

## Exploration of the Present State and Prospects for Mechanized Roasting of Highland Barley

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**Abstract:** Highland barley is an irreplaceable staple for the Tibetan people in the highland plateau area, not only as a vital food source but also a cornerstone of traditional culture and ethnic culinary practices. Recognized for its indispensable role in sustaining life and fostering development in the highland region, it is crucial to explore the mechanized roasting of this cherished grain, particularly in the context of producing zanba and other staple foods. Highlighting the current research status and identifying existing challenges in the mechanized roasting process, this study concludes with tailored development recommendations aimed at providing insights and guidance for furthering the mechanized roasting of highland barley.

**Keywords:** Highland Barley; Roasting; Mechanization

### 1. Introduction

Highland barley, known as the "life sustainer" and "wealth generator" for the Tibetan people, has a rich history of cultivation and consumption spanning 3,500 years. It plays an irreplaceable role in the highland region, providing essential nourishment and serving as a pillar for cultural heritage and ethnic economic development [1]. With a cultivation area of nearly 6 million mu nationwide, China possesses over two-thirds of the world's highland barley production. It serves as the main source of sustenance for 7 million Tibetan compatriots, ensuring their food security. The primary cultivation areas include Qinghai, Tibet, Sichuan, and Yunnan provinces, all located in high-altitude regions. However, the entire value chain of highland barley processing is largely concentrated in the economically underdeveloped Qinghai-Tibet Plateau region, which grapples with poor infrastructure and inadequate standards and

technical regulations for mechanized processing of highland barley. These limitations significantly hinder the advancement of the highland barley industry towards agricultural modernization.

Roasting is a crucial step in highland barley processing. Currently, there are two methods of roasting: manual and machine-based. Manual roasting primarily relies on firewood, cow dung, and coal as heat sources, resulting in time-consuming and labor-intensive processes with low production efficiency and significant environmental pollution. Machine-based roasting, on the other hand, depends on manual expertise to operate the equipment, offering minimal automation and intelligence. The key control points such as roasting temperature and time are not well-suited for highland barley roasting requirements, leading to issues such as pot sticking, low popping rate, and inconsistent color of the final product.

To address the challenges of low efficiency in traditional manual roasting, as well as the limited applicability and unsatisfactory performance of conventional roasting equipment, this study aims to provide a comprehensive analysis of the current state of mechanized roasting for highland barley. By exploring the research status and identifying existing problems in mechanized roasting technology, combined with the proposed development recommendations, this study aims to provide theoretical support and practical guidance for the sustainable development of the highland barley processing industry.

### 2. The Value and Role of Highland Barley

Highland barley, widely cultivated in the plateau region, not only provides a stable food source for the Tibetan people but also holds significant value as a precious health food due to its abundant nutrients and medicinal

properties. These attributes have rendered highland barley indispensable in the lives of the Tibetan people.

Abundant in protein, dietary fiber, minerals, and a variety of vitamins, highland barley offers remarkable benefits to human health. Its protein content surpasses that of many other grains, and its comprehensive amino acid composition satisfies the body's essential amino acid requirements. Not only does highland barley supply ample energy, but it also aids in muscle repair and growth. Its richness in dietary fiber improves digestive function, prevents constipation, and contributes to weight management. Additionally, dietary fiber reduces cholesterol levels, lowering the risk of cardiovascular diseases. Furthermore, highland barley contains essential minerals such as calcium, phosphorus, iron, and zinc, all crucial for maintaining normal physiological functions in the human body [2,3].

Beyond its nutritional value, highland barley also possesses significant medicinal properties. In Tibetan medicine, it is used to treat a diverse range of ailments. Its  $\beta$ -glucan component exhibits various biological activities, including enhancing immunity, combating tumors, and regulating blood sugar levels. These medicinal properties position highland barley as an integral element in healthcare practices across the plateau region.

