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Contents :

→A short review of microbial physiology and genetics

→A review of general metabolic pathways, control and application in industrial processes.

→Enzymes, microorganism utilization and their industrial importance

→Microbial growth curve and its importance

→Fermentation technology and its applications

→Industrial production of secondary metabolite: antibiotic . vitamins , organic acids.

→Methods for screening and selecting microorganisms of industrial importance.

Industrial biochemistry

Industrial biochemistry, microbiology and biotechnology involve the use of microorganisms and other micro and macro-molecules purposely to achieve specific goals. Basically, it involves:

(i) Production of new products with economy and/or social values.

(ii) Improving the standard of living and that of the environment under general acceptability

Industrial biochemistry focuses on production of products such as foods, drinks, pharmaceuticals and medical compounds e.g antibiotics, hormones, solvents, organic acids and enzymes that have **industrial processes microorganisms are often used simply because**

i-they are easier to handle (ii) easier to cultivate (iii) easier to manipulate

Most microbes employed are usually isolated from nature and then modified using classical mutation and/or selection procedures.

Analysis of the microbial cell composition have revealed that over 90% of the cells dry weight is made up of both micro and macro elements which includes C, O, N, H, S, K, Zn, Mg and Ni.

The C, O, N, H, S and P for instance are important component of carbohydrates, lipids, proteins and nucleic acids.

The K is required for activity of some enzymes while Mg could serve as cofactor for many enzymes.The S is needed for the synthesis of amino acids such as cysteine and methionine.

The Fe is usually part of cytochrome.Ca2+ ion contributes to the heat resistance properties of some bacteria endospores. The Zn2+ ion is usually present at the active site of some enzymes.The N is required for the synthesis of amino acids and NH3.Apart from these elements, microorganisms also required other source(s) for growth, in order reflect some special nature of their morphology. Other compounds such as vitamins are also utilized by microbes. For instance, biotin is necessary for

carboxylation of one carbon metabolism in *Leuconostoc mesenteroides* while folic acid which is for transfer of acyl group is required by *Lactobacillus casei.*

More so, thiamine (vit. B1) is involved in the transfer of aldehyde group in *Onchomonas mellamensis* while pantothenic acid serves as precursor of CoA in paramecium species.

ENZYMES AND MICROORGANISMS UTILIZATION IN THE INDUSTRY

It should be noted that industrial pracises are often confidential and information from any publication with regard to any industrial processes may be scarce or negligible. However, enzyme preparation of suitable purity and cost can be chosen in such a favorable case so as to achieve the desired chemical conversion without formation of toxic or dangerous or deleterious side products. This is often obtained by putting factors such as temperature, pH as well as activator(s) and/or inhibitor(s) at the right level and range. Enzymes have been known to excel in their ability to alter chemical components of foodstuffs.

For instance, the protein, fat and cellulose presence in food are ready made substrate for protease, lipases and cellulase respectively. Furthermore, most natural products have been known to be biodegradable due to the action of enzymes inherent in environmental microorganisms. Thus, production of substances of good economic, social and commercial values in the industrial processes have been made possible by combining the right organism and inexpensive substrate (like some waste product e.g mollases, saw-dust) and proper environment for both the enzyme and organisms involved in the industrial process. For instance, in fermentation, transformation of organic raw materials (substrate) by microorganism is usually carried out in a controlled favorable environment (created by fermentor) in order to form desired end product(s).

IMMOBILISING ENZYMES

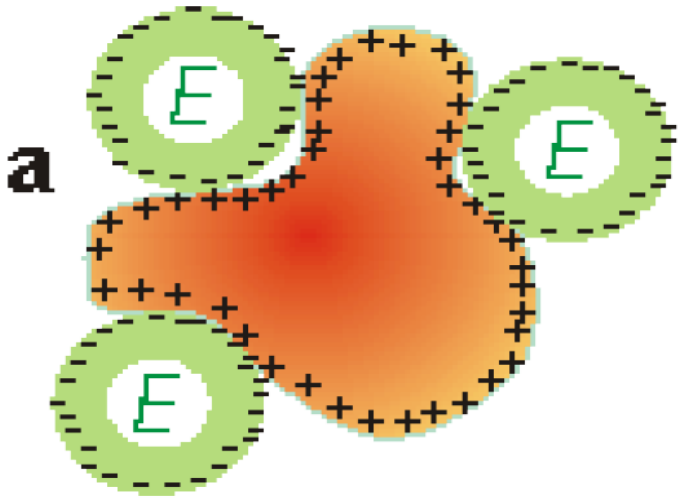
Immobilized enzyme

- **Enzyme attached to an inert, insoluble material such as calcium alginate**
- **Provides increased resistance to changes in conditions such as pH or temperature**
- **Allows enzymes to be held in place throughout the reaction,**
- **Easily separated from the products and may be used again**
- **A very efficient process**
- **Widely used in industry for enzyme catalysed reactions**
- **An alternative to enzyme immobilization is whole cell immobilization**

