

Role of *Saccharomyces cerevisiae* - Yeasts in Alcohol Fermentation

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Abstract

Since ancient age, yeast is the most common and dominantly used eukaryotic microorganism for alcohol (ethanol) production. Whereas the end product ethanol is used in many beverages such as wine, beer, and distilling concentrates of whiskey, rum, and other liquors. Yeast consumed glucose as energy source and convert it into ethanol anaerobically via glycolysis followed by ethanol fermentation. *Saccharomyces cerevisiae* is the first choice for alcohol fermentation and most of the industrially adapted microbe. Theoretically, 0.51 g of ethanol is produced per gram of glucose and the glucose can be obtained from any starchy or lignocellulosic substrates via enzymatic or chemical hydrolysis. Conversion of glucose to ethanol is a metabolic process where development of a yeast with ethanol tolerance would be challenging but most importance from productivity point of view. Thus, yeast *S.cerevisiae* is a crucial and industrially important model microorganism for alcoholic fermentation.

Keywords: *Saccharomyces cerevisiae*, alcohol, fermentation, alcoholic beverage

Introduction

Alcohol production is discovered 7000 years ago by our ancestors with a wine as a first alcoholic drink. It's a yeast mediated fermentation process. It has been first scientifically demonstrated by Paster and in later stage it has been commercially sold by different companies under different brands. Alcohol production is done from lignocellulosic or starchy substances by either enzymatic or chemical hydrolysis, called saccharification, which is one of the important steps before fermentation. These, saccharified simple sugars are metabolized (fermented) by yeast to ethanol. Yeast is not only used for alcohol production but also for the production of organic acid (lactic acid, pyruvic acid, propionic acid, acetic acid, and butyric acid), leavening agent in bakery products, hydrolytic enzymes (amylase, cellulase, invertase, proteases, pectinases, xylanase, phytases, lipases, beta-

glucosidases, carboxypeptidases, and aminopeptidases, etc), flavoring agents for aroma development (ethanol, glycerol, acetaldehyde, organic acids, esters, fatty acids, and higher alcohols), nutritive value enhancement and toxin reduction [1].

Yeasts, is the main microorganisms for alcohol fermentation, and more than 8,000 yeast strains have been classified and about 9-10 pure strains are used for grain-based fermentations that belongs types of *S. cerevisiae*. Each strain has its unique properties and imparts its special features to a distillate when used in fermentation. Non-*Saccharomyces* yeasts involved in alcohol fermentation are *Candida*, *Hanseniaspora*, *Torulopsis*, *Pichia*, *Kloeckera*, etc. Even though fermentation is important but it is equally

important to know about the feedstock, processing parameters and end product analysis of any kind of alcohol product and its application. Because of the multiple applications *S.cerevisiae* is a model organism for the biochemical engineering and bioprocesses [2].

Mechanism of Action

Microbial strains required sugars as energy source and was consumed by a metabolic pathway of glycolysis as a first step or fermentation or respiration initiation. Glycolysis generates 2 moles of ATP (adenosine triphosphate) per glucose molecule as energy and pyruvic acid, which further converted anaerobically to ethanol and carbon dioxide by alcohol fermentation pathway[3]. A schematic diagram of alcohol production in yeast is represented in chemical reaction 1 and Figure 1.

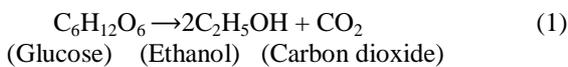
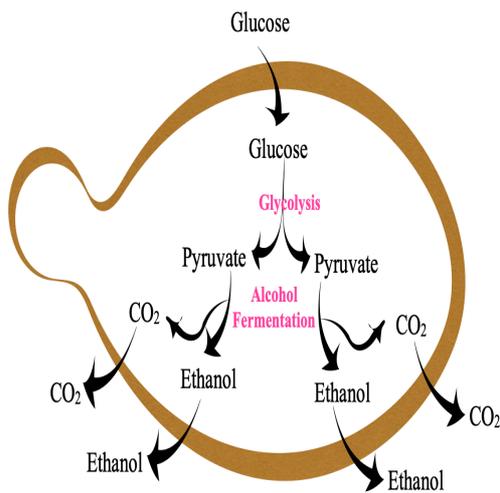


Fig. 1. Alcohol fermentations in yeast cell [3].

