DESIGNING AND MANUFACTURING OF FERMENTER FOR IDLI"

Dissertation 1 Report
Submitted by,

VISHWAJEET RAMCHANDRA GAIKWAD

11709261

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School of Agriculture

Lovely Professional University, Phagwara

Under the Guidance of

DR. ANIL PANGHAL

Coordinator

Department of Food Technology and Nutrition

School of Agriculture

Lovely Professional University, Phagwara

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CERTIFICATE

This is to certify that Vishwajeet Ramchandra Gaikwad (Registration No.11709261) has personally completed M.Tech. Dissertation 1 entitled, **"DESIGNING AND MANUFACTURING OF FERMENTER FOR IDLI"** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of pre-dissertation has ever been submitted for any other purpose at any University.

The project report is appropriate for the submission and the partial fulfilment of the conditions for the evaluation leading to the award of Master of Food Technology.

Date: 14 May 2018

Signature of Supervisor

Dr. Anil Panghal

Coordinator

Department of Food Technology And Nutrition

School of Agriculture

Lovely Professional University

Phagwara, Punjab, India

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INTRODUCTION:

India, being a huge nation, it has large number religious order of human population and variety in the climatic environment has resulted in a huge number of fermented food preparation. Most of the fermented food are prepared at home scale by back slopping and these preparation process is passed from generation to generation. Fermented foods are those foods that are prepared using microbial cultures which produce organoleptically and biochemically modified substrate, resulting in suitable product for human consumption (Tamang et. al., 1998). Fermented foods are prepared with lots of tradition and cultural preference according to the different geographical areas. As compared to the non-fermented foods, fermented foods are comsumed in large amount because of their long shelf-life, smaller cooking time, and high nutritive value and reduced volume. (Rolle and Satin et al., 2002). Different types of the fermented foods are prepared using a range of different substrate that are metabolized by various microorganism to increase the yield of the product with unique and pleasing characteristics (Campbell-Platt et al., 1994). Of all the fermented foods, idli, a spongy textured steam cooked product is enjoying its popularity especially in the south India due to its superior digestibility, unique sensory and textural attributes. (Kanchana et al., 2008). Naturally occurring microorganisms such as Streptoccous thermophiles and Leuconostoc mesenteroides in the grains or utensils grow quickly during fermentation. (Balasubramanium et al., 2006). Idli processing methods are reviewed by many authors (Soni and Sadhu et al., 1990). The best technique for standardizing idli fermentation process is addition of the variety of microflora with natural bacterial flora to enhance the nutritional constituents and organoleptic characteristics.

This is an age of mechanisation, where it is generally expressed as the manual strength replaced by the machines power in all degrees of automation. The process remains an important part of the system although with changing demands on physical input as the degree of mechanization is increased. Till recently, the preparation or processing of traditional foods was considered more an art than science and the mechanization has been thought of very recently. The successful process of any equipment depends mostly on the kinematics of the equipment. Design is a technique of prescribing the sizes, shapes, material composition and arrangement of parts so that the equipment will perform the prescribed task. The role of science in design process is to provide tools, to be used by the designed as they practice their art. However analysis is vital tool, inevitably be used as one of the steps in the design process. This covers the general introduction of idli, an Indian traditional food and conceptual design of the equipment.

Here we focus on the design of fermenter for idli batter that is used to produce the Indian traditional snacks called “IDLI” in automatic way for mass production, hygienically and safe. By implementing such machines, the Indian traditional food recipe can be made world famous by implementing food safety and uniformity (shape, size and taste).

PROBLEM BACKGROUND:

The traditional foods, for example idlis, dosa and many other product have been prepared for hundreds of years and the art of preparation has been perfected over years and varied through the country. The attempts to change these food habits have not been successful to the extent envisaged. As the value of time is increasing day by day, the demand for the ready-to- eat traditional foods like idli is also increasing. Living standard of peoples are improving day by day, they are demanding for safe and hygienically prepared food. Though the basic kitchen technology for the production of these foods is known, considerable research and development efforts are required to translate these technologies to the level of large- scale production.

REVIEW OF LITRETURE:

IDLI:

Ittali is the first word mention in tamil literature as early as the Meghapuranam of the 17th century AD. The Manasollasa of nearby 1130 AD engraved in Sanskrit defines the Iddarika as prepared of finely grounded urad dhal flour, shaped into small spheres, fried in ghee and then flavoured with pepper powder, jeera and asafoetida. In Karnataka the idli in1234 AD is described as being light, 'like coins of high value', which is not suggestive of rice base. The steaming receptacle in Kannada is allage, and the daligid. In all these references, three basics of the modern idli are missing. One is the usage of rice grits. The afterward is lengthy process of grinding and the full night fermentation of ground batter. The latter is the steaming of the fermented batter.

In 1485 AD and 1600 AD, the idli is judged against to the moon, which might propose that rice was in use; up till now there are mentions to other moon-like products only made from black gram flour. The Indonesians ferment numerous materials have alike fermented and steamed item called kedli. Steaming is a very earliest form of food preparation in the Chinese ethos, referred to by Xuan Zang saying that in 7th century AD India did not have a steaming bowl. It has been recommended that the chefs who go together with the Hindu kings of Indonesia for the duration of their visits home for the duration of the 8th to 12th centuries AD, conveyed fermentation methods along with them to their homeland. Possibly the usage of rice along with the pulse was essential as a source of mixed natural micro flora needed for an effective fermentation. Yeasts have enzymes which break down starch to simple sugar forms and bacteria which lead the idli fermentation convey enzymes for souring and leavening through carbon dioxide formation. Even Czechoslovakia has alike steamed product named the Knedlik. Steaming can of course be accomplished by very simple means, merely by tying up a thin cloth over the opening of a receptacle in which water is boiled and its antiquity would be difficult to establish. It is likely that the name of idli continued even though its appeal changed with time, resulting in differentiated forms of Idly (Achaya, 1994).

