temperatures 25°C. Detecting number of phase by naked eye. The anisotropy by cross polarizers. The single isotropic sample which will be dark under cross polarizers will be regarded to either cubic or micelle; which can be distinguished by viscosity. The anisotropic lamellar liquid crystal and hexagonal liquid crystal are determined by the cross polarizers. Detect the boundary of single phase; finally draw the phase diagram using Origin Pro 8.1 software.

Table: 2.3.1: weight ratios of oil phase and surfactant.

Tube No.	Surfactant(g)	Oil phase(g)
19	0.1	0.9
28	0.2	0.8
37	0.3	0.7
46	0.4	0.6
55	0.5	0.5
64	0.6	0.4
73	0.7	0.3
82	0.8	0.2
91	0.9	0.1

Table: 2.3.2: The amount of water added each time in titration.

Addition No.	Addition percentage (%)	Mass of addition(g)
1	4	0.0417
2	8	0.0453
3	12	0.0494
4	16	0.0541
5	20	0.0595
6	24	0.0658
7	28	0.0732
8	32	0.0817
9	36	0.0919
10	40	0.1042
11	44	0.1191
12	48	0.1374
13	52	0.1603
14	56	0.1894
15	60	0.2273
16	64	0.2773
17	68	0.3473
18	72	0.4466
19	76	0.5955
20	80	0.8337
21	84	1.207
22	88	2.0833
23	92	4.1667
24	96	12.5

Chapter Three:
Results and Discussions

3. Results and Discussions:

The work was started with comparing between phase behavior of two nonionic surfactant has different fatty acid chains, the first is Stearic acid in Sucrose stearate(S1570), the other fatty acid was Lauric acid in Sucrose laurate (C1216), with diesel and lemon oil in the first, then comparing between 1-Pentanol and Ethanol with previous formulas.

Then it was compare between phase behaviors of linear(C1216), and branched(C1205) surfactants, with same fatty acid chain(lauric acid), with diesel and lemon oil in the first, then comparing between 1-Pentanol, 1-Propanol and Ethanol as co-surfactant with previous formulas.

Phase diagrams without diesel were prepared with C1216 and C1205, to compare them with others that contain diesel. Finally, the best formula was obtained.

3.1: Phase Diagrams of Water/ Sucrose stearate(S1570) Systems.

3.1.1: Phase Diagram of Water/Sucrose Stearate(S1570)/ Lemon oil / Diesel System.

The phase diagram indicated the presence of low viscous isotropic and semisolid anisotropic LC regions at 50wt.% of surfactant . The remainder of the phase diagram represents the turbid region based on visual identification . No co-surfactant was used in order to simplify the system.(Fig. 3.1. a).

3.1.2: Phase Diagram of Water/Sucrose Stearate(S1570)/ 1-Pentanol / Lemon oil / Diesel System.

Micelle (L2) was formed at 20 wt.% of surfactant and continued until 40wt.% of surfactant and it was relatively small area . Highly viscous anisotropic LC region was also appeared at 60 wt.% of surfactant. Thus the remainder of the phase diagram represents the turbid region based on visual identification. (Fig.3.1. b).

3.1.3: Phase Diagram of Water/Sucrose Stearate(S1570)/ Ethanol/ Lemon oil / Diesel System.

Micelle (L2) was formed at 30 wt.% of surfactant and continued until 50wt.% of surfactant, and it was relatively small area .Thus the remainder of the phase diagram represents the turbid region based on visual identification. (Fig.3.1.c).

(a)