Each yeast fermentation reduces the fermentation pH and it has direct impact on good quality product in terms of taste, odor, texture, nutritional value and functional properties of fermented product. Yeast is used in many alcohols (beer, wine) and non-alcohols (fermented tea, milk, legume, meat products) beverages[4]. Hence it is necessary to select the best yeast strain which not only produced ethanol, carbon dioxide but also

tolerate the alcohol. Otherwise, alcohol accumulation at higher concentration kills the yeast cell. Generally, 10-15% alcohol tolerance is observed in many yeast strains and is the deal concentration in most of the beer and wines. So, to make the alcohol industry more profitable and productive, it is necessary to find out the high alcohol tolerance strain. It is also necessary to find the yeast with best sensory properties.

Types of Alcohol Fermentations

Alcoholic fermentations mean alcoholic beverages such as wine, beer, cedar and as a biofuel.

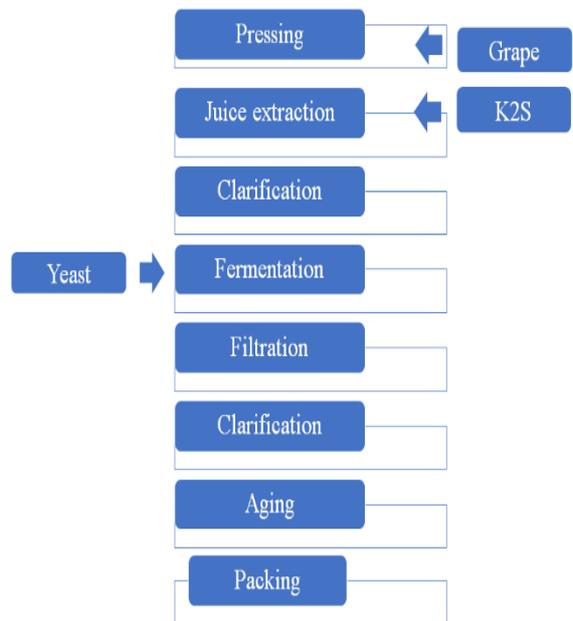


Fig. 2. Process flow for wine fermentation [1]

1. Wine Fermentation

In wine the yeast strains producing 11-13% ethanol and is the most common range in such beverages. Grape wine is old one but now a days lot of innovative wine products are emerging from various fruits including orange, apple, pineapple, strawberry, cherry, papaya, banana, etc. Yeast converts fruit sugars to ethanol and improve sensory quality of the beverages however, non-Saccharomyces yeasts have always been considered contaminants in the manufacture of wine and beer. Thus, pasteurization is important for elimination of such microbes. Wine fermentation is mainly depended on the type of

yeast strain used and reducing sugars. In general, wine fermentation initiated with sugar brix 14-24 brix⁰ and operating conditions of pH 3.5-5, Temperature 19-32⁰C and fermentation time 6-28 days. Alcohol production more than 12% will be a viable option but the strain with higher ethanol productivities would have economic benefit. Apart from alcohol, it is necessary to analyse the acidity or titratable acidity, volatile and other sensory properties of wine.

2. Beer Fermentation

Worldwide, beer is the most widely consumed alcoholic beverage which is manufactured with malt, water, hops and yeast. Malt is the source of sugars and enzyme, water is media, hops for bettering, flavoring and stabilizing agents and yeast for conversion of sugar to alcohol and carbon dioxide. Overall, all these ingredients contributed for the final test of beer. Manufacturing fermentation-based beer is called brewing and two types of yeast are used in brewing: *S. cerevisiae* as the top-fermenting yeast and *S. pastorianus* is a bottom-fermenting yeast used in lager brewing processes. In general, alcohol concentration in fermented beer is about 15%.

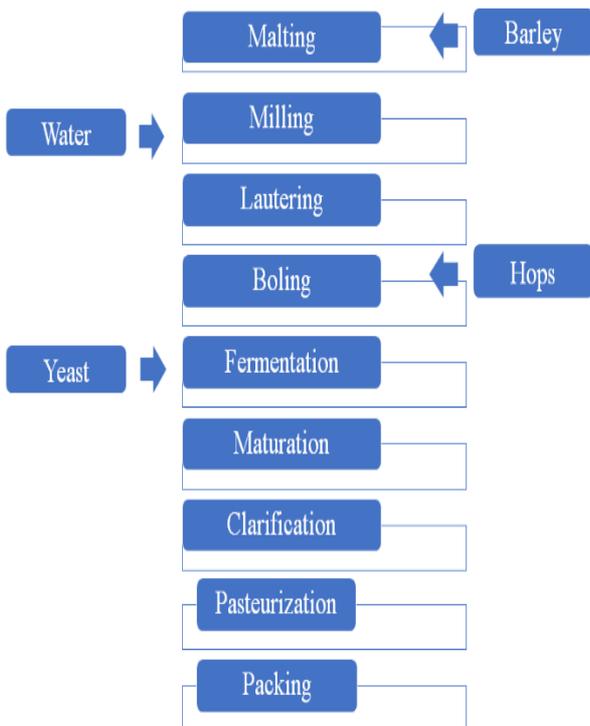


Fig. 3. Process flow for beer fermentation[5]