IDLI AND ITS PROPERTIES:

Production properties of idli:

During fermentation time of idli, batter increase in non-protein nitrogen and a drop in reducing sugars have been observed. The batters are normally formulated by soaking rice (*Oryza sativum*) and black gram (*Phaseolus mungo*) dhal in water, grinding them separately, mixing and allowing the mixture to ferment overnight. The titrable acidity and the volume has increased because of the fermentation and have been used as standards for assessing the development in the fermenter. Optimal temperature range has been found for fermentation is 25-30˚C. Both bacteria and the yeast are participate in the yeast in the fermentation has been shown using penicillin G and chlortetracylin as selective inhibitors. Acid and gas production relies on the microbe's growth belonging to the group of bacteria (Desikachar et al., (1993)

Significant increase in the methionine was not found after overnight fermentation of the idli made by fermenting of soaked and grinded parboiled rice and black gram, when idli is generally steamed. The digestibility and PER in rats were similar to the unfermented mixture. Riboflavin content reduces in the fermented batter because of the presence of the *Streptococcus faecalis.* The existence of pharmacological active amines such as tyramin was anticipated but they were not identified (Veen et al., (1993).

To produce a batter of desired consistency parboiled rice and black gram dhal are soaked and wet ground separately with addition of water. A small amount of salt is added and overnight fermentation is allowed, during that time Streptococcus faecalis and Leuconostoc mesenteroides which are naturally present on the grains or utensils grows rapidly more numerous than the initial contaminants and controlling the fermentation. The microorganism present in the batter produce carbon dioxide and lactic acid that makes the batter anaerobic and leavens the product (Reddy and Salunkhe et al., 1993).

As a supplier of micro-organisms and fermenting substrate black gram gives a most important contribution in idli fermentation (Radhakrishnamurthy et al., 1993).

The native fermentation of coarsely ground dehulled black gram dhal batter at 25, 30 and 35 ˚C for 12 and 18 h minimized the quantities of Phytic acid and polyphenols significantly ($P < 0.05$). The non-fermented black gram dhal batter had great quantities of polyphenols (998 mg / 100 g) and phytic acid (1000 mg / 100 g) and these were minimized to very nearly half in the produce fermented at 35 ˚C for 18 hrs. In vitro digestibility of starch and protein increased considerably ($P < 0.05$) with increases in the temperatures and time of fermentation. A considerable ($P < 0.01$) and negative relationship found among the in vitro digestibility and the anti- nutrient further strengthens. Yadav and Khetarpaul et al., (1994).

An automatic idli manufacturing machine that produces 1200 idlis per hour. The unit contains automatic idli batter 25 depositor, a distinctive idli pan conveyor, steam compartment and idli scooping system (Murthy et al., (1994)

The thermal diffusivity (α) of idli batter was defined experimentally assuming infinite slab geometry beneath transitory heat transfer environments. The continuous (1.1 × 10 -7 m2 s -1) idli steaming units and the value α of batter determined using batch (1.38 × 10 -7 m2 s -1) were compared with the value obtained using Riedel‘s equation (1.42 × 10 -7 m2 s -1) and Martens equation (1.1 × 10 -7 m2 s -1) Murthy and Rao et al., (1997).

Fermentation of idli was accumplished in the traditional way that the batter having rice and black gram in the proportion of 2:1, 3:1 and 4:1 at atmospheric temperature. Brookfield viscometer having disc spindles assessed the rheology of the product. Yield stress values were in between 13- 43 Pa and touched an extreme value after 7 hrs of fermentation. Flow performance includes were in the range 0.287- 0.605. Flow behaviour indices at 23 hrs were considerably lower than those at O h. Consistency index values, at any fermentation time, enhanced as the rice to black gram proportion improved. 500 to 600 μm was mean partical

size range and there was no fixed trend observed with respect to period of fermentation and rice to black gram proportion. There was a steep alteration in volume rise after 4 h fermentation. Nagaraju and Manohar et al., (2000)

Idli is eaten as breakfast or snack food. It is low calorie, starchy and healthful food. Steamed idli comprises nearly 3.4% protein, 20.3% carbohydrate and 70% moisture. Teniola and Odunfa et al., (2001).

The conventional fermented foodstuffs contain high nutritional value and developed a variety of flavours, aromas and consistencies in food substrates (Steinkraus et al., (2005).

With numerous hydrocolloids and certain surface active agents temperature (28- 30 ˚C) and refrigerated storing (4- 8 ˚C) the stabilization of the idli batter at room was examined. The slurry was assessed in terms of percentage reduction in volume and percent whey separation. Although hydrocolloids gave effective stabilization, surface active agents failed to stabilize the batter even though they minimized whey separation. Among the numerous hydrocolloids 0.1% guar gave greatest batter stabilization and idlis produced there from after 10 days of atmospheric temperature and 30 days of refrigerated storing of slurry were found to be of desirable quality (Nisha et al., (2005).

Nutritional composition of idli

Idli can be prepared locally also used as a nutritional supplement in emerging countries to cure the people suffering from kwashiorkor protein calorie malnutrition. Idli, a famous fermented breakfast foodstuff consumed mostly in the south India contains mostly of rice and black gram dhal. Idli fermentation was carried out in traditional manner in a batter having rice to black gram in the proportions of 2:1, 3:1 and 4:1 at normal temperature. Protein, calories and vitamins, specifically B-complex vitamins obtained from processed idlis equated to the unfermented raw ingredients. Nagaraju and Manohar, 2000).