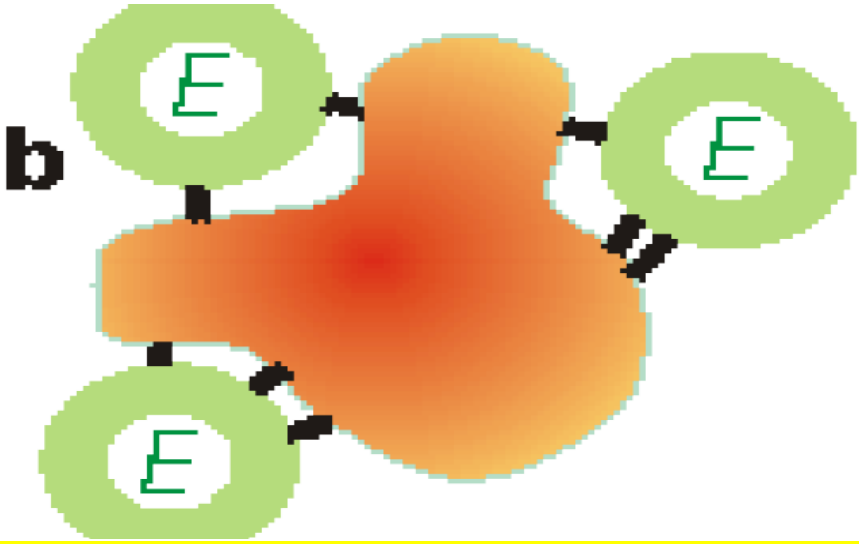
Methods of immobilization

There are four principal methods availablefor immobilising enzymes:

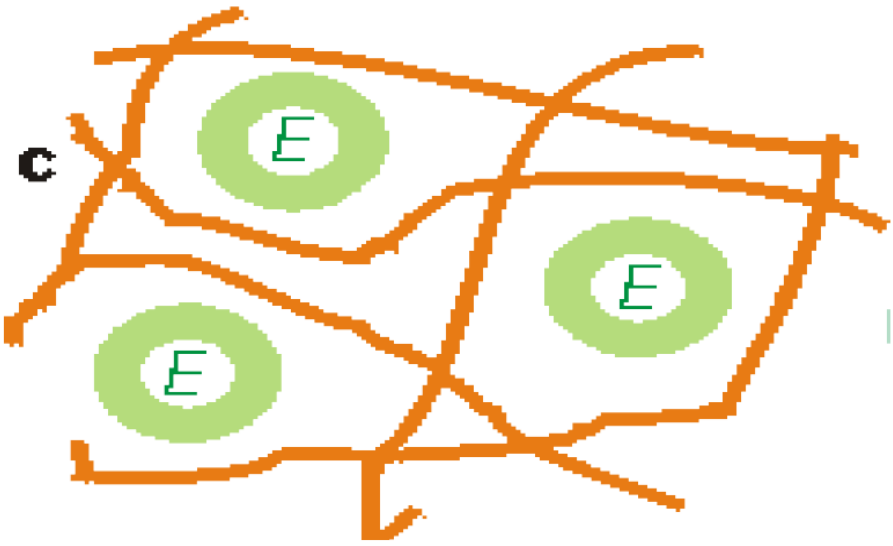
a- Adsorption b-Covalent binding c-Entrapment d-Membrane confinement



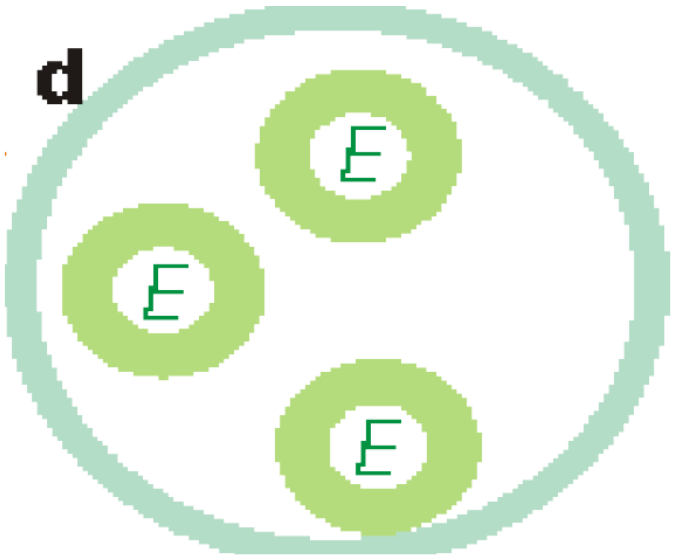
a. Adsorption:The enzyme (E, greenish) is non-covalently adsorbed to an insoluble particle (solid porous support) (reddish)



b-Covalent binding : The enzyme (E, greenish) is covalently attached to an insoluble particle (solid porous support) (reddish)



c Entrapment : The enzyme (E, greenish) is entrapped within an insoluble particle porous polymeric matrix (cross-linked polymer, brownish)



d-Membrane confinement: The enzyme (E, greenish) immbeded within a semipermeable membrane

z

Details were listed in the chapter of enzymes immobilization taken before (either normal. matrix Or nano-particles are used.