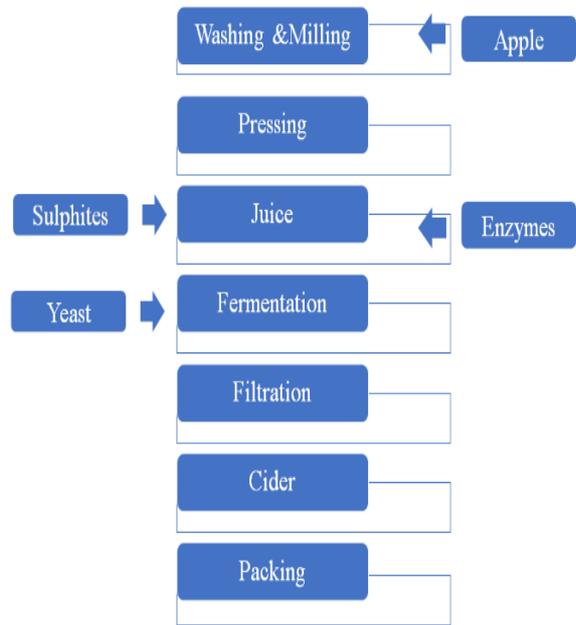


Fig. 4. Process flow for cider fermentation [6]

3. Cider Fermentation

Alcoholic beverages from apple are generated by cider fermentation and is very much popular in North America, Europe and Australia. Traditionally, ciders are produced by spontaneous fermentation of apple juice by autochthonous yeasts (*S. cerevisiae*) for producing unique flavor. Some non-*Saccharomyces* yeast species are also involved in spontaneous fermentation of apple juice for cider production. However, these yeasts have very less share as compared with *S. cerevisiae*. Alcohol content in cider fermentation is about 1.2 to 8.5% however, the cider contains 5.7 to 7.7% of alcohol.

4. Biofuel Production

Bioethanol is the most widely used biofuel contributing for the reduction in petroleum fuel and related environmental pollution. It is generated from various starchy and lignocellulosic biomasses by saccharification and fermentation process. Saccharification of complex sugar to simple one is done by enzymatic or chemical hydrolysis however; the fermentation is done by *Saccharomyces* and non-*Saccharomyces* yeast. Factors affecting bioethanol are fermentation temperature, sugar concentration, pH, fermentation

time, agitation rate, and inoculum size. Several processes were adapted for lignocellulosic biofuel production such as separate hydrolysis and fermentation (SHF), simultaneous saccharification and fermentation (SSF) and consolidated bioprocessing (CBP). SHF means enzymatic hydrolysis followed by fermentation[7-11]. However, SSF means enzymatic hydrolysis and yeast fermentations are simultaneously operated in one container[12]. CBP is the process where a microbial strain secretes enzyme for hydrolysis of lignocellulosic material and itself fermenting it into ethanol [13-14].

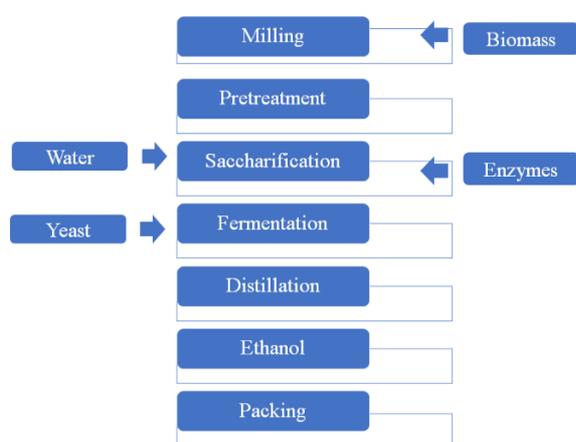


Fig. 5. Process flow for Biofuel (bioethanol) fermentation[2, 15-16]

Conclusion

Worldwide alcohol production and consumption is increasing day by day. Alcoholic beverages and biofuel as green fuel is on high demand where yeast strain development is very much important. A robust yeast strain with high ethanol conversion efficiency, yield, productivity and tolerance properties has more value for alcohol fermentation-based industries.

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