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Dietary Supplement Wastewater Treatment by Biological Methods

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DIETARY SUPPLEMENT WASTEWATER TREATMENT BY BIOLOGICAL METHODS

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ABSTRACT

Dietary supplements, pre-mixed meal like Slim Fast, are part of most people's lives. Since dietary supplements have a high order of complex sugars, low-fat milk, and all kinds of nutrients, they bring hazards to the environment if discharged to water bodies without any proper treatment. Therefore, wastewater from dietary supplement gains much more attention at the present time.

Dietary supplement wastewater contains amounts of organic compounds which may be bio- friendly and non-toxic. Biological treatment shows its strong advantages in dealing with this kind of wastewater.In this research, four kinds of Live Liquid Micro-organisms (LLMO) were used as the sources of microorganism since they are effective, cheap, and famous products in the industrial field. Metabolic processes are the way microorganisms degrade organic compounds in water. Slim Fast and Carnation Breakfast Essentials were used as synthetic wastewater in the thesis study and can be treated effectively by biological treatment. Both of them are powder forms that are easy to store, and the content of them issuitable for metabolic processes of microorganisms.The calibration curves of these substrates have a R^2 close to 1.0. All experiments were done in a 24-hour time frame, and the Shimadzu TOC Analyzer was used to determine the performance of LLMO.

A comparison of total organic carbon removal efficiency among four different types of LLMO (E1, S1, G1, and N1) with two kinds of substrates was carried out in the study.Results showed that N1 had the best percentage of total organic carbon removed with Slim Fast.The research alsorevealed that the performance of LLMO was good for low strength synthetic dietary supplement wastewater.

Key words: Live Liquid Micro-organism, Slim Fast, Carnation Breakfast Essentials, Dietary Supplement Wastewater

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INTRODUCTION

As the pace of working life become more rapid in modern society, meal supplements are widely used to help people control food intake. On the other hand, these kinds of substitute daily meals (such as drinks, tablets, and bars) are also employed for balancing the calories and nutrients people consume in order to lose weight.

Carnation Breakfast Essentials is produced by one of the largest food manufacturers, Nestle. It is produced as a typical breakfast, which covers a wide range of nutrient needs such as vitamins, minerals, protein and carbohydrates. Compared to a long time consumed traditional breakfast, Carnation Breakfast Essentials provides a simple option for people who may gain the same caloric value of a meal.It has products in both powder and liquid forms. Powder forms are selected in this research because that they are easy to store.

Slim Fast is a brand owned by Unilever which produces substitutes for cooked meals and other dietary supplementary food. It is one of the dietary supplement foods to assist people controlling the caloric intake. The ingredients of Slim Fast include stabilizers and preservatives, and also vitamins, and mineral supplements, so that

theycan make people feel quite full to eat anything else. The meal plan of the Slim Fast consists of bars, shakes and other products. Powder shakes are used in this research.

With the increasing amount of meal supplements consumed, it is necessary to consider about a proper way to treat the wastewater. Biological methods used in wastewater treatment arethe most widely used in different kinds of industries.Since biological treatment offers several advantages such as high removal efficiency of organic material, less sludge production, cost effective. LLMO (Live Liquid Micro-organism) is a kind of industrial microorganism product widespread in improving wastewater treatment.

CHAPTER II

OBJECTIVES

The purpose of this thesis is to determine the removal efficiency of organic material from the synthetic wastewaters by biological methods and to investigate several parameters which affect the result. There are three major objectives included in this research:

1. This thesis will compare two kinds of synthetic wastewater (Carnation Breakfast Essentials and Slim Fast) and suggest proper selection of a substrate that will encouragemicrobial synthesis.

2. There are four kinds of LLMO (G1, N1, E1, and S1) that will be used to determine which their effectiveness in biological treatment.

3. This thesis will compare and analyze the percentage removal of organic material based on the concentration of two kinds of synthetic wastewaters, and detention time and the bacteria concentration.

CHAPTER III

LITERATURE REVIEW

3.1 Food Processing Wastewater

Food processing wastes are the end products from food industries that cannot be used for any other purpose. The economic value of these wastes is less than the cost of collection and reuse; therefore, they discharge as waste [1]. The food processing wastes mainly come from the raw material cost during handling and processing, washing, filtration, separating, cooking and other kinds of food production processes.There are five types of wastes: the floating solids such as leaves, minced meat, fruit peel; the suspended material such as fat, starch, colloidal substances, protein; the liquids such as salt, sugar, acid, alkali dissolved in water; the raw materials such as slit and other organic matters; also drug and other pathogens.

Food production and processing do not need large quantity of water, so the excess water becomes waste [2]. These wastesinclude both solids and liquids.Marashlian and El-Fadel also mentioned that wastewaterloading rateincreased by 1.9% to 7.1% (SS) and 17% to 62% (BOD) when the domestic water consumption and corresponding increase in wastewater flow rates are relatively insignificant [3].These food industry wastewater have some following common characteristics.

First, the quantity of wastewater is different since the scale of food industries can be from small to a variety of large ones. Among these food industries, their product, raw material and techniques vary a lot. Second, the quality and quantity of wastewater change with the seasons since the products coming from the industries change with seasons. Third, compared to other industries, food industry processing wastewater contains more biodegradable compounds, because most of the raw material come from natural organicsubstances, then the composition of wastewater is also dominated by these non-toxic and biodegradable natural organic matter. The value of BOD_5/COD can reach up to 84% [4]. Fourth, the wastewater contains a variety of microorganisms, such as pathogenic microorganisms which can make the wastewater perishable and stink. Fifth, the concentration of nitrogen and phosphorus in the wastewater may be very high. The characteristics of food industry processing wastewater can be concluded as following:

1. Large amounts of organic materials such as proteins, carbohydrates and liquids;

2. Varying amounts of suspended solids depending on the source;

3. High biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

According to the characteristics of these wastewaters, food industry wastewater without treatment would result in potential adverse impact on the environment, human health, and the quality of urban life. This rapid increasingly dissolved organic matter will result in a lot of volume of sludge, accompanied with unpleasant gases.In addition, a high concentration of nutrients, such as nitrite and

phosphorus, will cause eutrophication, which can lead to accumulate excess sludge and dead algae, and also the death of fish and aquatic animals. These algae will settle down atthe bottom of the water, consuming more dissolved oxygen to degrade, while fats, oil and grease coming from both the small food operation and large scales food processing plants are other wastes of the food industry. The oil floating on the surface of water bodies will reduce the concentration of dissolved oxygen. There is no oxygen diffusion from air. In addition, the food industry uses a large amount of water, where the substrate it contains may cause pollution. As a result, these would deteriorate water quality and pollute the environment. Therefore, the wastewater cannot discharge into a municipal sewer system directly.

3.2Food Wastewater Treatment

The wastewater from food industry is relatively safe and bio-friendly compared to industries with heavy metals. However when discharged into the environment,these wastescan pose potential environmental hazardswithout anytreatment. According to the characteristics of food industrial wastewater, biological treatment is good choice to be adopted. For example, aerobic tanks can be used for biological filtering, or multi-stage rotating biological contactors, or a combination of anaerobic-aerobic biological systems in a series. In general, sewage treatment can be divided into three parts: primary treatment, secondary treatment, and tertiary treatment.

3.2.1 Primary Treatment

The primary treatment is used in solid-liquid separation and also to remove suspended solids and grits. It can also reduce biological oxygen demand (BOD) and chemical oxygen demand (COD) because of solid solubilization. Screening, grit

removal, flow equalization and pH adjustment can be considered as the preliminary steps that take benefit of the biological processes used to treat food processing wastewater successfully. There are a number of methods that have been introduced to treat the food industry wastewater separately or in combination.

Screening is another typically first step to separate suspended solids from water body. It is widely used as the pretreatment methods. The main role of screening is dispersion of coarse suspended solids such as particles or debris that could damage the pumps and the following equipment. The screening opening and geometry of screening are the key parameters for screening [5].

Sedimentation is the most economical method to remove inorganic solids and organic solids, and also to separate the solid and liquid phases in the biological treatment process in raw wastewater. The solids will settle down based on gravity in a settling tank. Retention time, tank geometry and loading rates are three important design parameters which should be considered for sedimentation tank [6].

Dissolved air flotation is a clarification system that use micro bubbles that released from saturated air-water mixture to separate suspend solids and dispersed liquid such as fats, oils and grease from water. The floc particles attach to the bubbles and float to the surface where they are mechanically skimmed into the float scum sludge chamber. The dissolved air comes out of air-water solution and produces a fine bubble steam when it is pressurized. Important design parameters include: air to solid ratio, recycle ratio, hydraulic loading rate and solids loading rate[7]. Before the wastewater going into the flotation tank, adding chemical coagulator coagulant aid in water can improve the removal of emulsified oils and suspended particles. Author

Wand and Tang mentioned that air-flocculation can remove more than 90% fat and 40%-80% of BOD and SS when the hydraulic retention time of flotation tank retainsgenerally 30 minutes [8].

Coagulation is the main chemical treatment method used in food industry processing wastewater. However, coagulation cannot be used alone. It must be combined with sedimentation or flotation as the pretreatment of biological treatment. Coagulation and sedimentation is a very important method to remove some small colloidal particles and colloidal solution. These are hard or cannot precipitate by themselves. Adding chemical coagulant can help them form large particles and then settle down. Food industry wastewater may contain more protein and polysaccharide in colloidal form. Therefore, coagulation is a good way to remove them. Lime, ferrous, ferric chloride and aluminum are common coagulants. The dosages of coagulant and pH value are two key points should be determined through experiments [9].

Electro-flocculation is one technique to neutralizing charge of the suspended particles by passing electric current. Similar as chemical coagulation, it is used to gather the small particles into big ones. But it can reduce the cost of purchasing the chemical coagulant and sludge produced by chemicals. So it can be considered as the fast and cheap pre-treatment compared to conventionaltreatment. Author Chen used aluminum as the electrode material to treat restaurantfood wastewater with high concentration of oil. The hydraulic retention time was less than 4.5 minutes. The removal of oil, COD and SS were 99%, 88%, and 98% respectively. The electro-flocculation techniques produced 0.20~0.37 kg sludge when 1 kg COD was removed and the quality were treated. The quality of treated effluent meets the governmental regulation [10]. AuthorsKhoufi, et al also introduce the electro-coagulation to treat the

olive oil mill wastewater which has high content of organics and high concentration of potassium, magnesium and phosphate salts [11]. The current of wastewater passed through the Fe anodes, then ferric and ferrous dissolved and attached on hydroxyl in the water. The formed coagulant metal hydroxyl is partly soluble in water under certain pH values. The results showed this coagulant can help remove 70.55% of TSS, 91% of the color and 70% of the residual COD [12].

3.2.2 Secondary Treatment

For food industries wastewater, secondary treatment uses biological method to remove organic compounds and other toxic substancesin water. The main aim for the secondary biological treatment process is degradation of COD and BOD in organic wastewater. The most common methods of secondary treatment include activated sludge, tricking filter,anaerobic system and the combination previously mentioned technologies.

Aerobic treatment is commonly used for wastewater with high concentration of organic matter since it is effective. Activated sludge and tricking filter are two primary methods of aerobic treatment based on the difference of growth form of microorganisms [13].

3.3.2.1 Activated Sludge

Activated sludge process is the most widely used as secondary treatment method because it has the advantage of producing high quality effluent with a reasonable cost. Microorganisms feed on organic matters in wastewater under aerobic condition to produce relatively clear water. With the growth of microorganisms, organic materials flocculate together then form a mass of microbes, which is easy to

settle down and be separated out.Parts of sludge are considered waste, and the remainder is collected and then recycled back to system in order to prove the quality of treated effluent. Any the dead microorganisms will settle down on the bottom of aeration tank.

Activatedsludge is the use of certain microorganisms in the process of growth and reproduction of the formation of larger floc surface area.This process can produce highwastewaterflocculation and adsorption of the colloidal suspension or dissolved pollutants, and absorption of these substances into the cell body, the participation of oxygen, theses substrate for the cell itself, the composition of the assimilation , or the complete oxidation of these substances will release energy, carbon dioxide and water. This has the activity of microbial floc or floc termed mud that granular activated sludge microbial community.

In order to generate activated sludge, sewage sludge, septic sludge and wastewater treatment sludge are taken and domesticated by the wastewater which will be treated.In the process of domesticated, the concentrationand productivity of wastewater would be improved step by step. Aftersludge microbes used to the wastewater, the active sludge can be used to treat a certain type of wastewater. Then the system of wastewater treatment can work well-balanced.

Activated sludge is widely used in wastewater treatment process because it is effective and economic way to remove organics, phosphorus and nitrogen. For example, it was used in Singapore to treat wastewater from soy beverage processing. It mainly consists of aerobic activated sludge tank and sedimentation tank. The HRT

were 86 hours. Analysis the final effluent, 95% of COD, 67% of nitrogen and 57% of phosphorus had been removed [14].

There are some kinds of activated sludge technologies [15]. The first one is extended aeration tank which means it has longer hydraulic retention time. The HRT of it in the process is usually 18 hours or more. Because of the longer retention time, extended aeration plants are one of the most stable process, as well as less sludge produced.And the reactions happen under aerobic condition. Authors Sotirakou et al took the wastewater sample form Metamorphosis/Attica combined treatment plantevery two hours which was treated by extended aeration tank. After analysis, the removal rates were 92% of COD, 87% ofsuspended solids removal, and a complete removal of ammonia. Orthophosphates and total phosphorus had the removal value of 28% and 15%, respectively [16].

3.3.2.2 Sequential Batch Reactor

The sequential batch reactor (SBR)process has gained a lot of attention recently because it iseffective, relatively less land needed and good on some hard degradable organics. This process combines equalization, aeration, and clarification in the same tank. It isfeasible and advantageous to treat food processing wastewater. It was employed to treat a food industry which mainly produces candy, cake and glucose. Wastewater includes amount of carbon organic and some salt. Discharging of the water is not continuously and well distributed. After one year operation, the equipment operates normal and quality of the effluent is good and stable. Average removal efficiency of COD was more than 95%, and SS was 86.4%. 78.1% of NH_3 had been removed. The advantages of SBR are that equipment which was used to

separate unused liquid and suspended solids, and the reduction of sludge production [17].

3.3.2.3 Oxidation Ditches

Oxidation ditches are another effective variation compared to the traditional activated sludge process, especially for some small or medium wastewater treatment plants. Oxidation ditch consists of one reactor with a circular channel and mechanical aeration device, capable of simultaneously completing BOD removal, nitrification and de-nitrification. When wastewater goes through the channel, BOD and the concentration of organics are reduced, as well as TSS and ammonia, producing a high quality effluent [18].A full scale experiment was taken in Oxford wastewater treatment plant where the oxidation ditch activated sludge process was employed to treat wastewater. After one month operation, the WWTP showed a good performance. Average 89% of ammonia and 50% BOD had been removed [19].

3.3.2.4 Trickling Filter

Trickling filter is another kind of aerobic treatment system to biodegrade organic matter. A trickling filter consists of a bed whose surface is attached by microorganism then develops a biological filter media. When influent passes through the filter, the filter will absorb the pollutant. Then the bacteria in the filter will break down the organic waste [20]. Therefore, this filter media is the key point to determine the performance of trickling filter. Author Lekang said that void ration, specific surface area, weight, homogeneous water flow and economics are factor which should be taken a consideration when chose the bio-filter material [21]. There is a wide variety of packing used for the bed such as rocks, granite, plastic and wood. Organic

loading rate is the most important factor of designing. Based on the organic loading rate, a trickling filter can be classified as a low rate trickling filter (LRTF), high rate trickling filter (HRTF), roughing filter (RF) and intermediate rate filer (IRF).Table I compares the effectiveness of BOD_5 removal based on various BOD_5 loading rate [59].

Table I. Four types of Trickling Filter

Filter type	Kg BOD_5/100 m^3/d	BOD_5 Removal (%)
LRTF	≤ 40	80-90
IRF	40-60	50-70
HRTF	64-160	65-85
RF	160-480	40-65

Activated sludge and trickling filter belong to aerobic system, which had been used to treat food processing wastewater successfully for many years. However, there are some disadvantages which cannot be ignored. These have relatively high-energy consumption and biomass production and also high operation cost. High sludge is production by the aerobic method, as well as odor and vector problem. High COD/IN ratio is needed in wastewater may require nutrient supplement [22]. Therefore, anaerobic methods are introduced to treat the food industry processing wastewater.

3.3.2.4 Anaerobic Treatment

A suitable treatment method should be selected carefully in order to meet the stringent discharge regulation and reduce the cost of treating the wastewater coming from food industries. Anaerobic treatment gains much more attention in many countries because it is less energy consuming compared to aerobic technology, as well as low waste sludge and high biogas production [23]. These treatment methodshave been employed increasingly in the last two decades. Anaerobic digestion, anaerobic

filter process, and contact process are the main anaerobic treatment methods. Without any oxygen supplying the bacteria in anaerobic system can breakdown the complex organic compounds such as fats, proteins and carbohydrates to some simpler compounds, then convert them into methane and carbon dioxide.Second, anaerobic treatment process is suitable for food processing wastewaters due to them rarely produce some toxicants or inhibitory compounds.

Several anaerobic technologies had been raised to treat food processing wastewater.

Anaerobic digestion (AD) is the most method used to treat the wastewater with high concentration of organic. AD has been used to treat agricultural industrial and municipal sewage and sludge for over 100 years. It is considered a natural process that converts the biomass into methane and carbon dioxide by the methanogenicbacteria in an oxygen free environment. AD process happens in digestion tank where the materials are fed or through the tank as a continuous flow. Temperature, hydraulic retention time (HRT) and ammonia concentration are three significant process parameters which make the success of AD [24]. Temperature is important because the end products of pathogen would be destroyed at a higher temperature. HRT is the period that the materials stay in the tank and calculated by the daily input volume dividing the reactor volume. Different types of organic matter will be digested by bacteria with HRT varying. For example, ammonia is an inhibitor of the methanogenic bacteria to digest protein rich material. Usually, carbon rich amendment can be added to limit this inhibition [25]. Moletta had successfully used AD to treat the winery wastewater. The removal efficiency was 90% - 95% COD removal[26].

Anaerobic filter reactorswere also introduced to deal with high concentration wastewater.This reactor is carrier fixed on biofilm. The specific area of the carrier is several hundred square meters per cubic meter of carrier. There are two types of reactors, contingent on the flow pattern — up-flow and down-flow. AuthorsOmils et al suggested that anaerobic filter reactor is relatively effective to degrade fat. Therefore, this is a new trend in dairy processing industries whose effluent mainly contains milk and other milk products which have been lost in the process. 3.9% of fat in the milk cannot be easily degraded biologically. The research had been operated in a full-scale plant for more than 2 years. A 12 m^3 anaerobic filter is the main reactor to treat the diary wastewater. When the organic loading rate maintaining 5-6 kg COD/m^3d, more than 90% of COD has been removed, and most of the milk fat was degraded successfully. Additional SBR reactor can ensure a final effluent whit COD content below 200mg/L and total nitrogen below 10mg N/L [27].

In Austria, an up-flow anaerobic filter (UFAF) was developed to treat food processing wastewater. The main device is a column made by PVC material, randomly filled with porous glass material with 9000 m^2/m^3 of specific surface area. The ideal medium of anaerobic filter layer should have a large surface area and porosity which can prevent the clogging of the filter lay which is easy for microorganisms to adhesive. This UFAF reactor can treat the effluent coming from milk and soybean beverage industries at a relatively high organic loading rate, with high stability and food processing result.

Anaerobic contact process is the earlier development which had been created to deal with a variety of food processing wastewater and other kinds of wastes. It has been used in many kinds of wastewater successfully, especially for the one with high

levels of suspended solids and oily substances. The key point of this process is long retention time for microorganisms [28].The U. K. Science and EngineeringResearch Council had constructed pilot-scale anaerobic filter, contact process and fluidized bed which were operated on ice-cream wastewater and compared the performance of these reactors. The contact process reactor always got the highest COD removal among them, which is 80%. Other can remove 67% and 60% respectively [29].

Up flow anaerobic sludge blanket reactor (UASB)hasbeen successfully used to treat variety of industrial as well as domestic wastewater. The principle of UASB is using the suspended granule to treat wastewater. The microorganisms are in the granule. The biogas produced and the recirculation of the wastewater is used to suspend the granule. At the top of the reactor, there is an internal settler which is used to hold back the granule into the digester [30]. Boari also did some research both at laboratory and pilot scale to treat olive oil mill wastewaters whose COD are up to 220 kg/m^3. The tank capacity is 15 liters and 5 m^3 separately. Olive oil processing is an important business in the Mediterranean area where 1.4 – 1.8 million tons of these products are produced each year[31]. COD removal rate was 70% when diluted waste (COD = 13-18 kg/m^3) was fed at a volumetric loading rate between 16 and 21.5 kg COD/m^3d [32].

Some of these techniques above are difficult for the treatment of degradable or high salinity wastewater. However,anaerobic fluidized bed reactors (AFBR) have the capacity to handle the hazardous recalcitrant composition, because the more biogas can relatively expand along the reactor when it is introduced, which provides a nice environment for methane bacteria growth [33]. Authors Wei etal applied a full scale AFBR to treat food processing wastewater coming from a factory named Lee

KumKeeCondimentCorporation, in Guangdong, China. Flour, soybean, tomato, pepper and salt are main raw material for this factory. Wastewater typically includedcarbohydrates, liquid and salinity [34]. The reactor had been constructed with three different zones: a reaction zone, a separation zone, and an auxiliary zone. After more than a 2 month operation, the reactor showed effectiveness and stability to treat the high organic wastewater withhigh BOD/COD valuewhich included amount of nutrient such as nitrogen and phosphorus. 80.1 ∓ 5% COD had been removed at the volumetricloader rate between 1.6 and 5.6 kg COD m^{-3}/day^{-1} in 24 hours of hydraulic retention time [35].In addition, AFBR offers other advantages such as high organic loading rates and short hydraulic retention time [36]. Authors Garcia - Calderon et al employed the AFBR for red wine distillery wastewater. The ground perlite, an expanded volcanic rock were used as the carrier which can reach a minimum fluidization velocity of 2.3 mh^{-1}. When the system maintain a constant organic loading rate of 4.5 kg TOC m^3d^{-1}, 85% TOC can be removed, at the HRT of 1.3 days. And it was found that the system require lower energy compared to other reactors [37].

Since the aerobic and anaerobic have their own advantages and disadvantages, Authors Garrido et.alintroduced a treatment system with two reactors. One is anaerobic filter of 12 m^3 and another is sequencing batch reactor of 28 m^3following by.The anaerobic system can be used to convert organic matter into methane. The remaining COD and nitrogen are removed by the following SBR system. This design is in order to reduce energy consumption and biomass production. The result showed AF can reduce 50-85% of COD. Overall removal rate of COD was around 98% and nitrogen removal varied from 60% to 99% [38].

The highly variable characteristics of food processing wastewater in terms of volume, pH, organic and suspended solids content makes it is difficult to choose an effective wastewater treatment method. Discharging the wastewater without proper treatment will lead to environmental hazards. Therefore it is critical to select a method to meet the governmental regulation and reduce the cost.

3.2.3 Tertiary Treatment

Sludge is produced during anaerobic and aerobic treatment process, as well as gases like methane and carbon dioxide. The concentration of BOD and COD from theeffluentof the secondary treatmentmay not meet the local governmental standard. Whenever regulation is strict, it may be necessary to consult tertiary treatment. Some of the more common methods includemembrane technologies, activated carbon,and advance oxidation processes (AOP) such as ozone.

Membranes are introduced to treat wastewater, especially for food industrial processing wastewater because of its efficiency and energy saving.A member is an inorganic polymer material with a special selective separation function. It can divide fluid into two parts without mutually connection. Several materials can pass through the membrane as the one part; the other part will be isolated [39]. Some of advantages include reusing purification wastewater,recyclinghigh-valuematerial, remarkable economic and environmentalbenefits. Membrane technologies include microfiltration(MF),ultrafiltration(UF),nano-filtration(NF),reverse osmosis(RO),electro-dialysis(ED),pervaporation(PV),and membrane bioreactor(MBR). These methods have been used in treating food industry processing wastewater since 1990 [40].

Authors Ma and Yuan had mentioned that ultrafiltration with 8000 daltion molecular weight cut-off membrane can recover almost all protein when treating whey wastewater. It is efficient to recover more than 90% of stachyose and raffinose. RO process can also help recover purifying water for reusing. It also can reduce the amount of effluent and achieve great economic benefit [41].

Authors Zheng and Gao did some research on the wastewater coming from cane sugar factory by ultrafiltration.The authors were resolving the difficulty of removingCOD, BOD and color produced by caramel due to the pore size of the ultra-filter membrane. Therefore MBR and NF were employed to treat the wastewater to reach the emission standard of COD and color, and the wastewater recovery was more than 80% [42].

Activated carbon can be defined as a porous material that mixed by coal, wood and coconut shells. It also can be powder, granule and extruded forms. Activated carbon is used to remove organic compounds by an adsorption process [43].

In order to treat some high concentration and non-biodegradable organic wastewater, strong oxidants had been introduced as a new method to treat wastewater. Sreethawongcompared the TOC removal efficiency by using Al_2O_3andFe_2O_3/ Al_2O_3 as the catalyst to treat brewery factory wastewater by ozonation. It shows at the same flow and retention time, Al_2O_3can removal 25% of TOC but Fe_2O_3/ Al_2O_3can remove 85% of TOC and also get rid of the color from water [44].

