ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

METHANE PRODUCTION FROM HYDROLYSIS PRODUCT OF ORGANIC FOOD WASTE AND BAKER'S YEAST PROCESS WASTEWATER

M.Sc. THESIS

Nazlı LERMİOĞLU

Department of Environmental Engineering

Environmental Biotechnology Programme

Thesis Advisor: Assist. Prof. Dr. Mahmut ALTINBAŞ

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

MAYA ÜRETİM ATIKSUYU VE ORGANİK YEMEK ATIĞI HİDROLİZ ÜRÜNLERİNDEN METAN ÜRETİMİ

YÜKSEK LİSANS TEZİ

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FOREWORD

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ABBREVIATIONS

COD : Chemical Oxygen Demand
sCOD : Soluble Chemical Oxygen Demand
AD : Anaerobic Digestion
TKN : Total Kjeldahl Nitrogen
EGSB : Expanded Granular Sludge Bed
AMBR : Anaerobic Membrane Bio Reactor
VFA : Volatile Fatty Acids
VLR : Volumetric Organic Loading Rate
UASB : Upflow Anaerobic Sludge Bed
HRT : Hydraulic Retention Time
SRT : Sludge Retention Time
OFMSW : Organic Fraction of Municipal Solid Waste
TSS : Total Suspended Solids
VSS : Volatile Suspended Solids
OFMSW : Organic Fraction of Municipal Solid Waste
OL : Organic Loading

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METHANE PRODUCTION FROM HYDROLYSIS PRODUCT OF BAKER'S YEAST PROCESS WASTEWATER AND ORGANIC FOOD WASTE

SUMMARY

After the 19th century, with increasing human population and developings in industrial area waste generation has risen. Since waste piles reached big amounts, waste management became an important issue to solve. Wastes which are generated by human activities, commercial or industrial, should be managed for not to be dangerous for both environmental and publich health. With increasing in population, having new and renewable energy sources have became an important problem also. Organic part of solid waste has been accepted as a worthy resource which can be converted to important product with helps of microbially mediated transformantions. There are several methods to treat organic wastes. In these methods, anerobic degradation seems to be a promising approach. Since biogas is one of the most precious end product of anaerobic degradation, it can be considered as an recovery process for the management of these wastes.

The aim of this study is to investigate methane production potential and treatibility of baker's yeast process wastewater and organic food waste. For that purpose two-stage anaerobic system is used. Yeast wastewater is a wastewater with high COD that contains polysaccharides, organic polymers, salinity and suphate. High sulphate concentrations generates some problems for anaerobic treatment of wastewater. It is indicated that as a result of anaerobic treatment of wastewaters with high sulphate, sulphite accumulation occurs.(Khanal and Huang, 2003) On the other hand high sulphate concentration in wastewater could relate various problems in anaerobic treatment processes; a) sulphate could be reduced to sulphite inhibitin methanogens, b) sulphite could cause high dissolved oxygen concentration demand in the effluent, c) excess production of H_2S in biogas could lead corosion problems, d) the competition between sulphate reducing bacteria and methanogens could decrease the methane production from the organic substance(Lettinga and Hulshoffpol, 1991; Rinzema and Lettinga, 1988).

The first stage of the system was operated in another study, then the effluent of that study used in this study for methane production. In this scope, firstly baker's yeast process wastewater and organic food waste were treated in AnMBRs, which are operated under thermophilic conditions and at neutral pH. After this first stage, high VFA content effluent is obtained and used as an influent for the second stage. In the second stage EGSB reactors are used for methane production and they are operated under mesophilic conditions. In total, reactors are operated approximately one and a half year. The systems has started with 2 g.COD/L.day volumetric organic loadings for both reactors and increased to around 12 g.COD/L.day.

On the first term of EGSBR, which is fed with hydrolysis products of baker's yeast wastewater, with VLR of 2 g.COD/L.day, COD removal efficiency is calculated as 75%, theoretical and observed methane productions are measured as 0.64, 0.18

$L.CH_4$/day respectively. On the last term with VLR of 11.37 g.COD/L.day during the 11 days of operation period, it is observed that COD removal efficiency is decreased by 40%, therefore methane production could not be observed. The optimum methane production for EGSB reactor which is fed with hydrolysis products of baker's yeast wastewater is detected as 7,49 g.COD/L.day with methane production of 0.43 LCH_4/day.

COD removal efficiency, theoretical and observed methane production on the first period of EGSB reactor with is fed with hydrolysis products of organic food waste are calculated and measured as 87%, 0.67, and 0.55 $L.CH_4$/day respectively. In the last term of VLR of 12.07 g.COD/L.day it is seen that COD removal efficiency is dropped to 65% and consequently methane production could not be observed. The optimum methane production of EGSB which is fed with hydrolysis products of organic waste, is measured as 0.89 LCH4/day on the second term of 3.95 g.COD/L.day VLR with 85% COD removal efficiency.

MAYA ÜRETİM ATIKSUYU VE ORGANİK YEMEK ATIĞI HİDROLİZ ÜRÜNLERİNDEN METAN GAZI ÜRETİMİ

ÖZET

19. yüzyıldan sonra, insan nüfusu giderek artmıştır ve bu artış yüzünden artan endüstriyel sahadaki gelişmeler atık üretimi fazlalaştırmıştır. Fazlalaşan bu atık miktarları günümüzde önemli bir sorun haline gelmiştir. Fazlalaşan atık miktarı, atık yönetimini çözülmesi gereken önemli bir konu haline getirmektedir. İnsan aktivitelerinden, ticari ve endüstriyel çalışmalar tarafından açığa çıkan bu atıkların çevre ve insan sağlığına zarar vermeden arıtılması gerekmektedir. İnsanlar çağlardan beri daha ileriye doğru ilerlemeyi hedeflemiş olup yaptıkları gelişmeler ile endüstriyel faaliyetleri artırmışlardır. Artan endüstriyel faaliyetler ve değişen yaşam koşulları enerjiye olan ihtiyacı arttırmış ve insanları bu konu ile ilgili bir çözüm bulmaya yöneltmiştir. Giderek artan bu atık miktarı özellikle Türkiye gibi gelişmekte olan ülkelerde doğru yönetilememekte, hem görsel olarak kötü durmakta, ülke prestijini zayıflatmakta, hemde aynı zamanda insan sağlığına dolaylı ve direkt olarak zarar vermektedir. Türkiye gibi özellikle enerji konusunda büyük ölçüde dışarıya bağımlı olan ülkelerde bu sorun ciddi olarak ele alınmalı ve bu problem fırsata dönüştürülmelidir. Gelişmiş bir çok ülkede bu sorun uzun zaman önce ele alınmış olup konu ile ilgili çözümler üretilmiş, yeni teknolojiler ortaya çıkmış ve sıfır atık politikası güdülmüştür. Artan nüfus artışıyla birlikte yeni ve sürdürülebilinir enerji kaynaklarının eldesi önemli bir konu olarak hayatımıza girmektedir. Nüfus artışıyla enerji ihtiyacı orantılı olarak artmaktadır. Hayatımızın her alanında kullandığımız enerji kaynakları giderek azalmakta ve büyük bu durum büyük bir tehdit oluşturmaktadır. Bu büyük sorunun varlığını farkeden bir çok ülke yenilenebilinir enerji kaynakları ile olan çalışmalara destek vermekte ve teşvikler hazırlamaktadır. Günümüzde özellikle çöp sahaları, atık su arıtma tesisleri, hayvan atıkları ve organik atıklar ile çalışan tesislerin sayısı giderek artmakta olup halkımız bu konuda yönetiminde katkıları ve teşvikleri sayesinde giderek artan bir biçimde bilinçlenmektedir. Bu projelerden elde edilen enerji sayesinde dışarıya olan bağımlılık giderek azalmakta ve atık oranları büyük ölçüde azalmaktadır. Bu konu ile ilgili yapılan çalışmalar her yeni projede bir zorunluluk haline gelmekte hem enerji verimliliği hemde yenilenebilir enerji kaynakları üzerine verilen önem artmakta ve bu sayede dünyamız daha yaşanılır bir hale gelmektedir.

Atıkların organik kısımları mikroorganizmalar tarafından önemli ürünlere dönüştürülmektedir. Bu ürünler enerji eldesi için önemli birer kaynak olarak kabul edilmektedir. Organik atıkların arıtımında bir çok yöntem kullanılmakta olup anaerobik ayrıştırma bu yöntemler arasında umut verici bir method olarak göze çarpmaktadır. Organik maddelerin anaerobik arıtımı oksijensiz ortamda anaerobik mikroorganizmalar sayesinde gerçekleşmektedir. Anaeobik arıtım sonucu elde edilen ürünler enerji eldesi açısından faydalı olup, organik atıkların, anaerobik arıtımı enerji eldesi ve arıtım performansı bakımından daha fazla ele alınması gereken bir konu olmuştur. Anaerobik arıtım sonucu ortaya çıkan metan gazı bir çok şekilde değerlendirilebilinir bir gaz olup, yenilenebilinir bir enerji kaynağı olması dolayısıyla çevre koşullarını iyileştirmede büyük rol oynamaktadır.

Anaerobik arıtım sonucu oluşan biyogaz (metan ve hidrojen) enerji için kullanılabilinirken, katı atıkların anaerobik arıtımı sonucu elde edilen son ürün gübre olarak kullanılabilinmektedir. Anaerobik arıtım sonucu ortaya kullanılabilir iki ürün çıkması, metan gazının enerjide, son ürünün ise gübre olarak kullanılabilinir olması anaerobik arıtımın faydalarını daha fazla göz önüne sermektedir. Metan ve hidrojen günümüzde kullanılan fosil atıklardan daha az zararlı oldukları için, çevresel kirlenmenin azalmasına da yardımcı olmaktadırlar. Bu yüzden bu projelere olan ilgi artmalı ve yetkili kişiler bilinçlendirilmelidir. Anarobik arıtım bir çok atık çeşidine uygulanan bir arıtım türüdür. Örnek olarak hayvan gübresi tesisleri Avrupa'nın bir çok ülkesinde oldukça yaygın olup ülkemizde de yavaş yavaş ilgi görmektedir. Çöp sahalarında bulunan organik atıklarda anaerobik arıtım ile metan gazına dönüşmekte ve çöp sahaları artık daha düzenli hale gelerek birer enerji santrali olarak karşımıza çıkmaktadırlar. Anaerobik arıtmaya verilecek bir diğer örnek ise oldukça sık rastladığımız atık su arıtma tesisleridir. Özellikle evsel atıksu arıtma tesislerinden elde edilen çamurun anaerobik çürütücülerde metan gazına dönüştürülmesi ve bu metan gazından enerji elde edilmesi büyük ölçüde fayda sağlamaktadır. Ülkemizde atık su arıtma tesislerinde bulunan bu enerji santralleri giderek artmakta olup bu durum ülke ekonomisi içinde oldukça yararlı bir durum olarak nitelendirilmektedir.

Yukarıda da anlatıldığı gibi anaerobik arıtım yenilenebilir enerji kaynakları üzerine oldukça faydalar sağlamakta ve birçok atık grubu üzerine uygulanabilmektedir. Bu çalışmada kullanılan atıklar maya üretim atıksuyu ve organik yemek atığı olmak üzere iki çeşittir. Bu çalışmanın amacı, maya atıksuyu ve organik yemek atığının havasız ortamda arıtılması ve metan üretiminin incelenmesidir. Maya atıksuyu ve yemek atığı organik atıklar olup enerji içerikleri oldukça yüksektir. Maya atıksuyu maya üretim endüstrisi atığı olup anaerobik arıtım ile arıtılan ve enerji elde edilen bir çok tesis bulunmaktadır. Bu çalışmada maya atıksuyu ve organik yemek atığının anaerobik ortamda arıtılması ve metan gazı üretilmesi amacı ile iki aşamalı anaerobik sistem kullanılmıştır. Maya atıksuyu polisakkarit ve organik polimerler, tuzluluk ve sülfat konsantrasyonlarını içeren yüksek KOI'ye sahip bir atıksudur. Bununla birlikte atıksularda bulunan yüksek sülfat konsantrasyonu anaerobik arıtma proseslerinde bazı sorunlara yol açabilmektedir; bu sorunları dört madde ile vermek verekirse bunlar; a) sülfatın sülfat indirgeyen metanojenler tarafından kullanılması, b) sülfitin çıkış suyunda yüksek miktarda çözünmüş oksijen konsantrasyonuna neden olması, c) biyogaz içinde fazla bulunan H_2S'in aşındırıcı etkisi, d) sülfat indirgeyici bakterilerle metanojenler arasındaki rekabetin metan üretimini etkileyip düşürmesi olarak belirtilebilir.

Yukarıda da belirtildiği gibi bu çalışmada iki aşamalı anaerobik arıtmanın ikinci aşaması incelenmektedir. Sistemin ilk aşaması başka bir çalışmada incelenmiş olup, sistemin çıkış suyu ikinci aşamada besleme olarak kullanılmıştır. Bu kapsamda, ilk olarak maya atıksuyu ve organik yemek atığı AnMBR kullanılarak termofilik koşullarda nötral pH ile işletilmiştir. Bu ilk aşamadan sonra elde edilen yüksek UYA içerikli atıksu ikinci aşamada besleme olarak kullanılmıştır. İkinci aşamada metan üretimini gözlemek için yapılan çalışmada HÇY tipi reaktör kullanılmış olup, mezofilik koşullarda işletilmiştir. Toplamda reaktörler yaklaşık olarak 1,5 sene boyunca işletilmiştir. Sistem 2 g.KOİ/L.gün'lük hacimsel yükleme hızı ile başlamış, ve çalışmanın sonlarında metan üretimini artan hacimsel oranlar bazında incelemek amacıyla hacimsel oranlar artırılmıştır. Sözü geçen hacimsel yükleme hızları çalışmanın sonunda yaklaşık 12 g.KOİ/L.gün'e kadar çıkarılmış olmaktadır.

Maya atıksuyu hidroliz ürünleri ile beslenen HÇYR'nin 2 g.KOİ/L.gün hacimsel yükleme hızı ile işletilen ilk döneminde KOİ giderim verimi %75 olarak hesaplanmış, teorik ve gözlenen günlük metan üretimleri ise sırasıyla; 0.64 ve 0.18 L.CH_4/gün olarak ölçülmüştür. 11.37 g.KOİ/L.gün hacimsel yükleme oranı ile 11 gün işletilen son dönemde ise KOİ giderim veriminde %40'lik bir düşüş hesaplanmış ve metan üretimi gözlenmemiştir. Maya atıksuyu hidroliz ürünleri ile beslenen HÇYR'de elde edilen en iyi günlük metan üretimi ise 4. dönemde 7.49 g.KOİ/L.gün hacimsel yükleme hızı koşulunda 0,43 LCH_4/gün olarak ölçülmüştür.

Yemek atığı hidroliz ürünleri ile beslenen HÇYR'den elde edilen KOİ giderim verimi, teorik ve gözlenen günlük metan üretimi ise sırasıyla; %87, 0.67 ve 0.55L.CH_4/gün olarak bulunmuştur.

12,07 g.KOİ/L.gün hacimsel yükleme hızı koşulu ile 11 gün işletilen son dönemde ise KOİ giderim verimi %65'lere kadar düşmüş ve metan üretimi gözlenmemiştir. Yemek atığı hidroliz ürünleri ile beslenen HÇYR'de gözlenen en iyi günlük metan verimi ise 2. dönemde 3.95 g.KOİ/L.gün hacimsel yükleme hızı koşulu altında gerçekleşmiş olup, 0.89 L.CH_4/gün olarak ölçülmüştür.

1. INTRODUCTION

1.1 Relevance of the Subject

Environmental pollution is one of the biggest problem human beings face in the twenty-first century. Since climate change, increased global demand on fossil fuels, energy insecurity, and continuous exploitation of limited natural resources are become problems, new treatment methods are considered. The traditional treatment methods, which focuses on ridding pollutants from a single medium, that is, transformation of pollutants from liquid to solid or gas phases and vice versa, is no longer a desirable option. It has become enormously important to direct research efforts toward sustainable methods that not only alleviate environmental pollution, but also ease the stress on depleted natural resources and growing energy insecurity. Employing a biotechnology option is seems to be the The most cost-effective and sustainable approach. Even though aerobic processes are generaly used worldwide for municipal wastewater treatment, anaerobic processes still play a significant role in overall waste treatment. Anaerobic biotechnology is a sustainable approach which combines waste treatment with the recovery of useful byproducts and renewable biofuels.

With application of anaerobic technology, emission of toxic air pollutants can be limited and also can be a solution for energy problem.

Anaerobic treatment have been largely used in different kinds of waste and wastewater such as solid wastes including agricultural wastes, food and beverage industries animal excrements, sludge from sewage treatment plants and urban wastes and it is estimated that millions of anaerobic digesters have been built all over the the world with this purpose.

Anaerobic digestion is a simple process which requires a low to zero energy that is used for converting organic material from a wide range of wastewater types, solid wastes and other types of biomass into and precious energy source, methane.

Anaerobic degradation process has four subdivided phases according to the characteristic microorganisms and important conversions taking place. In hydrolysis phase, The complex polymeric matter is hydrolyzed to monomer by fermentative bacteria. In acidogenesis, acidogenic bacteria excrete enzymes for hydrolysis and convert soluble organics into volatile fatty acids and alcohols. In acetogenesis, products of the first phase convert to simple organic acids, carbon dioxide and hydrogen by acetogenic bacteria and in the last phase, methanogenesis, methane is produced from two ways, cleavage of acetic acid for producing CO_2 and CH_4, or from reduction of CO_2 to H^+ by methanogens.

In anaerobic digestion, there are two system types of anaerobic digesters. They are single and multi-stage systems. In single stage systems, all reactions take place in one reactor and environmental conditions are maintained at levels that suit all types of bacteria. Therefore,operating conditions for a particular stage are not optimal.

In multi stage systems, digesters have physically separated biochemical reactions of hydrolysis and acidogenesis in different reactors. Each reactor maintains the optimal environmental conditions for the microorganisms that facilitate the specific reaction that is happening inside. That is why these systems can be more efficient.

1.2 Aim and Scope of the Study

This study aims to, investigate optimum methane production from hydrolysis products of food waste and baker's yeast wastewater in two-stage anaerobic digestion. Food wastes are collected from luch hall in İTÜ Ayazağa Campus and baker's yeast wastewater is taken from Pakmaya factory in İzmit as a feedstock of the hyrolysis reactors.