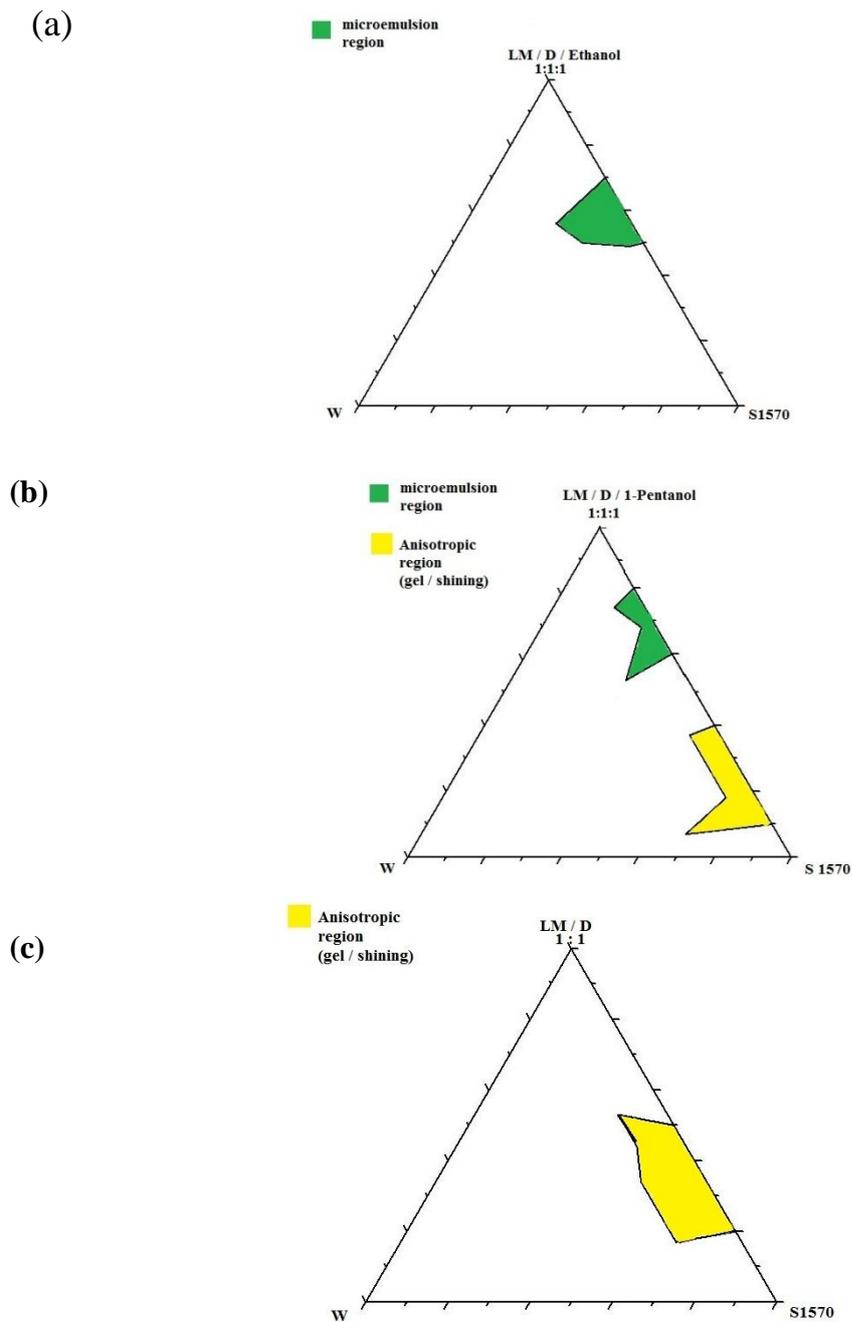


Fig.3.1: Pseudo -Ternary Phase Diagrams of: (a) Water/Sucrose Stearate(S1570) / Lemon oil / Diesel System. (b) Water/Sucrose Stearate(S1570)/ 1-Pentanol / Lemon oil / Diesel with ratio (1:1:1) System. (c) Water/Sucrose Stearate(S1570)/ Ethanol / Lemon oil / Diesel with ratio (1:1:1) System at 25°C.

3.2: Phase Diagrams of Water/Sucrose laurate (C1216) Systems.

3.2.1: Phase Diagram of Water/Sucrose laurate (C1216)/ Lemon oil / Diesel System.

Ternary phase diagram was studied upon addition of water to sucrose laurate /lemon oil /diesel with ratio (1:1) system at 25°C (Fig 3.2.a) . Micelle (L2) was formed at 10 wt.% of surfactant and continued until 39wt.% of surfactant . Highly viscous isotropic LC region was also appeared at 40 wt.% of surfactant with 60wt.% of oil . Thus the remainder of the phase diagram represents the turbid region based on visual identification. No co-surfactant was used in order to simplify the System.

3.2.2: Phase Diagram of Water/Sucrose laurate (C1216)/1-pentanol / lemon oil / diesel System.

The observed ternary phase diagram shown(Fig.3.2.b) Indicated the presence of L1 at 50wt.% of surfactant and 10 wt.% oil, L2 at 20wt.% of surfactant , semisolid isotropic at 50wt.% surfactant with 50wt.% oil and highly viscous anisotropic LC regions at 90wt.% surfactant . The remainder of the phase diagram represents the turbid region based on visual identification .Highly viscous anisotropic LC regions shrink more compared to Figure(3.2.a) and a microemulsion region expands more.

3.2.3: Phase Diagram of Water/Sucrose laurate (C1216)/ Ethanol /lemon oil / diesel System.

The observed ternary phase diagram at 25°C is shown(Fig.3.2.c) Indicated the presence of L1 at 60wt.% of surfactant and 25 wt.% oil , L2 at 40wt.% of surfactant , and highly viscous anisotropic LC regions at 55wt.% surfactant with 45wt.% oil . The remainder of the phase diagram represents the turbid region based on visual identification . The L2 microemulsion region was smaller compared with fig. 3.2.a and b.