Since food industry wastewater has amount of sugar, protein, biomass and nitrogen and phosphorus compound, ozone was mentioned to treat these food wastewater with high biodegradable organics. There are many advantages

includingeffectiveness, high rate of degradation, reduction of scum and sludge produced,small land needed and high degree of automotive. It has alsocan be used to sterilize, bleach and so on. AuthorsJiangbing Li et.al analyzed the following four aspects which are flow quantity of ozone, pH of wastewater, temperature of reaction and oxidation time to find the factors to treat the honey alcohol wastewater. When the flow was 0.10 m^3/h, pH = 9.0, time = 90 min, it can get 56.92% of removal efficiency [45].

A new type of advanced treatment for micro pollutedremoval from wastewater is known asozone-biological activated carbon (O-BAC) process for use in food industry wastewater treatment. O-BAC technology is a combination of biologicalactivated carbon adsorption and ozone. It promotes oxidation, adsorption, biodegradationfunctionality, and is effectivelycapable of removingorganic matter,disinfection by-products,andammoniaat the same time. It can also improve the color, smell, taste and many other indicators of water bodies. It can oxidize some toxicsubstances such as cyanide, phenol to harmless substances[46].

3.3 Microorganisms

The activated sludge consists of different kinds of microorganisms such as bacteria, fungi, protozoa, rotifer and other bacteria. More than 95% are bacteria. Bacteria use the organic compounds to gain carbon and energy. Therefore, it can convert organic pollutant to carbon dioxide, water and new cell.

3.3.1 Bacteria

Activated sludge bacteria consist of general bacteria, bacilli, and pylori, and other advanced filamentous bacteria. Individual cells of these bacteria interconnect to

form a thin wire chain. Sulfur bacteria is one which has soft hyphae can be bent movement that can oxide the hydrogen sulfide in wastewater into sulfur which will be stored in bacteria in the form of grain. These bacteria consist of 50% carbon, 20% of oxygen and 14% of nitrogen [47].Other common bacteria include alcaligenes, brevibacterium, sp tufted, fiber strain, pseudomonas, handle bacteria, jersey bacteria, sticks moving bacteria, and small flavobacteriumbacteria to name a few. Bacteria can be divided into two classes based on the source of electron donors −heterotrophy and another is autotrophy [48]. According to the absence of oxygen, bacterial can have aerobic bacteria and anaerobic bacteria [49].

In the wastewater treatment system, various bacteria combine into the community instead of living in the free-state. This combination of many bacterial groups formed certain of colloid call zoogloea. The shape of zoogloeavaries. In activated sludge the common shapes are oval-shaped, branch-shaped, and chuisi(mushroom-shaped). The size of zoogloea affects the adsorption and flocculation of activated sludge. Therefore, they need to be in control in wastewater treatment processes.

In addition, microorganisms in wastewater not only live together as a group, but also mutually supportive when they are going to remove organic compounds. In wastewater treatment even though one kind of bacteria does be dominant, in order to reduce BOD and COD significantly and meet the requirement of effluent, a variety of microbial cooperation is really needed.

3.3.2 Fungi

Fungi, including yeast and mold fungi, can grow and reproduce in acidic condition in activated sludge [50].Fungi require less nitrogen than bacteria. Therefore, theyplay an important role in dealing with certain special industrial wastewater with organic solid residue. Fungi also have a higher capacity to convert mold and phenyl. In general, in wastewater treatment there are not many fungal species, and the number is small. Candida, penicillium and fusarium fungi are some common fungi.

Xu and Nakhla described fungi for the pre-fermentation of wastewater for the enhancement of tomatoes food processing water biodegradability in an anaerobic/aerobic ultrafiltration system. Attempting to increase the removal efficiency of nitrogen and phosphorus, the authors used a pilot-scale system to show the performance of per-fermentation. At hydraulic retention time of 1.5 days, 99.4% of BOD and 91.9% of ammonia had been removed [51].Authors Merzokiet al also didresearchusing a bench-scale anaerobic-anoxic sequencing batch reactor. It had been successfully demonstrated that the removal efficiency of COD, NH_3N and PO_4^{3-} was 99%, 85% and 99%, respectively [52]. Using fungi as the pre-treatment process could help improve the removal efficiency.

3.3.3 Protozoa

The majority of protozoa are aerobic heterotrophic animal with single cell. These often take bacteria and organic particles as food and energy in the wastewater treatment process. Therefore they have an important role in wastewatertreatment. Protozoa can be divided into five categories: meat footed class, flagellates class, sporozoans class, straw type class and ciliated class. Ciliated class in wastewatertreatment is the most important one which include the bell-shaped

paramecium and insects. Inactivated sludge, thereis an increase of swimming paramecium will increase as compared to free bacteria.This paramecium will follow the bacteria and consume a lot of bacteria and organic particles. When the sludge is mature, free bacteria are reduced, then fixed bell-shaped insects (attached to the solid or on the floc) increase. The presence of different types of ciliates, to a certain extent, can reflect the different stage of wastewater treatment.

3.3.4 Metazoan

Metazoan is amulti-cellular animal, an aerobic heterotrophic, that spreads through bacteria and organic particles for food. Metazoan demand dissolvedoxygen for reproduction. In the activated sludge, the appearance of metazoan shows that the wastewater generally has reached the better level of quality. In recent years, many researchers are trying to observe of the type, quantity, and activities of protozoa and metazoan to infer the quality of effluent and the consequent of wastewater treatment. These can be considered as the indicator of wastewater treatment. Micro-metazoan rotifers, beetles and nematodes are the most common metazoan.

CHAPTER IV

MATERIALS AND METHODS

4.1 Material

4.1.1 Slim Fast Shake Mixes

Slim Fast was in form of powdered and stored in a metal can, purchased from a local store. There are approximately 13 ounces in the can. In order to develop a calibration curve, amount of powder form of Slim Fast was measured of 20, 50, 100, and 150 mg/L. Each powder was dissolved into 2 L contain with hot tap water. Then put contain with a magnetic stirrer on the stirrer at the highest rotation in order to get most dissolved solution.

4.1.2 Nestlé'sCarnation Breakfast Essentials

Nestlé'sCarnation Breakfast Essentials consisted of a powered form packed in individual packets.These were purchased froma local convenient store. Each package contains 10% protein, 9% total carbon compounds, and 7% potassium. In order to get the calibration curve of Carnation, the same steps did at the Slim Fast.

4.1.3 LLMO

The LLMO (Live Liquid Micro-organism) is akind of water treatment product made by General Environmental Science (GES). GES has been engaged in studying

the application of microbial commercialdevelopment since 1947. Having experienced continuous development and perfection of products, the company's series of products are sold around the world today. The LLMO gains its fame because of a world leading technology and rich experience in industrial microorganism field [53].

LLMO is a kind of liquid active microbial agent used to solve the problem of water pollution. Some LLMO contain fungi that widely exist in nature. Scientists have optimized and developed this kind of effectivebiological agent without any negative impact to human, or other biological living and the environment [54].

LLMO can mineralize organic in water converting them into carbon dioxide and water which are virulent and harmless. It is alsocapable of converting some harmful matters such as ammonia nitrogen from nitrite into nitrogengas. The application s of LLMO includes wastewater treatment plants to improve the effective of pollutants removal and reduce the sewage sludge. LLMO is very useful to inhibit the growth of algal to control eutrophication, restore the water quality and recover sediments.

LLMO is becoming so popular in industrial microorganism field because it has several advantages. First, the bacteria and fungi in LLMO have strong activity and rapid reaction because it is liquid form. Second, it is easy to store for a long time without refrigeration or other equipment needed. Third, it is easy to use －LLMO can just be pouring directly into the waste need to betreated. Sometimes, the simple aeration equipment is the only machine needed. Finally, it is cheap, safe, and effective for wide application range without producing any pollutants [55].

The LLMO product line includes six specialized bacteria for emulations: *Nitrosomonas, Nitrobacter, Aerobacteraerogenes*, several*Bacillus spp.*, *Cellulomonasbiazitea*, and *Pseudomonas spp.*Each of the six LLMO productsisused for the purpose of degrading various wastewater types. Four of them were used as following research [56]. Table II provides information on the various functions of LLMO used within the thesis research [55].

Table II. Function of LLMO

LLMO E-1	Excellent for rapid plant start-up, recovery from toxic shock, reduction of BOD and SS and help in cold weather applications. Increases overall plant efficiency, often used to improve final effluent. Effective for phenols and hydrocarbons.
LLMO S-1	Most often used for sludge treatment in lakes, ponds and wastewater treatment plants. Broad based product hydrolyzes a wide variety of organic solids.
LLMO G-1	Used for grease and fat solubilization. Applications include sewage collection systems, wet wells, grease traps, drain lines and septic tank maintenance. Also for industrial waste with high grease/fat content.
LLMO N-1	Suspension of nitrifying bacteria, converts ammonia to nitrite to nitrate, (nitrification) also denitrifies. Common uses: lakes, ponds, aquaculture, aquariums and wastewater treatment plants. Best in fresh water.

4.1.4Biofilters

These sample bottles were used for the purpose of completing batch experiments. These filters have a volume of 110 ml plastic bottles with a cap to tighten them.

4.1.5 Containers

These small plastic containers were used to store the filtered sampler after shaking. Three to five drops of concentrated hydrochloric acid was dropped in the containers and place them into the refrigerator before TOC measurements were taken.

4.1.6 Total Organic Carbon Analysis

4.1.6.1 Shimadzu TOC Analyzer 5050

Shimadzu is widely used in the analysis of TOC(Total Organic Carbon) and water. The measuring range of this equipment (Shimadzu's TOC –5050 series combustion oxidation instruments) is 50 ppb to 4000 ppm. The high sensitivity of the machine allows for various applications such as wastewater. The operation and analysis parameters can be entered via the keyboard and then displayed on the monitor. In this experiment each 50 μL volume samples are injected automatically via micro liter syringe. Combustion infrared gas analysis method is used in this equipment at the temperate of 680 $^{\circ}C$. It averagely takes 2 to 3 minutes to analyze each sample.

4.1.2.2Whatman Glass Filter Paper

The glass filter paper with a pore size of 1.5 um and diameter of 4.7 cm were used for the filtration prior to TOC.

4.1.2.3 Schimadzu Glass Vials

The Schimadzu glass vials were filled by supernatant of filtered samples. Samples were placed into the sample vial holder and held for measuring.

4.1.2.4 Vacuum filter

Vacuum filter was used in filtration procedures. Pour the wastewater into Gooch crucible with glass filter paper then turn the filter on.The filtered water will flow down to the sample container.

4.2 Methods

4.2.1 Prepare Solution for Each TOC Concentration (20, 50, 100, 150 mg/L)

1. Measure desired value of Carnation Breakfast Essentials for each TOC concentration in Petri dish on scale.

2. Fill the 1L volumetric flask with hot tap water. When the flask is filled to about 85% capacity, use small plastic beaker to fill flask slowly until value is below the meniscus of the point desired on the flask.Pour water into a 2L container. Repeat the steps to prepare 2L solution.

3. Add measured Carnation Breakfast Essentials powdered onto the beaker. Place onto magnetic stirrer and apply magnets to stir the solution until the constituents have been completely dissolved into hot water.

4.2.2 Prepare Bottles with LLMO

1. Apply G1 LLMO using 1, 5.5, or 10mL volume.

2. Pour solution into each biofilter until it arrives to 100 mL.

3. Repeat the above step until desired number of bottles a given LLMO type.

4. Label each bottle for time interval and concentrationfor each run. Repeatstep for all concentrations and time intervals.

5. Repeat step 1-4 to make solution with E-1, C-1, and F-1.

4.2.3 Filtration

1. Remove bottles at desired shaking time pouring into empty biofilter.

2. Place one Whatman Glass Filter Paper intoa Gooch cruciblelocated on the top of the vacuum filter.

3.Fill Gooch crucible with distilled water to wet filter paper before applyingtreated sample. Turn on vacuum and allow suction to filter distilled water.Remove rinsings from plastic tube located within the vacuum flask.

4. Add 2-3 drops of concentration H_2SO_4 into filtered water. Cover with lid. Put them into refrigeration and wait for next step.

4.2.4 Prepare TOC

1. Poursupernatant of filtered sample fromrefrigerator into a Schimadzu glass sample vial.

2. Place vial onto the sample vial holder which is on the left side of TOC machine.

3. Read the operation instructionson how to use this TOC machine, then following it to make determination of TOC.Read the result from printed material from Schimadzu TOC analyzer.

4.2.5 Measuring TOC of Synthetic Slim Fast Wastewater

Repeat the above step to measure the TOC of treated wastewater made by Slim Fast Shake Mix.

4.2.5 Run Description

Run #1 20, 50, 100 and 150 mg/L of Slim Fast with G1.

Run #2 20, 50, 100 and 150 mg/L of Slim Fast with S1.

Run #3 20, 50, 100 and 150 mg/L of Slim Fast with E1.

Run #4 20, 50, 100 and 150 mg/L of Slim Fast with N1.

Run #5 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with low strength of G1, S1, and E1.

Run #6 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with medium strength of G1, S1, and E1.

Run #7 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with high strength of G1, S1, and E1.

Run #8 20 and 100 mg/L of Carnation Breakfast Essentials with four kinds strength of N1.

Table III.Run #1 20, 50, 100 and 150 mg/L of Slim Fast with low strength of G1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE (ml)	SHAKING TIME(hr)
1	Slim Fast	20	G1	1	0
2	Slim Fast	20	G1	1	2
3	Slim Fast	20	G1	1	4
4	Slim Fast	20	G1	1	6
5	Slim Fast	20	G1	1	12
6	Slim Fast	20	G1	1	24
7	Slim Fast	50	G1	1	0
8	Slim Fast	50	G1	1	2
9	Slim Fast	50	G1	1	4
10	Slim Fast	50	G1	1	6
11	Slim Fast	50	G1	1	12
12	Slim Fast	50	G1	1	24
13	Slim Fast	100	G1	1	0
14	Slim Fast	100	G1	1	2
15	Slim Fast	100	G1	1	4
16	Slim Fast	100	G1	1	6
17	Slim Fast	100	G1	1	12
18	Slim Fast	100	G1	1	24
19	Slim Fast	150	G1	1	0
20	Slim Fast	150	G1	1	2
21	Slim Fast	150	G1	1	4
22	Slim Fast	150	G1	1	6
23	Slim Fast	150	G1	1	12
24	Slim Fast	150	G1	1	24

Table IV. Run #1 20, 50, 100 and 150 mg/L of Slim Fast with medium strength of G1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim fast	20	G1	5.5	0
2	Slim fast	20	G1	5.5	2
3	Slim fast	20	G1	5.5	4
4	Slim fast	20	G1	5.5	6
5	Slim fast	20	G1	5.5	12
6	Slim fast	20	G1	5.5	24
7	Slim fast	50	G1	5.5	0
8	Slim fast	50	G1	5.5	2
9	Slim fast	50	G1	5.5	4
10	Slim fast	50	G1	5.5	6
11	Slim fast	50	G1	5.5	12
12	Slim fast	50	G1	5.5	24
13	Slim fast	100	G1	5.5	0
14	Slim fast	100	G1	5.5	2
15	Slim fast	100	G1	5.5	4
16	Slim fast	100	G1	5.5	6
17	Slim fast	100	G1	5.5	12
18	Slim fast	100	G1	5.5	24
19	Slim fast	150	G1	5.5	0
20	Slim fast	150	G1	5.5	2
21	Slim fast	150	G1	5.5	4
22	Slim fast	150	G1	5.5	6
23	Slim fast	150	G1	5.5	12
24	Slim fast	150	G1	5.5	24

Table V. Run #1 20, 50, 100 and 150 mg/L of Slim Fast with high strength of G1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim fast	20	G1	10	0
2	Slim fast	20	G1	10	2
3	Slim fast	20	G1	10	4
4	Slim fast	20	G1	10	6
5	Slim fast	20	G1	10	12
6	Slim fast	20	G1	10	24
7	Slim fast	50	G1	10	0
8	Slim fast	50	G1	10	2
9	Slim fast	50	G1	10	4
10	Slim fast	50	G1	10	6
11	Slim fast	50	G1	10	12
12	Slim fast	50	G1	10	24
13	Slim fast	100	G1	10	0
14	Slim fast	100	G1	10	2
15	Slim fast	100	G1	10	4
16	Slim fast	100	G1	10	6
17	Slim fast	100	G1	10	12
18	Slim fast	100	G1	10	24
19	Slim fast	150	G1	10	0
20	Slim fast	150	G1	10	2
21	Slim fast	150	G1	10	4
22	Slim fast	150	G1	10	6
23	Slim fast	150	G1	10	12
24	Slim fast	150	G1	10	24

Table VI. Run #2 20, 50, 100 and 150 mg/L of Slim Fast with low strength of S1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim Fast	20	S1	1	0
2	Slim Fast	20	S1	1	2
3	Slim Fast	20	S1	1	4
4	Slim Fast	20	S1	1	6
5	Slim Fast	20	S1	1	12
6	Slim Fast	20	S1	1	24
7	Slim Fast	50	S1	1	0
8	Slim Fast	50	S1	1	2
9	Slim Fast	50	S1	1	4
10	Slim Fast	50	S1	1	6
11	Slim Fast	50	S1	1	12
12	Slim Fast	50	S1	1	24
13	Slim Fast	100	S1	1	0
14	Slim Fast	100	S1	1	2
15	Slim Fast	100	S1	1	4
16	Slim Fast	100	S1	1	6
17	Slim Fast	100	S1	1	12
18	Slim Fast	100	S1	1	24
19	Slim Fast	150	S1	1	0
20	Slim Fast	150	S1	1	2
21	Slim Fast	150	S1	1	4
22	Slim Fast	150	S1	1	6
23	Slim Fast	150	S1	1	12
24	Slim Fast	150	S1	1	24

Table VII. Run #2 20, 50, 100 and 150 mg/L of Slim Fast with medium strength of S1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim fast	20	S1	5.5	0
2	Slim fast	20	S1	5.5	2
3	Slim fast	20	S1	5.5	4
4	Slim fast	20	S1	5.5	6
5	Slim fast	20	S1	5.5	12
6	Slim fast	20	S1	5.5	24
7	Slim fast	50	S1	5.5	0
8	Slim fast	50	S1	5.5	2
9	Slim fast	50	S1	5.5	4
10	Slim fast	50	S1	5.5	6
11	Slim fast	50	S1	5.5	12
12	Slim fast	50	S1	5.5	24
13	Slim fast	100	S1	5.5	0
14	Slim fast	100	S1	5.5	2
15	Slim fast	100	S1	5.5	4
16	Slim fast	100	S1	5.5	6
17	Slim fast	100	S1	5.5	12
18	Slim fast	100	S1	5.5	24
19	Slim fast	150	S1	5.5	0
20	Slim fast	150	S1	5.5	2
21	Slim fast	150	S1	5.5	4
22	Slim fast	150	S1	5.5	6
23	Slim fast	150	S1	5.5	12
24	Slim fast	150	S1	5.5	24

Table VIII.Run #2 20, 50, 100 and 150 mg/L of Slim Fast with high strength of S1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim fast	20	S1	10	0
2	Slim fast	20	S1	10	2
3	Slim fast	20	S1	10	4
4	Slim fast	20	S1	10	6
5	Slim fast	20	S1	10	12
6	Slim fast	20	S1	10	24
7	Slim fast	50	S1	10	0
8	Slim fast	50	S1	10	2
9	Slim fast	50	S1	10	4
10	Slim fast	50	S1	10	6
11	Slim fast	50	S1	10	12
12	Slim fast	50	S1	10	24
13	Slim fast	100	S1	10	0
14	Slim fast	100	S1	10	2
15	Slim fast	100	S1	10	4
16	Slim fast	100	S1	10	6
17	Slim fast	100	S1	10	12
18	Slim fast	100	S1	10	24
19	Slim fast	150	S1	10	0
20	Slim fast	150	S1	10	2
21	Slim fast	150	S1	10	4
22	Slim fast	150	S1	10	6
23	Slim fast	150	S1	10	12
24	Slim fast	150	S1	10	24

Table IX.Run #3 20, 50, 100 and 150 mg/L of Slim Fast with low strength of E1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim Fast	20	E1	1	0
2	Slim Fast	20	E1	1	2
3	Slim Fast	20	E1	1	4
4	Slim Fast	20	E1	1	6
5	Slim Fast	20	E1	1	12
6	Slim Fast	20	E1	1	24
7	Slim Fast	50	E1	1	0
8	Slim Fast	50	E1	1	2
9	Slim Fast	50	E1	1	4
10	Slim Fast	50	E1	1	6
11	Slim Fast	50	E1	1	12
12	Slim Fast	50	E1	1	24
13	Slim Fast	100	E1	1	0
14	Slim Fast	100	E1	1	2
15	Slim Fast	100	E1	1	4
16	Slim Fast	100	E1	1	6
17	Slim Fast	100	E1	1	12
18	Slim Fast	100	E1	1	24
19	Slim Fast	150	E1	1	0
20	Slim Fast	150	E1	1	2
21	Slim Fast	150	E1	1	4
22	Slim Fast	150	E1	1	6
23	Slim Fast	150	E1	1	12
24	Slim Fast	150	E1	1	24

Table X.Run #3 20, 50, 100 and 150 mg/L of Slim Fast with medium strength of E1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim fast	20	E1	5.5	0
2	Slim fast	20	E1	5.5	2
3	Slim fast	20	E1	5.5	4
4	Slim fast	20	E1	5.5	6
5	Slim fast	20	E1	5.5	12
6	Slim fast	20	E1	5.5	24
7	Slim fast	50	E1	5.5	0
8	Slim fast	50	E1	5.5	2
9	Slim fast	50	E1	5.5	4
10	Slim fast	50	E1	5.5	6
11	Slim fast	50	E1	5.5	12
12	Slim fast	50	E1	5.5	24
13	Slim fast	100	E1	5.5	0
14	Slim fast	100	E1	5.5	2
15	Slim fast	100	E1	5.5	4
16	Slim fast	100	E1	5.5	8
17	Slim fast	100	E1	5.5	12
18	Slim fast	100	E1	5.5	24
19	Slim fast	150	E1	5.5	0
20	Slim fast	150	E1	5.5	2
21	Slim fast	150	E1	5.5	4
22	Slim fast	150	E1	5.5	6
23	Slim fast	150	E1	5.5	12
24	Slim fast	150	E1	5.5	24

Table XI. Run #3 20, 50, 100 and 150 mg/L of Slim Fast with high strength of E1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim fast	20	E1	10	0
2	Slim fast	20	E1	10	2
3	Slim fast	20	E1	10	4
4	Slim fast	20	E1	10	6
5	Slim fast	20	E1	10	12
6	Slim fast	20	E1	10	24
7	Slim fast	50	E1	10	0
8	Slim fast	50	E1	10	2
9	Slim fast	50	E1	10	4
10	Slim fast	50	E1	10	6
11	Slim fast	50	E1	10	12
12	Slim fast	50	E1	10	24
13	Slim fast	100	E1	10	0
14	Slim fast	100	E1	10	2
15	Slim fast	100	E1	10	4
16	Slim fast	100	E1	10	6
17	Slim fast	100	E1	10	12
18	Slim fast	100	E1	10	24
19	Slim fast	150	E1	10	0
20	Slim fast	150	E1	10	2
21	Slim fast	150	E1	10	4
22	Slim fast	150	E1	10	6
23	Slim fast	150	E1	10	12
24	Slim fast	150	E1	10	24

Table XII. Run #4 20, 50, 100 and 150 mg/L of Slim Fast with low strength of N1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim Fast	20	N1	1	0
2	Slim Fast	20	N1	1	2
3	Slim Fast	20	N1	1	4
4	Slim Fast	20	N1	1	6
5	Slim Fast	20	N1	1	12
6	Slim Fast	20	N1	1	24
7	Slim Fast	50	N1	1	0
8	Slim Fast	50	N1	1	2
9	Slim Fast	50	N1	1	4
10	Slim Fast	50	N1	1	6
11	Slim Fast	50	N1	1	12
12	Slim Fast	50	N1	1	24
13	Slim Fast	100	N1	1	0
14	Slim Fast	100	N1	1	2
15	Slim Fast	100	N1	1	4
16	Slim Fast	100	N1	1	6
17	Slim Fast	100	N1	1	12
18	Slim Fast	100	N1	1	24
19	Slim Fast	150	N1	1	0
20	Slim Fast	150	N1	1	2
21	Slim Fast	150	N1	1	4
22	Slim Fast	150	N1	1	6
23	Slim Fast	150	N1	1	12
24	Slim Fast	150	N1	1	24

Table XIII. Run #4 20, 50, 100 and 150 mg/L of Slim Fast with medium strength of N1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim fast	20	N1	5.5	0
2	Slim fast	20	N1	5.5	2
3	Slim fast	20	N1	5.5	4
4	Slim fast	20	N1	5.5	6
5	Slim fast	20	N1	5.5	12
6	Slim fast	20	N1	5.5	24
7	Slim fast	50	N1	5.5	0
8	Slim fast	50	N1	5.5	2
9	Slim fast	50	N1	5.5	4
10	Slim fast	50	N1	5.5	6
11	Slim fast	50	N1	5.5	12
12	Slim fast	50	N1	5.5	24
13	Slim fast	100	N1	5.5	0
14	Slim fast	100	N1	5.5	2
15	Slim fast	100	N1	5.5	4
16	Slim fast	100	N1	5.5	6
17	Slim fast	100	N1	5.5	12
18	Slim fast	100	N1	5.5	24
19	Slim fast	150	N1	5.5	0
20	Slim fast	150	N1	5.5	2
21	Slim fast	150	N1	5.5	4
22	Slim fast	150	N1	5.5	6
23	Slim fast	150	N1	5.5	12
24	Slim fast	150	N1	5.5	24

