Analysis of the main harmful factors in wine and suggestions

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Abstract: This paper analyzes the main hazard factors of wine and the exposure levels. Suggestions for strengthening wine safety and quality are put forward from the aspects of improving the regulatory system and perfecting regulations.

Keywords: Wine, Hazard, Exposure

1. Introduction

With the continuous promotion of wine culture and the improvement of consumers' living standards, the consumption of wine in China has been growing rapidly. In 2011, it reached 36.16×10^7 L, and with a total consumption value of 45billion yuan, China surpassed the UK to become the world's fifth-largest wine-consuming country. At the same time, issues such as inconsistent quality and counterfeit products have emerged, which directly endanger public health. Therefore, analyzing the main hazard factors of wine is of great significance for effectively improving food safety management levels, protecting consumer rights, promoting the healthy development of the industry, and breaking through foreign technical barriers. This paper will briefly discuss the sources, types, and current status of the main hazard factors in wine from several aspects, and provide consumers with some intuitive data on wine.

2. Additives

2.1. Sulfur dioxide

Before the juice enters the main fermentation process, an appropriate amount of sulfur dioxide (SO_2) must be added to serve functions such as sterilization, clarification, acidification, and color protection. During fermentation, sulfur dioxide will naturally dissipate. The added sulfur dioxide can be in gaseous or liquid form, or it can be introduced as sulfite salts. However, if the dosage is improper or the fermentation time is too short, residual sulfur dioxide may remain.

In Europe and America, if the sulfur dioxide content in wine exceeds 10 mg/kg, it is required to label the product as "contains sulfur dioxide." However, the amount naturally produced during fermentation is often higher than this threshold, which is why almost all wines carry this label. Regarding the upper limit of sulfur dioxide in wine, the United States sets it at 350 mg/kg, while China sets it at 250 mg/kg. The Joint Expert Committee on Food Additives (JECFA)has established a safety intake limit for sulfur dioxide of 0.7 mg per kg of body weight per day. For an adult weighing 60 kg, this is equivalent to a daily intake of 42 mg. If we assume an average concentration of 100 mg/kg, then 400 mL of wine would contain 40 mg, which is close to the "maximum intake level." The "safety intake limit" means that consuming sulfur dioxide within this amount will not cause visible harm even with long-term exposure.

However, some individuals are more "sensitive" to sulfur dioxide, similar to other food allergies. According to statistics from the United States, about 1%of the general population and approximately 5%of asthma patients are sensitive to sulfur dioxide. The amount required to trigger "sensitive symptoms" varies among individuals, and the symptoms generally include nausea, vomiting, abdominal pain, dizziness, and difficulty breathing. In severe cases, it may even be life-threatening.

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2.2. Colorants

Color is one of the important indicators for evaluating the sanitary quality of wine. Analysis of monitoring results from various regions shows that the use of artificial synthetic food colorants in wine has become very widespread, especially in medium and low-end wines where the problem is particularly prominent. The national standard GB2760-2007"Hygienic Standard for the Use of Food Additives" clearly stipulates the scope and maximum usage levels of food additives in wine. Wine is classified as a fermented alcoholic beverage, and the standard prohibits the addition of artificial synthetic colorants such as Tartrazine (lemon yellow) and Amaranth (amaranth red) in fermented wines. According to relevant literature surveys, the synthetic colorants commonly used in commercially available wines mainly include Amaranth, Carmine, Sunset Yellow, Tartrazine, and Brilliant Blue, among five types.

2.3. Sweeteners (sodium saccharin, cyclamate)

Excessive intake of cyclamate, sodium saccharin, and synthetic colorants can lead to accumulation in the body, posing risks to the liver, kidneys, and nervous system. This is particularly significant for the elderly, pregnant women, and children, who have weaker metabolic detoxification capabilities. The national standard GB2760—2007 clearly stipulates the scope and maximum usage levels of food additives in wine.