The finest technique used for standardization of idli fermentation is Adding microflora Saccharomyces cerevisiae, together with natural bacterial flora of the ingredients to improved leavening, nutritional constituents and organoleptic characteristics. Traditional idli fermentation includes a number of bacteria and yeasts, from the raw materials rice, black gram and the atmosphere, with overall 6dominance of the former in bringing about various changes. Idli fermentation increases total acids, batter volume, total soluble solids, reducing sugars, non-protein nitrogen, free amino acids, amylases, proteinases and water soluble vitamins B1, B2 and B12 contents, therefore accounting for enhanced digestibility and nutritious value of the staples. Novel idli batter are mostly preferred than traditional black gram with additional legumes, shown substantial alteration but using alteration in the levels of some biochemical components (Soni and Sandhu, 1989).

The fermented batter of idli and dosa contained greater quantity of existing lysine, cystine and methionine in fermented idli batter. After processing, maximum preservation of lysine, methionine and cystine was detected after processing idli (Riat and Sadana, 2009).

Progress and nitrogen stability serving practices were evaluated using rats to define the protein value of idli, a fermented steamed cake manufactured by using beans (*Phaseolusvulgaris*) and rice. Feed Efficiency Ratio (FER), Protein Efficiency Ratio (PER) and Relative PER (RPER) in unfermented idli are significantly higher than the fermented idli. The Digestibility Coefficient (DC) and Net Protein Utilization (NPU) of non-fermented idli intakes are significantly higher than the DC and NPU of fermented idli intakes. The BV of a casein control intake was alike to Biological Value (BV) of fermented also non-fermented idli intakes Fermentation does not increase the protein value of idli manufactured by usin beans and rice (Joseph and Swanson, 1994).

FERMENTER DESIGN:

Fermentation technology:

Fermentation process is the oldest technology of all biotechnological process continued from hundreds of years. The study of fermentation process, application and techniques are simply defined as fermentation technology. The fermenter or bioreactor are defined as the heart of fermentation process within this fermenter many reactions and activities occur. In fermentation technology whole study is involve activities like downstream, upstream and mid-stream studying and controlling them.

Fermentation technology studies needs essential efforts from different disciplines such as bioprocess and chemical engineering, microbiology, biochemistry, genetics and even physics and mathematics. (Jagani et. al, 2010)

Fermenter*:*

The bioreactor / fermenter is the vessel that provides biomechanical and biochemical environment which regulate the transfer of oxygen, nutrient to cells and metabolic products from cell. Bioreactor vessel are designed to utilize activity of catalyst to attain desired chemical transformation (Sharma K.R, 2012; El AJ Haj et. al, 2005; Bueno E.M et al, 2004). Bioreactors are also defined as engineered device designed for metabolic activity and optimal growth of organisms with the help of the microorganism, enzyme, biocatalyst and the cells of plants and animal. With fermenter metabolic fluxes are altered and cell resource are diverted to the more anticipated pathways while undesirable one are inhibited. For instance, by commanding a temperature profile given on the culture, certain enzymes are denatured, thus arranging the metabolic routes over others within the cells (Gueguim-Kana et al., 2002). Fermenter or Bioreactor are cylindrical shape vessel having hemispherical bottom and top and they are mostly made of glass and stainless steel. Difference between classic composting system and the bioreactor is controlling and measurement of the composting process parameters is more in

bioreactor (Jagani et. al, 2010). Bioreactors are dissimilar from the conventional chemical reactor to some extent. They support biological entities and control them. Bioreactor system should be tough enough to provide greater degree of control over contamination and when the organism are less stable and more sensitive than chemicals (Williams J.A., 2002).

The fermenter is involved in processing of beer, wine, vinegar, yoghurt, sauerkraut. The evolution from native art to commercial practice of these product requires improvement in process to increase shelf life and to maintain acceptability and the quality of the product, equipment and the process control parameters remained simple (N. Blake brough). Adequate heat transfer, mass transfer, substrate in appropriate amount, no under or over dosing of feed in bioreactor should maintained. Proper supply of the adequate substrate, salts, oxygen, suspended solids and water availability for aerobic system should be ensured. Care should be taken in gas evolution product and by-product. Some factors regarding to the attributes of bioreactor design requirement are scale-up, regulating techniques, typical construction and measuring, sterilization, flexibility in operations, process control devices that are compatible with upstream and downstream processes and antifoaming measures. (Sharma K.R, 2012).

Aseptic environment is well defined as defense against entry of the unwanted microorganism and contamination is preventing escape of viable cell form the process. Fermenter system provide both type of the environment where ever they are mandatory. Contamination is applicable in all of the process of fermentation but containment is essential after the pathogenic organism occurrence in the fermentation practice. (Gudin C et al, 1991) stated that condition of the fermenter for living organism should be favorable to display their activity in defined condition. This calls for a series of special attributes in the engineering reaction of biocatalytic processes. Many times Bioreactor and fermenter term are used synonymously. The slight difference between these two is fermenter is used for microbial culture and bioreactor is used for mass culture of animal and plant cells.

Bioreactor design and operation:

The fermenter design should provide high quality product in low cost with improved productivity and authentication of the desired parameters. The design of the fermenter and mode of operation relies upon microorganism production, product value, condition necessary for the desired product formation and production scale. The effective fermenter provides positive influence on the biological reaction and prevents foreign contamination. In fermenter capital investment and operating cost are important factors that to be considered. (Eibl R et.al, 2008) reported that during the fermentation process proper mixing, uniform shear rates, mono septic conditions should be maintained. Aeration of the culture is achieved by one of the following methods: increasing atmospheric pressure or increasing the partial pressure of oxygen and direct sparging, indirect and/or membrane aeration or by medium perfusion. Naraendranathan (1998) discussed about characteristics of a good bioreactor design which include: a simple, economical and robust mechanical design, beneath aseptic conditions easy operation, flexibility in the process, nonappearance of dead zones and transfer of heat and mass. The bioreactor design must control pH, temperature, oxygen tension, allow aseptic operation and the shear stress. The system should also allow for automated processing steps. This all is essential not only to control, but also for future routine manufacturing martin (2004).