Table XIV. Run #4 20, 50, 100 and 150 mg/L of Slim Fast with high strength of N1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Slim fast	20	N1	10	0
2	Slim fast	20	N1	10	2
3	Slim fast	20	N1	10	4
4	Slim fast	20	N1	10	6
5	Slim fast	20	N1	10	12
6	Slim fast	20	N1	10	24
7	Slim fast	50	N1	10	0
8	Slim fast	50	N1	10	2
9	Slim fast	50	N1	10	4
10	Slim fast	50	N1	10	6
11	Slim fast	50	N1	10	12
12	Slim fast	50	N1	10	24
13	Slim fast	100	N1	10	0
14	Slim fast	100	N1	10	2
15	Slim fast	100	N1	10	4
16	Slim fast	100	N1	10	6
17	Slim fast	100	N1	10	12
18	Slim fast	100	N1	10	24
19	Slim fast	150	N1	10	0
20	Slim fast	150	N1	10	2
21	Slim fast	150	N1	10	4
22	Slim fast	150	N1	10	6
23	Slim fast	150	N1	10	12
24	Slim fast	150	N1	10	24

Table XV. Run#5 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials withlow strength of S1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	S1	1	0
2	Carnation	20	S1	1	2
3	Carnation	20	S1	1	4
4	Carnation	20	S1	1	6
5	Carnation	20	S1	1	12
6	Carnation	20	S1	1	24
7	Carnation	50	S1	1	0
8	Carnation	50	S1	1	2
9	Carnation	50	S1	1	4
10	Carnation	50	S1	1	6
11	Carnation	50	S1	1	12
12	Carnation	50	S1	1	24
13	Carnation	100	S1	1	0
14	Carnation	100	S1	1	2
15	Carnation	100	S1	1	4
16	Carnation	100	S1	1	6
17	Carnation	100	S1	1	12
18	Carnation	100	S1	1	24
19	Carnation	150	S1	1	0
20	Carnation	150	S1	1	2
21	Carnation	150	S1	1	4
22	Carnation	150	S1	1	6
23	Carnation	150	S1	1	12
24	Carnation	150	S1	1	24

Table XVI. Run#5 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with low strength of E1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	E1	1	0
2	Carnation	20	E1	1	2
3	Carnation	20	E1	1	4
4	Carnation	20	E1	1	6
5	Carnation	20	E1	1	12
6	Carnation	20	E1	1	24
7	Carnation	50	E1	1	0
8	Carnation	50	E1	1	2
9	Carnation	50	E1	1	4
10	Carnation	50	E1	1	6
11	Carnation	50	E1	1	12
12	Carnation	50	E1	1	24
13	Carnation	100	E1	1	0
14	Carnation	100	E1	1	2
15	Carnation	100	E1	1	4
16	Carnation	100	E1	1	6
17	Carnation	100	E1	1	12
18	Carnation	100	E1	1	24
19	Carnation	150	E1	1	0
20	Carnation	150	E1	1	2
21	Carnation	150	E1	1	4
22	Carnation	150	E1	1	6
23	Carnation	150	E1	1	12
24	Carnation	150	E1	1	24

Table XVII. Run#5 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials withlow strength of G1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	G1	1	0
2	Carnation	20	G1	1	2
3	Carnation	20	G1	1	4
4	Carnation	20	G1	1	6
5	Carnation	20	G1	1	12
6	Carnation	20	G1	1	24
7	Carnation	50	G1	1	0
8	Carnation	50	G1	1	2
9	Carnation	50	G1	1	4
10	Carnation	50	G1	1	6
11	Carnation	50	G1	1	12
12	Carnation	50	G1	1	24
13	Carnation	100	G1	1	0
14	Carnation	100	G1	1	2
15	Carnation	100	G1	1	4
16	Carnation	100	G1	1	6
17	Carnation	100	G1	1	12
18	Carnation	100	G1	1	24
19	Carnation	150	G1	1	0
20	Carnation	150	G1	1	2
21	Carnation	150	G1	1	4
22	Carnation	150	G1	1	6
23	Carnation	150	G1	1	12
24	Carnation	150	G1	1	24

Table XVIII. Run #6 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with medium strength of S1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	S1	5.5	0
2	Carnation	20	S1	5.5	2
3	Carnation	20	S1	5.5	4
4	Carnation	20	S1	5.5	6
5	Carnation	20	S1	5.5	12
6	Carnation	20	S1	5.5	24
7	Carnation	50	S1	5.5	0
8	Carnation	50	S1	5.5	2
9	Carnation	50	S1	5.5	4
10	Carnation	50	S1	5.5	6
11	Carnation	50	S1	5.5	12
12	Carnation	50	S1	5.5	24
13	Carnation	100	S1	5.5	0
14	Carnation	100	S1	5.5	2
15	Carnation	100	S1	5.5	4
16	Carnation	100	S1	5.5	6
17	Carnation	100	S1	5.5	12
18	Carnation	100	S1	5.5	24
19	Carnation	150	S1	5.5	0
20	Carnation	150	S1	5.5	2
21	Carnation	150	S1	5.5	4
22	Carnation	150	S1	5.5	6
23	Carnation	150	S1	5.5	12
24	Carnation	150	S1	5.5	24

Table XIX. Run #6 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with medium strength of E1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	E1	5.5	0
2	Carnation	20	E1	5.5	2
3	Carnation	20	E1	5.5	4
4	Carnation	20	E1	5.5	6
5	Carnation	20	E1	5.5	12
6	Carnation	20	E1	5.5	24
7	Carnation	50	E1	5.5	0
8	Carnation	50	E1	5.5	2
9	Carnation	50	E1	5.5	4
10	Carnation	50	E1	5.5	6
11	Carnation	50	E1	5.5	12
12	Carnation	50	E1	5.5	24
13	Carnation	100	E1	5.5	0
14	Carnation	100	E1	5.5	2
15	Carnation	100	E1	5.5	4
16	Carnation	100	E1	5.5	6
17	Carnation	100	E1	5.5	12
18	Carnation	100	E1	5.5	24
19	Carnation	150	E1	5.5	0
20	Carnation	150	E1	5.5	2
21	Carnation	150	E1	5.5	4
22	Carnation	150	E1	5.5	6
23	Carnation	150	E1	5.5	12
24	Carnation	150	E1	5.5	24

Table XX. Run #6 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with medium strength of G1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	G1	5.5	0
2	Carnation	20	G1	5.5	2
3	Carnation	20	G1	5.5	4
4	Carnation	20	G1	5.5	6
5	Carnation	20	G1	5.5	12
6	Carnation	20	G1	5.5	24
7	Carnation	50	G1	5.5	0
8	Carnation	50	G1	5.5	2
9	Carnation	50	G1	5.5	4
10	Carnation	50	G1	5.5	6
11	Carnation	50	G1	5.5	12
12	Carnation	50	G1	5.5	24
13	Carnation	100	G1	5.5	0
14	Carnation	100	G1	5.5	2
15	Carnation	100	G1	5.5	4
16	Carnation	100	G1	5.5	6
17	Carnation	100	G1	5.5	12
18	Carnation	100	G1	5.5	24
19	Carnation	150	G1	5.5	0
20	Carnation	150	G1	5.5	2
21	Carnation	150	G1	5.5	4
22	Carnation	150	G1	5.5	6
23	Carnation	150	G1	5.5	12
24	Carnation	150	G1	5.5	24

Table XXI. Run#7 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with high strength of S1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	S1	10	0
2	Carnation	20	S1	10	2
3	Carnation	20	S1	10	4
4	Carnation	20	S1	10	6
5	Carnation	20	S1	10	12
6	Carnation	20	S1	10	24
7	Carnation	50	S1	10	0
8	Carnation	50	S1	10	2
9	Carnation	50	S1	10	4
10	Carnation	50	S1	10	6
11	Carnation	50	S1	10	12
12	Carnation	50	S1	10	24
13	Carnation	100	S1	10	0
14	Carnation	100	S1	10	2
15	Carnation	100	S1	10	4
16	Carnation	100	S1	10	6
17	Carnation	100	S1	10	12
18	Carnation	100	S1	10	24
19	Carnation	150	S1	10	0
20	Carnation	150	S1	10	2
21	Carnation	150	S1	10	4
22	Carnation	150	S1	10	6
23	Carnation	150	S1	10	12
24	Carnation	150	S1	10	24

Table XXII. Run #7 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with highstrength of E1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	E1	10	0
2	Carnation	20	E1	10	2
3	Carnation	20	E1	10	4
4	Carnation	20	E1	10	6
5	Carnation	20	E1	10	12
6	Carnation	20	E1	10	24
7	Carnation	50	E1	10	0
8	Carnation	50	E1	10	2
9	Carnation	50	E1	10	4
10	Carnation	50	E1	10	6
11	Carnation	50	E1	10	12
12	Carnation	50	E1	10	24
13	Carnation	100	E1	10	0
14	Carnation	100	E1	10	2
15	Carnation	100	E1	10	4
16	Carnation	100	E1	10	6
17	Carnation	100	E1	10	12
18	Carnation	100	E1	10	24
19	Carnation	150	E1	10	0
20	Carnation	150	E1	10	2
21	Carnation	150	E1	10	4
22	Carnation	150	E1	10	6
23	Carnation	150	E1	10	12
24	Carnation	150	E1	10	24

Table XXIII. Run #7 20, 50, 100 and 150 mg/L of Carnation Breakfast Essentials with high strength of G1.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	G1	10	0
2	Carnation	20	G1	10	2
3	Carnation	20	G1	10	4
4	Carnation	20	G1	10	6
5	Carnation	20	G1	10	12
6	Carnation	20	G1	10	24
7	Carnation	50	G1	10	0
8	Carnation	50	G1	10	2
9	Carnation	50	G1	10	4
10	Carnation	50	G1	10	6
11	Carnation	50	G1	10	12
12	Carnation	50	G1	10	24
13	Carnation	100	G1	10	0
14	Carnation	100	G1	10	2
15	Carnation	100	G1	10	4
16	Carnation	100	G1	10	6
17	Carnation	100	G1	10	12
18	Carnation	100	G1	10	24
19	Carnation	150	G1	10	0
20	Carnation	150	G1	10	2
21	Carnation	150	G1	10	4
22	Carnation	150	G1	10	6
23	Carnation	150	G1	10	12
24	Carnation	150	G1	10	24

Table XXIV. Run #820 mg/L of Carnation Breakfast Essentials with N1 measured Vs. Time.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	20	N1	1	0
2	Carnation	20	N1	1	2
3	Carnation	20	N1	1	4
4	Carnation	20	N1	1	6
5	Carnation	20	N1	1	12
6	Carnation	20	N1	1	24
7	Carnation	20	N1	3	0
8	Carnation	20	N1	3	2
9	Carnation	20	N1	3	4
10	Carnation	20	N1	3	6
11	Carnation	20	N1	3	12
12	Carnation	20	N1	3	24
13	Carnation	20	N1	5	0
14	Carnation	20	N1	5	2
15	Carnation	20	N1	5	4
16	Carnation	20	N1	5	6
17	Carnation	20	N1	5	12
18	Carnation	20	N1	5	24
19	Carnation	20	N1	10	0
20	Carnation	20	N1	10	2
21	Carnation	20	N1	10	4
22	Carnation	20	N1	10	6
23	Carnation	20	N1	10	12
24	Carnation	20	N1	10	24

Table XXV. Run #8100 mg/L of Carnation Breakfast Essentials with N1 measured Vs. Time.

BOTTLE NO.	WW TPYE	WW TOC (mg/L)	MICROORGAN TYPE	DOSAGE(ml)	SHAKING TIME(hr)
1	Carnation	100	N1	1	0
2	Carnation	100	N1	1	2
3	Carnation	100	N1	1	4
4	Carnation	100	N1	1	6
5	Carnation	100	N1	1	12
6	Carnation	100	N1	1	24
7	Carnation	100	N1	3	0
8	Carnation	100	N1	3	2
9	Carnation	100	N1	3	4
10	Carnation	100	N1	3	6
11	Carnation	100	N1	3	12
12	Carnation	100	N1	3	24
13	Carnation	100	N1	5	0
14	Carnation	100	N1	5	2
15	Carnation	100	N1	5	4
16	Carnation	100	N1	5	6
17	Carnation	100	N1	5	12
18	Carnation	100	N1	5	24
19	Carnation	100	N1	10	0
20	Carnation	100	N1	10	2
21	Carnation	100	N1	10	4
22	Carnation	100	N1	10	6
23	Carnation	100	N1	10	12
24	Carnation	100	N1	10	24

CHAPTER V

RESULTSAND DISCUSSION

5.1 Preliminary Research

Before this research, predecessorsMr. Erick Butlerand Ms. Tianzhu Bi also tried differentsubstrates for the experiment, such as Hershey's Cocoa, Kool Aid, Gatorade, potato starch and flour. However, Carnation Breakfast Essential and Slim Fast were selected as the primary substrate due to their readily available organic material for the microorganisms. And as powder forms, both can be stored easily and quickly reproduced without the necessary purchase of fresh liquid form.

Slim Fast includes some vitamin and minerals which are required for reproduction of organism. Vitamin C, E, D, K and some inorganic such as calcium, zinc, iron, copper and manganese will provide nutrient for organism. On the other hand, Slim Fast has many differences with Carnation Breakfast Essential. First, the mass of protein in Slim Fast is two times higher than Carnation Breakfast Essential. Second, soy protein as a main ingredient has been introduced in Slim Fast. Soy protein is a type of complex sugar. In addition maltoelextril consists of several glucose chains. Due to its content, Slim Fast becomes the primary option for the experiment.

The pH of different of substrates had been measured as Table XXVI. The result showed the pH is stable. And room temperature was used in this experiment which is 24ºC.

5.2 Results and Discussion

5.2.1 Result of Run#1

Run 1 considered the TOC removal efficiency of 20, 50, 100, 150 mg/L Slim Fast by applying low, medium, and high strength of G1 respectively. When low strength (1mL) of G1 was used to treat 20, 100, 150 mg/L of Slim Fast, Figure I showed that the largest TOC removal wasat 12 hours, where the removal rateswere 63%, 52%, and 42%. The largest TOC removal happened for 50 mg/L Slim Fast at 24 hours which was 64%. And the removal efficiency did not change too much from 12 hours to 24 hours.

When medium strength (5.5 mL) of G1 was used to treat the prepared substrate at four various concentration during 24 hours, three of them (TOC concentration 20, 50, and 100 mg/L) reached the highest removal rate at 24 hours from Figure II. The removal efficiency was 59%, 62%, and 52%,respectively. 150 mg/L of Slim Fast arrived at its largest removal rate at 12 hours which was 56%. But compared to all of the substrate treated, the largest removal occurredat 24 hours that 62% of 50 mg/L Slim Fast had been removed.

Analysis of high strength (10 mL) of G1 was done in a twenty-four hour time frame. Comparingthe four various concentrations of substrates, Figure III showed that the largest removal rate for 20 mg/l of Slim Fast was 63% at 12 hours and 24 hours. This wasalso the highest removal rate overall. At 24 hours, the removal efficiencies of

the four substrates were63%, 58%, 52%, and 45% separately.So it concluded that at 24 hours, all of these samples achieved the treatment effect.

Compared to higher concentration of Slim Fast, the lower one such as 20 mg/L and 50 mg/L can get a larger removal rate, concluding that G1 is more suitable to treatSlim Fast at lower organic concentrations. And all of removal rates were around 60%. Figures from I to IIIalso show that the remove efficiency reduce at first 6 hours and then increase in the rest of time. When shaking time is longer, Slim Fast has more readily available nutrient and minerals are dissolved in water for the microorganism.After the first six hours, the removal efficiency is decreased but increased later on.

5.2.2 Result of Run #2

Run#2 used the 1 mL, 5.5 mL and 10 mL of S1 to treat the synthetic wastewater mixed by Slim Fast with four various concentrations (20, 50, 100 and 150 mg/L). When the low strength (1mL) of S1 was employed to deal with the organic material, the highest removal rate was after 24 hours, where the % TOC removed was 67%, 75%, 43%, and 55% respectivelypresented in Figure IV. The highest removal efficiency was 75% for 50 mg/L of Slim Fast. Consider 20 mg/L and 50 mg/L as the substances with lower concentration, while 100 mg/L and 150mg/L are higher. In the first part, the removal efficiency of 20 mg/L of Slim Fast is higher than 50 mg/L, but after 12 hours shaking, 50 mg/L of Slim Fast offered a better result.The same as the first part, in 100 mg/L of substance, only 20% of TOC had been removed, which was much less than 100 mg/L of Slim Fast. After several hours shaking, it increased to 55% which is better than 100 mg/L of Slim Fast. Overall, substance with low concentration showedbetter removal efficiency than the high ones. The presents that the organic

components within the 50 mg/L of Slim Fast can assist in constant reproduction of organisms in the 24-hour time frame. Compared to 150 mg/L of Slim Fast, the content in 20 mg/L is easy to dissolve in the water. Therefore, there is a tendency of the removal rate do not remarkably change.But it is decreased first then increased with the higher concentration of substrates.

When medium strength (5.5 mL) of S1 was used in the experiment, substrates reached the highest removal rate at 24 hour wherethe % TOC removal registered at 66%, 73%, 63%, and 52% respectively. Figure Vshowed that at lowstrength(50 mg/L) substrate the removal efficiency was the largest after a treatment time of 24 hours. The lower strengths of Slim Fast indicated an increase removal rate during the first four hours.If shaking time is longer, it is increased during the rest of the timeframe. However, higher strengths increased as treatment time increased. Compared to low strength of S1, medium strength S1 can provide more bacteria and fungi to consume the organic material in water. Therefore, the differences of the removal efficiency among the samples were reduced, even though the substances with lower concentration had higher removal rates than the higher ones.

When the high strength (10 mL) of S1 was applied to treat 20, 50, 100, and 150 mg/L Slim Fast, it decreased before it increased. When the biofilters were shaken, more Slim Fast wasdissolved in the water, where the microorganisms had highly used the organics.However, when the consumption of organics was much more than the Slim Fast released, the removal rate will increase. Therefore, from Figure VI, we can find out that the removal rate arrived at the highest point at 24 hours, which was 71%, 74%, 72%, and 60% respectively. Analysis of these figures of Run #2, it shows that the highest removal rate stay around 70% no matter which level of S1 was used.

According to Figures from IV toVI, compared to low and medium of S1, the higher strength of S1 will improve the removal of TOC for substances with high concentrations.The high strength of S1 can remove more organics in the wastewater and the substances with highconcentration can provide more organicmaterial for microorganisms. Therefore, the removal efficiency of substrates with higher concentration became better.

5.2.3 Result of Run #3

Run 3 used low, medium and high strength (1, 5.5, and 10 mL)of E1 to treat four different concentrationsof Slim Fast (20, 50, 100, and 150 mg/L). When 1 mL S1 was introduced to the synthetic wastewater, at low strength wastewater (20 mg/L)the highest removal efficiency was 71% at 12 hours. And it is the highest one overall. At 2 hours, the removal rates of the four samples were 70%, 60%, 47%, and 28%, respectively. It can be concluded that all the substrates at 2 hours remove the majority of organics from wastewater. The bacteria composited of E1 have rapid reaction with organic compounds because of the bacteria life cycle [57]. The lag phase, the log phase, the stationary phase and the death phase are four phases that composited the bacteria life cycle.

The first one is lag phase or adjustment phase. During this period, bacteria do not grow. They require a time to adjust to the new environment. The log phase is also called generation time that means the bacterial reproduce rapidly. During the stationary phase, the growth of bacteria decreases, but they still replicate. When the death phase is coming, bacterial lose their ability to reproduce.

Several factors will influence the growth, thus affecting the bacteria life cycle. The factors include temperature, energy sources and the presence of oxygen, nitrogen, minerals and water. For example, if the environment supplies amount of nutrient, the lag phase will be shorter.

In the first 12 hours, the removal rate stayed around 70% and did not change too much.The tendency of the curve from Figure VIIshowed the removal rate was stable during the 24 hours but with some fluctuation. Then it is easy to say that since the concentration of organism is low in 1 ml of E1, the organics in 20 mg/L of substrate is enough to sustain them to survive. And the efficiency of lower substrates has big difference with the higher substrates, which can also provide the previous conclusion. And the organisms had rapid reaction with organic compounds since the most removal efficiency happened at 2 hours.

When medium strength (5.5 mL) of S1 was employed in dealing with four kind's concentrations of substrates (20, 50, 100 and 150 mg/L), Figure VIII showed that there is a difference of removal efficiency between 20 mg/L and 50 mg/L. The substrate with 20 mg/L, had the highest removal rate at 2 or 60%. And the substrate with 50 mg/L had the maximum removal rate of 59%, at 12 hours, which was exceed the removal efficiency of 20 mg/L of Slim Fast at the same time. The higher concentration of substrates arrived at the highest removal efficiency of themselves at 2 hours as well, which were 45% and 26% respectively.

The third part of run 3 was high strength (10 mL) of E1 is added to the synthetic wastewater. Since the higher concentration of organism was added, the data showed a different story compared to previous ones. All the four different

concentration of substrates (20, 50, 100, and 150 mg/L) reached the highest removal rate at 12 hours which were 62%, 61%, 48%, and 32% respectively. The removal efficiency wassimilar between 20 mg/L and 50 mg/L of Slim Fast in Run #3. During the 24-hour time frame, the removal rate decreases during the first 6 hours then rises up to the 24-hour time frame. In order to support more organisms, the powder form needed more shaking time to completely dissolve in water. Figure IXshow that when dissolved organic is less than consumed organic, the removal efficiency will increase.

Comparing the processing effect of three different strength of E1, using high strength of E1 to treat the substrate with 20 mg/L after 12 hour can get the best result. The higher concentration the substrates included, the less effect by E1. The higher the strength of E1 employed, the better removal rate can be achieved. But the preponderance is not remarkable.

5.2.4 Result of Run #4

Run 4 considered the TOC removal efficiency of Slim Fast with four kinds of concentrations (20, 50, 100 and 150 mg/L) by low, medium and high strength (1, 5.5, and 10 mL) of N1.

Low strength(1 mL) N1 was used to treat 20, 50, 100, and 150 mg/L of Slim Fast. The TOC removal was recorded−68%, 60%, 54% and 48% respectivelyat 24 hours. At 4 hours, the % TOC removal was at the peak, but then increased. As treatment time increased, the non-dissolved materialdecomposes into the water providing more food for the organism from N1. At the concentration of 20 mg/L of substrate was most effective for low strength of N1, which was 68%.

When medium strength (5.5 mL) N1 was used to treat Slim Fast, from the Figure XI, we can observe a deduction first four hours, the removal efficiency reached the highest at 24 hours, which were 70%, 57%, 54%, and 42% respectively. Also 70% was the best result.

When high strength (10 mL) of N1 was employed in this experiment, except the substrate with highest concentration (150 mg/L), highest TOC removal rate occurred at 24 hours. Figure XII showed the rateswere 71%, 57% and 55% respectively. For the 150 mg/L of Slim Fast, it had the most effective rate at 12 hours, which was 42%.

F/M ratio is introduced here to analyze the data showed from Figures X to XII. Food to Microorganism Ratio compares the amount of income food with the microorganism in the system [57]. The food is based on theavailability of the organic constituents and what is readilyavailable for the microorganisms. The microorganisms are contingent onthe life cycle and presence.When the F/M ratio is within the optimum point, the result of treatment is good; otherwise, it may be not so good. For example, F/M ratio is between 0.2 and 0.5, the quality of effluent is good by activated sludge or conventional biological treatment. The values vary what types of treatment are used. When the F/M ratio is high, excessive nutrients will lead to the large population of bacteria produced and speed up the metabolic. When the F/M is low, too little nutrition is leading to endogenous respiration. The living organism will oxidize some of their own cellular mass then the death rate of organism will be higher than growth rate. Therefore, when 20 mg/L of substances was treated by 10 mL N1, the F/M ratio is within the optimum point. Comparing the three strengths of N1 of Figure XVI, the differences ateachtwo-hour interval in this part were not remarkable.

5.2.5 Summary of Results from Run #1 to Run #4

In these four runs, Slim Fast was used as the substrate with four different types of LLMO (G1, S1, E1, and N1) using low, medium and high strengths were taken as the source of microorganisms. Comparing all of the conditions, it is easy to find using low strength of S1 to treat 50 mg/L of Slim Fast, easily removed 75% of TOC at 24 hours. However, for medium and high strength of S1, the highest removal efficiency did not change too much.

The same as S1, the removal efficiency did keep stable with various strength of N1. And the highest removal rate was around 60%. When G1 was used to treat Slim Fast, the % TOC increased with the rising of the volume of G1 used in the experiments, especially in the first six hours. For example, at 2 hours, 20% of TOC had been removed by 1 mL G1; 38% of TOC had been removed by 5.5 mL G1; 46% of TOC had been removed by 10 mL. For S1, N1 and G1, the removal rates decreased at first six hours and increased after that. On the contraryE1 showed that TOC removal was stable at first six to twelve hours but decreased after that. This is possible due to a shorter bacteria life as compared to other microorganisms. Perhaps after 12 hours, the bacteria was almost enter the death phase.

