Promosing biomass-based bio-butanol production technologies; improvement and research trends.

Dr. Nidhi Katyal,
Government P.G.P.G. College for Women, Rohtak
nidhigpgcw@gmail.com

ABSTRACT

There are proposed many ways to produce the four carbons Alcohol from different starting feedstock and substrates, bio-substrates, and microorganisms biologically prepared /synthesized bio-butanol and for enhancements regularly from one and half-century overcoming a challenge by various researchers. In this chapter, the characteristics and uses of bio-butanol, its all properties are compared with other fuels, feedstock, their types, and usage as biomass research is briefly discussed to show feasibility and use of the metabolic pathway. Also, species and various genetically modified strains are created with different feedstock and provide a better yield than bio-ethanol. Some fermentation techniques their applications and models are essential in the prediction of outcomes. Also, some required methods in Pretreatment, their feasibility techniques for various feedback were mentioned. The yield of bio-butanol in each process is calculated with limitations. Various other enhancements are going on for better work, thereby improving biotechnological advancements, or genetic engineering is also done accordingly.

Keywords: biobutanol, bio-substrates, feedstock, Pretreatment, and enhancement.

1. Introduction

Butanol is the most severe fuel added substance to supplant gas straightforwardly some bio-fuels resources counting as gas, ethanol, methanol, diesel, and Butanol moderately elevated warming worth, 30% added vitality than ethanol. Bio-butanol or biologically produced Butanol is a second-age alcoholic fuel with a higher vitality thickness and lower instability contrasted with ethanol. Butanol application is widely applicable to swap gas. It helps in reducing pressure on bio-ethanol, bio-diesel, and hydrogen. Some advancements help in security, as well as effortlessness utilization of technology is done. Butanol is a significant concoction of crude material and natural dissolvable, generally utilized in Industry, medication, and food (1). As a superior planned new biofuel than ethanol, Butanol has broad application prospects because of its great water-insolubility, low fume pressure, high calorific worth, and different qualities (2). Butanol can arrive at a higher blending rate with gas contrasted with ethanol fuel, and its vitality thickness is nearer to gas, which is more appropriate for the current fuel gracefully and dissemination frameworks. Simultaneously, Butanol is all the more ecologically inviting when contrasted with powers from oil refining and thus diminishes the discharge of ozone-depleting substances during the gas refining

measure (3). In this chapter many areas are explored to understand types of biomass as resource (substrate), many microbes including algae, comparison with conventially demanded and utilized, fermentation, its modes of application, enhancement methods, yield pathways, mathematical models and Economics of yield mentioned.

2. Bio-butanol: characteristics and uses

It is blended in a particular ratio with diesel or petroleum (gasoline) found better than ethanol in terms of separation at the base in case of water contamination in fuel. It is also helpful to facilitate the distribution stage of power, which is blended. It is easier in the case of n-butanol potential as the next generation of biofuel compared to ethanol (4). The various other experimental and engine functioning-based applications are investigated and proved and demonstrated the advantage of bio-fuel, its safety in usage, transportation, functioning, and the performance of engines; some properties like thermo-physical ones when compared with any specific blend ratio of gasoline and diesel (5).

Table1. Butanol comparison with conventional fuels

Fuel	Molecular formula	Density (g/mL) at 20°C	Boiling point (C)	Autoignition temp. (C)	Flash-point(^{o}C) at Closed cup	Heating value at Low temp. (MJ/kg)	Latent heating (kJ/kg at 25°C)	Flamm-ability limits (%volume)	Octane number
Butanol	C_4H_9OH	0.808	117.7	385	35	33.1	582	1.4–11.2	96
Gasoline	C_4–C_{12}	0.72–0.78	25–215	~300	−45 to −38	42.7	380–500	0.6–8	80-99
Ethanol	C_2H_5OH	0.790	78.4	434	8	26.8	904	4.3–19	108
Methanol	CH_3OH	0.796	64.5	470	12	19.9	1109	6.0–36.5	111
Diesel	C_{12}–C_{25}	0.82–0.86	180–370	~210	65-88	42.5	270	1.5–7.6	20-30

As per table 1, there are many physical properties of bio-butanol as fuel is compared with other powers, especially gasoline is more conventionally utilized fuel and easily flammable, more excellent heating value and less density then Butanol concluded not good energy than gasoline but if blended not more than 20% in gas and diesel achieved greater efficiency also reduces the non-renewable energy. Butanol also has a good octane number shows better flammability and calorific content (6).

3. Bio-Butanol production from feedstock

The high value of unprocessed feed is well thought-out one of the primary boundaries; business manufacturing of Butanol. Using cheaper and plentiful feed-stocks corn Stover can decorate system's trade and industry practicability (7).

Bio-technological treatment has permitted any microbe for less expensive resource feedstock or any proactive fuel (glycerol) in preference to complex or straightforward glucose. It is essential to understand those fermentation techniques the bare Substrate needed glucose or its derivatives also some from ingredients (8,9). Now, it is considered a negative approach to generate bio-butanol directly from food or its

sources. Butanol production from glycerol is inexpensively viable; use of metabolic pathways that exist Clostridium *pasteurianum* bacterium (10).

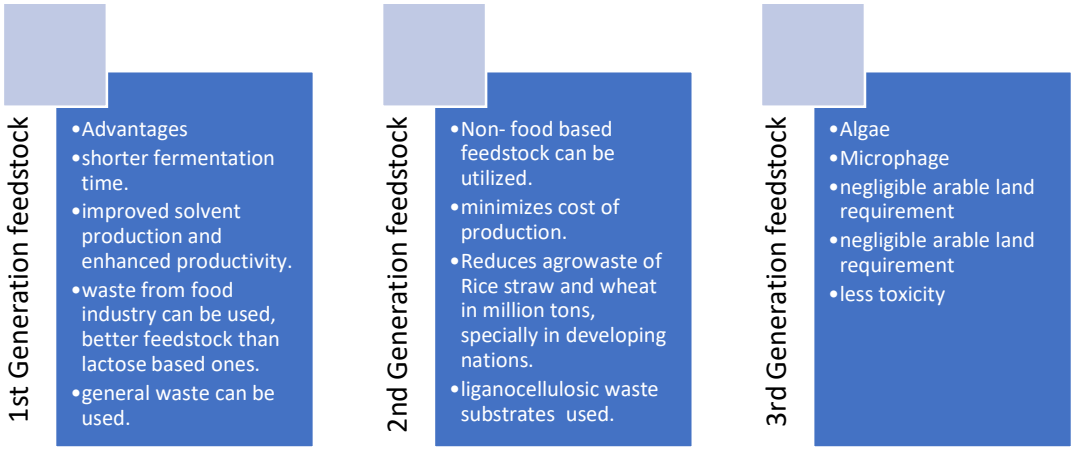

Figure 1: Demonstration of all three types of Generation of Feedstock

Instead, there is growing value and interest for some alternate source of this additive to fuel. In search of new energy and fuel resources (gasoline/food energy 11): waste management/ minimization, lignocellulose, lactic acid, and glycerol (12). This is treasured as a new resource valued as a great, confined waste product of biodiesel manufacturing (14). There is excellent up-gradation of market required for economical production of biobutanol also feasible to use metabolic pathways in Clostridium pasteurianum bacterium (15).

First-generation feedstock: Mainly, primary 1^{o} feedstock is waste taken from food and beverages industries. Feedstocks for A.B.E. fermentation are cereal grains, Sugarcane, and food industry wastes utilized. Optimum operating conditions and challenges associated with feedstocks and processes to produce bio-butanol. Food and its processing industrial waste act as attractive feedstock with extra advantage of waste management (16). i.e., wastes (a) Cane molasses having a concentration of sugars (50-55%) is better and most commonly utilized feedstock; fermenting to Butanol (17). (b) Cheese whey brilliant feed-stock over additional substrates (i.e., lactose) productivity for biobutanol (18). Productivity in the semi-continuous mode is higher. Also, results are better than batch mode (total production 1.34g/l as compared to 19.6g/l) in 72 hours. Here also improved yield of solvent and butanol productivity in cane molasses determined validates shorter time for fermentation also at industrial scale.

2^{o} Second-generation feedstock: Mostly utilized lignocellulosic biomass in bio-butanol production by large countries or higher cultivated area. This lignocellulosic biomass includes wood chips, grain residues, and agricultural waste may reduce production cost and requirement of food or related biomass (19).

United Nations Environment Programme,2015 an estimates $50*10^{7}$ tons of oil equal to $140*10^{7}$ tons of agricultural biomass. As per studies leading countries like Brazil, Costa Rica, Cambodia, and India are agro-waste producers. India has (415.5 million tons) agro-waste (almost equals 104 million tons of oil) producing nation (20).

Table 2: Table showing various biomass with % of Substrate and cellular components studied by different researchers.

Biomass	Cellulose and Hemicellulose %	Lignin%/ Other Components %	References
Algae as biomass	7.1 &16.3	1.52/Carbohydrate-60	23
Straw Barley	42/28	7/ Ash-11	89
Corn fibre	-/-	0.1/Starch-20 Non-starch-50-60	90
Corn Stover	38/26	23/Ash-6	95
Corn Cobs	44/31 Moisture-12.77	16/Ash-2.3	15
Degermed Corn	nil	-/starch-73,Ash-3	121
Rice bran	32/24	-/fibre-7-24 Moisture- 8.41	17
Rice straw	30/24	13/Ash-11.69 Moisture- 15	9
Rye Straw	37/4	22/-	58
Soy Molasses	-/-	-/Proteins-10 Fat-20 Mineral-10	106
Sugarcane bagasse Sugarcane Straw	47/16 43/15	27/sugars-19.7 23/Red. Sugars-25.1	10
Switch Grass	37/29	19/--	105

Rice straw(major agro-waste) is most deserved and better on any excellent source in case fermentable carbohydrates/sugars account in 667.6 million tons waste as compared to wheat straw 354.34 million tons(21) for biobutanol production. With Pretreatment 1% (V/V) H_2SO_4 (22) and gas stripping, there is continuous product recovery and enhancement of solvent recovery and bio-butanol produced by bacteria Clostridium sporogenes BE01, some inhibitors like acetic acid, furfurals, and formic acid decreased yield from 5.52 to 3.43 g/l of

Butanol(23). While in wheat straw, Qureshi et al. (2007) shown the work of approximately 12.0 g/l of Butanol and more than double production (25g/l of A.B.E. fermentation yield) without performing any detoxification process determined is better than Rice.

Demerits with lignocellulosic waste substrates are a) seasonal variation, b) geographical changes and position, c) necessity of huge arable land, d) superior Lignin content e) water supply(Sun and Cheng 2002(30), if these demerits are covered, there may be good economic conversion to Bio-butanol. Many demerits in above 1^o and 2^o feedstocks will put the need for 3^o feedstock and pursue economic benefits (24,25).

3^o third-generation feedstock: Algae is a potential source of green energy utilization due to its capacity to assimilate CO_2 and eliminate inorganic nutrients from effluents, non-feedstock, or maybe wastewater bodies (26). Some merits are a) negligible arable land requirement b) accessible in great measure globally c) negligible arable land requirement d) Higher carbohydrate e) less toxicity. The above characteristics make algal sp. more capable, and sustainable feedstock also fits bio-butanol and ethanol production (23).

Presence of alginate creates nuisance in converting microalgae into Alcohols so microalgae can easily used in production of butanol(27) so stain selection and optimization algal species in butanol fermentation. Algal species of Lyngbyalimnetica and Oscillatoria obscura in growth optimization experiments determined increased carbohydrates (0.316 to 0.691g/g) and biomass (0.279-0.652g/g) dry wt. nearly double (Kushwaha et al. 2017b). Such as some species can tolerate toxins (5-hydroxymethyl furfural) to some extent, others have very considerable low amount of toxic compounds (algal hydrolysate and furfural) thereby no toxification required. Growth optimization of some algal species for sugar and other substrates with carbohydrates content, i.e. Chlorella vulgaris (microalgae) treated with 1% alkali NaOH and 3% Acid treatment (H_2SO_4) and resulted production of bio-butanol (13.1g/l) (28). There is no detoxification required for glucose fermented solution and shows 97.5% efficiency. Algal residue (Lipid removed) for butanol fermentation also proven efficient in case of C. vulgaris UTEX 2714. (23) bio-butanol concentration determined 8.005 g/l concentration from fermented acid hydrolysate. Only hexane extracted algal hydrolysate needs detoxification for butanol production.

4. Bio-butanol from microorganism

In this section, all the microorganisms, whether bacteria, viruses, and algae, are utilized by various scientists, also modification of microbial species is done in experiments. Here all organisms are discussed below.

4.1 Saccharomyces cerevisiae

Saccharomyces cerevisiae, a eukaryotic sp., is well known due to yeast production but also capable of isobutanol production and also enhances through Biosynthetic valine route cycle (29). Many other scientists provide reasons that this species can be quickly grown at lower values of pH, less inhibiting as well as toxic to Substrate industrial) and very much reducing the chances of contamination in bioreactors for Iso-butanol production (30).

This microbe is commonly seen no effect or troubled by bacteriophage attachment in the reactor when observed genetically with E.Coli; it is found more complex also control the product. But S.cerevisiae uses lignocellulosic biomass, so it may affect the fuel, fodder, and food ratio and impact human consumption of isobutanol. This microbe maybe has a limitation as it could not use five-carbon sugar for the formation of isobutanol. It might be due to its inherent biology (31).

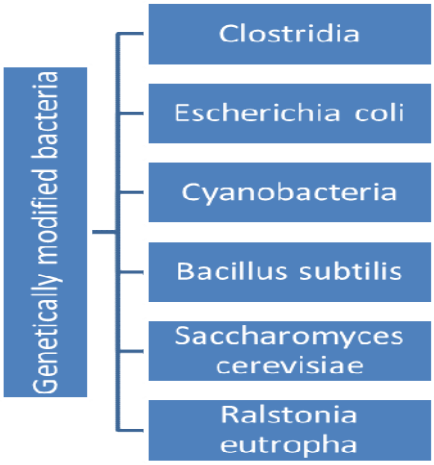

Figure 2: Some Commercial and genetically modified bacteria.

4.2 Escherichia coli

Escherichia coli, these particular gram-negative bacteria, can utilize in commercial production. Some analysis must improve its effectiveness for metabolic activities (31) for the generation of large amounts of isobutanol, ultimately commercial production. Some researchers found this E. coli particularly ideal for bio-synthesis of Butanol and utilizing tools of biotechnology for its genetic makeup, manipulation, and capacity to use ligno-cellulose for production of Bio-butanol especially from the waste materials agriculture. It has two benefits of using lingo-cellulose, one fuel price may be reduced or influenced, and the secondly preventing it from indirect human consumption (32).

Along with a drawback as bacteriophage is easily liable to grow here will shut down entire bioreactors possibly. In this phase, it may primarily react to limit the concentration of isobutanol due to this process cell not being able to tolerate and sensitivity must be diminished insignificant amount with utilizing mutagenesis and selected mutant may be able to less effected with bacteriophage and enhance the total yield with this precaution for isobutanol or bio-butanol(33).

4.3 Bacillus subtilis

B. *subtilis*, gram-positive, rod-shaped microbes produce lingo-cellulosic based isobutanol and are also efficiently measured with metabolic pathway standard hereditary practices (34).