### **3. The Current State of Mechanized Roasting for Highland Barley**

Since the 1990s, the thriving development of the highland barley processing industry has presented both Chinese and international opportunities for the advancement of roasting machinery. Continuous technological research and market expansion have driven progress in the roasting machinery industry, leading to the emergence and application of various types of roasting machinery. Drum roasting machinery, distinguished by its unique drum design and heating method, ensures even heating and rolling during the roasting process, resulting in high-quality roasted products with excellent flavor and aroma. Conversely, mesh belt roasting machinery achieves large-scale, continuous production through an efficient mesh belt transmission system and precise temperature control, significantly boosting production efficiency. As roasting equipment

types have evolved, heat sources have transitioned from firewood to coal, natural gas, and electric power, emphasizing the industry's gradual move toward higher efficiency and cleanliness. Despite the significant progress made in the development of roasting machinery, both in China and internationally, challenges persist. These include limited technological innovation, low levels of automation, complex operation, high labor intensity, restricted applicability, and suboptimal roasting outcomes, all of which fall short of meeting the distinctive requirements for highland barley roasting.

To address these challenges, Li Jie et al. [4] integrated an intelligent temperature control system to precisely regulate and control roasting temperatures. This innovative approach led to enhanced production efficiency and improved the yield of high-quality roasted highland barley. Their system adapts in real time, adjusting the heating parameters based on the unique characteristics of different raw materials and processing requirements, thereby ensuring the stability of product quality in each batch. In a similar vein, Yang Zhicheng et al. [5] developed an integrated automatic roasting machine that combines feeding, heating, tossing, separating, and discharging into a single unit. Their meticulous design and optimization of the automatic roasting machine, including key automated temperature control systems and tossing mechanisms, have effectively enhanced its automation level.

### **4. Issues in Mechanized Roasting of Highland Barley**

#### **4.1 Lagging Development in Mechanized Roasting Technology**

The production of Zamba, a staple food for the Tibetan people, after the roasting of highland barley, is greatly influenced by different roasting times and methods. The precise control of roasting time and technique is pivotal to the entire process of highland barley roasting [6,7]. Traditionally, highland barley roasting involves over ten steps including fuel collection, storage, hot water soaking, tossing, and sand separation, making it time-consuming, labor-intensive, environmentally polluting, and resulting in low production efficiency. Furthermore, existing

machine roasting lacks specialization, struggles with temperature control during roasting, and fails to meet the specific requirements of highland barley, often leading to issues such as pot sticking, low puffing rates, and uneven product color. With China being home to 7 million Tibetan compatriots and a high demand for highland barley roasting, the current highland barley roasting technology and equipment no longer suit the requirements of modern agricultural scale and intensive production, seriously hindering the high-quality development of the highland barley processing industry.

#### **4.2 Lack of a Standardized System for Mechanized Roasting Technology in Highland Barley**

At present, the standards for roasted barley are insufficient because an integrated system of local, industrial, and national standards has yet to be developed. Important parameters, such as expansion rate and energy usage, lack explicit standards and set guidelines. This insufficiency has brought many challenges to the highland barley roasting sector. Because of the lack of standardization, manufacturing techniques, equipment selection, and quality control varies significantly amongst production organizations. Some businesses may rely on past experience, while others may adopt new technologies and equipment, resulting in discrepancies and instability in product quality. This circumstance has an impact not just on the industry's competitiveness, but also on consumer trust and happiness with roasted highland barley goods.

#### **4.3 Inadequate Promotion of Mechanized Roasting Technology for Highland Barley**

While some regions have introduced mechanized roasting equipment, the scope of its technological dissemination remains inadequate [8]. Many herdsman lack the knowledge and skills necessary to operate and maintain these devices, limiting their practical utilization [9,10]. Additionally, disparities in technical expertise and limitations in equipment investment have hindered the transition from traditional to modern processing of highland barley in many regions. Consequently, most herders continue to use primitive manual roasting methods, which not

only affect production efficiency but also compromise product quality consistency and market competitiveness.