Anaerobic membrane bioreactors are operated as a first stage, and effluent collected from these reactors were used as influent for the second stage. At the second stage two EGSB reactors are run for approximately one and a half year. For investigating the maximum methane production, reactors are operated with six different volumetric loading rates.

2. LITERATURE REVIEW

2.1 Anaerobic Treatment

Anaerobic digestion is a process which, in the absence of oxygen, decomposes organic matter. The main product is biogas which is a mixture of approximately 65% methane and 35 % carbon dioxide, along with a reduced amound of a bacterial biomass.. the development of anaerobic digestion technology took place at the beginning of the 19^{th} century, owing to the energy crises anaerobic digestion processes digestion technology underwent significant growth. (Mata – Alvarez, 2003).

Traditionally, anaerobic digestion (AD) has been used to trat liquid wastes with or without suspended solids such as manures, domestic or industrial wastewaters, sludges from biological or physico-chemical treatments, etc. AD occurs in 3 steps. These steps are hydrolysis, and acidogenesis, acetogenesis and methanogenesis. (Mata – Alvarez, 2003)

2.1.1 Hydrolysis and acidogenesis

Since the microorganisms are not capable of assmilating particulate organic matter, the first phase in the anaerobic digestion process consists in the hydrolysis of complext particulate material (polymers) into simpler dissolved materials (smaller molecules), which can penetrate through the cell membranes of the fermentative bacteria. Particulate materials are concerted into dissolved materials by action of exoenzymes excreted by the hydrolytic fermentative bacteria. The hydrolysis of polymers usually occurs slowly in anaerobic conditions, and several factors may affect the degree and rate at which the substrate is hydrolysed (Lettinga et al., 1996). These factos are; operational temperature of the reactor, residence time of the substrate in the reactor, subsrate compostion, size of particles, pH of the medium, and concentration of products from hydrolysis.

The soluble products from the hydrolysis phase are metabolised inside the cells of the fermentative bacteria and are converted into several simpler compounds, which are then excreted by the cells. The compounds produced inclued volatile fatty acids, alcohols, lactic acid, carbon dioxide, hydrogen ammonia and hydrogen sulfide, besides new bacterial cells.

Acidogenesis is carried out by a large and diverse group of fermentative bacteria. Usual species belong to the clostridia group, which comprises anaerobic species that form spores, able to survive in very adverse environments and the family Bacteroidaceaea, organisms commonly found in digestive tracts, participating in the degradation of sugars and amino acids (De Lemos Chernicharo, 2007)

2.1.2 Acetogenesis

Acetogenic bacteria are responsible for the oxidation of the products generated in the acidogenic phase into a substrate appropriate for the methanogenic microorganisms. In this way, acetogenic bacteria are part of an intermediate metabolic group that produces substrate for methanogenic microorganisms. The products generated by acetogenic bacteria are acetic acid, hydrogen and carbon dioxide.

During the formation of acetic and propionic acids, a large amound of hydrogen is formed, causing the pH in the aqueous medium to decrease. However there are two ways by which hydrogen is consumed in the medium, first, through the methanogenic microorganisms, that use hydrogen and carbon dioxide to produce methane and second, through the formation of organic acids, such as propionic and butyric acids, which are formed though the reaction among hydrogen, carbon dioxide and acetic acid (De Lemos Chernicharo, 2007).

Among all the products metabolized by the acidogenic bacteria, only hydrogen and acetate can be directly used by methanogenic microorganisms. However at 50% of the biodegradable COD are converted into propionic and butyric acids, which are later decomposed into acetic acid and hydrogen by the action of acetogenic bacteria (De Lemos Chernicharo, 2007).

2.1.3 Methanogenesis

The final phase in the overall anaerobic degradation process of organic compounds into methane and carbon dioxide is performed by the methanogenic archaea.

They use only a limited number of substrate, comprising acetic acid, hydrogen/carbon dioxide, formic acid, methanol, methylamines and carbon monoxide.

In the view of their affinity for substrate and extent of methane production, methanogenic microorganisms are divided into two main groups, one that forms methane acetic acid or methanol (acetate using microorganisms, aceticlastic methanogens) and the other that produces methane from hydrogen and carbon dioxide (hydrogen using microorganisms, hydrogenotrophic methanogens) (De Lemos Chernicharo, 2007).

2.1.3.1 Acetislastic methanogens

Although only a few of the methogenic species are capable of forming methane from acetate, these are usually the microorganisms prevailing in anaerobic digestion. They are repsonsible for about 60 to 70% of all methane production, starting from the methyl group of the acetic acid. (Zinder, 1993)

2.1.3.2 Hydrogenotrophic methanogens

Unlike the aceticlastic organisms, practically all the well known methanogenic species are capable of producing methane from hydrogen and carbon dioxide. The genera more frequently isolated in anaerobic reactors are Methnanobacterium, and Methanobrevibacter. Both the aceticlastic and the hydrogenotrophic methanogenic microorganisms are very important in the maintenance of the course of anaerobic digestion,since they are responsible for the essential function of consuming the hydrogen produced in the previous phases. (De Lemos Chernicharo, 2007).

2.2 Factors Affecting AD Process

From both the waste treatment and resource recovery perspectives, it is important to examine some of the important factors that govern the anaerobic bioconversion process. These include organic loading rate, biomass yield, substrate utilization rate, HRT and SRT, start-up time, microbiology, environmental factors, and reactor configuration. (Khanal, 2008)

2.2.1 Volumetric organic loading rate

Anaerobic processes are characterized by high volumetric organic loading rates (VOLRs).

High-rate anaerobic reactors such as UASB, EGSB, anaerobic filter, and fluidized bed reactors are capable of treating wastewater at VOLR of 10-40 kg COD/m^3.day, and on occasion can exceed 100 kg COD/m^3.day in fluidized bed reactors. A high VOLR indicates that more wastewater can be treated per unit of reactor volume. VOLR is one of the most important factors in designing or sizing an anaerobic bioreactor. (Khanal, 2008)

2.2.2 Biomass yield

Biomass yield is a quantitative measure of cell growth in a system for a given substrate. Anaerobic degradation of organic matter is accomplished through a number of metabolic stages in a sequence by several groups of microorganisms. This differs from the aerobic treatment process, in which such synergistic relation does not exist. The yield coefficient of acid-producing bacteria is significantly different from that of methane-producing bacteria. The aerobic treatment process gives a fairly constant yield coefficient for biodegradable COD irrespective of the type of substrates. For an anaerobic system, the yield coefficient depends not only on COD removed but also on the types of substrates being metabolized. (Khanal, 2008)

2.2.3 Hydraulic retention time (HRT) and solids retention time (SRT)

HRT and SRT are two important design parameters in biological treatment processes. HRT indicates the time the waste remains in the reactor in contact with the biomass. The time required to achieve a given degree of treatment depends on the rate of microbial metabolism. Waste containing simple compounds such as sugar is readily degradable, requiring low HRT, whereas complex wastes, for example, chlorinated organic compounds, are slowly degradable and need longer HRT for their metabolism. SRT, on the other hand, controls the microbial mass (biomass) in the reactor to achieve a given degree of waste stabilization. SRT is a measure of the biological system's capability to achieve specific effluent standards and/or to maintain a satisfactory biodegradation rate of pollutants.

Maintaining a high SRT produces a more stable operation, better toxic or shock load tolerance, and a quick recovery from toxicity. The permissible organic loading rate in the anaerobic process is also determined by the SRT (Khanal, 2008).

It is indicated that HRT is a deciding factor in process design for complex and slowly degradable organic pollutants, whereas SRT is the controlling design parameter for easily degradable organics (Speece, 1996).

2.2.4 Microbiology

The microbiology of the anaerobic treatment system is much more complicated than that of the aerobic one. An anaerobic process is a multistep process in which a diverse group of microorganisms degrades the organic matter in a sequential order resulting a synergistic action. The stability of an anaerobic treatment system is often debated, mainly due to the fragile nature of microorgan¬isms especially methanogens to the changes in environmental conditions such as pH, temperature, ORP, nutrients/trace metals availability, and toxicity. When an anaerobic treatment system fails because of lack of proper environmental factors or biomass washout from the reactor, it may take several months for the system to return to a normal operating condition because of an extremely slow growth rate of methanogens. (Khanal, 2008)

2.2.5 Temperature

Anaerobic processes, like other biological processes, strongly depend on temperature. The anaerobic conversion of organic matter has its highest efficiency at a temperature 35-40°C for mesophilic conditions and at about 55°C for the thermophilic conditions (van Haandel and Lettinga 1994). Anaerobic processes, however, can still operate in a temperature range of 10-45°C without major changes in the microbial ecosystem. Generally, anaerobic treatment processes are more sensitive to temperature changes than the aerobic treatment process. (Khanal, 2008)

2.2.6 Operating pH

There are two groups of bacteria in terms of pH optima, namely acid-producing bacteria (acidogens) and methane-producing bacteria (methanogens). The acidogens prefer a pH of 5.5-6.5, while methanogens prefer a range of 7.8-8.2. In an environment where both cultures coexist, the optimal pH range is 6.8-7.4.

Since methanogenesis is considered as the rate-limiting step, where both groups of bacteria are present, it is necessary to maintain the reactor pH close to neutral. (Khanal, 2008)

2.2.7 Nutrients and trace metals

All microbial-mediated processes require nutrients and trace elements during waste stabilization. A question may arise how nutrients and trace elements are involved in waste stabilization. In fact nutrients and trace metals are not directly involved in waste stabilization; but they are the essential components of a microbial cell and are thus required for the growth of an existing microbial cell and synthesis of new cell. Besides, nutrients and trace metals also provide a suitable physicochemical condition for optimum growth of microorganisms. It is important to note that if the waste stream in question does not have one or more of the important nutrients and trace elements, the waste degradability is severely affected. This is because of inability of microbial cell to grow at optimum rate and to produce new cells. (Khanal, 2008)

2.2.8 Toxicity and inhibition

Anaerobic microorganisms are inhibited by the substances present in the influent waste stream and by the metabolic byproducts of microorganisms. Ammonia, heavy metals, halogenated compounds, and cyanide are examples of the former, while ammonia, sulfide, and volatile fatty acids are examples of the latter. It is interesting to point out that many anaerobic microorganisms are also capable of degrading refractory organics (Stronach et al. 1986) that otherwise might be considered toxic. In some cases, toleration is manifested by acclimation to toxicants. These observa¬tions provide a considerable cause for optimism about the feasibility of anaerobic treatment of industrial wastewaters that contain significant concentrations of toxic compounds (Parkin and Speece 1982).

2.3 Anaerobic Reactor Types

2.3.1 Batch Systems

In batch systems, digesters are filled once with fresh wastes, with our without addition of seed material and allowed to go through all degradation steps sequentially in the dry mode, at 30 – 40% TS.

Through batch systems may appear as nothing more than a landfill – in – a- box, they are in fact achieve 50 to 100 fold higher biogas production rates than those observed in landfills because of two basic features. The first is that the leachaste is continously recirculated, which allows the dispersion of inoculant, nutrients acids and in fact is the equivalent of partial mixing. The second is that batch systems are run at higher temperatures than that normally observed in landfills. Batch systems have up to now not succeeded in taking a substantial market share.

However, the specific features of batch process, such as a simple design and process control, robutness towards coarse and heavy contaminants and lower the investment cost make them particulary attractive for developing countries (Ouedraogo, 1999)

2.3.2 One – stage sytems

The biomethanization of organic wastes is accomplished by a series of biochemical transformations, which can be roughly separeted into a first step where hydrolysis, acidification take place and a second step where acetate, hydrogen and carbon dioxide are transformed into methane. In one – stage systems, all these reactions take place simultaneously in a single reactor, where in two or multi – stage systems, the reactions take place sequentially in at least two reactors.

About 90% of the full scale plants in use in Europe for anaerobic digestion of OFMSW and biowastes rely on one- stage systems and these are approximately evenly split between wet and dry conditions (De Baere, 1999). This industrial trend is not mirroed by the scientific literature, which reports as many investigations on two or multi – stage or batch systems as on one – stage systems. A likely reason for this discrepancy is that two and multi – stage systems afford more possibilities to the researcher to control and investigate the intermediate steps of the digestion process. Industrialists, on the other hand, prefer one – stage systems because simpler designs duffer less frequent technical failures and have smaller investment costs. Biological performance of one – stage systems is, for most organic wastes, as high as that of two- stage systems, provided the reactor is well designed and operating conditions carefully chosen (Weiland, 1992).

2.3.3 Two – stage systems

The rationale of two and multi – stage systems is that the overall conversion process of OFMSW to biogas is mediated by a sequence of biochemical reactions which do not necessarily share the same optimal environmental conditions. Optimizing these reactoions separately in different stages or reactors may lead to a larger overall reaction rate and biogas yield (Ghosh et al., 1996).

Typically, two stages are used where the first one harbors the hydrolysis, acidogenesis reactions, with a rate limited by the hydrolysis of cellulose and the second one carries out the acetogenesis and methanogenesis with a rate limited by the slow microbial growth rate (Liu and Ghosh, 1997; Palmowski and Müller, 1996).

With these two steps occuring in distinct reactors, it becomes possible to increase the rate of methanogenesis by designing the second reactor with a biomass retention scheme or other means (Capela et al., 1999; Wellinger et al., 1999).

The increased technical complexity of two stage relative to single stage systems has not, however, always been translated in the expected higher rates and yields (Weiland, 1992). In fact, the main advantage of two – stage systems is not a putative higher reaction rate, but rather a greater biological reliability for wastes which cause unstable performance in one – stage systems. It should be noted however that, in the context of industrial applications, even for the challenging treatment of highly degradable biowastes, prefence is given to technically simpler one – stage plants. Biological reliability is then achieved by adequate buffering and mixing of incoming wastes, by precisely controlled feeding rate and, if possible, by resorting to co – digestion with other types of wastes (Weiland, 2000). Industrial applications have up to now displayed little acceptance for two- stage systems as these represent only 10 % of the curren treatment capacity (De Baere, 1999).

2.3.3.1 EGSB reactor

The UASB reacttor represented a remarkable progress for the envrionmental technology and mainly for the anaerobic processes. Nevertheless, some modifications were suggested in order to expand its field of applications resulting in the EGSB reactor (de Man et al., 1998) The features of both reactors are similar, however, in the EGSB the granular sludge bed is expanded due to the application of V higher than those imposed in UASB reactors (Van der Last and Lettinga, 1992)

High V exceeding 5-6 m/h, is activated by applying high liquid recirculation rates. Additionaly EGSB reactors are tall reactors with a limited diameter (high height/diameter ratio) and a relatively small footprint. As a result of the V applied mainly hydraulic and gas loads applied to the EGSB reactor will improve the granular sludge – wastewater contact in two ways (Kato, 1994).

These two ways are expanding the sludge bed allowing the even distribution of the wastewater by preventing dead zones and short circuit, and the other one the turbulence enables convective transport of substrates from the bulk into the biofilm increasing the toal rate of substrate transport beyond that of diffusion alone.

However, a recent study indicated that a direct relationship between V and substrate consumption could not be found. Instead, it was demonstrated that the anaerobic biofilms play a more relavent role in fully expanded EGSB reactors. Apparently, the characterisitics of granular sludge are the main factors responsible of the internall mass transport limitations of the anerobic sludge. (Gonzalez et al., 2001)

Due to the characterisitcs of the EGSB reactor (high V and recirculation ratios) the systems can be applied for the treatment of low-strength wastewaters and for the treatment of wastewaters from the chemical and petrochemical industries where high recycle rates may decrease the potential toxicity of such streams. (Razo-Flores, et al., 1999, Macarie, 2000). It has been proposed that the lowest feasible COD influent concentration that can be treated in an EGSB reactor is 13 mg/L at VOLR of 5kg COD/m^3.day. On the other hand VOLR up to 40 kg COD/m^3.day can be applied in EGSB reactors (Seghezzo et al., 1998)

The design of the EGSB reactors is similar to the one described for UASB reactors. EGSB reactor is not hydraulically limited when treating strongly diluted wastewater, however, it must be clear that this systems is not adequate for the removal of SS.

3. MATERIALS and METHODS

3.1 Wastewater Characteristics

Two kinds of wastewater are used during the experiments, these are hydrolysis products from food waste and baker's yeast wastewater from anaerobic membran bioreactors. Wastewater characteristics which are used in the second stage of system are showed below in Table 3.1

Table 3.1 : Wastewater characterisitics

pH	COD (mgCOD/L)	Alkalinity ($mgCaCO_3/L$)	Conductivity (mS/cm)	Volatile Fatty Acids (mgCOD/L)	Total Kjehdahl Nitrogen (mgN/L)	Ammonia Nitrogen (mgN/L)
Baker's Yeast Process Wastewater						
7,69	46456	11704	42	25543	3138	1966
Organic Food Waste						
7,03	44227	5600	21	26701	459,5	144

3.1.1 Inoculum

Inoculum which is added to methanogenesis reactors is a mixture of full scale treatment plant of baker's yeast, pulp and paper and brewery industries. pH, TSS and VSS values are 7.96, 113 gTSS/L and 57.4 gVSS/L, respectively, in the mixture of inoculum. Inoculum concentration are provided as 40 gTSS/L in both reactors.

3.2 Reactor Operation

In this study EGSB reactor type are used as methanogenesis reactors. The effective volume of both reactors were 1,041 L and they are made of glass.

System configuration is given in Figure 3.1.

