



REVIEW ARTICLE OF ACETIC ACID PRODUCTION BY WASTES AND STRAINS

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ABSTRACT:

Acetic acid or ethanoic acid is a carboxylic acid, is the oldest organic acid exists from the ancient history. In general, Acetic acid is commonly called as vinegar which contains around 4% acetic acid produced by acetic acid bacteria, *Acetobacter* and *Gluconobacter*. The acetic acid is generally regarded as safe and as a versatile compound it has diverge application in many industrial sectors which made the demand and supply of acetic acid in increasing annually. The acetic acid are produced either by chemical or biological route. In biochemical process either surface or submerged fermentation process is carried out. Various renewable substrates like kitchen waste and dairy waste are employed to for the effective production of acetic acid by biological route and it also helps reduce the waste and minimizes the environmental pollution.

KEYWORDS: Acetic acid, Acetic acid bacteria, *Acetobacter*, *Gluconobacter*, Vinegar

INTRODUCTION

Acetic acid name comes from Latin word '*acetum*' which means vinegar known from the ancient times for its usage in diverse field. Carboxylic acid generally known as Acetic acid (AA), ethanoic acid, vinegar, methane carboxylic acid. AA is highly versatile compound and hence it is widely utilized as crude materials in various industries such as food, textile, polymer and paint, beverages and pharmaceutical industry. Acetic acid are produced either by chemical or biological route. The chemical route are more prevalent method for the industrial large scale production when compared to biological route (Hassan M et al.,2012) [25]. It can able to react with both acid and base powerfully and at higher concentration it can corrodes metals, rubber and plastic Diluted form of acetic acid with 4 to 5% is known as vinegar has numerous industrial applications. Wood chips, green crops, manure, farm and mill waste are used as the crude for processing of acetic acid. Bacteria and yeast are more commonly

employed for the production of acetic acid, while bacteria convert the organic materials into acetic acid whereas the yeast organic materials into ethanol and later ethanol are converted into acetic acid by acetic acid bacteria (Yang Li., Dongwei He., Dongjie Niu., Youcai Zhao,2014) [9]. Acetic acid is one of the simplest carboxylic acid after formic acid and exists occurs as liquid in standard condition. The general physiochemical properties of AA are sour taste, colorless with pungent odor, hydrophilic protic solvent with the boiling point of 118°C. The viscosity and density are 1.22 mPa.S and 1.049g cm⁻³ respectively.

Types of acetic acid

Vinegar are used all over globe to increase the flavour, health related benefits. It serves as main ingredient in food. Many varieties of acetic acid/ vinegar is available in the market as white wine vinegar, balsamic vinegar, spirit vinegar. *Gluconobacter xylinus* AAB and *Gluconobacter europaeus* species were employed for the production of White wine vinegar from the natural fruit. Balsamic vinegar has aromatic smell, sweet-sour flavour and naturally produced from grapes or Trebbiano using *Saccharomyces* and *Zygosaccharomyces* and AAB are needed. Spirit vinegar are produced from diluted with ethyl alcohol and coloured with caramel. It is strong acidic and contains small quantity of amino acids (Peter Raspor et al., (2008). Suman Vikas Bhat et al., 2014) [15,3].

Market Scenario

Acetic acid is more volatile compound and generally considered as safe organic acid with multifarious application which leads to have strong demand and supply in the market.[1] The Compound Annual Growth Rate (CAGR) of acetic acid is 4.7% during 2019 to 2024 and continues to grow annually. The application of AA is discussed in table1. The AA has produced either chemical or biological route. The commercial production of acetic acid via chemical route has increased from 60 to 70% over two decades and whereas the biological route remains 10%. The necessities of AA have increased the production rate from 7.8 million tons to 13 million tons over the decade and the market value also increased considerably from US \$1200 and \$1600 per ton across the globe. China and USA are the leading producer of acetic acid with 54% and 17% of the total production of AA and the Asian countries are the largest consumer over 70% of the total production. VAM (Vinyl Acetate Monomer), Purified Terephthalic acid (PTA) and ethyl acetate are the major technological product derived from AA in the ratio of 3:2:1 of its total production. The figure 1 represents the global acetic acid production.

