Lycium barbarum Deep-Processing Products of Fermentation

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Lycium barbarum, a homology of medicine and food, contains many active ingredients including polysaccharides, polyphenol, betaine, and carotenoids, which has health benefits and economic value. The bioactive components in *Lycium barbarum* exhibit the effects of antioxidation, immune regulation, hypoglycemic effects, and vision improvement.

Keywords: Lycium barbarum ; bioactive components ; health benefits

1. Introduction

Lycium barbarum, also known as wolfberry, has both medicinal and edible effects due to its high medical and health care value. Wolfberries are planted in the arid to semiarid environments of Eurasia, Africa, and North and South America [1]. The clean tillage and intercropping with Gramineae are used to cultivate wolfberry, which can increase productivity and sustainability in modern agriculture [2][3]. A total of 31 out of 97 wolfberry species have been recorded to be used as both food and medicine all over the world [4]. Different natural environments, such as the difference in diurnal temperature, rainfall amount, soil thinness, and salinity, lead to different bioactive ingredients [5]. *Lycium barbarum* is placed in the Chinese Pharmacopoeia and Organic Product Certification Catalogue, containing a variety of bioactive components such as polysaccharides, flavonoids, phenolic acids, betaine, and carotenoids [6][7]. Wolfberry recorded in Chinese medicine has the effect of protecting the liver and brightening the eyes, nourishing the kidney and generating essence, dispelling diseases and longevity [8]. It has been confirmed in modern medicine that the overall potency of *Lycium barbarum* includes anti-tumor, anti-inflammatory, and promoting gut health in cell or animal levels [9][10][11].

In recent years, the demand of health products was raised with people's health awareness increasing. The health value of *Lycium barbarum* was paid great attention, which drove the development of the processing industry. Nowadays, the processing amount of *Lycium barbarum* accounts for one-eighth of its total output. Fresh wolfberry fruits soften rapidly in the ripening period, and then they are stored by drying. And fresh fruits are pressed to retain the concentrated juice for use in the production of various drinks [1][3]. Along with the popularity of wolfberry fruits, they have been transformed into globally traded commodities. In China, wolfberry products are sold that must comply with the Local Food Safety Standard—Goji Berry and the General Hygienic Specification for Food Production [12][13]. In the United States, wolfberries are sold as dietary supplements. They are also widely sold in the EU market as food ingredients. Modified atmosphere packaging and the plant growth regulator such as methyl jasmonate are used to package wolfberry, which minimize the loss of quality and nutritional value in the storage period [14]. The development of deep-processing-related products of wolfberry is still not enough. Therefore, it is urgent to improve the development of the wolfberry industry using modern science and technology.

2. *Lycium barbarum* Deep-Processing Products of Fermentation

As the wolfberry contains a variety of active functional ingredients, the medical health care function of wolfberry has been gradually paid attention to in recent years. Recently, with people's health care awareness increasing, the market demand for wolfberry products needs to be expanded continuously. However, the fresh wolfberry fruit is seasonal, has a short harvesting period, and is easy to decay and deteriorate; therefore, it is difficult to preserve and needs to be processed in time to extend the shelf life. China is the most important place for plant, production, and consumption of wolfberry. At present, 80% of wolfberries are sold as primary processed products of dried fruits [15]. The products are relatively single in the market, and deep-processing products are less. The primary processing products of wolfberry had low technological content products, insufficient market recognition, and backward processing equipment, which restricted the development of the modern industry of wolfberries [16][17]. Therefore, deep-processing products are needed to research and develop. Due to the lower nutrients loss and more active ingredients brought by fermentation, the fermented deep-processed products of wolfberry can be better exploited and promote the technological progress of the wolfberry industry. The wolfberry deep-processing products via fermentation are shown in **Figure 1**.