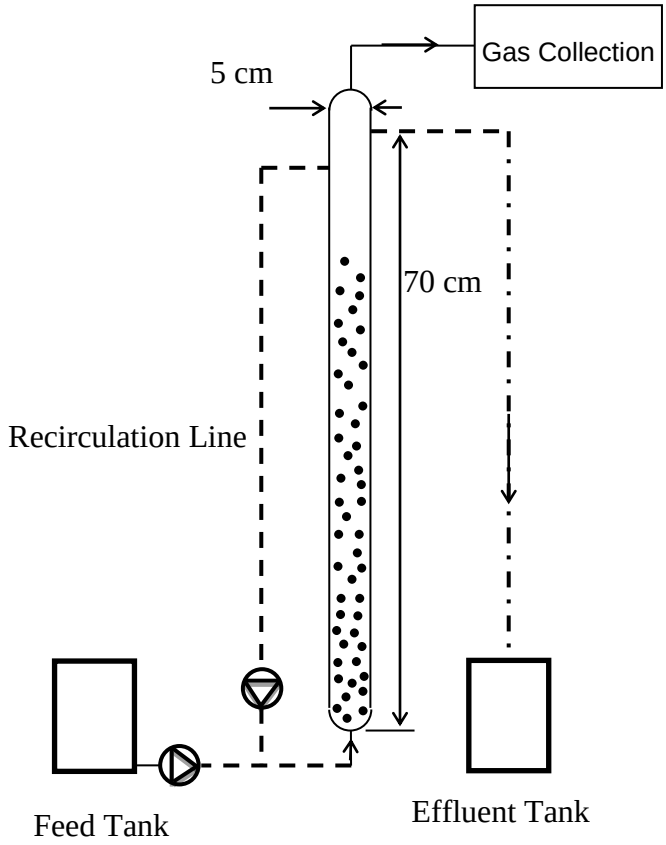

Figure 3.1 : Reactor design

Wastewater is fed by a pump (Seko, Rieti Italy) to keep granular biomass in suspension, peristaltic pump is used by recycling the effluent of anaerobic reactor. The effluent of the reactor is collected at the effluent tank. Biogas is collected in 5 L Tedlar Bags (Grace, IL, USA) and biogas volume is determined daily by wet gas meter (Ritter, Bochum, Germany). 1 mL of this biogas sample is used for the determination of gas composition.

Methanogenesis reactors are operated in mesophilic conditions (37 ^{o}C) and with 2 days of HRT throughout the study. Reactors are operated with six different volumetric loading rates which are 2, 4, 6, 8, 10 and 12 g.COD/L.day.

Influent are reserved at refrigerator (+ 4 ^{o}C) before feeding through reactor. It is diluted for requested volumetric loading rates (VLR). pH is adjusted by adding either 1 N HCl or 1 N NaOH.

3.2.1 Reactor System and Calculations

System design and calculations of both reactors were given below.

$$Q = \frac{L_v * V}{S_o} \tag{3.1}$$

Effective Volume (V) : 1,041 L

L_v : Volumetric Loading Rate , kgCOD/m^3day

Q : Flowrate, L/day

At beginning organic loading rate for operating the reactors, was 2 kgCOD/m^3day with time and stable gas production and COD removal efficiency, organic loading rate will be increased till 10 kgCOD/m^3day

Upflow velocity of EGSB is chosen as 0,5 – 1,0 m/hr

Flowrate needed for suspension of granulles;

$$Q = U_{ave} * S \tag{3.2}$$

$$Q = 6\frac{m}{hr} * 0{,}00196\, m^2 = 0{,}0118\,\frac{m^3}{hr} = 0{,}196\,\frac{L}{\min} = 283\,\frac{L}{day} \tag{3.3}$$

3.3 Analytical Methods

The parameters measured in this study listed in Table 3.2

Table 3.2 : Analytical parameters

Parameter	Sampling location	Method	Device
Total COD	Influent, Effluent	5220 B Titrimetric method	-
Soluble COD	Influent, Effluent	5220 B Titrimetric method	-
TKN	Influent, Effluent	4500 B: Titrimetric method	Gerhart
NO_2^- ve NO_3^-	Influen, Effluent	Ion Chromatography	Dionex ICS – 3000
PO_4^{3-}	Influent, Effluent	Ion Chromatography	Dionex ICS – 3000
SO_4^{2-}	Influent, Effluent	Ion Chromatography	Dionex ICS – 3000
Cl^-	Influent, Effluent	Ion Chromatography	Dionex ICS – 3000
Na^+	Influent, Effluent	Ion Chromatography	Dionex ICS – 3000
Mg^{2+}	Influent, Effluent	Ion Chromatography	Dionex ICS – 3000
K^+	Influent, Effluent	Ion Chromatography	Dionex ICS – 3000
Ca^{2+}	Influent, Effluent	Ion Chromatography	Dionex ICS – 3000
VFA	Influent, Effluent	Gas Chromatography	GC 1750 A Shimadzu-2100
Alkalinity	Influent, Effluent	2320 B: Titrimetric method	-
Gas Analysis	Reactor	Gas Chromatography	GC Perichrom P1525

Samples, which are taken for soluble COD and VFA are centrifuged at 9000 rpm for 15 minutes and the resulting supernatant, filtrated through a Millipore PVDF filter (0.45 mm) for COD and Millipore PVDF filter (0.22 mm) for VFA. COD samples are preserved with H_2SO_4, VFA samples with 10M H_3PO_4.

The volatile fatty acids (VFA) levels were determined by a gas chromatograph (Shimadzu GC-2010) equipped with a flame-ionisation detector and a 30 m × 0.25 mm TRB-FFAP capillary column (film thickness = 0.25 μm). The temperature of the injection port and detector were 250°C and 250°C, respectively. The oven temperature reached 60°C in first 1 min and then 60°C to 230°C (5°C/min) and fixed at 230 °C in 1 min. Nitrogen was the carrier gas at 30 ml/min. In addition, hydrogen gas is used at 40 ml/min flow rate and air flow was used at 400 ml/min. The sample (1.0 mL) is transferred into a gas chromatography vial to which 0.2 mL of 10% phosphoric acid is added.

Hydrogen, carbon dioxide, methane contents of the biogases are measured with a gas chromatograph (Perichrom PR2100, France) equipped with a thermal conductivity detector (TCD) and helium and nitrogen served as the carrier gas.
To identify the gas composition GC with TCD detector (Perichrom P2100, France) is used with samples of biogas which are collected in 5 L Tedlar Bags. Helium and nitrogen are used as carrier gases. For every sample, GC used 1 mL biogas and analyses are made with automatic valves. After 15 minutes gas composition is expressed in terms of H_2,CO_2, N_2, O_2, CH_4 in percentages.

Elemental analysis (Na^{+1}, Ca^{+2}, K^+, Mg^{+2}, NH_4^+, SO_4^{-2}, PO_4^{-3}, Cl^-, NO_3^-) are made with ion chromotograph Dionex ICS – 3000 (Thermo Scientific, USA)
Samples, which were taken for elemental analysis, filtrated through a Millipore PVDF filter with 0,22 mm pore size (Merck Millipore, USA) and diluted 50 times. IonPac AS19 and IonPac CS12A colomns are used in Ion chromatograph.

4. RESULTS AND DISCUSSION

Biomethane production studies, with hydrolysis products of food waste and baker's yeast wastewater, are endured for 546 and 548 days respectively. In this operation period six different volumetric loading rates are applied and results are given below.

4.1 Biomethane Production From Hydrolysis Products of Baker's Yeast Wastewater

4.1.1 Chemical oxygen demand (COD)

Organic load is defined as the organic matter applied daily to the reactor. In this study six different organic loads are applied to the EGSB reactor to observe the COD removal efficiency and methane production. Different organic loads and volumetric loading rates that applied in six different terms are given in Table 4.1

Table 4.1. Operating conditions and periods of EGSB of hyrolysis products of baker's yeast wastewater

Term	Periods	Volumetric Loading Rate (gCOD/L.day)
I	1 – 67	2,00
II	68 - 326	3,63
III	327 - 379	5,85
IV	380 - 442	7,49
V	443 – 536	9,23
VI	537 - 548	11,37

Influent and effluent COD concentrations with removal efficiency of EGSB reactor of hydrolysis product of baker's yeast wastewater are given in Figure 4.1

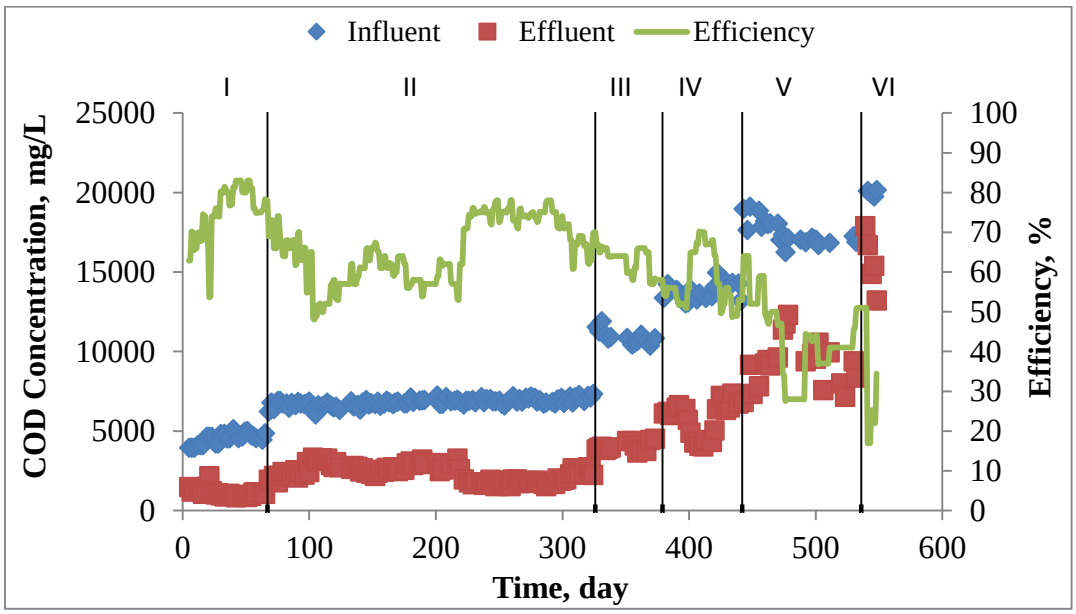

Figure 4.1 : Influent and effluent COD concentrations of EGSB reactor of hydrolysis products of baker's yeast wastewater.

Soluble COD concentrations of influent and effluent of EGSB reactor of hydrolysis products of baker's yeast wastewater were given in Figure 4.2

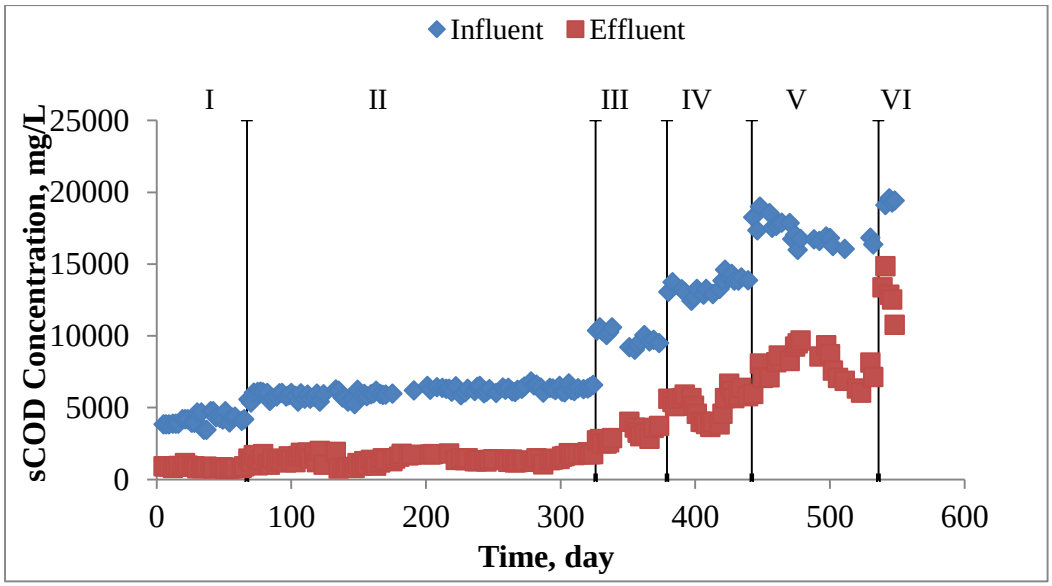

Figure 4.2 : sCOD concentrations of influent and effluent of EGSB reactor of hydrolysis products of baker's yeast wastewater.

Average COD concentrations of influent and effluent for EGSB reactor which was fed with baker's yeast wastewater for the six terms are given in Table 4.2

Table 4.2 : COD concentration variation for six terms of EGSB reactor of hydrolysis products of baker's yeast wastewater.

Term	Influent COD (mgCOD/L)	Effluent COD (mgCOD/L)	Removal Efficiency (%)	Influent sCOD (mgCOD/L)	Effluent sCOD (mgCOD/L)
I	4520	1128	75	4158	875
II	6817	2310	65	6094	1404
III	10920	4028	63	9889	3099
IV	13858	5760	58	13498	5181
V	17531	9223	43	17203	7883
VI	19965	15602	32	19365	12892

Influent, effluent, influent sCOD, effluent sCOD concentrations averages of the EGSB reactor which was fed with hydrolysis product of baker's yeast wastewater for the first term are; 4519, 1128, 4158, 875 mgCOD/L. For the second period these concentrations are; 6816, 2310, 6093, 1403 mgCOD/L. At the third period, COD concentrations for influent and effluent are 10919, 4028 and sCOD concentraions of influent and effluent are calculated as 9889 and 3099 mgCOD/L. Average COD and sCOD concentrations of influent and effluent at the forth period are, 13858, 5759, 13498, 5181. For the fifth term, 17531, 9223, 17203, 8993. Average COD and sCOD concentrations for the sixth and last term are calculated as; 19965, 15602, 19365, 12892. Total COD removal efficiency for all six terms are calculated as 75%, 65%, 63%, 58%, 43%, and 32%. COD concentraions are increasing with high organic loading rates none the less there is a drop 40% in removal efficiencies between first and last term.

Volumetric organic loading rates with sCOD removal efficiency for six different terms is given in Figure 4.3

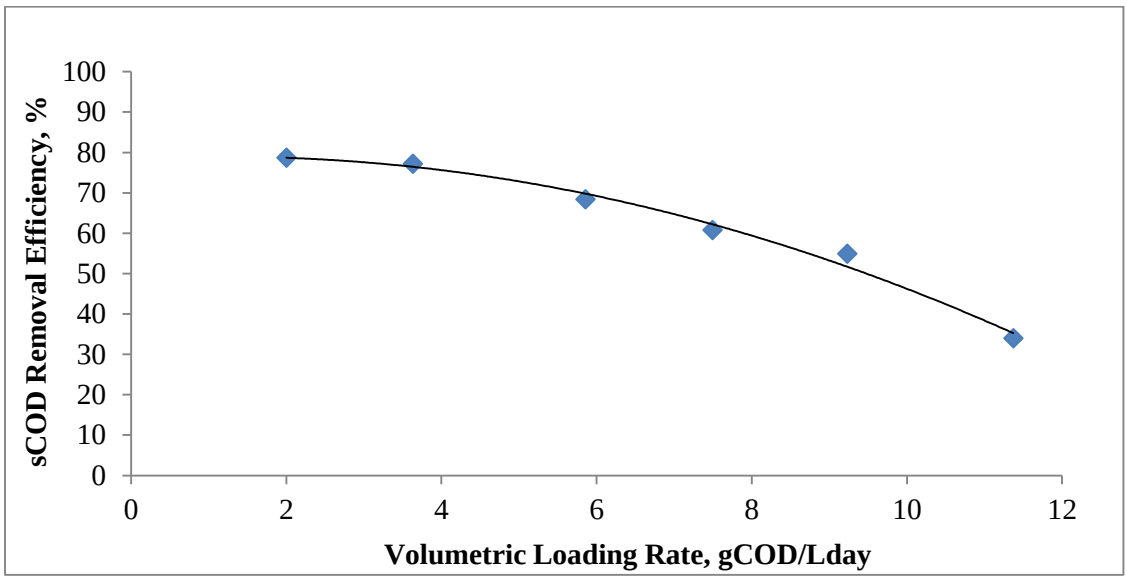

Figure 4.3 : VLR and sCOD removal efficiency of EGSB of hydrolysis products of baker's yeast wastewater.

4.1.2 Alkalinity and pH

Alkalinity in biological systems show that, the pH value required for the decomposition leads to drop below the desired level and other volatile acids indicates a buffering capacity.

In anaerobic systems and the alkalinity is expected to decrease in the formation of CO2 and VFAs. The volatile fatty acids produced in the system consumes alkalinity.

However, depending on the type of waste water, the breakdown of proteins in such cases there may be increased in alkalinity. The increase of alkalinity in anaerobic systems can be explained by the formation of ammonia and bicarbonate. (Alvarez, 2003)

Influent and effluent alkalinity and pH values for EGSB reactor which was fed with hydrolysis product of baker's yeast wastewater are given in Figures 4.4. and 4.5.

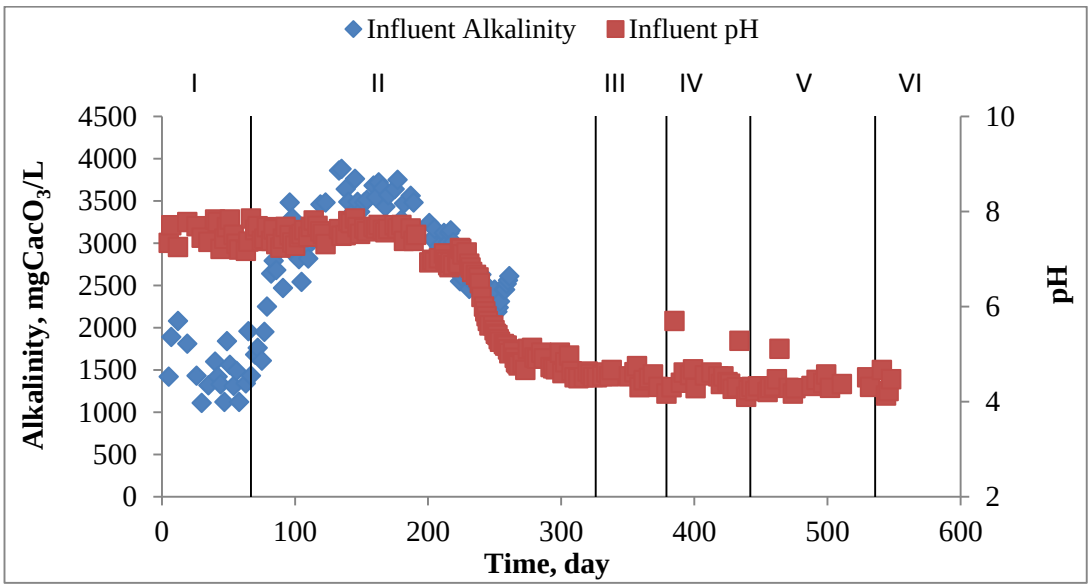

Figure 4.4 : pH and alkalinity concentration of influent of EGSB reactor of hydrolysis products of baker's yeast wastewater

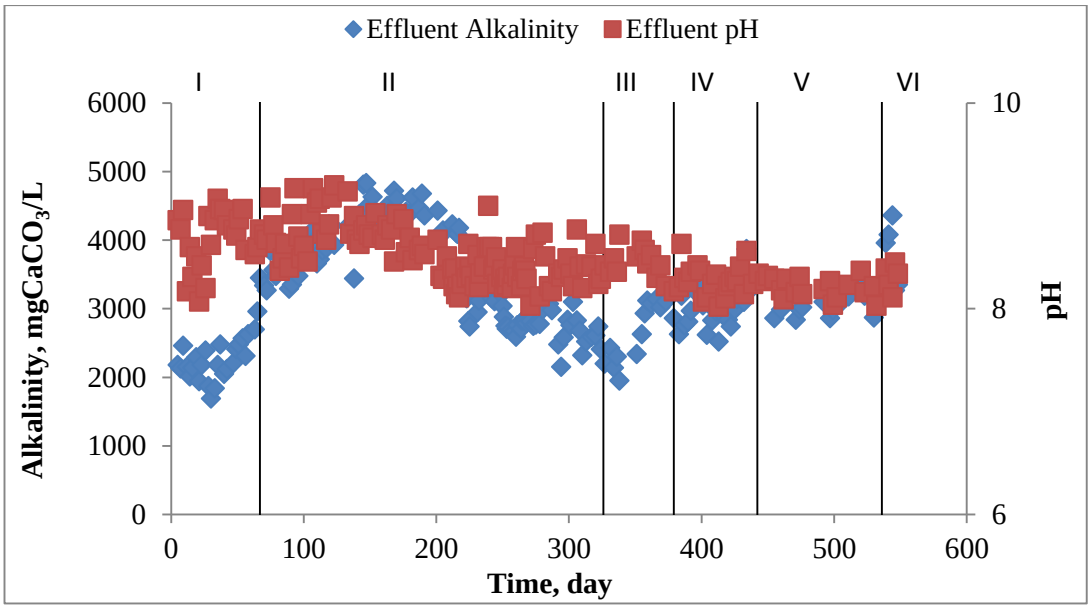

Figure 4.5 : pH and alkalinity concentration in effluent.

