

A Review on The Production of Wine as a Post-Harvest Processing Alternative for Mango, Banana, and Purple Sweet Potato

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Abstract

West Java is one of the regions in Indonesia that produces large numbers of mango, banana, and purple sweet potato. After harvesting, these commodities will undergo physical, chemical, and physiological changes so that further post-harvest processing is needed. One of the post-harvest processing that can be done is fermentation. Fermenting mango, banana, and purple sweet potato into wine is a simple and efficient method that can increase the economic value of the product. Wine is an alcoholic beverage made from grapes; however, any fruit and tuber could be used for wine-making. The article reviews the potential of mango, banana, and purple sweet potato for wine production, the microbes involved, and pretreatments of mango, banana, and purple sweet potato.

Keywords: banana, mango, pretreatments, West Java, wine

1. Introduction

West Java is a region in Indonesia that produces a significant commodity of fruits, such as mango and banana, and tuber, such as purple sweet potato. The production of mango, banana and purple sweet potato increased every year. The latest data obtained from BPS-statistics Indonesia in 2018 West Java produced around 404,543 tons of mangos and approximately 1,13 million tons of bananas [1]. In 2015, West Java had about 456,176 tons of purple sweet potatoes [2].

Fruit and tuber commodities such as mango, banana, purple sweet potato contain a good and complete number of nutritional contents. If consumed according to the recommended portion, it can help maintain health and reduce the risk of micronutrient deficiencies. Moreover, it can also help the healing processes of several diseases, e.g., diabetes, coronary heart disease, bone, and many more [3]. Apart from their nutritional contents, fruits and tubers also have antioxidant activities originated from their pigments, flavonoids, and vitamins that they naturally contain to help protect the body from free radicals [4,5]. The physical condition of fruits and tubers is generally soft so that it is easily damaged. When harvested, they require immediate post-harvest processing. Indonesians usually consume fruits and tubers

directly or make them into other products such as chips [6], flour [7], or food coloring [8].

Although the production of mango, banana, and purple sweet potato commodities is abundant, based on the BPS data, the consumption of these commodities in the Indonesian population is incomparable, and a decline occurred in the last five years. The level of public consumption is less than half the recommended level of consumption. Most Indonesians only consume 173 grams of fruit per day, lower than Recommended Dietary Allowances (RDA) of 400 grams per capita per day [3].

In 2014, Indonesia produced approximately 8,097,938 tons of fruit waste [9]. On the other hand, researchers have already predicted that these fruits and tuber production will continue to increase due to Indonesia's potentials, land availability, ecological, climate diversity, germplasm, and human resources that can still be developed more [10]. The amount of these commodities that are already overproduced is not proportional to these fruits and tuber utilization. Therefore, to not make any more waste and create a larger loss, there must be an innovation for their post-harvest processing. The purpose of post-harvest processing is to overcome the short shelf life of fresh products. One of the many post-harvest processing that can be used is fermentation. Fermentation is a simple and efficient method that can transform both fruits and tuber into various products such as pickles [11],

kombucha [12], or other fermented beverages like cider and wine [13,14]. It is a simple and efficient procedure, and the end product can increase the quality and economic value of fruits and tubers.

According to Indonesia National Standard (SNI), wine is a fermented alcoholic beverage made from grape (*Vitis vinifera*) [15]. However, due to market demand and technological development, wine is not necessarily made from the grape. There are already a lot of wine made from non-grape fruits and tubers. To achieve a smooth fermentation process, these fruits and tubers need a pre-fermentation process called pretreatment. Fruits and tubers have different compositions; therefore, before the fermentation process starts, it is necessary to make adjustments so that the microbes used as starters can work well to metabolize properly. There are several types of pretreatments; chemical, physical, and biochemical using an enzyme. Pre-treatment is used to prepare the media condition before the microbial inoculation so that the process can run smoothly, produce optimal products, increase yield, and speed up the fermentation process [16]. This paper conducts a review to learn more about the pretreatment and fermentation process for mangoes, bananas, and purple sweet potatoes to turn into wine.

