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OVERVIEW OF VINEGAR PRODUCTION

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ABSTRACT
Vinegar is a fermentative product produced from the conversion of (C_2H_5OH) into acetic acid (CH_3CO_2H) by Acetobacter. It is the product obtains through alcoholic and acetic fermentation of agricultural origin substances containing about 5% acetic acid in water, fruit acids, colouring matter, salts and fermentation products for flavor and aroma. The quality of vinegar is a combined effect of acetic acid bacteria species, technological process and aging. Vinegar is used as a food preservative. In this review, detailed on processing methods, different types of substrates and microbes have been used for vinegar production is discussed.

INTRODUCTION

Vinegar is a french word where vin means wine and aigre means sour (surana et al) which is a liquid containing 5% acetic acid in water (Bhat et al, 2014), made from various sugary and starchy materials (san chiang tan). Vinegar is "a liquid carrying starch, sugars, or both, formed by process of fermentation, firstly alcoholic fermentation and then acetous fermentation, i.e double fermentation suitable for humans consumption stated by the codex alimentarius (1980)" (Bhat et al, 2014).

In human history, vinegar can be known back over 10,000 years during the starting of agriculture with finding of alcoholic fermentation (Kehrer 1921; Conner 1976). Vinegar has been used basis for simple remedies for animals and plants since ancient past. However vinegar production is always chemical process as obtaining product environmental friendly is need of chemical industry. Ethanol production has been report by using different typed of agricultural origin raw materials.

Orleans process priorly which is called slow method used in france 1670, also called as French process. Generator process which is quick process began in 1832 by German chemist Schutzenbach (Hickey and Vaughn) also called as trickling method. Generator and submerged fermentation process are used for vinegar production today. The surface culture called as submerged culture process from (Ory et al, 2002) improved fermentation parameters like aeration, stirring, heating etc (Hromatka and Ebner 1951).

Vinegar can be produced from different raw materials. Substrates used are wine (red, white, and sherry wine), malted barley, fruits must, cider and pure alcohol etc. Vinegar production includes traditional methods using wood barrels to surface fermentation in acetators (Ory et al 2002*).*

Vinegar is primarily, widely and traditionally used as preservatives in food industries. It is colorless, corrosive with sour taste and pungent smells. Vinegar is acetic acid solution with 4-6% dilution used directly as flavouring agent, food preservative as cleaning agent and as ingredient in salad dressing and marinade. In this paper a detailed on processing methods, types of substrates and microbes have been used for vinegar production is discussed.

HISTORICAL BACKGROUND

This occurrence in many places, the Sumerians was the first to record civilization that reported vinegar as useful condiment. Infact vinegars have been formed for almost 5,000 years. Babylon vinegar enriched with fruits, honey, malt, etc, to epicure of times in 5000BC. The medicinal uses of vinegar were recorded by old Testament and Hippocrates (Kehrer 1921, Conner 1976). A statement made by Albucases that distillation of vinegar must be over low fire in 1100. In first half of 18^{th} century "Acetic acid was sour principle of vinegar", discovered by Chemist Stahl. Durande made glacial acetic acid a more concentrated product in 1778. Berzelius made the first complete analysis of acetic acid in 1814. Schulzenbach introduced quick process of manufacturing vinegar from alcohol in 1955. Joslyn studied Hromatka evolved amethod called submerged fermentation in 1955 (Cruess 1958).

GLOBAL STATUS OF VINEGAR PRODUCTION

Vinegar is a versatile product with diversified applications used across the world over thousands of years, increasingly popular among costumers. White distilled and cider vinegar has a slight decrease in consumption according to Nielsen from Crisco Company 2005. From 2000-2002, there was maintained consumption of red wine and other vinegar and In the same time period there was enhanced use of balsamic and rice vinegar. This increase might show that flavor is key for consumers.

There are some reports that suggest that vinegar purchasing habits are changed among consumers. According to IRI, data vinegar is sold in the northeast, southeast compared to reminder of the USA from 1994-1998. (San Chiang Tan *et al*) In 2003, AC Nielsen noted that enhanced consumption of red wine vinegar and balsamic vinegar, while white distilled remains the strongest in sales (Crisco, 2005). In europe, per capita utilization reached 1.8 l/year, where vinegar used as disinfectant, degreaser and odor neutralizer. In Brazil, inspite less extensive and limited to use s seasoning the average use of vinegar reached 0.8 L/year. Due to

increase in obtained power, vinegar use is increased mainly from European countries.