When the shaking time increased, it is more effective to removal the organics in the wastewater. This same conclusion followed as the concentration of substrate and the strength of LLMO. But the economic part should be taken into consideration.

5.2.6 Result of Run #5

Run #5 considered removing TOC from Carnation by low strength (1 mL) LLMO.

In the first part, low strength S1 was used to get rid of the TOC from synthetic wastewater. When 20 mg/L of Carnation was applied to S1, 99% of TOC had been removed at 24 hours where treatment was 80% during the first 2 hours of treatment from Figure XIII. However, for higher concentrations of Carnation Breakfast, optimum treatment at 24 hours was 50%, 29% and 28% TOC removal respectively.

LLMO - El also removed TOC from wastewater at four various concentrations (20, 50, 100, and 150 mg/L) of organics.Figure XIVshows that at 24 hours, TOC had been completely removed at 20 mg/L of Carnation. The removal rate was increasing and finally the microorganism in low E1 removed all of the organics in the water. The removal efficiency was not good with the higher concentration of substrates. The wastewater with 50 mg/L of substrate achieved maximum removal at 6 hours and 55% of TOC. For 100 mg/L and 150 mg/L of substrates, the removal rates were less than 30% during the 24 hours. Even though shaking time was longer, the removal rate was higher for both of them.

LLMO - G1 was employed to treat the synthetic wastewater. The performance was good to treat low concentration of substrates (20 mg/L), which gave 91% of TOC removal rate at 12 hours. There was also more than 50% of TOC had been removed by low strength G1in water with 50 mg/L of substrate at 12 hours.The higher concentration of substrates did not show good capacity of organic removing, just less than 30% of removal rate during the twenty-four hour time frame.

5.2.7 Result of Run #6

Run #6 considered the TOC removal efficiency of Carnation treated by medium strength (5.5 mL) of LLMO.

When medium strength (5.5 mL) S1 was added into the Carnation Wastewater (20, 50, 100, and 150 mg/L), all removal rates increased hourly. Figure XVI showed that percent TOC removal did not change much across the various concentration of substrate. When treatment time was 24 hours, S1 was very effective. The removal rates of the four concentration substances were around 57%, which were 56%, 58%, 56% and 58% respectively. These results indicate that at medium strength S1 works with any concentration of substrates, and as longer time, the efficiency is better.

When 5.5 mL medium strength E1 was considered as the organism resource, the result made by E1 was best among four different types of LLMO. Also the removal rates were increasing hourly. At 24 hours treatment time, the medium strength of E1 was most effective. The removal rates at 24 hours were 60%, 74%, 65% and 79% respectively showed in Figure XVII. To treat the Carnation with 150 mg/L, S1 had good performance. 79% of TOC had been removed. The removal rate was lower for 150 mg/L of Carnation compared to others, but when more and more organics dissolved in the water after shaking, it suddenly changed to the most effective one.

When 5.5 mL medium strength G1 was used to treat the four kinds of concentration of substrates, the result of the experiment in Figure XVIII, medium strength G1 was not good enough to remove the organic in the substrates. The average removal rate was less than 50% at 24 hours, and only got 71% for substrates with 20 mg/L of Carnation.

5.2.8 Result of Run #7

Run #7 used high strength (10 mL) of LLMO to treat the Carnation with four kinds of concentration (20, 50, 100 and 150 mg/L).

When 10 mL high strength S1was used to remove the organic in the Carnation wastewater, from Figure XIX we can see there were distinct differences among the removal efficiency with the four concentrations of substrates (20, 50, 100, and 150 mg/L). S1 was last effective at 150 mg/L of substrate which contained the higher TOC (% TOC). On the contrary, it was effective for 20 mg/L of Slim Fast 12 hours, which was 60%. At shaking time of 6 hours 50, 100 and 150 mg/L of substances had the highest removal rate of 46%, 23%, and 9%. From this it is easy to say S1 is not the best one to remove TOC.

When high strength E1(10 mL) was added into the wastewater to treat the wastewater, the Figure XX showed that medium strength E1 presented good performance to remove organic from High strength E1 removes TOC in medium concentration of substrates at a relatively short period of time. At 4 hours, E1 removed 55% of TOC of 20 mg/L of Carnation. From the time interval between eight hours, the removal rate stayed stable. The same as the substrate with 50 mg/L, the removal rate remainedsteady. This is different from high concentration (100 and 150 mg/L) of Carnation. The removal rate was decreased as compared to the higher concentration of organic in water to provide enough food for the organism. There was not able to remove more organic from the water, but after shaking, more organics were released into the water. It specifically expressed in removal efficiency is lower compared to the beginning of the experiment.

When high strength G1was employed to treat the wastewater, the removal rates were also not good enough when high strength of G1 was used to treat the substrates mixed by the Carnation. For 20 mg/L of Carnation, the highest removal rate occurred at 6 hours showed in Figure XXI. It reduced when the organics had been removed within the first 6 hours. The removal efficiency of 50 mg/L Carnation gradually increased.When the shaking time increased, the more organicdissolved in the water to help organism survive. It is difficult to completely dissolve in the water for a high concentration substrate. At 100 mg/L and 150 mg/L of substrates, TOC removal was less than 10%. This means that G1 was not able to remove the high TOC concentration from the wastewater. However, the highest TOC removal was at 24 hours.

5.2.9 Result of Run #8

Run #8 took four level of strength of N1 into consideration to treat 20 mg/L and 100 mg/L of Carnation.

Analysis of Figure XXII indicated that, all different strengths (1, 3, 5, and 10 mL) of N1 showed the same tendency when they were used to treat 20 mg/L of Carnation. When shaking time is longer, the removal rate increased with some fluctuation. Therefore, they reached their best removal efficiency at 24 hours which was 40%, 46%, 42%, and 50%, respectively.When more bacteria were applied to treat the wastewater, the removal efficiency increased. For example, at 12 hours, 1 mL N1 removed 36% of TOC; 3 mLN1 removed 38% of TOC; 5 mL N1 removed 44% of TOC; 10 mL N1 removed 46% of TOC.

Figure XXIII showed that high strength of N1 can remove more organic compounds from wastewater. Overall the highest removal efficiency occurred at 24 hours. 10 mL of N1 removed 60% of TOC. Other applications (1, 3, and 5 mL) offered different removal rates. The treatment increased during the first six hours then decreased. Therefore, 33%, 44%, and 48% of TOC had been removed at 6 hours respectively.

Compared these two figures, based on the theory of bacterial life cycle, the wastewater with higher concentration will provide more nutrients so that bacteria can short their lag phase. Thus the removal rate can arrive at the peak shortly.When high concentration of Carnation was treated, thedifferences of every two interval were greater.

5.2.10 Summary of Results from Run #5 to Run #8

From Figure XIII to Figure XXIII, we can see at 24 hours, low S1 and E1 can almost remove the organic completely. But when the strength of LLMO increased, it is ineffective to treat the wastewater. High strength of S1 and E1 only can remove 60 % of TOC at 12 hours.

When low and medium strength of LLMO were used to treat the Carnation Breakfast, the removal rates increased with the shaking time increased. And the tendency of removal rate was more distinct among medium strength of S1, E1 and G1.

5.2.11 Summary of all Runs

The batch reactor was used in this research. All the reactants are added in the reactor before operation. Nothing will be added or taken out until the reaction is done. During the operation, the temperature, concentration and reaction speed varies with

time. The advantages of batch reactor are simple construction, high conversion, convenient and flexible operation, and easy to clean [58].The batch reactor can make the experiment control easily.

Figure XXIV showed 100% of TOC had been removed by 1 mL of E1 from 20 mg/L of Carnation Breakfast,while the highest removal efficiency of Slim Fast was 75% which happened at 24 hours, 1 mLS1 at 50 mg/L of Slim Fast.The mass of protein in Slim Fast is two times higher than Carnation Breakfast Essential. And Slim Fast has soy protein, a type of complex sugar, as a main ingredient.

5.3 Kinetics Comparison

Four different types of LLMO were compared by Figures XXV-XXXI and Tables L-LXI. The kinetics had been determined. These graphs were made for medium strength of E1, G1, N1 and S1 with Slim Fast (50 mg/L) and Carnation Breakfast Essential (50 mg/L) respectively. Figure XXV and Table LI showed the reaction rate of 5.5 mL E1 was zero order at 50 mg/L of Slim Fast. The K value was -0.1464 and the $R^2$was 0.0057. The rest of reactors runs were determined as the second order.1/TOC vs time was presented. The higher R^2 showed a good fit. All the kinetics of samples were presented.

dS/dt calculations were made four types of LLMO for Slim Fast and Carnation Breakfast Essentials. These graphs were produced by calculation dS/dt for each two hour interval.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Analysis from the entire experiment, low strength of E1 (1 mL) showed the best ability to treat the Carnation Breakfast Essentials (100%) wastewater, while S1 (1 mL) can remove 75% of TOC for Slim Fast wastewater.

Form the results discussed above, several factors played very important roles in this experiment. Microorganisms that use the substrates for their metabolic processes, the proper substrates that provide microorganism for high total organic removal, shaking time, strength level of microorganism, and concentration of substrates are also the important factors which impact the total organic carbon removal efficiency from the synthetic wastewater.

First, shaking helps dissolve Slim Fast and Carnation Breakfast Essentials. Even though hot water was used to mix with these substrates, they still need more time to dissolve in the water completely. In addition, shaking improves the intimate contact between water and microorganisms. Shaking time can be used as a factor to determine breakdown of the nutrient and complex sugar into simple compound. It will also increase the amount of organic substrate present in wastewater.

As previously discussed, the solubility of substrate is important in the biological waste treatment efficiency of wastewater.If the substrates used had higher solubility, it can reduce the time frame and also make it easy and accurate to determine TOC removal efficiency without any solid settled down at the bottom of bottle. And the content of substrates is another factor should be taken into consideration. Microorganisms in LLMO are varied so that mixture of nutrients can meet their various requirements for energy source.

Finally, the strength level of LLMO can havepositive or negative effect on the removal efficiency of total organic carbon. As the results showed when 10 mL LLMO was added in the synthetic wastewater, lower removal rate was obtained comparing to the case when the medium strength of LLMO was used.

6.2 Recommendations

During the research, the errors caused by the experimental equipment cannot be eliminated. But we can try to reduce the human errors to improve the experiment results.

And there are some recommendations for the further research. The temperature and pH could be considered as the factors which will affect the treatment efficiency.The experiments need to provide more oxygen for bacteria in carrying out bio-oxidation.

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APPENDIX

TableXXVI. Run #1 TOC of Slim Fast with Low G1 measuredResult

Low G1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	81.87	0
2	45.897	44
4	61.25	25
6	71.83	12
12	29.93	63
24	32.75	60
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	128.49	0
2	102.43	20
4	106.9	17
6	105.64	18
12	47.97	63
24	46.62	64
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	200.2	0
2	134.74	33
4	173.3	13
6	171	15
12	96.79	52
24	105.69	47
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	252.5	0
2	220.8	13
4	231.4	8
6	233	8
12	146.7	42
24	167	34

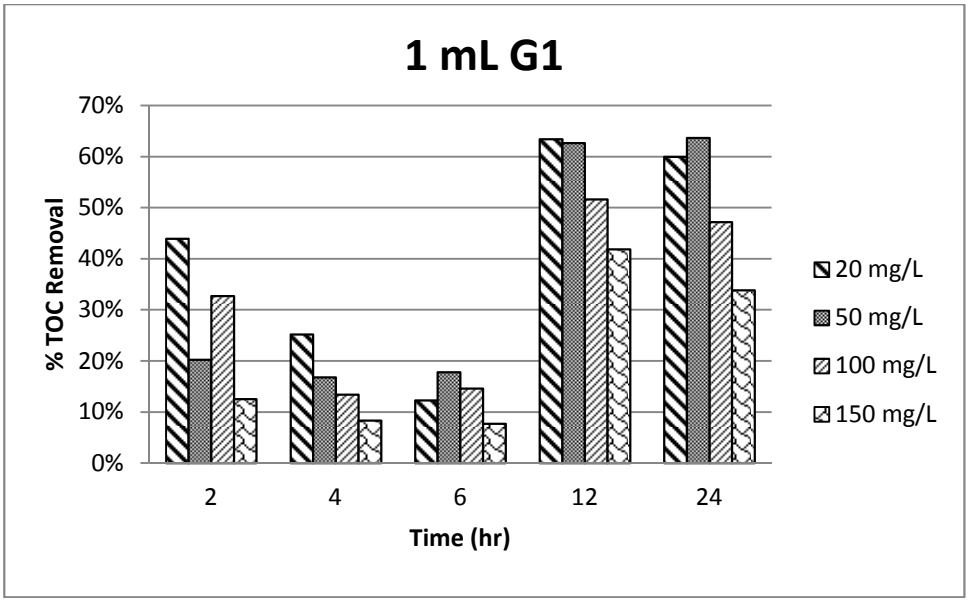

Figure I. TOC removal rate of Slim Fast with time by 1 mL G1.

Table XXVII. Run #1 TOC of Slim Fast with Medium G1 measuredResult

Medium G1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	81.87	0
2	45.85	43
4	51.68	37
6	55.95	32
12	32.44	40
24	33.58	59
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	128.49	0
2	79.51	38
4	81.69	36
6	89.57	30
12	51.27	40
24	49.01	62
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	200.2	0
2	136.17	32
4	154.9	23
6	162.03	19
12	97.12	49
24	96.34	52
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	252.5	0
2	194.02	23
4	199.53	21
6	215.07	15
12	140.9	56
24	143.02	43

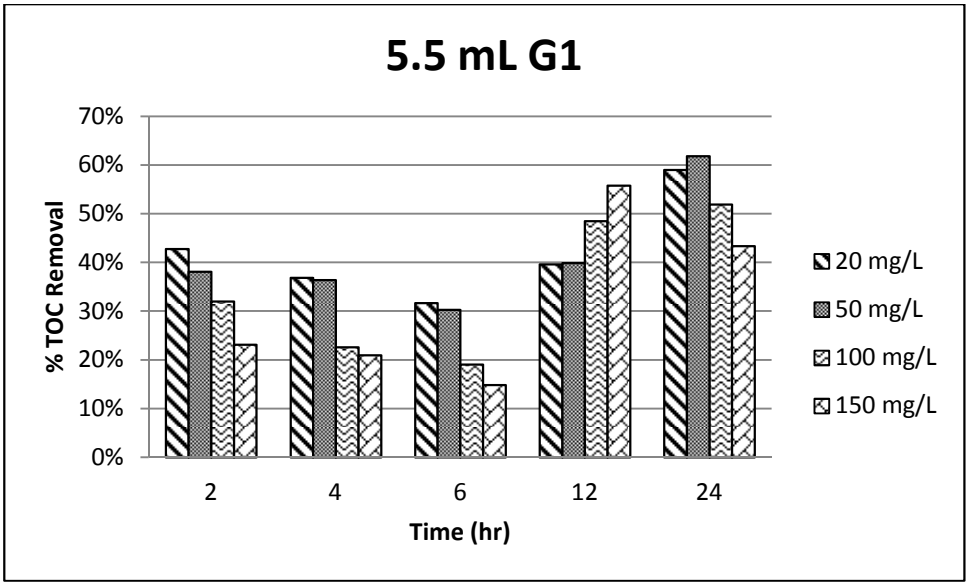

Figure II. TOC removal rate of Slim Fast with time by 5.5 mL G1

Table XXVIII. Run #1 TOC of Slim Fast with High G1 measuredResult

High G1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	81.87	0
2	39.97	51
4	41.25	50
6	44.36	46
12	30.68	63
24	29.91	63
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	128.49	0
2	69.12	46
4	75.26	41
6	81.25	37
12	53.47	58
24	55.95	56
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	200.2	0
2	129.31	35
4	135.28	32
6	139.75	30
12	96.45	52
24	99.17	50
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	252.5	0
2	168.26	33
4	177.31	30
6	208.5	17
12	137.7	45
24	143.09	43

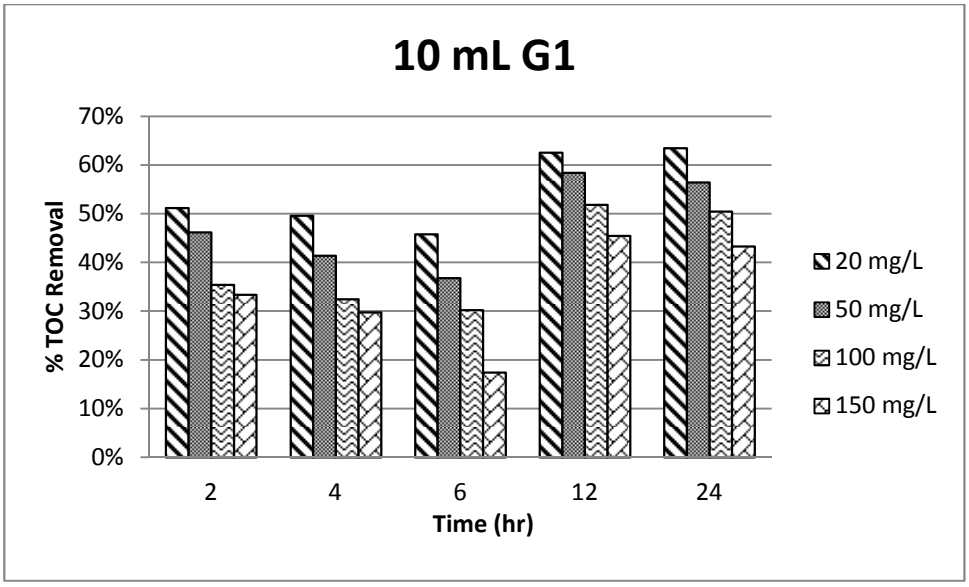

Figure III. TOC removal rate of Slim Fast with time by 10 mL G1

Table XXIX. Run #2 TOC of Slim Fast with Low S1 measuredResult

Low S1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	63.75	0
2	30.05	53
4	29.4	51
6	30.05	53
12	21.5	66
24	21.3	67
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	90.13	0
2	52.84	41
4	53.3	41
6	59.96	33
12	28.77	68
24	22.1	75
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	140.2	0
2	97.77	30
4	102.38	27
6	112.74	20
12	87.57	38
24	79.51	43
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	195.2	0
2	156.9	20
4	167	14
6	151.5	22
12	118.09	40
24	87.74	55

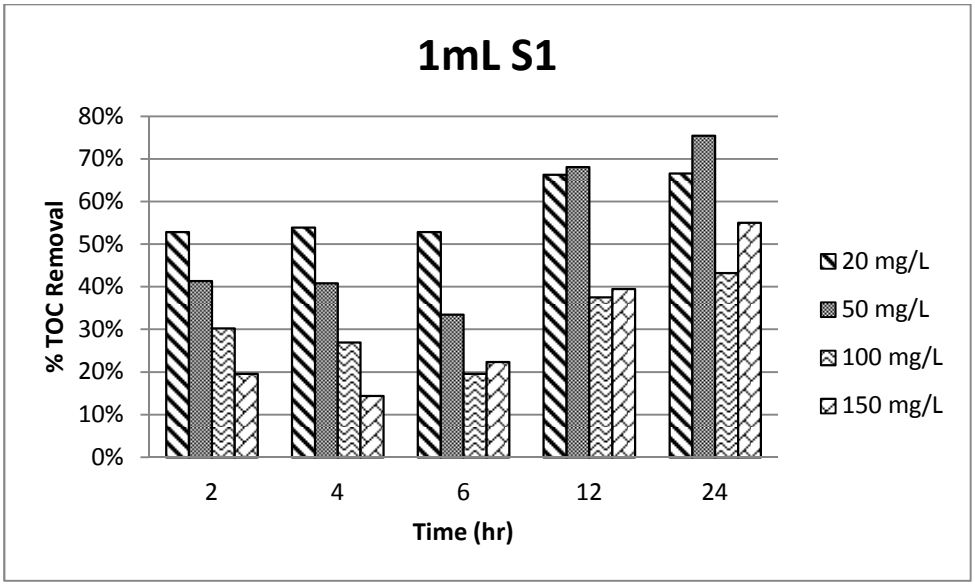

Figure IV. TOC removal rate of Slim Fast with time by 1 mL S1

Table XXX. Run #2 TOC of Slim Fast with Medium S1 measuredResult

Medium S1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	63.75	0
2	29.2	54
4	32.22	49
6	32.05	50
12	23.5	63
24	21.7	66
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	90.13	0
2	51.56	43
4	58.73	35
6	56.34	37
12	38.05	58
24	24.7	73
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	140.2	0
2	107.38	23
4	100.19	29
6	101.59	28
12	73.64	47
24	51.83	63
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	195.2	0
2	163.6	16
4	145.9	25
6	138.1	29
12	108.9	44
24	94.03	52

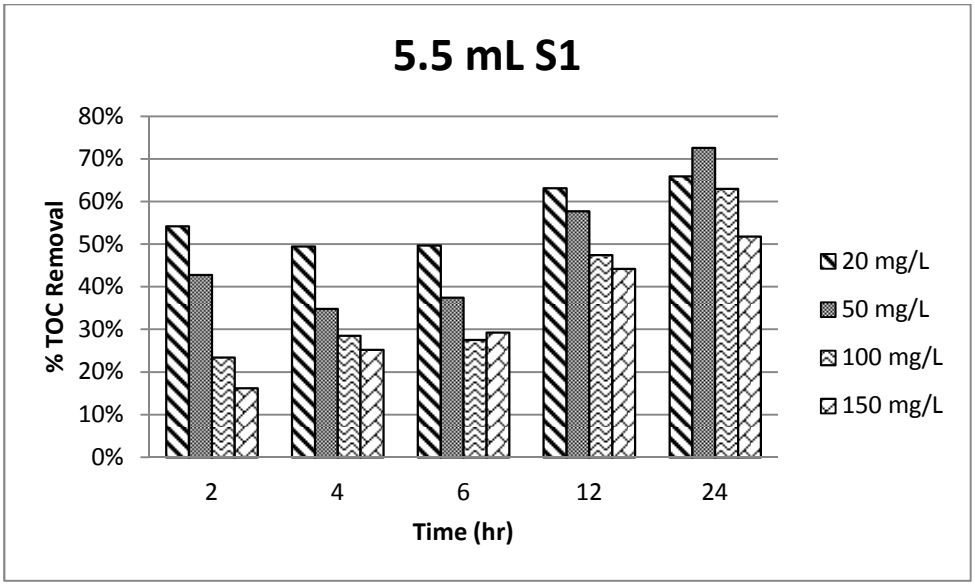

Figure V. TOC removal rate of Slim Fast with time by 5.5 mL S1

Table XXXI. Run #2 TOC of Slim Fast with High S1 measuredResult

High S1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	63.75	0
2	31.5	51
4	36.848	42
6	32.53	49
12	24.7	61
24	18.6	71
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	90.13	0
2	52.84	41
4	50.07	44
6	58.54	35
12	39.888	56
24	23.3	74
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	140.2	0
2	95.6	32
4	110.35	21
6	96.74	31
12	86.34	38
24	39.90	72
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	195.2	0
2	146.2	25
4	142.5	27
6	147.9	24
12	116.21	40
24	78.54	60

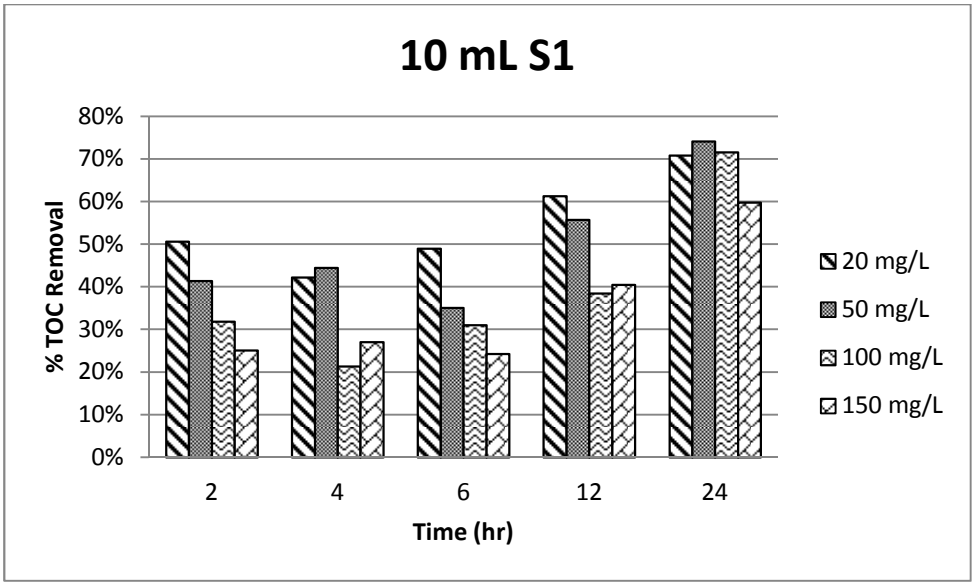

Figure VI. TOC removal rate of Slim Fast with time by 10 mL S1

Table XXXII. Run #3 TOC of Slim Fast with Low E1 measuredResult

Low E1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	52.72	0
2	15.8	70
4	16.8	68
6	16.3	69
12	15.5	71
24	29.37	44
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	75.79	0
2	30.68	60
4	31.09	59
6	32.61	57
12	33.38	56
24	46.47	39
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	98.79	0
2	52.29	45
4	63.34	42
6	63.03	40
12	84.84	35
24	71.28	27
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	129.75	0
2	75.26	26
4	86.38	22
6	86.65	24
12	64.69	23
24	90.05	20