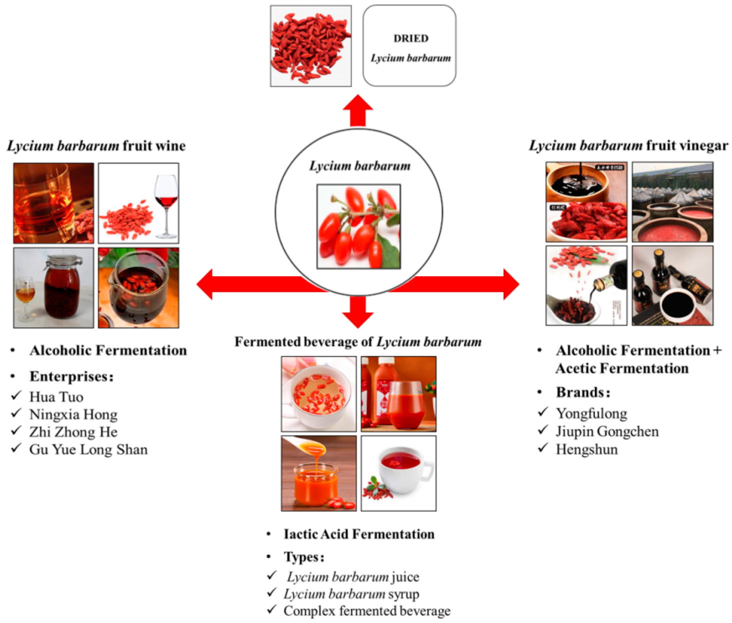

Figure 1. *Lycium barbarum* fermentation deep-processing products.

2.1. Wolfberry Fruit Wine

Wolfberry wine can be divided into fermented type and mixed type according to different production processes. Fermented wolfberry wine is made by adding yeast to raw materials through alcohol fermentation, which is one of the modern wines of health care [18]. At present, wolfberry wine mainly focuses on developing the new type of wolfberry wine. The production technology of wolfberry wine is stable, and there are representative wolfberry wine enterprises such as Hua Tuo and Ningxia Hong.

During the fermentation process, maceration plays an important role in extracting compounds from the fruit skin into the wine, and these compounds after the maceration process can be metabolized, producing better flavor and taste during the fermentation and aging processes. A study reported that wolfberry wine was macerated via short-time maceration (SM, 48 h), middle-time maceration (MM, 72 h), and long-time maceration (LM, 96 h) during alcohol fermentation. The contents of flavor substances in the MM wine were highest. In addition, esters and ketones were higher in the MM wine compared with those in SM and LM, which provide the better flavor and fruity aroma for the wine. The composition of aromatic compounds is mainly determined by the fruit genotype and maceration, and the appropriate maceration time is the key factor to enhance aromatic compounds and the sensory attributes of wine [19]. Another study reported that wolfberry juice at a concentration of 50 g/L was added into amber ale beer to improve the sensory and nutritional values. The fermented beer was characterized by lower turbidity and higher antioxidant ability and bioactive compounds (rutin and 2-O-b-D-glucopyranosyl-L-ascorbic acid) [20]. Ren et al. studied the optimization for the fermented process of wolfberry wine, which used different maturity levels as raw materials (mature berries, mildly over-matured berries, and severely over-matured berries). Wine with mature berries was the best fermentation product, which was based on critical indicators of nutritional and organoleptic quality. The highest contents of polysaccharides (1050 ± 0.13 mg/L) and total flavonoids (1216.0 ± 2.49 mg/L) were both found in wine with mature berries. It indicated that the quality of wolfberry wine was mainly determined by raw materials, which was agreed to be a primary factor in producing high-quality wolfberry wine [21]. A previous study reported that wolfberry fruit wine had antioxidant properties in vitro, which, determined by DPPH and ABTS trialsm were 1.27–1.87 g/L and 1.61–2.13 g/L, respectively. The antioxidant properties of wolfberry fruit wine were much higher than those of Chinese wine [22]. Although wolfberry wine has high nutritional and health value, the development of wolfberry needs to improve through several aspects, such as improving product quality, reducing production costs, and clarifying product functional attributes.

2.2. Wolfberry Fruit Vinegar

The wolfberry vinegar is a kind of sour drink with excellent nutritional value and flavor, which is made using modern production technology. Fruit vinegar is the common fermented beverage known as the fourth generation of beverages. Its taste is sweet and sour and also has the healthy effects of both vinegar and fruit. Due to the raw materials and fermentation, the products contain a variety of nutritional and active components, such as organic acids, amino acids, and polyphenols [23][24]. Some studies have reported that fruit vinegar has the effects of antibacterial and antioxidant activities, anti-aging, and anti-fatigue [25][26][27].