FEEDSTOCKS

The important step in vinegar production is to prepare feedstocks. Acetified fermentable sugars and juice solution can be obtained by this step. The production of vinegar includes feedstocks like alcohol containing liquids, agricultural feedstocks, mango, banana peels, honey, barley and cider. Different raw materials used for vinegar processing. Herbs and fruits are also used to enrich taste of vinegar, includes raspberries, cherries and lemons. Vinegar can be processed from variety of alcohol products which are diluted, mostly used are wine and beer. Fermentation of carbohydrate rice, sugarcane, or malt can produce alcoholic product by anaerobic microorganisms like yeast and the obtained product from fermentation is pasteurized , filtered and then diluted alcohol to caliberate the content and then utilized for the production of vinegar.

Mihn examined fermentation of star juice by using *Sachromyces cerevisae* and *Acetobactor* bacteria for production of vinegar (Mihn et al). Roda et al used pineapple wastes for vinegar production. Vinegar production reported research made from apples by Dabija and Hatnean. Diba et al used decomposed fruits for screening of acetic acid bacteria. Vinegar produced from fermentation pineapple examined by Krusong and Vichitraka studies interaction between yeast and acetic acid bacteria.

RICE

It is widely used by asian people. Rice vinegar is produced by submerged fermentation by immersion of acetic acid in liquid for fermentation (Spinosa et al, 2015). Spinosa et al reported work on rice by using alcoholic fermented rice for production of vinegar in which alcoholic solution with 6.28% ethanol by submerged fermentation was oxidized to produce vinegar (Spinosa et al, 2005). Hua-Wei Yuan reported work that for processing of vinegar to promote health by post distillation slurry to establish zero emission process, new variety of rice was used i.e shochu which includes caproic acid and lactic acid. *Acetobacter aceti* CICC 21684 selected for vinegar production (Yuan, 2017). Chang-wei Hsieh reported work rice vinegar with synthetic acetic acid used SNIF-NMR method and identified adulteration of spirit vinegar molasses .This work focused on using three models of rice vinegar to evaluate and identification of pure rice .

COCONUT WATER

Coconut water vinegar is used in India from coconut water waste from copra processing units by conversion of sugar to acetic acid , exclusively produced by double fermentation. It includes alcoholic fermentation and then followed acetous fermentation (Panjikkaran et al). Othaman et al, 2014 reported work of production of vinegar by using coconut water substrate which was compared with other common feedstocks such as coconut sap and pineapple juice, have excess level of sugar content which was more than 14 degree Brix. Addition of sucrose prior fermentation adjusted low brix value of coconut water to 14 brix value. By aerobic incubation at room temperature 7-8% alcohols yielded within 7-10 days using Sacchromyces cerevisiae substrate. The back slopping technique and 10%

inoculum size showed best results by reducing process time of production of coconut water vinegar (Othaman et al, 2014).

OLIVE OIL

Leonardis et al, (2018) reported work on feedstock olive oil press mill wastewaters to produce vinegar and informed that olive oil press mill a waste material, made olive vinegar environmentally-friendly and nutraceutical product.

SUGARCANE

Fresh sugarcane juice is used in production of yellow brown coloured with aromatic effervence and cane flavor, low alcoholic and strong odour of vinegar by using wine yeast and LB acetate bacteria by submerged fermentation. Gurvinder singh kocher reported work on sugarcane vinegar production by using sugarcane juice as substrate by *Sacchromyces cerevisiae* strain 35 producing 9.5% (v/v) ethanol. For the production of vinegar ethanol is used, packed in polyvinyl chloride colum by immobilized cells of acetobacter aceti .(kocher et al , 2013)

OVERVIEW OF VINEGAR PRODUCTION FROM FRUITS

Vinegar can be produced from fruits such as apple using cider as intermediate product results in production of cider vinegar, mango using fermented mango juice results in production of mango vinegar, plum using fermented palm juice results in production of Ume-su vinegar, blackberry using fermented blackberry juice results in production of blackberry vinegar, grape using red or white wine results in grape vinegar production (Solieri et al).

MICROBES FOR VINEGAR PRODUCTION

After preparation of feedstocks, acetification and fermentation of alcohol play vital role in vinegar production. Yeast, lactic acid and acetic acid bacteria are mainly used in vinegar production. Yeast is used for fermenting alcohol and acetic acid bacteria for acetificcation (Nanda et al. 2001; Haruta et al.2006).