2. Fermentation of Wine

Fermentation of food from raw materials is a process found in all parts of the world and a part of some human cultures. One of the numerous fermentation products is wine. Wine is a product from a fermentation process of a grape juice or "must" [17]. The conversion of grape must into wine is a biotechnological tradition that has existed since ancient times probably one of the oldest biotechnology products that ever exists [18]. Over the centuries, many wine-making technologies and strategies have developed, resulting in a wide variety of wine products available and sold in the market today.

Wine is an alcoholic fermented beverage made with the grape as the main ingredient. In general, the first step of wine-making process is the selection of grape and crushing them until the grape must is formed. After moving the must into a tank or barrel, fermentation can start naturally or by adding the starter culture. Wine fermentations are usually carried out for roughly one to two weeks [19]. Following alcoholic fermentation, fermentation can be continued into malolactic fermentation spontaneously or purposely with lactic acid bacteria. The fermentation conditions of wine are as follows: pH range around 3.0-3.5 [20], temperature range around 20-30°C (optimum temperature with *Saccharomyces cerevisiae* inoculum is 32.3°C) [20,21], fermentation can be done by batch fermentation and liquid state fermentation [22].

3. Microbes in Wine Fermentation

Microbes do the fermentation process in wine either it is spontaneous or added. The three most common microorganisms groups involved in food fermentation are bacteria, mold, and yeast [23]. However, *Saccharomyces cerevisiae* as a starter culture is the most universal practice in the wine-making process [24]. In this day and age, yeast from other groups, such as *Metschnikowia pulcherrima*, *Torulaspota delbrueckii*, or *Lactobacillus acidophilus* is also used for wine-making process. The yeast species that dominates the production of fermented alcoholic beverages in the world is *S. cerevisiae*. This strain will have a significant influence on the taste and aroma characteristics of different types of drinks. *S. cerevisiae* is a spherical or ellipsoidal yeast elongated, with a diameter of 5-10 µm. All yeasts are unicellular organisms possessing ultrastructural features. *S. cerevisiae* is eukaryotic cells [25]. In addition, this yeast has a cell wall, nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus, vacuoles, microbodies, and secretory vesicles with complex extracellular and intracellular networks [26].

S. cerevisiae is the most crucial yeast species involved in the fermentation process of alcoholic beverages. This yeast was added as an inoculum because of its optimal fermentative properties. Therefore, this yeast is widely used in the fermented beverage manufacturing industry. *Saccharomyces cerevisiae* has the advantage of being a biocontrol agent through the production of toxins for spoilage microbes in making fermented drinks. This toxin will function as an antimicrobial that will inhibit the growth of spoilage microbes. This yeast can convert simple sugars into ethanol and CO₂ through the fermentation process efficiently. One of the disadvantages of this yeast is that the resulting product does not have a distinctive taste and aroma [27].

Another yeast that is often used in wine-making is *M. pulcherrima*. This yeast is known to have the ability to produce low amounts of alcohol [28]. *M. pulcherrima* has a natural antimicrobial component called pulcherrimin. Pulcherrimin has been shown to inhibit the activity of some yeasts and fungi that can interfere with the fermentation process, but *S. cerevisiae* is not affected by this antimicrobial. Therefore, the combination of *M. pulcherrima* and *S. cerevisiae* is often used to make wine [29]. When combined, both yeasts can produce aromatic components such as esters, improving the final quality of fermented beverage products. However, if used as a single inoculum, this yeast will lead to overproduction of the ethyl acetate component, which will negatively affect the product's sensory characteristics. The aroma of wine produced using a single culture of *M. pulcherrima* will smell like nail polish remover because they produce high ethyl acetate [30].

T. delbrueckii is another non-*Saccharomyces* yeast used in wine-making [31]. This yeast is the most suitable for use in fermented beverages when combined with *S. cerevisiae* because *T. delbrueckii* has better fermentation performance than other non-*Saccharomyces* yeasts. This yeast has several roles in the fermentation process, such as producing several parameters including low acetic acid, low ethanol concentration, increasing glycerol production, releasing mannoproteins and polysaccharides, having malolactic fermentation ability, increasing some aromatic components, and decreasing the value of some aromatic components like higher alcohol which is undesirable to improve the quality of the final fermented beverage products [32].