Li et al. reported on the production process of composite fruit vinegar using wolfberry and grapes as the main raw materials. The optimal technological conditions for alcohol fermentation were 6% yeast addition, initial pH of 4.0, fermentation temperature of 28 °C, and fermentation time of 6 days. Under these optimized conditions, the alcohol content reached 8.28%vol. The optimal process conditions for acetic acid fermentation were 4% acetic acid bacteria inoculation, fermentation temperature of 32 °C, and fermentation time of 6 days. Under these optimized conditions, the total acid content was 4.27 g/100 mL, which made the fruit vinegar have pure flavor and special fruit aroma [28]. Another study reported that wolfberry wine was inoculated 10% acetic acid bacteria and fermented for 6 days at 30 °C and 180 rpm, and wolfberry vinegar was brewed. The total phenolic and flavonoid contents in wolfberry vinegar were 2.42 mg GAE/mL and 1.67 mg RE/mL, respectively. The contents of betaine and carotenoid were 2.88 ± 0.22 and 0.42 ± 0.02 mg/mL, respectively. In addition, *Lycium barbarum* polysaccharides were the main bioactive components in WFV with a content of 8.94 ± 0.27 mg/mL. Furthermore, there is a protective effect of wolfberry fruit vinegar on the liver. It was found that wolfberry fruit vinegar treatment effectively alleviated liver injury by inhibiting oxidation levels and increasing antioxidant levels in CCl_4-treated mice [29]. Taken together, the fermentation process of wolfberry fruit vinegar can improve the utilization rate of raw materials, screen excellent strains, and enhance fermentation efficiency, which are the key factors to control cost. At present, there are less kinds of wolfberry fruit vinegars on the market, such as Haitian, Guanli, and Hengshun. Therefore, wolfberry fruit vinegar needs to further increase research and development to improve market competitiveness and market sales.

2.3. Fermented Wolfberry Beverage

In recent years, the fermented beverage has gradually concerned itself with beneficial effects on the human body. At present, most of fermented wolfberry beverages are brewed using lactic acid bacteria, yeast, and acetic acid bacteria [3][30]. The products fermented with single or mixed strains of lactic acid bacteria are mainly occupying the market share of beverages. It has been reported that fermentation can sufficiently use the nutrition of wolfberry, which is an important research direction in the field of deep processing wolfberries [31]. Fermentation technology influences the active ingredients of wolfberry, which is an important factor to determine the quality and function of the products [32]. Current research is mainly focused on the optimization of fermentation process and the influence on the active substances in fermented wolfberry beverages.

Wang et al. reported the effects of four different lactic acid bacteria (*L. brevis strain* CICC 6239, *L. plantarum* strain CICC 6240, *L. acidophilus* strain CICC 22150, and *L. plantarum* strain CICC 23138) on the growth rate and antioxidant activity during the fermentation. The results showed that the *L. brevis* CICC 6239 strain had the best growth rate in wolfberry juice. Total polyphenols and antioxidant activity gradually increased during fermentation, and the *L. acidophilus* strain CICC 22150 had the highest content of total polyphenols (4.23 g GAE/L) and antioxidant activity (81%) at the end of fermentation [33]. Another study reported the effects of six different lactic acid bacteria (*Lactobacillus plantarum* 90, *Lactobacillus casei* 37, *Lactobacillus paracasei* 01, *Lactobacillus acidophilus* 85, *Lactobacillus helveticus* 76, and *Bifidobacterium lactis* 80) on bioactive substances and antioxidant activity during wolfberry juice fermentation. Among the six strains, the total phenols and total flavonoids contents were the highest throughout the *Lactobacillus helveticus* 76 fermentation, which significantly rose from 1460 mg GAE/mL to 1800 mg GAE/mL and 412 mg RE/mL to 530 mg RE/mL, respectively. Additionally, the highest content of rutin was during *Lactobacillus casei* 37 fermentation, which was increased from 23.76 to 100.52 mg/L. *Lactobacillus paracasei* 01 had the strongest ability to increase betaine, the content raising from 8237.77 to 24,529.63 mg/L [34]. In addition, another study reported that fermented wolfberry beverage via *Lactobacillus plantarum*, *Lactobacillus reuteri,* and *Streptococcus thermophilus* exhibited better anti-inflammatory effects than unfermented wolfberry beverages. The fermented wolfberry beverage modulated gut microbiota and attenuated dextran sodium sulfate-induced ulcerative colitis in mice [35]. At present, the wolfberry beverages mainly included wolfberry juice, which occupied most markets. However, there are few types of wolfberry-fermented beverages in the market. Wolfberry-fermented beverages have the advantages of soft taste, unique flavor, and various nutrients, which needs to be further explored to broaden the market of wolfberries.

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