YEASTS

Yeasts are useful microorganisms during alcoholic fermentation because of its impact on fermentation speed, wine flavor and other wine qualities.(Pretorious et al.2006). Raineri and Zambonelli in 2009 reported work on substrate sugar by using yeast belonged to class Saccharomycetes by optimization of fermenting alcohol, converting sugar into ethanol (Raineri and Zombonelli 2009). The feedstocks used for metabolism of yeast were mainly monosaccharides like glucose , fructose and mannose by Embden-Meyerhof-Parnas pathway by metabolizing pyruvate into glycolysis (Raineri and Zombonelli, 2009). Fleet et al ., (2003) reported that the *Sacchromyces* genus is used mostly in beverage industry as they have excessive capability for fermenting sugar. Kocher et al (2006), studied that *Sacchromyces* has ability to convert sugarcane juice into ethanol using corn cobs, bagasse and wood shavings for production of vinegar (Suman vikas bhatt et al, Rehana Akhtar et al.,2014).

Krusog et al., 2010 studied pineapple vinegar fermentation interaction between Acetobacter aceti WK and flocculate yeast *Saccharomyces cerevisae* M30.

ACETIC ACID BACTERIA

Acetic acid bacteria are bacterias which are gram negative ,ellipsoidal or cylindrical can be observe under microscope alone, in pairs or in chain and the main agent in the production of vinegar. They are aerobic and oxygen is final electron acceptor, the bacteria can be found on substrate like fruit juice, urine, cider beer and vinegar.

Gullo and Giudici described that acetic acid bacteria were available in environment but cannot grow due to anaerobic conditions during alcoholic fermentation but when come in contact to oxygen, the acetic acid bacteria grow on surface. Garcia-Garcia et al (2009) conducted study on acetous fermentation by acetic acid bacteria results in conversion of ethanol into acetic acid.

CONVERSION PROCESS OF VINEGAR PRODUCTION

The production of vinegar includes oxidation of alcohol in a sugar containing fruit juice, molasses, vegetables and grains. Alcoholic fermentation and acetous fermentation are the two stage process of fermentation. Alcoholic fermentation rapidly exhausts most sugar in three weeks. By the action of yeasts, sugars which are fermentable are converted into ethanol .In acetous fermentation, acetic acid bacteria oxidizes ethanol into acetic acid, mainly member of genus *Acetobacter*. Anaerobic conditions are required for the alcoholic fermentation and aerobic conditions required for acetous fermentation (Lazim et al.).

CHEMICAL REACTION AND FORMULATION

In 1822, the theory of production of acetic acid from alcohol which was initiated by Dobereiner (Kehrer 1921) and equation of process mentioned below from Kehrer 1921:

1. Formation of acetaldehyde: in first step two hydrogen ions and two electrons are released and alcohol is converted into acetaldehyde with the help of enzyme alcohol dehydrogenase .
2. Hydration of acetaldehyde: In the next step, aldehyde is formed by hydration of acetaldehyde and two hydrogen ions bind with oxygen forming water.
3. Formation of acetic acid: in step three, aldehyde forms acetic acid and releases two hydrogen ions and two electrons. This conversion is by aldehyde dehydrogenase.
4. Electron transfer: During this step hydrogen ions and electrons are converted to water by cytochrome system (San chiang tan, 2005).

TECHNIQUES OF VINEGAR PRODUCTION

Vinegar production techniques include traditional methods from slow process employed in wooden barrels (Orleans process) and generator process and the submerged fermentation using immobilized cells. Industrial production of vinegar comprise of many technical devices which catalyzes the speed of alteration of ethanol into acetic acid in presence of acetobactor acetic acid bacteria. In Submerged fermentation method, acetic acid bacteria are in direct contact with atmospheric air and are placed on air-liquid interface. It is also considered as static

method due to presence of bacteria on surface of acidifying liquid (Vidra et al, 2018).

THE ORLEANS METHOD

The Orleans method is well known, oldest and traditional method originated in france 1670 for the production of vinegar (Vidra et al, 2018). It is a slow process with high grade vinegar used as starter culture and at weekly intervals wine added to this. The vinegar is fermented in large wooden barrels filled with alcohol fermenting liquid having holes at end of barrel above few inches with capacity of 200 litres. Peppler and Beaman (1967) reported that bacteria settled in liquid formed gelatinous slime layer on standardizing with addition of 20-25% fresh vinegar into barrel for optimal growth of bacteria. Raspor and Goranovic (2008) reported that due to the slow production process of vinegar (Orleans method) developed taste and fragrance. It was found that this method of processing provides a persistant availability of vinegar. Maazaand Murooka (2009) reported that orleans method used seed culture from previous production batch and depends on acetobacter present in raw material.