The biotechnological process has several aspects, which needs special care in bioreactor designing. The cell growth, reaction rate and process strength in the bioreactor depends upon environmental condition. Condition in bioreactor like pH, temperature, agitation speed, dissolved oxygen level, foam production, gas low rates etc. necessary to control and closely monitored (Chen H.C. et.al, 2006).

Size of bioreactor vessel and material:

The sizes of the bioreactor vary widely from the microbial cell (few mm3) to shake flask (100-1000 ml) to laboratory scale vessel (1 – 50L) to pilot level (0.3 – 10 m3) to industrial scale (2 – 500 m3) for large volume industrial applications. The thickness of the manufacturing material increases with scale. At 300,000–400,000 dm3 capacity, 7-mm plate are used for the side of the vessel and 10-mm plate for the top and bottom, should be hemispherical to resist pressures.

The material used for the fabrication of the fermenter are discussed by Cowan and Thomas (1988). Lab scale fermenter are typically constructed with the glass and the pilot scale and the industrial scale vessel are normally fabricated with stainless steel or at they should have cladding of the stainless steel. The presence of a thin hydrous oxide film on the surface of the metal reduces the corrosion of stainless steel. The configuration of film differs with industrial process treatment and altered steel alloys. Chromium is used to alleviate the film and considered as insoluble, nonporous and self-healing. When exposed to environment or oxidising agent damaged film will be repair itself. (Duurkoop, 1992) suggested that in chromium steel high percentage of nickel improves engineering properties and enhances their resistance. The resistance of stainless steels is improved by the existence of molybdenum to solutions of halogen salts and opposing by chloride ions in brine or sea water. Nowadays molybdenum commonly used in the construction of the fermenter containing 10% nickel and 18% chromium. Wood, plastic and concentrate are used where no chance of contamination in the system.

Basic feature of fermenter design:

The basic feature of bioreactor which include agitation system, foam control, oxygen delivering system, headspace volume, sampling port, temperature and pH control system, sterilization system and lines for charging & emptying the reactor. (Alaghlavi, et. al, 2013).these are described in table below.

Sr.	Parts of fermenter	Function
1	Impellor (agitator)	Continuous stirring of media, distribution of the oxygen throughout the system and prevent cells from settling down
2	Sparger (Aerator)	Introduce sterile air or oxygen to the media in the aerobic fermentation process
3	Baffles (vortex breaker)	Provides better mixing by disrupting the vortex formation
4	Temperature probe	Measure and monitor temperature change in the medium during the fermentation process
5	Cooling Jacket	maintains the temperature of process
6	pH probe	Evaluate and monitor the change in pH of the medium
7	Level probe	Measure the level of medium
8	Foam probe	Detect the presence of the foam
9	Acid	Neutralizes the basic environment and maintain the pH
10	Base	Neutralizes the acidic environment and maintains the required pH
11	Antifoam	Breakdown and avoid foam occurrence in the medium
12	Sampling point	To acquire samples throughout the process
13	Valves	Regulate and limit the flow of liquids and gases
14	Control panel	Monitor all parameters in the system
15	Inlet air filter	Filtration of air before entering the fermenter
16	Exhaust air filter	Prevention of contaminants from escaping
17	Rotameter	Measure flow rate of liquid or air

18	Dissolve oxygen probe	Measure dissolve oxygen in the fermenter
19	Pressure gauge	Measure internal pressure of the fermenter

Types of bioreactor*:*

There are three different types of operation of the fermenter that are batch, continuous and fed-batch or semi-continuous depending on feed of the fermentation media and the cultures into bioreactor (Brian McNeil & Linda M Harvey, 2008). The relationship of the feeding of substrate to the biomass and yields suggest the excellent fermentation mode (Raj and Karanth 2006). For the centuries Traditional batch stirred tank reactors (STRs) and continuously stirred tank reactors (CSTRs) are existed. Due to their simplicity they are commonly used in bioprocessing industries (Brian McNeil & Linda M Harvey, 2008). Other bioreactor having different design and operational attributes are membrane bioreactor, drum reactors, photo-bioreactors, fluidized bed bioreactors, air lift bioreactors and bubble column reactor. These all are developed to provide various application in specific processes.

Batch Process:

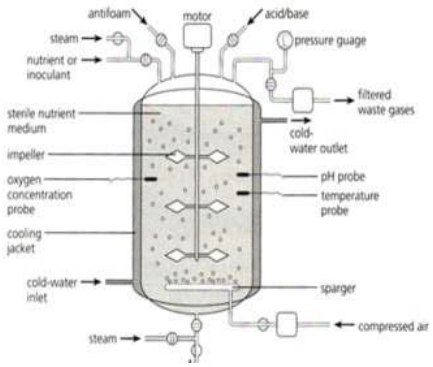
Batch fermentation is a closed culture technique in which the small quantity of nutrient is inoculated with the variety of organism to let the fermentation. Batch fermentation is the traditional process, during fermentation process no ingredient are added after inoculation, except base or acid in controlling pH. In this fermentation process, organism effects in high substrate concentration primarily and a high product concentration lastly. (Williams J.A, 2002) reported that for the promotion of aerobic cultivation in fermenter, the aeration of medium with sterile air to provide constant flow of oxygen. Gaseous by-product such as carbon dioxide are removed, gas removal processes and the aeration takes place in this process.