Influent and effluent alkalinity and pH average values for six terms of EGSB reactor with was fed with hydrolysis product of baker's yeast wastewater were given in Table 4.3 below.

Table 4.3 : pH and alkalinity concentration averages of EGSB reactor of hydrolysis products of baker's yeast wastewater.

Period	Influent Alkalinity ($mgCaCO_3/L$)	Effluent Alkalinity ($mgCaCO_3/L$)	Influent pH	Effluent pH
I	1504	2300	7,5	8,7
II	2925	3491	6,5	8,5
III	-	2660	4,5	8,4
IV	-	3003	4,5	8,2
V	-	3055	4,4	8,2
VI	-	3804	4,3	8,3

For the first two terms, influent alkalinity concentration averages are calculated as; 1504, 2958 $mgCaCO_3/L$. Effluent alkalinity concentration averages for six terms are given as; 2300, 3491, 2660, 3003, 3055, 3804 mgCaCO3/L. Average pH values of influent are measured as; 7.5, 6.5, 4.5, 4.4, 4.3. Average pH values of effluent are given as; 8.7, 8.5, 8.4, 8.2, 8.2, 8.3. It ıs observed that 2000 mg CaCO3/L, which is the minimum alkalinity concentration for anaerobic treatment, is provided.

4.1.3 Conductivity

Influent and effluent conductivity values of the EGSB reactor which is fed with hydrolysis product of baker's yeast wastewater were given in Figures 4.6 and 4.7 for all six terms.

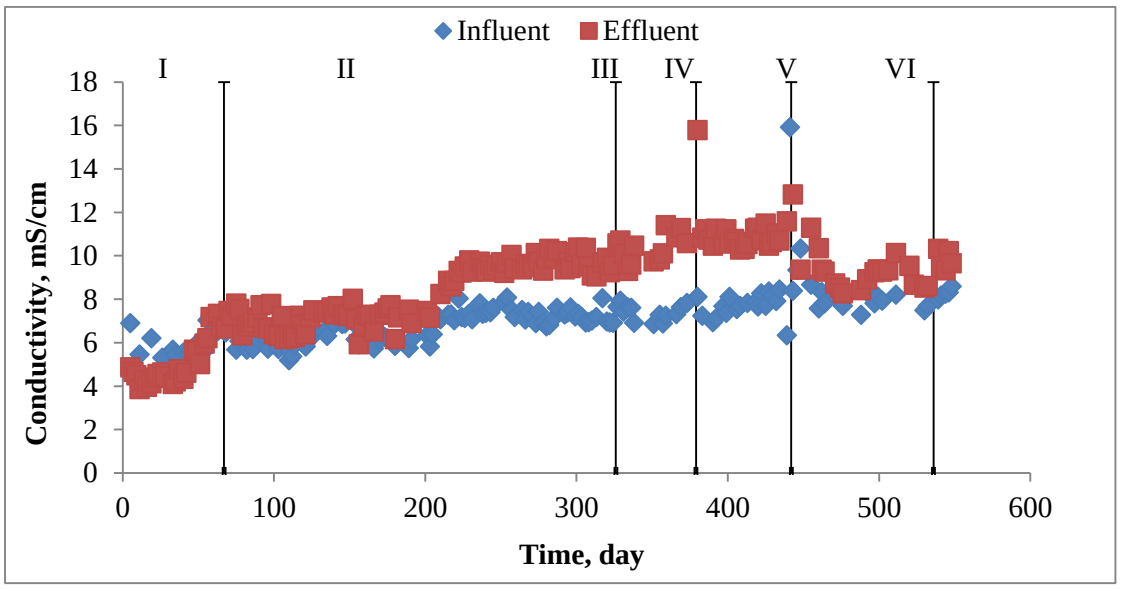

Figure 4.6 : Conductivity of influent and effluent of EGSB reactor of hydrolysis product of baker's yeast wastewater.

In table 4.4 average conductivity values for influent and effluent of EGSB reactor which is fed with hydrolysis products of baker's yeast wastewater are given.

Table 4.4 : Conductivity of influent and effluent.

Terms	Influent Conductiviy (mS/cm)	Effluent Conductivity (mS/cm)
I	5,9	5,1
II	6,7	8,2
III	7,4	10,4
IV	8,1	11,1
V	8,2	9,5
VI	8,3	9,8

Effluent conductivity values are higher than influent conductiviy values for all six terms which is seen in Table 4.4. The reason of this situation is, increase of soluble matter because of the biodegradation of organic matter. It is considered that conductivity values, of EGSB reactor of hydrolysis products of baker's yeast wastewater do not have a negative effect on anaerobic biodegradation.

Na and some other elemements' concentrations are given in Table 4.5.

Table 4.5 : Average values of concentration of some elements of influent and effluent from EGSB reactor of hydrolysis products of baker's yeast wastewater.

	Influent				
Terms	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Chloride (mg/L)
I	580	796	23	96	397
II	1200	1185	33	156	1189
III	1290	2410	71	284	1281
IV	2999	2282	71	95	3841
V	4246	3906	159	327	4502
V	3359	5370	129	569	4434
	Effluent				
I	533	719	23	69	363
II	1294	1355	38	50	1302
III	1345	2451	67	83	1717
IV	3111	2642	82	30	3689
V	9088	8813	367	35	14252
VI	8993	8726	366	36	14100

For achieving the purpose of feeding the reactors with constant COD concentration, raw wastewater is diluted with tap water. With higher loading rates, COD concentration is increased. With decreased dilution rates, it is observed that ion concentrations are at higher levels. Dilution rates are changed with terms because of different COD concentration of raw wastewater, because of this different concentration in COD, increase rates of ion concentrations are different also. Despite that, ion concentraions are increased inversely to dilution rates. It is observed that concentrations of magnesium and calcium are not displayed a big varition with different terms and with different organic loadings, despite that with decreased dilution rates, concentrations of sodium, potassium and chloride are increased. The higher sodium concentration is observed on last term. A study about sodium inhibition (İsmail et al. 2008) shows that, 15 g/L sodium concentration does not affect metanogenic activity. But with this high concentration of sodium, a reduction of strength is observed in granular part.

Sulphate concentrations of influent and effluent of EGSB reactor which was fed with hydrolysis products of baker's yeast wastewater are given for all six terms in Figure 4.7.

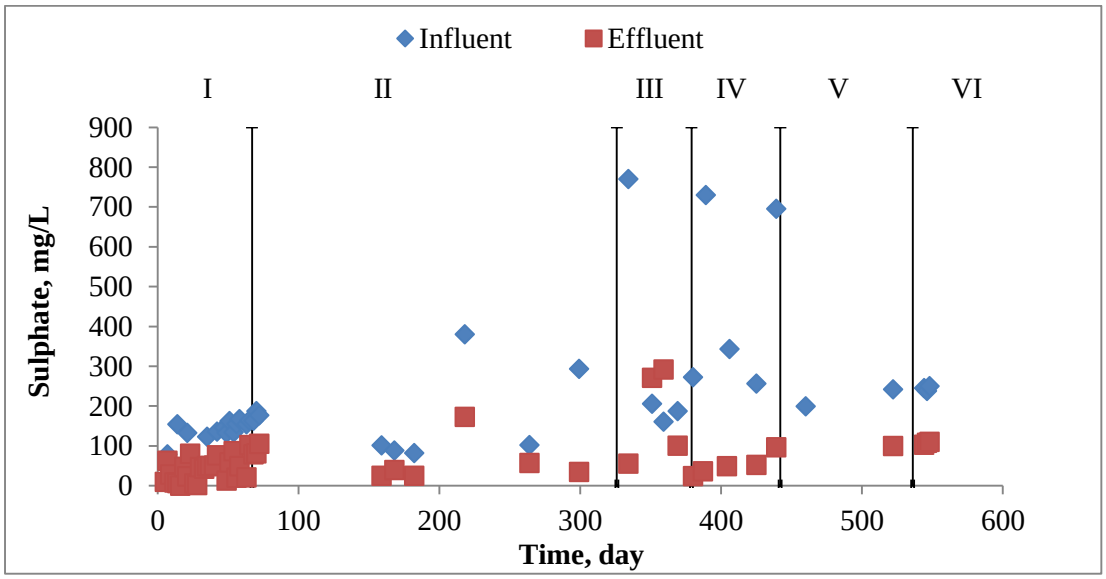

Figure 4.7 : Sulphate concentration of influent and effluent of EGSB reactor which is fed with hydrolysis products of baker's yeast wastewater.

Average concentration values of influent and effluent of EGSB reactor are given in Table 4.6

Table 4.6 : Average sulphate concentration of influent and effluent of EGSB reactor which was fed with hydrolysis products of baker's yeast wastewater

Term	Influent Sulphate Concentration (mg/L)	Effluent Sulphate Concentration (mg/L)	Efficiency (%)
I	142	41	72
II	175	69	61
III	319	180	44
IV	460	52	89
V	221	100	55
VI	224	107	56

It is observed for all six terms that sulphate concentration in effluent is much more less than sulphate concentration in influent. The reason of this situation is that sulphate reducing microorganims are being active. That is why sulphate concentrations are decreasing.

Total phosphorus concentration of influent and effluent of EGSB reactor which was fed with hydrolysis products of baker's yeast wastewater is shown in Figure 4.8.

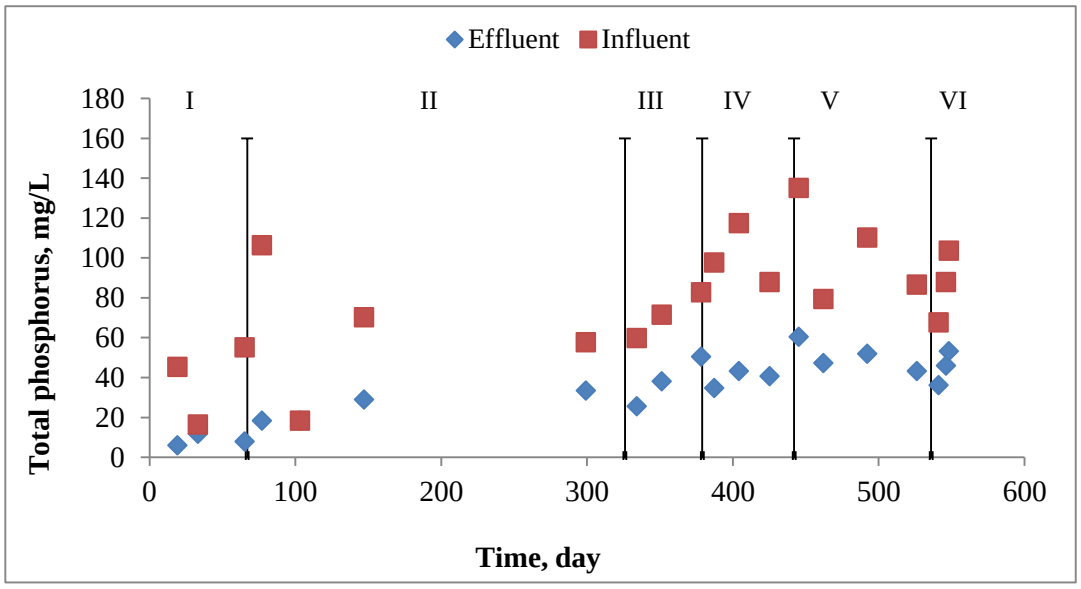

Figure 4.8 : Total phosphorus concentration of influent and effluent of EGSB which is fed with hydrolysis products of baker's yeast wastewater.

Average phosphorus concentrations of influent and effluent are given in Table 4.9.

Table 4.7 : Average phosphorus concentrations of influent and effluent of EGSB which was fed with hydrolysis products of baker's yeast wastewater.

Period	Influent Phosphorus (mg/L)	Effluent Phosphorus (mg/L)
I	39	9
II	63	25
III	71	38
IV	101	40
V	103	51
VI	86	45

4.1.4 Total Kjehdal Nitrogen (TKN) and Ammonium

Main nitrogen compunds in wastewater can be listed according to their oxidation levels, as Nitrate nitrogen (NO3-N), nitrite nitrogen (NO2-N), ammonia nitrogen (NH3-N) and organic nitrogen (org-N). Organic nitrogen and ammonia nitrogen can be measured together and are expressed as Total Kjehdal Nitrogen (TKN-N). TKN concentration values of influent and effluent from EGSB reactor which is fed with baker's yeast wastewater were given in Figure 4.9 below.

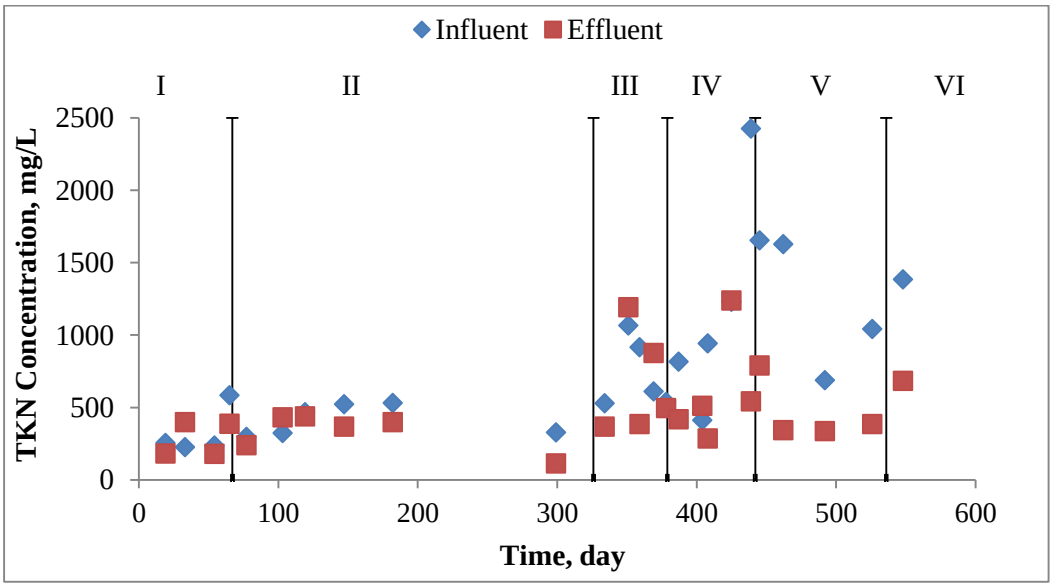

Figure 4.9 : TKN concentrations of influent and effluent of EGSB reactor of hydrolysis product of baker's yeast wastewater.

The average TKN concentrations of influent and effluent from the EGSB reactor which was fed with baker's yeast wastewater were given in Table 4.8 below

Table 4.8 : TKN concentration of influent and effluent.

Term	Influent TKN (mg/L)	Effluent TKN (mg/L)
I	273	314
II	436	399
III	762	623
IV	916	692
V	1138	613
VI	937	1032

Average influent TKN concentrations for all six terms are; 272, 435, 762, 916, 1138, 937 mg/L. Average effluent TKN concentrations for six terms are; 313, 399, 623, 692, 613, 1032.

It is determined that, concentraion of 50-200 mg/L ammonium in wastewater, is useful for the treatment and while it is also determined that concentration of 200-1000 mg/L ammonium does not have any negative effects for the anaerobic systems. However concentration range between 1500 and 5500 mg/L has an inhibitory effect at high pH values. And more than 5800 mg/L concentration values are determined to be toxic for certain microorganisms. (Bayram et al., 2008)

Ammonia nitrogen concentrations for influent and effluent from the EGSB reactor which was fed with baker's yeast wastewater for the first and second period were given in Figure 4.10.