Bacillus subtilis could concentrate to advanced or higher yields of isobutanol being produced with modification (35).

4.4 Clostridium/Clostridia

C. Acetobutylicum is utilized for "A.B.E. fermentation" changed into as soon as it yields acetone (starch). Bio-butanol changed into spinoff fermentation feedstock (in tons about double Butanol). Bio-based butanol (feedstock) and ethanol(feedstock) are vegetation or agricultural waste mostly: “sugar beets, sugar cane, Bamboo, switch-grass, corn grain, wheat bran waste and cassava”, in addition to agricultural byproducts including bagasse, all cereal straws and corn stalks. bio-ethanol flora can be-correctly valued and refitted in bio-butanol manufacturing (36). Furthermore, bio-butanol manufacturing from bio-materials and agricultural end-products might be more resourceful (i.e., engine purpose control added consistent with element solar power fed on) in ethanol/ methanol manufacturing (37).

Table 3: A.B.E. production with different feedstock and Microorganisms utilized.

Feedstock	Microorganism	A.B.E. Production	Technique	References no.
Arthrospira platensis	*C. acetobutylicum*	Bark: 4.3/96 0.43 butanol/96Lower butanol yield	Thermal and 0.1 mM H_2SO_4	100
Bamboo	*C. beijerinckii*ATCC 55025-E604	6.45 butanol/73	Simultaneous pretreatment and saccharification (laccase and cellulase) Lower production	120
Barley straw	*C. beijerinckii*P260	26.64/68	Continuous mode of toxicity by 1g/l Hypo solution	96
Corn fiber	*C. beijerinckii*BA101	9.3/72	Acid hydrolsis(0.5% H2SO4) and enzymatic treatment	95
Corn steep liquor	*Clost. beijerinckii*BA101	81.3/120	Fermentation recovery process	121
Corn stover	*C. beijerinckii*P260	26.27	Large production limit due to inhibitors	96
Degermed Corn	*C. beijerinckii*BA101	14.28/110	Continuous mode better yield	91
Distiller’s grain	*C. beijerinckii*BA101	5.46/96	Toxins conc. Reduced with water	132

Laminaria digitata	*C. beijerinckii*DSM-6422	8.1/101	Product contains Lactic and Alginate	153
Rice Straw	*C. acetobutylicum 2337*	13.5/288	Acidic treatment	57
Switch grass	*C. acetobutylicum ATCC 824*	17	Physicochemical treatment, removal by carbon	137
Sweet sorghum	*C. acetobutylicum ABE 1201*	20.9/72	Furfural and Phenolic toxicity removed by pervaporation and laccase	27
Sugarcane Bagasse	*C. acetobutylicum GX01*	21.12/120	Enzyme hydrolysis treatment	21
Palm Kernal	*C. saccharoperbutylacetonicum N1-4*	3.27/126	-	25
Pine apple peel	*C. acetobutylicum E 527*	5.23	Furfural and Phenolic toxicity removed by activated carbon	47
Restaurant food waste	*C. beijerinckii*P260	18.9/41	Vacuum stripping for toxicity removal of cells	129
Wheat bran	*C. beijerinckii*ATCC 55025	11.8/72	Fermentation	106
Wheat straw	*C. beijerinckii*P260	22.7/72	Fermentation	138
Wastewater algae	*Saccharoperbutylacetonium ATCC 27021*	0.13g/g	Higher non-fermented sugars then low yield	12
Willow biomass	*C. beijerinckii*NCIMB 8052	4.5	Phase conversion from acidic to solventogenic	11

clostridium sp. anaerobic but under pressure, Clostridium sp. can capable of converting almost any kind of cellulose into Butanol aerobically too (38). Clostridium cellulolyticum (cellulose-degrading microbe) gives iso-butanol instantly from cellulose sugars under stress.

In a studies succinate and ethanol mixture is fermented and obtained butyrate (pioneer to butanol gas) when metabolic pathways of Clostridium kluyveri utilized.T.C.A.

cycle, in which glucose developed via succinate with C. *acetobutylicum* and Clost. *saccharobutylicum* (anaerobically), have those pathways (39). Succinate after activation be concentrated within response (i.e. 2 steps) to 4-hydroxybutyrate, metabolized here. Crotonyl-CoA can also converted to butyrate. In E. Coli. genes are likewise replicated from clostridium and have butanol production pathways (40).
Limitations to clostridia
1. Another crucial bottleneck in developing the desired strain that is cost-effective in bio-butanol manufacture too.
2. Here, the main drawbacks of the solvent-producing clostridia were spore formation, small butanol lenience, somewhat slow rate of growth of this bacterium. In many cases, there's the formation of end products in reaction; many of them are disintegrated and degenerated in media, and bacteriophage infectivity decaying.
3. Efficient conversion of waste, mainly lignocellulosic living material, mass into solid hydrolysates. It's also observed that a considerable amount of sugar concentration, enzyme inhibitors, and stimuli resistors are challenges for cheap bio-butanol production (41).

4.5 Cyanobacteria

Cyanobacteria, photosynthetic bacteria suitable for biosynthesis when hereditarily engineered to obtain iso-butanol and its equivalent (42). cyanobacteria suggest numerous benefits as biofuel synthesizers: Cyanobacteria grow faster than vegetation and is replenished earlier than plants. Altered biofuel biosynthesizes also dependent, maybe grown up on non-arable land, competition amongst food possessions and gas assets isn't mandated (43).
Merits: There is need of growth parameters, as similar to plants(photosynthetic).
-Can be harvested under control lab. Conditions in beakers in normal/ Brackish to saline waters even.
-all species are not capable of iso-butanol manufacturing,
- Food or meals dependent sources and supplies not required,
-very much efficient in absorption (i.e. CO_2 in air)
- capable of bioremediation(44),
- grows faster and replenish production

Demerits are:

-susceptible to weather and environmental conditions, where harvested

-It is affected with a) CO_2 concentration b) salinity of water c) water stress

d) Difficulty in manipulating for production of Isobutanol,

e) great loss due to poison and toxin formed(45).

It have to give continuous power supply for functioning of culuture, strains of senistive sp./ strain maintained with their growth parameters and mixing conditions at

Lab. to be optimized (46). These up-written difficulties if reduced certainly help in efficient yield of isobutanol via culturing Cyanobacterial sp.

Some blue-green algae may also be re-engineered for growth, certain pathways shows significant utilization for yield. acetyl-CoA pathway is potent in production but difficulty is formation of two acetyl-CoA molecules is not feasible due to dG = 6.8 kcal/mol. Therefore pathway is not favoured in synthesis economically(47).

4.6 Ralstonia *eutropha*

It is a gram-negative soil bacterium with beta-proteobacteria class and can convert varying electrical strength into long chain iso-butanol also concluded; series of reactions such as Anodes are positioned in a mixture of H_2O and CO_2. Electricity runs from the anodes; electrochemical cells H_2O and CO_2 are mixed with synthesizing formic acid. All species of these microbes are tolerant species strain helpful in generating better strength of acid i.e. formic acid by putting mixture of CO_2 and H_2O into isobutanol. The amount of alcohol generated is actually bio-synthesised from acid mixture (aggregate) is improved to higher yield and used as bio-fuel(48,49).

Fermentation Methods

Impact of fermentation any degradation relies upon the number of working boundaries and conditions like tumult or Agitation, media pH value, hatching time, temperature, and poisonous impact. Tumult assumes a significant part for keeping up with; homogeneity in supplements with microorganisms in the aging stock. It is commonly seen more enhanced fermentation speed further develops stock homogeneity, lessens temperature inclination/variations, and favors the creation of the product (Butanol). Yet, at exceptionally high fomentation, the cell may harm and make an antagonistic effect; thus, the ideal intensities of produce, for excellent level of formation ought to be optimized. Important concern is fermenting media's pH is another factor that impacts the usefulness by and large in terms of product formation (yield), also its impact examined within broad reach of values. The most extreme creation has been accounted for pH 4.5–5.5 (50).(51) at pH 4.5 affirmed impact values of pH, the design also got the most extreme values yield is (9.1 g/l).

It is need to accessible of air inert N_2 concentrations in developing bacterial media at lower pH also, maintaining dissolvable creation via solventogenesis cycle (52). Each detailed outcomes (Maddox et al. 2000) showed lower pH positive discrimination(favors) butanol creation; however, its effect and quantity of yield are influenced by fluctuating microbial culture; it also forestalls corrosive or acidic collide due to overabundance corrosive development(acidogenic stage).

A significant influencing boundary is breeding time; separates its maturation pathway into both acidogenic and solventogenic stages. Acidogenesis begins before long vaccination and stretches out for a more drawn-out period (almost 30 hours) to generate different acids. Afterward, solventogenesis stage is reaching out for more than 90 h (53,54). As particularly stages rely upon accessibility (glucose) at a specific

temp. and pH. (C. *acetobutylicum* ATCC 824) and SA-2 strain is mixed in various set-up; butanol fixations (0.0% at 22°C, 1.0%-37°C, 1.5%-42°C, v/v) (55).
The unaffected freak strain shows expanded film smoothness seen particularly with local strain with the expansion in fixation (butanol). Also antagonistic impact at higher T (42°C) while Lower T (22°C and 37°C) expanded immersion of unsaturated fat proportion for both the strains(56).

(23)utilization recreated (hydrolysate) artichoke, concentrated as well impact on extra-cellular redox potential (−460 mV), got expanded iso-Butanol (13g/l) capability of NADH credited to further developed accessibility in ATP as well as NADH, worked under metabolic shift and dissolvable creation(yield). Intracellular changes of NADH/NAD+ proportion occurs their NADH is approx. 4 moles required to yield of butanol forming pathway also its redox potential need to improve. Clostridium sp. (NJP7) yields combination of iso-propanol in redox reaction mechanism it act on enzymes s-ADH(Auxiliary ethanol DeHydrogenase) and BuH (5.84 g/l) (57).

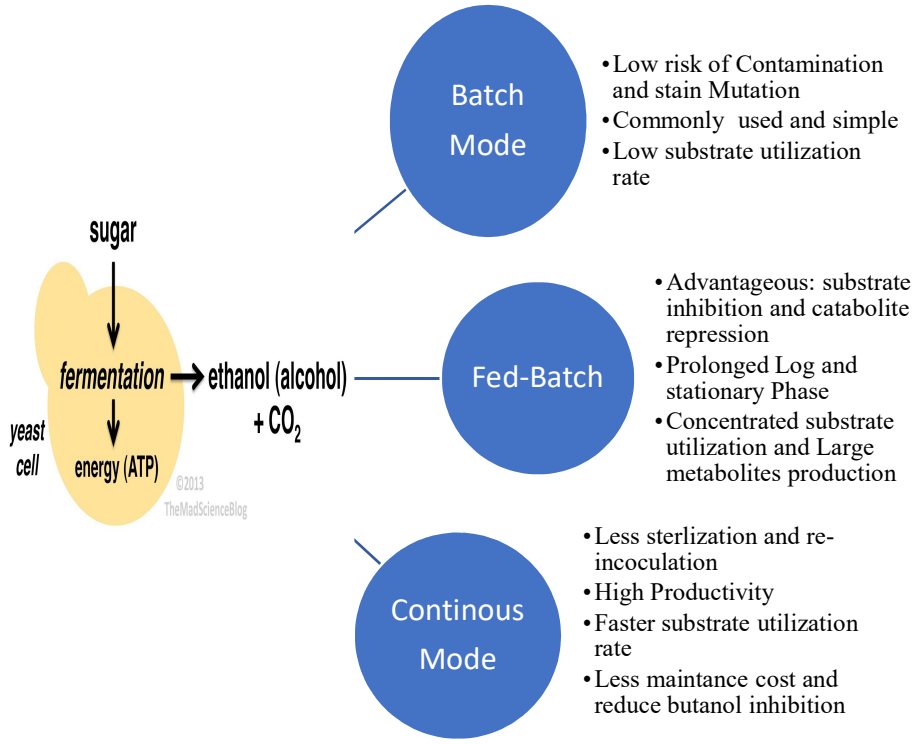

Figure 3: Various modes of fermentation of sugar-based feedstock
In above figure easily seen the three different modes of fermentation process, along with it some merits are too highlighted. There can demonstrate high productivity and less sterilization is needed in continuous mode. Some immobilized cells grown on fibrous-bed designed bioreactor worked constantly (nearly 800 hrs for 16 consecutive batches) obtained 18–20 g/l butanol yield (58).
Various studies have thoroughly examined the batch, fed-batch, and continuous fermentation modes, and their comparison is presented in Figure 3. Although continuous fermentation allows for less sterilizing, butanol inhibition, and re-inoculation of microorganisms,

researchers are nonetheless interested in batch fermentation because of its high output (59). (60)utilized butanol tolerant species JB200 of C. acetobutylicum for pilot-scale production.

Fed-batch and pervaporation both combined utilizing silicate- silicone-based composite artificial membrane (Qureshi et al.2010(90) also proved A.B.E. (154.97g/l) superior to batch mode only. A.B.E. production is a maximum of (9.74 g/l in 96 h) (61) from "wastewater algae" after enzymatic hydrolysis, 0.7 g/l of A.B.E. obtained; utilizing "non-pretreated or hydrolyzed algal biomass" (62). Also, many studies on other algal biomass to bio-butanol synthesis in the Batch mode were reported. Continuing stability and constancy maintained for C. *pasteurianum* (NRRL B-598) yields about 0.70 g/l/h done by process Continouuus Batch-packed bed over other process at dilution of 0.120 per hour (700 h, 35 cycles) (63). However in development of Butanol, most commonly used mode id fed-batch and continuous mode due to less expenditure and best efficiency.

6. Treatment for enhancement of yield

Pretreatment becomes necessary for a few feedstocks to get rid of their toxic levels, biomass degradability, and reduction in the production of higher yield. Improvement in the efficiency of fermentation of all kinds of substrates, especially some carbohydrates biomass, Pretreatment is an essential and upgraded process (Durre 2007). Many procedures are utilized looking at the characteristics and composition of feedstocks. As shown in figure 4, Pretreatment is differently categorized. Each strategy discussed is physical, chemical, Enzymatic hydrolysis, organosolv, and physical-chemical pretreatment methods (64).