Batch bioreactor design:

The impellers in STRs connected to an exterior motor, which runs the stirrer system. The assembly of agitator including seal is a way of contamination so the shaft has to pass from aseptic seals into bioreactor (Abbott M.S.R et.al, 2013). (Garcia- Ochoa F& Gomez E, 2009; Martin M. et. al, 2008) reported about contribution of the impellers in the uniform mixing and the termination of the essential atmospheric oxygen into aqueous phase.

The efficiency of the agitation is determined by the shape of impeller blades and speed of agitation. The mass transfer rates and mixing are affected due to variety of stirrer, stirrer speed and the rate of gas flow used. Batch type of fermenter are preferred for high value end product and low volume, particularly to obtain product yield. Such type of fermenter are used when more than one products are produced prepared in same equipment or in the case of highly viscous liquid where continuous flow is difficult. (William J.A, 2002). Batch type fermenter

are more flexible with varying product system, they low down the risk of contamination and the investment is also low as compared to the continuous processes for same volume.



Continuous process*:*

In the continuous process of the fermenter fresh medium is constantly added in the system along with that continuously removal of the product from the bioreactor. (Acharya T, 2013; Abbott M.S.R et. al., 2013). This supports the cells in growth phase and keeps the capacity of reactor constant. Thus, steady state is attained, the connection between microorganism behaviour is established depending upon the availability conditions of the nutrient. The continuous product are formed with higher yield. In continuous stirred-tank, the reactants are very well mixed. Other name for the reactor is back mix reactor. Continuous feeding process is the specific feature of continuous bioreactor. (Martin M, Montes F.J et. al, 2008) suggested that hydraulic or mechanical agitation is required to accomplish uniform temperature and composition. To maintain steady state, the culture is continuously fed to medium in the bioreactor. The control parameters and the reaction variables remain consistent, within bioreactor it establish a time perpetual state. This result in the continuous output (Brian McNeil & Linda M. Harvey, 2008). (kaushik) suggested that by automating the process, time could be saved in filling, emptying, and sterilizing the bioreactor with reduced toxicity risks and reduce labour cost. CSTRs can yield high product quality, due to presence of the mechanical pumps CSTRs consume more energy.

Type of continuous fermenter:

There are two simple classes of continuous fermentation reactors

1. Continuous stirred tank reactor (CSTR)

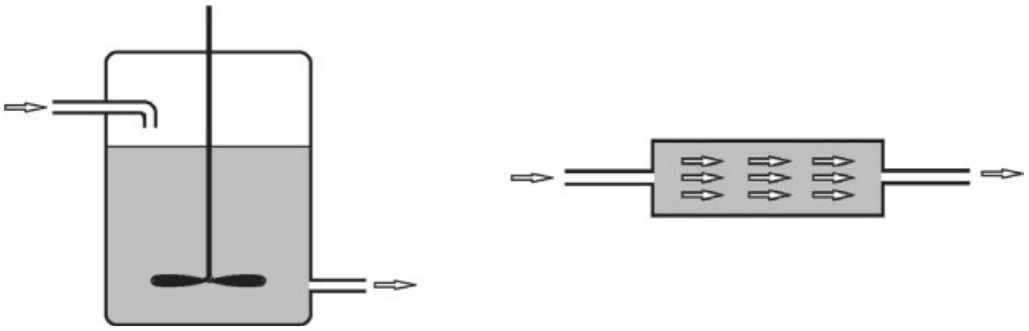
In the CSTR, with one or extra agitator, fermentation broth is continuously stirred and the composition is identical and homogeneous to that for outgoing flow into the reactor. Such type of reactor are usually operated in syngas fermentation. Application of the CSTR is constant flow of the gas throughout the liquid, that normally consists of a diluted solution of basic nutrients for the organism to grow and survive on. (Y.Q. Tang 2010) has evaluated the

performance of reactor in concurrent and ethanol fermentation in addition with flocculating yeast strain. Using gas stripping the product removed from fermentation media also reported with the Continuous stirred tank reactor (H.S. Liu 1990).

2. Plug flow reactor (PFR)

In the plug flow reactor (PFR), the reactants are driven via tube or pipe with a constant velocity profile across the radius, and the reaction continues as the reagents travel through the PFR, with diffusion expected to be small in the axial direction (Ananda. S. 2014).

In PFR operation, inoculum is continuously fed to the reactor.



Fed batch or semi-continuous process:

Fed-batch fermentation process is a system in the middle of batch fermentation and continuous fermentation. During whole fermentation process in Fed batch or semi-continuous process, broth is taken off from the reactor, however the rate of nutrient are limited that helps in increasing yield of product and controlling reaction rate. In this process sterilized condition are maintained during the operation and the yield is collected at the end of the process as in batch bioreactor (Abbott M.S.R et.al, 2013). Such type of vessel perform safer and stable operation in the batch bioreactor. An elaborate sequences of equipment is necessary to maintain suitable feed rates with the right constituent in the fed-batch reactors. However, the fed-batch technique has so many advantages over batch and continuous process.

Basically two simple types of fed-batch fermentation reactors:

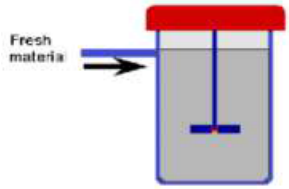
(1) The constant volume or fixed volume fed-batch reactors:

In this type of fed-batch reactor, the substrate is provided in the limited amount without diluting a culture. The growth limiting substance are fed in undiluted form, e.g. solid or concentrated liquid volume of culture can be maintained constant. Alternatively, addition of substrate by dialysis without disturbing the culture volume can be done. (Ananda. S. 2014)
A periodic removal of a part of the culture is mandatory in a fix cyclic fed batch reactor.