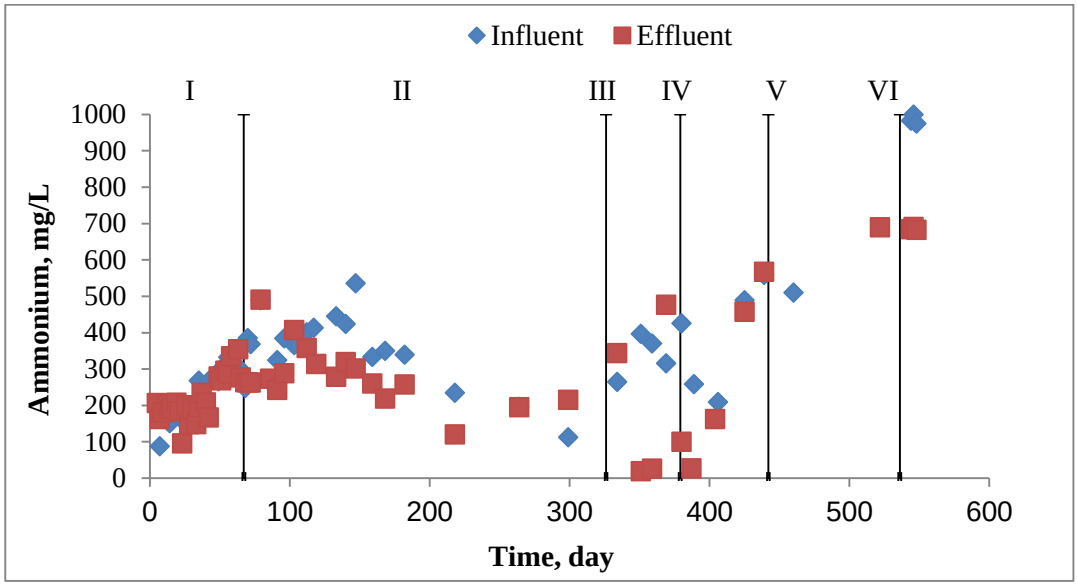

Figure 4.10 : Ammonia concentrations of influent and effluent of EGSB reactor of hydrolysis product of baker's yeast wastewater.

Average ammonia nitrogen concentration values for influent and effluent for six terms are given in Table 4.9.

Table 4.9 : Average ammonia nitrogen concentrations of influent and effluent of EGSB reactor of hydrolysis products of baker's yeast wastewater.

Term	Influent Ammonia Nitrogen (mgN/L)	Effluent Ammonia Nitrogen (mgN/L)
I	263	217
II	349	281
III	337	217
IV	389	263
V	756	690
VI	986	686

Ratio of ammonium and TKN of influent and effluent of EGSB reactor which was fed with hydrolysis products of baker's yeast wastewater is given in Figure 4.11

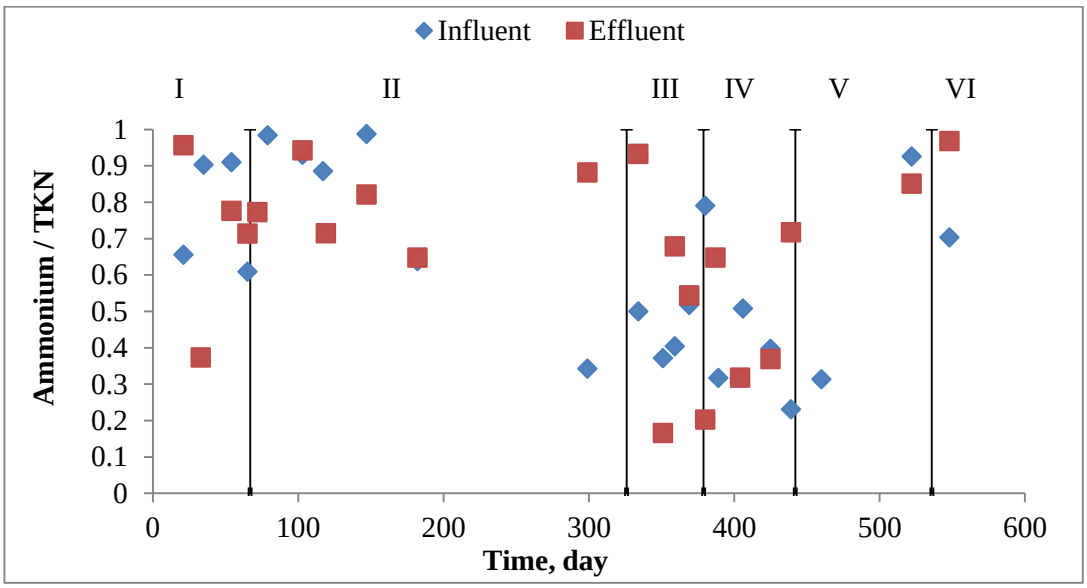

Figure 4.11 : Ratio of ammonium and TKN of influent and effluent of EGSB which is fed with hydrolysis products of baker's yeast wastewater.

Average ratios of ammonium and TKN concentrations of influent and effluent are given in Table 4.10.

Table 4.10 : Ratio of ammonium and TKN of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Terms	Influent Ammonium/TKN	Effluent Ammonium/TKN
I	0,77	0,70
II	0,79	0,80
III	0,45	0,58
IV	0,45	0,45
V	0,62	0,85
VI	0,70	0,96

4.1.5 Volatile fatty acids (VFA)

Volatile fatty acids concentrations for influent and effluent from the EGSB reactor which was fed with baker's yeast wastewater for six terms were given in Figure 4.12.

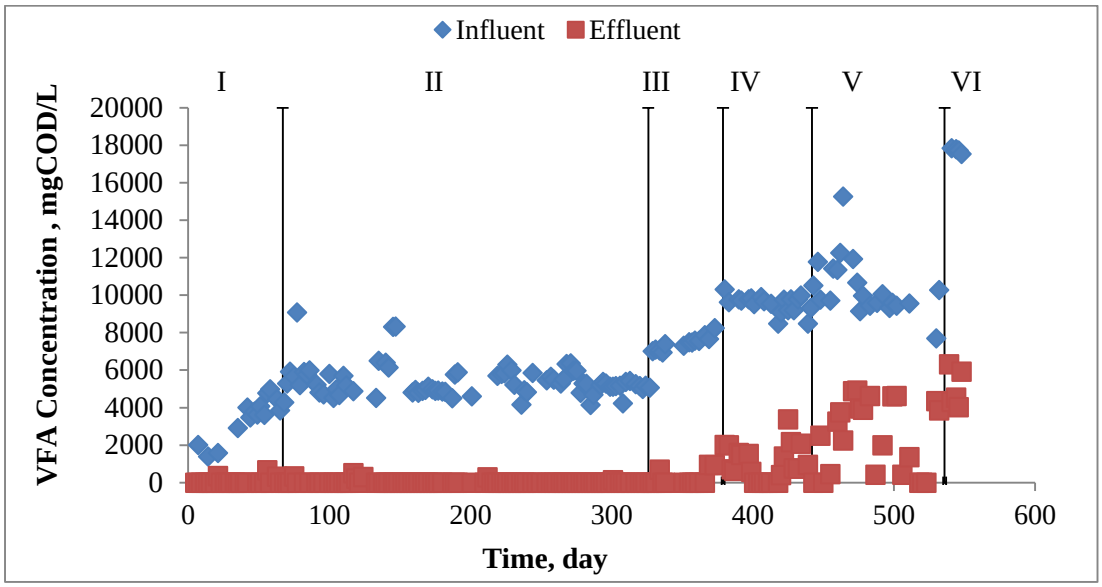

Figure 4.12 : VFA concentrations of influent and effluent of EGSB reactor which was fed with hydrolysis products of baker's yeast wastewater.

Average VFA concentrations of influent and effluent from the EGSB reactor which was fed with baker's yeast wastewater was given in Table 4.11.

Table 4.11 : Average VFA concentration of influent and effluent of EGSB reactor of hydrolysis products of baker's yeast wastewater.

Term	Influent VFA (mgCOD/L)	Effluent VFA (mgCOD/L)
I	3470	56
II	5404	84
III	7267	398
IV	9536	974
V	10420	2440
VI	17723	5023

It is observed that influent VFA concentrations are increased proportionaly to volumetric loading rates. Average effluent VFA concentrations of EGSB reactor which was fed hydrolysis products of baker's yeast wastewater are measured as; 56, 84, 398, 974, 3701, 5023 mgCOD/L.

Low VFA concentrations on first, second and thirt terms showed that the synthrophy of metanogenes and asetogenes is efficient for the system. On the last three terms, because of the increase in VFA concentration of effluent, COD removal efficiencies are dropped also, since 300 mg/L VFA have a inhibitory effect on metanogenes.

It is shown in Figure 4.13 and Figure that some volatile fatty acids and their concentrations that are existed in influent and effluent of EGSB reactor which is fed with hydrolysis products of baker's yeast wastewater.

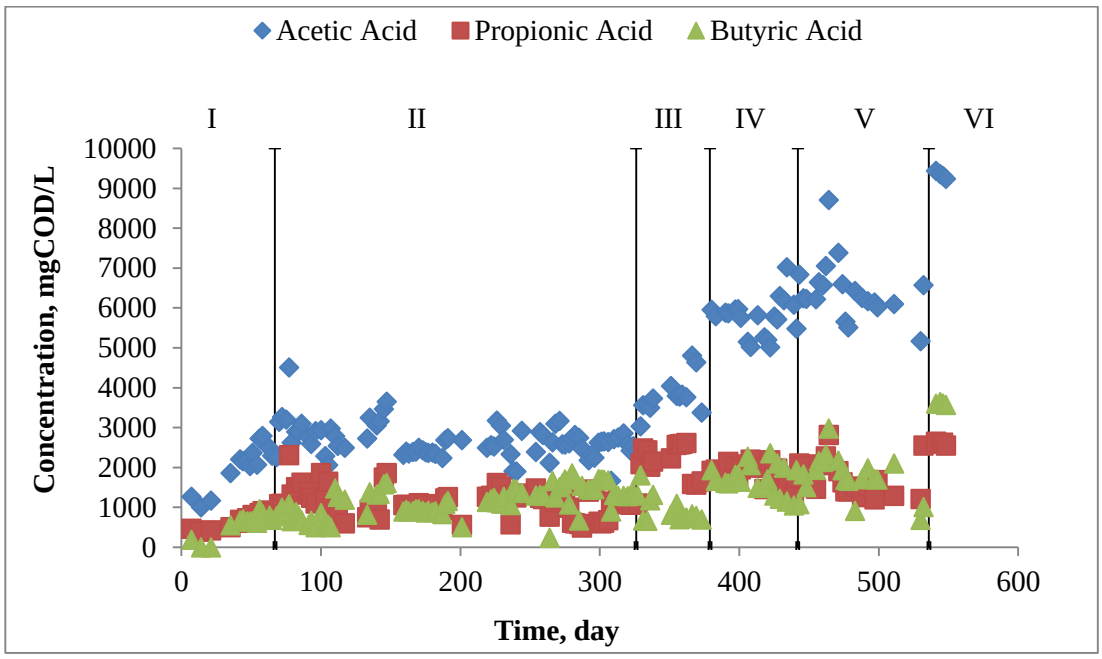

Figure 4.13 : Acetic, propionic and butyric acid concentrations in influent of EGSB reactor which is feed hydrolysis products of baker's yeast wastewater.

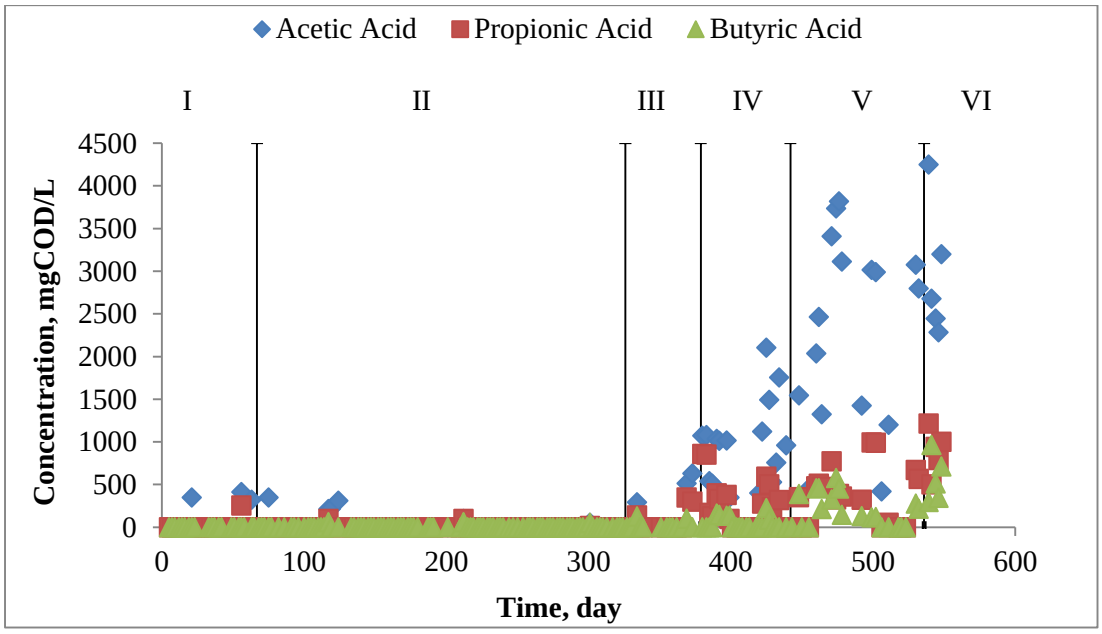

Figure 4.14 : Acetic, propionic and butyric acid concentrations in effluent of EGSB reactor which is feed hydrolysis products of baker's yeast wastewater.

Average concentrations of acetic, propionic and butyric acid concentrations influent and effluent from the EGSB reactor which was fed with baker's yeast wastewater was given in Table 4.12.

Table 4.12 : Average VFA concentration of influent and effluent of EGSB reactor of hydrolysis products of baker's yeast wastewater.

Influent			
Terms	Acetic Acid (mgCOD/L)	Propionic Acid (mgCOD/L)	Butyric Acid (mgCOD/L)
I	2045	688	568
II	2669	1131	1134
III	3706	2120	953
IV	5762	1849	1712
V	6426	1773	1711
VI	9338	2607	3606
Effluent			
I	45	11	0
II	13	2	2
III	103	56	16
IV	655	213	37
V	1753	345	184
VI	2971	888	566

4.1.6 Biogas production

Biogas production data are given below for the all six term of EGSB reactor which was fed with hydrolysis product of baker's yeast wastewater were given in Figure 4.15.

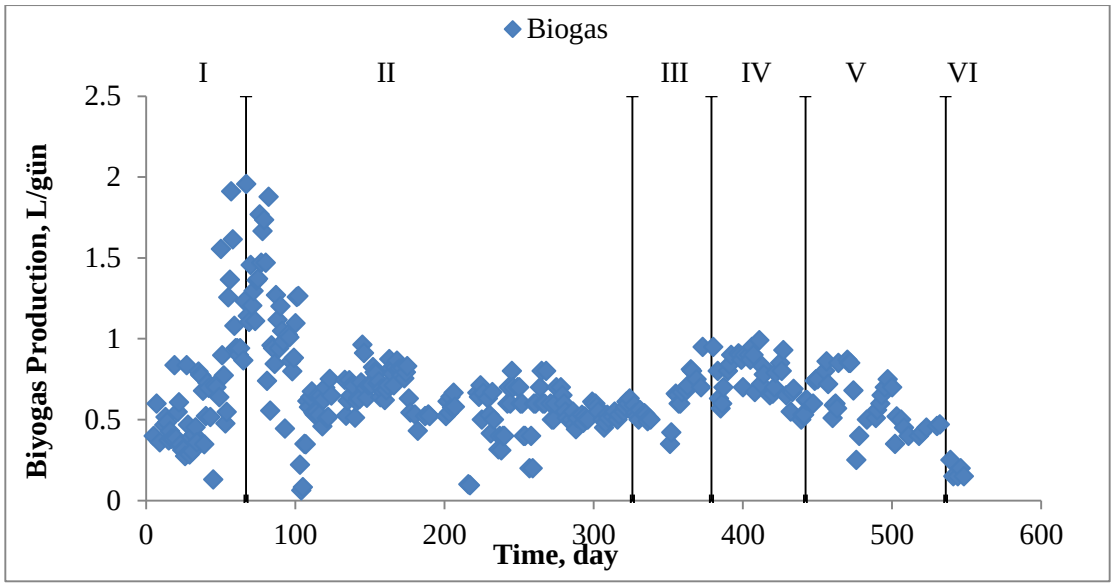

Figure 4.15 : Biogas production of EGSB reactor of hydrolysis product of baker's yeast wastewater.

Theoritical and observed methane concentrations for six terms of EGSB reactor which was fed with hydrolysis products of baker's yeast wastewater is given Figure 4.16

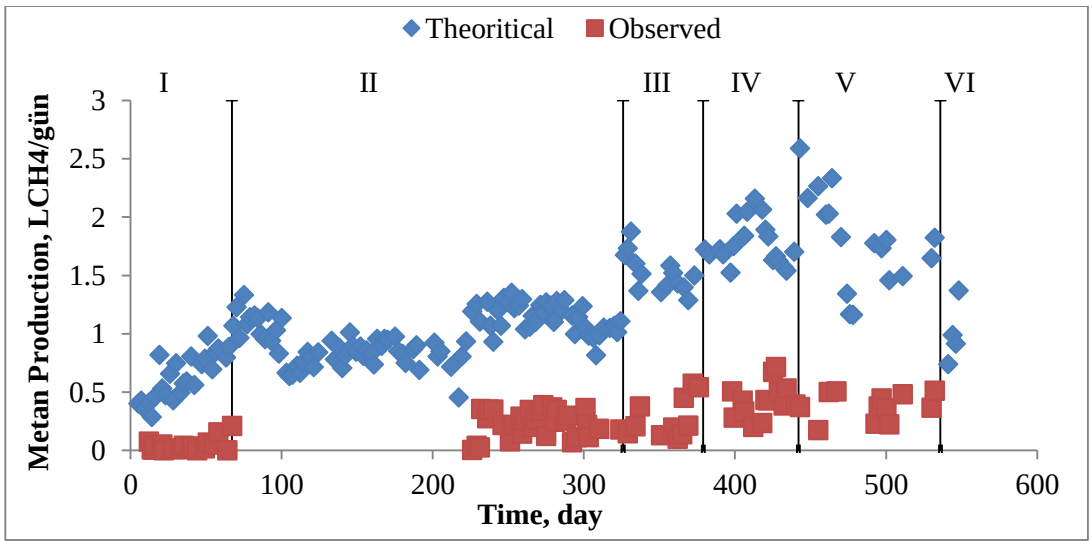

Figure 4.16 : Theoritical and observed methane concentrations of EGSB reactor of hydrolysis product of baker's yeast wastewater.

Average methane concentration data were given in Table 4.13 for the EGSB reactor for six terms.

Table 4.13 : Average methane concentrations of EGSB reactor which was fed with hydrolysis products of baker's yeast wastewater.