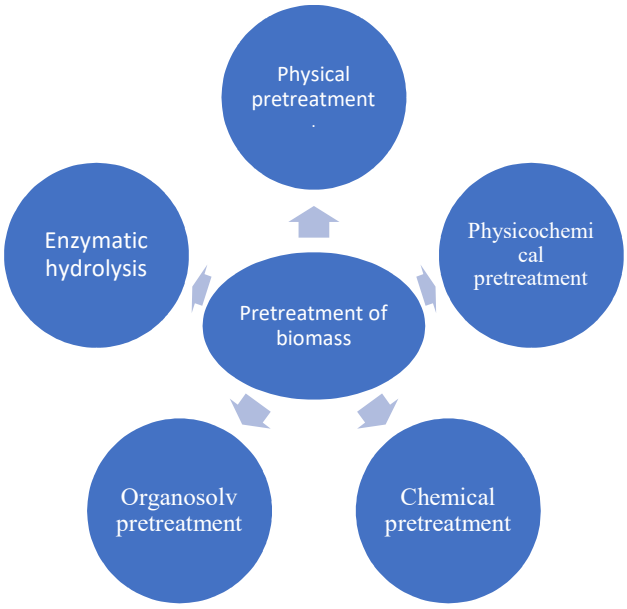

Figure 4: differing types of Pretreatment processes

Physical Pre-treatment Method:

Actual pretreatment procedures are nearly utilized for every feedstock preceding being presented with some emerging techniques. It's a dry cycle building crude surface space as lessening their molecule sizes (Barakat et al., 2015). The foremost well-known actual procedures, grinding also commutation both methods wet and dry ball processing, expulsion, roster-light(microwave), pyrolysis, and γ-illumination(65,66,67,102). Among the particular strategies recorded below in Table-4, the expulsion (Extrusion) procedure is best because it, to a reasonable extent, modifies cellulose and lignin conveyance which further builds the

productivity of various medicines. The numerous elements of actual Pre-treatment rely on attributes like biomass, energy residual required, damp-ness value, molecule dimensions as volume/size and level of alteration desired (Barakat et al., 2015). Best and most effective disservice of actual pre-treatment measures is that elevated explicit energy necessity.

Table 4: Physical Pretreatment

Methods	**Lignin structure**	**Toxicant release**	**Procedure remarks**	**References no.**
Gamma-irradiation	Lower impact	Low	Not viable for Industry, very Costly and lab-scale	94
Microwave Irradiation	No change	Low Furfural present	Temperature:160-250^{o}C and few min. to Hours	56
Pyrolysis	Lower impact	Low	Temperature: 500^{o}C and few minutes to Hours Great heat transfer	67
Wet Milling	Low impact	Nil	Surface area increase and particle size up to 0.003-30mm	109
Dry Milling	-	No release	Surface area increase and particle size up to 0.003-30mm	102
Extrusion	Large Alteration	Furfural and H.M.F. in Low Amounts	Temperature:40-160^{o}C and time:4-12 minutes	132

Physico-Chemical Pretreatment:

It combines physical and chemical pretreatment processes; steam explosion is considered the most feasible physicochemical treatment. It includes two important advances, for example, “Auto-hydrolysis” and “de-compression”. “Auto-hydrolysis” (68) consist an arrangement of acidic corrosive treatment with extreme heat (Temp.) its de-compression breaks bonds found within the intricate construction (109).

Disadvantage in treating cycle is the arrival of giant measures of inhibitory mixtures due to inadequate breakdown lignin-starch lattice (69). Enacted charcoal won’t to retain the dissolvable Lignin, and NaOH peroxide treatment taken to decrease inhibition for the duration of treatment. The employment of acids, for vapour blast (explosion)

diminishes inhibition altogether further developing the treatment effectiveness of crude solvent (70).

Many treatment strategies are less usually utilized to their impediment of lignin or hemicelluloses solubilisation in solvent (71). Formulation of fibre with CO_2 blast is viable strategies due to practically no inhibitor creation during the preparation.
Yet, the disadvantages related these are:
-Various Chemical formed within cycle creates the inhabitation in reaction mixture.
-Incomplete and inadequate breakdown
-Lignin degraded with charcoal (entacted) retains its preparations.
-if any peroxide and antacid is treated it will degrade inhibitors and help in development of toxins and chemicall degraded.
-Acid utilized in steam furnance diminsed the inhibitators but not cost effective.
- Crude material contains high lignin content.
Many researchers had undergo many test and examinations to rectify the above demerits involved (i.e. inhibition by some microbes and not dissolution of Hemi-cellulosic and other lignin in corn stover or any other substrate (agro-waste) by vapourised blast techniques (72).

Physicochemical pretreatment methods that are over and over-utilized preceding A.B.E. Fermentation are recorded in Table 5.

Table 5: Physico-Chemical Pretreatment and procedure

Technique	Lignin structure	Toxin release	Procedure remarks	References no.
Hot water treatment/7batch (75^oC)	High Impact	Low	Seven stage hot water treatment for tannins removal	74
Liquid hot water	Less impact	Low	Temp:100-230^oC, Pressure:0.1-2.8 MPa	109
Autoclave	Less impact	High	121^oC for 1 hour	12
Blast Steam furnace	Incomplete destruction of Lignin	High conc. Of Furfural	160-260^oC, 0.7-4.8MPa for few seconds to minutes	33
Supercritical $C0_2$ explosion	No Change	Nil	Not viable for pilot scale	76
Wet Air Oxidation	Lower Impact	Almost Nil	Costly and Lab. Scale only	40

Ammonia fiber explosion	Largely altered structure	Low	High Lignin reduces efficiency in biomass	109

Chemical Pretreatment:

This is the category of various pretreatment processes which include all other methods to be utilized on a Laboratory Scale; it provides treatment with acid or alkali, particularly at high temperatures for degradation and also enhancement of temperatures; other chemical methods may include Peroxides, mainly hydrogen, treatment with Strong oxidizing gas Ozone and Organosolovs pretreatment. Almost all chemical pre-treatment will changes lignocellulosic structure, the release of toxins, change of cellulosic and hemicellulosic content with degradation. Even some enzymes may play a vital role in destruction together with chemical pretreatment (73).
It is further categorised as Acidic, alkaline, Enzymatic, organosolov and treatment with some modifications or with nano-particles, all discussed. These treatments may enhance breakdown and yield.

Acidic chemical Pretreatment:

In this method there is breakdown of 2^0 products into xylose-33% of biomass (lignocellulosic) content enhances (rich content) into xylan, It is like blessing when financial aspects of treatment cycle, expands, accessibility of cellulose in developing enzymatic hydrolysis (Mosier et al. 2005(33,74).
Weaken corrosive agent for pre-treatment are best than concentrated acids are seen in cycle exceptionally poisonous, destructive, as well as hurtful. It could also be utilized with hot temperature as low strong stacking (upto less than 10%). if at reduced temperature with high stacking (between ten to forty %(75). It is affirmed significant sugar yield (upto 83%) and 9 g/l ABE from alcohol. It is treated with 1% v/v H_2 SO_4 heated with hot Temp. (About 200 °C up to 5 minutes) followed by (β-galactosidase) enzymatic hydrolysis. It is announced productivity of corrosive breakdown by water recovered in 95% Kraft dark alcohol.

Some technique effectively used in non-cellulosic feedstock/biomass. Even few algae may show irrelevant lignin content and acidic treatment yields the best sugar yield of 0.30 g/g in dry biomass here 1.63 m H_2 SO_4. (76) nearly 100°C appox. 60 min.) likewise upgraded carbon content glucose produced mainly discharge from green wastewater growth utilizing H_2 SO_4 (0 to 1.5 m). Almost 160 g/kg carbohydrates acquired, diagnosed also biomass about 1 m H_2 SO_4 (nearly 90°C /120 min). Like this, 3.74 g/l proficient butanol; weakening corrosive alongside high warm treatment. A combinational pre-treatment strategy could be unique modifying the complicated construction and working on additional cycles' adequacy (77).
Substance pre-treatment of biomass is finished utilizing different pretreatment specialists like those recorded. Main strategy is efficacious for biomass by means of enormous lignin values bringing about the further developed degradation measure (78).

Alkali pretreatment:

Some Alkali (Antacid) utilized to biomass pre-treatment works specially for removal of lignin and mixing of hemi/liganocelluloses within biomass has enormous amount (glucose) however demands longer perfect opportunity to arrive at an adequate amount of sugar (79). Corrosive (Acidic) Pretreatment is cheap only as woody and hemicellulose in lignin-containing biomass like hardwood hold good for acidic treatment before fermentation, while antacid pre-treatment added appropriate to soft-wood (80). Saponification of bonds and porosity in cellulosic or polymeric construction can be developed in pre-treating biomass (81). Some Cyanobacterial sp. treated with 1.7M acid 1 hour at 100°C followed by alkali (NaOH) pretreatment, means both can be applied at same biomass in batch continuous is followed. A similar assessment done in varied antacid specialists like NaOH, KOH, Na_2CO_3, and weak alkali explored on substrates such i.e. a) woody plants: eucalyptus b) Soft wood plants: Pinus c) fodder of cereals: rice straw and grain straw. Many more al**so** used to assess the adequacy/ need some special procedures to determine the absorbability of biomass (Park and Kim 2012).

Table 6: Chemical pretreatment and Procedures

Technique	Lignin structure	Toxin release	Procedure remarks	References no.
Acidic	Moderate alteration	High	1M HCl/H_2SO_4 Neutralization is necessary for filtrate and avoids corrosion	137
Alkali	High Alteration	High	Different Molar conc of NaOH	109
Peroxide	High Alteration	minute	10-30% H_2O_2	30
Ozonolysis	Moderate alteration	Nil	0.5 M O_3	120
Organosolovs	Efficient Destruction	High	Organosolov (75%v/v ethanol and 1% w/w 1M HCl/H_2SO_4)	23

Higher enzymatic absorbability (95.0%) has been accounted for grain straw absorbed 15% weak alkali (82, 109). Be that because it may, Caustic Soda found effective in expanding the inner "surface space" of cellulose, bursting content of lignin, also diminshing the extent of polymerization and crystalinity of "biomass structures"(83, 23).

Organosolv Pretreatment:

The organosolv interaction includes a natural or fluid natural stage (aqueous) with inorganic impetus (HCl, H_2 SO_4, KOH & NaOH) determine removal of lignin content (delignification). Alcohols mainly ethyl is utilized for organosolv pretreatment alongwith Chemical i.e. acidic/alkali in particular concentration (v/v or w/w) with Ethyl alcohol C_2H_5OH. In remaining of corn stalk biomass C_2H_5OH- 60% (v/v) and NaOH -40% (w/w) treated, found more changes in lignin structure then hemicelluloses is less affected at 110 ^oC (84). Some research shows production of ABE, after using Alcohol/ Alkali/ Acid or Enzyme or treating with water at hot water treatment/ steam pretreatment also obtained, a few toxic/inhibitory/ non-essential particles like furan, organic compounds (i.e. aldehydes, carboxylic acids, and phenolic) are delivered during artificial pretreatment of ligno-cellulosic biomass that gets in water breakdoen or hydrolysis and maturation of such products (85,86).

It is basically more advantageous than single treatment as follows, its advantages

- Lower level of harmful / toxin substances
- Used in aqueous media with high concentration
- Less oxidative potential

The viability of the further cycles is expanded essentially after the organosolv Pretreatment, which continues to be monetarily ugly (not economical) due to the numerous expense associations for the dissolvable and detoxification measures taken (Chen et al., 2015(23). Adsorbents (initiated carbon), essential synthetic substances, polymeric added substances, and decreasing specialists are ordinarily will not to limit the impact of those inhibitory particles. The efficiencies of dissipation, liming, enacted dark carbon/ glucose observed individually (from 8-48%, 8.6%, 44.9%, 33.6%, and 47.6%(87). Degradation, as technically-financial assessment of detoxification cycle is unavoidable advance legitimize the final item cost at pilot/ commercial scale (88).

Pre-treatment along with Nano-particles applications

As of late, specialists working within the space biofuels develop interest among researchers utilizing nanoparticles as impetuses; in pretreating feedstocks to deliver sugars, reusable and can change the science at the atomic level working with designated adjustment, consequently engaged on the productivity of the widely speaking biochemical response aside from decreasing the ecological contamination. Diverse metal nanoparticles are utilized proficiently drymass in biomass. Since their smaller size, they communicate flawlessly with various bio-molecules and deliver sugars for bio-butanol creation (89).

Almost 15.26% of sugars discharge from C. Vulgaris; stain utilizing silver nanoparticles(150 µg/g about 40 minutes) arranged throughout a natural course. The Pretreatment of wheat straw with action corrosive functionalized (sulphonic reagentat 160°C) as attractive nanoparticles i.e. perfluoro-alkyl-sulfonic (PFS) and alkyl-sulfonic results into 66.3% oligosaccharide formed by altered from Hemicellulose utilizing PFS nanoparticles. Also here usage of those nanoparticles by isolating them with solid particles, attractive area; demonstrates the aptitude and economic-cost-viability interaction (90).

Enzymatic hydrolysis

In this enzymatic degradation or hydrolysis measures required subsequent to pretreatment of biowaste, agro waste and other (ligno-cellulosic) biomass, discretionary for algae and photosynthetic microbes. Increment in discharge (sugar) done for few folds using enzyme

cellulase fundamentally expanded A.B.E. creation (upto eighttimes). It is specific and after treatment done on degraded Lignocellulose or not degraded or lignified components. It is discovered with enhancement of glucose discharge and enzymes like FPase - 0.25 FPU/ml, xylanase - 5.5 IU/ml, cellulose – 1.42 /ml, CMCase - 0.18 IU/ml and β-glucosidase, treated and found that improve the saccharin formation effectiveness impressively (Jain et al. 2014). The utilization of $NiCo_2$ O_4 nanoparticles for cellulase creation from Aspergillus fumigatus NS brought about worked on warm dependability of catalyst under the concentrated on conditions (90). Almost 40% higher channel paper movement seen as expansion (10 of 1 mm) $NiCo_2O_4$ nano-particles. Exercises of enzymes are endoglucanase-49%, β-glucosidase-53% and xylanase-19.8% had influenced. Many compounds delivered found to be thermally stable at 80°C, temperature independent also steady with duration of 7 hours within agreement about 4 hours to control in nano-particles. In case of compounds when reused as well as immobilized over these nano-particles plane, probably going to develop cycle prudent also alluring with an enormous scope(91).

Table7: Genetic engineered microorganisms in several feedstocks with the production of Butanol.

Microorganism	**Feedstock**	**Genetical expression/ reference**	**Production of Butanol (g/l) / productivity(g/l/h)**
C.cellulovorans DSM 743B C.beijerinckii NCBI 8052	Alkali revived Corn corbs	Cellulosic based Butanol,co-culture in mesophilic media, developed overexpression of xylR,xylT, buk, and ctfAB/ Wen et al. 2017	11.5
C.cellulovorans DSM 743B C.celluloyticum ATCC 35319	Cellulose In crystalline form	Quickly and directly utilize the cellulose as in crystalline form, Adh E_2 gene over-expressed/ Yang et al. 2015, Gaida et al.2106.	1.42/.0056 0.13/0.000 25
C.acetobutylicum BEKW_E1AB-atoB	Glucose	Over-expression of adh E1,atoB, and ctfAB genes./ lee et al. 2016	55.8/2.72

C.beijerinckii CC101-SV6	Glucose substrate	Same inhibition/over-expression as above but resistance, as well as acid assimilation, improved. Lu et al. 2017	12
C.tyrobutyricum pTBA,Ct	Glucose and Xylose	Co-expression of xylT, xylA,B coincides with $adhE_2$ also with C.acetobutylicumATCC. /Yu et al. 2015	12 with respect to 0.17
C.*pasteurianum*	Soybean hull	Increased biobutanol production and lower acid formation due to deletion of genes hyde, rex. /Schwarz et al. 2017	15.7 and 0.27
C.beijerinckii CC101 SV6	Sugarcane Bagasse	Over-expression of ctfAB, adhE2	7.6
C.tyrobutyricum Ct(ack) pscrBAK	Sucrose	scrA, B, K and adhE2/ Zhang et al. 201753	16/0.33

AdhE1,E2- aldehyde-alcohol dehydrogenase, atoB-thiolase, scrK-fructokinase, xylA-xylose isomerase,xylB-xylulokinase,xylT-xylose proton symporter,ctfAB- CoA transfrerase,buk- butyrate kinase

Table 7 presents an outline of the new advancements in metabolic designing for creating different butanol delivering strains with usefulness.