(2) The variable volume fed-batch reactors

In the variable volume fed-batch reactor, change in size occurs with fermentation time due to substrate feed. Volume change can be controlled depending on the need such as

microorganism characteristics and fermentation kinetics. In this reactor, liquid volumes are used as a variables in optimizing the product yield. For example, at certain stage the culture is replaced from the system with fresh medium where the fermentation process is not effective anymore. The reduction of volume in the process results in rise in the specific growth rate, followed by a steady fall as the quasi-steady state is created.



Fed-batch bioreactor (Abbott M.S.R. et.al, 2013)

Comparison on basis of Mode of Operation (Baron G.V, Willaert R.G et. al, 1996)

Mode of Operation	Advantages	Disadvantages
Batch fermenter	Simple equipment; appropriate for small production volumes together with multi-product flexibility	Downtime for filling and cleaning; reaction circumstances alters with time
Fed batch or semi-continuous fermenter	High productivity; good product quality due to constant conditions; suitable for kinetic Studies	Need flow control, endurance of catalyst necessary, organisms stability
Continuous	Control of environmental conditions e.g. substrate inhibition, introduction to product development; most flexible for selecting optimum conditions; normally used in biotechnological processes and in fine chemical industry	Requires feeding strategy e.g. to keep perpetual temperature or Substrate concentration.

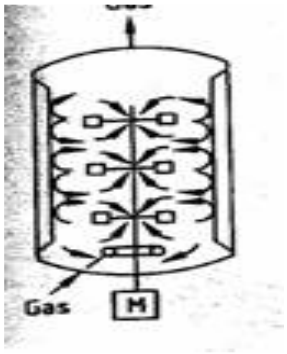
OTHER TYPES OF FERMENTER*:*

Stirred tank fermenter:

Stirrer tank fermenter (STF) are known for their flexibility so they one of the most frequently used fermenter. (Chisti 2010). STF are cylindrical in shape and in STF motors drives the shaft and stir the content in the tank. Depending on the scale of process and other aspect agitator might be bottom driven or top driven. Commonly used are top entry-stirrer (agitator) model, it has so many benefits such as robustness, reliability and easily operated and rarely used are the bottom entry–stirrer (agitator) model. The agitator might be top driven or bottom. The shaft support more than two impellers positioned almost one impeller-diameter separately (Chisti 2010). The characteristic decision variables are: size, type, impellers and sparger size. This type of reactor has following functions: aeration of liquid, solids suspension, homogenization, gas-liquid mixture dispersion and exchange of the heat.

Laboratory-scale stirrer tank fermenter are fabricated with the borosilicate glass and the stainless steel lid. Capacity of these fermenter is 1 to 100 Lts. Fermenter with stainless steel has special requirement in the laboratories. Ali et al. (2002) has studied about laboratory-scale stirred fermenter that was designed for production of citric acid using *Aspergillus niger* GCBT7 having capacity of the 15 lit with working capacity of 9 lit.

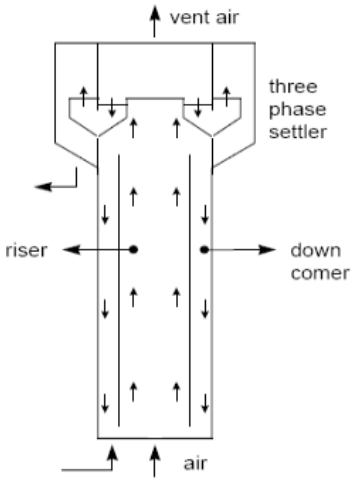
(Vamanu et. al., 2009) reported the condition of fermenter that properly mixes the medium for 15 min. Such type of tanks suffer because of their low productivity. The Stirred tank reactor's provides tremendous mass transfer and advantageous mixing. Attrition problem occurs in the vessel with the immobilized cells, however by splitting the zone of mixing one can easily and effectively function the system.



Airlift fermenter:

Airlift fermenter is also recognized such as tower reactor. An airlift fermenter vessel is cylindrical in shape in which air is presented at the bottom of receptacle which arises through the column to the medium. Operational proportion of the airlift fermenter is more than 6:1 (height /weight). ALFs capable of using for free or together with immobilized cells, that are suitable for bacteria, yeast, fungi and animal and plant cells. These type of the fermenter does

not have agitation system, but contents in the vessel is agitated with the air introduced from the bottom. The cell mixture flows all over the place in the column as a significance of the gradient of air bubbles in the various sections of the fermenter. The fluid of volume is separated within two connected regions by means of draft tube or baffles for improving circulation & oxygen transmission and aligning shear forces in the apparatus (Veera U.P & Joshi J.B, 1999). From the two zones only one zone is sparged with the gas or air. Zone that is not sparged is known as downcomer, and the region which receives gas is the receiver (Chisti and Moo-Young 2001). These comes in 2 model i.e. external loop design and the internal loop design. Riser and the downcomer enclosed in similar shell in the internal-loop and in the external- loop downcomer and riser are distinct tubes interconnected near bottom and the top (Chisti 1999). In the production of citric acid, airlift fermenter was used with 900 m3 volume using *A. niger*. The airlift fermenter are fabricated with the stainless steel to resist the acidity because ordinary steel dissolve at pH 1-2. Airlift fermenter is generally suitable for the aerobic organism due to the oxygen mass transmission coefficient is higher than stirred tank reactors. This fermenter is perfect for the creation of SCP as carbon substrate from methanol. Generation of the excess heat during agitation is avoided in this fermenter. The knowledge of producing SCP from methanol procedure related to Imperial Chemical Industries (ICI, UK).