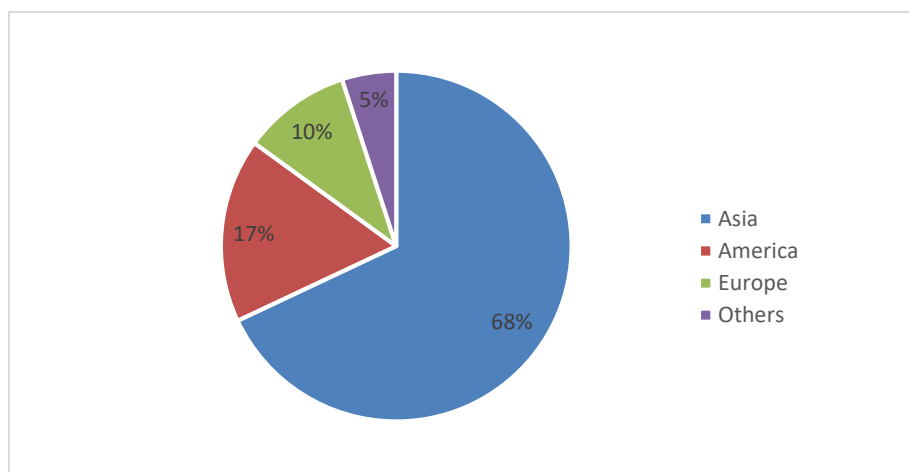


Fig 1: Global acetic acid demand by major region

Chemical route

Aldehyde oxidation, methanol carbonization, hydrocarbon oxidation are most common chemical and prevalent route accounts 60% of the total production. The oxidation of acetaldehyde is the first ever commercialized practice for the production of acetic acid where acetaldehyde reacts with oxygen in the presence of heterogeneous catalyst. More than 75% of the acetic acid production by chemical route is carried out by methanol carbonization method. This method is cheap and easy to control when C-O is added to acetaldehyde in the presence of alcohol and catalyst the acetic acid is formed at the temperature of 300°C. Hydrocarbon oxidation method usually carried for the petroleum products to generate acetic acid using the catalyst at the temperature around 250°C and high pressure. However, hydrocarbon oxidation fails to produce pure acetic acid and produces a mixture other organic acid by products.

Fermentative process

Fermentation processes of acetic acid are generally carried out by either by surface or submerged fermentation process. Orleans method are traditional method and are called French method (Kieran M. Lynch,2017) [7]. Surface fermentation is the oldest techniques and is called Trickling method where Acetic acid bacteria grow abundantly over the surface of the medium. The submerged fermentation processes are generally used for the industrial fermentation processes (Luz Maria Luzon-Quintana., Remedios Castro., Enrique Durran-Guerrero,2021) [5]. *Molelekoa et al.* (2018) used surface and submerged culture for the production of marula vinegar (a fruit from South Africa) (Luz Maria Luzon-Quintana., Remedios Castro., Enrique Durran-Guerrero,2021) [5].

Orleans Method

Orleans method is the oldest and slowest techniques used for the acetic acid production developed by Raspor and Goravonic in 1690 (Abhishek Kumar Singh,2020) [8]. This method very rarely practiced

in small scale level in wooden barrels with 200 litres of alcohol, wine with *Saccharomyces cerevisiae*. Fresh vinegar of 20-25% is added along with bacteria as a mother inoculant to form gelatinous slim layer (Suman Vikas Bhat., Rehana Akhtar., Tawheed Amin,2014) [3]. At $25\pm 3^{\circ}\text{C}$ with the pH of 2.8 ± 0.2 are the optimized condition maintained over 60 to 90 days for the effective production of AA to develop a taste and aroma and high organoleptic complexity (Albert Mass et al.,2014) [4]. Barrel design, wood type, selection of strain, purity of alcohol, and other physiochemical properties influences the production of AA greatly (Luz Maria Luzon-Quintana., Remedios Castro., Enrique Durran-Guerrero, 2021) [5]. The merit of the process are the low production cost, easy maintenance and the demerits are time consumption and high cost per volume (Nilgun et al., 2014) [6].