GENERATOR TECHNIQUE

The Generator processes, also called as "trickling" or "German" processes introduced in Germany by German chemist Schutzenbach in 1832 and have been traced back for almost 200 years. It is also known as fast process in which vinegar production uses wood shavings which is a fast process, increasing acetification surface (Vidra et al, 2017). In this technique generator is used, cylindrical tank filled with wood shaving, charcoal, or coke and devices for allowing alcoholic solution for trickling down and to increase the flow of air from bottom to top (Vidra et al, 2017). This is a surface process which includes immobilization of microbes on wood shavings. Overheating can be prevented by performing the process at 27-30 degree Celsius. (Bhat et al, 2014).

SUBMERGED FERMENTATION TECHNIQUE

This technique is most common production technique introduced around 1952 for vinegar production (Vidra et al, 2017) in which there is improvement of fermentation parameters like aeration, stirring, heating etc, used in industrial scale. In this method, mash is aerated and stirred regularly and the fermenter is fitted with heat exchanger to maintain optimum temperature during the fermentation process (Tan, 2005). Fring Sacetator was the first submerged type bioreactor in early 1950 and it was succeeded by other patented methods, like cavitators and bubble column fermenter (Bhat et al, 2014)

This technique basically includes stainless steel, fermenting tank, with cooling system, foam controller, valves i.e loading and unloading valves and air supplier system. It consists of batch method, semicontinous method and continous method . The batch method includes three steps i.e loading raw materials, inoculating in fermenting medium and the final unloading of medium.Next is semicontinous which is similar to batch , but here finished product unloaded and remaining left in vessel for further use for inoculation in next cycle. The continous method which includes continous unloading of small aliquot of biotransformed product i.e in constant time and continous addition of substrate which maintain the volume of

fermenting medium in bioreactor.The most important factor is to maintain bacterial cultutre is exponential growth phase, in this time , nutrients and oxygen are provided for the viability of bacteria (Vidra et al, 2017). Submerged fermentation system provides fast and efficient aeration. Aeration system is capable of smashing air bubbles and for easy transfer of oxygen from medium to bacteria, thus it is essential step in order to prevent *Acetobacter* cell death (Bhat et al, 2014).

MATHEMATICAL MODELING

Mathematical modeling narrates the mathematical relation which describes some real life situations, which help to study the effects of different components to predict behavior mathematically. It is derived from verbal model and mathematical modeling following parameter analysis and optimum parameters and finally testing models to solve optimization problems. Abiodun reported work on substrate mango for thr production and quality evaluation of mango vinegar showed results that pH, alcoholic content and garlic acid were 4.02, 6.17 and 0.513 g/ml respectively (Omowonuola et al).

Ghosh reported work on substrate palm juice to produce palm juice vinegar under physical parameters of fermentation conditions results showed the optimum ph, temperature and time were 5.5 , 30ºC, and 72 hrs for highest yield of acetic acid (68.12 g/l) (Ghosh, 2012). Viana reported work on substrate brazilin kefir grains injected in apple must for production of vinegar by using new technique Biospeckle Laser .The results obtained the yield of acetic acid was less than 79% in kefir vinegar and the concentration was less than 49 % of acetic acid, where kefir grains showed good results (Viana et al,2017)

Pooja saha reported work on substrate banana fruit pulp by using yeast and *Acetobacter* for production of vinegar by double fermentation. The physical parameters for banana alcohol was 7.77% at 10% , 8% for sugar level and yeast cell respectively for 48 hours at 28 and for banana vinegar , obtained results are 4.67% , 15% of alcohol and acetic acid respectively (saha et al).

Dias reported work on substrate Jabuticaba fruit pulp which is viscous and whitish and sweet in taste by using inactivated acetic acid bacteria (Dias et al, 2016). Ghosh reported work on substrate palm by applying surface technique to control optimal composition in fermenting media of palm vinegar. The results obtained were 70.79 g/L of acetic acid concentration. The ratio of glucose, sucrose and glycerol was 12:15:2 g/L and the final obtained result contained vitamin B3 and B5 in high quantities (Ghosh et al, 2014).

Ghosh reported work on the substrate palm juice to produce palm juice vinegar, by Acetobacter aceti (NCIM 2251), biochemical process. The physical conditions such as temperature, pH, and time were 5.5, 30 °C and 72 hrs respectively for the highest yield of acetic acid (68.12 g / L).

APPLICATION OF VINEGAR

Vinegar is brewed formed by fermentation of fruits , grains, or as synthetic vinegar formed by dilution of acetic acid with drinking water .Vinegar is famous condiment having different applications in food industry and medical field .