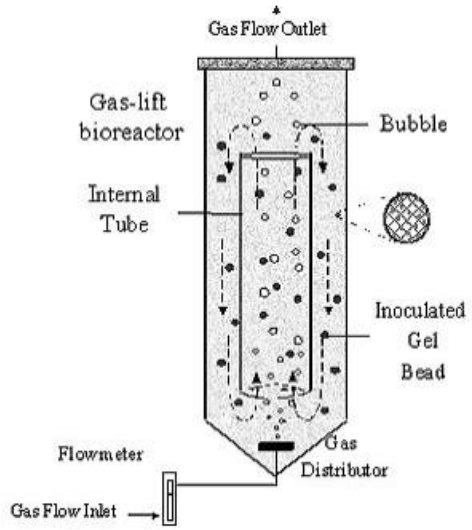


Airlift reactor (Siegel M.H & Robinson C.W, 1992).

Bubble column reactor:

The reactor is one of the simplest type of the reactor and it is easy to scale up (Kantarci N, *et al* 2005). A bubble column reactor is generally cylindrical shape receptacle which contain gas provider at the bottom side. Helmut Gerstenberg applied it for first time. . (Borakb & Kutlu O. Ulgena, 2005) reported that in bubble column reactor gas is sparged in the manner of bubbles into liquid–solid suspension or liquefied phase. The existence of solid phase in the vessel commonly mentioned as slurry bubble column reactors. The mixing in the reactor is achieved by gas sparging also it needs very small amount energy than the mechanical stirring (Nigar et al. 2005). Comparing with other reactor having agitator bubbles make less shear stress

(Kantarci N, *et al* 2005). Bubble column reactor has many advantages as comparing with other type of reactors. These type of reactor requires less maintenance and have good heat and mass transfer attributes, operating cost is less because of their compactness along with stability of the catalyst. Bubble column reactor are utilized by many industries such as biochemical, petrochemical, and metallurgical and chemical industries (Degaleesan et al. 2001). Use of these reactor especially in the production of artificial fuels by transformation of the gas process, chemical processing such as chlorination, polymerization, alkylation, and hydrogenation and in biochemical process for example biological waste water management and fermentation (Prakash et al. 2001). Accessible chemical agent addition and taking out ability and plug-free process are additional benefits that reduce bubble columns an appealing reactor choice (Prakash et al. 2001). (Ogbonna et al. (2001) study was depending on ethanol fuel production from sugar-beet juice in bubble column reactor. Yeast cells (*Saccharomyces cerevisiae*) were used so as to examine the possiblity of climb up the procedure.

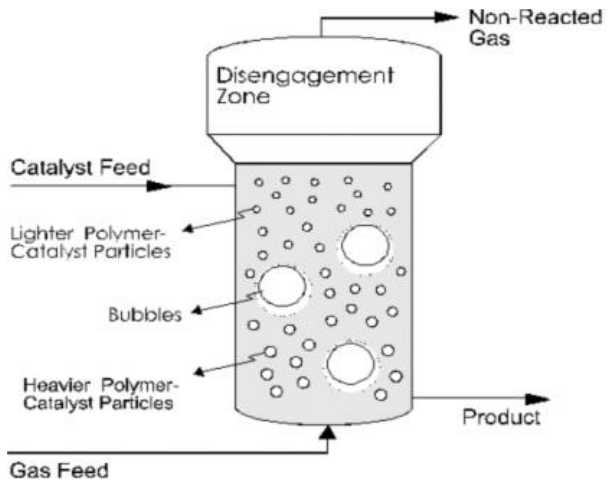


Bubble column bioreactor (Wilkinson P.M et.al, 1992).

Fluidized bed reactor:

FBB has many advantages over other type of reactor so in current years use of this type of reactor has increased. Fluidized bed reactor are developed for the biological system has cells as biocatalyst that are three phase system (liquid, solid and gas). This type of reactor contains packed bed with small size particles which moves the fluid. The minor particle size accelerates higher rate of oxygen transfer, mass transfer, higher mixing rates and nutrients to the cells. Mostly the constituents used in FBBs can be of three different types: (i) inert core on which the biomass is produced by cell attachment. (ii) Porous particles in which the biocatalyst is entrapped. (iii) Cell aggregates/ flocs (self-immobilization). Some problems occurred in the packed bed reactor such as high liquid pressure drop, channelling, clogging, compaction of bed is completely prevented in fluidized bed reactor. Operation is in continuous state with temperature gradient and uniform particle mixing. FBB are same as bubble column reactor

with expanded cross section area at the top of the vessel so as to recirculate the liquid that is constantly pumped from the bottom of the receptacle at a velocity that is satisfactory to preserve them in suspension (Chisti 2010). Agitation of the medium is supported with the action of the pump in this bioreactor. FBB is one method for sustaining high biomass concentration and excellent mass transfer in continuous process. The concentration of the biocatalyst is significantly greater and washout limitations of free cell systems is affected (Gibilaro L.G, 2001). FBBs provides lesser attrition of solid particle than the conventional mechanical stirrer reactor and also volumetric productivity is higher than the packed bed reactor. There are so many examples of the FBBs use in bioprocess improvement. The efficiency of fluidized bed reactor depends on the attachment of particles that are maintained in suspension by an upward flow rate of the fluid to be treated. These particles are also called as biofilm carrier either they are inert core on which the biomass is created by cell attachment; or porous particles in which the biocatalyst is entrapped (self-immobilization).

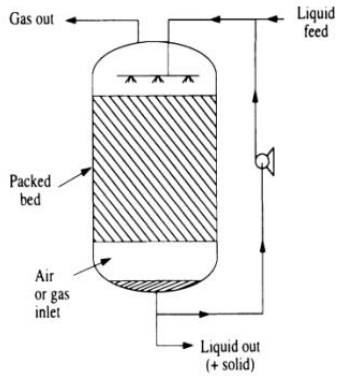


Fluidized bed reactor (Kwong W.H, 2000).

