Research on Comprehensive Utilization and Fruit Vinegar Fermentation Technology of Pineapple Bran

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Abstract. This paper briefly described the biological characteristics of pineapple bran and current status of research on key technology for its comprehensive utilization. Through the study on such production processes as liquid-state, solid-state and liquid/solid-state fermentations to make fruit vinegar from pineapple bran, existed problems and their solutions for current production processes were put forward and a broad prospect for the development of fermenting pineapple bran into fruit vinegar was demonstrated.

1. Preface
Pineapple is one of the tropical fruits with the most prominent advantages and characteristics in China’s tropical and subtropical areas and mainly grown in such provinces and regions as Guangdong, Guangxi, Hainan, Yunnan, Fujian and so on. When pineapple matures, both its skin and flesh look yellow or golden yellow with not only bright color, but also sweet taste, aromatic odor and high nutrition, so is favored by general consumers.

Pineapple harvesting is seasonal. Its skin is thin and juicy, so it is not easy to store at room temperature and also to transport. In addition to the small part which is eaten as fresh fruit, most of them are processed into canned food, juice and preserved fruit. During the process, its by-products - bran will account for more than 40% of the whole fruit. Pineapple bran has as rich juice, good flavor and high nutrition as fruit. Test and analysis showed that the proportions of water, citric acid, total sugar and so on contained in pineapple bran are almost as high as those of pulp and the proportions of crude protein and ash are even higher than those of pulp, respectively 2.5 and 3.0 times that of pulp [1]. Each ton of the fresh bran can be extracted into 700kg of the juice.

In view of current low utilization of pineapple bran where most of it become processing factory’s waste and pollution source and low efficiency of pineapple processing industry, some foreign scholars did a lot of research on pineapple bran’s comprehensive development and utilization and made certain progress, and the comprehensive development technology where pineapple bran is used as raw material and its industrialized operation also become perfect gradually. There are many researches on the comprehensive utilization of pineapple bran in China too, but few of them can be converted into productive force [2]. At present, only a very small part of the pineapple bran in China is used as low-value feed processing and most of it is discarded, resulting in a high waste of natural resources and serious pollution to the ecological environment. Therefore, vigorous research on comprehensive utilization of pineapple bran can turn trash into treasure and will have important significance in improving the comprehensive utilization of the by-products from pineapple processing, raising
processing’s added value, safeguarding our pineapple industry’s sustainable, stable and efficient development and reducing such prominent industry problems as waste of resources and pollution to ecological environment.

2. Current status of research on technology for comprehensive utilization of pineapple bran

According to reports, pineapple bran not only can be used to extract juice to make wine, vinegar, jelly, brandy and lactic acid drinks but also can be used as raw material to make ethanol and marsh gas with the advantage of low cost. In addition, pineapple bran can be extracted into a variety of industrial raw materials such as lactic acid, pectin, pineapple proteinase, phenolic antioxidants, citric acid and other substances. Also, products developed from pineapple bran include livestock and poultry feeds, biological organic fertilizers and animal proteins. Both skin and residue after being juiced can also be extracted for dietary fibers [3]. As early as in 1919, American scholar Johnson [4], et al. conducted an experiment on the production of alcohol from pressed juice of pineapple bran. After that, Ramirez Spurgin, Richardson, et al. studied and proposed successfully the process conditions and implementation plan to make wine and vinegar from pressed juice of pineapple bran by means of microbial fermentation.

In order to obtain high-quality protein from pineapple bran, Peng Chaowei in China conducted a pork-pig fattening experiment by adding basal diet with a mass fraction of 15%-25% into pineapple bran sealed and ensiled for 20 days. The results showed that after feeding for 100 days, there were no significant differences in pig growth and meat quality compared with the control group, but the cost was decreased by 2.72% - 12.06% [5]. Huang Faxin, et al. studied and put forward a new process to make brandy from pineapple bran. In recent years, China has made great progress in the development of pineapple feeds and organic bio-fertilizers. Guangdong Fengshou Sugar Industry Development Co., Ltd. has applied pineapple bran in the practice of making organic fertilizers. Ye Shengquan, et al. successfully developed a nutrient-rich pineapple-bran feed additive [2].