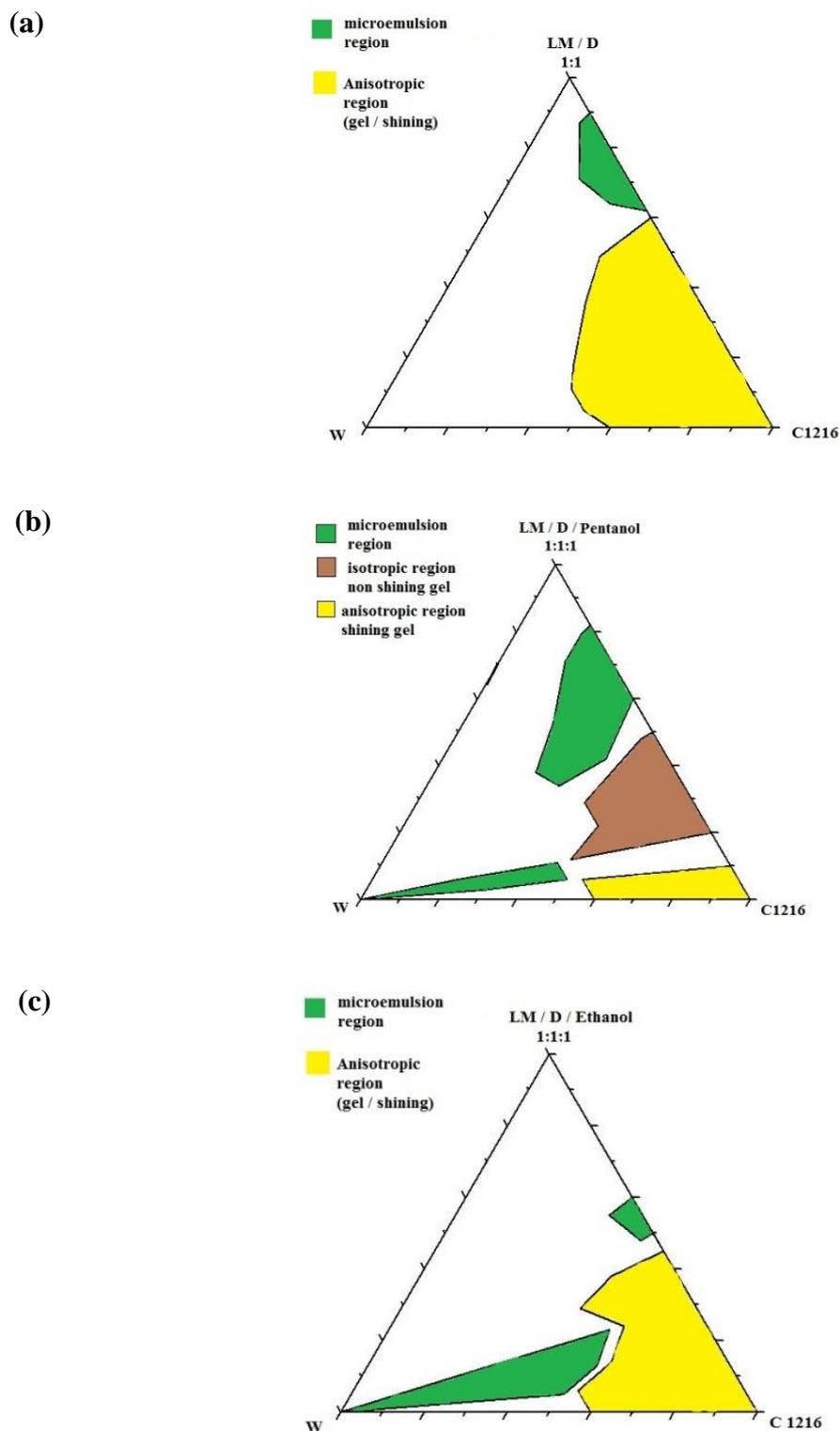


Fig.3.2: Pseudo-Ternary Phase Diagrams of: (a) Water/C1216 / Lemon oil / Diesel System. (b) Water/C1216/ 1-Pentanol / Lemon oil / Diesel with ration (1:1:1) System. (c) Water/C1216/ Ethanol / Lemon oil / Diesel with ration (1:1:1) System at 25°C.

Phase behavior of sucrose Laurate (C1216) was better than sucrose stearate (S1570), as it is shown in the figures, microemulsion regions were formed in (C1216) more than in (S1570).

1-Pentanol was better as co-surfactant than ethanol, due to the chain length of alcohol. Water in diesel microemulsions were formulated using 10 wt.% of single sugar ester surfactant (L1695); combined with $\delta = 0.12$ of co-surfactant (1-pentanol) at 25°C. [wadaa'h, S. 2012]. But in my work, water in diesel microemulsion were formulated using 10wt.% of single sugar ester surfactant C1216 without co-surfactant.

3.3: Phase Diagrams of Water/Sucrose dilaurate (C1205) Systems.

3.3.1: Phase Diagram of Water/Sucrose dilaurate (C1205) /Lemon oil / Diesel System.

Ternary phase diagram was studied upon addition of water to sucrose laurate /lemon oil /diesel with ratio (1:1) system at 25°C (Fig 3.3.a) . Micelle (L2) was formed at 20 wt.% of surfactant and continued until 60wt.% of surfactant . Highly viscous anisotropic LC region was also appeared at 70 wt.% of surfactant with 30wt.% of oil . Thus the remainder of the phase diagram represents the turbid region based on visual identification. No co- surfactant was used in order to simplify the System.

3.3.2: Phase Diagram of Water/Sucrose dilaurate (C1205) /1-Pentanol / Lemon oil /Diesel System.

The observed pseudo-ternary phase diagram shown(Fig.3.3.b) Indicated the presence of L2 at 18 wt.% of surfactant , and highly viscous anisotropic LC regions at 70wt.% surfactant . The remainder of the phase diagram represents the turbid region based on visual identification .

3.3.3: Phase Diagram of Water/Sucrose dilaurate (C1205) /Ethanol / Lemon oil /Diesel System.

The observed pseudo-ternary phase diagram shown(Fig.3.3.c) Indicated the presence of L2 at 20 wt.% of surfactant ,semisolid isotropic region at 65 wt.% and highly viscous anisotropic LC regions at 90wt.% surfactant . The remainder of the phase diagram represents the turbid region based on visual identification .