Also , the factors aaecting enzymes activities and regulation can be included herin

Please list contents of these chapters here in

CHOICE OF ENZYME AND ITS CONTROL

Substantial biochemical efforts are needed in order to understand the choice of enzyme in the context of the process or products desired. This required fundamental research efforts into classical parameters of enzyme kinetics under working condition such as pH and temperature optimum, Km, Vmax, presence or absence of inhibitor(s) and/or activator. Also, the structure and nature of enzyme in relation to its mode of catalytic functions needs to be understood. In addition, in most cases, before an enzyme is added or used in food or food related processes, its level of toxicity is normally assessed

It should be noted that the task of regulatory machinery is a bit complex and the pathway must be regulated and co-coordinated effectively such that all the cell components and other required materials would be present in precisely or relatively correct amount. Furthermore, a microbial cell is expected to respond to the environmental changes by using the nutrients present at a particular moment. It therefore meant that it must possess ability to synthesis as well as alter biosynthetic activity in response to changes in nutrient availability.

Note that regulation is necessary for the enzyme or cultivated cells to

(i) Conserve microbial energy and materials (ii) maintain metabolic balance

(iii) prevent over/under production of materials (iv) save cost

(v) avoid production of toxic substances. e.t.c

For instance, if a particular energy source is unavailable, the enzyme required for its use(s) are not needed and further synthesis of such is a waste of C, N and energy. Similarly, it will be extremely wasteful for microorganism to synthesize the enzyme required to manufacture a certain product if that product(s) were already present in adequate amount.

Note that there are at least three (3) means of controlling or regulating enzymes of industrial importance these are:

(i) feedback inhibition (ii) covalent modification (iii) allosteric control or regulation

Feedback inhibition: This is a process whereby a reaction pathway is inhibited by the final product. It usually involves inhibition of the enzyme catalyzing the first or earlier part of the pathway. **OR Feedback inhibition is the process** whereby the end product control the metabolic flux by inhibiting one or more of the enzyme catalyzing the first reaction of the pathway.

There exist at least four (4) types of feedback inhibition namely:

(i) sequential feedback inhibition (ii) concerted feedback inhibition

(iii) cumulative feedback inhibition and (iv) synergistic feedback inhibition

The principal uses of enzymes in industries involved in the :

1-For alcoholic beverages production 2- For bread making 3-for cheese making

4- For meat tenderizing 5 - As sweetners 6- For clarification of beer, wine and fruit juice

6-For production of detergent

7- for medical application e.g use of trypsin as an anti-inflammatory agent and wound cleanser; streptokinase from streptococcus haemolyticus is used to relief peripheral thrombosis.

The summary of some enzymes with their corresponding industrial applications is given below:

INDUSTRIES	ENZYMES	USES
Baking	fungal protease	soften dough
	Fungal α-amylase	general improvement
	Lipoxidase	whitens bread
Brewing	bacterial x-amylase	liquefaction cereal
	Bacterial protease	adjuncts
	Fungal amylo-glucosidase	removal of dextran from wort or beer
	Papain	chill haze stability
	β-glucanase	lowers viscocity of wort or beer
Syrups	bacterial α-amylase	solubilizes starch at high temperature
	Fungal amyloglucosidase	to complete the conversion of starch
	Inveetase	to convert sucrose to invert sugar
Cheese	rennin	curds milk by precipitation
	Catalase	removes H202 from milk
Ice cream	lactose	to remove crystallised lactose
Fruit	pectinase	general improvement
Vegetable	cellulose	softening and flavour promotion
Egg	glucose oxidase	removes glucose.
Meat	papain	tenderization
Textile	bacterial α-amylase	desizing
Paper	bacterial α-amylase	dextran adhesive
Laundering	bacterial proteases	protein stain removal
Medical	Many enzymes	various uses

The reactor can be used to caltivate a given cell type (bacteria,) to synthesize single cell protein, drugs and others. Also, inside the reactor, immobilized enzymes to catalyze a given enzymatic reaction (the details will be summarized below:

REACTORS

Introduction

Almost all industrial processes contain three operation levels.

Raw material ⇨ (Cleaning operation) ⇨ (Chemical reaction) ⇨ (separation Unit) ⇨ Product

What does chemical reactor design means?

Reactors

- **It is the vessels in which the biotechnological or industrial biochemistry processes are done.**
- **The most important component in the industry.**
- **There are the upstream units**
- **There are also the downstream units.**

Quality of good Reactors

High productive capacity

1-Depends on output which is expressed by quantity of raw material consumed per unit time or the quantity of product obtained per unit time.

2– Output can be increased by increasing the size of the reactor

There are 3 problems associated with the big sized reactors:

1– Space to place raw material 2– Mixing of raw materials

3-Stress on the material of the reactor or strength of the material.

However, the big size reactor has some advantages

1– Reduces cost of production 2– Reduces time 3– Reduces labour of production

Big size reactor has high operation intensity

– Is the ratio of production capacity to that of production parameter (e.g. production time or product quantity)

– Entails

– High product yield

– Maximum selectivity, in case of presence of multiple products, so that the condition will favors the selection of the desired Product.

Minimum power consumption

– Power is used for mixing, maintaining temperature, refrigeration, etc.

– The Power used must be as low as possible.