3. Technology to ferment pineapple bran into vinegar

At present, most of the vinegars sold are apple cider vinegar, of course including pear vinegar, jujube vinegar, persimmon vinegar, etc. [6], but vinegars made from pineapple and pineapple bran are very rarely seen. Pineapple bran contains sugar as much as 10%, but also contains rich protein, vitamins, minerals, and a variety of nutrients necessary for microbes’ growth, so is an ideal material to make wine and vinegar. Pineapple bran vinegar uses pineapple bran as main raw material by means of alcoholic fermentation and then acetic acid fermentation. A new type of vinegar which covers both vinegar’s and fruit’s nutrition and health-care functions can not only reach the acidity of table vinegar but also keep the nutrients of a fruit to some extent with mellow taste, strong flavor, high nutrition and health-care efficacy but also low cost. Based on the fermentation states, processes to ferment pineapple bran into vinegar include liquid-state fermentation, solid-state fermentation and liquid/solid-state fermentation. The research focus of fermentation technologies includes mainly two aspects, one is the selection and optimization of the fermentation bacteria and the other is the establishment of acetic acid fermentation conditions and the optimization of the most suitable fermentation parameters. The fermentation processes are as follows:

- **Liquid-state fermentation:** Pineapple → Cleaning → Hot-water blanching → Peeling → Pulverizing → Juicing (Removing pomace) → Crude juice → Yeast inoculation → Liquid-state alcoholic fermentation → Adding acetic acid bacteria → Liquid-state acetic acid fermentation → Filtration → Sterilization → Aging → Finished products
- **Solid-state fermentation:** Pineapple → Cleaning → Hot-water blanching → Peeling → Pulverizing → Adding a small amount of rice husk and yeast → Solid-state alcoholic fermentation → Adding wheat husk, rice husk and acetic acid bacteria → Solid-state acetic acid fermentation → Filtration → Sterilization → Aging → Finished products
- **Liquid/solid-state fermentation:** Pineapple → Cleaning → Hot-water blanching → Peeling → Pulverizing → Juicing (Removing pomace) → Crude juice → Yeast inoculation → Liquid-state
alcoholic fermentation → Adding wheat husk, rice husk and acetic acid bacteria → Solid-state acetic acid fermentation → Filtration → Sterilization → Aging → Finished products

3.1. Selection and processing of raw material
Fresh pineapple which matures eighty percent, has no plant diseases and insect pests, does not get rotten, and contains much sugar should be chosen, then cleaned with tap-water and blanched with hot water to remove the various bacteria on its surface. After that, drain the water, cut out the bran from the pineapple, and pulverize the bran into pieces of about 12 mm in diameter.

3.2. Liquid-state fermentation
Liquid-state fermentation is now the most commonly used method to ferment pineapple bran into vinegar. After raw materials are treated by the above process, alcoholic fermentation will be conducted on pineapple bran with sugar degree of the bran mixture adjusted to 16° Brix and pH value to 3.5. After heating for sterilization and cooling, yeast inoculation is set at 0.3% and fermentation temperature is controlled between 22-28℃. Shake or stir it two times a day. During fermentation, sealing is absolutely needed by using two layers of the gauze and attention should be paid to preventing bacterial pollution [7]. This process takes 4 to 10 days typically. If room temperature reaches as high as 28-30℃, fermentation will be faster and about a few hours later, you will hear rustle like silkworms eating mulberry leaves and juice surface is foaming. This means that sugar is changed into alcohol by yeast and at the same time, carbon dioxide is released. If it is too slow for this phenomenon to appear, maybe yeast is too little or air is insufficient in the juice, or temperature is too low. If so, please add the juice immediately which is fermenting vigorously, or move it to another jar, or heat it appropriately.

If alcohol level stops rising, the alcoholic fermentation is finished. Generally, alcohol content is about 10% vol. now. Dilute the wine to alcohol degree of about 5% with mineral water or purified water. Add sucrose to make the diluted wine’s sugar level to about 10%. Add acetic acid bacteria by referring to the yeast specification sheet for the quantity needed and stir it evenly. At present, price difference is very large for various yeasts. Cheap yeasts have slight difference in flavor. The best fermentation temperature is 25-32℃, of course below 25℃ can also be accepted, but acid will form slowly. When the acidity no longer rises during fermentation, stop the fermentation with salt. Acetic acid fermentation belongs to aerobic fermentation and acetic acid bacteria are especially sensitive to oxygen. Only when oxygen is abundant, can vigorous physiological activities be carried out. In particular, when deep fermentation is carried out, acetic acid bacteria may die even pass of oxygen is interrupted only for a short time. If both oxygen and sugar sources are sufficient, acetic acid bacteria will decompose the fructose in juice into acetic acid. So, if only a small quantity of juice is available, shaking bed may be used for fermentation. If a small batch of juice is to be fermented, oxygen-filling tank may be adopted. But oxygen-filling fermentation tank is expensive, so jar plus air pump to inflate for increased oxygen may be used, or if ventilation is good, mouth of jar may be sealed perfectly with several layers of gauze and juice is stirred a few times a day to supplement oxygen needed for fermentation for a fermentation time of 1 to 2 weeks.