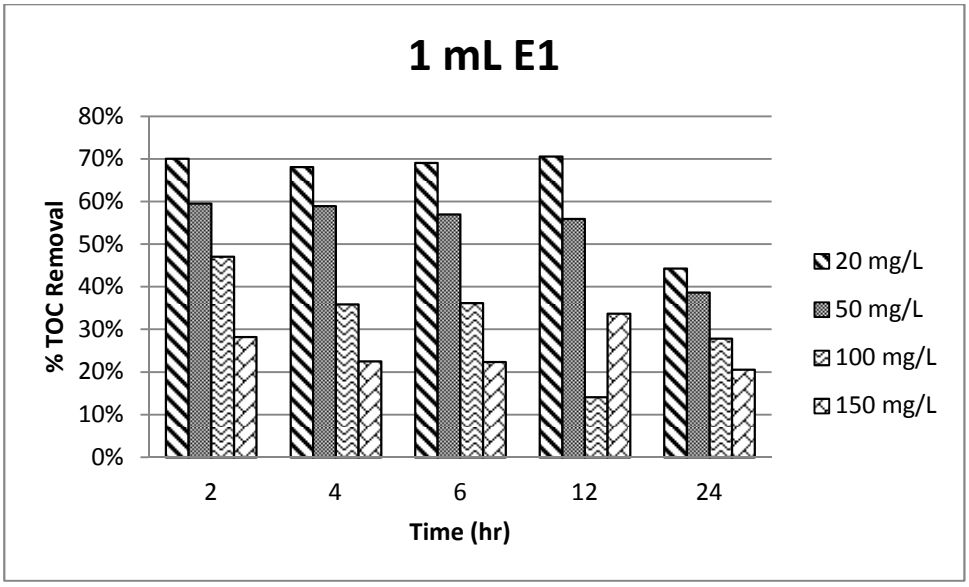

Figure VII. TOC removal rate of Slim Fast with time by 1 mL E1

Table XXXIII. Run #3 TOC of Slim Fast with Medium E1 measuredResult

Medium E1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	52.72	0
2	21.2	60
4	21.9	58
6	22.3	58
12	22.8	57
24	42.951	19
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	75.79	0
2	33.23	56
4	37.379	51
6	37.041	51
12	30.82	59
24	53.04	30
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	98.79	0
2	51.38	45
4	57.28	42
6	59.5	40
12	64.57	35
24	72.24	27
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	129.75	0
2	80.11	26
4	87.01	22
6	83.13	24
12	84.65	23
24	91.28	20

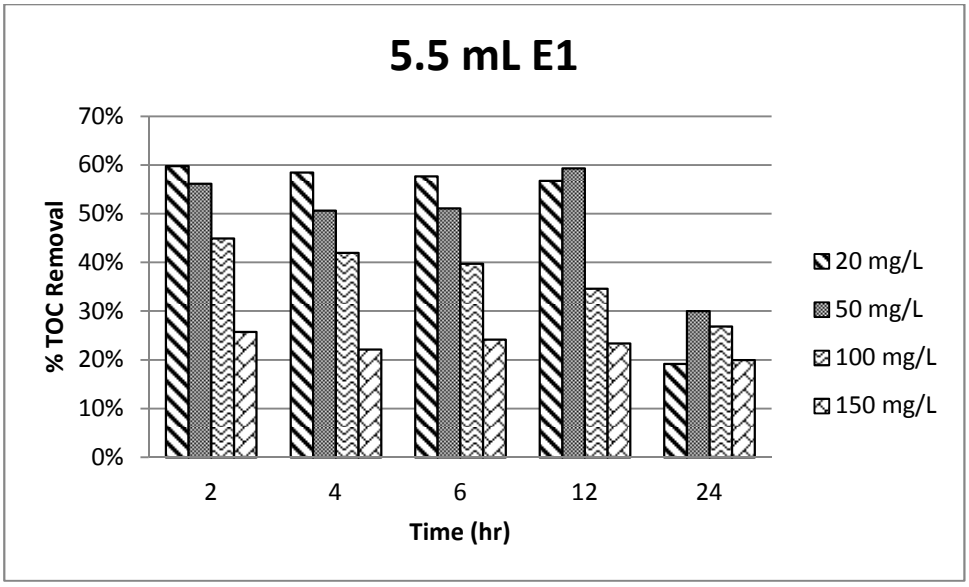

Figure VIII. TOC removal rate of Slim Fast with time by 5.5 mL E1

Table XXXIV. Run #3 TOC of Slim Fast with High E1 measuredResult

High E1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	52.72	0
2	20.5	61
4	22.1	58
6	23.1	56
12	20.3	61
24	25.1	52
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	75.79	0
2	33.91	55
4	34.2	55
6	34.54	54
12	29.57	61
24	40.86	46
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	98.79	0
2	55.98	43
4	58.75	41
6	63.7	36
12	50.33	49
24	59.8	39
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	129.75	0
2	79.31	26
4	90.51	20
6	83.88	24
12	66.67	33
24	65.75	33

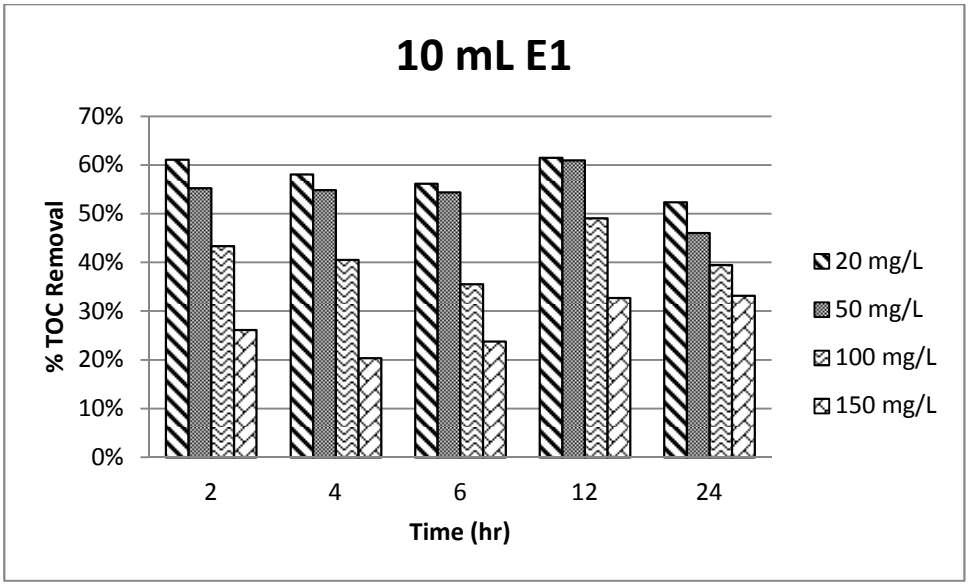

Figure IX. TOC removal rate of Slim Fast with time by 10 mL E1

Table XXXV. Run #4 TOC of Slim Fast with Low N1 measuredResult

Low N1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	63.36	0
2	28.7	55
4	38.199	40
6	36.08	43
12	25	61
24	20	68
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	94.66	0
2	53.42	44
4	65.21	31
6	49.32	48
12	46.018	51
24	38.32	60
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	154.2	0
2	102.17	34
4	116.74	24
6	92.18	40
12	85.23	45
24	71.4	54
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	184.2	0
2	134.14	26
4	171.5	6
6	128.98	29
12	112.11	39
24	94.06	48

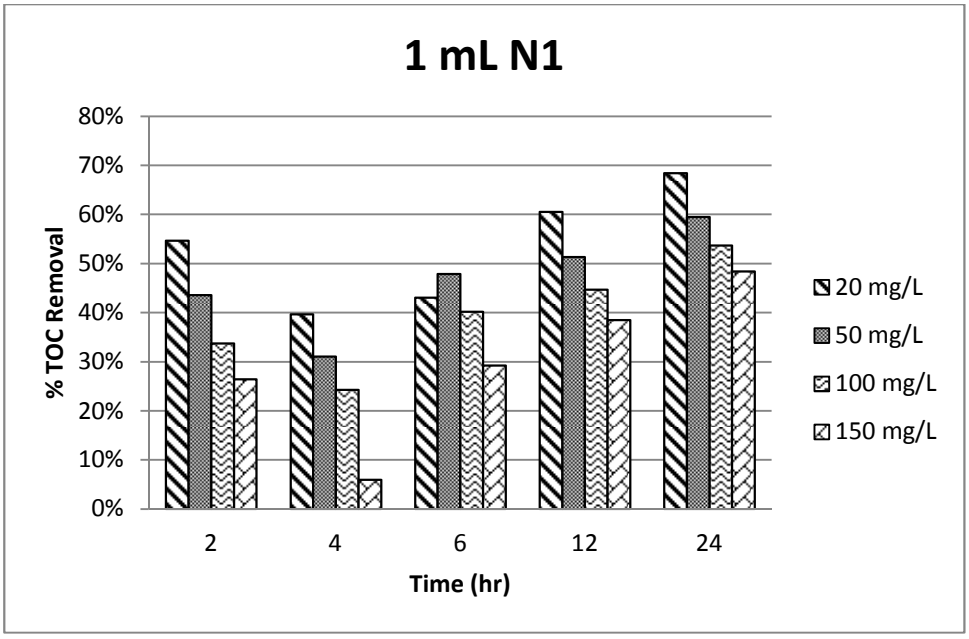

Figure X. TOC removal rate of Slim Fast with time by 1 mL N1

Table XXXVI. Run #4 TOC of Slim Fast with Medium N1 measuredResult

Medium N1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	63.36	0
2	29.01	54
4	35.76	44
6	29.47	53
12	29.85	53
24	18.7	70
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	94.66	0
2	53.54	43
4	57.6	39
6	50.53	47
12	45.052	52
24	40.491	57
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	154.2	0
2	97.87	37
4	106.1	31
6	92.01	40
12	81.1	47
24	71.01	54
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	184.2	0
2	138.2	24
4	156.1	14
6	135.71	26
12	123.96	32
24	105.76	42

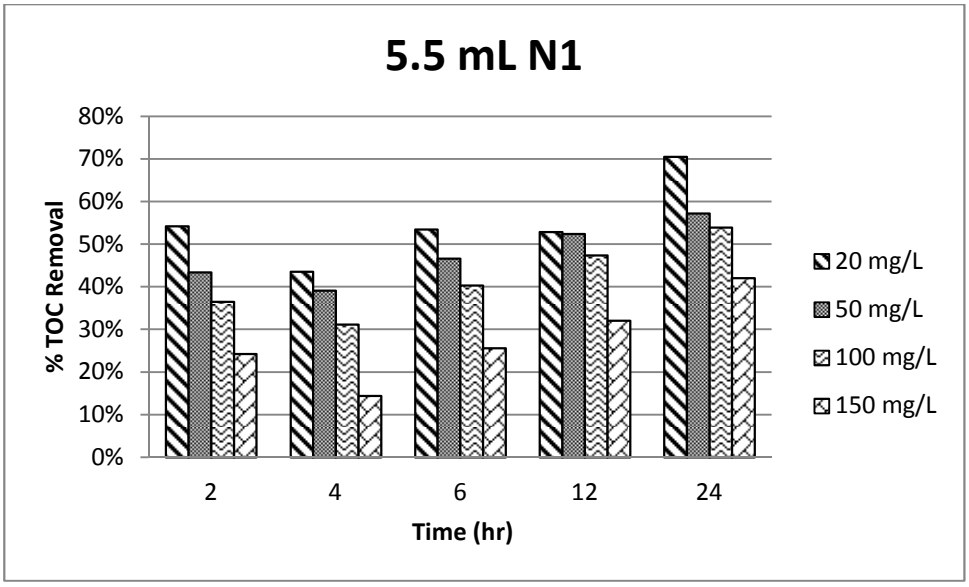

Figure XI. TOC removal rate of Slim Fast with time by 5.5 mL N1

Table XXXVII. Run #4 TOC of Slim Fast with High N1 measuredResult

High N1		
20 mg/L Slim Fast		
Hour	TOC	%Removal
0	63.36	0
2	25.4	60
4	28.24	55
6	26.94	57
12	26.12	59
24	18.1	71
50 mg/L Slim Fast		
Hour	TOC	%Removal
0	94.66	0
2	46.018	51
4	57.62	39
6	46.86	50
12	42.35	55
24	36.695	58
100 mg/L Slim Fast		
Hour	TOC	%Removal
0	154.2	0
2	92.51	40
4	117.66	24
6	106.03	31
12	82.5	46
24	69.61	55
150 mg/L Slim Fast		
Hour	TOC	%Removal
0	184.2	0
2	117.22	36
4	153.9	16
6	127.43	30
12	103.81	43
24	115.27	37

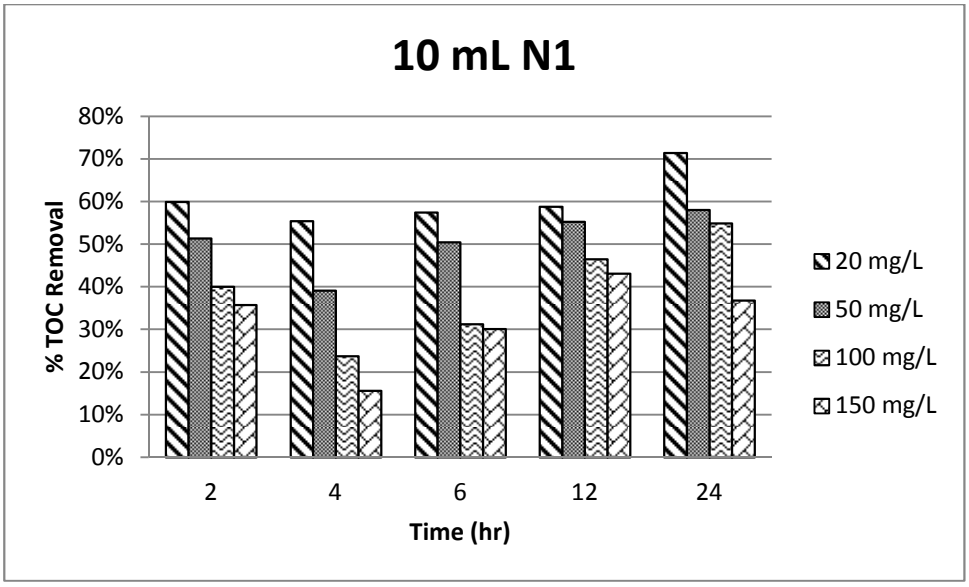

Figure XII.TOC removal rate of Slim Fast with time by 10 mL N1

Table XXXVIII. Run #5Carnation TOC with Low S1 measuredResult

Low S1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	29.15	0
2	5.695	80
4	2.775	90
6	2.15	93
12	1.58	95
24	0.27	99
50 mg/L Carnation		
Hour	TOC	%Removal
0	70.02	0
2	40.17	43
4	40.56	42
6	32.5	54
12	32.21	54
24	34.91	50
100 mg/L Carnation		
Hour	TOC	%Removal
0	133.7	0
2	98.84	26
4	99.05	26
6	106.3	20
12	103.15	23
24	94.71	29
150 mg/L Carnation		
Hour	TOC	%Removal
0	196.6	0
2	163.9	17
4	167.9	15
6	140.5	29
12	155.4	21
24	141.3	28

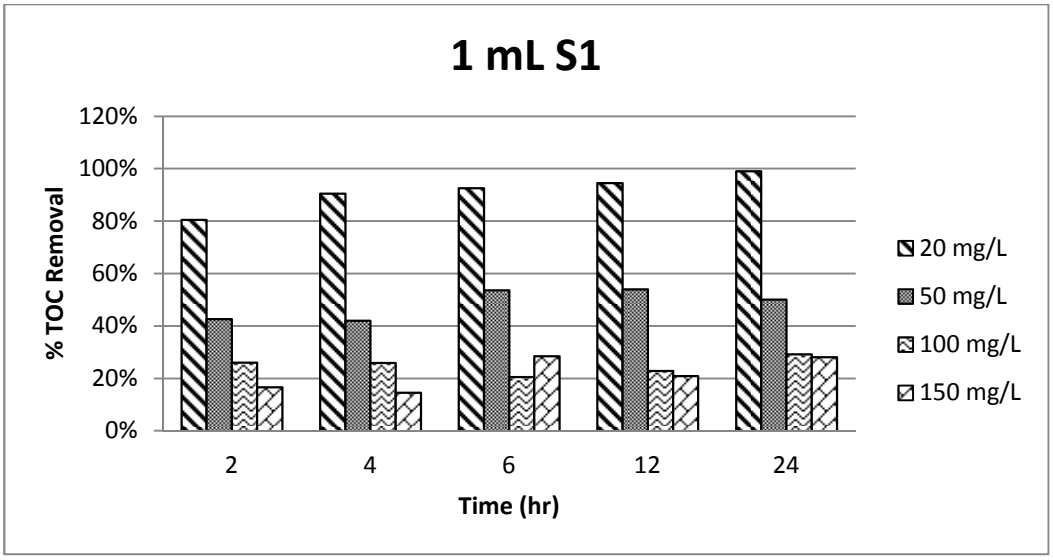

Figure XIII. TOC removal rate of Carnation Breakfast with time by 1mL S1

Table XXXIX. Run #5 Carnation TOC with Low E1 measuredResult

Low E1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	29.15	0
2	10.51	64
4	7.842	73
6	5.381	82
12	3.957	86
24	0.048	100
50 mg/L Carnation		
Hour	TOC	%Removal
0	70.02	0
2	42.3	40
4	42.08	40
6	31.78	55
12	35.17	50
24	40.46	42
100 mg/L Carnation		
Hour	TOC	%Removal
0	133.7	0
2	111.4	17
4	102.5	23
6	117	12
12	99.25	26
24	94.13	30
150 mg/L Carnation		
Hour	TOC	%Removal
0	196.6	0
2	166.7	15
4	168.6	14
6	151.6	23
12	153.9	22
24	154.6	21

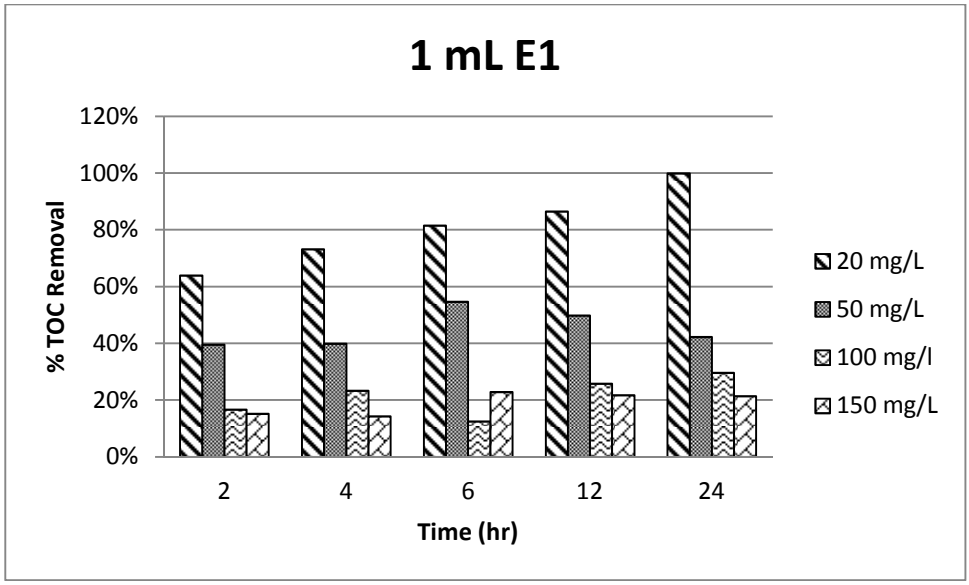

Figure XIV. TOC removal rate of Carnation Breakfast with time by 1mL E1

Table XL. Run #5 Carnation TOC with Low G1 measuredResult

Low G1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	29.15	0
2	28.23	3
4	7.504	74
6	6.057	79
12	2.823	90
24	2.71	91
50 mg/L Carnation		
Hour	TOC	%Removal
0	70.02	0
2	39.16	44
4	39.85	43
6	42.59	39
12	32.45	54
24	33.147	53
100 mg/L Carnation		
Hour	TOC	%Removal
0	133.7	0
2	94.17	30
4	98.84	26
6	99.05	26
12	106.3	20
24	111.53	17
150 mg/L Carnation		
Hour	TOC	%Removal
0	196.6	0
2	155.4	21
4	163.9	17
6	167.9	15
12	140.5	29
24	171.81	13

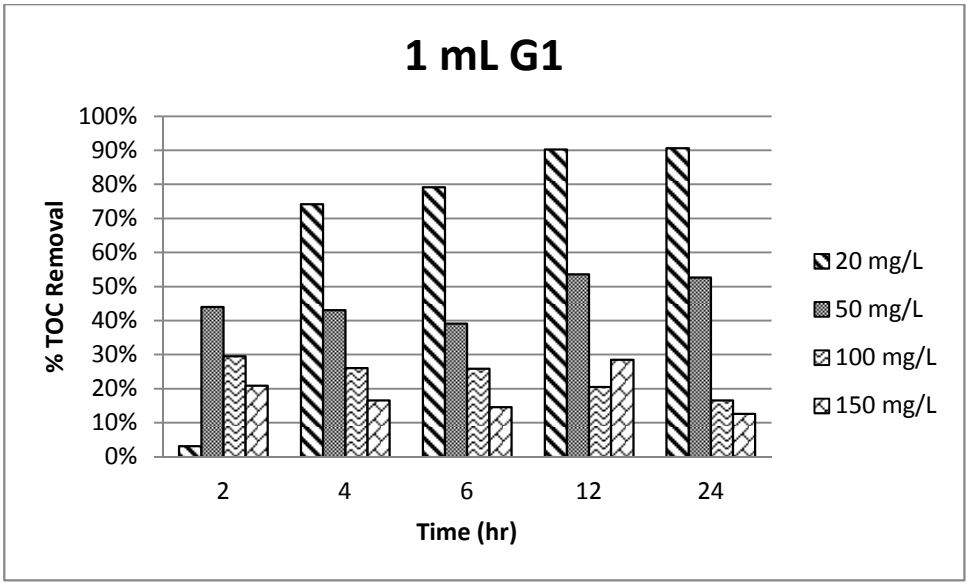

Figure XV. TOC removal rate of Carnation Breakfast with time by 1mL G1

Table XLI. Run #6 Carnation TOC with Medium S1 measuredResult

Medium S1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	53.6	0
2	37.403	30
4	34.25	36
6	34.15	36
12	31.25	42
24	23.5	56
50 mg/L Carnation		
Hour	TOC	%Removal
0	93.55	0
2	67.1	28
4	66.84	29
6	61.19	35
12	50.98	46
24	39.188	58
100 mg/L Carnation		
Hour	TOC	%Removal
0	166.1	0
2	114.55	31
4	107.33	35
6	93.5	44
12	83.49	50
24	73.11	56
150 mg/L Carnation		
Hour	TOC	%Removal
0	226	0
2	161.3	29
4	131.73	42
6	123.6	45
12	111.05	51
24	94.76	58

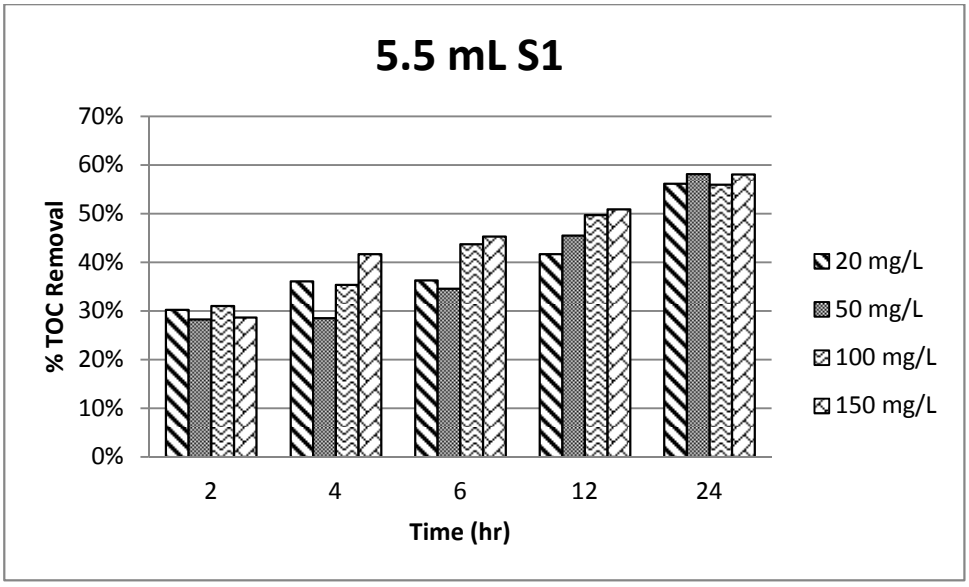

Figure XVI. TOC removal rate of Carnation Breakfast with time by 5.5 mL S1

Table XLII.Run #6 Carnation TOC with Medium E1 measuredResult

Medium E1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	53.6	0
2	30.19	44
4	29.83	44
6	25.6	52
12	25.2	53
24	21.5	60
50 mg/L Carnation		
Hour	TOC	%Removal
0	93.55	0
2	56.44	40
4	50.14	46
6	49.81	47
12	33.06	65
24	24.6	74
100 mg/L Carnation		
Hour	TOC	%Removal
0	166.1	0
2	99.95	40
4	93.12	44
6	89.26	46
12	69.11	58
24	58.1	65
150 mg/L Carnation		
Hour	TOC	%Removal
0	226	0
2	157.2	30
4	136.7	40
6	121.95	46
12	114.52	49
24	47.39	79