2.4. Preservatives

Sodium Benzoate: Sodium benzoate is a white granule or crystalline powder, odorless or slightly smelling of benzaldehyde, with a slightly sweet and astringent taste. It has astringent properties and is highly soluble in water and ethanol. It is the most commonly used food preservative in China, effective against bacteria, molds, and yeasts, especially in acidic foods. The lower the pH, the better the effect. At pH 3.5 and a concentration of 0.05%, it can completely inhibit yeast. However, it tends to precipitate when in contact with acids, so the order of addition should be carefully considered. Sodium benzoate has relatively low acute toxicity, with a maximum no-effect dose (MNL)of 500 mg/kg body weight in animals. However, it can be converted into the more toxic benzoic acid in the acidic environment of the stomach. Benzoic acid has very low chronic toxicity and can be completely metabolized and excreted from the body. Some experimental studies have shown that benzoic acid is non-accumulative, non-teratogenic, non-carcinogenic, non-mutagenic, and non-allergenic. The acceptable daily intake (ADI)for sodium benzoate is 0–5 mg/kg body weight, with an LD_{50} of 2.7 g/kg (oral, in rats).

Sorbic Acid (Potassium Sorbate): Sorbic acid (potassium sorbate) is a white to light yellow flake-like crystal, crystalline powder, or granule; it is hygroscopic and readily soluble in water,5%brine, and 25%sugar solution, as well as in propylene glycol and ethanol. It has a strong inhibitory effect on spoilage bacteria, yeasts, and molds but is less effective against bacteria. It is low in toxicity and functions effectively as a preservative under acidic conditions. It is commonly used in foods such as soy sauce, dried fish, pastries, bread, and lactic acid bacteria beverages, with a maximum usage level of 1 g/kg. Its antimicrobial mechanism is believed to involve the inhibition of microbial thiol enzymes. Sorbic acid is considered essentially non-toxic, non-mutagenic, and non-carcinogenic, and is classified as a GRAS (Generally Recognized As Safe) food additive. The ADI for potassium sorbate is 0–25 mg/kg body weight, with an LD_{50} of 4.20–6.17 g/kg (oral, in rats).

3. Methanol

3.1. Hazard analysis

Methanol is highly toxic to the human body, with 4–10 g being sufficient to cause severe poisoning. Its metabolism in the body is extremely slow, and its oxidation is incomplete, leading to accumulation. The metabolic products of methanol in the body are formic acid and formaldehyde. Formic acid is six times more toxic than methanol, while formaldehyde is 30 times more toxic. Therefore, even a very small amount of methanol can cause chronic poisoning. It is evident that the toxicity of methanol in alcoholic beverages is actually the combined effect of the toxicity of methanol, formic acid, and formaldehyde. In acute poisoning, symptoms such as headache, nausea, stomach pain, and blurred vision may occur. As the condition progresses, it may lead to difficulty breathing, respiratory center paralysis, coma, and even death. Chronic

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poisoning is mainly characterized by symptoms such as mucous membrane irritation, dizziness, somnolence, headache, digestive disturbances, blurred vision, and tinnitus, which can ultimately result in blindness.

3.2. Main causes of formation

The primary source of methanol in wine is the raw materials. The hydrolysis of pectin substances, deamination of amino acids, and moldy fermentation materials in the raw materials can all produce significant amounts of methanol. The degree of grape drying has a considerable impact on fermentation. If fermentation is complete and the alcohol content is high, the methanol content will also be higher. In sufficient aging time and the absence of oak barrel aging can also lead to increased methanol levels.

4. Fusel Oils

4.1. Hazard analysis

During fermentation, in addition to the production of ethanol, higher alcohols such as methanol and propanol are also generated. These higher alcohols are primarily produced through the catabolic pathways of proteins, resulting from the breakdown of amino acids. The so-called higher alcohols mainly include isobutanol and isoamyl alcohol. Because they appear as oily substances in aqueous solutions, they are also referred to as fusel oils. The toxicity of these alcohols increases with the lengthening of the carbon chain; for example, the toxicity of amyl alcohol is four times greater than that of ethanol.