Easy to be controlled

– To reduce accidents – To reduce personnel number

– Should be automatically controlled

Cheap or low cost of production

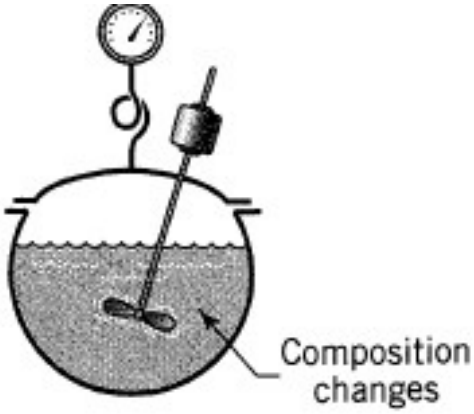
– Material of the reactor should be cheap – Running cost should be low

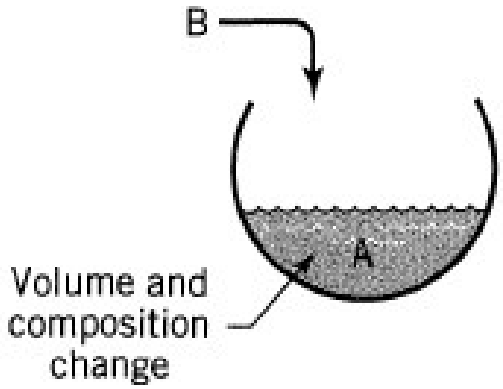
Types of reactors

- Batch reactor
- Continuous reactor

A.Batch reactor : uniform composition everywhere in reactor but this composition changes with time.

B-Semi batch reactor : in semi-batch, one reactant will be added when reaction will proceed.



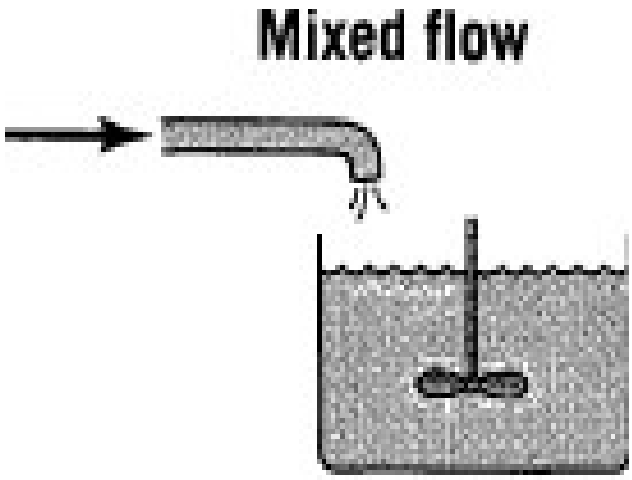


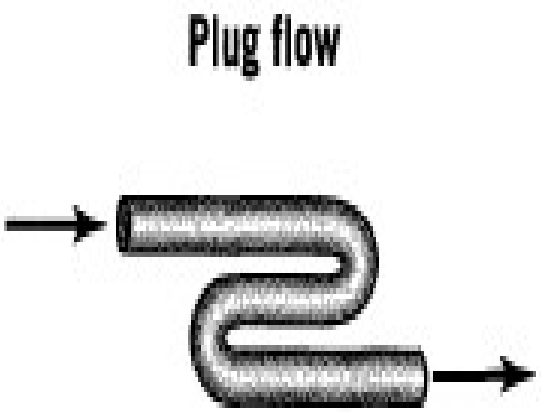
Types of reactors

2. Continuous reactor

a.Mixed flow: This is uniformly mixed , same composition everywhere, within the reactor and at its exit end.

b. Plug flow : Flow of fluid through the reactor with order, i.e. one by one, ***so that only lateral mixing of the products*** is possible.





Continuous reactors (continued):)

- Fresh media is continuously added and bioreactor fluid is continuously removed.
- Cells continuously receive fresh medium and products and waste products and cells are continuously removed for processing.
- The reactor can thus be operated for long periods of time without having to be shut down.
- Many times more productive than batch reactors.

Continuous reactors (continued):)

- The growth rate of the bacteria in the reactor can be more easily controlled and optimized.
- Cells can also be immobilized in continuous reactors, to prevent their removal.

A continuous-culture laboratory setup

BACTERIAL GROWTH CURVE

Since industrial processes involved the use of microbes,, it is important to have idea of the nature of their growth pattern in order to know when and how best to cultivate, manipulate and handle them for the required process.

In the laboratory for instance, under favorable conditions, a growing bacterial population is usually double at regular interval. Also note that the growth is usually by geometric progression i.e 1, 2, 4, 8, 16 e.t. c. This type of growth is called exponential growth and in most cases, it is only part of bacteria life cycle and not total representation of the normal pattern of bacterial nature.

When a fresh medium is inoculated with a given number of bacteria cells and the population growth is monitored over a given period of time. The plot of logarithm of viable cells/ml against time (hrs) could be represented as shown below:

There are four (4) characteristic phases of the growth curve namely:

(i) Lag phase (ii) Exponential phase (iii) Stationary phase (iv) Death phase

i-LAG PHASE: Immediately after inoculation of the cells into fresh medium, the population remain temporarily unchanged. Although, there is no apparent cell division occurring, however, the cells may be growing in volume or mass, synthesing enzymes, proteins, RNAs e.t.c. This will bring about increase in metabolic activities. Note that the length or period of lag phase depends on some factors such as :

(i) the size of the inoculums

(ii) the time necessary for the cell to recover from physical damage or shock during transfer

(iii) the time required for the synthesis of essential co-enzymes or division factors (iv) the time required for the synthesis of inducible enzymes that are necessary to metabolize the substrate presence in the medium.

ii-EXPONETIAL (LOG) PHASE: This is the portion of the bacteria growth curve that demonstrates a pattern of balanced growth wherein all cells are dividing regularly by binary fission and are grown by geometric progression.