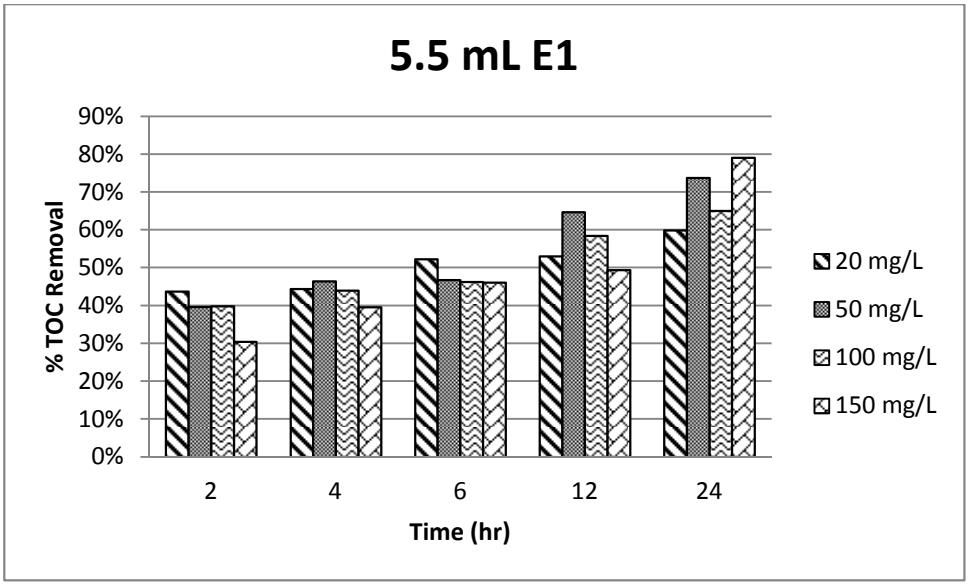

Figure XVII. TOC removal rate of Carnation Breakfast with time by 5.5 mL E1

Table XLIII. Run #6 Carnation TOC with Medium G1 measuredResult

High G1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	53.6	0
2	39.888	26
4	38.344	28
6	32.39	40
12	30.99	42
24	15.3	71
50 mg/L Carnation		
Hour	TOC	%Removal
0	93.55	0
2	69.71	25
4	75.77	19
6	67.3	28
12	55.13	41
24	48.18	48
100 mg/L Carnation		
Hour	TOC	%Removal
0	166.1	0
2	134.62	19
4	125.14	25
6	113.8	31
12	91.19	45
24	80.09	52
150 mg/L Carnation		
Hour	TOC	%Removal
0	226	0
2	179.5	21
4	158.6	30
6	147.6	35
12	120.43	47
24	116.77	48

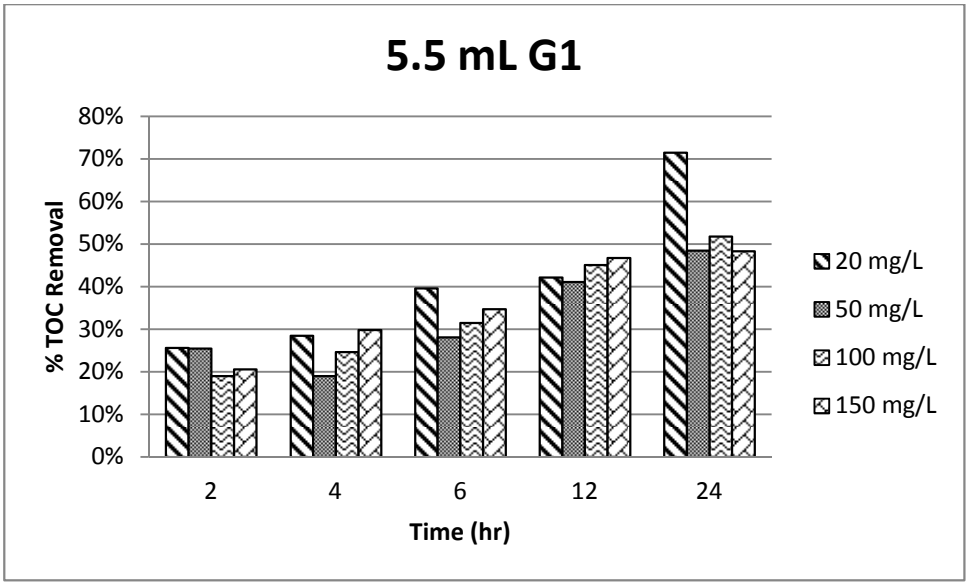

Figure XVIII. TOC removal rate of Carnation Breakfast with time by 5.5 mL G1

Table XLIV. Run #7 Carnation TOC with High S1 measuredResult

High S1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	58.8	0
2	53.16	10
4	27.35	53
6	26.21	55
12	23.6	60
24	30.29	48
50 mg/L Carnation		
Hour	TOC	%Removal
0	92.2	0
2	70.14	24
4	56.95	38
6	49.83	46
12	50.38	45
24	59.86	35
100 mg/L Carnation		
Hour	TOC	%Removal
0	119.35	0
2	103.57	13
4	98.14	18
6	91.74	23
12	97.58	18
24	106.34	11
150 mg/L Carnation		
Hour	TOC	%Removal
0	148.6	0
2	139.7	6
4	138.02	7
6	134.67	9
12	146.5	1
24	146.21	2

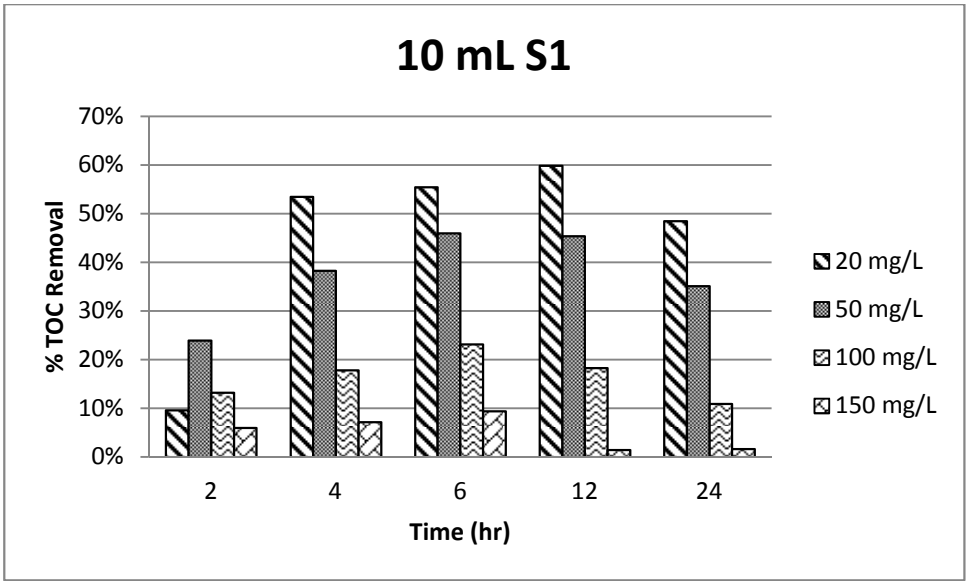

Figure XIX. TOC removal rate of Carnation Breakfast with time by 10 mL S1

Table XLV. Run #7 Carnation TOC with High E1 measuredResult

High E1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	58.8	0
2	40.636	31
4	26.67	55
6	25.4	57
12	25.1	57
24	31.74	46
50 mg/L Carnation		
Hour	TOC	%Removal
0	92.2	0
2	44.015	52
4	55.52	40
6	54.68	41
12	51.68	44
24	60.18	35
100 mg/L Carnation		
Hour	TOC	%Removal
0	119.35	0
2	82.21	31
4	97.53	18
6	92.27	23
12	96.59	19
24	118.17	1
150 mg/L Carnation		
Hour	TOC	%Removal
0	148.6	0
2	123.55	17
4	136.15	8
6	137.7	7
12	140.02	6
24	147.89	0

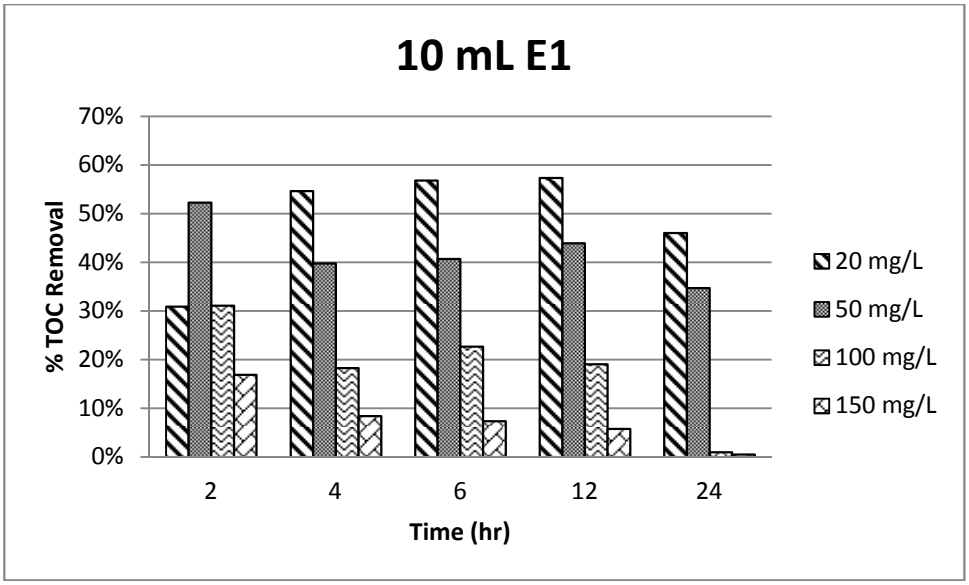

Figure XX. TOC removal rate of Carnation Breakfast with time by 10 mL E1

Table XLVI. Run #7 Carnation TOC with High G1 measuredResult

High G1		
20 mg/L Carnation		
Hour	TOC	%Removal
0	58.8	0
2	47.75	19
4	41.843	29
6	25.4	57
12	34.49	41
24	29.06	51
50 mg/L Carnation		
Hour	TOC	%Removal
0	92.2	0
2	87.08	6
4	78.16	15
6	74.46	19
12	63.14	31
24	58.22	37
100 mg/L Carnation		
Hour	TOC	%Removal
0	119.35	0
2	104.94	10
4	108.67	7
6	114.59	3
12	117.15	1
24	100.79	12
150 mg/L Carnation		
Hour	TOC	%Removal
0	148.6	0
2	140.5	5
4	147.3	1
6	144.8	3
12	146.7	1
24	135.51	9

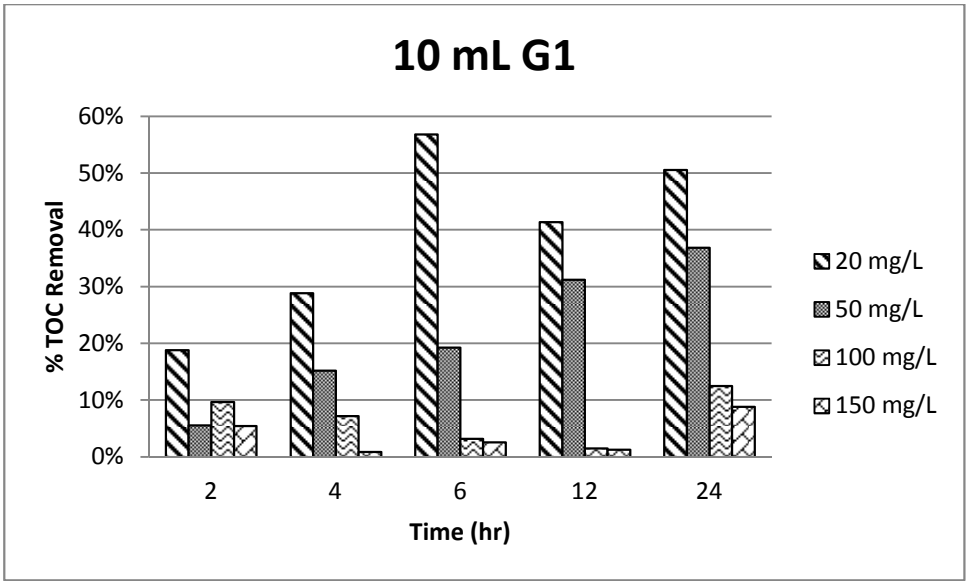

Figure XXI. TOC removal rate of Carnation Breakfast with time by 10 mL G1

Table XLVII. Run #8 20 mg/L of Carnation TOC with N1 measuredResult

20 mg/L Carnation		
1 ml N1		
Hour	TOC	%Removal
0	53.61	0
2	33.84	37
4	36.365	32
6	33.5	38
12	34.56	36
24	32.27	40
3 ml N1		
Hour	TOC	%Removal
0	53.61	0
2	31.09	42
4	33.08	38
6	32.22	40
12	29.78	44
24	28.7	46
5ml N1		
Hour	TOC	%Removal
0	53.61	0
2	32.99	38
4	35.14	34
6	31.79	41
12	33.38	38
24	30.75	43
10 ml N1		
Hour	TOC	%Removal
0	53.61	0
2	27.35	49
4	29.59	45
6	28.77	46
12	28.77	46
24	27.01	50

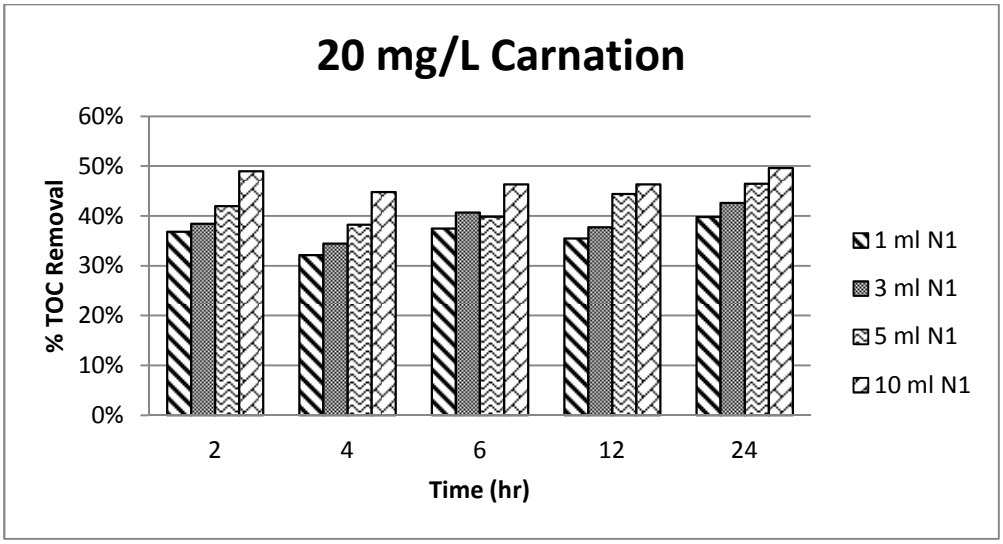

Figure XXII. TOC removal rate of 20 mg/L Carnation Breakfast with time by N1

Table XLVIII. Run #8 100 mg/L of Carnation TOC with N1 measuredResult

100 mg/L Carnation		
1 ml N1		
Hour	TOC	%Removal
0	166.1	0
2	53.75	32
4	49.45	30
6	55.03	33
12	25.1	15
24	6.29	4
3 ml N1		
Hour	TOC	%Removal
0	166.1	0
2	64.01	39
4	63.55	38
6	73.2	44
12	56.24	34
24	31.07	19
5 ml N1		
Hour	TOC	%Removal
0	166.1	0
2	73.61	44
4	71.27	43
6	79.47	48
12	65.94	40
24	49.75	30
10 ml N1		
Hour	TOC	%Removal
0	166.1	0
2	91.13	55
4	86.52	52
6	75.06	45
12	86.62	52
24	100.44	60

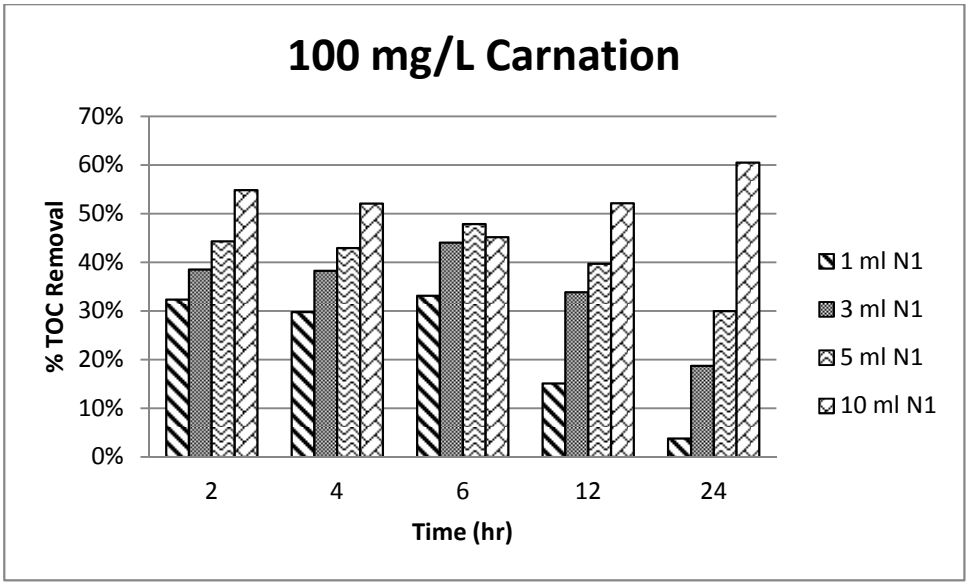

Figure XXIII. TOC removal rate of 100 mg/L Carnation Breakfast with time by N1

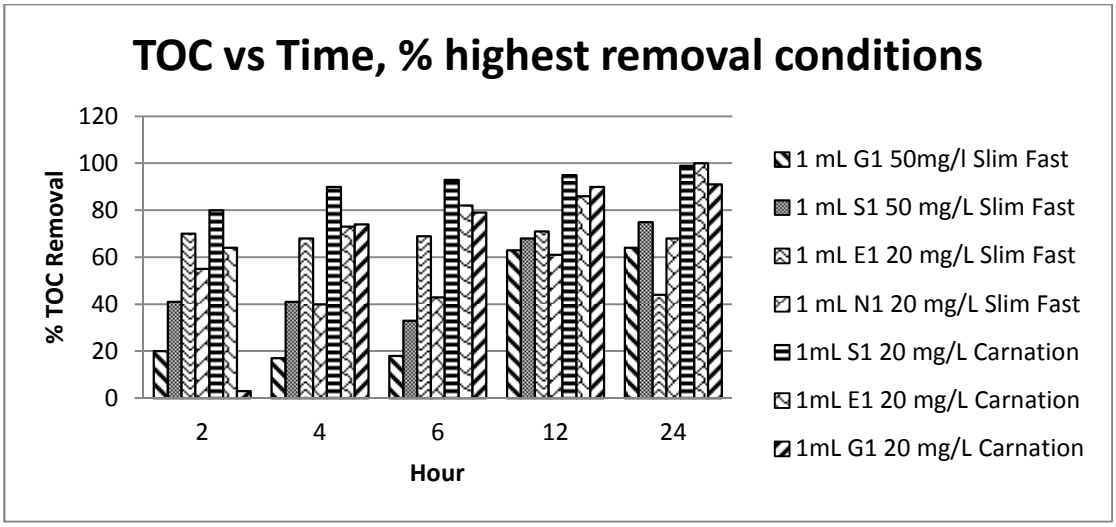

Figure XXIV. Highest Removal Efficiencies at Various Conditions

Table XLIX. Kinetics and K valued of E1

E1	ORDER	K VALUE	R^2 VALUE	EQUATION
E1 (1 mL) at Slim Fast (20 mg/L)	Zero	-0.2154	0.0165	y=-0.2154x+26.138
E1 (1 mL) at Slim Fast (50 mg/L)	Zero	-0.2626	0.0172	y=-0.2626x+43.771
E1 (1 mL) at Slim Fast (100 mg/L)	Second	-5E-05	0.0178	y=-5E505x+0.0148
E1 (1 mL) at Slim Fast (150 mg/L)	Zero	-0.7878	0.0992	y=-0.7878x+95.099
E1 (5.5 mL) at Slim Fast (20 mg/L)	Second	-0.0004	0.0808	y=-0.0004x+0.0405
E1 (5.5 mL) at Slim Fast (50 mg/L)	Zero	-0.1464	0.0057	y=-0.1464x+45.721
E1 (5.5 mL) at Slim Fast (100 mg/L)	Second	-5E-05	0.0152	y=-5E505x+0.0159
E1 (5.5 mL) at Slim Fast (150 mg/L)	Zero	-0.5966	0.081	y=-0.5966x+97.428
E1 (10 mL) at Slim Fast (20 mg/L)	Zero	-0.5014	0.1246	y=-0.5014x+31.315
E1 (10 mL) at Slim Fast (50 mg/L)	Zero	-0.6215	0.1024	y=-0.6215x+46.45
E1 (10 mL) at Slim Fast (100 mg/L)	Zero	-0.8431	0.1851	y=-0.8431x+71.303
E1 (10 mL) at Slim Fast (150 mg/L)	Second	0.0002	0.6341	y=0.0002x+0.0102

TableL. Calculated Values of TOC for E1 (5.5 mL) at Slim Fast (50 mg/L)

Time	TOC
0	75.79
2	33.23
4	37.379
6	37.041
12	30.82
24	53.04

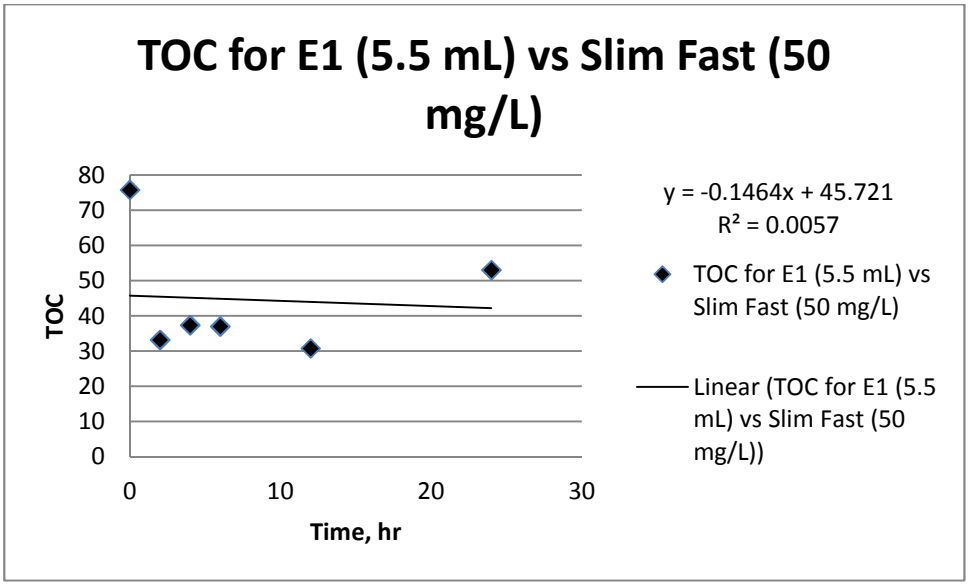

Figure XXV. TOC vs Time for E1 (5.5 mL) at Slim Fast (50 mg/L)

Table LI. Kinetics and K Value of G1

G1	ORDER	K VALUE	R^2 VALUE	EQUATION
G1 (1 mL) at Slim Fast (20 mg/L)	Second	0.0008	0.5852	y=0.0008x+0.0152
G1 (1 mL) at Slim Fast (50 mg/L)	Second	0.0006	0.808	y=0.0006x+0.008
G1 (1 mL) at Slim Fast (100 mg/L)	Second	0.0002	0.5821	y=0.0002x+0.0058
G1 (1 mL) at Slim Fast (150 mg/L)	Zero	-3.7694	0.6363	y=-3.7694x+238.72
G1 (5.5 mL) at Slim Fast (20 mg/L)	Second	0.0007	0.6578	y=0.0007x+0.0167
G1 (5.5 mL) at Slim Fast (50 mg/L)	Second	0.0005	0.7917	y=0.0005x+0.01
G1 (5.5 mL) at Slim Fast (100 mg/L)	Second	0.0002	0.7327	y=0.0002x+0.0059
G1 (5.5 mL) at Slim Fast (150 mg/L)	Second	0.001	0.7527	y=0.001x+0.0009
G1 (10 mL) at Slim Fast (20 mg/L)	Second	0.0007	0.6475	y=0.0007x+0.0194
G1 (10 mL) at Slim Fast (50 mg/L)	Second	0.0003	0.577	y=0.0003x+0.0113
G1 (10 mL) at Slim Fast (100 mg/L)	Second	0.0002	0.6677	y=0.0002x+0.0065
G1 (10 mL) at Slim Fast (150 mg/L)	Second	0.0001	0.5471	y=0.0001x+0.0049