VINEGAR AS MEDICINE

KUROSU VINEGAR

It is used to inhibit the proliferation of cancer cells (HSC-5). Here HSC cells were treated with vinegar used to to 4.2% for 72 hrs (Ali et al. 2017).

NYPA PALM VINEGAR

It is used to enhance antiglycemic effect and enhanced insulin level upto 79.8% by single oral administration of nypa palm vinegar for 7 hours.

TOMATO VINEGAR

Dosage and duration for tomato vinegar includes 7 ml tomato vinegar per day for 5 weeks which wil decrease body viseceral fat weight and reduces cholesterol level and inhibit adipogenic 3T3-L1 cells.

POMEGRANATE VINEGAR

Dosage and duration includes one pouch of placebo for 8 weeks to increase phosphorylation of activated protein kinase and increased lipolysis and fatty acid oxidation.

VINEGAR AS REMEDY OF DIABETES

Diabetes mellitus is a metabolic disorder of endocrine system with high level of sugar in blood due to deficiency in insulin secretion, action or both (Ali et al). Beta cell of pancreas secretes insulin to control blood sugar levels. Diabetes is divided into three main classes which are type 1 diabetes (insulin dependent), type 2 diabetes (adult onset diabetes) and gestational diabetes mellitus (juvenile diabetes) (adapa et al, 2015).

Due to anti-glycemic impact of vinegar ingestion obtained in 1988. Vinegar can be consumed as diabetic treatment according to recent studies in humans and animals. The curve of insulin retort declined 20% after consuming vinegar with sucrose in humans. Mane placebo controlled investigation studied effective uses of vinegar for blood glucose absorbtion and decrease blood sugar level (Ali et al).

VINEGAR AS REMEDY OF CARDIOVASCULAR DISEASES

Cardiovascular disease is defined as coronary heart disease, rheumatic and congenital heart disease (stewart et al). It is a cluster of disease affecting cardiovascular system. Vinegar contains high concentration of polyphenol which provide defensive effect and decreases fatality from cardiovascular diseases. Apple cider vinegar contains polyphenol such as chlorogenic acid in high amount which can reduce oxidation of low density lipoprotein (LDL) and reducing risk of cardiovascular diseases (Ali et al).

ANTIMICROBIAL ACTIVITY OF VINEGAR

Antibiotic resistance is worldwide problem due to increase in pathogens showing drug resistance .Several microbial infections results in sepsis which leads to systemic inflammation and organ failure. Historically, vinegar produced over 5000 years by process of alcoholic fermentation and acetous fermentation by using variety of raw materials such as wine, barley and fruit peels. Apple cider vinegar is produced by acetous bioconversion and low acedic containing polyphenol, vitamins, flavonoids and minerals, addressed as supplement for weight loss ,

nutritional support and lowering blood pressure. Yagnik reported that apple cider vinegar have antimicrobial capacity against *E.coli*, *S.aureus* and *C.albicans* (Yagnik et al)

THERAPEUTIC EFFECTS OF VINEGAR

Due to antibacterial property of vinegar, it have therapeutic effect for injuries like burns .

Bielecki and others in 2000 reported that acetobacter xylinum assisted tissue repair in rats due to extracellular structure. Sugiyma and others in 2009 implied oral intake of acetic acid bacteria which helps in attenuating muscle damage (budak et al).

IMPACT ON BRAIN

The building block of brain tissue is sphingolipids and it has been reported tha acetic acid bacteria produces precursors of sphingolipids known as alkali stable lipids (budak et al). Alkali stable lipids showed effect on model rats and after being treated with 10 d, showed significant improvements in cognitive ability reported by Fakumi and others in 2010 .(budak et al)

VINEGAR IN FOOD INDUSTRY

Posca is a beverage prepared using vinegar and ancient greek oxymel drink made from vinegar and honey. Many other products known as shrubs produced by simply mixing sugar water and honey with fruity vinegar, for making syrups and some prefers boiling of shrubs. Different types nearly all types of vinegars can be used for pickling. Vinegar is used as condiment for beetroot, fish and chips chilled, chooked or sprinkled on chips. White vinegar is frequently used in Canada. It is used as flavouring agent for potato chips in countries like America, Ireland, Canada and australia flavoured with vinegar and salt. In countries like southern U.S. it is used to essence green beans, black eyed peas to enhance taste (Prasad et al).

CONCLUSION

The vinegar has been produces by different types of raw materials. Vinegar is important role as a food preservative in food industries. It is used as flavouring agent, for pickling and beverages and is also contain medicinal properties. Qualities of vinegar are depending on the efficiency of microorganisms. There are different methods for vinegar production from Orleans method to generator method to submerged fermentation.

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