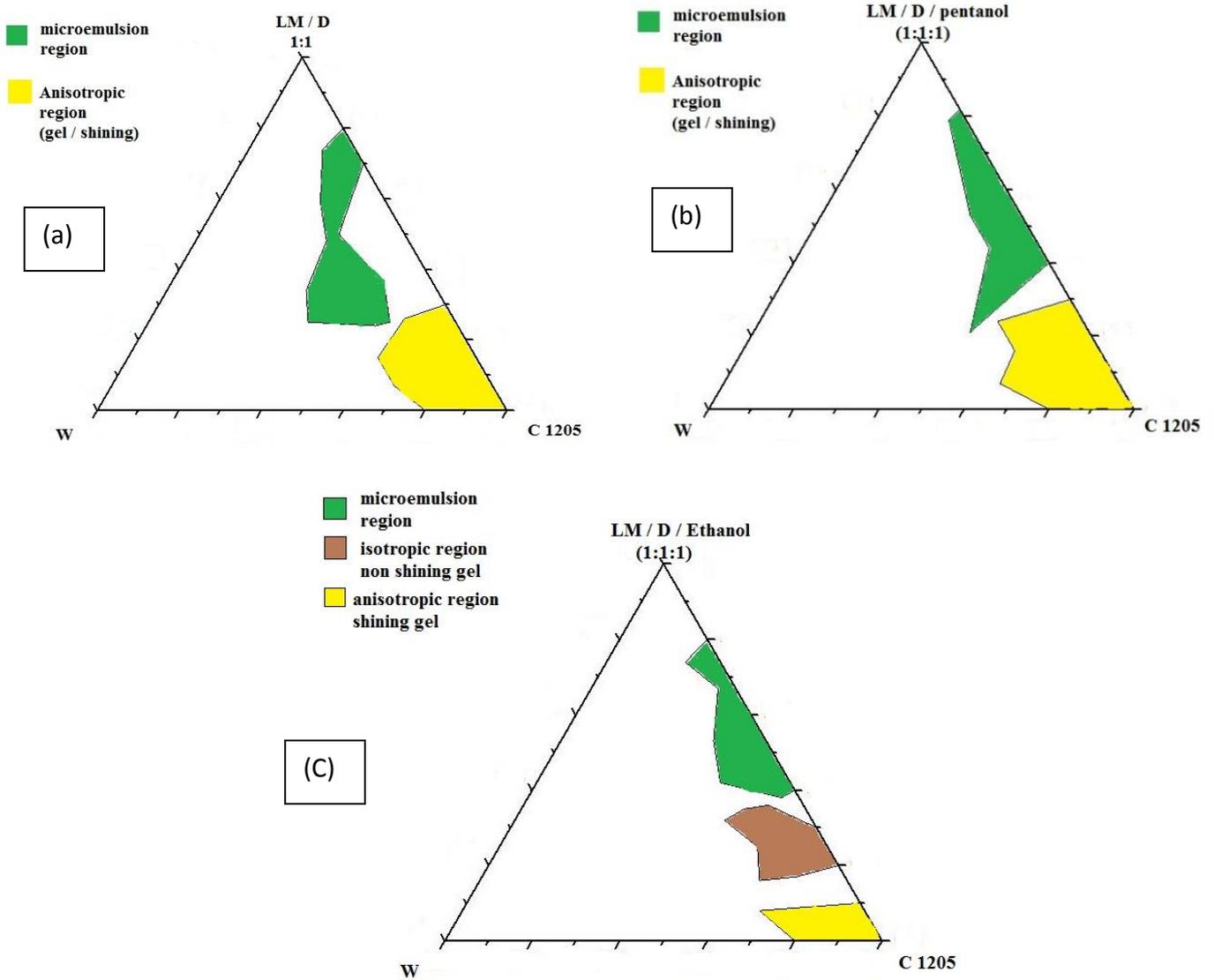


Fig.3.3: Pseudo-Ternary Phase Diagrams of: (a) Water/C1205 / Lemon oil / Diesel System. (b) Water/C1205/ 1-Pentanol / Lemon oil / Diesel with ration (1:1:1) System. (c) Water/C1205/ Ethanol / Lemon oil / Diesel with ration (1:1:1) System at 25°C.

LC regions in sucrose dilaurate was smaller than same regions in sucrose laurate, due to its structures. Packing ratio of Surfactant molecular decreases as the branches increases, so the LC region become smaller.

Microemulsion region was larger in phase diagram of Ethanol with sucrose dilaurate, compared with the same area in sucrose laurate.

3.4: Phase Diagrams of Sucrose laurate with 1-Propanol Systems.

The composition of the amphiphilic film is the tuning parameter of the mean curvature in quaternary temperature-insensitive systems [Cosima, 2009].(Fig 3.4).Schematically shows the change of the curvature with increasing fraction of alcohol in the amphiphilic film of water/sucrose monolaurate (L1695)/(diesel/medium chain alcohol) system. Knowing that the head group area of alcohols is smaller than that of sucrose monolaurate (L1695), one observes that an increasing fraction of alcohol in the mixed interfacial film causes a decrease of the mean curvature from $H > 0$ for o/w-microemulsion to $H < 0$ for w/o-microemulsion. [wadaa'h, S. 2012]