Table LII. Calculated Values of 1/TOC for G1 (5.5 mL) at Slim Fast (50 mg/L)

Hour	TOC	1/TOC
0	252.5	0.00396
2	194.02	0.005154
4	199.53	0.005012
6	215.07	0.00465
12	140.9	0.007097
24	143.02	0.006992

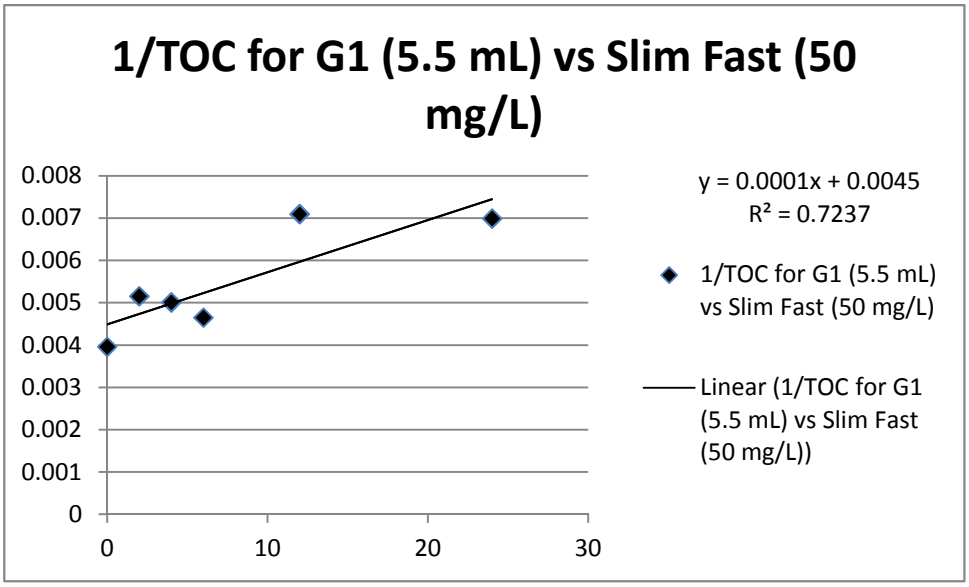

Figure XXVI. Ln (TOC) vs Time for G1 (5.5 mL) at Slim Fast (50 mg/L)

Table LIII. Kinetics and K value of N1

N1	ORDER	K VALUE	R^2 VALUE	EQUATION
N1 (1 mL) at Slim Fast (20 mg/L)	Second	0.0012	0.775	y=0.0012x+0.0229
N1 (1 mL) at Slim Fast (50 mg/L)	Second	0.0005	0.7507	y=0.0005x+0.0146
N1 (1 mL) at Slim Fast (100 mg/L)	Second	0.0003	0.8214	y=0.0003x+0.0081
N1 (1 mL) at Slim Fast (150 mg/L)	Second	0.0002	0.8428	y=0.0002x+0.0061
N1 (5.5 mL) at Slim Fast (20 mg/L)	Second	0.0012	0.7794	y=0.0012x+0.0235
N1 (5.5 mL) at Slim Fast (50 mg/L)	Second	0.0005	0.6924	y=0.0005x+0.0152
N1 (5.5 mL) at Slim Fast 100 mg/L)	Second	0.0003	0.7891	y=0.0003x+0.0085
N1 (5.5 mL) at Slim Fast (150 mg/L)	Second	0.0001	0.8491	y=0.0001x+0.0062
N1 (10 mL) at Slim Fast (20 mg/L)	Second	0.0012	0.6771	y=0.0012x+0.0275
N1 (10 mL) at Slim Fast (50 mg/L)	Second	0.0005	0.6367	y=0.0003x+0.0162
N1 (10 mL) at Slim Fast (100 mg/L)	Second	0.0003	0.7803	y=0.0003x+0.0081
N1 (10 mL) at Slim Fast (150 mg/L)	Second	0.0001	0.3587	y=0.0001x+0.0069

Table LIV. Calculated Values of 1/TOC for N1 (5.5 mL) at Slim Fast (50 mg/L)

Hour	TOC	1/TOC
0	94.66	0.010564
2	53.54	0.018678
4	57.6	0.017361
6	50.53	0.01979
12	45.052	0.022197
24	40.491	0.024697

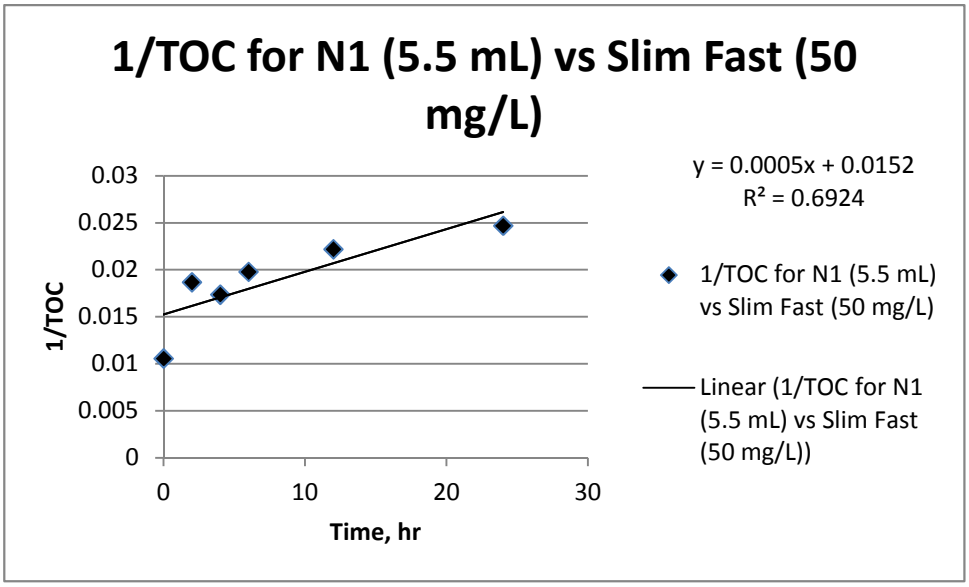

Figure XXVII. 1/TOC vs Time for N1 (5.5 mL) at Slim Fast (50 mg/L)

Table LV. Kinetics and K value of S1

S1	ORDER	K VALUE	R^2 VALUE	EQUATION
S1 (1 mL) at Slim Fast (20 mg/L)	Second	0.001	0.6528	y=0.001x+0.0266
S1 (1 mL) at Slim Fast (50 mg/L)	Second	0.0014	0.9261	y=0.0014x+0.013
S1 (1 mL) at Slim Fast (100 mg/L)	Second	0.0002	0.07176	y=0.0002x+0.0085
S1 (1 mL) at Slim Fast (150 mg/L)	Second	0.0003	0.9799	y=0.0003x+0.0053
S1 (5.5 mL) at Slim Fast (20 mg/L)	Second	0.001	0.6814	y=0.001x+0.0255
S1 (5.5 mL) at Slim Fast (50 mg/L)	Second	0.0011	0.9521	y=0.0011x+0.0129
S1 (5.5 mL) at Slim Fast (100 mg/L)	Second	0.0005	0.9848	y=0.0005x+0.0076
S1 (5.5 mL) at Slim Fast (150 mg/L)	Second	0.0002	0.9392	y=0.0002x+0.0057
S1 (10 mL) at Slim Fast (20 mg/L)	Second	0.0014	0.8861	y=0.0014x+0.0223
S1 (10 mL) at Slim Fast (50 mg/L)	Second	0.0012	0.9383	y=0.0012x+0.0129
S1 (10 mL) at Slim Fast (100 mg/L)	First	-0.046	0.9139	y=-0.046x+4.8556
S1 (10 mL) at Slim Fast (150 mg/L)	Second	0.0003	0.963	y=0.0003x+0.0055

Table LVI. Calculated Values of 1/TOC for S1 (5.5 mL) at Slim Fast (50 mg/L)

Hour	TOC	1/TOC
0	90.13	0.011095
2	51.56	0.019395
4	58.73	0.017027
6	56.34	0.017749
12	38.05	0.026281
24	24.7	0.040486

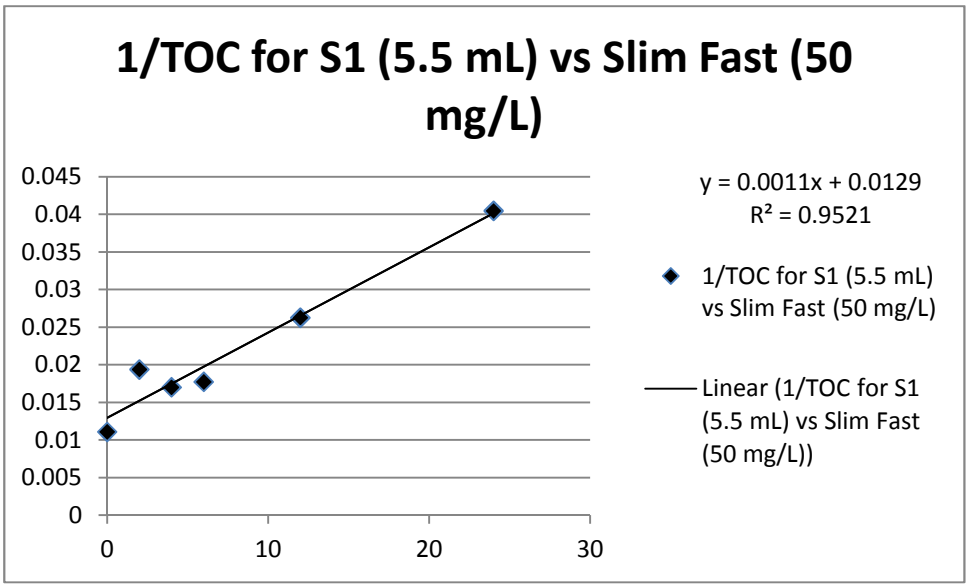

Figure XXVIII. 1/TOCvs Time for S1 (5.5 mL) at Slim Fast (50 mg/L)

Table LVII. Calculated Values of L1/TOC for S1 (5.5 mL) at Carnation Breakfast Essentials (50 mg/L)

Time	TOC	1/TOC
0	93.55	0.010689
2	67.1	0.014903
4	66.84	0.014961
6	61.19	0.016343
12	50.98	0.019616
24	39.188	0.025518

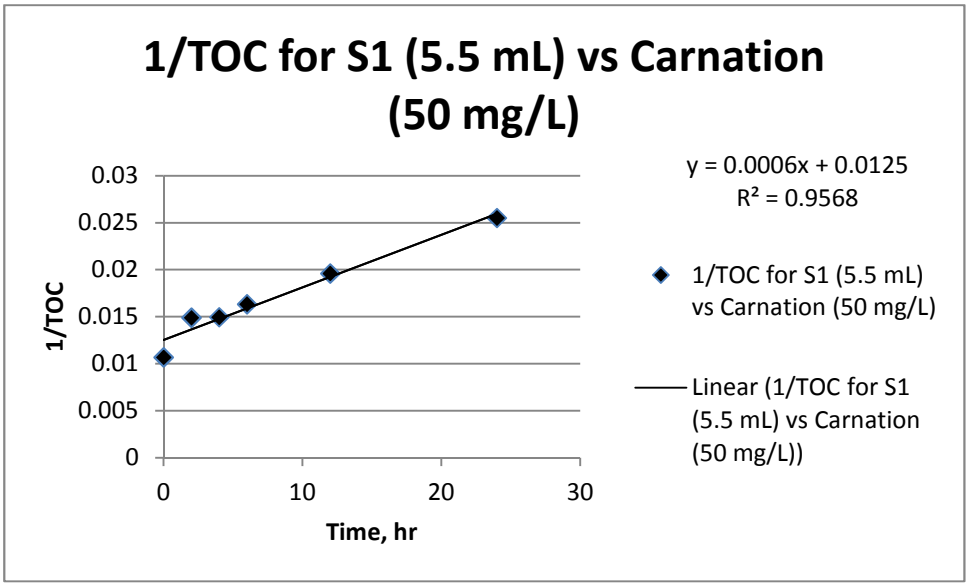

Figure XXIX. 1/TOCvs Time for S1 (5.5 mL) at Carnation Breakfast Essentials (50 mg/L)

Table LVIII. Calculated Values of 1/TOC for E1 (5.5 mL) at Carnation Breakfast Essentials (50 mg/L)

Time	TOC	1/TOC
0	93.55	0.010689
2	56.44	0.017718
4	50.14	0.019944
6	49.81	0.020076
12	33.06	0.030248
24	24.6	0.04065

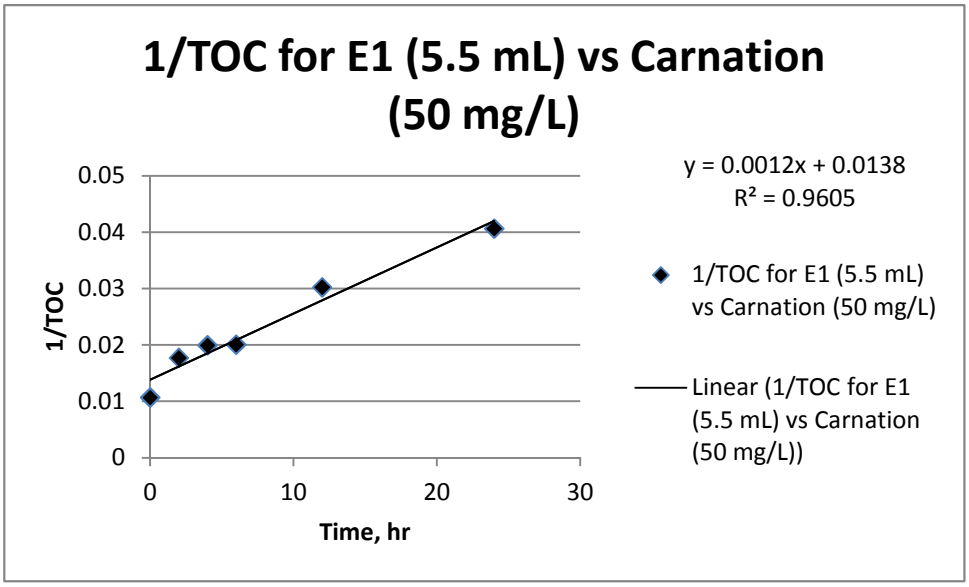

Figure XXX. 1/TOCvs Time for E1 (5.5 mL) at Carnation Breakfast Essentials (50 mg/L)

Table LIX. Calculated Values of 1/TOC for G1 (5.5 mL) at Carnation Breakfast Essentials (50 mg/L)

Time	TOC	1/TOC
0	93.55	0.010689
2	69.71	0.014345
4	75.77	0.013198
6	67.3	0.014859
12	55.13	0.018139
24	48.18	0.020756

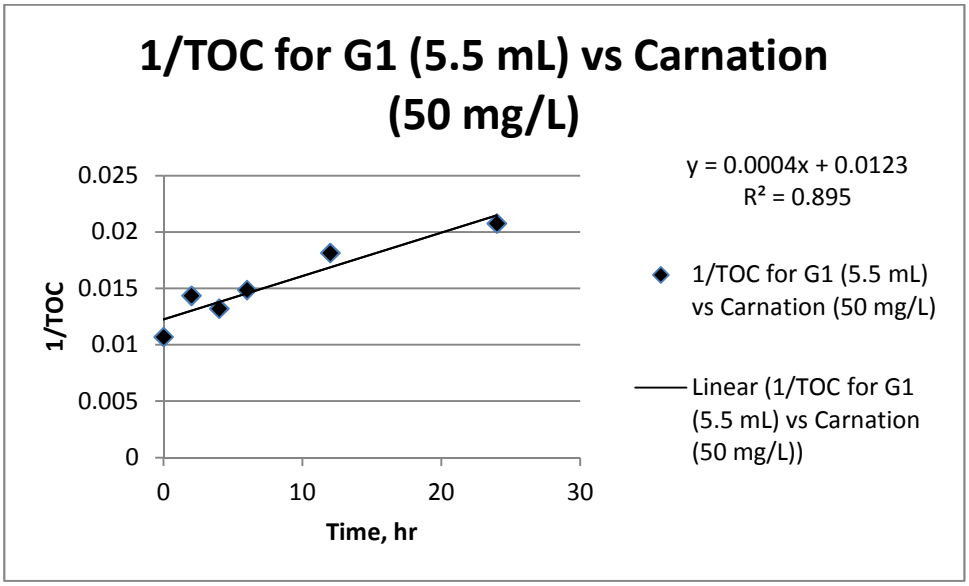

Figure XXXI. 1/TOCvs Time for G1 (5.5 mL) at Carnation Breakfast Essentials (50 mg/L)

Table LX. Kinetics and K value of Carnation Breakfast

SUBSTRATE	ORDER	K VALUE	R^2 VALUE	EQUATION
S1 (1mL) at Carnation (20 mg/L)	Second	0.1482	0.8887	y=0.1482x+0.2902
S1 (1mL) at Carnation (50 mg/L)	Second	0.0004	0.3295	y=0.0004x+0.0225
S1 (1mL) at Carnation (100 mg/L)	Second	7E-05	0.3347	y=7E-05x+0.009
S1 (1mL) at Carnation (150 mg/L)	Second	6E-05	0.4871	y=6E-05x+0.0058
E1 (1mL) at Carnation (20 mg/L)	First	-0.2443	0.9385	y=-0.2443x+3.2557
E1 (1mL) at Carnation (50 mg/L)	Zero	0.6577	0.1838	y=-0.6577x+48.896
E1 (1mL) at Carnation (100 mg/L)	Second	0.0001	0.0084	y=0.0001x+0.0084
E1 (1mL) at Carnation (150 mg/L)	Second	4E-05	0.4006	y=4E-05x+0.0058
G1 (1mL) at Carnation (20 mg/L)	Second	0.0152	0.8223	y=0.0152x+0.06
G1 (1mL) at Carnation (50 mg/L)	Second	0.0005	0.5238	y=0.0005x+0.021
G1 (1mL) at Carnation (100 mg/L)	Second	-8E-06	0.0039	y=-8E-06x+0.0095
G1 (1mL) at Carnation (150 mg/L)	Zero	-0.4736	0.0505	y=-0.4736x+169.81
S1 (5.5 mL) at Carnation (20 mg/L)	Second	0.0008	0.8868	y=0.0008x+0.0231
S1 (5.5 mL) at Carnation (50 mg/L)	Second	0.0006	0.9568	y=0.0006x+0.0125
S1 (5.5 mL) at Carnation (100 mg/L)	Second	0.0003	0.8241	y=0.0003x+0.0079
S1 (5.5 mL) at Carnation (150 mg/L)	Second	0.0002	0.8163	y=0.0002x+0.0059
E1 (5.5 mL) at Carnation (20 mg/L)	Second	0.0009	0.6752	y=0.0009x+0.0281
E1 (5.5 mL) at Carnation (50 mg/L)	Second	0.0012	0.9605	y=0.0012x+0.0138
E1 (5.5 mL) at Carnation (100 mg/L)	Second	0.0004	0.8758	y=0.0004x+0.0083
E1 (5.5 mL) at Carnation (150 mg/L)	First	-0.0569	0.9352	y=-0.0569x+5.2547
G1 (5.5 mL) at Carnation (20 mg/L)	First	-0.0463	0.9435	y=-0.0463x+3.8623
G1 (5.5 mL) at Carnation (50 mg/L)	Second	0.0004	0.895	y=0.0004x+0.0123

G1 (5.5 mL) at Carnation (100 mg/L)	Second	0.0003	0.9226	y=0.0003x+0.0069
G1 (5.5 mL) at Carnation (150 mg/L)	Second	0.0002	0.7915	y=0.0002x+0.0054
S1 (10 mL) at Carnation (20 mg/L)	Zero	-0.3371	0.0761	y=-0.3371x+34.265
S1 (10 mL) at Carnation (50 mg/L)	Zero	-0.8332	0.2122	y=-0.8332x+69.892
S1 (10 mL) at Carnation (100 mg/L)	Zero	-0.1543	0.0204	y=-0.1543x+104.02
S1 (10 mL) at Carnation (150 mg/L)	Second	-1E-05	0.09993	y=-1E-05x+0.0071
E1 (10 mL) at Carnation (20 mg/L)	Zero	-0.6721	0.204	y=-0.6721x+40.101
E1 (10 mL) at Carnation (50 mg/L)	Zero	-0.4172	0.0484	y=-0.4172x+63.05
E1 (10 mL) at Carnation (100 mg/L)	Second	-7E-05	0.1624	y=-7E-05x+0.0106
E1 (10 mL) at Carnation (150 mg/L)	Second	-2E-05	0.1879	y=-2E-05x+0.0074
G1 (10 mL) at Carnation (20 mg/L)	Zero	-0.9494	0.4536	y=-0.9494x+47.152
G1 (10 mL) at Carnation (50 mg/L)	Second	0.0003	0.9116	y=0.0003x+0.0115
G1 (10 mL) at Carnation (100 mg/L)	Second	4E-05	0.2897	y=4E-05x+0.0088
G1 (10 mL) at Carnation (150 mg/L)	Second	2E-05	0.5102	y=2E-05x+0.0068

Table LXI. pH of Slim Fast and Carnation Breakfast

pH	20 mg/L	50 mg/L	100 mg/L	150 mg/L
Slim Fast	7.6	7.4	7.4	7.4
Carnation Breakfast	7.4	7.4	7.4	7.4

Table LXII. Calculated Values of dS/dt for G1 (1 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	81.87	0	128.49	0	200.2	0	252.5	0
2	45.897	17.9865	102.43	13.03	134.74	32.73	220.8	15.85
4	61.25	5.155	106.9	5.3975	173.3	6.725	231.4	5.275
6	71.83	1.673333	105.64	3.808333	171	4.866667	233	3.25
12	29.93	4.328333	47.97	6.71	96.79	8.6175	146.7	8.816667
24	32.75	2.046667	46.62	3.41125	105.69	3.937917	167	3.5625

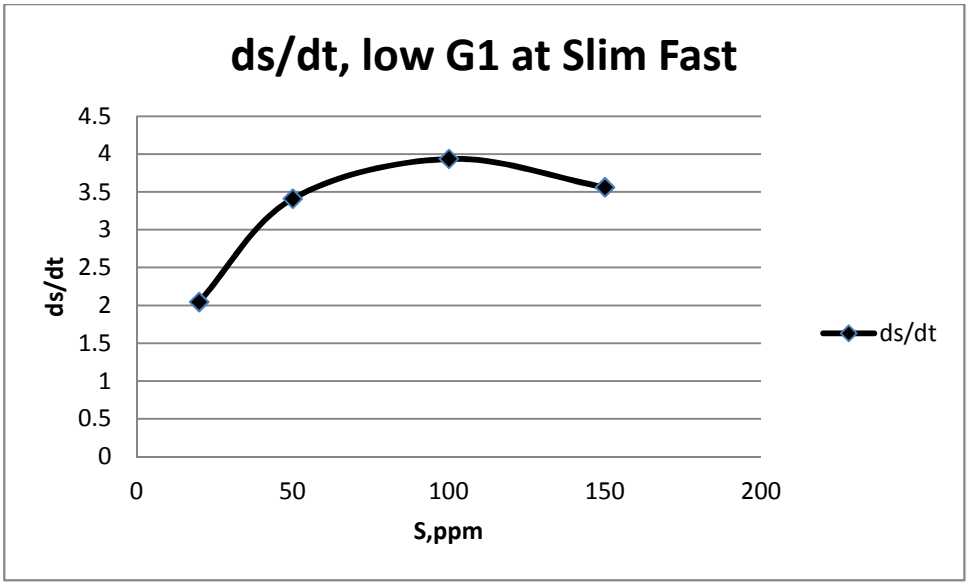

Figure XXXII. dS/dt of low G1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXIII. Calculated Values of dS/dt for G1 (1 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	81.87	0	128.49	0	200.2	0	252.5	0
2	45.85	18.01	79.51	24.49	136.17	32.015	194.02	29.24
4	51.68	7.5475	81.69	11.7	154.9	11.325	199.53	13.2425
6	55.95	4.32	89.57	6.486667	162.03	6.361667	215.07	6.238333
12	32.44	4.119167	51.27	6.435	97.12	8.59	140.9	9.3
24	33.58	2.012083	49.01	3.311667	96.34	4.3275	143.02	4.561667