German Method

In 1832, German chemist Schutzenbach established German process which is one of the quick process (trickling method). It is also one of the oldest method of acetic acid production. Acetic acid bacteria are Gram-negative and aerobic bacteria (Taiyuan,2015) [20]. The *acetic acid bacteria* were grown and fermented thick slim coating beech wood shavings occurs in 5000-6000 litres of wood /steel tank while the alcoholic liquid distributes of spray mechanism covered with AAB (Suman Vikas Bhat., Rehana Akhtar., Tawheed Amin,2014) [3]. During, the pH maintained in the range between 2.5-3.2 and they produced at $27-30^{\circ}\text{C}$ of 88-90% of acetic acid from ethanol and remaining substrate is used in biomass production. Depending the size of the acetifier, production capacity was 70000- 100000 at 10% acidity (Jacques F. BOURGEOIS., Francois BARJA,2009) [23]. The acetic acid yield is approximately $1-2\text{ kg/m}^3\cdot\text{h}$. High yield of acetic acid was produced in surface culture of 57 611 mg/L with inoculum techniques (Tumisi B.J.Molelekoa et al.,2018)[18]. We followed three parameters: (i) mash circulation, (ii) cooling water through heat exchanger, (iii) amount of air passed through the system. Advantages is it requires low space requirements, Low costs, high acetic acid concentration. Drawbacks, high risk of clogging because of cellulose and high loss of ethanol by evaporation and difficult to produce AA production.

Submerged Fermentation

Compare to surface, submerged fermentation has high productivity and faster time (Kieran M. Lynch, 2017) [7,4]. In 1949, Hromatkar and Ebner applied this techniques, improved fermentation process like aeration, heating, etc. (Abhishek Kumar Singh,2020) [8]. Submerged fermented are made up of 10000-40000 litres of Stainless steel tank are widely used in industrial purpose. This process used for the vinegar production either continuous, batch and semi-continuous system maintained by exponential growth phase (Bacterial culture) (Luz Maria Luzon-Quintana., Remedios Castro., Enrique Durran-Guerrero, 2021 and Hassan M et al.,2012) [5,25]. Du Toit and Pretorius (2002) announced that mostly AAB development was seen between pH 5.4 - 6.3, yet they additionally could develop at pH esteems lower than 4. Acetic acid bacteria are *Gluconabactor* and *Komagataeibacter* species because it has low

acid content and produce high yield (Albert Mass et al., 2014 and Rodrigo Jose Gomes et al., 2018) [4,10]. Altered types are include rice, spirit and cider comes under this method (Jay Hemke et a., 2019) [11]. It maintains 8-9 acetic degree within 24-28 hours to reach high acetification range (Aladar Vidra., Aron Nemeth,2017) [21]. Temperature should be maintained 40-20°C. The yield of acetic acid in AAB found 20.51 g/L (Yang Li., Dongwei He., Dongjie Niu., Youcai Zhao ,2014) [9]. Kombucha beverages is one of the fastest and used in soft-drinks (Jonas De Roos., Luc De Vuyst.,2018) [14]. Advantages of this, is aeration and high yield. Drawbacks, power failure causes bacteria death even for short period and high rate of power consumption (Hassan M et al.,2012) [25].

In this study, acetic acid are produced by kitchen waste, dairy waste was carried out in the low cost substrate for the effective production of aa (Jacques F. BOURGEOIS., Francois BARJA,2009) [22].