The cells divide at a constant rate depending on:

(i) the composition of the growth medium (ii) the condition of inoculationThe rate of exponential growth of a bacterial culture is expressed as Generation time (G) which is defined as the time (t) per generation and given by the expression:

G=t/n Where n is the number of generation and is equal to (n=3.3 log b/B.

Where t = time interval in hrs or mins B = number of bacteria at the beginning of a time interval b = number of bacteria at the end of time interval G = number of generation (number of times the cell population doubles during the time interval)

iii-STATIONARY PHASE: Since exponential growth curve cannot continue forever, the population growth is therefore limited by at least three (3) factors namely:

(i) availability of essential nutrients (ii) accumulation of inhibitory metabolite or end product

(iii) lack of biological space

(It should be noted that it is during the stationary phase of the growth curve

(i) that the bacteria produces secondary metabolites such as antibodies

(ii) that the spore forming bacteria induces or unmasks the activities of several genes that may be involved in other metabolic processes.

iv-DEATH PHASE; If incubation continues after the population reaches stationary phase, a death

phase is bound to follow during which the viable cells population declines. This usually comes into play since there would not be enough biological space and the nutrients available will not be sufficient for the existing/viable cells.Note that the generation time for bacteria varies from about 12 minutes to 24 hrs or more depending on the :

(i) culture medium (ii) temperature (iii) pH (iv) Microorganism itself.

The generation time for some bacteria under optimum conditions is given below:

BACTERIUM	MEDIUM	GENERATION TIME
Escherichia coli	glucose-salts	17 minutes
Streptococcus lactis	milk	26 minutes
Bacillus megaterium	sucrose-salt	25 minutes
Streptococcus lactis	lactose broth	48 minutes
Rhizodium paponicum	mannitol-salt	344 minutes
Treponema pallidum	rabbit testis	1980 minutes

The importance of these phases is that it will enables one to have ideas as to the appropriate time to culture, harvest and manipulate the microorganism concern in relation to the desired enzyme(s) and/or other product(s).

Practical example

What is the generation time of bacteria population that increases from10,000 cells to 10,000,000 in four hours of growth?

Solution:

Since n = 3.3 log b/B

Then n = 3.3 log 10,000,000/10,000

Therefore n = 3.3 log 1000

Thus, n = 3.3x3= 9.9

Therefore G = 4/9.9= 0.404 hrs= **24.24 minutes**

CONTROL OF MICROBIAL GROWTH

The control of microbial growth could be effected basically by the use of either

(i) chemical agents or **(ii) physical agents**

This could involve the use of inhibitory agents or by physical killing agents.

Agents that kill cells are called 'cidal'agents while those that inhibits growth of cell without killing the are called 'static' agents.

Definition of terms:

Sterilization: This is the process by which living cells, viable spores and viruses are either destroy or remove from an object or habitat in such a way that the object will be totally free from any form of viable microorganism. Chemical agents used to sterilization are called sterilant

Disinfection: This is the killing, inhibition or removal of micro-organism that may cause disease and the chemical agent used for that are called disinfectant.

Note that a disinfectant does not necessarily sterilize an object because

(i) viable spores and a few micro-organisms may remain and

(ii) disinfectants are normally used on inanimate objects

Antiseptics: These are chemical agents commonly applied to tissues to prevent infection by killing or inhibiting the growth of such pathogen. Antiseptics are generally not as toxic as disinfectants since they do not, in most cases, destroy the host tissues.

Physical methods of control includes among others;

(i) application of heat (ii) low temperature (refrigeration and/or freezing

(iii) filtration (iv) Radiation.

First application of heat: Use of moist or dry heat has been known to be able to kill viruses, bacteria and fungi. Exposure to boiling water for about 10 minutes is enough to destroy vegetative cells but may not be high enough to destroy bacteria endospores. Most food processing industries used to combine the two methods of moist and dry heat applications in order to eliminate completely the risk of contamination.

Dry heat has the advantages in the it can be used to sterilize compounds like powder and oil.

Also, it can be used to on glass ware and metal without corrosion.

Second refrigeration and/or freezing: Low temperature is only good for short term storage of food and other items since it only slows down microbial growth. However, freezing at about 200C or lower would stop microbial growth completely. Thus, freezing is a very good method for long term storage, if properly carried out.

Thirdly, filtration: This is an excellent way of reducing microbial population especially in solution of heat sensitive materials. Two types are known namely:

(i) Depth filter which consist of fibrous or granular materials.

(ii) Membranes filter which consist of porous membrane made of cellulose acetate,cellulose nitrate or other synthetic materials. It is commonly use for oil, antibiotics and other heat sensitive materials or solutions.

Fourth, Radiation: These are of two types:

(i) Ultra-violent which is used in only a few specific situations because it burn skin and could damage the eye. Though, commercial UV unit is often used in water purification

(ii) Ionizing radiation which could penetrate and sterilize subjects by destroying the cell nature be it the endospore or the vegetative cells. Gamma radiation from cobalt-60 source is used in cold sterilization of antibiotics, hormones and plastic disposable

substances such as syringes.