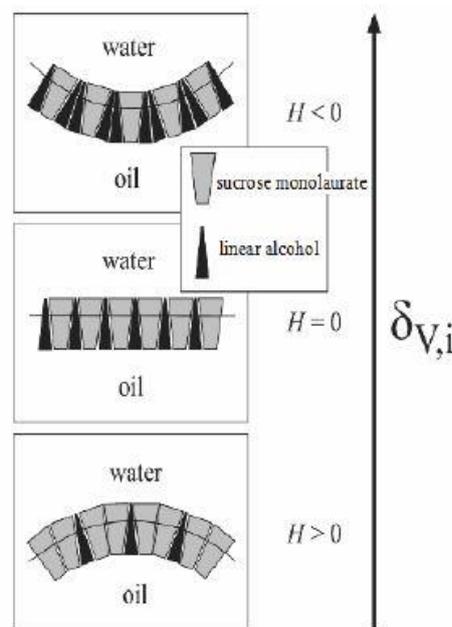


Fig.3.4: Mean curvature H of sucrose monolaurate (L1695) film at the water/oil interface as a function of the composition of the internal interface $\delta v, i$.

3.4.1: Phase Diagram of Water/Sucrose laurate (C1216)/1-Propanol / lemon oil / diesel System.

This phase diagram (fig.3.4.1) demonstrated that; a narrow area of reversed micelle (L2) was formed at 4wt.% of surfactant, and highly viscous anisotropic LC regions at 60wt.% surfactant. The remainder of the phase diagram represents the turbid region based on visual identification.

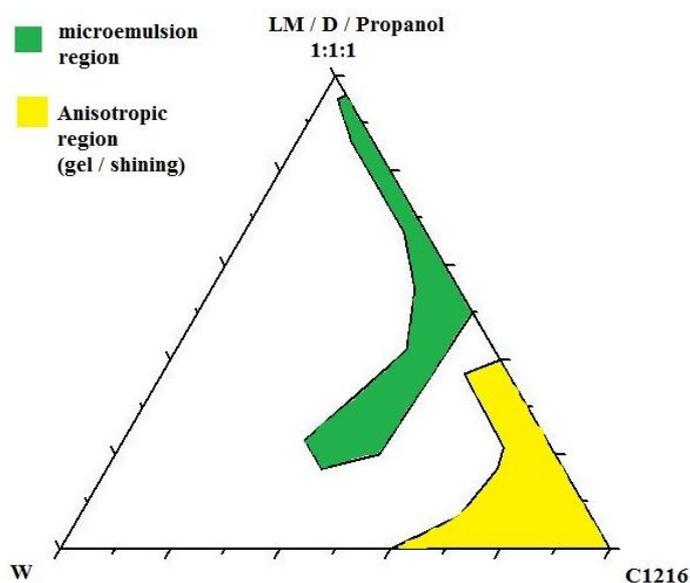


Fig.3.4.1: Pseudo-Ternary Phase Diagrams of Water/Sucrose laurate (C1216)/1-Propanol / lemon oil / diesel System at 25°C.

3.4.2: Phase Diagram of Water/Sucrose dilaurate (C1205) /1-Propanol / Limon oil /Diesel System.

This phase diagram demonstrated that; a wide area of reversed micelle (L2) was formed at 8wt.% of surfactant, and a small area of highly viscous anisotropic LC regions at 90wt.% surfactant. The remainder of the phase diagram represents the turbid region based on visual identification.

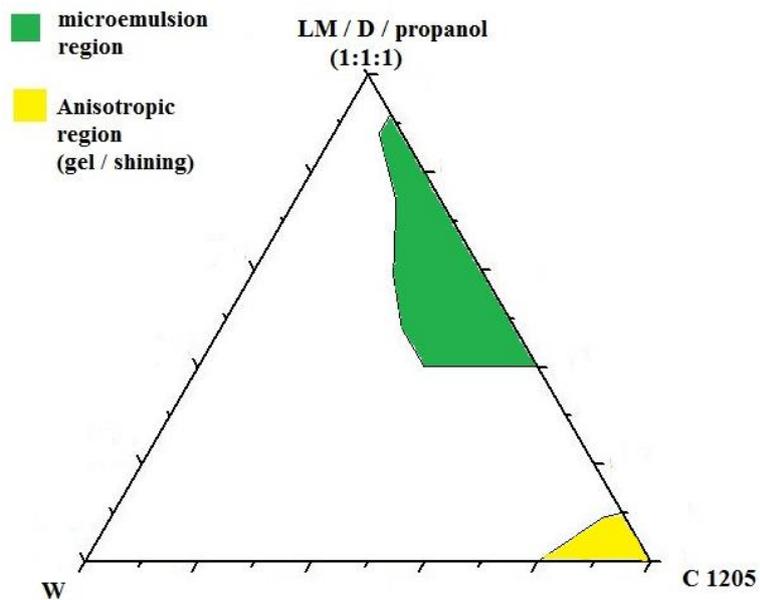


Fig.3.4.2: Pseudo-Ternary Phase Diagrams of Water/Sucrose dilaurate (C1205)/1-Propanol / lemon oil / diesel System at 25°C.

Propanol enhanced the formation of microemulsion, and decreases the viscosity, so the LC regions become smaller.

3.5: Phase Diagrams of Sucrose laurate without diesel .

3.5.1: Phase Diagram of Water/Sucrose laurate (C1216)/ lemon oil System.

Micelle (L1) was formed at 50 wt.% of surfactant. Highly viscous anisotropic LC region was also appeared at 80 wt.% of surfactant. Thus the remainder of the phase diagram represents the turbid region based on visual identification. (Fig.3.5. 1).