Kitchen Waste

Every year there is rapid increase in food and agricultural waste accounts 30% to total agricultural waste which ultimately reduces substrate as well as the production cost (Yang Li., Dongwei He., Dongjie Niu., Youcai Zhao 2014) [9]. The left out items after cooking are generally categorized as kitchen waste and usually loaded with cellulose, starch. Protein which could easily initiate the growth of microorganisms. Wastes of mango, banana, pineapple, pumpkin peel, beef, chicken were also effectively utilized as a substrate for the production of AA Kimchi cabbage waste undergoes hydrolysis process and produce simple fermentable sugars (Ho Myeong Kim et al.,2018 and Ho Myeong Kim.,2019) [12,24]. *Acetobacter aceti*, *Clostridium species* are mostly used to produce Acetic acid by waste materials. The substrates were cleaned mixed with 1.0M of phosphate buffer pH of 6.98 by the ratio of 1:1 (C.W Loh et al., 1999) [13]. Compare to cellulosic material sources of cotton, jute, fruits is high cellulosic material. At very low concentration 0.43g/l and temperature greater than 40°C of micro-aerobic fermentation process with boiling points of 78.4,186.4°C (Yang Li., Dongwei He., Dongjie Niu., Youcai Zhao 2014) [9]. Yield of acetic acid can depends on inoculum concentration and the age of inoculate. Advantages of using kitchen waste as substrate are cheap, alternative methods of disposal of household wastes, significant reduction of municipal solid waste, high yield and low production cost (C.W Loh et al., 1999) [13]. The various factor which significantly influences the acetic acid production from kitchen waste are pH, temperature, organic load composition. When compared to industrial and municipal solid waste kitchen waste produces high yield of acetic acid. Around 26 gram of acetic acid per litre of fermentable kitchen waste and thus reusing the kitchen waste was successful.

Whey

Production of acetic acid from cheese whey is cheap, eco-friendly and renewable source. Whey is obtained as by product and waste from dairy industries and which as high protein content around 90g/kg. *Acetobacter aceti* are used to produce acetic acid to reduce the log phase fermented with whey permeate at 85.73°F overnight and then inoculated in membrane integrated reactor system. Fermentation carried out

high quality Stainless steel temperature should be maintained at 85.73°F and 150rpm. In batch fermentation, the productivity rate is 0.66-0.7 g L⁻¹h⁻¹ and high yield is 80-98% has reported (Jayato Nayak., Parimal Pal,2013) [28]. Saeki et al. (1997) reported *Acetobacter rances* SKU 1102 gave 43.0 g/L and supplement of 10g/L acetic acid (Chang YC., 2021) [29]. The biological oxygen demand for whey is 40,000 mg/L (Shang-Tian Yang., Zuwei Jin,1997) [30].

Other industrial waste like POME, distillery waste and biodiesel waste Chozhavendhan et al., (2016) [33] are employed for the production of acetic acid via biological route using *Acetobacter aceti*, *Acetobacter rances*, *Gluconobacter*, *Clostridium*.

Table 1: Application of acetic acid and uses of various sectors.

S. No	Applications	Role/Function	References
1	Orthopaedic surgery	Managing soft tissues injury.	(Yousuf Hashmi,2021) [16]
2	Homecare	Used in laundry detergents.	(Marc-Kevin Zinn and Dirk Bockmuhl.s, 2020) [32]
3	Machineries	Laboratory washing.	(Gunjan Deshmukh., Haresh Manyar,2020) [17]
4	Petrochemical industry	Used in paper coatings, emulsion, resins for paints.	(Xenia Christodoulou., Sharon B., Velasquez-Orta. 2016) [19]
5	Antidiabetic effect	Used for diabetic treatment and decrease blood sugar levels.	(Nilgun H. Budak,2014) [6]
6	Cardiovascular diseases	Defensive effect and decrease fatality.	(Abhishek Kumar Singh,2020) [8]
7	Food industry	Food condiment and preserving meats and vegetables.	(Abhishek Kumar Singh,2020) [8]
8	Beverages industry	Used to prevent growth, spoilage and preserve.	(Peter Raspor and Dusan Goranovic. (2008)) [15]
9	Therapeutic effects	Antibacterial property for injuries like burns.	(Abhishek Kumar Singh. ,2020) [8]

Conclusion

The acetic acid is more volatile compound known for its application from the ancient time. Submerged method of fermentation shows more productivity and yield when compared with other method. The utilization of organic waste like kitchen waste and industrial waste helps to reduce the waste recycling and legal sanctioning of waste disposal. The organic content in the waste can be utilized as carbon source for the microorganism to produce acetic acid effectively. This methods are now called as green technology and boost up the biological production of acetic acid the economic viability of acetic acid manufacturing industries.

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