### **5. Recommendations for the Advancement of Mechanized Roasting of Highland Barley**

#### **5.1 Facilitating the Intelligent Evolution of Highland Barley Roasting**

The rapid development of advanced technologies such as artificial intelligence, the Internet of Things, and big data has significantly bolstered the intelligent progression of roasting machinery. Evolving from simple mechanical devices, these machines are now equipped with high levels of automation and intelligence [11]. They can actively monitor production processes in real-time and autonomously adjust production parameters, thereby achieving higher efficiency and precision in production. Furthermore, through comprehensive big data analysis, roasting machinery enterprises can gain profound insights into market demands and consumer preferences, providing invaluable guidance for product development and strategic market decision-making.

#### **5.2 Driving the Green Transformation of Highland Barley Roasting**

In today's era, environmental conservation and sustainable development have become universal priorities across global industries. Consequently, the roasting machinery sector, as a pivotal component within the highland barley processing machinery domain, must earnestly undertake environmentally conscious initiatives. This entails prioritizing energy efficiency, emission reduction, and resource recycling to actively align with worldwide environmental initiatives. Embracing eco-friendly materials and processes is paramount to minimize energy consumption and waste emissions. Furthermore, through technological innovation and industrial modernization, the entire roasting machinery industry can be steered toward a greener and more environmentally responsible trajectory.

#### **5.3 Accelerating the Establishment of Technical Standards for Highland Barley Roasting**

The lack of explicit technical standards for highland barley roasting not only impedes the

industry's capacity to meet diverse market demands and production efficiency imperatives but also constrains its modernization and mechanization process. Thus, the expeditious development and implementation of pertinent technical standards are imperative.

It is essential for governmental bodies and industry associations to swiftly establish a technical standard system tailored to the distinctive characteristics of highland barley roasting. This includes defining the prerequisites for various process parameters and quality benchmarks, ultimately elevating the integration between agricultural machinery and agronomy [12]. By enforcing standardized norms and technical requirements, enterprises can be incentivized to adopt state-of-the-art roasting equipment, fostering heightened production efficiency and product quality, while effectively reducing energy consumption and production costs, consequently steering the industry toward sustainable and eco-friendly development. Simultaneously, enterprises should be guided to bolster their technological investments, propelling the innovation and modernization of roasting machinery, ultimately amplifying the industry's overall competitiveness and market influence.

#### **5.4 Increasing the Dissemination and Proficiency Development of Mechanized Roasting Technology for Highland Barley**

Aligning with the distinctive demands of highland barley roasting and industry developmental trends, collaborative efforts between governmental bodies, industry associations, and enterprises are essential. This necessitates the implementation of comprehensive training programs encompassing theoretical instruction, practical operations, and case analyses to equip practitioners with the expertise to intricately regulate roasting temperatures, manipulate roasting durations, and capitalize on the intelligent functionality of roasting machinery. Coupled with fiscal support, technical guidance, and on-site exposure, these initiatives can encourage greater participation in the training of mechanized roasting technology, consequently upgrading the industry's technical proficiency and talent reservoir. Moreover, to ensure enduring and

pragmatic training outcomes, the establishment of periodically updated training courses and materials is pivotal. As technological advancements and equipment upgrades unfold, the optimization and customization of training content is necessary, ultimately aligning with the developmental needs of the highland barley roasting industry.

#### **6. Conclusion**

The healthy and orderly development of the highland barley roasting industry not only provides safe and healthy food for more Tibetan compatriots but also further strengthens interactions, exchanges, and integration among ethnic groups, making significant contributions to promoting ethnic unity and progress. This holds tremendous social significance. This study offers a detailed study on the highland barley roasting industry. It categorizes existing domestic equipment, explores core issues, and advocates for bold innovations in the mechanization of highland barley roasting. This involves active pursuit of automation, intelligence, and eco-friendliness, thereby developing superior quality roasting equipment. Moreover, urgent measures include the formulation of technical standards to guide production, intensified promotional efforts, and the dissemination of professional knowledge in mechanized applications.

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