Term	Theoritical CH_4 Concentration (LCH_4/day)	Observed CH_4 Concentration (LCH_4/gCOD)	CH_4 concentration with Removed Organic Loading ($LCH_4/gCOD_{rem.}$)
I	0,64	0,18	0,196
II	0,99	0,23	0,171
III	1,51	0,28	0,183
IV	1,77	0,43	0,213
V	1,60	0,38	0,165
VI	-	-	-

With increasing volumetric loading rates, there is no augmentation in methane production for the first three terms, oppositely for last two terms, there is an increase in methane production in EGSB reactor which was fed with baker's yeast wastewater. Ratio of observed and theoritical methane concentrations are calculated as; 43%, 22%, 19%, 24%, 24%

A study made with sunflower oil prosses factory wastewater with a high sulphate concentration (Saatçi ve Demirci, 2007) UASB type reactor is used, and operated for 83 days under mesophilic conditions with neutral pH and HRT of 2 days. A 90% of COD is removal is observed when the sulphate concentration is under 300 mg/L and sulphate removal efficiency is calculated about 30 – 40 %. With increasing sulphate concentration, COD removal efficiency and methane production rate are decreased. COD removal in influent is measured around 5610 – 11460 mg /L. And methane production is calculated as 0,367 LCH_4/day.

A study (Wijekoon et al.,2011) focused on the VFA (volatile fatty acid) profile variation with organic loading rate (OLR) of a two stage thermophilic anaerobic membrane bioreactor (TAnMBR). The two stage TAnMBR treating high strength molasses-based synthetic wastewater was operated under a side-stream partial sedimentation mode at 55 ^{o}C. Reactor performances were studied at different OLR ranging from 5 to 12 kg COD. Metanogenesis reactor has a volume of 6 L. HRT is chosen as 32 days and reactor is operated with under normal pH. COD concentration in the in the effluent is measured as 7500 – 18600 mgCOD/L, and COD removal

efficiency is calculated around 78-81%. Optimum methane production is observed in 8 gCOD/L.day organic loading, as 0,217 LCH_4/day.

Two-phase anaerobic digestion of cheese whey was investigated in a system consisting of a stirred acidogenic reactor followed by a stirred methanogenic reactor The methanogenic reactor received an organic load up to 19.78 g COD/l d, corresponding to a HRT of 4 days, at which 79% CODs removal efficiency was obtained. Reactor was operated under mesophilic conditions and pH is kept around 6.5. COD concentration in the influent is measured as, 68000 mg/L and methane production is calculated as 0,30 LCH_4/day.

In Table 4.14 methane production yields are given for other and this study with high sulfate wastewater.

Table 4.14 : Methane production values of some other studies with high sulphate content wastewater.

Waste Type	Reactor Type	HRT (day)	Temperature (^oC)	Methane Production (LCH_4/day)	Organic Loading (gCOD/day)	References
Sunflower Oil Process Wastewater with high Sulfate Content	UASB	2	37	0,367	5,3	Saatçi ve Demirci, 2007
Cheese Whey	AnMBR	4	37	0,30	11,5	Saddoud et al., 2006
Molasses	AnMBR	32	55	0,217	8	Wijekoon et al.,2010
Baker's yeast process wastewater	EGSB	2	37	0,165	9,23	This Study

4.2 Biomethane Production from Hydrolysis Products of Food Waste

4.2.1 Chemical oxygen demand (COD)

To observe efficencincy of EGSB reactor, COD experiments are made regularly with influent and effluent. COD resutls of, EGSB reactor which is fed with hydrolysis products of food waste, with 6 different volumetric loading and organic loading rates are given in Table 4.15 with terms and periods.

Table 4.15 : Operating conditions and periods of EGSB of hyrolysis products of food waste.

Term	Period	Volumetric Loading Rate (gCOD/Lday)
I	1 – 66	1,95
II	67 – 263	3,95
III	264 – 324	6,74
IV	325 – 408	7,55
V	409 – 534	9,54
VI	535 - 546	12,07

Total COD concentrations of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste are given in Figure 4.17.

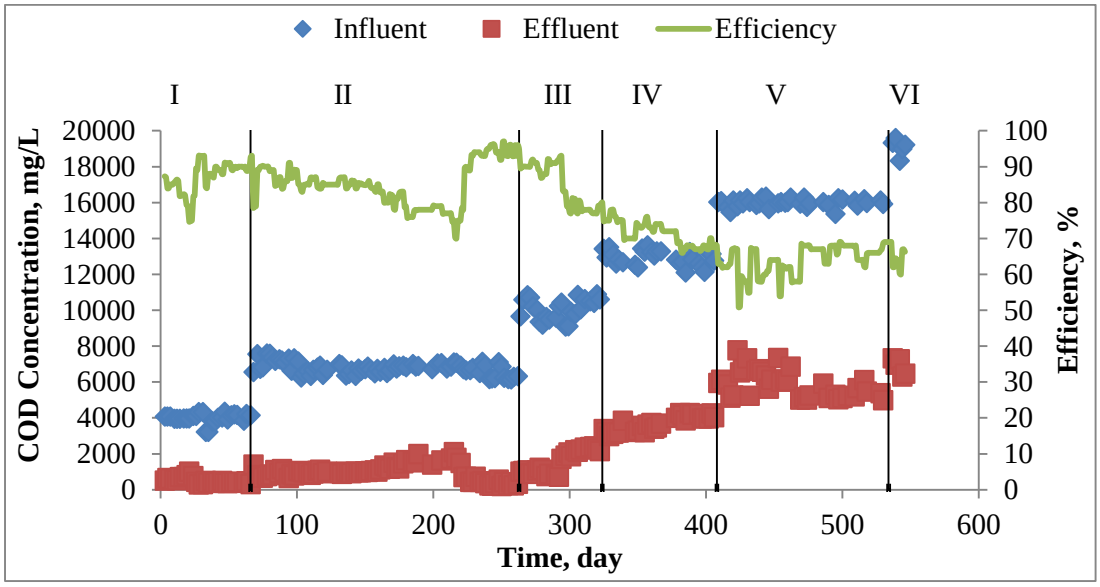

Figure 4.17 : Total COD concentrations of influent and effluent of EGSB reactor of hydrolysis products of food waste.

Soluble COD concentrations of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste are shown in Figure 4.17.

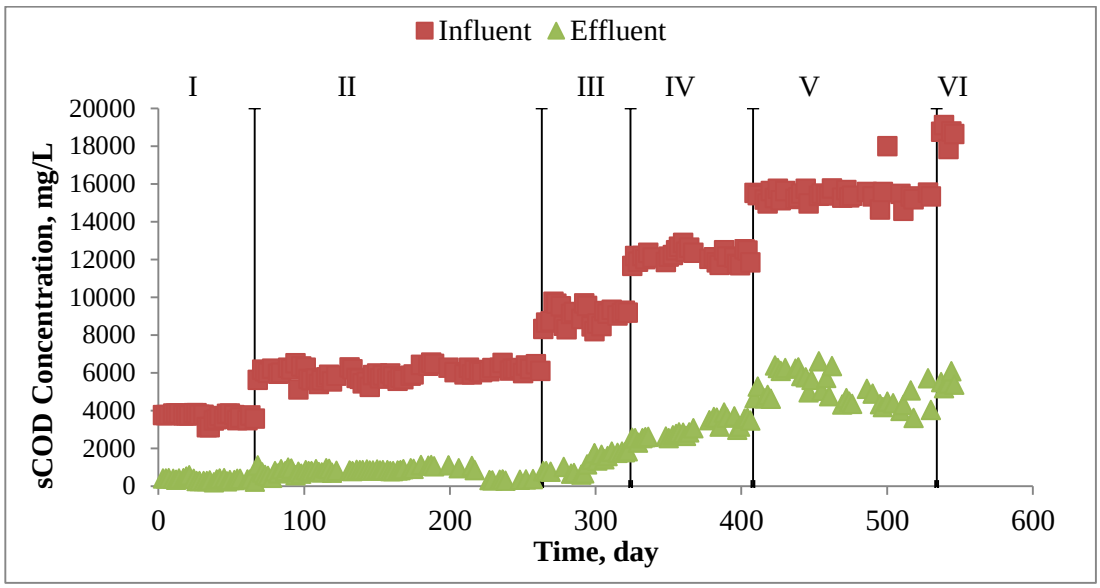

Figure 4.18 : sCOD concentrations of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Average COD concentrations of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste are given in Table 4.16.

Table 4.16 : Average COD concentration values of EGSB reactor which was fed with hydrolysis products of food waste.

Term	Influent COD (mgCOD/L)	Effluent COD (mgCOD/L)	tCOD Removal Efficiency (%)	Influent sCOD (mgCOD/L)	Effluent sCOD (mgCOD/L)
I	4302	513	87	3673	355
II	6708	1039	85	6084	754
III	10076	1553	77	8999	1266
IV	12920	3691	71	12169	3031
V	15992	5875	64	15434	5114
VI	19093	6870	65	18629	5520

Influent, effluent, influent sCOD, effluent sCOD concentrations averages of the EGSB reactor which was fed with hydrolysis product of baker's yeast wastewater for the first term are; 4302, 513, 3673, 355 mgCOD/L. For the second term these concentrations are; 6708, 1039, 6084, 754 mgCOD/L.

At the third term, COD concentrations for influent and effluent are 10076, 1553 and sCOD concentraions of influent and effluent are calculated as 8999 and 1266 mgCOD/L. Average COD and sCOD concentrations of influent and effluent at the forth term are, 12920, 3691, 12169, 3031. For the fifth term, 15992, 5875, 15434, 5114. Average COD and sCOD concentrations for the sixth and last term are calculated as; 19093, 6870, 18629, 5520. Total COD removal efficiency for all six terms are calculated as 87%, 85%, 77%, 71%, 64%, and 65%. COD concentraions are increasing with high organic loading rates none the less as it is seen from the graphs and tables COD removal efficiency are decreasing with high organic loadings.

Volumetric organic loading rates with sCOD removal efficiency for six different terms is given in Figure 4.19.

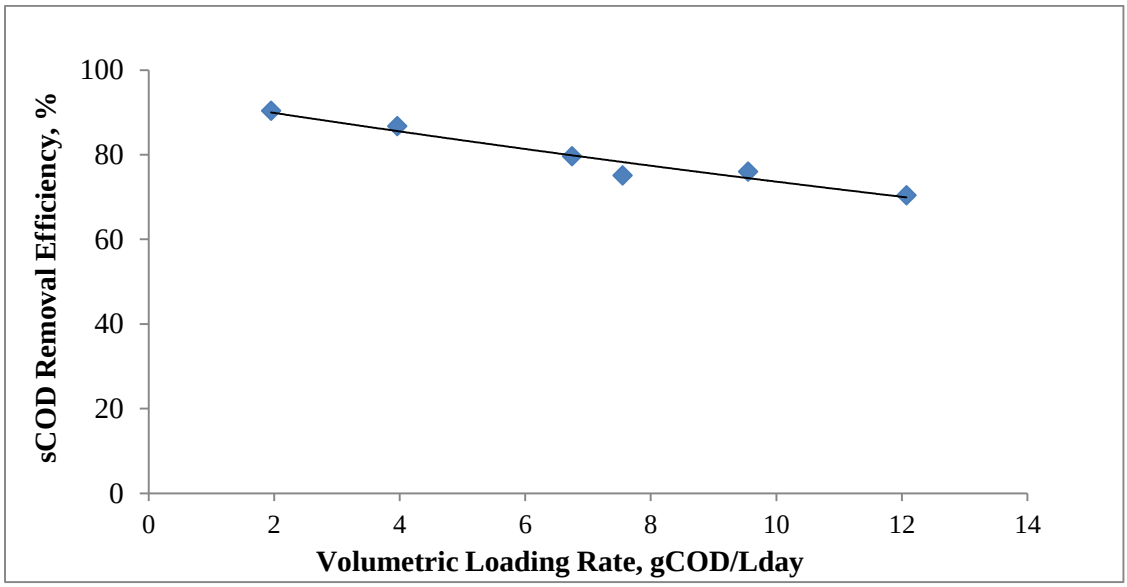

Figure 4.19 : VLR and sCOD removal efficiency of EGSB reactor which was fed with hydrolysis products of food waste.

4.2.2 Alkalinity and pH

Influent and effluent alkalinity concentration and pH values for EGSB reactor which is fed with hydrolysis product food waste are given in Figures 4.20 and 4.21.

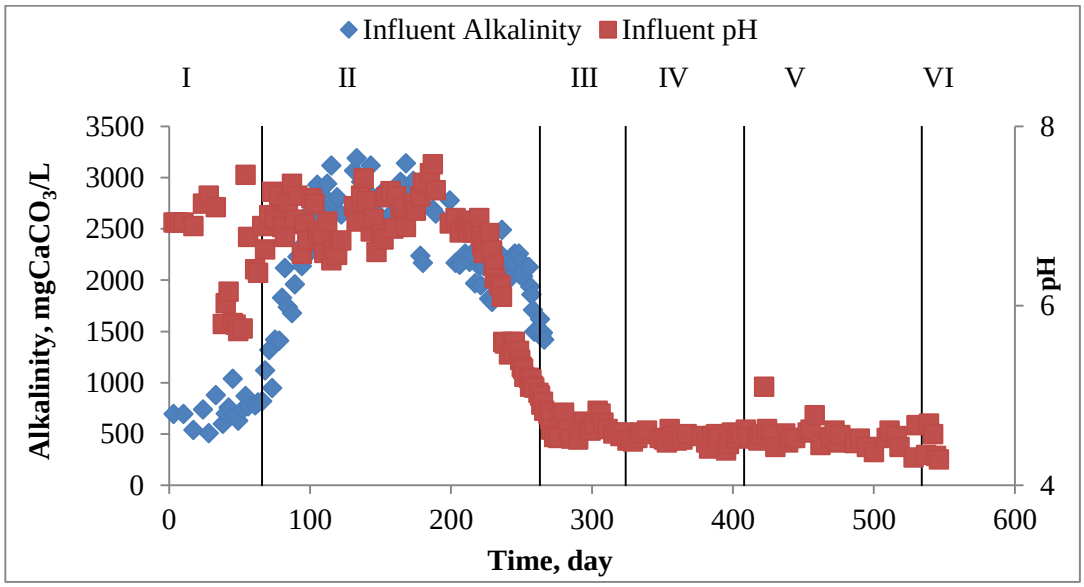

Figure 4.20 : pH and Alkalinity concentration of influent of EGSB reactor which was fed with hydrolysis products of food waste.

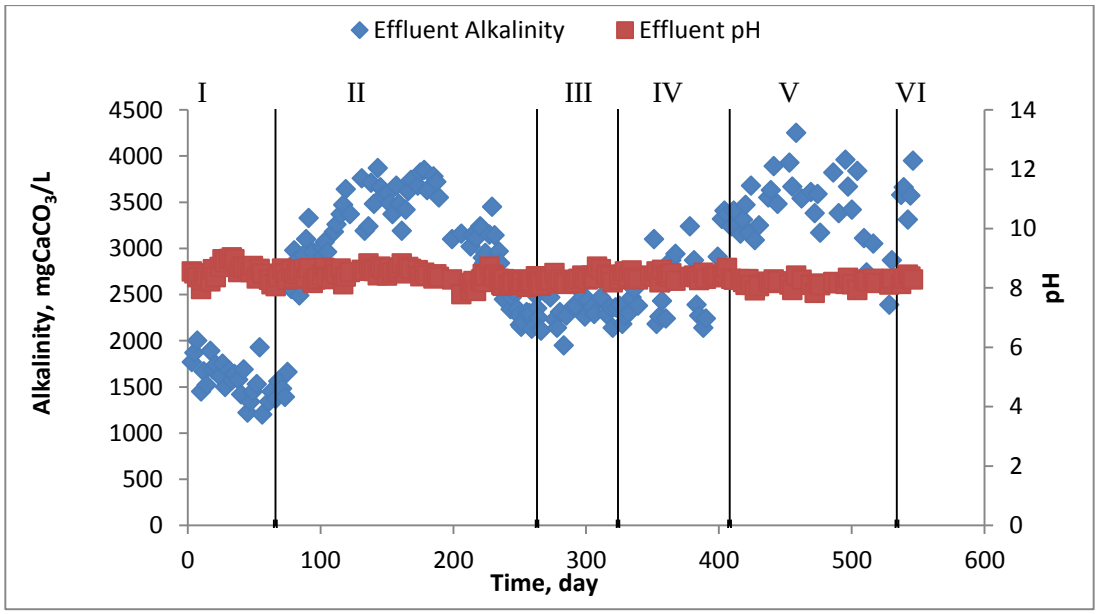

Figure 4.21 : pH and alkalinity concentration of effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Influent and effluent alkalinity and pH average values for the six terms of EGSB reactor with was fed with hydrolysis product food waste were given in Table 4.17 below.

Table 4.17 : Alkalinity and pH values of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste.

Term	Influent Alkalinity ($mgCaCO_3/L$)	Effluent Alkalinity ($mgCaCO_3/L$)	Influent pH	Effluent pH
I	756	1588	6,6	8,5
II	2994	3098	6,4	8,3
III	-	2346	4,7	8,3
IV	-	2624	4,5	8,4
V	-	3405	4,5	8,2
VI		3614	4,4	8,3

For the first two terms, influent alkalinity concentration averages are calculated as; 756, 2994 $mgCaCO_3/L$. Effluent alkalinity concentration averages for six terms are given as; 1588, 3098, 2346, 2624, 3405, 3614 mgCaCO3/L. Average pH values of influent are measured as; 6.6, 6.4, 4.7, 4.5, 4.5 and 4.4. Average pH values of effluent are measured as; 8.5, 8.3, 8.3, 8.4, 8.2, 8.3,

Alkalinity concentration in influent is less then the alkalinity concentration in effluent, as it can be seen in the Table 4.16

4.2.3 Conductivity

Influent and effluent conductivity values of the EGSB reactor which is fed with hydrolysis product of food waste are given in Figures 4.22 and Table 4.17 for six terms of different organic loads.