Calculated 30% huge glucose discharge without lignin (73.0 g/l) pretreated strong stacking boiling water and biomass, just 20% of 61.0 g/l with blast steam-extracted and biomass (delignified) strong stacking inside 72 hours (92). About all process except without-lignification expands defenseless destinations designed for proteins too utilized in case of polysaccharide configuration consequential enhanced in sugar discharge (93). Hatching

temperature is an additional significant aspect, influences catalyst action and solidness commonly. Cellobiose hydrolysis impacted at 40-70°C concentrated above same temperature also discovered chemical deactivation. Metallic nanoparticles utilization and immobilization help material for compound has excited a lot important to build the movement and solidness of protein (94).

Different elements influence the hydrolysis proficiency, such as biomass molecule shape; size its stacking, cellulose level, crystallinity, polymerization(levels), lignin value or amount and dispersion, response heterogeneity, protein restricting due to surface area, heated inactivation catalysts, and then forth (95).

7. Butanol Yield

Butanol poisonousness and yield the greatest barrier of butanol aging by local strains is item restraint fixation of Alcohol, powerlessness formation in mechanical level through using microbes and corrosive/ acidic gathering for the duration of aging/fermentation. Some microbes rehashed as well sub-refined, Clostridium sp. decreases its bio-butanol-framing capacity because water repellent expands cell film ease, altered trans-layer, its pH inclination, total quantity of intracellular (ATP) level and glucose take-up ability.

The impacts is antagonistically reduces butanol efficiency (96). Clostridia sp. can endure lower butanol focuses (2%app. v/v), and an almost 30% increment in layer smoothness was found in C. acetobutylicum by presenting cells to only 1% butanol (97). To assess poison's impact of butanol, few blended societies C. *saccharoperbutylacetonicum*, and other species developed and discovered most extreme focus (1.5 % of butanol) lenient way of life (98). As proposed by butanol creation; modern scale by utilizing normal strain is a nonviable alternative. High butanol lenient strains created by irregular designated mutagenesis in normal strains with non-butanol-delivering microorganisms (99). Designated mutagenesis utilized over-expression of designated qualities (chromo-somal reconciliation and plasmids) inactivation of transcriptional repressor qualities (integrative plasmids and gathering II introns) additionally quality down guideline (antisense RNA) to further develop the butanol efficiency (100).

Additionally, C. beijerinckii IB4, a changed strain acquired by low-energy particle applied, shown elevated inhibitor resilience also huge ABE creation, pH maintained in progression of cluster maturations (101). In bio-genetic designing methodology fit for working on the exhibition of stage progress (acidogenesis to solventogenesis)microbial population maintained for upgrading the amount generated of bio-fuel(butanol) also currently standing without specialists because of mechanical pertinence (102). The advancement of designed acid tolerant (C. acetobutylicum ATCC 824) displayed advanced butyric acid developed end product higher than butyric corrosive/acidic corrosive proportion favors formation of butanol). Sequence (pta-ctfB-adhE1) lacking C. *acetobutylicum* sp. gave butyric acid (30 g/l) at pH 6.0, which resulted into greater yield approx four times then regular strain(7.2 g/l) (103).

Hereditary change of some not directly butanol yielding strain additionally a hopeful option for effective yield of bio-butanol(96).

Table 8: Some significant Fermentation ventures modes using microorganisms at the feedstock and butanol maturation and yield.

Feedstock	Mode	Dissolver agent produced(in g/g)/Total yield (g/l/h)	Bio- C_4H_9OH (ABE) yield	References no.
Switch grass	Batch Mode	0.37/ 0.09	(14.67)	90
"Wheat" straw	Fermentation	0.41/ 0.31	(21.42)	96
Barley straw	Batch	0.29/	7.8(13.5ABE)	38
Microbial biodiesel		0.13	3.86	23
Residue				
Cassava bagasse	Fed-Batch	0.32/0.32	76.4/(108.53)	137
Glucose	Fermentation	0.24/1.91	9.12/(14.53)	128
Wheat straw		--/0.36	(16.59)	95
Degermed Corn	Free Cell Continous Fermentation	--/0.3	(14.28)	121
Glucose	Cell fermentation	0.35/2.5	16.9(25.32)	45
Sago starch	Fermentation	0.29/0.85	(9.1)	93
Glucose	Continuous	0.4/13.66	(14.32)	112
Corn	Fermentation	0.42/4.12	12.5	129
Xylose	Cell recycling	--/3.32	4.26	132

Escherichia coli and yeasts both is alluring host for various substrates for this reason because of quality knockout and quality enhancement issues experienced in the event of normal butanol creating species strain (102). Escherichia coli utilized as host because of accessibility in case complete genomic and physiological data its reasonableness with current hereditary device, studies followed on S. Cerevisiae determined can be used as potential host. A few analysts have endeavored to improve butanol usefulness utilizing designed species E. coli and most extreme quantity generated(8.6 g/l of butanol) accomplished also took care of group mode while the underlying stage fixation. (103).enzymatic enhancements activates likewise on E. coli different scientists been communicated with the exception of enzyme bcd, (butyryl-CoA dehydrogenase), just identified (104). In some bio-chemical pathway showed limitation in S. cerevisiae, cytosol gave better over expression (butanol isomers of specific qualities ILV2, ILV3, ILV5) (105).

A comprehension of foundational metabolic designing to further develop butanol resistance, substrate usage and decrease in result arrangement is fundamental and use of in silico displaying and reproduction can be utilized proficiently for such reason (106). (107) created C. acetobutylicum(ATCC 824) strain, altogether improved iso-

propanol, butanol or ethanol creation in the course of expanded creation of all intermediates i.e. butyric acid by repressing the precursor (butyrate).

In formation of elevated bio-synthesised butanol conc. (16 mg/l), superior than the announced qualities with yeast (approx 7g/l) affirmed the productivity its reasonableness of designing with some not producing strains.

8. Improving microbial species strains

When fundamental component reacts with C. acetobutylicum forms butanol stress as not easily formed, also ineffectively comprehended. As indicated by ongoing investigations, if any stress is developed (i.e. butanol) then glycolysis process in C. acetobutylicum might hindered, as only cycling of TCA advanced. Input elements decide may be metabolic or microbial reactions Clostridium sp.

Stress (butanol) supposed changes in lipid, unsaturated fat syntheses in bacterial cells, to intracellular digestion also to osmoregulator focuses. Similar creators recommended C. acetobutylicum cells decay degrees long acyl chain immersed unsaturated fats also long chain amino acids alter their ease keep up trustworthiness of cell layers under butanol stress (108).

Pure distillation and liquid-liquid extraction plus distillation thermal coupling have differently altered quite significantly considered and compared. TAC and Eco-indicator determined mainly economic and environmental impact other sequences may not affected.

Expanded degrees of many amino acids such as alanine, aspartate, phenylalanine, glycine,tyrosine, tryptophan, threonine, and glutamate likewise liable for expanding resilience of C. acetobutylicum forming butanol. Expanded degrees glycerol in like manner related with osmoregulation controlling redox balance. Much outcomes focuses towards chance combining butanologenic strains as of clostridium producing higher butanol resilience.

About 80 % reduction when compared all process of TAC jointly when determined shows fall upto 55 % lessening in environmental indication. When all data studied showing decreasing in economic and environmental issues, thereby it is more lucrative for biobutanol use (alternative energy source) by fermentation (109).

Following a year under ideal stockpiling circumstances at 37 °C, cell endurance rate, amount containing 16 g/L butanol blended in g/L glycerol 80% also bacterial cells demonstrated improved resistance of butanol is 32 g/L. Around 2-overlap more than wild-type strain. (110) built up novel methodology known as 1-butanoleglycerol capacity improve butanol resistance forestall beneficial deterioration C. acetobutylicum for the duration of lengthy haul safeguarding. Additionally, butanol yield marginally superior contrasted with control. Most outcomes found under the conditions societies its safeguarded significant in improving butanol resistance also forestalling loss of profitability.

Table 9: Comparison and utilization of various Recovery Techniques for bio-butanol

Adopted Recovery Techniques	Advantages	Disadvantages	Bio-butanol/ABE yield(g/l)	References
Liquid –liquid extraction	a) facillates stage wise phase contact b) solvent properties flexible	a) Emulsion formation b) loss of extractant c) toxicity of extractant microorganisms	16.9/13.58	Bankar et al.
Gas- stripping	a) better butanol Productivity b) Easy Operation c) Prevents fouling	a) very costly, high operating cost b) less selectivity	444.8/232.8	Ezeji et al.
Adsorption	a) low Energy demand b) Adsorbents can be re-used	a) Not Viable at industrial scale	54./59.8	Xue et al.
Perstraction		a) Energy requirement high b) Membrane fouling c) Costly	136.58	Qureshi and Maddox
Pervaporation	a) Efficient butanol recovery	a) Lower durability b) less/low flux c) Membrane fouling and swelling d) Costly	142.1/451.98	Wu et al.

An utilization in metabolic designing can possibly build butanol creation (111). Procedures to forestall the decimation of bacterial cells by butanol orchestrated by means of aging cycles incorporate the hereditary building of increased butanol creating strains (112).As executed arbitrary mutagenesis to transform the deoxyribonucleic acid (DNA) grouping qualities liable for butanol development. This freak strain “C. acetobutylicum ATCC 824” created using sequential improvement of weakened long chain C_4H_9OH (butanol). Few developed strain has essentially privileged quantities (butanol) due to resistance (i.e.125%) local species. Also epic freak created C. acetobutylicum, treated with blend of ethyl methane sulphonate alongwith N-methyl-N'- nitro-N-nitrosoguanidine (MMNG) (113). It demonstrated more noteworthy strength 20% more than for molasses also yields higher butanol in contrast with parent strain.

Frameworks with different levels in metabolic designing clostridia, may prompt the disclosure of completely recently discovered biosynthetic pathways in butanol, the advancement, novel strains defeat current also recent restrictions in butanol aging by clostridia (114).

Metabolic and mechanical designing initially needed investigation, metabolic framework energy also its intracellular enzymatic responses. Some chosen living being would then be able to be exposed to hereditary or ecological changes. It is important to change the protein substance of the life form, yet in addition enzymatic species. Recognizing as well demonstrating key enzymatic responses, butanol proportion C. acetobutylicum hence a significant initial move towards development metabolically-designed creation strains (115). Also main decade of twenty-first century, genomes butanol (2^0) delivering clostridia sequenced completely, Clostridia sp. (116). When (C_4H_9OH) and $(CH_3)_2CO$ delivering qualities had been recognized, hereditary changes were endeavored to diminish or wipe out the creation of $(CH_3)_2CO$ creation throughout bio-butanol aging. TargeTron innovation utilized upset aceto-acetate decarboxylase quality (adc), mainly liable $(CH_3)_2CO$ creation. Accordingly, bio- butanol creation expanded starting 70% to 80% $(CH_3)_2CO$ as creation diminished to 0.20 g/L. In sequenced genomes show hyper forming iso-butanol creating microorganisms more further have opportunities in hereditary designing also to improve cycle of butanol maturation (117).

Innovation in recombinant DNA technology, Some alluring instrument for improvement, dissolvable creation and hereditary designing. A procedure first utilized assortment strain C. *acetobutylicum* (ATCC 824). Notwithstanding, altered strain couldn't create $(CH_3)_2CO$ and butanol, likely because of the decimation of dissolvable delivering qualities in specially these strains following sequential sub-refined (118). A pSOLI(Plasmid) may determine such qualities embedded i.e. bacterial freaks. Lamentably, designed strains as yet incapable, create butanol and $(CH_3)_2CO$, because of the devastation of the embedded plasmid. Comparable outcomes accounted for by (119),utilized clostridia sp. hosts butanol-delivering qualities. Because of the hereditary multifaceted nature of clostridia and the absence of reasonable hereditary devices, their endeavors were fruitless (120).

Different living beings have been explored as potential hosts for butanol-creating qualities. Butanol-delivering qualities most ordinarily brought Bacillus subtilis, Saccharomyces cerevisiae, E. coli and Pseudomonas putida. Greatest amount of butanol creation 20 g/L gotten designed strains of E. *coli* (EB243), local qualities erased also 5 heterologous qualities presented. Strain (EB243), delivered butanol with yield of 34% clump maturations, demonstrated extraordinary potential in case of modern applications (121). An investigation qualities sequences brought into β-hydroxybutyryl-CoA dehydrogenase, acetyl-CoA acetyltransferase, E. coli, butyraldehyde dehydrogenase, 3-hydroxybutyryl-CoA dehydratase, butyl-CoA dehydrogenase, and butanol dehydrogenase (122). Another investigation, strain of C.

saccharo-butylicum with high hemi cellulosic movement separated, its qualities embedded into E. coli, encoding crotonase, acetoacetate decarboxylase, liquor dehydrogenase. Practically the entirety qualities additionally communicated in the host microscopic organisms Lactobacillus brevis (123). Effective articulation likewise accomplished in S. cerevisiae, yet without a noteworthy improvement in butanol creation (124). As rundown, recombinant DNA innovation non-clostridial microorganisms demonstrated unequipped for improving yields of butanol. Local Clostridium spp. Zero in be supposed to currently be focused on further improvement hereditary apparatus quality articulation cells (125). Nano-catalysts to beat difficulties in bio-butanol created additionally accepting additional intrigue.

9. Modeling for "ABE" and bio-butanol production

Numerical models for the ABE aging cycle, few examinations bunch have endeavored to foster numerical models ABE aging studied. Such models can comprehensively assemble i.e. (dynamic, physiological and extractive-fermentative) models. As far as reaching audit on bio-butanol definite record of different numerical models obtained. About modeling concise record of different models is introduced for area reference.

(126) applied a model on examining microbial digestion of Stomach muscle maturation to get distinctive physiological conditions, also fermentation/aging. (127) stretched out the model on C_3H_7COOH (Propanoic acid) and C_4H_8 $(OH)_2$ (butanediol) and blended corrosive maturation. Peculiarity found as a result of associating pathways for certain intermediate formation constraint in developing models and makes the computation of in vivo motions troublesome. To Change and better results analysts gathered the $(CH_3)_2CO$ pathway by supplanting in vivo motions with the net creation pace of $(CH_3)_2CO$, acetic acid derivation and butyrate. This, notwithstanding, brought about the deficiency of data relating to physiologically significant in-vivo motions. Endeavors to beat this constraint by estimating one of the in vivo transitions and presenting the optimality guideline.(128) instanced on ABE maturation utilizing immobilized specific C. beijerinckii; fostered a progression of models utilizing physical compound in "chemical or organic" nature boundaries. In any case of parameter hindrance disregarded immobilizing (homogeneous mass) network and inert center considered. Condition utilized portray as such substrate (glucose) utilization, Monod model for the particular development pace.