Packed bed bioreactor:

Packed bed bioreactor is well known as fixed bed bioreactor. It is normally used in wastewater engineering with biofilms attached. The use of packed reactor gains significance after whole cell immobilization technique when it is demonstrated. The nutrients are fed from the top or bottom with immobilized biocatalyst packed in the column. The packed bed reactor are commonly used with the immobilized cells. The reactor constitute a bed of packing, made with glass, ceramic, polymer, natural material and they exist in various size and shapes which

allows the flow of fluid from one end to other end. Packed bioreactor can run in the dribble flow mode or in the submerged mode with aeration. The flow rate in the channels can be increase to remove external mass transfer limitation in the adjacent liquid film. The rate of high pressure drops, at the same time, plugging can be avoided in the reactor (Wang G et.al, 1992). During operation, due to modifications in the bed porosity variation in the flow characteristics arises in the packed bed bioreactor. Packed bed belongs to the group of plug flow reactor where backmixing is not present, but in this reactor slight backmixing arises which affects the attributes of the fermentation. They are normally used as soon as substrate inhibition administers the rate of reaction Several modification are made to the reactor such as tapered bed are used to decrease the pressure drop, horizontal bed, inclined bed, rotary horizontal reactors have been tested with limited achievement.



Packed bed reactor (Siegel M.H & Robinson C.W, 1992)

Membrane bioreactor:

Membrane bioreactor contains hollow fibre system which is developed for the immobilization of the yeast, enzymes and bacteria. The hollow fibres are prepared with cellulose acetate with a uniform wall matrix or from polysulfone fibers or acrylic copolymer with asymmetric wall configuration (Raj and Karanth 2006). Advantages of hollow-fibre reactor for microbial system are biocatalyst regeneration and immediate separation of biomass and the product. Major drawbacks of the reactor are, they are difficult to control and monitor the growth and breakdown of the culture and excessive development of microorganism because of the less oxygen transfer rates. The metabolic activity of cells is inhibited by accumulation of the toxic products in the hollow fibre. In various microbial cell production membrane bioreactors has been widely used (Chang and Furusaki 1991). Some investigation are reported on the production of the probiotic cells in membrane reactor, such type of system supports volumetric productivities and high cells yield.

OBJECTIVES:

1. To Design and fabricate the fermenter
2. Standardization of idli fermentation process with idli fermenter
3. Mass and energy balancing of fermenter
4. To Calculate Heat and mass transfer in fermenter

MATERIALS AND METHODOLOGY:

MATERIALS:

AISI SS stainless steel 316L plates

AISI SS stainless steel 316L Pipes (1 inch size)

Butterfly valve

Oxygen concentration probe

Digital pH meter

Pressure measurement gauge

Digital thermometer

AISI SS stainless steel 316L rod (1 inch thickness)

Motor 1/2 HP

Transport pump (1/2) HP

METHODOLOGY:

The methodology outlined as follows:

1. Literature survey:

Literature survey of idli traditional food, idli properties, production properties, idli batter fermentation.

Fermenter designs system, working principles, types of fermenter.

2. Selection of material:

Fabrication of materials required for food processing equipment, process piping and efficacies are standardised, sanitized (smooth, non-porous, non-absorbent, non-toxic, easy cleanable, resistant and non-mold supporting), inert (non-reactive to oil, fat, salt, etc.; may not contaminate the food by conveying harmful substances to it, nor affect its organoleptic characteristics), resistant to chemical (corrosion proof; non-degrading and maintaining its original surface finish after sustained contact with product, process chemicals, cleaning agents and disinfectants), physically robust and mechanical stable and easily to conserve. All the exteriors are exposed to straight contact with the product as well as indirectly impacted surfaces from which streaked product, condensate, solid or liquid particles may run off, drop off, or may fall into the product - are being constructed of materials that meet the highest hygienic requirements, while resources used in the fabrication of components located in the non-food contact area may be of a lower grade. Especially chrome-nickel or chrome-nickel-molybdenum steels are used for the construction of equipment and machining in the food industry. Stainless

steel AISI SS 316(L) is commonly preferred as construction material for food processing equipment.

3. Designing of fermenter:

I will be starting by analysing the combined flow diagram to categorize the necessity of the equipment. After the needs are recognized, they are described in the form of well-designed requirements which is a detailed description of what the equipment has to do. Functional necessities specify the needs in technical terms and in this methodology they are specified in two stages. Firstly, we set the target functional requirements. Then generation of concepts for the equipment and select one of the concepts. Once a concept has been selected, the target functional requirements are refined in the context of the selected concept. These refined equipment functional requirements are detail designed. Fermenter will be designed to meet the sub-system related requirements while satisfying the product and process related requirements.

4. Experimental set-up:

Fabrication of fermenter, by introducing agitation system, baffles, cooling jacket and monitoring loops such as pH meter, temperature measurement probe, oxygen concentration probe, rota meter etc. These all material will assembled as design.

5. Study, inspection and testing:

Overall study of will fermenter, calculation of heat and mass transfer, energy and mass balancing of fermenter. Inspection and testing of fabricated fermenter.

RESEARCH OUTCOMES:

In India traditional foods such as Idli, Dosa prepared from rice grain mostly preferred as their staple diet. Design and development of equipment for diverse Indian traditional foods, which can be a specialized area of research for the future work. Design of fermenter will be responsible for a growth of organism in controlled environment, or a definite mixture of microorganism, to achieve a desired product. Time consuming and the tedious process of idli fermentation will automated, hence human work force is eliminated in every possible situation, leading to an increase in the efficiency to a large extent. Production of idli batter for mass food preparation and by considering cost, usability, safety, easy handling and hygiene. Texture and aroma of the idli will improve.

Different parameters which are essential for the preparation of the idli batter such as soaking time, swelling ratio, moisture content in batter, mixing and fermentation time will discussed.

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