USE OF CHEMICAL AGENTS in controlling microbial growth

Although, chemicals agent meant to be used should be toxic to the pathogen, it should not be toxic to the people. Effective and continuous use of some chemical agents has led to frequency of antibiotic resistance in some cases. Examples of chemical often used are phenolics and hexachlorophene. Some of these agents act by denaturing proteins. However, they have disadvantages in having offensive odor and in being able to cause skin irritation and brain damage.

The summary of some chemicals often used in controlling microbial growth is given below:

CHEMICAL	ACTIONS	USES
Ethanol	dentures protein and solubilise lipids	antiseptic used on skin
Isopropanol	denatures protein and solubilise lipids	antiseptics used on skin
Formaldehyde	reacts with –NH2, -SH groups disinfectant	kills endospore
Chlorine gas	oxidizing agent	disinfect drinking water
HgCl2	inactivate protein	disinfectant on skin
NH4 compounds	disrupts cell membrane	skin antiseptics
Ethylene oxide	alkylating agent	disinfectant on rubber/plastics

Commonly used preservatives are also summarized below:

PRESERVATIVES	CONCENTRATION	USES
Propionic acid	0.32%	antifugal agent in bread, cake
Sorbic acid	0.2%	antifugal agent in syrup, cheese
Benzoic acid	0.1%	antifugal in margarine, relishes
Lactic acid	0.1-10%	antimicrobial in yoghurt
Sulfur dioxide	200-300ppm	antimicrobial in dried fruits
Sodium nitrite	200 ppm	antimicrobial in meat and fish
Sodium chloride	unknown	prevents spoilage of fish, meat
Wood smoke	unknown	prevents spoilage of fish, meat.

COMMONLY USED CHEMOTHERAPEUTIC AGENTS

CHEMICAL CLASS	EXAMPLE	MODE OF ACTION
B-lactams	penicillin, cephalothin	inhibits cell wall synthesis
Clavulanic acid	clavamox, amoxicillin	inhibits betalactomases
Aminoglycosidase	streptomyces	inhibits translation
Macrolides	erythromycin	inhibits translation
Rifamycins	rifampicin	inhibits transcription
Tetracyclines	tetracycline	inhibits translation
Chloramphenicol	chloramphenicol	inhibits translation.
Monobactams	aztreonam	inhibits cell wall synthesis

FERMENTATION AND ITS INDUSTRIAL APPLICATIONS

Fermentation is a metabolic process in which energy is derived from partial oxidation of an organic compound using immediate as electron donors or electron acceptors. It occur by substrate level phosphorylation in which the substrate is oxidized and ATP is form directly from the reaction. A typical example is the conversion of glucose to two molecules of lactate which is accompanied with the production of two mole of ATP

Glucose→2 pyruvate→2 lactate (resultant 2ATP is produced).

Note that abundant and renewable sources of fermentable carbohydrate are plant starch, cellulose from agricultural wastes; molasses from sugar and whey fro cheese manufacturing industries.

Processes of fermentation take place in a Fermentor or Bioreactor.

A fermentor is described as a vessel designed to carry out fermentation processes under biological controlled conditions. It is designed to maximize yield. It is operated under aseptic condition with adequate agitation and regular or appropriate supply of nutrients. It has pH and temperature control units or system with drain or over-flow facilitiesA fermentor has adequate mass transfer and work best in sterile environment. It has gentle heat transfer with optimum mixing with low and uniform shears. The diagram of a typical fermentor is shown below.

Classification of bioreactor could be based on a number of criteria among which are:

(i) type and form of biocatalyst e.g free cells in submerged

(ii) configuration of the bioreactor such as the tank height, diameter and the column size.

(iii) The nature of energy input required i.e in form of liquid, gaseous or combined

(iv) Hydrodynamics i.e perfect mixing or partial mixing or no-mixing al all.

(v) The mode of operation which could be in form of batch or continuous or feed-batch

mode of operation.

TYPES OF BIOREACTOR/FERMENTOR

(i) STIRRED TANK BIOREACTOR (STB): This is used industrially for production of human therapeutic proteins e.g tissue plasmogen activator and usually made of stainless steel constructed with a working volume of about 2000-5000 litres.

(ii) AIR LIFT BIOREACTOR (ALB): It is similar to STB, but in term of dimension is usually longer than STB and it has a kind of bullet shape, thus, uses air sparked at the bottom as a mixing device.

(iii) FLUIDIZED BED BIOREACTOR (FBB): This is often a plastic bioreactor used in industrial up-stream processes on cells that are fixed in a compartment or media which is constantly pumped into the bioreactor, while the product is also constantlywithdrawn and pulled for down-stream process.

(iv) HOLLOW-FIRBRE BIOREACTOR: In this case, the cells are grown inside hollow fibre or tubes and media is pumped either through the hollow fibre and the product is constantly withdraswn and pulled for down-stream processing

(v) PACKED CELL BIOREACTOR (PCB): This is commonly used with attached biofilms especially in waste water engineering. It involved packing of immobilized bio-catalyst in a column after which it is fed with nutrients be it from top or below.However, one of the disadvantage is the change in flow characteristics that could be observed as a result of alteration in bed porosity during operation.