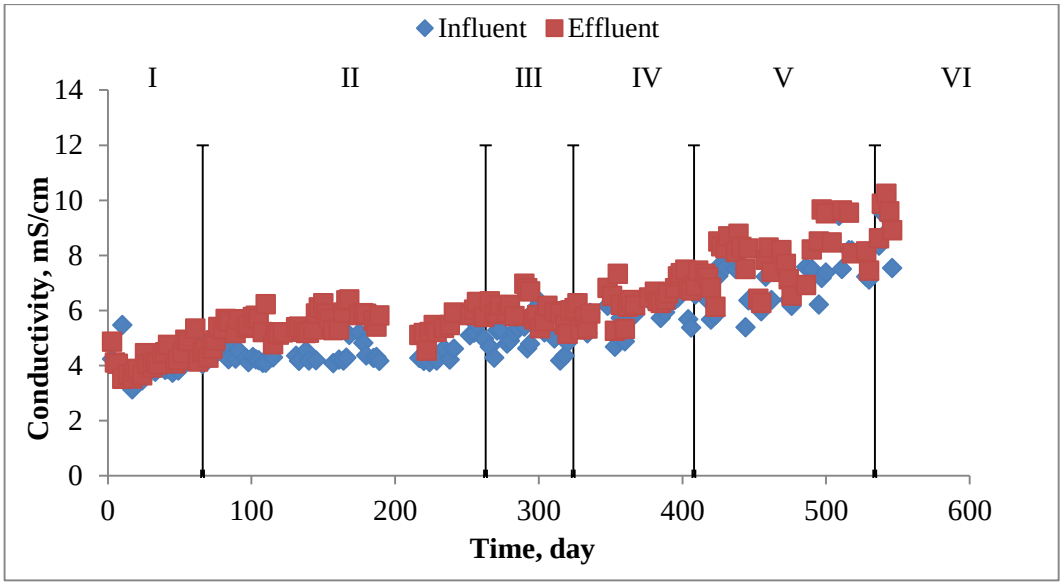

Figure 4.22 : Conductivity of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste.

Table 4.18 : Conductivity of influent and effluent of EGSB reactor of hydrolysis products of food waste.

Term	Influent Conductiviy (mS/cm)	Effluent Conductivity (mS/cm)
I	4,5	4,3
II	4,5	5,7
III	5,1	6,0
IV	6,0	6,4
V	7,1	7,9
VI	8,8	9,5

It is observed that conductivity in effluent is higher than in influent for all six terms. The reason is, increase of soluble matter concentration because of the biodegradation of organic matter. It is considered that these values of conductivity have no negative impact on anaerobic degradation. Na and some other elemements' concentrations are given in Table 4.18.

For achieving the purpose of feeding reactors with constant COD concentration, raw wastewater is diluted with tap water. With higher loading rates, COD concentration is increased. With decreased dilution rates, it is observed that ion concentrations are at higher levels. Dilution rates are changed with terms because of different COD concentration of raw wastewater, because of this different concentration in COD, increase rates of ion concentrations are different also. Despite that, ion concentraions are increased inversely to dilution rates. It is observed that concentrations of magnesium and calcium are not displayed a big varition with different terms and with different organic loadings, despite that with decreased dilution rates, concentrations of sodium, potassium and chloride are increased. The higher sodium concentration is observed on last term. A study about sodium inhibition (İsmail et al. 2008) shows that, 15 g/L sodium concentration does not affect metanogenic activity. But with this high concentration of sodium, a reduction of strength is observed in granular part.

Table 4.19 : Average values of some elements of influent and effluent from EGSB reactor.

Influent					
Terms	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Chloride (mg/L)
I	899	45	11	52	648
II	1031	59	11	55	371
III	1354	82	14	61	895
IV	2485	148	18	67	1466
V	2560	180	21	74	1998
VI	2658	146	23	33	1496
Effluent					
I	904	59	12	56	599
II	1204	69	11	35	537
III	1469	78	15	50	825
IV	3024	163	23	41	1675
V	3437	237	27	74	1935
VI	5804	338	44	37	2084

Sulphate concentrations of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste are shown in Figure 4.23.

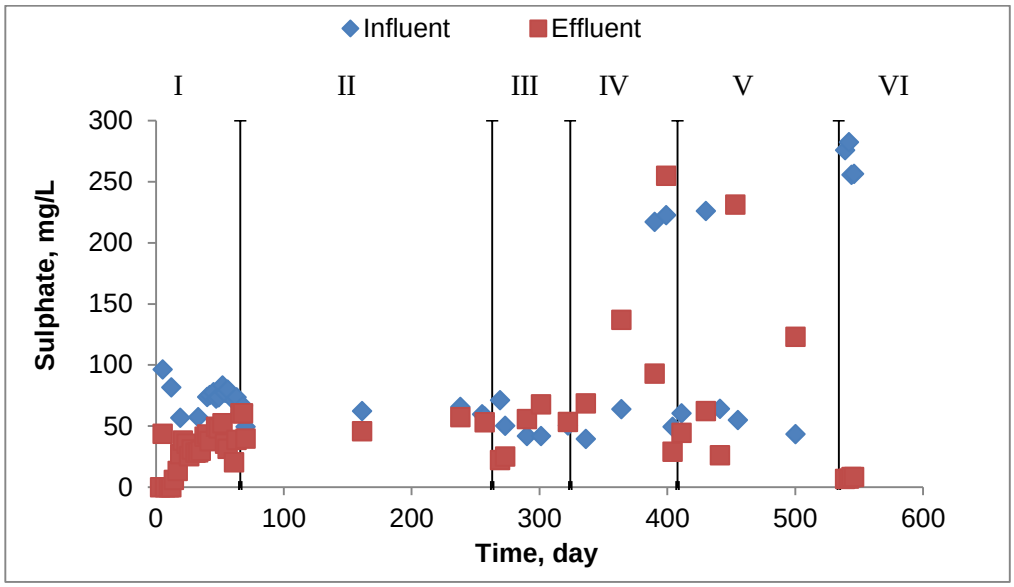

Figure 4.23 : Sulphate concentrations of influent and effluent of EGSB reactor of hydrolysis products of food waste.

Average sulphate concentration values of influent and effluent from EGSB reactor which was fed with hydrolysis products of food waste are given in Table 4.120.

Table 4.20 : Sulphate concentration of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste.

Term	Influent Sulphate (mgN/L)	Effluent Sulphate (mgN/L)	Removal Efficiency (%)
I	74	35	53
II	60	51	15
III	51	45	12
IV	119	117	2
V	90	98	-
VI	268	8	97

It is observed that sulphate concentration in influent and effluent are not distinctive except the last term. The reason of this situation is that, threshold level of sulphate reducing bactearia is high and that is why they are not active. But for the last term with high sulphate concentration in influent, sulphate reducing bacteria are become active and lower the sulphate concentration in effluent.

Total phosphorus concentration of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste are shown in Figure 4.24

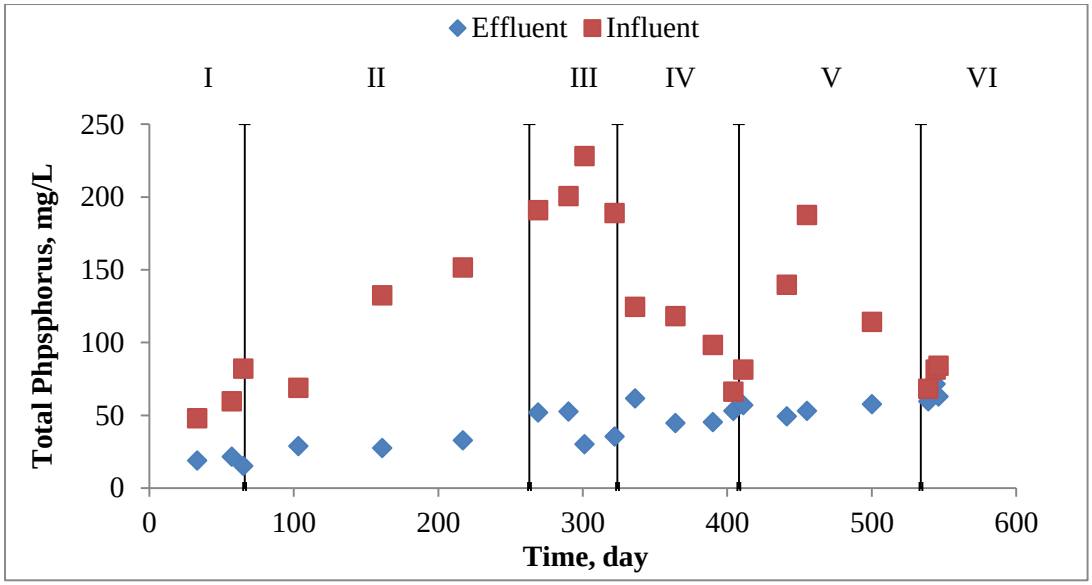

Figure 4.24 : Total phosphorus concentrations of influent and effluent of EGSB reactor of hydrolysis products of food waste.

Average concentrations of total phosphorus of influent and effluent of EGSB reactor are given in Table 4.21.

Table 4.21 : Total phosphorus concentration of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste.

Term	Influent Phosphor (mg/L)	Effluent Phosphor (mg/L)
I	63	19
II	118	30
III	202	42
IV	102	51
V	131	54
VI	78	65

4.2.4 Total Kjehdal Nitrogen (TKN) and Ammonium

TKN concentration values of influent and effluent from EGSB reactor which is fed with hydrolysis products of food waste are given in Figure 4.25 below.

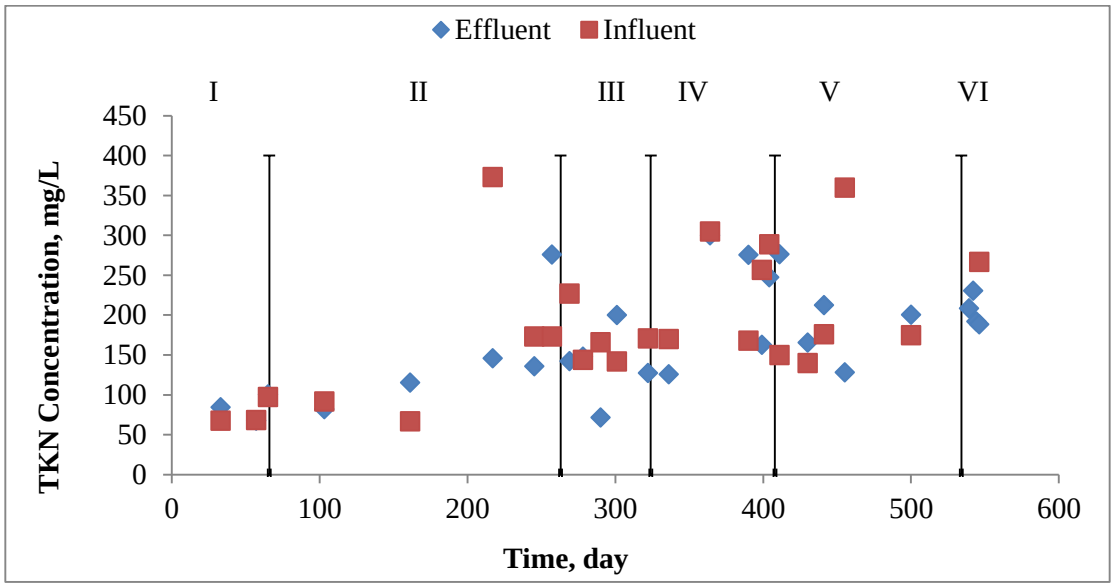

Figure 4.25 : TKN concentrations of influent and effluent of EGSB reactor of hydrolysis products of food waste.

The average TKN concentrations of influent and effluent from the EGSB reactor which is fed with hydrolysis products of food waste are given in Table 4.22 below.

Table 4.22 : TKN concentration of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Term	Influent TKN (mgN/L)	Effluent TKN (mgN/L)
I	78	84
II	176	151
III	170	138
IV	238	222
V	200	197
VI	267	205

Average TKN values for influent for the five periods are respectively, 78, 176, 170, 238, 200, 267 mgN/L. Effluent TKN values are 84, 151, 138, 222, 197, 205 mgN/L. As it is seen in the Table 4.13 effluent TKN values are increased with organic load proportionally.

It is determined that, concentraion of 50-200 mg/L ammonium in wastewater, is useful for the treatment and while it is also determined that concentration of 200-1000 mg/L ammonium does not have any negative effects for the anaerobic systems. However concentration range between 1500 and 5500 mg/L has an inhibitory effect at high pH values. And more than 5800 mg/L concentration values are determined to be toxic for certain microorganisms. (Bayram et al., 2008)

Ammonium concentrations of influent and effluent from the EGSB reactor which is fed with hydrolysis products of food waste for six terms are given in Figure 4.26.

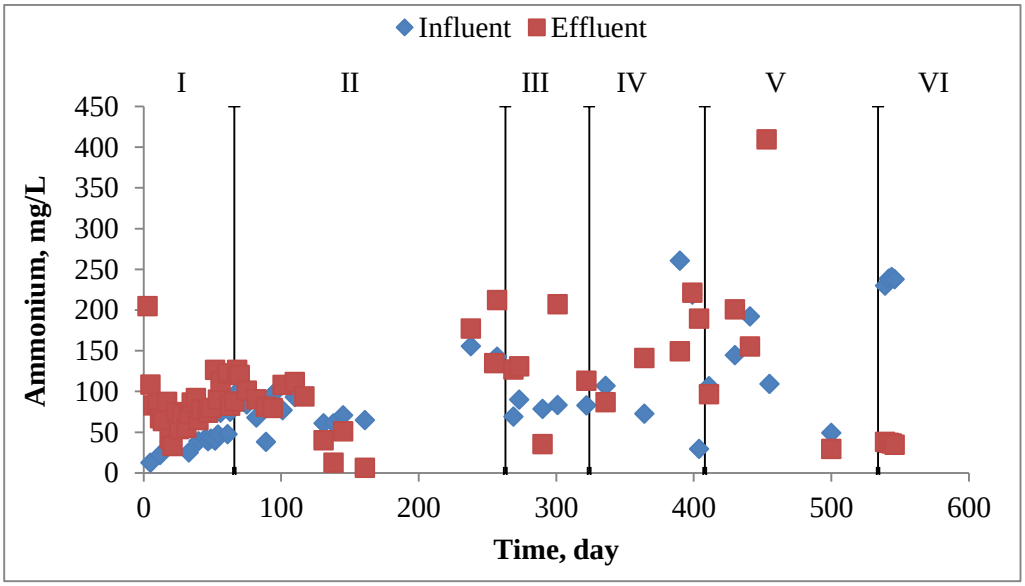

Figure 4.26 : Ammonium concentrations of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste.

Average ammonium concentration values for influent and effluent for six terms were given in Table 4.23.

Table 4.23 : Ammonia nitrogen of influent and effluent of EGSB reactor of hydrolysis products of food waste.

Term	Influent Ammonia Nitrogen (mgN/L)	Effluent Ammonia Nitrogen (mgN/L)
I	47	84
II	90	96
III	80	122
IV	137	157
V	120	178
VI	236	36

As it can be seen in the Table 4.23 influent ammonia concentration is increasing with organic load. Effluent ammonia concentration values are also increasing without any inhibitory effects to microorganisms.

Ratio of ammonium and TKN of influent and effluent of EGSB reactor which was fed with hydrolysis products of food waste is shown in Figure 4.27.

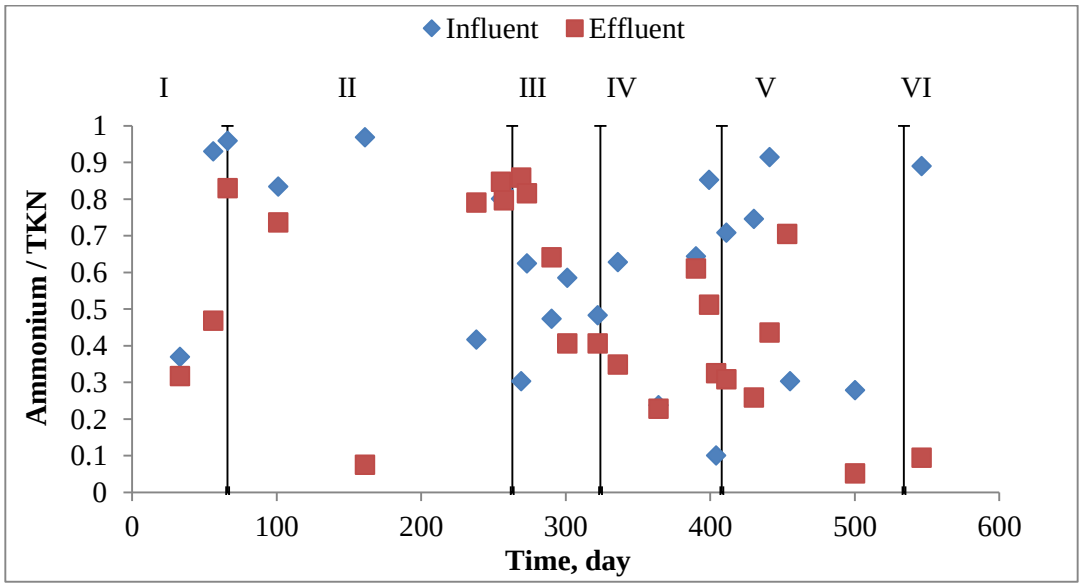

Figure 4.27 : Ratio of ammonium and TKN of influent and effluent of EGSB reactor of hydrolysis products of food waste.

Average ratio of ammonium and TKN are given in Table for influent and effluent of all six terms are given in Table 4.24.

Table 4.24 : Ammonium and TKN ratios of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Term	Influent Ammonia Nitrogen (mgN/L)	Effluent Ammonia Nitrogen (mgN/L)
I	0,75	0,54
II	0,77	0,65
III	0,49	0,63
IV	0,49	0,41
V	0,59	0,35
VI	0,89	0,1

4.2.5 Volatile fatty acids (VFA)

Volatile fatty acids concentrations for influent and effluent from the EGSB reactor which is fed with hydrolysis products of food waste for six terms are given in Figure 4.28.