These higher alcohols are both components that contribute to the aromatic flavor of wine and substances that possess unique tastes and toxicities. The main higher alcohols in wine include propanol, butanol, isobutanol, amyl alcohol, and isoamyl alcohol. Because they can combine with organic acids to form esters, which impart a unique aroma to wine, higher alcohols are important constituents of the secondary aroma in wine. Moderate levels of higher alcohols can enhance the sensory characteristics of wine. However, excessive concentrations of higher alcohols are toxic to humans, causing congestion of the nervous system and symptoms such as headaches. Their toxicity increases with molecular weight. The metabolism of higher alcohols is much slower than that of ethanol, resulting in a more prolonged intoxicating effect. They can damage brain nerve cells, leading to symptoms such as oxygen deficiency and headaches. This is why consumers often experience a “heady” sensation after consuming excessive amounts of wine. As a byproduct of wine fermentation, the content of fusel oils is one of the important indicators for evaluating wine quality.

4.2. Main causes of formation

The content of fusel oils in wine varies depending on the type of yeast used. The metabolic by-products of wine yeast differ significantly at different fermentation temperatures. Wines fermented at high temperatures generally have higher levels of fusel oils. When the sugar content of grapes is low, additional sugar must be added to achieve the desired alcohol content. The more sugar that is added, the more fusel oils are produced. Moreover, the method of sugar addition during fermentation also affects the content of fusel oils.

5. Heavy metals (Iron, Copper, Manganese)

5.1. Iron and copper

5.1.1. Hazard analysis

The types and levels of metal elements are closely related to human immune function, endocrine function, growth and development, and nerve conduction. Excessive levels of heavy metals in food can cause serious harm to the human body, leading to protein coagulation and affecting metabolism and growth and development. The oxidation in wine mainly depends on the content of copper, Iron, and manganese. Among them, iron plays an activating role in the formation of complexes with acetaldehyde and polyphenols, thus having a significant impact on the stability, color, and clarity of wine.

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5.1.2. Main causes of formation

Due to factors such as soil, fertilizers, and pesticides, grapes naturally contain certain metal elements. If the winery's equipment is poor, metal ions from containers, pipes, pumps, and tools can dissolve into the wine, leading to excessive levels of metal ions in the wine, which in turn affects the quality and stability of the wine. The metals that significantly affect wine quality are mainly iron and copper. Measures to prevent and control iron and copper include: avoiding direct contact between wine and iron or copper containers, pipes, and tools; using appropriate iron removal methods; adding a suitable amount of citric acid; and preventing contact between wine and air to avoid oxidation.

5.1.3. Manganese

Manganese is one of the common elements in wine, and it significantly affects the reactions of acetaldehyde and other chemical substances in wine. This directly relates to the oxidation of wine and changes in its sensory characteristics. Although neither national nor international standards have set specific limits for manganese in wine, the potential hazards of manganese in wine have attracted the attention of many scholars. Naughton D P et al. [7] conducted a target hazard quotient (THQ)analysis of heavy metals in wine and found that excessive manganese content in wine can pose risks to individuals who consume wine regularly over the long term.

6. Conclusion

In recent years, with the improvement of living standards and consumption levels, people’s requirements for food have not only focused on satisfying hunger but also on nutrition and hygiene. This has strongly promoted the development of the food industry. Meanwhile, in order to save on labor costs for bottling and labeling abroad, many wine importers bring in bulk wine or unlabeled neutral packaged wine, and then conduct secondary bottling and labeling in factories within China’s special regulatory areas. Some even engage in blending, adulteration, watering down, and adding preservatives after the bulk wine has been warehoused, yet they market these products as originally bottled imports at high prices. Some unscrupulous merchants even bottle the wine on the high seas, forge relevant documents, and sell the products in China. There are also cases where domestically produced wine is sent to special regulatory areas for a “one-day tour” and then re-inspected and re-imported, misleading consumers into thinking it is an imported product. The flow of substandard products into the market not only causes economic losses to consumers but also poses potential risks to their health.

To ensure the quality and safety of wine, it is recommended that: Enterprises should focus on controlling hazard factors during production or import processes. Regulatory authorities should establish a wine quality and safety traceability system suitable for China’s national conditions and strengthen source regulation, including the construction and management of wine raw material bases, the use of brewing equipment that meets technological requirements, and the application of scientific and rational production technologies. At the same time, the threshold for entering the imported wine industry should be raised, and a comprehensive and robust quality and technical standards system for Chinese wine should be established to ensure that wine management is regulated and supported by clear guidelines and laws.

7. References

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