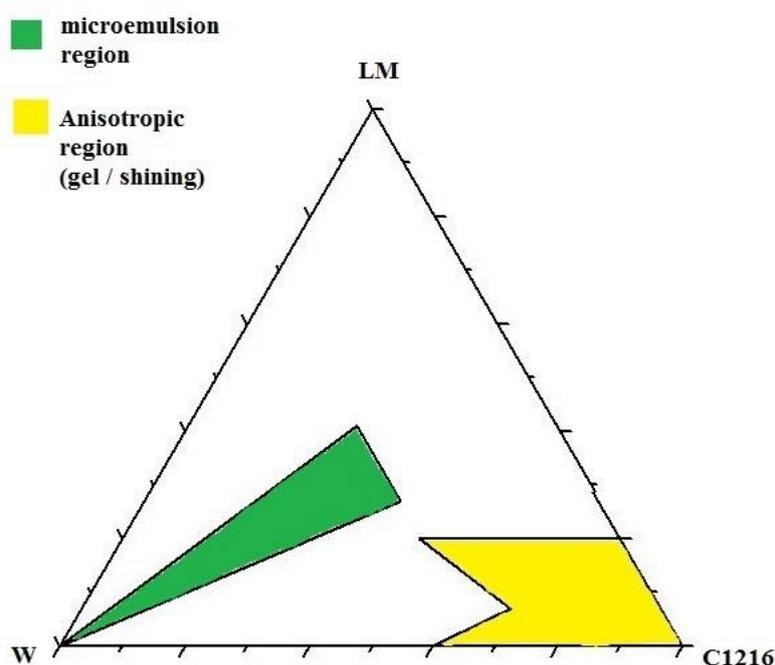


Fig.3.5.1: Pseudo-Ternary Phase Diagrams of Water/Sucrose laurate (C1216) / lemon oil System at 25°C.

3.5.2: Phase Diagram of Water/Sucrose dilaurate (C1205) / Limon oil System.

This phase diagram demonstrated that; a very narrow area of reversed micelle (L2) was formed at 18wt.% of surfactant . The remainder of the phase diagram represents the turbid region based on visual identification .(Fig.3.5.2).

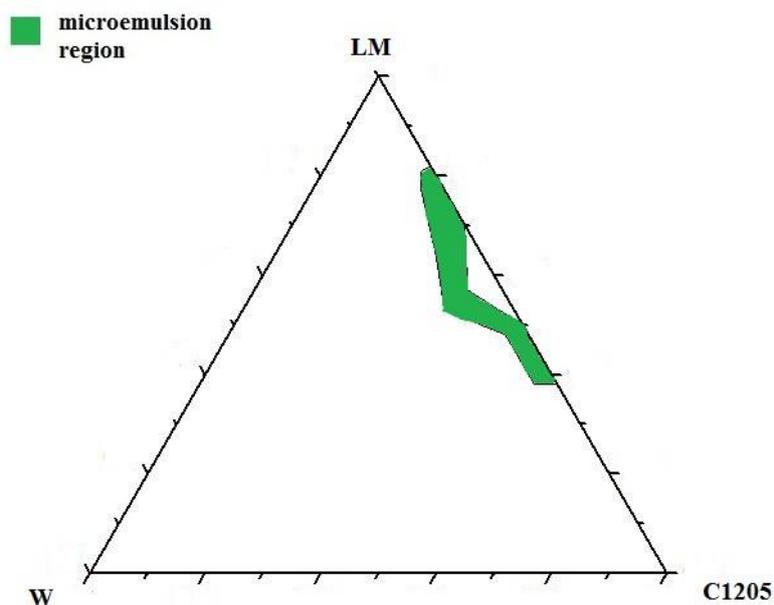


Fig.3.5.2: Pseudo-Ternary Phase Diagrams of Water/Sucrose dilaurate (C1205) / lemon oil System at 25°C.

3.5.3: Phase Diagram of Water/Sucrose laurate (C1216)/1-Propanol / lemon oil System.

This phase diagram that shown in figure (3.5.3) , demonstrated that; a very wide area of reversed micelle (L2) was formed at 5wt.% of surfactant , and a highly viscous anisotropic LC regions at 80wt.% surfactant . The remainder of the phase diagram represents the turbid region based on visual identification .

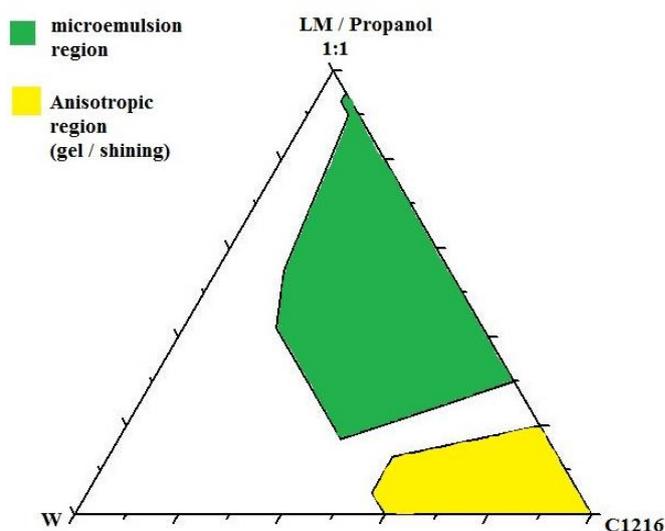


Fig.3.5.3: Pseudo-Ternary Phase Diagrams of Water/Sucrose laurate (C1216)/1-Propanol / lemon oil System at 25°C.