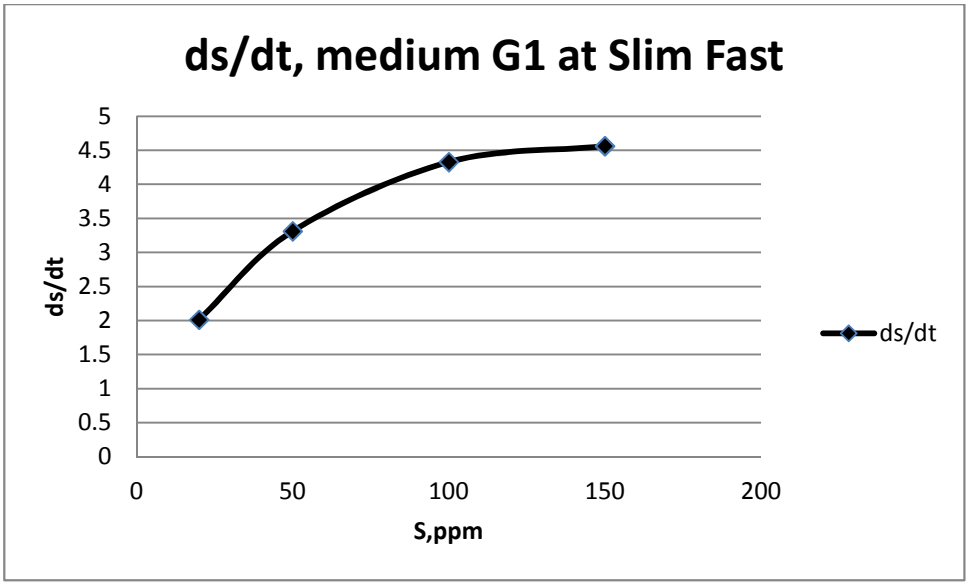

Figure XXXIII. dS/dt of mediumG1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXIV. Calculated Values of dS/dt for G1 (10 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	81.87	0	128.49	0	200.2	0	252.5	0
2	39.97	20.95	69.12	29.685	129.31	35.445	168.26	42.12
4	41.25	10.155	75.26	13.3075	135.28	16.23	177.31	18.7975
6	44.36	6.251667	81.25	7.873333	139.75	10.075	208.5	7.333333
12	30.68	4.265833	53.47	6.251667	96.45	8.645833	137.7	9.566667
24	29.91	2.165	55.95	3.0225	99.17	4.209583	143.09	4.55875

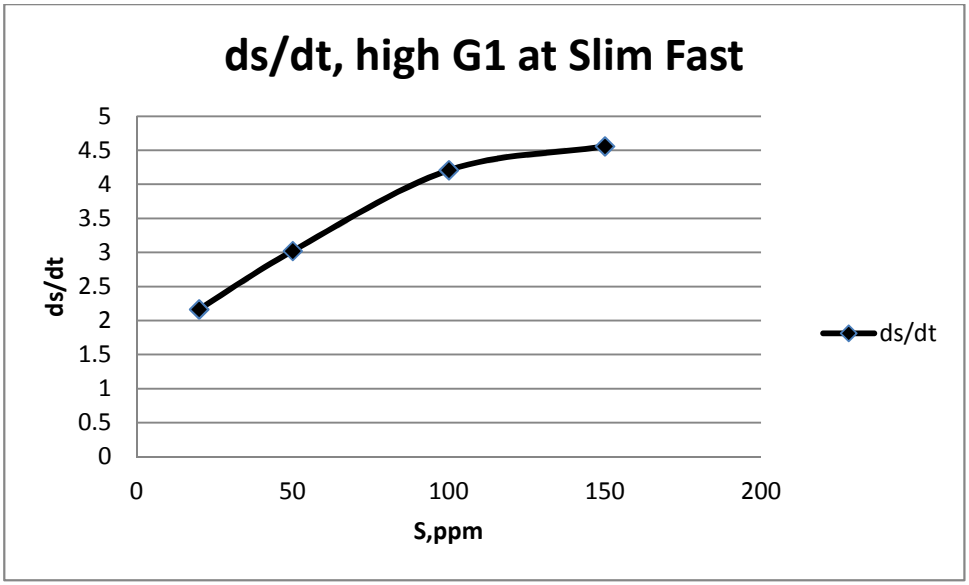

Figure XXXIV. dS/dt of highG1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXV. Calculated Values of dS/dt for S1 (1 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	63.75	0	90.13	0	140.2	0	195.2	0
2	30.05	16.85	52.84	18.645	97.77	21.215	156.9	19.15
4	29.4	8.5875	53.3	9.2075	102.38	9.455	167	7.05
6	30.05	5.616667	59.96	5.028333	112.74	4.576667	151.5	7.283333
12	21.5	3.520833	28.77	5.113333	87.57	4.385833	118.09	6.425833
24	21.3	1.76875	22.1	2.834583	79.51	2.52875	87.74	4.4775

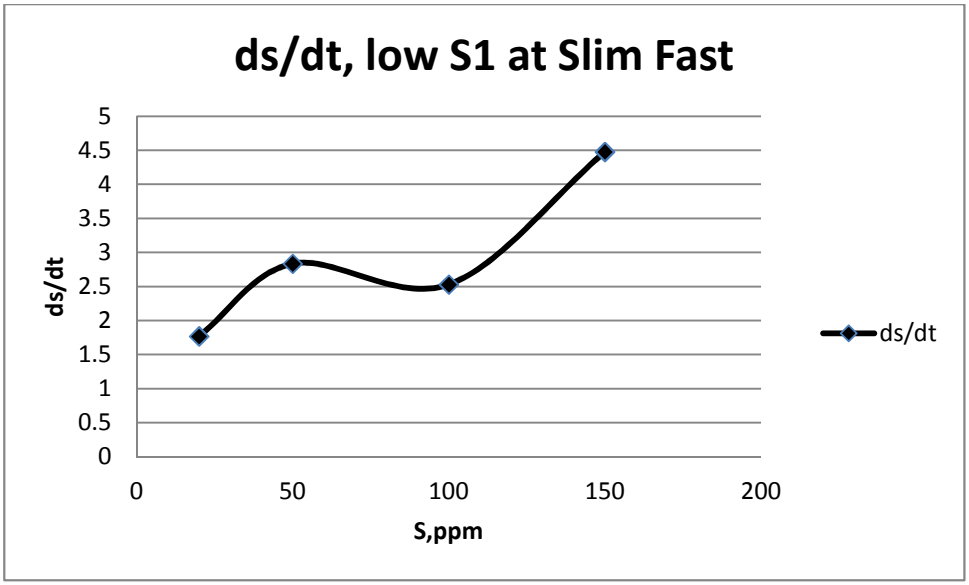

Figure XXXV. dS/dt of low S1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXVI. Calculated Values of dS/dt for S1 (5.5 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	63.75	0	90.13	0	140.2	0	195.2	0
2	29.2	17.275	51.56	19.285	107.38	16.41	163.6	15.8
4	32.22	7.8825	58.73	7.85	100.19	10.0025	145.9	12.325
6	32.05	5.283333	56.34	5.631667	101.59	6.435	138.1	9.516667
12	23.5	3.354167	38.05	4.34	73.64	5.546667	108.9	7.191667
24	21.7	1.752083	24.7	2.72625	51.83	3.682083	94.03	4.215417

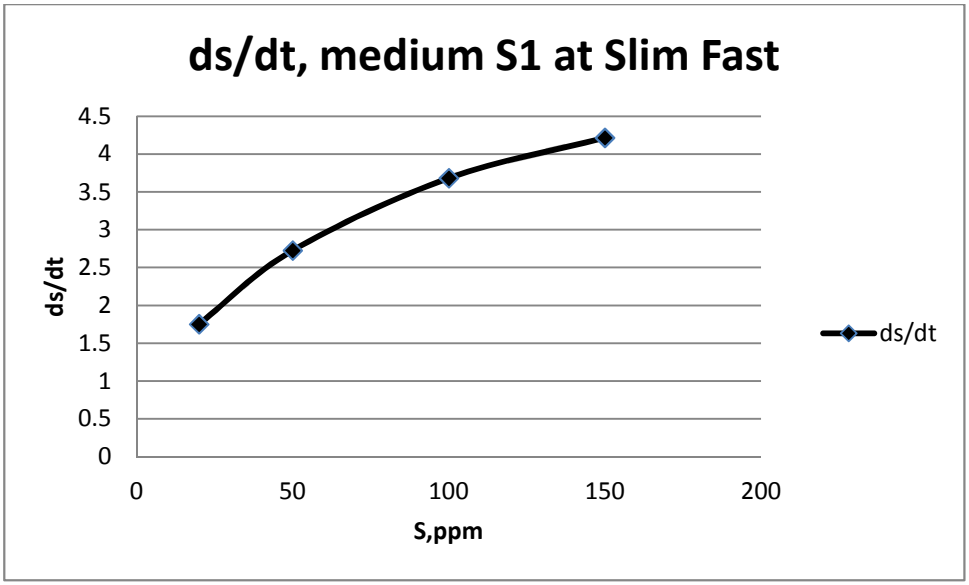

Figure XXXVI. dS/dt of mediumS1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXVII. Calculated Values of dS/dt for S1 (10 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	63.75	0	90.13	0	140.2	0	195.2	0
2	31.5	16.125	52.84	18.645	95.6	22.3	146.2	24.5
4	36.848	6.7255	50.07	10.015	110.35	7.4625	142.5	13.175
6	32.53	5.203333	58.54	5.265	96.74	7.243333	147.9	7.883333
12	24.7	3.254167	39.888	4.186833	86.34	4.488333	116.21	6.5825
24	18.6	1.88125	23.3	2.784583	39.9	4.179167	78.54	4.860833

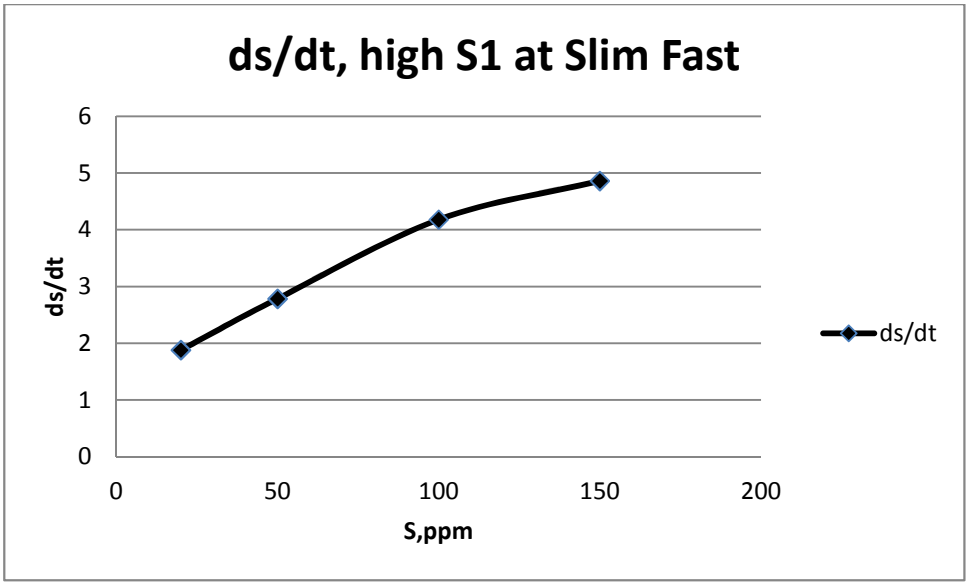

Figure XXXVII. dS/dt of highS1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXVIII. Calculated Values of dS/dt for E1 (1 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	52.72	0	75.79	0	98.79	0	129.75	0
2	15.8	18.46	30.68	22.555	52.29	23.25	75.26	27.245
4	16.8	8.98	31.09	11.175	63.34	8.8625	86.38	10.8425
6	16.3	6.07	32.61	7.196667	63.03	5.96	86.65	7.183333
12	15.5	3.101667	33.38	3.534167	84.84	1.1625	64.69	5.421667
24	29.37	0.972917	46.47	1.221667	71.28	1.14625	90.05	1.654167

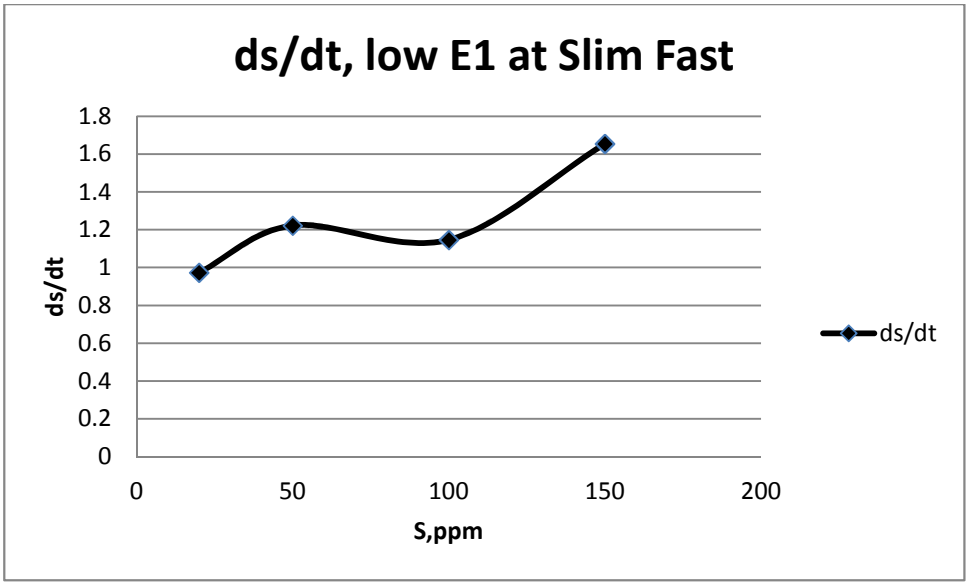

Figure XXXVIII. dS/dt of low E1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXIX. Calculated Values of dS/dt for E1 (5.5 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	52.72	0	75.79	0	98.79	0	129.75	0
2	21.2	15.76	33.23	21.28	51.38	23.705	80.11	24.82
4	21.9	7.705	37.379	9.60275	57.28	10.3775	87.01	10.685
6	22.3	5.07	37.041	6.458167	59.5	6.548333	83.13	7.77
12	22.8	2.493333	30.82	3.7475	64.57	2.851667	84.65	3.758333
24	42.951	0.407042	53.04	0.947917	72.24	1.10625	91.28	1.602917

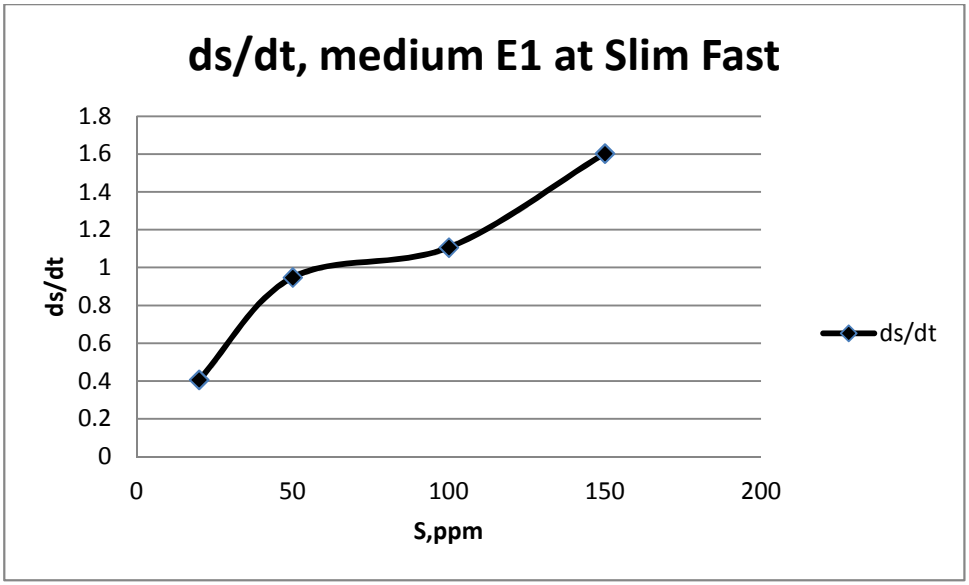

Figure XXXIX. dS/dt of mediumE1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXX. Calculated Values of dS/dt for E1 (10 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	52.72	0	75.79	0	98.79	0	129.75	0
2	20.5	16.11	33.91	20.94	55.98	21.405	79.31	25.22
4	22.1	7.655	34.2	10.3975	58.75	10.01	90.51	9.81
6	23.1	4.936667	34.54	6.875	63.7	5.848333	83.88	7.645
12	20.3	2.701667	29.57	3.851667	50.33	4.038333	66.67	5.256667
24	25.1	1.150833	40.86	1.455417	59.8	1.624583	65.75	2.666667

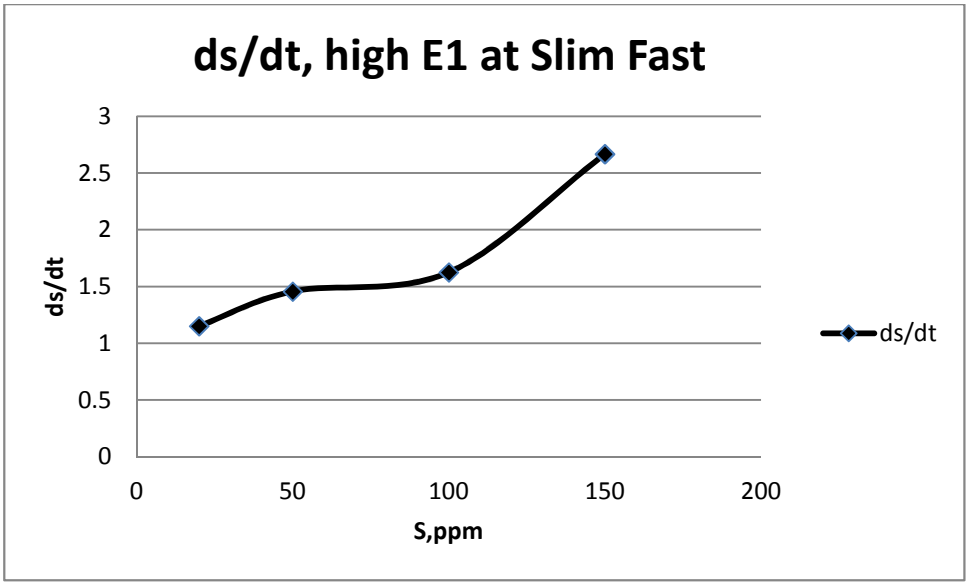

Figure XL. dS/dt of highE1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXXI. Calculated Values of dS/dt for N1 (1 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	63.36	0	94.66	0	154.2	0	184.2	0
2	28.7	17.33	53.42	20.62	102.17	26.015	134.14	25.03
4	38.199	6.29025	65.21	7.3625	116.74	9.365	171.5	3.175
6	36.08	4.546667	49.32	7.556667	92.18	10.33667	128.98	9.203333
12	25	3.196667	46.018	4.0535	85.23	5.7475	112.11	6.0075
24	20	1.806667	38.32	2.3475	71.4	3.45	94.06	3.755833

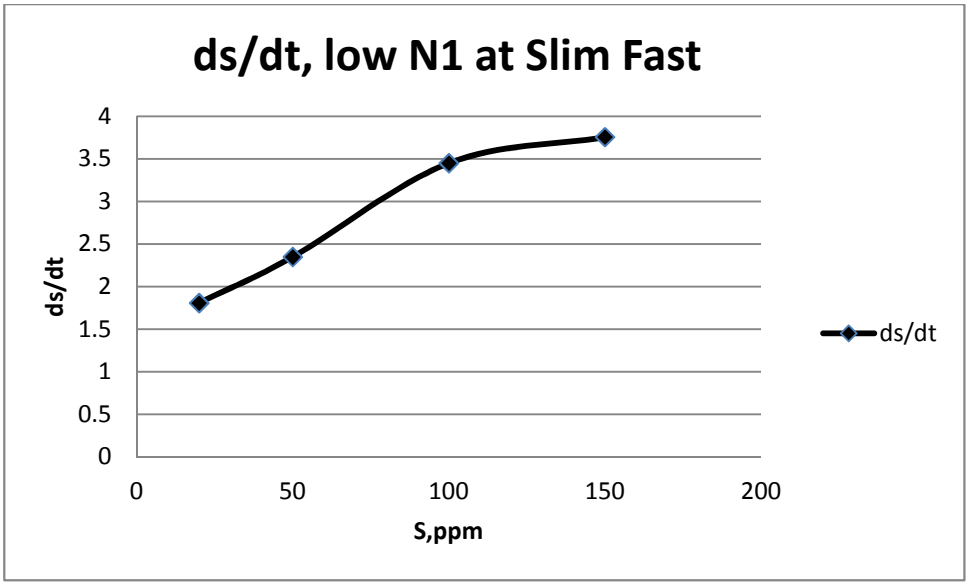

Figure XLI. dS/dt of low N1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXXII. Calculated Values of dS/dt for N1 (5.5 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	63.36	0	94.66	0	154.2	0	184.2	0
2	29.01	17.175	53.54	20.56	97.87	28.165	138.2	23
4	35.76	6.9	57.6	9.265	106.1	12.025	156.1	7.025
6	29.47	5.648333	50.53	7.355	92.01	10.365	135.71	8.081667
12	29.85	2.7925	45.052	4.134	81.1	6.091667	123.96	5.02
24	18.7	1.860833	40.491	2.257042	71.01	3.46625	105.76	3.268333

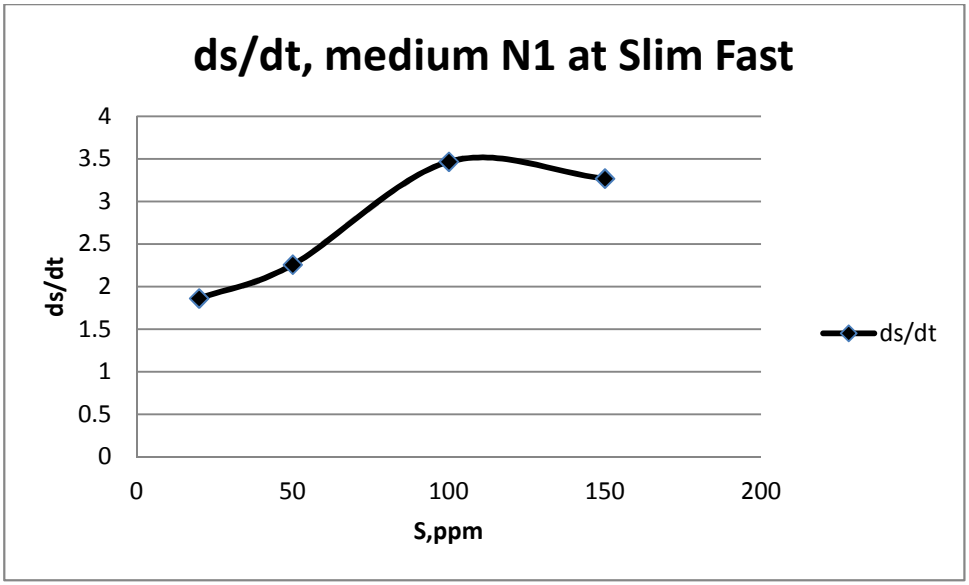

Figure XLII. dS/dt of mediumN1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours

Table LXXIII. Calculated Values of dS/dt for N1 (10 mL) atVariousApplications of Slim Fast Concentrations (20,50, 100, 150 ppm)

	20 ppm		50 ppm		100 ppm		150 ppm	
Time	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt	TOC	ds/dt
0	63.36	0	94.66	0	154.2	0	184.2	0
2	25.4	18.98	46.018	24.321	92.51	30.845	117.22	33.49
4	28.24	8.78	57.62	9.26	117.66	9.135	153.9	7.575
6	26.94	6.07	46.86	7.966667	106.03	8.028333	127.43	9.461667
12	26.12	3.103333	42.35	4.359167	82.5	5.975	103.81	6.699167
24	18.1	1.885833	36.695	2.415208	69.61	3.524583	115.27	2.872083

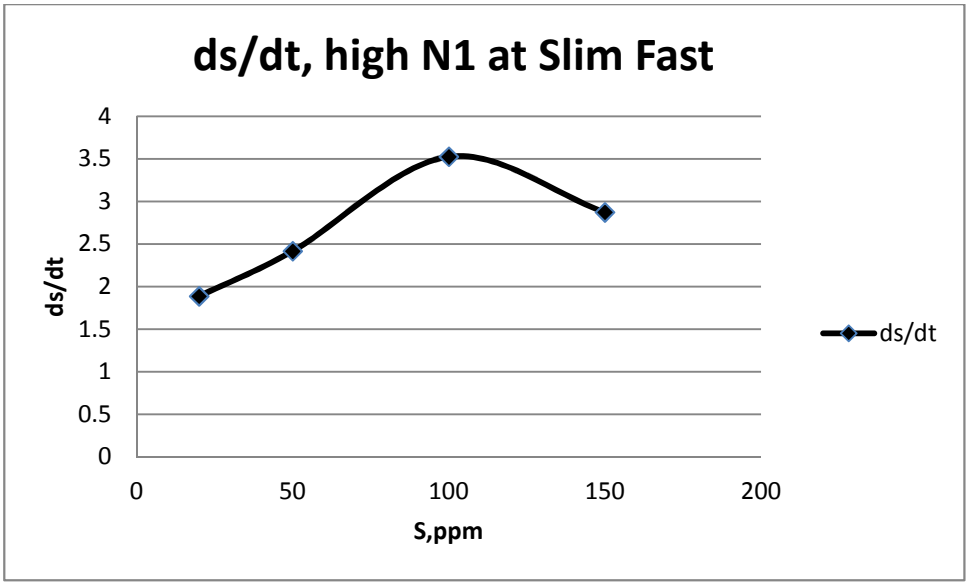

Figure XLIII. dS/dt of highN1vs SubstrateRemoval of Slim Fast Concentration (20, 50, 100, 150 ppm) at 24 hours