SELECTION OF BIOREACTOR

The preliminary choice of a bioreactor depends on a number of factors which includes:

(i) physiological state of the cell (ii) sterility (iii) value or desired product

(iv) culture and culture medium metabolic state (v) product formation kinetics

(vi) processing method i.e if it is batch, fed-batch or continuous method

(vii) reaction and processing area or application (viii) bubbles dispersion and foam control

(ix) biological i.e substrate dosage and energy dissipation.

SOME UNIQUE ASPECTS OF BIOLOGICAL PROCESSESS IN A BIOREACTOR

It should be noted that certain substances such as inhibitors, effector molecules, precursors and metabolic product(s) could influence the rate and mechanism of reaction as well as intracellular regulations taking place in the bioreactor. Also, some microorganism can metabolized unconventional or even contaminated raw materials to yield useful products.

Microorganisms can adapt the structure and activity of their enzymes to the process condition(s), thereby making the selectivity and productivity change. In some cases mutation could set in especially under sub-optimal biological conditions.Furthermore, cell growth, the structure of intracellular enzyme and product formation depend not only on the nutritional needs of the cell but also on the maintenance of optimum biological condition within narrow limits. Finally, it should be noted that microorganisms are frequently sensitive to strong shear stress, thermal and chemical influences.

APPLICATIONS OF FER:MENTATION: The applications include

(i) production of organic solvents such as citric and lactic acids

(ii) production of foods and food products such as ogi, fufu, gari e.t.c

(iii) production of condiments

(iv) production of dairy products such as yoghurt, butter milk, sour cream

(v) processing of meat and fish to refined products like sausages, cured harms, fish sauce

(vi) production of beverages and related products such as beer, ale, vinegar, palmwine

(vii)pharmaceutical industries for producing compound such as antibiotics and vaccines

(viii) food supplement production such as production of single cell protein, amino acids,vitamins in production of organic solvents e.g acetone, butanol ethanol e.t.c

INDUSTRIAL PRODUCTION OF SOME METABOLITES

1. Production of cyanocobalamin (vitamin B12).

VitaminB12 is a water soluble vitamin. It contain a molecule of cobinamide linked to a molecule of nucleotide which has 5, 6-dimethylbenziminazole as its base instead of a purine or pyrimidine. The cobinamide molecule has a central atom of cobalt linked to a cyanide group and surrounded by four reduced pyrole ring joined to form a macro-ring. Although in nature, vitamin B12 is synthesized by microorganisms. However, for industrialproduction of a number of microorganism are also involved in its synthesis.Commercial production is by a continous culture method whereby two fermentors are used in a series. Each fermentor is kept for at least 60 hrs (for the operation).The first fermentor is usually operated under anaerobic condition while the second one is operated in aerobic condition.

The whole process involved a system containing glucose corn steep + betain (5%) + cobalt (5 ppm). All these are kept at pH 7.5. The fermentor will now be inoculated with *propionibacterium freudenreichin*. It will be allowed to undergo anaerobic fermentation for about 60-70 hrs. During this period, cobinamide produced from cobalt accumulates in the broth, thereafter the base (5,6-dimethylbenziminazole) could be added at 0.1% and the fermentor is now kept for another 50 hrs under aerobic condition. Durng this period, nucleotide is synthesized to yield about 20 ppm cobinamide. The culture is then acidified to pH of about 2.0-3.0, then gently heated and filter to remove cell debris. Finally, potassium cyanide at 5 ppm is added to the filterate

to give cyanocobalamine. N.B: In some cases, sodium sulfide mixed with the product solution so that cyanocobalamine will not be oxidized.

2. Amino acids derivatives e.g monosodium glutamate (MSG)

The first amino acid to be produced and commercialized is L-glutamate in which *Corynebacterium glutamicum* is used for successful production.***The biochemical pathway for the production of L-glutamate is shown below:***

Glucose→ →phosphoenolpyruvate→pyruvate→acetylcoA→citrate→isocitrate→xketoglutarate→ L-glutamate.

The flow chart for industrial/commercial production ia as thus:

Sugar tank→continous stirrer→buffer tank→seed fermentor→NH4, pH control unit→batch sterilizer→production fermentor→harvesting tank.

N.B: Some factors that may affect glutamate synthesis are pH , dissolved oxygen and NH4 concentration,

Also, surfactant (Tween 80) is normally added to control the onset of excretion of glutamate.

More so, when fermentation is over, broth containing glutamate form of NH4 salt is separated through down stream processing and monosodium glutamate is separated by elution with NaOH solution after which the monosodium glutamate is crystallized directly.

3. Production of organic acids e.g citric acid

One of the organic acids that could be produced commercially is citric acid and this could be **done through three (3) methods namely:**

(i) by liquid-surface culture fermentation process (ii) by submerged culture fermentation process (iii) by multi-tank system fermentation.

MULTI-TANK SYSTEM FERMENTATION

This is used for large scale production and required continuous fermentation process wherein cell growth and metabolic product occurring at different stages could be controlled and monitored.

The outline for citric acid production is summarized below:

Mixture of CHO, KH2PO4, MgSO4.7H20,Cu, Fe, pH 1.8-2.0 (inoculated with Aspergillus niger strain)→fermentor→fermentor broth (with added lime, (CaOH)) →calcium citrate→calcium sulphate+citric acid→citric acid→citric acid crystal→ crystalline sodium salt (anhydrous powder).