Biobutanol creation (129) fostered a complete model-based general condition for ABE aging in acidic(butyric acid) environment microscopic organisms utilizing stoichiometric equilibrium for carbon(C), hydrogen(H), oxygen(O) and nitrogen(N) including 4 responses of each in E-M-P pathway factors. Also utilized natural components or piece within that natural substrate its growth of microbial biomass and extracellular portion. Many qualities for different components, experimental equation biomass acquired its natural investigation. It joined level of reductant of different mixtures characterized also quantity of counterparts of electrons per C in substrate, biomass particle and extra-cellular chemical species delegate arrangement of biomass (glucose, pyruvate and acetyl-CoA concentrations >0 accepted).

Any model effectively anticipated development of acids even on account, solid substrate constraint their impact of expanded weakening speed decreasing butanol fixation its presentation persistent aging information acquired (130).(131) fostered another model consider acidic take-up to catalyze butyric acid a similar chemical and acquired connection. in-vivo takes-up during the butyrate- $(CH_3)_2CO$ pathway forming acetic acid derivation $(CH_3)_2CO$. Since the convergences of acetic acid derivation and butyrate element; their individual paces of arrangement, showing replica introduced some non-linear limitation. (132) stretched out this model to rehashed group and rehashed took care of clump maturations. (133) utilized model also assess presentation of Stomach muscle aging in expansion of oleyl liquor an extractant for product also "benzyl benzoate" intermeadiate to give $(CH_3)_2CO$. Such as addition among extractants at the same time, huge improvement in efficiency and item focus on yield obtained.

(134) stoichiometric methodology utilized to decide in-vivo motions(engineered) depicting the digestion of ABE producing clostridia. The benefits in such model seen as per the following: (i) feasible to determine peculiarity in the stoichiometric model utilizing a physio-logically based non-linear imperative, (ii) grants consolidation of nonlinear conditions in the stoichio-metric models (iii) solitary metabolic organization depicts the digestion of a scope of substrate combinations without deduced assurance of individual transitions.

(135) fostered an overall structure for extractive aging relevant for cluster, successive clump and rehashed took care of bunch modes; utilized overseeing differential conditions for biomass fixation, substrate usage and convergence of different items. Another factor "G" taken as starting point (on-off component) of Catabolic/Chemical responses in presence as well as non-appearance of energy currencies (ATP and NADH) likewise presented (136). Reenactments directed with and without the G factor demonstrated that test information harmonize good model with the G factor. Nonetheless, model anticipated persistent corrosive development even get-togethers utilization, hence negating the trial information.

The development rate characterized result of normal development rate got from Monod energy and hindrance coefficient (contingent upon the creation pace of an inhibitory item and the restraint consistent for the item). The differential conditions were addressed as a series arrangement, and the connection between creation pace of a specific item and creation of biomass for a group cycle was gotten(137).

The pervaporation module: development and fitted within fermented framework. As studied and utilized Monod energy also with hindrance. Some aftereffects obtained from reenactment showed glucose focus diminished gradually in the slack stage system of development (138). From beginning a) solventogenesis: diminished quickly pending the cell development hindered at higher butanol focus yielded in stock. Biobutanol creation within the sight pervaporation module, glucose utilization rate expanded immediately in early beginning of solventogenesis. A saw-tooth-type conduct seen with shifting layer thickness also glucose utilization speed expanded such with diminishing film thickness (139).

Monod-type :(140) fostered a model for cell development under synergistic hindrance of numerous items/results utilizing Monod-type connection under item restraint conditions. Its connection for the proportion of the particular development rates below un-inhibited (not reacted) in repressed circumstances utilizing exploratory information. The model considered the restraint brought about by $(CH_3)_2CO$, butanol, ethanol, acetic acid derivation and butyrate. It was seen that the presence of inhibitors like acetic acid derivation and butyrate expanded the restraint of butanol. Then again, $(CH_3)_2CO$ and ethanol neither caused a lot of restraint nor cooperated with different items. pH influenced the degree of restraint in the course of ionizing species furthermore cell "internal organelles" their membrane layer also physio-logical capacities changed. Taking into account these perceptions, pH is to be maintained (141).

Motor model: ABE aging based metabolic/ engineered pathway of "C. *acetobutylicum* ATCC 824". Motor articulations responses engaged, stretched "PPP"(pentose phosphate pathway) for xylose use, causing affectability examination showed most of outcomes similar to glucose maturation.

(142) introduced model for concurrent aging and detachment in fermented im-mobilized cell, from solution in "stream bed reactor" decayed solvent and used gas stripping at constant temperature. Im-mobilizing framework, and surface area in bed balance stage with the consistent state, without dispersion in stripping area with two sovent. Maintaining discretized mass equilibrium conditions created in different parts in bioreactor within two segments.

Around more than fifty percent enhancements "glucose level change" accomplished stripper area utilizied "in-situ" portion material evacuation. elevated gas stream rate expanded "glucose change" and item partition. Activity beneath vacuum with gas flow additionally further developed glucose change. Additionally, a model for took care of cluster butanol aging with concurrent pervaporation was created by Park and Geng (143).

Fermentation Model: "fermenter-cum hollow fiber film" element module (144) utilized "Fermentation" examinations and fostered a numerical model for framework of microorganism societies im-mobilized on wastage of Timber, its minute chips maintained floating in stock, after suspension 2-ethyl-1-hexanol utilized as an extracting solution (extractant). Many assumptions and conditions in model included also concurrent dissolvable extraction is monitored and mass equilibrium studies undertaken. model expected the shortfall of mass exchange outspread way in the fermenter and presence of the consistent state. For yield all out grouping of 8mg/l expontential capacity of the complete focus as a straight capacity for fixation equivalent (approx 8-13.9 g/l (145).

Model developers presumed about general usefulness expanded greater 1/3% with extractant course through film filaments. Model didn't represent the restraint because of butanol focus worked inside holes/ minute pores of timber waste chips; created

error between any hypothetical, non-proved exploratory pace of glucose utilization. The outcomes showed when gas stripping measured unaccompanied found less difficult compared with fluid extraction. In whole cycle observation there is with a reduction of affordable due to generally significant expenses of azeotropic frameworks (146).

Here recreation outcome demonstrated an exceptionally focused feed would further develop presentation impressively; all out usefulness was improved by the dissolvable appropriation rate however brought about loss of energy usage proficiency, and the two-vessel streak framework didn't bring about concurrent enhancement of both item virtue and energy productivity.

10. Chemical Processes for Producing Butanol from Bio-Ethanol.

In exemplary way, here deal with delivering bio-butanol starting to bio-ethanol continues in three stages. To begin with, the business item is altogether dried out to acquire a 100% anhydrous/ Dry state. It is then oxidized also-with $(CH_3)_2CO$ (acetyladehyde) within sight of aluminum iso-propanolate to frame acetaldehyde $(CH_3)_2CO$)147. Profoundly unpredictable acetaldehyde isolated by means of partial refining. In case such subsequent advance, acetal-aldehyde about dense an emphatically basic condition, determining crotonaldehyde. As in last juncture, crotonaldehyde hydrogenated to butanol due to treatment as isopropanol within sight such as titanium.(Ti or aluminum iso-propanolate).

Build-up of dried out bio-C_2H_5OH (100% anhydrous state) to bio-C_4H_9OH within sight of Aluminum (Al or titanium (Ti) iso-propanolate(147). In this chapter already discussed the various techniques for development of new strains and their optimization for commercial use. Synthetic enzyme or catalyst may be proven effective and enhance the quantity also.

11. Economics and industrialization demands

BUTALCO GmBH founded in 2007 for production of bio-butanol and bioethanol and other biochemical using lignocellulose with yeasts extract and based in Switzerland. Available of six major bio-butanol plants in China, only one left producing about 30,000 ton butanol per year (27,148).

In blending experiments, lots of things can be improved with a scope as far as addition of gases, stripping process as coordinated with butanol and ethanol longevity, as coordinated with acetyldehyde and many more such activities enhance the yield acetylaldehde-butanol and ethanol and also production and Butanol with 0.34g/L/h Maturation coordinated with gas usually higher than earlier efficiency. As a result in butanol of resistance in some strains might have reduced production and recuperation. Stages for stripping developed about 155.6 g/l in concentrates butanol, with subsequent stages there is enhanced quantity is obtained in natural strain is about 610.8g/l butanol. While the other process called pervaporation in this second process, with concentrate amount produced is 441.7g/l butanol, especially if it is blended with other natural stage is 521.3 g/l butanol here(149).

Table 10: Bio-butanol Commercial scale Plants (pilot) and countries with viable feedstock utilized

Plant for Bio-butanol production	**Country**	**Feedstock used for Bio-butanol generation**
HCSucroquimica	Brazil	Sugarcane bio-refinery
Butamax	United States	Microbes and Sea weed, Macro algae
Gevo. Inc,	United States	Cellulosic Sugars from corn Stover, switch grass, forest residue and other forest feedstock- 1 Million gallon per year
Green Biologics(GBL)	UK	Biomass fermented sugars
Bioenergy International	Stockholm, Europe	Plant based biomass
Arbor Fuels	Farmington United states	Cellulose
BUTALCO GmBH	Zug, Switzerland	Ligano-cellulose
METabolic Explorer	France	Fermenting Starch, Sugar, sugar cane juice, molasses and Hemicellulose.
TetraVitae Bioscience	Chicago, US	Cellulosic feedstock on Clostridium beijerinckii
Cobalt Biofuels		Plant material

Financial matters of butanol creation especially concentrated with nature of feedstock, creation cycle and detachment procedure control the interaction financial matters. The financial attainability of butanol creation (corn, wheat straw, whey saturate and molasses) analyzed by a few analysts (150). The expense of manufacturing bio-butanol is not economical, much higher ($1.87/kg) than developed by petrochemicals per kg is compared, 0.35 dollars per kg in regular (151). As yet to be prepared with feedstock (lower amounts), handling cost and eco-friendly/ recyclable nature is to maintained.(Jiang et al. 2015).

Significant interest for bio-fuels(butanol) also its demand expanded with a percentage approx more than 2.5% annually upto 2015 and yearly worldwide interest is more than 2.1 billion gallons, bio-butanol usefulness and use of algal sp. may permit the value decrease. Shockingly, absence of sufficient data relating to algal biomass represents prevention toward this path. An estimated contribution around 8.8 million on Research and development exercises for utilizing kelp biomass for business butanol created (DuPont and Bio Design Lab). Economic cycle financial matter of an item is straightforwardly connected to the bio-mass and energy balance (152).

The worldwide market for butanol yield; predictable to become all the more quickly during last five years motivated essentially some area nations.

12. Pilot Scale limitations and Challenges

There are many industries starting up with green initiative as a challenge to bio-ethanol and bio-butanol production, although the pilot projects are needed for commercial use of bio-butanol production, with growing demands speedily, industries and market is still facing variety of Provocations that require beating economical production (153). In exacting, research is limited to laboratory scale, costly, development of butyl alcohol tolerant strain, overall value competitiveness, lower yield produced require needful enhancement methods, slow fermentation, too expensive item for consumption recuperation also division of microbial sp. need to be studied (154). Preparation methods based on algae utilization and bio-butanol production continues to be in developing, despite all its recompense and advantages, presently with many bottlenecks with the intention of utilization of Substrates, biomass at the pilot scale. The supply of appropriate protoctist species with massive super-molecule content and restricted information regarding algal ordination prohibit developing a hereditarily changed and resistant also protoctist strain with the belongings of enormous super-molecule, toxin and some unwanted chemical accumulation, lower biomass yield of varied microalgae and true bacteria which will synthesis and treatment under business scale and inaccessibility of appropriate substrate recovery methods (155).

For fruitful commercialization of bio-butanol, it is fundamental to think about every single applicable factor and choose different systems engaged with the creation to utilization chain for guaranteeing its stock and supply to the customer toward the end.

13. Needs and Future requirement as green fuel prospective

Lower butanol concentrations and final product toxicity are major concerns; These problems can be solved using transfection engineering as well as co-cultivation of microbes to get the most out of raw biomass and an integrated fermentation sludge recovery system to reduce toxicity and damage to the final product (156). Extensive research is needed in this direction. biomass is open and promising. Research is still needed to investigate its use in fermentation to increase yields and address related problems, namely:

- advances extra flexible nanocatalysts for biomass of wide series of species (157)

- Synthesis of nanoparticles, used as biocatalysts to convert extracted sugars to bio-butanol(158).

– Economical viable nanoparticles to increase the effectiveness of substrate handing out and assembly of biobutanol on an industrial scale (159).

Sustainable future demands: developing many comprehensive upstream and downstream schemes such as great resourceful microbes associated, with cheaper fermentative substrates with sustainable and economic viability of biobutanol production; piolet scale bio-alcohols/bioethanol, may be any biobutanol or bio-glycerol can be converted to oxygenate

fuel additives a new process is very attractive (160); therefore the butanol oxidation to butyl aldehyde may be a way more consistent with the current environmental policies.

14. Conclusion

There may be wide range of energy potential as fuel and additive, as a promising future in transportation sector as alone can be used liquid fuel when compared to other categories of fuels. Here some facts demonstrated such potential of various techniques, processes and procedures in enhancing the efficiency, yield and efficacy of Bio-butanol quantity and synthesis. All methods have been characterized as Chemical treatment routes, some conventional techniques and largely biotechnological routes. Main concern is for profit as well as completing economic concerns especially bio-butanol synthesis at pilot scale. There is aimed research of some of the green techniques, improved methods for genetic level change of microorganisms; biotechnological improvement in different strains of bacteria and algal species for bio-butanol production. It is thoughtful and taken into practical implementation of fermentation, microorganism engineering and development, adjustment of butanol recuperation handing out and compound catalysis in flourishing manufacturing process indicated. Butanol production is probable may grow to be an economically possible process in near future. Much of industrial processes utilize chemical treatment, best processes in chemical solutions having coupling of bio-ethanol, to form dimer of butanol; this chemical processes is continuous and single step reaction process. Production from algal biomass wastes such as microalgae residues can be an alternative energy source also an excellent and sustainable potent fertilizer for agricultural crops.