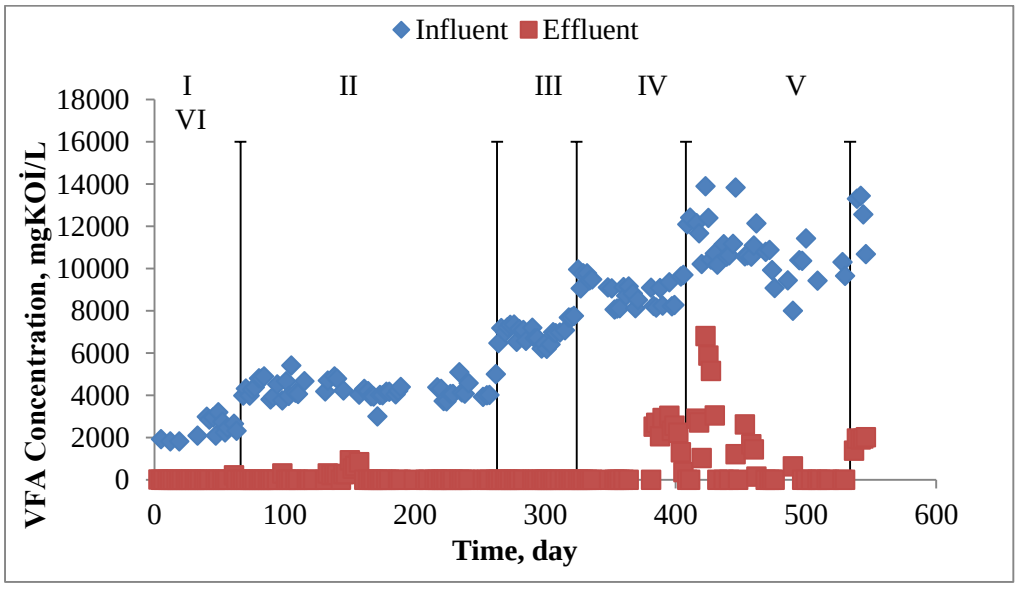

Figure 4.28 : VFA concentration of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Average VFA concentrations of influent and effluent from the EGSB reactor which is fed with food waste was given in Table 4.25.

Table 4.25 : VFA concentration of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Period	Influent VFA (mgCOD/L)	Effluent VFA (mgCOD/L)
I	2524	51
II	4253	78
III	7985	0
IV	8904	957
V	10883	1104
VI	12499	1846

It is observed that influent VFA concentrations are increased proportionaly to volumetric loading rates. Average effluent VFA concentrations of EGSB reactor which was fed hydrolysis products of baker's yeast wastewater are measured as; 51, 78, 0, 957, 1104, 1846 mgCOD/L. Low VFA concentrations on first, second and thirt terms showed the synthrophy of metanogenes and asetogenes is efficient for the system. On the last three terms, because of the increase in VFA concentration of effluent, COD removal efficiencies are dropped also, since 300 mg/L VFA have a inhibitory effect on metanogenes (Speece, 1995). On the fifth term, VFA concentration is high at the beginning but then it is decreased in effluent. With a short period of time in the sixth term, it is not fair to make a comment about high VFA concentrations in effluent.

In Figure 4.29. and Figure 4.30., acetic, propionic and butyric acid concentrations are shown for all six terms of EGSB which is fed with hydrolysis products of organic food waste.

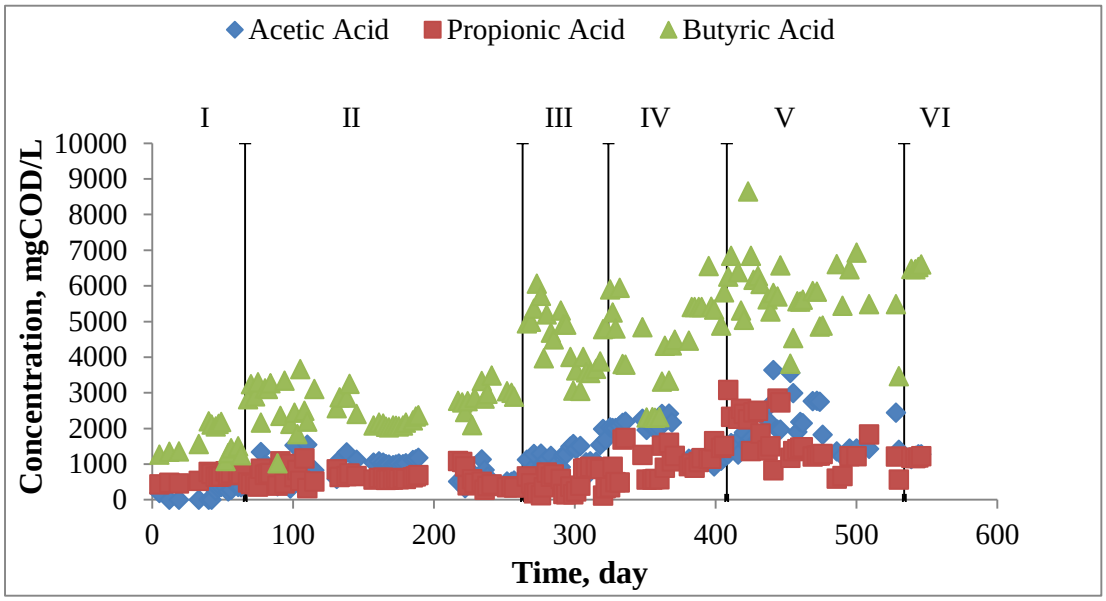

Figure 4.29 : Acetic, propionic and butyric acid concentrations in influent of EGSB reactor which is fed with hydrolysis products of food waste.

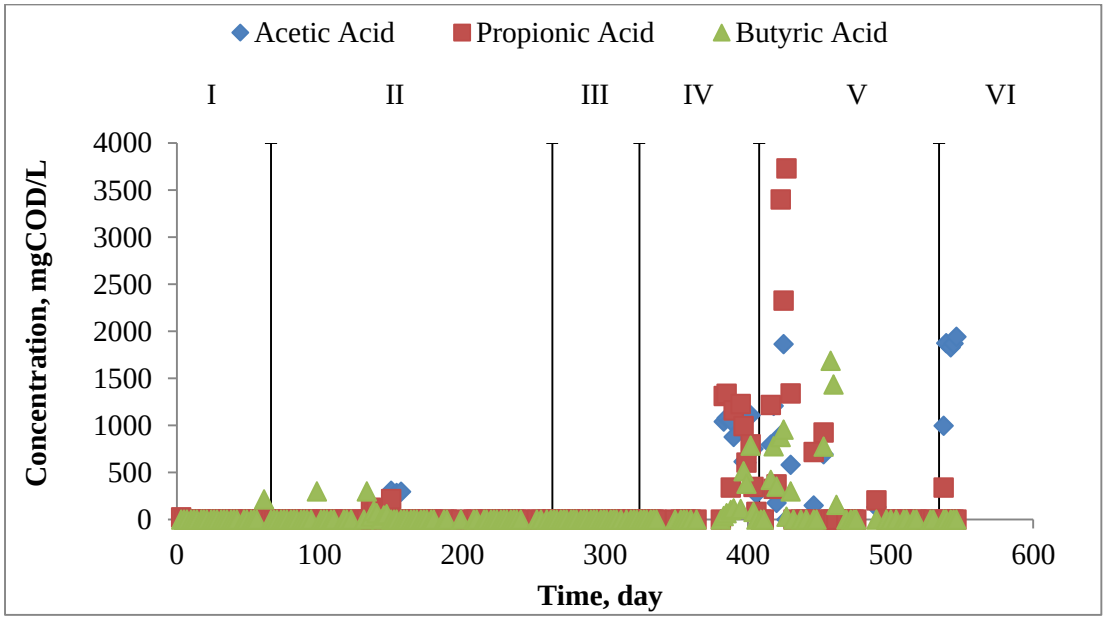

Figure 4.30 : Acetic, propionic and butyric acid concentrations in effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Average concentrations of acetic, propionic and butyric acid in influent and effluent are given in Table 4.26.

Table 4.26 : VFA concentration of influent and effluent of EGSB reactor which is fed with hydrolysis products of food waste.

Influent			
Terms	Acetic Acid (mgCOD/L)	Propionic Acid (mgCOD/L)	Butyric Acid (mgCOD/L)
I	193	652	1632
II	841	621	2606
III	1222	483	4464
IV	1710	1062	4521
V	2007	1665	5785
VI	1233	1188	6520
Effluent			
I	0	1	9
II	18	10	14
III	0	0	0
IV	375	357	96
V	203	456	243
VI	1004	68	0

4.2.6 Biogas production

Biogas and methane production data are given below for six terms of EGSB reactor which was fed with hydrolysis product of food waste is shown in Figure 4.31 and Figure 4.32.

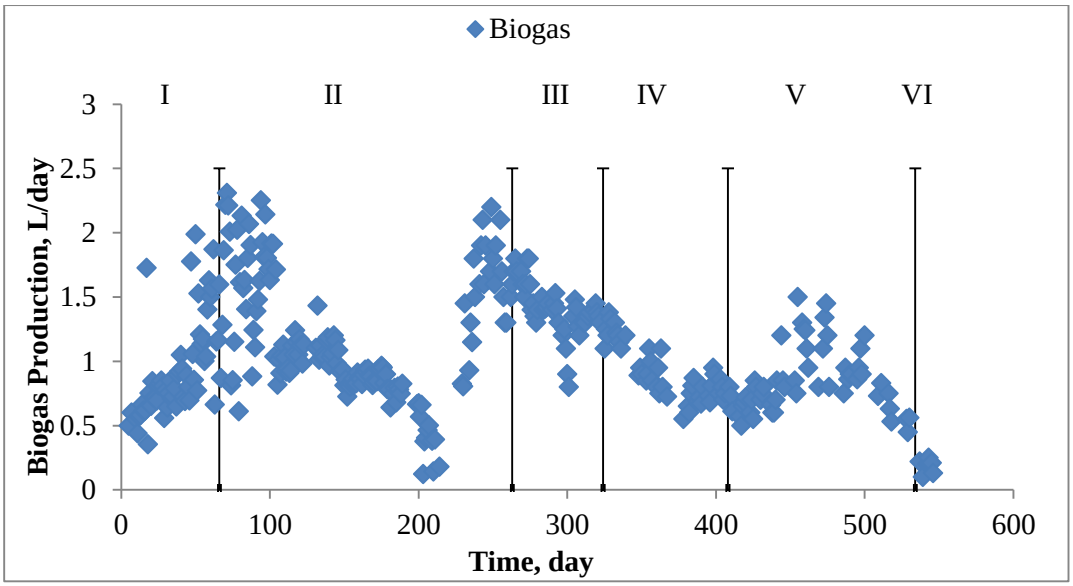

Figure 4.31 : Biogas production of EGSB reactor of hydrolysis products of food waste.

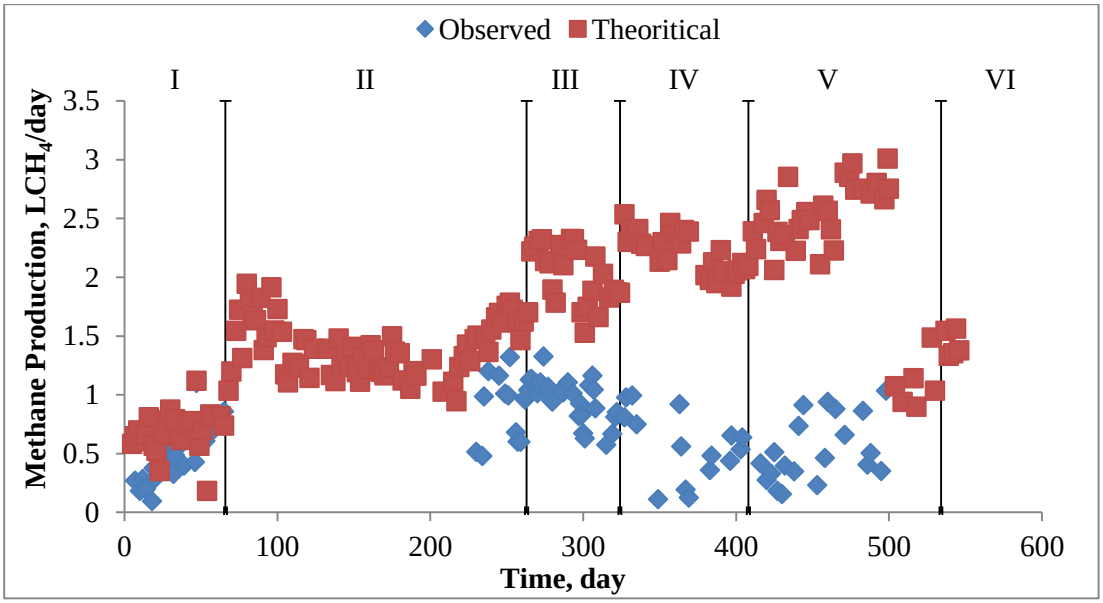

Figure 4.32 : Observed and theoritical methane production of EGSB reactor of hydrolysis products of food waste.

Average methane concentration data are given in Table 4.27 for the EGSB reactor for six terms.

Table 4.27 : Average methane data for EGSB reactor which is fed with hydrolysis product of food waste.

Term	Observed CH_4 Concentration (LCH_4/day)	Theoritical CH_4 Concentration (LCH_4/day)	CH_4 Concentration with Removed Organic Loading ($LCH_4/gCOD_{rem}$)
I	0,55	0,67	0,12
II	0,89	1,40	0,26
III	0,83	2,12	0,22
IV	0,57	2,2	0,13
V	0,53	2,31	0,10
VI	-	1,44	-

On the first three term, an increase is observed in EGSB reactor with is fed with hydrolysis products of organic food waste. But oppositely on the last three term, a diminution is detected.

(Held et al., 2001) worked on anaerobic treatment of organic waste. In that study a 50 L UFAF reactor was used with 6,2 HRT and under neutral pH and mesophilic conditions. Applied organic loading rate is 12.2 gCOD/L.day, COD removal efficiency is calculated as 37,5% and biogas production is 1.8 L/day. And methane production yield is calculated as, 0,31 LCH_4/day.

In another study (Chu et al., 2008) a 40 L filter reactor is used for methane production in the two-stage system. In this study HRT is chosen as 5 days and reactor is operated for 150 day under neutral pH and mesophilic conditions. With 16 gCOD/L.day organic loading methane production yield is calculated as 0,354 LCH_4/day.

Another study with two-stage anaerobic systems with food waste (Zhu et al., 2011) methane reactor is chosen as 5 L. This study was endured for 280 days, and the reactor was operated under mesophilic conditions without any pH control. Total COD is measured as 8867 mgCOD/L and COD removal efficiency is calculated as 33% with 0,344 LCH_4/day methane production yield.

Kim et al. (2012) worked on food waste with a two-stage anaerobic system. Reactor type is chosen as batch reactor for the methane production. Reactor is operated with a HRT of 15 days and mesophilic conditions with neutral pH. COD concentration of

influent is measured as 58000 mgCOD/L, and COD removal efficiency is calculated as 65%. Volumetric loading rate is 3,6 gCOD/L.day and methane production yield is 0,250 LCH_4/day

In Table 4.28. methane production and operating conditions of anaerobic reactor which are fed with organic food waste.

Table 4.28 : Methane productions of other anaerobic studies of food waste.

Waste Type	Reactor Type	HRT (day)	Temperature (^oC)	Methane Production (LCH_4/day)	Organic Loading (gCOD/day)	References
OFMSW	UFAF	6.2	37	0,31	12.2	Held et al., 2001
Food Waste	Two-Staged System	7.5	37	0,354	16	Chu et al., 2006
Food Waste	Two-Stage System	35	37	0,344	5,2	Zhu et al.,2011
Food Waste	Two-Stage System	15	37	0,250	3,6	Kim et al., 2012
Food Waste	EGSB	2	37	0,10	9,57	This Study

5. CONCLUSION AND RECOMMANDATIONS

In this study hydrolysis products of baker's yeast process wastewater and hydrolysis products of organis food waste are used for methane production. Considering the first stage of anaerobic treatment, hydrogen and methane, which energy molecules are recovered effectivley.

Studies with hydrolysis products of baker's yeast process wastewater with six different volumetric loading rate, are show different results. For all six periods, methane production and COD removal efficiencies are given in Table 5.1.

Table 5.1 : VLR, COD Removal Efficiency and Observed Methane Production of EGSB reactor which is fed with baker's yeast wastewater.

Term	Volumetric Loading Rate (gCOD/Lday)	COD Removal Efficiency (%)	Observed Methane Production (LCH_4/day)
I	2,00	75	0,18
II	3,63	65	0,23
III	5,85	63	0,28
IV	7,49	58	0,43
V	9,23	43	0,38
VI	11,37	32	-

With increased VLR, COD removal efficiencies are dropped with observed methane production. As it can be seen from Table 5.1 optimum methane production is provided in forth term, with 7,49 COD/L.day of VLR and 58% COD removal efficiency. A reduction is observed in both COD removal efficieny and methane production after the forth period.

In influent, with higher loading rates, VFA concentraions are increased also as it can be seen in acetic acid concentration in influent, however propionic acid and butyric acid concentrations are not changed with higher organic loadings except the last

term. It is observed VFA concentration in effluent is increased with high organic loadings and less COD removal efficiencies.

Since the raw baker's yeast effluent has very high sulphate content, which is around 4000 mg/L, around 70% is reduced in the hydrolysis reactor. But still the remaining sulphate is high to be taken into consideration in the methane reactor. It is observed for all six terms that sulphate concentration in effluent is much more less than sulphate concentration in influent. The reason of this situation is that sulphate reducing microorganims are being active. That is why sulphate concentrations are decreasing.

Beside these, other specific compounds may have adverse effect on the anaerobic biomass.

Studies with hydrolysis products of organic food waste with six different volumetric loading rate, are show different results. For all six periods, methane production and COD removal efficiencies are given in Table 5.2.

Table 5.2 : VLR, COD Removal Efficiency and Observed Methane Production of EGSB reactor which is fed with baker's yeast wastewater.

Term	Volumetric Loading Rate (gCOD/Lday)	COD Removal Efficiency (%)	Observed Methane Production (LCH_4/day)
I	1,95	87	0,55
II	3,95	85	0,89
III	6,74	77	0,83
IV	7,55	71	0,57
V	9,54	64	0,53
VI	12,07	65	-

With an increase in VLR, COD removal efficiencies are dropped andobserved methane productions also. As it can be seen from Table 5.2 optimum methane production is provided in second term, with 3,95 gCOD/L.day of VLR and 85% COD removal efficiency. A reduction is observed in both COD removal efficieny and methane production after the second period.

In influent, with higher loading rates, VFA concentraions are increased also as it can be seen in butyric acid concentration in influent, however propionic acid and acetic acid concentrations are not changed with higher organic loading. It is observed that

VFA concentration in effluent is increased with high organic loadings and because of less COD removal efficiencies.

It is observed that sulphate concentration in influent and effluent are not distinctive except the last term. The reason of this situation is that, threshold level of sulphate reducing bactearia is high and that is why they are not active. But for the last term with high sulphate concentration in influent, sulphate reducing bacteria are become active and lower the sulphate concentration in effluent.

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