The difference between *T. delbrueckii* and *S. cerevisiae* is the rate of CO₂ production and O₂ consumption of *T. delbrueckii* is higher than *S. cerevisiae*. Therefore, the possibility of a defect in the larger-scale production of fermented drinks with these microbes increases because their O₂ consumption differ [33]. Another disadvantage of *T. delbrueckii* is its poor growth under a strict anaerobic conditions because this yeast still needs oxygen for their growth and metabolism [34].

Furthermore, some winemakers combined yeast with lactic acid bacteria to achieve more flavorful wine products [35]. *L. acidophilus* is a rod-shaped, Gram-positive, anaerobic homofermentative bacteria that can use the glycolysis pathway or Embden-Meyerhof-Parnas pathway to ferment sugars and produce DL lactic acid. Because these bacteria can survive at pH 4-5, they are often used in the development of fermented drinks for their ability to enter malolactic fermentation [36]. Malolactic fermentation has an important role in determining the final quality of fermented beverage products. Sugars that are not used by yeast in the alcoholic fermentation process will be used by these bacteria and produce aromatic components to produce products with flavor that consumers like [37]. *S. cerevisiae*, *M. pulcherrima*, *T. delbrueckii*, and *L. acidophilus* can produce metabolites, such as alcohol and other organoleptic properties by utilizing sugar in the must through the Leloir, glycolysis pathway, and produce an alcohol content around 5.75-13.9% [38-43]

4. Wine from Mango, Banana, and Purple Sweet Potato

Although grape has been known as the primary raw material for making wine, the development of technology and market demands has allowed the same methods to be used with non-grape raw materials to create wines with a distinctive flavor and unique color. Moreover, many studies have already investigated the suitability of non-grape ingredients, such as apple [44], mango [45], banana [39], purple sweet potato [38], roselle [46], and also fruit peels [47] to make wine. Wine can be made from a large variety of

fruits, tubers, and others as long as they contain enough sugar to convert into alcohol by microbes during the whole fermentation process [48]. The abundant mango, banana, and purple sweet potato require a fast and appropriate post-harvest processing to prevent great losses. One of many post-harvest processes that can be used is fermentation to make those commodities into wine. With a suitable pre-treatment, mango, banana, and purple sweet potato can be used for wine brewing using the same microbes and technique in conventional wine-making.

4.1. Pretreatment Process Before Fermentation

In making fermented drinks, pre-treatment is carried out before fermentation by adding the prepared inoculum. To have a smooth fermentation process, paying attention to what fruits and tubers contain is crucial. Sometimes microbes cannot use the complex components contained in fruits and tubers and hamper the fermentation process. For this reason, it is important to convert the complex components into simpler ones so that the microbes can use them for their nutrients. The end product of fermentation depends on this. Suppose there are no nutrients available for the inoculum. In that case, some unwanted things will happen, such as no fermentation or fermentation occurring with unwanted microbes resulting in contamination that can be dangerous. Contamination can be hazardous as it might lead to safety concerns, health problems, and foodborne diseases. The main goal of this process is to adjust and prepare the media before fermentation takes place. Several pre-treatment methods can be done by using chemical, physical, and biochemical (Figure 1).

Chemical pre-treatment is the addition of chemicals such as sulfur dioxide or sodium metabisulfite. Both sulfur dioxide and sodium metabisulfite are often used in the food and drinks industries as preservatives and antioxidants. The addition of these chemical compounds prevents the presence of microbes other than those added to grow in the fermentation medium [49]. The addition of food additives such as carbon sources, nitrogen sources, and others to support the fermentation media to create optimal conditions for the inoculum is also common. Examples of food additives are sweeteners (sucrose), preservatives (sulfites), and others.

Physical pre-treatment is by sorting, washing is a common practice to remove excess dirt, soil, pesticide residue, and lower microbes' contamination [50], cutting into a smaller size, crushing using a blender until must or juice is formed. Other physical pre-treatments that use heat are pasteurization and sterilization to kill unwanted microbes. Decomposition can occur because heat can cut the glycosidic chain in starch, converting polysaccharides into simple monomers. Heat treatment is the most commonly used technique since it

effectively maintains product safety because it can prevent the contamination of spoilage microbes [51].