15. References

1. Scott F., Quintero J., Morales M., Conejeros R., Cardona C., Aroca G. Process Design and Sustainability in the Production of Bioethanol from Lignocellulosic Materials. Electron. J. Biotechnol. 2013;16 doi: 10.2225/vol16-issue3-fulltext-7. [CrossRef] [Google Scholar]
2. Goldemberg J. Ethanol for a Sustainable Energy Future.Science. 2007;315:808–810. doi: 10.1126/science.1137013. [PubMed] [CrossRef] [Google Scholar]
3. Mussatto S.I., Dragone G., Guimarães P.M.R., Silva J.P.A., Carneiro L.M., Roberto I.C., Vicente A., Domingues L., Teixeira J.A. Technological Trends, Global Market, and Challenges of Bio-Ethanol Production. Biotechnol. Adv. 2010;28:817–830. doi: 10.1016/j.biotechadv.2010.07.001. [PubMed] [CrossRef] [Google Scholar]
4. Anbarasan P., Baer Z.C., Sreekumar S., Gross E., Binder J.B., Blanch H.W., Clark D.S., Toste F.D. Integration of Chemical Catalysis with Extractive Fermentation to Produce Fuels. Nature. 2012;491:235–239. doi: 10.1038/nature11594. [PubMed] [CrossRef] [Google Scholar]
5. Lin Y., Tanaka S. Ethanol Fermentation from Biomass Resources: Current State and Prospects. Appl. Microbiol. Biotechnol. 2006;69:627–642. doi: 10.1007/s00253-005-0229-x. [PubMed] [CrossRef] [Google Scholar]
6. Bai F.W., Anderson W.A., Moo-Young M. Ethanol Fermentation Technologies from Sugar and Starch Feedstocks.Biotechnol. Adv. 2008;26:89–105. doi: 10.1016/j.biotechadv.2007.09.002. [PubMed] [CrossRef] [Google Scholar]

7. Szopa J., Patelski P. Biotechnological trends in sugar beet processing. Sug. Ind. Mag. 2006;11:326–327. [Google Scholar]
8. Dodić S., Popov S., Dodić J., Ranković J., Zavargo Z., Jevtić Mučibabić R. Bioethanol Production from Thick Juice as Intermediate of Sugar Beet Processing. Biomass Bioenergy. 2009;33:822–827. doi: 10.1016/j.biombioe.2009.01.002. [CrossRef] [Google Scholar]
9. Smuga –kogut Influence of the crystalline structure of cellulose on the production of ethanol from lignocellulose biomass int.agrphy.2016.30.83-88 DOI:10.1515/intag-2015-0072
10. Moretti M.dS, Bocchini-Martins DA, Nunes CdCC, Villena MA, Perrone OM, da Silva R, Boscolo M, Gomes E Pretreatment of sugarcane bagasse with microwaves irradiation and its effects on the structure and on enzymatic hydrolysis. 2016 Appl Energy 122:189–195
11. Han et.al Biobutanol production from 2-year-old willow biomass by acid hydrolysis and acetone–butanol–ethanol fermentation 2013 energy 61:13-17
12. Jernigan, A.; May, M.; Potts, T.; Rodgers, B.; Hestekin, J.; May, P. I,; McLaughlin, J.; Beitle, R. R.; Hestekin, C. N. Environmental Progress & Sustainable Energy Effects of Drying and Storage on Year-Round Production of Butanol and Biodiesel from Algal Carbohydrates and Lipids using Algae from Water Remediation 2013, 32, 4, 1013-1022
13. Fukuda H., Kondo A., Noda H. Biodiesel Fuel Production by Transesterification of Oils. J. Biosci. Bioeng. 2001;92:405–416. doi: 10.1016/S1389-1723(01)80288-7. [PubMed] [CrossRef] [Google Scholar]
14. Barnwal B.K., Sharma M.P. Prospects of Biodiesel Production from Vegetable Oils in India. Renew. Sustain. Energ Rev. 2005;9:363–378. doi: 10.1016/j.rser.2004.05.007. [CrossRef] [Google Scholar]
15. BijoyBiswas, NidhiPandey,YashasviBisht,RawelSingh,JitendraKumar,ThalladaBhaskar Pyrolysis of agricultural biomass residues: Comparative study of corn cob, wheat straw, rice straw and rice husk Bioresource Technology.Vol. 237. 2017, 57-63
16. Van Gerpen J. Biodiesel Processing and Production. Fuel Process. Technol. 2005;86:1097–1107. doi: 10.1016/j.fuproc.2004.11.005. [CrossRef] [Google Scholar]
17. Obuli P. Karthikeyan & C. Visvanathan Bio-energy recovery from high-solid organic substrates by dry anaerobic bio-conversion processes: a review *Reviews in Environmental Science and Bio/Technology* volume 12, pages257–284 (2013)
18. Leung D.Y.C., Wu X., Leung M.K.H. A Review on Biodiesel Production Using Catalyzed Transesterification. Appl. Energy. 2010;87:1083–1095. doi: 10.1016/j.apenergy.2009.10.006. [CrossRef] [Google Scholar]
19. Atadashi I.M., Aroua M.K., Abdul Aziz A.R., Sulaiman N.M.N. The Effects of Catalysts in Biodiesel Production: A Review. J. Ind. Eng. Chem. 2013;19:14–26. doi: 10.1016/j.jiec.2012.07.009. [CrossRef] [Google Scholar]
20. Talebian-Kiakalaieh A., Amin N.A.S., Mazaheri H. A Review on Novel Processes of Biodiesel Production from Waste Cooking Oil. Appl. Energy. 2013;104:683–710. doi: 10.1016/j.apenergy.2012.11.061. [CrossRef] [Google Scholar]
21. Z.Pang, W.Lu, H.Zheng, Z. Liang Butanol production employing fed-batch fermentation by Clostridium acetobutylicum GX01 using alkali-pretreated sugarcane bagasse hydrolysed by enzymes from Thermoascus aurantiacus QS 7-2-4 2016Bioresource Technology 212DOI:10.1016/j.biortech.2016.04.013
22. Mata T.M., Martins A.A., Caetano N.S. Microalgae for Biodiesel Production and Other Applications: A Review. Renew. Sustain. Energy Rev. 2010;14:217–232. doi: 10.1016/j.rser.2009.07.020. [CrossRef] [Google Scholar]
23. Chen C.-Y., Yeh K.-L., Aisyah R., Lee D.-J., Chang J.-S. Cultivation, Photobioreactor Design and Harvesting of Microalgae for Biodiesel Production: A Critical Review. Bioresour. Technol. 2011;102:71–81. doi: 10.1016/j.biortech.2010.06.159. [PubMed] [CrossRef] [Google Scholar]

24. Kröger M., Müller-Langer F. Review on Possible Algal-Biofuel Production Processes. Biofuels. 2012;3:333–349. doi: 10.4155/bfs.12.14. [CrossRef] [Google Scholar]
25. Hafiza Shukor , Najeeb Kaid Nasser Al-Shorgani , Peyman Abdeshahian , Aidil Abdul Hamid , Nurina Anuar , Norliza Abd Rahman , Mohd Sahaid Kalil Production of butanol by Clostridium saccharoperbutylacetonicum N1-4 from palm kernel cake in acetone-butanol-ethanol fermentation using an empirical model 2016doi: 10.1016/j.biortech.2014.07.055.
26. H. Biebl, K. Menzel, A.-P. Zeng ,W.-D. Deckwer Microbial production of 1,3-propanediol. Applied Microbiology and Biotechnology1999 volume 52, pages 289–297

27. Cai, Di, et al**.** "Biobutanol From Sweet Sorghum Bagasse Hydrolysate By a Hybrid Pervaporation Process." Bioresource Technology, vol. 145, 2013, pp. 97-102.
28. Luterbacher J.S., Rand J.M., Alonso D.M., Han J., Youngquist J.T., Maravelias C.T., Pfleger B.F., Dumesic J.A. Nonenzymatic Sugar Production from Biomass Using Biomass-Derived-Valerolactone. Science. 2014;343:277–280. doi: 10.1126/science.1246748. [PubMed] [CrossRef] [Google Scholar]
29. González-García S., Moreira M.T., Feijoo G. Comparative Environmental Performance of Lignocellulosic Ethanol from Different Feedstocks. Renew. Sustain. Energy Rev. 2010;14:2077–2085. doi: 10.1016/j.rser.2010.03.035. [CrossRef] [Google Scholar]
30. Sun, Y. and Cheng, J.Y. Hydrolysis of Lignocellulosic Materials for Ethanol Production: A Review. 2002 Bioresource Technology, 83, 1-11.
31. Xue C., Zhao X.-Q., Liu C.-G., Chen L.-J., Bai F.-W. Prospective and Development of Butanol as an Advanced Biofuel.Biotechnol. Adv. 2013;31:1575–1584. doi: 10.1016/j.biotechadv.2013.08.004. [PubMed] [CrossRef] [Google Scholar]
32. Pfromm P.H., Amanor-Boadu V., Nelson R., Vadlani P., Madl R. Bio-Butanol vs. Bio-Ethanol: A Technical and Economic Assessment for Corn and Switchgrass Fermented by Yeast or Clostridium Acetobutylicum. Biomass Bioenergy. 2010;34:515–524. doi: 10.1016/j.biombioe.2009.12.017. [CrossRef] [Google Scholar]
33. Mosier, N., Wyman, C., Dale, B.**,** et al**.** (2005) Features of Promising Technologies for Pretreatment of Lignocellulosic Biomass. Bioresource Technology, 96, 673-686.
34. Shi S., Yue C., Wang L., Sun X., Wang Q. A Bibliometric Analysis of Anaerobic Digestion for Butanol Production Research Trends. Procedia Environ. Sci. 2012;16:152–158. doi: 10.1016/j.proenv.2012.10.021. [CrossRef] [Google Scholar]
35. Gautam M., Martin D.W. Combustion Characteristics of Higher-Alcohol/gasoline Blends. Proc. Inst. Mech. Eng.A J. Power Energy. 2000;214:497–511. doi: 10.1243/0957650001538047. [CrossRef] [Google Scholar]
36. Patakova P., Maxa D., Rychtera M., Linhova M., Fribert P., Muzikova Z., Lipovsky J., Paulova L., Pospisil M., Sebor G., et al. Biofuel's Engineering Process Technology. In Tech; Zagreb, Croatia: 2011. Perspectives of Biobutanol Production and Use; pp. 243–266. [Google Scholar]
37. Mascal M. Chemicals from Biobutanol: Technologies and Markets. Biofuel Bioprod. Biorefin. 2012;6:483–493. doi: 10.1002/bbb.1328. [CrossRef] [Google Scholar]
38. Kumar M., Goyal Y., Sarkar A., Gayen K. Comparative Economic Assessment of ABE Fermentation Based on Cellulosic and Non-Cellulosic Feedstocks. Appl. Energy. 2012;93:193–204. doi: 10.1016/j.apenergy.2011.12.079. [CrossRef] [Google Scholar]
39. Jurgens G., Survase S., Berezina O., Sklavounos E., Linnekoski J., Kurkijärvi A., Väkevä M., van Heiningen A., Granström T. Butanol Production from Lignocellulosics. Biotechnol.Lett. 2012;34:1415–1434. doi: 10.1007/s10529-012-0926-3. [PubMed] [CrossRef] [Google Scholar]

40. Banerjee S, Sen R, Pandey RA, Chakrabarti T, Satpute D, Giri BS, Mudliar S. Evaluation of wet air oxidation as a pretreatment strategy for bioethanol production from rice husk and process optimization. Biomass Bioenergy 2009; 33: 1680–1686.
41. Ndaba B., Chiyanzu I., Marx S. N-Butanol Derived from Biochemical and Chemical Routes: A Review. Biotechnol. Rep. 2015;8:1–9. doi: 10.1016/j.btre.2015.08.001. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
42. Robinson G.C. A study of the acetone and butyl alcohol fermentation of various carbohydrates. J. Biol. Chem. 1922;53:125–155. [Google Scholar]
43. Killeffer D.H. Butanol and acetone from corn. Ind. Eng. Chem. 1927;19:46–50. doi: 10.1021/ie50205a013. [CrossRef] [Google Scholar]
44. Gabriel C.L., Crawford F.M. Development of the butyl-acetonic fermentation industry. Ind. Eng. Chem. 1930;22:1163–1165. doi: 10.1021/ie50251a014. [CrossRef] [Google Scholar]
45. Davies R., Stephenson M. Studies on the acetone-butyl alcohol fermentation. 1. Nutritional and other factors involved in the preparation of active suspensions of Cl. acetobutylicum (Weizmann) Biochem. J. 1941;35:1320–1331. doi: 10.1042/bj0351320. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
46. Langlykke A.F., van Lanen J.M., Fraser D.R. Butyl alcohol from xylose saccharification liquors from corncobs. Ind. Eng. Chem. 1948;40:1716–1719. doi: 10.1021/ie50465a025. [CrossRef] [Google Scholar]
47. M.khedkar, P. Nimbalkar, S.Gaikward Sustainable biobutanol production from pineapple waste by using Clostridium acetobutylicum B 527: Drying kinetics study Bioresource Technology 225. 2017 DOI:10.1016/j.biortech.2016.11.058
48. Rosenberg S.L. Fermentation of pentose sugars to ethanol and other neutral products by microorganisms. Enzyme Microb. Technol. 1980;2:185–193. doi: 10.1016/0141-0229(80)90045-9. [CrossRef] [Google Scholar]
49. Weigel J. Fermentation of ethanol by bacteria. A pledge for the use of extreme thermophilic anaerobic bacteria in industrial ethanol fermentation processes. Experientia. 1980;36:1434–1446. doi: 10.1007/BF01960144. [CrossRef] [Google Scholar]
50. Zeikus J.G. Chemical and fuel production by anaerobic bacteria.Annu. Rev. Microbiol. 1980;34:423–464. doi: 10.1146/annurev.mi.34.100180.002231. [PubMed] [CrossRef] [Google Scholar]
51. Calam C.T. Isolation of Clostridium acetobutylicum strains producing butanol and acetone. Biotechnol.Lett. 1980;2:111–116. doi: 10.1007/BF00142035. [CrossRef] [Google Scholar]
52. Haggstrom L., Molin N. Calcium alginate immobilized cells of Clostridium acetobutylicum for solvent production. Biotechnol.Lett. 1980;2:241–246. doi: 10.1007/BF01209440. [CrossRef] [Google Scholar]
53. Maddox I.S. Production of n-butanol from whey filtrate using Clostridium acetobutylicum NCIB 2951.Biotechnol.Lett. 1980;2:493–498. doi: 10.1007/BF00129545. [CrossRef] [Google Scholar]
54. Gheshlaghi R., Scharer J.M., Moo-Young M., Chou C. Metabolic pathways of clostridia for producing butanol. Biotechnol. Adv. 2009;27:764–781. doi: 10.1016/j.biotechadv.2009.06.002. [PubMed] [CrossRef] [Google Scholar]
55. Kushwaha D., Srivastava D., Mishra I., Upadhyay S.N., Mishra P.K. Recent trends in biobutanol production. Rev. Chem. Eng. 2018 doi: 10.1515/revce-2017-0041. [CrossRef] [Google Scholar]
56. Lan E.I., Liao J.C. Microbial synthesis of n-butanol, isobutanol, and other higher alcohols from diverse resources. Bioresour. Technol. 2013;135:339–349. doi: 10.1016/j.biortech.2012.09.104. [PubMed] [CrossRef] [Google Scholar]

57. A.Ranjan,S.Khanna, V.S. Moholkar, Feasibility of rice straw as alternate substrate for biobutanol production , Applied energy 103. 2013 pp32-38