NOTES:

(i) CHO source could be cane juice, glucose, sucrose or molasses

(ii) After inoculation, the culture solution must be aerated by bubbling the air to allow maximum growth for the fungus

(iii) Calcium hydroxide is added to allow precipitate of citric acid in the form of calcium citrate

(iv) The precipitate is treated with sulphuric acid to precipitate to precipitate insoluble calcium sulphate

(v) Fe and Cu in the culture medium serves as essential cofactor for some important enzyme of citric acid cycle

(vi) Growth of A. niger on high concentrations of sugars and low concentrations of Fe3+ and Mn2+ gives high yield of citric acid

(vii) Fermentation is carried out aerobically.

IMPORTANCE OF CITRIC ACID: **Citric acid is used in:**

(i) food industries e.g fruit drinks, wine and confectionery

(ii) pharmacy e.g blood transfusion processes

(iii) cosmetics (astringent, lotions sharmpoos and hair setting fluids)

(iv) oil and gas (for clearing of pipes and also for reactivation of old oil wells).

4.Production of antibiotics

Antibiotics are defined as the complex chemical substances in forms of secondary metabolites, which are produced by micro-organism purposely to act against other micro-organisms. Four (4) major broad groups of antibiotics are most extensively used throughout the world and these are;

(i) penicillins (ii) tetracyclines (iii) erythromycins (iv) cephalosporin

Outline for the commercial production of penicillin is given below:

This is usually carried out in a fermentor which is meant to provide optimum growth condition for *P. chrysogenum* for its maximum yield. The following steps are to be followed:

(i) inoculate 100ml medium in 500ml flask with spores of *P.chrysogenum* strain and incubate at 25oC by keeping on a rotary shaker

(ii) after 4 days transfer the content to another 4 litre flask and leave for another 4 days

(iii) transfer to 800litre containing 500litre medium

(iv) after 3 days, use the contents for inoculation of about 180,000 litre medium kept in a fermentor (250,000 litre capacity)

(v) filter the content of fermentor after 6 days of inoculation

(vi) the filtrate containing penicillin is then extracted with amyl or butyl-acetate

(vii) from this, transfer the penicillin into aqueous solvent by extracting with phosphate buffer

(viii) then crystallize the penicillin out of the mixture.

Thus, the major steps are:

(i) preparation of the innoculum (ii) preparation and sterilization of medium

(iii) inoculation of the medium in the fermentor

(iv) forced aeration with sterile air during incubation

(v) removal of the mold mycelium after fermentation

(vi) extraction and purification of the penicillin.

PRODUCTION OF WINE FROM GRAPE

Grape→crush (to increase surface area) →alcoholic fermentation by addition of yeast) →aging→filtration→wine (the filterate).

PRODUCTION OF ETHANOL FORM CASSAVA

Cassava (peeling, washing) →milling→cassava flour (add water and α-amylase) →liquefaction(90-95oC, pH 4-4.5, at 400 rpm)→saccharification→cooling→fermentation→filteration→distillation→ethanol.

PRODUCTION OF ETHANOL FROM MOLASSES

Molasses (dissolution in water) → molassesin solution→fermentation of molasses for 2-3 days→filtration→distillation→ethanol.

PRODUCTION F BEER FROM BARLEY

Barley→malting→kilning→malted barley→brewing→separation of sweet wort →boiling of sweet wort(with hops added) →fermentation→concentration→beer.

PRODUCTION OF CHEESE FROM MILK

Milk→acidification→colouring→coagulation by renin→separation of curd from whey→addition of flavor to curd→compression of curd→aging→finished cheese

SCREENING AND STRAIN IMPROVEMENT IN INDUSTRIAL ORGANISMS.

Some screening methods are by:

(i) Enrichment (ii) Testing against susceptible organism (iii) Enzyme inhibition

(iv) Use of toxic analogues (v) Morphological changes in microbial test organism

(vi) Animal tests (vii) Assay of chemicals

However, some problems are often associated with the search for new metabolites of industrial

importance, and these include:Possibility of spending effort, time and money in discovering a metabolite whose value is already known. To avoid this, rapid tests like paper and thin layer chromatograph as well as proximate analysis of the content of the compound if carried out.

Another problem is that the potent compound may be present at low concentration.

Strain Improvement.

Several options are open to an organization pursing industrial biochemistry to help maximize its profit in the face of its competitor's race for the same market. The organization may undertake more aggressive marketing tactics, including more active packaging while leaving its technical procedures unchanged. It may use its human resources more efficiently and hence reduce cost or it may adopt a more efficient extraction system for obtaining the material from the fermentation broth. The operations in the fermentor may also be improved in term of a better medium, better environmental conditions, or better engineering control of the fermentor process. To appreciate the basis of strain improvement it is important to remember that the ability of an organism to make any particular product is predicated on its capability for the secretion of a particular set of enzymes. The production ot the enzyme itself depends ultimately on the genetic make-up of the organisms.

Improvement of strain can therefore be put down in simple terms as follows:

(i) selecting suitable producing strains from a natural population with the varying geneticconfigurations

(ii) manipulation of the existing genetic apparatus in a particular organism

(iii) regulating the activity of the enzymes

(iv) in the case of metabolites secreted extra-cellularly, increasing the permeability of the organism so that the material can find its way more easily into the environment.