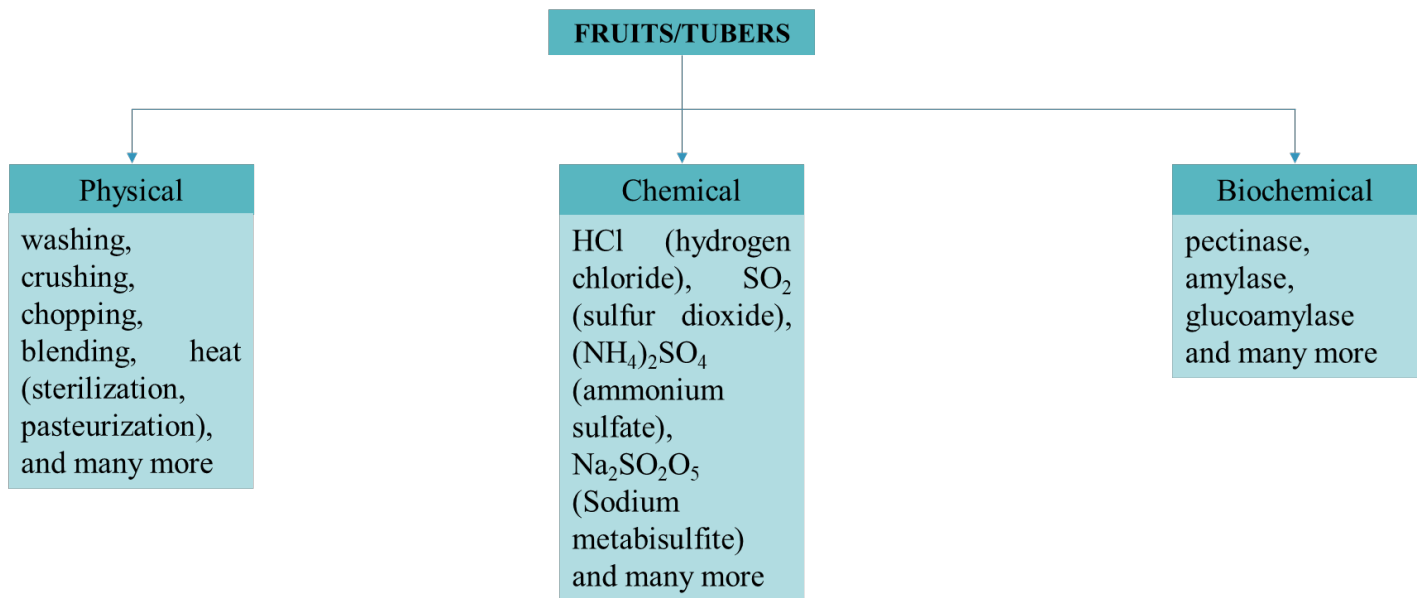


Figure 1. Three Types of Pretreatments

Biochemical pre-treatment with various additional enzymes has a function to catalyze the conversion process of complex compounds in media where the added inoculum does not have this ability. Some enzymes function to reduce various compounds that can inhibit the fermentation process [52]. The use of enzymes, e.g., pectinase, amylase, and glucoamylase, can benefit the beverage manufacturing process due to several reasons, i.e.,

- The use of enzymes in pre-treatment will increase the efficiency of fermentation seen from the fermentation time, which becomes shorter when the complex compounds in the raw materials have been broken down into simpler compounds.
- The use of enzymes will increase the yield; when substrate availability increases, the final product produced by the inoculum in the form of alcohol will also increase.
- No additional filtration steps are needed because enzymes in fermentation can make the final product clear, which will improve the sensory quality.

4.2. Pre-treatments for Mango, Banana and Purple Sweet Potato

Mango is a fruit that can be easy to get in West Java. In general, mango is a fruit with a fresh sour and sweet taste and a thick to a soft texture. The pectin content influences the texture of this fruit. Mango contains approximately 0,35% of pectin. Pectin is a heteropolysaccharide component composed mainly of galacturonic acid linked by α -1,4

glycosidic bonds [53]. *Saccharomyces cerevisiae* cannot use pectin for their metabolism. That is why before fermentation they are some preparations and adjustments. Pre-treatment using pectinase is one of the easiest ways to transform pectin into simple sugar like galactose. *S. cerevisiae* can utilize galactose for the Leloir pathway and then use glucose for the glycolysis pathway [53]. The functions of the pectinase enzyme are shortening fermentation time, increasing yield and sensory quality, clarifying the final product [41].