3.5.4: Phase Diagram of Water/Sucrose laurate (C1216)/Ethanol / lemon oil System.

The observed pseudo-ternary phase diagram shown(Fig.3.5.4) Indicated the presence of L2 at 28 wt.% of surfactant , and highly viscous anisotropic LC regions at 80wt.% surfactant . The remainder of the phase diagram represents the turbid region based on visual identification .

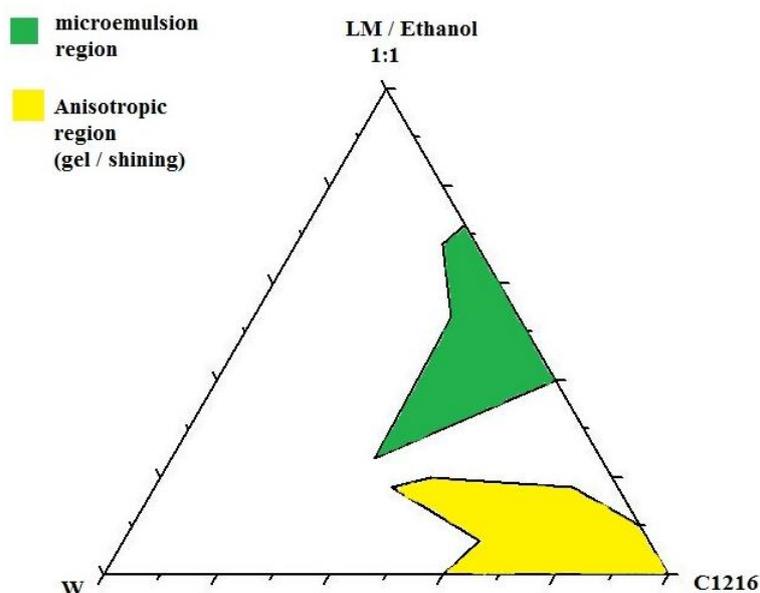


Fig.3.5.4: Pseudo-Ternary Phase Diagrams of Water/Sucrose laurate (C1216)/Ethanol / lemon oil System at 25°C.

3.5.5: Phase Diagram of Water/Sucrose dilaurate (C1205) /1-Propanol / Limon oil System.

Micelle (L2) was formed at 4 wt.% of surfactant, and the area was wide. Thus the remainder of the phase diagram represents the turbid region based on visual identification. (Fig.3.5. 5).

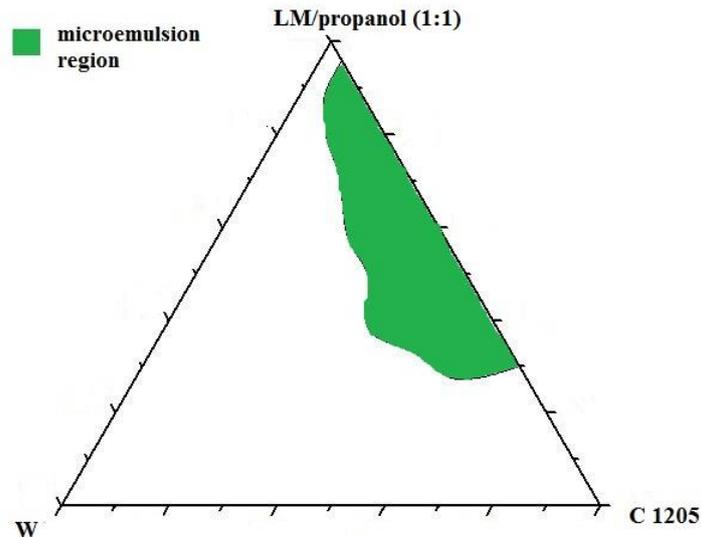


Fig.3.5.5: Pseudo-Ternary Phase Diagrams of Water/Sucrose dilaurate (C1205)/1-Propanol / lemon oil System at 25°C.

3.5.6: Phase Diagram of Water/Sucrose dilaurate (C1205) /Ethanol / Limon oil System.

Narrow area of micelle (L2) was formed at 18 wt.% of surfactant. Highly viscous anisotropic LC region was also appeared at 70 wt.% of surfactant and it was narrow too. The remainder of the phase diagram represents the turbid region based on visual identification. (Fig.3.5. 6).

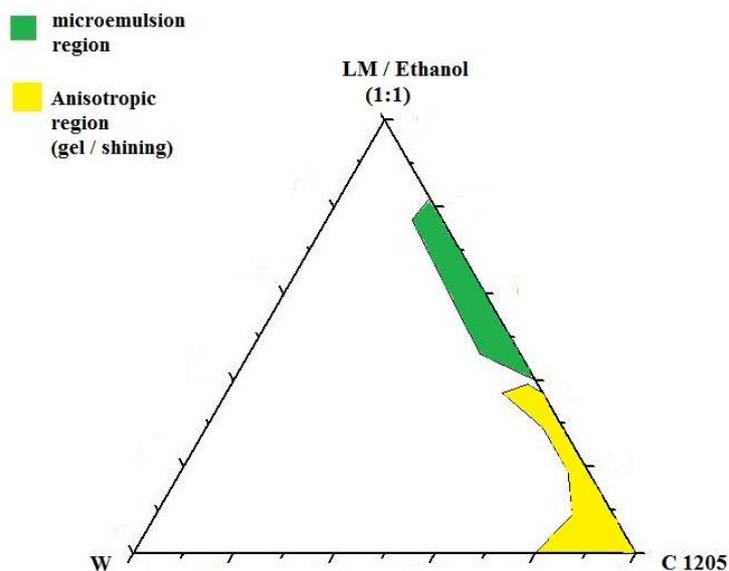


Fig.3.5.6: Pseudo-Ternary Phase Diagrams of Water/Sucrose dilaurate (C1205)/Ethanol / lemon oil System at 25°C.