3.3. Aging
Just fermented vinegar does not have good taste and soft flavor, but with too strong aroma and pungent sourness, so needs to be put in an airtight container to age for more than 2 months at room temperature by avoiding contact with oxygen to improve the quality and flavor of vinegar. When aging, vinegar should fill up the jars. As the aging time becomes longer, ketones contained by vinegar will reduce gradually, but acids, alcohols, and esters will increase. As ketones’ relative contents decrease slowly, some bad pungent odours can be eliminated, making the vinegar flavor softer [8]. After 2 months of aging, the finished products of pineapple vinegar will look golden, clear and transparent, with fragrance of both sour and pineapple, and soft and refreshing taste.
4. Problems existed in the production process of fermenting pineapple bran into vinegar

The acetification process which uses pineapple bran to make fruit vinegar may adopt solid-state fermentation which adds wheat bran, rice husk ash, rice chaff, etc. as supplements. The vinegar made from this process owns good flavor but with longer fermentation time, too more waste, higher labor intensity, and higher production cost than liquid-state fermentation. In most cases, traditional fermentation process which uses soaking, spraying, and other liquid-state fermentation processes adopts single yeast for alcoholic and acetic fermentation but with longer acetification time of 8~18 days. Another method which uses solid-state fermentation first during alcoholic fermentation and then liquid-state fermentation during acetic fermentation was studied. Its acetification time can be shortened by 4~5 days, but generally, liquid-state fermentation’s requirements for equipment are higher, so the investment is higher, and also vinegar’s fruity aroma is not prominent, sourness is not soft enough, taste is poor, flavor is insufficient, quality is not so good, etc. Currently, some are using liquid-state mixed-bacteria fermentation to make pineapple vinegar, trying to solve the problems of pineapple vinegar’s insufficient flavor made by liquid-state method. But, it stays only at the research stage now.

A study was reported which used semi-solid fermentation and secondary carbon source supplementation to make vinegar from pineapple bran. Its basic fermentation materials are peel and residue with a small amount of fruit juice. Pineapple bran was used as the carrier of acetic acid bacteria to form a loose environment for acetic fermentation, thus satisfying the demand of acetic acid bacteria on oxygen. The optimum carbon source for acetic acid bacteria is glucose, fructose, and other hexoses. Yeasts’ competition for nutrients extended vinegar’s fermentation time, which indicated that supplementation of carbon source to a mixture of wine in time after alcoholic fermentation can shorten acetic fermentation time. Compared with liquid-state fermentation, semi-solid fermentation may increase yield of total acid and shorten fermentation time significantly. But studies have not yet been reported on how to shorten acetic fermentation time and increase the yield of acid by carbon source supplementation.

In addition, pineapple bran contains rich pectin, protein, polyphenol and other substances, so turbidity and sedimentation may be caused easily after brewing vinegar. Therefore, elimination of vinegar turbidity and improvement of its color and luster and accordingly its sensory quality become one of the important processes in vinegar production [11]. Also, quality stability after fermentation of vinegar fermented from pineapple, especially that from liquid-state fermentation is bad and the number of effective microorganisms in fermented liquid drops rapidly with the extension of storage time. Therefore, keeping stability is also a key indicator of the fermented product’s quality [12]. However, the research on vinegar still mainly focuses on the preparation process currently, and the research on the comparison and action mechanism of antioxidant activities is relatively rare. So, based on the bad room-temperature preservation stability after the fermentation, the number of effective microorganisms and storage time of the pineapple vinegar fermented and aged in sealed state should be explored to find the effect of fermentation process on fermented product’s room-temperature preservation stability and further optimize the fermentation process.

Therefore, it would be of important practical significance and research value by researching the key technology of fermenting pineapple bran into vinegar, studying the solid-state and liquid-state microbial vinegar fermentation and processing technology, optimizing the existing fermentation process, performing a comprehensive analysis of various influencing factors during fermentation, and exploring a kind of method brewing pineapple bran into vinegar which can not only shorten fermentation time with high acid yield but also make vinegar with better flavor, less investment and convenient operation to solve current technologies’ problems of low yield, poor room-temperature preservation stability, processing cost, etc.

5. Conclusion

Pineapple belongs to a kind of tropical fruit with high seasonality and is not easy to store at room temperature. Pineapple resources are rich in China and the effective and comprehensive development
of pineapple bran can add the value of pineapple fruit processing by 10% or more. This not only can improve the utilization and conversion rate of pineapple bran, but also realize the comprehensive utilization of limited natural resources by making waste profitable, achieve the efficient utilization of pineapple by-products, reduce resource waste, and ease the pollution of pineapple by-products on ecological environment significantly. So, wide market prospect and high social and economic benefits can be found from it.

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