Another fruit that can be easily accessible in West Java is the banana. Banana (*Musa sapientum*) can be found everywhere in traditional markets or supermarkets. The pectin content influences the texture of bananas. The pectin in bananas ranges from 0.65 to 1.28% [54]. The composition of bananas will change drastically as they ripen. There are a total of 9 stages in the ripening process of bananas. In stage 1, when the banana has a green skin color, the starch complex carbohydrate content is 61.7%. Entering stage 9, the last stage with yellow fruit skin with brown spots, the starch content will change to 2.6%. While the content of simple carbohydrates in the disaccharide group at stage 1 was 1.2% and increased at stage 9 to reach 53.2% [55]. The decomposition of starch in bananas occurs rapidly during the fruit ripening process. This is due to the activity of several enzymes that exist naturally in bananas [56]. By using pectinase and amylase enzyme, they can help breakdown these complex components into simple sugar that yeast can use to utilize for their metabolism.

Not only fruits but tubers can also be used in the making of wine from non-grape. Purple sweet potato is one type of tuber widely produced in the West Java region to be found easily. Purple sweet potato is rich in starch content of around 40.1-55.1% [57], amylose content of about 15.4%, and amylopectin content of approximately 84.6% [58]. Unfortunately, the yeast used for wine fermentation, *S. cerevisiae*, cannot utilize starch for the metabolism system. It will lead to failure because the yeast does not have enough sugar for their nutrient. Therefore, starch in purple sweet potato has to be converted into simple sugar.

Two enzymes can help with the transformation, i.e., α -amylase and glucoamylase. These enzymes can break starch into glucose. The first step is liquefaction using an α -amylase enzyme that works as a catalyst for hydrolysis reaction of α -1,4-D-glycosidic linkages. Then the second step is saccharification using glucoamylase. Glucoamylase enzyme functions as a catalyst for hydrolysis reaction of α -1,4-D-glycosidic linkages and α -1,6-D-glycosidic linkages [59]. When they have already transformed into simple sugar like glucose, *S. cerevisiae* can use that for the glycolysis pathway. In short, during the glycolysis pathway, the simple sugar that enzymes already prepared before fermentation can turn into ethanol or alcohol and other metabolites that can make an excellent quality of the wine.

Enzymes added to making fermented drinks will also influence the sensory attributes of the final product. The addition of enzymes in making fermented drinks has been proven to add aroma, improve color, make fermented beverages clear, help with the filtering and sedimentation process to affect the texture of fermented beverages [60].

5. Conclusion

West Java is a region in Indonesia that produces a large commodity of mango, banana, and purple sweet potato. These commodities contain a good and complete number of nutritional contents. The physical condition of fruits and tubers is generally soft so that it is easily damaged with a short shelf life. When harvested, they require immediate post-harvest processing. One of the post-harvest processing that can be used is fermentation. Mango, banana, purple sweet potato can be used as raw materials for making wine fermented drinks. Wine made from non-grape has been widely developed using the same methods, and microbes such as *Saccharomyces cerevisiae*, *Metschnikowia pulcherrima*, *Torulopsis delbrueckii*, and *Lactobacillus acidophilus* can produce wine mango, banana, purple sweet potato. Almost all fruits and tubers can be transformed into wine by paying attention to the composition so it can determine the appropriate pre-treatment. Pre-treatment is a process before fermentation to prepare and adjust the mango, banana, and purple sweet potato must so that fermentation will run smoothly because of the optimum conditions for the

added microbes. Several pre-treatment methods can be done by using chemical, physical, biochemical with enzymes. Mango uses pectinase, which can decompose the pectin content. Banana uses pectinase and amylase, which can decompose pectin and starch content. Purple sweet potato uses amylase, and glucoamylase can decompose the starch content. Using appropriate pre-treatments, fermentation will run smoothly, and high quality with great organoleptic properties will be produced.

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