3.6. Conclusion :

This work shows that the addition of medium chain alcohol as a co-surfactant at different mass fraction in the diesel/ alcohol mixture is necessary to initiate the formation water in diesel microemulsions.

Water in diesel microemulsions were formulated using 4 wt.% of sugar ester surfactant C1216, combined with co-surfactant 1-Propanol at 25°C. Also microemulsion was formulated using minimum amount of nonionic sugar ester surfactant C1216 values as low as 5wt.% of surfactant at room temperature with 1-Propanol as co-surfactant without diesel.

Microemulsion was formed at 4 wt.% of surfactant C1205 with 1-Propanol/ lemon oil 1:1 ratio. Thus 1-Propanol gives best result comparing with ethanol and 1-Pentanol in all phase diagrams.

Ethanol and 1-Pentanol as co-surfactants had almost the same behavior in the microemulsion region in C1205, however ethanol produced an extra isotropic region that did not exist in the 1-Pentanol phase diagram.

At last the reasonable amount of surfactant required to form water in diesel microemulsion provide realistic options in the search for alternative fuel that would reduce the level of both nitrogen oxides and soot in the emission.

3.7. Future work.

Dynamic light scattering and conductivity can be performed on the formulation. And Construct a new phase diagrams with different ratio (1:1:2),(2:1:1) ,(2:0.5:1),(1:0.5:2) of 1-propanol , diesel , lemon oil and (1:2),(2:1),(1:3),(3:1) of 1-propanol , lemon oil respectively. We can also test the phase behavior at different temperature .

Combustion experiments can be performed on such formulation. In order to investigate suitable, stable and applicable microemulsion formula serves water-Diesel fuel.

Chapter Four :

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4.1. References

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صياغة وتوصيف الزيوت المستدامة بمستحلب المايكرو وتطبيقها في الوقود

الحيوي

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المشرف الثاني: منذر فنون.

4.2: الملخص:

في الوقت الحاضر هناك تركيز كبير في المحافظة على البيئة والتفكير في سبل للحد من الغازات الضارة التي تطلق يوميا الى الغلاف الجوي، نتيجة لحرق المنتجات البترولية. أيضا هناك نقص في مصادر الطاقة مثل البترول ومشتقاته. لذلك، يجب علينا أن نجد بدائل اعتمادا على المنتجات الطبيعية لإنتاج الطاقة المتجددة التي لا تضر بالبيئة وتقلل من تلوث الهواء.

تهدف هذه الدراسة إلى تحضير صيغ لمستحلب المايكرو (microemulsion) يخدم وقود الماء - الديزل ، وذلك باستخدام الحد الأدنى من منشط السطوح غير الأيوني (nonionic surfactant) و في هذه الدراسة استخدمنا منشط السطوح السكري (sugar base surfactant) C1205 , C1216 و S1570 . والطبقة الزيتية المستخدمة هي زيت الليمون والديزل. ولقد استخدمنا عدة انواع من مساعد منشط السطوح (co-surfactant) هي الايثانول و البروبانول والبنتانول .

في هذا البحث درسنا تأثير النسب المئوية المختلفة لمنشط السطوح (surfactant) على سلوك الطور (phase behavior) على النظام المكون من زيت الليمون والديزل بنسبة (1:1) و الماء و منشط السطوح . ثم درسنا تأثير مساعدات منشط السطوح (co-surfactant) المختلفة على أولا : الانظمة المكونة من زيت الليمون والديزل بنسبة (1:1) و الماء و منشط السطوح (surfactant) ، وثانيا: تأثيرها على الانظمة المكونة من زيت الليمون و الماء و منشط السطوح بدون الديزل .

تم تكوين صيغه لمستحلب المايكرو (microemulsion) يخدم وقود الماء - ديزل باستخدام 4% من منشط السطوح سكر الايستر (sugar ester surfactant) C1216 بوجود مساعد منشط السطوح 1-بروبانول و زيت الليمون والديزل بنسبه (1:1:1) على درجة حرارة 25 درجة سيلسيوس.

وأيضاً تم تكوين مستحلب المايكرو بدون وجود الديزل باستخدام 5% من منشط السطوح سكر الايستر C1216 (sugar ester surfactant) بوجود مساعد منشط السطوح 1-بروبانول (co-surfactant) و زيت الليمون بنسبة (1:1) على درجه حراره 25 درجه سيلسيوس ، وكانت المنطقه كبيره .

في النهاية تم تكوين مستحلب المايكرو بكميه مناسبة من منشط السطوح اللازمه لوقود الماء - الديزل التي توفر خيارات واقعية في البحث عن وقود بديل والتي من شأنها أن تخفض مستوى كل من أكاسيد النيتروجين (NO_x) والسخام (soot) في الانبعاثات.