58. Mitchell W.J. Physiology of carbohydrates to solvent conversion by clostridia. Adv. Microb. Physiol. 1998;39:31–130. doi: 10.1016/S0065-2911(08)60015-6. [PubMed] [CrossRef] [Google Scholar]
59. Li H, Qu Y, Yang Y, Chang S, Xu J. Microwave irradiation – a green and efficient way to pretreat biomass. Bioresour Technol 2016; 199: 34–41
60. Gottwald M., Hippe H., Gottschalk G. Formation of n-butanol from d-glucose by strains of "Clostridium tetanomorphum" group. Appl. Environ. Microbiol. 1984;48:573–576. [PMC free article] [PubMed] [Google Scholar]
61. George H.A., Johnson J.L., Moore W.E.C., Holdeman L.V., Chen J.S. Acetone, isopropanol, and butanol production by Clostridium beijerinckii (syn. Clostridium butylicum) and Clostridium aurantibutylicum. Appl. Environ. Microbiol. 1983;45:1160–1163. [PMC free article] [PubMed] [Google Scholar]
62. George H.A., Chen J.S. Acidic conditions are not obligatory for onset of butanol formation by Clostridium beijerinckii (synonym. C. butylicum) Appl. Environ.Microbiol. 1983;46:321–327. [PMC free article] [PubMed] [Google Scholar]
63. Jones T.J., Woods D.R. Solvent production. In: Minton N.P., Clarke D.J., editors. Clostridia. Plenum Press; New York, NY, USA: 1989. pp. 105–144. [Google Scholar]
64. Johnson M.J., Peterson W.H., Fred E.B. Oxidation and reduction relations between substrate and products in the acetone-butylalcohol fermentation. J. Biol. Chem. 1931;91:569–591. [Google Scholar]
65. Bahl H., Andersch W., Braun K., Gottschalk G. Effect on pH and butyrate concentration on the production of acetone and butanol by Clostridium acetobutylicum growing in a continuous culture. Eur. J. Appl. Microbiol. Biotechnol. 1982;14:17–20. doi: 10.1007/BF00507998. [CrossRef] [Google Scholar]
66. Ballongue J., Amine J., Mason E., Petitdemange H., Gay R. Induction of acetoacetate decarboxylase in Clostridium acetobutylicum. FEMS Microbiol.Lett. 1985;29:273–277. doi: 10.1111/j.1574-6968.1985.tb00875.x. [CrossRef] [Google Scholar]
67. Fond O., Matta-Ammouri G., Petitdemange H., Engasser J.M. The role of acids on the production of acetone and butanol by Clostridium acetobutylicum. Appl. Microbiol. Biotechnol. 1985;22:195–200. doi: 10.1007/BF00253609. [CrossRef] [Google Scholar]
68. Kell D.B., Peck M.W., Rodger G., Morris J.G. On the permeability to weak acids and bases of the cytoplasmic membrane of Clostridium pasteurianum.Biochem.Biophys. Res. Commun. 1973;99:81–88. doi: 10.1016/0006-291X(81)91715-0. [PubMed] [CrossRef] [Google Scholar]
69. Moreira A.R., Ulmer D.C., Linden J.C. Butanol toxicity in the butylic fermentation. Biotechnol.Bioeng.Symp. 1981;11:567–579. [Google Scholar]
70. Vollherbst-Schneck K.J.A., Sands A., Montencourt B.S. Effect of butanol on lipid composition and fluidity of Clostridium acetobutylicum ATCC 824. Appl. Environ. Microbiol. 1984;47:193–194. [PMC free article] [PubMed] [Google Scholar]
71. Bowles L.K., Ellefson W.L. Effects of butanol on Clostridium acetobutylicum. Appl. Environ. Microbiol. 1985;50:1165–1170. [PMC free article] [PubMed] [Google Scholar]
72. Rogers P. Genetics and biochemistry of Clostridium relevant to development of fermentation processes. Adv. Appl. Microbiol. 1986;31:1–60. doi: 10.1016/S0065-2164(08)70438-6. [CrossRef] [Google Scholar]
73. Kotze J.P. Glycolytic and related enzymes in clostridial classification. Appl. Microbiol. 1969;18:744–747. [PMC free article] [PubMed] [Google Scholar]

74. M.Mirfakhar,Mohammad AliAsadollahi,HamidAmir,KeikhosroKarimi Co-fermentation of hemicellulosic hydrolysates and starch from sweet sorghum by *Clostridium acetobutylicum*: A synergistic effect for butanol production 2017, ind crops and products
75. Thauer R.K., Jungermann K., Dekker K. Energy conservation in chemotropic anaerobic bacteria. Bacteriol. Rev. 1977;41:100–180. [PMC free article] [PubMed] [Google Scholar]
76. Benazzi T, Calgaroto S, Astolfi V, Rosa CD, Oliveira JV. Pretreatment of sugarcane bagasse using supercritical carbon dioxide combined with ultrasound to improve the enzymatic hydrolysis. Enzyme Microb Tech 2013; 52: 247–250.
77. Ounine K., Petitdemange H., Raval G., Gay R. Acetone-butanol production from pentoses by Clostridium acetobutylicum. Biotechnol.Lett. 1983;5:605–610. doi: 10.1007/BF00130841. [CrossRef] [Google Scholar]
78. Cynkin M.A., Delwiche E.A. Metabolism of pentoses by clostridia. I. Enzymes of ribose dissimilation in extracts of Clostridium perfringens. J. Bacteriol. 1958;75:331–334. [PMC free article] [PubMed] [Google Scholar]
79. Mosier N, Wyman C, Dale B, Elander R, Lee YY, Holtzapple M, Ladisch M. Features of promising technologies for pretreatment of lignocellulosic biomass. Bioresour Technol 2005; 96: 673–686.
80. Uyeda K., Rabinowitz J.C. Pyruvate-ferredoxin oxidoreductase. IV. Studies on the reaction mechanism. J. Bacteriol. Chem. 1971;246:3120–3125. [PubMed] [Google Scholar]
81. Kim B.H., Bellows P., Datta R., Zeikus J.G. Control of carbon and electron flow in Clostridium acetobutylicum fermentations: Utilization of carbon monoxide to inhibit hydrogen production and to enhance butanol yields. Appl. Environ. Microbiol. 1984;48:764–770. [PMC free article] [PubMed] [Google Scholar]
82. Hartmanis M.G.N., Gatenbeck S. Intermediary metabolism in Clostridium acetobutylicum: Levels of enzymes involved in the formation of acetate and butyrate. Appl. Environ. Microbiol. 1984;47:1277–1283. [PMC free article] [PubMed] [Google Scholar]
83. Seedorf H., Fricke W.F., Veith B., Brüggemann H., Liesegang H., Strittmatter A., Miethke M., Buckel W., Hinderberger J., Li F., et al. The genome of Clostridium kluyveri, a strict anaerobe with unique metabolic features. Proc. Natl. Acad. Sci. USA. 2008;105:2128–2133. doi: 10.1073/pnas.0711093105. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
84. Jang Y.-S., Lee J., Malaviya A., Seung Y., Cho J.H., Lee S.Y. Butanol production from renewable biomass: Rediscovery of metabolic pathways and metabolic engineering. Biotechnol. J. 2012;7:186–198. doi: 10.1002/biot.201100059. [PubMed] [CrossRef] [Google Scholar]
85. Köpke M., Held C., Hujer S., Liesegang H., Wiezer A., Wollherr A., Ehrenreich A., Liebl W., Gottschalk G., Dürre P. Clostridium ljungdahlii represents a microbial production platform based on syngas. Proc. Natl. Acad. Sci. USA. 2010;107:13087–13092. doi: 10.1073/pnas.1004716107. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
86. Munasinghe P.C., Khanal S.K. Biomass-derived syngas fermentation into biofuels: Opportunities and challenges. Bioresour. Technol. 2010;101:5013–5022. doi: 10.1016/j.biortech.2009.12.098. [PubMed] [CrossRef] [Google Scholar]
87. Tracy B.P., Jones S.W., Fast A.G., Indurthi D.C., Papoutsakis E.T. Clostridia: The importance of their exceptional substrate and metabolite diversity for biofuel and biorefinery applications. Curr.Opin.Biotechnol. 2012;23:364–381. doi: 10.1016/j.copbio.2011.10.008. [PubMed] [CrossRef] [Google Scholar]
88. Jones D.T., Woods D.R. Acetone-butanol fermentation revisited. Microbiol. Rev. 1986;50:484–524. [PMC free article] [PubMed] [Google Scholar]

89. Qureshi N., Blaschek H.P. Recent advances in ABE fermentation: Hyper-butanol producing Clostridium beijerinckii BA101. J. Ind. Microbiol. Biotechnol. 2001;27:287–291. doi: 10.1038/sj.jim.7000114. [PubMed] [CrossRef] [Google Scholar]
90. Qureshi N., Lolas A., Blaschek H.P. Soy molases as fermentation substrate for production of butanol using Clostridium beijerinckii BA101. J. Ind. Microbiol. Biotechnol. 2001;26:290–295. doi: 10.1038/sj.jim.7000131. [PubMed] [CrossRef] [Google Scholar]
91. Ezeji T., Groberg M., Qureshi N., Blaschek H.P. Continous production of butanol from starch-based packaking peanuts. Appl. Biochem. Biotechnol. 2003;105–108:375–382. doi: 10.1385/ABAB:106:1-3:375. [PubMed] [CrossRef] [Google Scholar]
92. Madihah M.S., Ariff A.B., Sahaid K.M., Suraini A.A., Karim M.I.A. Direct fermentation of gelatinized sago starch to acetone butanol ethanol by Clostridium acetobutylicum. World J. Microbiol.Biotechnol. 2001;17:567–576. doi: 10.1023/A:1012351112351. [CrossRef] [Google Scholar]
93. Thang V.H., Kanka K., Kobayashi G. Production of acetone-butanol-ethanol (ABE) in direct fermentation of cassava by Clostridium saccharoperbutylacetonicum N1-4. Appl. Biochem. Biotechnol. 2010;161:157–170. doi: 10.1007/s12010-009-8770-1. [PubMed] [CrossRef] [Google Scholar]
94. Liu Z., Ying Y., Li F., Ma C., Xu P. Butanol production by Clostridium beijerinckii ATCC 55025 from wheat bran. J. Ind. Microbiol. Biotechnol. 2010;37:495–501. doi: 10.1007/s10295-010-0695-8. [PubMed] [CrossRef] [Google Scholar]
95. Qureshi N., Saha B.C., Cotta M.A. Butanol production from wheat straw hydrolysate using Clostridium beijerinckii. Bioprocess Biosys. Eng. 2007;30:419–427. doi: 10.1007/s00449-007-0137-9. [PubMed] [CrossRef] [Google Scholar]
96. Al-Shorgani N.K., Kalil M.S., Yusoff W.M. Biobutanol production from rice bran and de-oiled rice bran by Clostridium saccharoperbutylacetonicum N1-4. Bioprocess Biosyst. Eng. 2012;35:817–826. doi: 10.1007/s00449-011-0664-2. [PubMed] [CrossRef] [Google Scholar]
97. Al-Shorgani N.K., Al-Tabib A.I., Kalil M.S. Production of butanol from acetyl chloride-treated deoiled rice bran by Clostridium acetobutylicum YM1. Bioresources. 2017;12:8505–8518. doi: 10.15376/biores.12.4.8505-8518. [CrossRef] [Google Scholar]
98. Lopez-Contreras A.M., Claassen P.A.M., Mooibroek W., De Vos W.M. Utilisation of saccharides in extruded domestic organic waste by Clostridium acetobutylicum ATCC 824 for production of acetone, butanol and ethanol. Appl. Microbiol. Biotechnol. 2000;54:162–167. doi: 10.1007/s002530000374. [PubMed] [CrossRef] [Google Scholar]
99. Claassen P.A.M., van Lier J.B., Lopez Contreras A.M., van Niel E.W.J., Sijtsma L., Stams A.J.M., de Vries S.S., Weusthuis R.A. Utilisation of biomass for the supply of energy carriers. Appl. Microbiol. Biotechnol. 1999;52:741–755. doi: 10.1007/s002530051586. [CrossRef] [Google Scholar]
100. Efremenko E.N., Nikolskaya A.B., Lyagin I.V., Senko O.V., Makhlis T.A., Stepanov N.A., Maslova O.V., Mamedova F., Varfolomeev S.D. Production of biofuels from pretreated microalgae biomass by anaerobic fermentation with immobilized Clostridium acetobutylicum cells.Bioresour. Technol. 2012;114:342–348. doi: 10.1016/j.biortech.2012.03.049. [PubMed] [CrossRef] [Google Scholar]
101. Ellis J.T., Hengge N.N., Sims R.C., Miller C.D. Acetone, butanol, and ethanol production from wastewater algae. Bioresour. Technol. 2012;111:491–495. doi: 10.1016/j.biortech.2012.02.002. [PubMed] [CrossRef] [Google Scholar]
102. Lee S.Y., Park J.H., Jang S.H., Nielsen L.K., Kim J., Jung K.S. Fermentative butanol production by clostridia. Biotechnol.Bioeng. 2008;101:209–228. doi: 10.1002/bit.22003. [PubMed] [CrossRef] [Google Scholar]

103. Zverlov V.V., Berezina O., Velikodvorskaya G.A., Schwarz W.H. Bacterial acetone and butanol production by industrial fermentation in the Soviet Union: Use of hydrolyzed agricultural waste for biorefinery. Appl. Microbiol. Biotechnol. 2006;71:587–597. doi: 10.1007/s00253-006-0445-z. [PubMed] [CrossRef] [Google Scholar]
104. Chen H. Biotechnology of Lignocellulose: Theory and Practice. Chemical Industry Press; Beijing, China: Springer Science Business Media; Dordrecht, The Netherlands: 2014. [Google Scholar]
105. Blanch H.W., Simmons B.A., Klein-Marcuschamer D. Biomass desconstruction to sugars. Biotechnol. J. 2011;6:1086–1102. doi: 10.1002/biot.201000180. [PubMed] [CrossRef] [Google Scholar]
106. Qureshi N., Saha B.C., Dien B., Hector R.E., Cotta M.A. Production of butanol (a biofuel) from agricultural residues: Part I—Use of barley straw hydrolysate. Biomass Bioenergy. 2010;34:559–565. doi: 10.1016/j.biombioe.2009.12.024. [CrossRef] [Google Scholar]
107. Qureshi N., Saha B.C., Hector R.E., Diena B., Hughes S., Liu S., Iten L., Bowman M.J., Sarath G., Cotta M.A. Production of butanol (a biofuel) from agricultural residues: Part II—Use of corn stover and switchgrass hydrolysates. Biomass Bioenergy. 2010;34:566–571. doi: 10.1016/j.biombioe.2009.12.023. [CrossRef] [Google Scholar]
108. Nunes A.A., Franca A.S., Oliveira L.S. Activated carbons from waste biomass: An alternative use for biodiesel production solid residues. Bioresour. Technol. 2009;100:1786–1792. doi: 10.1016/j.biortech.2008.09.032. [PubMed] [CrossRef] [Google Scholar]
109. Hendriks ATWM, Zeeman G. Pretreatments to enhance the digestibility of lignocellulosic biomass. Bioresour Technol 2009; 100: 10–18

110. Zhu, Y. and Yang, S. T. Continuous production of butanol by clostridium acetobutylicum immobilized in a fibrous bed bioreactor. (2004), Biotechnol. Prog. 19, 365–372.
111. Voget C.E., Mignone C.F., Ertola R.J. Butanol production from apple pomace. Biotechnol.Lett. 1985;7:43–46. doi: 10.1007/BF01032418. [CrossRef] [Google Scholar]
112. Survase S.A., Sklavounos E., van Heiningen A., Granström T. Market refused vegetables as a supplement for improved acetone–butanol–ethanol production by Clostridium acetobutylicum DSM 792. Ind. Crop. Prod. 2013;45:349–354. doi: 10.1016/j.indcrop.2012.12.049. [CrossRef] [Google Scholar]
113. Qureshi N., Ezeji T.C., Ebener J., Dien B.S., Cotta M.A., Blaschek H.P. Butanol production by Clostridium beijerinckii. Part I: Use of acid and enzyme hydrolyzed corn fiber. Bioresour. Technol. 2008;99:5915–5922. doi: 10.1016/j.biortech.2007.09.087. [PubMed] [CrossRef] [Google Scholar]
114. Qureshi N., Saha B.C., Hector R.E., Hughesb S.R., Cottaa M.A. Butanol production from wheat straw by simultaneous saccharification and fermentation using Clostridium beijerinckii: Part I-batch fermentation. Biomass Bioenergy. 2008;32:168–175. doi: 10.1016/j.biombioe.2007.07.004. [CrossRef] [Google Scholar]
115. Qureshi N., Saha B.C., Hector R.E., Cotta M.A. Butanol production from wheat straw by simultaneous saccharification and fermentation using Clostridium beijerinckii: Part II—Fed batch fermentation. Biomass Bioenergy. 2008;32:176–185. doi: 10.1016/j.biombioe.2007.07.005. [CrossRef] [Google Scholar]
116. Qureshi N., Saha B.C., Hector R.E., Cotta M.A. Removal of fermentation inhibitors from alkaline peroxide pretreated and enzymatically hydrolyzed wheat straw: Production of butanol from hydrolysate using Clostridium beijerinckii in batch reactors. Biomass Bioenergy. 2008;32:1353–1358. doi: 10.1016/j.biombioe.2008.04.009. [CrossRef] [Google Scholar]

117. Mariano A.P., Costa C.B.B., Angelis D.F., Filho F.M., Atala D.I.P., Maciel M.R.W., Filho R.M. Optimisation of a continuous flash fermentation for butanol production using the response surface methodology. Chem. Eng. Res. Des. 2010;88:562–571. doi: 10.1016/j.cherd.2009.11.002. [CrossRef] [Google Scholar]
118. Zheng Y.N., Li L.Z., Xian M., Ma Y.J., Yang J.M., Xu X., He D.Z. Problems with the microbial production of butanol. J. Ind. Microbiol. Biotechnol. 2009;36:1127–1138. doi: 10.1007/s10295-009-0609-9. [PubMed] [CrossRef] [Google Scholar]
119. Becerra M., Cerdán M.E., González-Siso M.I. Biobutanol from cheese whey. Microb.Cell Factories. 2015;14:27. doi: 10.1186/s12934-015-0200-1. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
120. Kumar M., Gayen K. Developments in biobutanol production: New insights. Appl. Energy. 2011;88:1999–2012. doi: 10.1016/j.apenergy.2010.12.055. [CrossRef] [Google Scholar]
121. Ezeji T.C., Qureshi N., Blaschek H.P. Acetone butanol ethanol (ABE) production from concentrated substrate: Reduction in substrate inhibition by fed-batch technique and product inhibition by gas stripping. Appl. Microbiol. Biotechnol. 2004;63:653–658. doi: 10.1007/s00253-003-1400-x. [PubMed] [CrossRef] [Google Scholar]
122. Ezeji T., Qureshi N., Blaschek H.P. Butanol production from agricultural residues: Impact of degradation products on Clostridium beijerinckii growth and butanol fermentation. Biotechnol.Bioeng. 2007;97:1460–1469. doi: 10.1002/bit.21373. [PubMed] [CrossRef] [Google Scholar]
123. Munoz-Paez K.M., Alvarado-Michi E.L., Buitron G., Valdez-Vazquez I. Distinct effects of furfural, hydroxymethylfurfural and its mixtures on dark fermentation hydrogen production and microbial structure of a mixed culture. Int. J. Hydrog. Energy. 2019;44:2289–2297. doi: 10.1016/j.ijhydene.2018.04.139. [CrossRef] [Google Scholar]
124. Cho D.H., Lee Y.J., Um Y., Sang B.I., Kim Y.H. Detoxification of model phenolic compounds in lignocellulosic hydrolysates with peroxidase for butanol production from Clostridium beijerinckii. Appl. Microbiol. Biotechnol. 2009;83:1035–1043. doi: 10.1007/s00253-009-1925-8. [PubMed] [CrossRef] [Google Scholar]
125. Palmqvist E., Hahn-Hagerdal B. Fermentation of lignocellulosic hydrolysates. I: Inhibition and detoxication. Bioresour. Technol. 2000;74:17–24. doi: 10.1016/S0960-8524(99)00160-1. [CrossRef] [Google Scholar]
126. Gottumukkala D.L., Haigh K., Görgens J. Trends and advances in conversion of lignocellulosic biomass to biobutanol: Microbes, bioprocesses and industrial viability. Renew. Sustain. Energy Rev. 2017;76:963–973. doi: 10.1016/j.rser.2017.03.030. [CrossRef] [Google Scholar]
127. Jang Y.-S., Malaviya A., Cho C., Lee J., Lee S.Y. Butanol production from renewable biomass by clostridia. Bioresour. Technol. 2012;123:653–663. doi: 10.1016/j.biortech.2012.07.104. [PubMed] [CrossRef] [Google Scholar]
128. Dolejs I., Rebroš M., Rosenberg M. Immobilisation of Clostridium spp. for production of solvents and organic acids. Chem. Pap. 2014;68:1–14. doi: 10.2478/s11696-013-0414-9. [CrossRef] [Google Scholar]
129. Huang W.-C., Ramey D.E., Yang S.-T.Continuous production of butanol by Clostridium acetobutylicum immobilized in a fibrous bed reactor. Appl. Biochem. Biotechnol. 2004;113:887–898. doi: 10.1385/ABAB:115:1-3:0887. [PubMed] [CrossRef] [Google Scholar]
130. Napoli F., Olivieri G., Marzocchella A., Russo M.E., Salatino P. Production of butanol in a continuous packed bed reactor of Clostridium acetobutylicum. Chem. Eng. Trans. 2010;20:193–198. doi: 10.1007/s10295-010-0707-8. [PubMed] [CrossRef] [Google Scholar]

131. Qureshi N., Lai L.L., Blaschek H.P. Scale-up of a high productivity continuous biofilm reactor to produce butanol by adsorbed cells of Clostridium beijerinckii. Food Bioprod.Process. 2004;82:164–173. doi: 10.1205/0960308041614891. [CrossRef] [Google Scholar]
132. Zheng J., Tashiro Y., Yoshida T., Gao M., Wang Q., Sonomoto K. Continuous butanol fermentation from xylose with high cell density by cell recycling system. Bioresour. Technol. 2013;129:360–365. doi: 10.1016/j.biortech.2012.11.066. [PubMed] [CrossRef] [Google Scholar]
133. Sánchez-Ramírez E., Quiroz-Ramírez J.J., Segovia-Hernández J.G., Hernández S., Ponce-Ortega J.M. Economic and environmental optimization of the biobutanol purification process. Clean Technol. Environ. 2016;18:395–411. doi: 10.1007/s10098-015-1024-8. [CrossRef] [Google Scholar]
134. Grady M.C., Jahic M., Patnaik R. A Method for Producing Butanol Using Two-Phase Extractive Fermentation.No. 12/478,389.U.S. Patent. 2009 Jun 4;
135. Roffler S., Blanch H., Wilke C.R. Extractive Fermentation of Acetone and Butanol: Process Design and Economic Evaluation. Biotechnol.Prog. 1987;3:131–140. doi: 10.1002/btpr.5420030304. [CrossRef] [Google Scholar]
136. Evans P.J., Wang H.Y. Enhancement of Butanol Formation by Clostridium acetobutylicum in the Presence of Decanol-Oleyl Alcohol Mixed Extractants. Appl. Environ. Microbiol. 1988;54:1662–1667. [PMC free article] [PubMed] [Google Scholar]
137. Xue C., Liu F., Xu M., Zhao J., Chen L., Ren J., Bai F., Yang S.-T. A novel in situ gas stripping-pervaporation process integrated with acetone-butanol-ethanol fermentation for hyper n-butanol production. Biotechnol Bioeng. 2016;113:120–129. doi: 10.1002/bit.25666. [PubMed] [CrossRef] [Google Scholar]
138. Wang Y.-F., Tian J., Ji Z.-H., Song M.-Y., Li H. Intracellular metabolic changes of Clostridium acetobutylicum and promotion to butanol tolerance during biobutanol fermentation. Int. J. Biochem. Cell Biol. 2016;78:297–306. doi: 10.1016/j.biocel.2016.07.031. [PubMed] [CrossRef] [Google Scholar]
139. Liu X., Gua Q., Liao C., Yu X. Enhancing butanol tolerance and preventing degeneration in Clostridium acetobutylicum by 1-butanol–glycerol storage during long-term preservation. Biomass Bioenerg. 2014;69:192–197. doi: 10.1016/j.biombioe.2014.07.019. [CrossRef] [Google Scholar]
140. Lin Y.L., Blaschek H.P. Butanol production by a butanol-tolerant strain of Clostridium acetobutyricum in extruded corn broth. Appl. Environ. Microbiol. 1983;45:966–973. [PMC free article] [PubMed] [Google Scholar]
141. Syed Q., Nadeem M., Nelofer R. Enhanced butanol production by mutant strains of Clostridium acetobutylicum in molasses medium. Turk. J. Biochem. 2008;33:25–30. [Google Scholar]
142. Duerre P. Fermentative production of butanol–the academic perspective.Curr.Opin.Biotechnol. 2011;22:331–336. doi: 10.1016/j.copbio.2011.04.010. [PubMed] [CrossRef] [Google Scholar]
143. Jin C., Yao M., Liu H., Lee C.F., Ji J. Progress in the production and application of n-butanol as a biofuel. Renew. Sustain. Energy Rev. 2011;15:4080–4106. doi: 10.1016/j.rser.2011.06.001. [CrossRef] [Google Scholar]
144. Lee J., Jang Y.S., Choi S.J., Im J.A., Hyohak Song H., Cho J.H., Seung D.Y., Papoutsakis E.T., Bennett G.N., Lee S.Y. Metabolic Engineering of Clostridium acetobutylicum ATCC 824 for Isopropanol-Butanol-Ethanol Fermentation. Appl. Environ. Microbiol. 2012;78:1416–1423. doi: 10.1128/AEM.06382-11. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

145. Tashiro Y., Yoshida T., Noguchi T., Sonomoto K. Recent advances and future prospects for increased butanol production by acetone-butanol-ethanol fermentation. Eng. Life Sci. 2013;13:432–445. doi: 10.1002/elsc.201200128. [CrossRef] [Google Scholar]
146. Torres N.V., Voit E.O. Pathway Analysis and Optimization in Metabolic Engineering. Cambridge University Press; Cambridge, UK: 2002. [Google Scholar]
147. Papoutsakis E.T. Engineering solventogenic clostridia. Curr.Opin.Biotechnol. 2008;19:420–429. doi: 10.1016/j.copbio.2008.08.003. [PubMed] [CrossRef] [Google Scholar]
148. Mood SH, Golfeshan AH, Tabatabaei M, Jouzani GS, Najafi GH, Gholami M, Ardjmand M. Lignocellulosic biomass to bioethanol, a comprehensive review with a focus on pretreatment. Renew Sust Energy Rev 2013; 27: 77–93
149. Jiang Y., Xu C., Dong F., Yang Y., Jiang W., Yang S. Disruption of the acetoacetate decarboxylase gene in solvent-producing Clostridium acetobutylicum increases the butanol ratio. Metab. Eng. 2009;11:284–291. doi: 10.1016/j.ymben.2009.06.002. [PubMed] [CrossRef] [Google Scholar]
150. de Gérando H.M., Wasels F., Bisson A., Clement B., Bidard F., Jourdier E., López-Contreras A.M., Ferreira N.L. Genome and transcriptome of the natural isopropanol producer Clostridium beijerinckii DSM6423. BMC Genom. 2018;19:242. doi: 10.1186/s12864-018-4799-2. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
151. Garcia V., Pakkila J., Ojamo H., Muurinen E., Keiski R.L. Challenges in biobutanol production: How to improve the efficiency? Renew. Sustain. Energy Rev. 2011;15:964–980. doi: 10.1016/j.rser.2010.11.008. [CrossRef] [Google Scholar]
152. Cornillot E., Nair R.V., Papoutsakis E.T., Soucaille P. The genes for butanol and acetone formation in Clostridium acetobutylicum ATCC 824 reside on a large plasmid whose loss leads to degeneration of the strain. J. Bacteriol. 1997;179:5442–5447. doi: 10.1128/jb.179.17.5442-5447.1997. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
153. Hou ,IriniAngelidaki,Wouter J.J.Huijgen,Anne-BelindaBjerre Butanol fermentation of the brown seaweed *Laminaria digitata* by *Clostridium beijerinckii* DSM-6422,Biosource technology vol. 238, 2017 pp 16-21
154. Dong H., Zhao C., Zhang T., Zhu H., Zhao L., Tao W., Zhang Y., Li Y. A systematically chromosomally engineered Escherichia coli efficiently produces butanol. Metab. Eng. 2017;44:284–292. doi: 10.1016/j.ymben.2017.10.014. [PubMed] [CrossRef] [Google Scholar]
155. Inui M., Suda M., Kimura S., Yasuda K., Suzuki H., Toda H., Yamamoto S., Okino S., Suzuki N., Yukawa H. Expression of Clostridium acetobutylicum butanol synthetic genes in Escherichia coli. Appl. Microbiol. Biotechnol. 2008;77:1305–1316. doi: 10.1007/s00253-007-1257-5. [PubMed] [CrossRef] [Google Scholar]
156. Berezina O.V., Zakharova N.V., Brandt A., Yarotsky S.V., Schwarz W.H., Zverlov V.V. Reconstructing the clostridial n-butanol metabolic pathway in Lactobacillus brevis. Appl. Microbiol. Biotechnol. 2010;87:635–646. doi: 10.1007/s00253-010-2480-z. [PubMed] [CrossRef] [Google Scholar]
157. Steen E.J., Chan R., Prasad N., Myers S., Petzold C.J., Redding A., Oellet M., Keasling J.D. Metabolic engineering of Saccharomyces cerevisiae for the production of n-butanol. Microbial Cell Factories. 2008;7:36–43. doi: 10.1186/1475-2859-7-36. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
158. Veibel S., Nielsen J.I. On the mechanism of the Guerbet reaction.Tetrahedron. 1967;23:1723–1733. doi: 10.1016/S0040-4020(01)82571-0. [CrossRef] [Google Scholar]
159. O'Lenick A.J., Jr. Guerbet chemistry. J. Surfactants Deterg. 2001;4:311–315. doi: 10.1007/s11743-001-0185-1. [CrossRef] [Google Scholar]

160. Knothe G. Synthesis, applications, and characterization of Guerbet compounds and their derivatives. Lipid Technol. 2002;14:101–104. [Google Scholar]
26th European Symposium on Computer Aided Process Engineering E. Sanchez-Ramírez, J.G. Segovia-Hernández, in Computer Aided Chemical Engineering, 2016.
28th European Symposium on Computer Aided Process Engineering Iulian Patraşcu, Anton A. Kiss, in Computer Aided Chemical Engineering, 2018.
Hamid Amiri, Keikhosro Karimi, in Advanced Bioprocessing for Alternative Fuels, Biobased Chemicals, and Bioproducts, 2019.
Biochemical production of bioalcohols, M. Melikoglu, ... C.S.K. Lin, in Handbook of Biofuels Production (Second Edition), 2016.