ANALYZING TURMERIC JUICE STERILIZATION FOR COMMERCIAL SCALE: AN HTST AND PEF APPROACH

(Analisis Sterilisasi Sirup Kunir untuk Skala Komersial : Sebuah Pendekatan HTST dan PEF)

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ABSTRACT

Turmeric (Curcuma longa L.)is a multifunctional plant, functional food and its production is quite high in Indonesia, but turmeric processing is very limited and the shelf life of processed products in the form of juice is low so it is easily damaged. This study aims to evaluate the combined application of Pulsed Electric Field (PEF) and Low Temperature Long Time (LTLT) treatment for producing turmeric juice that effectively eliminates microorganisms while preserving the color, aroma, and nutritional content of the final product. The goal is to achieve a commercially sterile turmeric juice in compliance with the Indonesian National Standard (SNI). Two sterilization methods were tested: (1) LTLT followed by PEF, and (2) High Temperature Short Time (HTST) followed by PEF. The Total Plate Count (TPC) after treatment was 3.0×10^4 CFU/mL. The most effective method for meeting SNI sterility standards was the HTST + PEF combination, with a TPC of 0.3×10^4 CFU/mL achieved at 75°C for 9 seconds. The HTST + PEF method demonstrated superior effectiveness in producing turmeric juice that meets commercial sterility standards while maintaining product quality. This study provides an efficient and practical approach for communities and industry to process turmeric juice using rapid methods that ensure safety, retain quality, and comply with SNI standards.

Keywords: Sterilization, PEF (Pulsed Electric Field), SNI, TPC (Total Plate Count), Turmeric juice.

ABSTRAK

Kunyit (Curcuma longa L.) merupakan tanaman multifungsi, pangan fungsional dan produksinya cukup tinggi di Indonesia, namun pengolahan kunyit sangat terbatas dan daya simpan produk olahan berupa sari buah rendah sehingga mudah rusak. Penelitian ini bertujuan untuk mengevaluasi penerapan gabungan perlakuan Pulsed Electric Field (PEF) dan Low Temperature Long Time (LTLT) untuk menghasilkan sari buah kunyit yang efektif menghilangkan mikroorganisme dengan tetap mempertahankan warna, aroma, dan kandungan gizi produk akhir. Tujuannya adalah untuk mendapatkan sari buah kunyit yang steril secara komersial sesuai dengan Standar Nasional Indonesia (SNI). Dua metode sterilisasi yang diuji adalah: (1) LTLT diikuti dengan PEF, dan (2) High Temperature Short Time (HTST) diikuti dengan PEF. Total Plate Count (TPC) setelah perlakuan adalah $3{,}0 \times 10^4$ CFU/mL. Metode yang paling efektif untuk memenuhi standar sterilitas SNI adalah kombinasi HTST + PEF, dengan TPC $0{,}3 \times 10^4$ CFU/mL yang dicapai pada suhu 75°C selama 9 detik. Metode HTST + PEF menunjukkan efektivitas yang unggul dalam menghasilkan sari kunyit yang memenuhi standar sterilitas komersial dengan tetap menjaga kualitas produk. Penelitian ini memberikan pendekatan yang efisien dan praktis bagi masyarakat dan industri untuk mengolah sari kunyit menggunakan metode cepat yang menjamin keamanan, mempertahankan kualitas, dan mematuhi standar SNI.

Kata Kunci: Sterilisasi, PEF (Pulsed Electric Field), SNI, TPC (Total Plate Count), Jus kunyit.

INTRODUCTION

Market trends further reveal that consumer willingness to pay is affected by factors including the origin of the turmeric, and organic certification, with many preferring locally sourced and sustainably produced products (Abhinav & Doskaliuk, 2024). Additionally, turmeric quality determined by

cultivation practices and post-harvest processing, results in considerable price variation in the market (Buckle et al., 1987). While high-quality turmeric juice often commands premium prices, the presence of lower-quality products can undermine consumer confidence, posing challenges to maintaining strong market dynamics and long-term brand trust.

Although curcumin exhibits anti-inflammatory, antioxidant, and anticancer properties, the complexity of its action on a wide range of diseases requires further investigation to understand its diverse roles (Chudasama et al., 2024). The quality and nutritional content of turmeric juice play a significant role in determining its market value, primarily through consumer preferences and the health benefits associated with its bioactive compounds. As turmeric continues to gain popularity, factors such as curcumin content, sensory attributes, and production methods are becoming increasingly important in shaping market demand and pricing strategies.

Research on turmeric processing has been conducted in various countries, including China (Chudasama et al., 2024), Malaysia (D. Pujimulyani, 2025), Eropa Europe (Eka N. et al., 2011), India (BPOM, 1989), and also Indonesia (Abhinav & Doskaliuk, 2024; Gasperz, 1992; Krishi Vidyapeeth et al., 2018; Standar Nasional Indonesia, 2000). Most of these studies focus on herbal medicine combinaing with other raw materials such as ginger, kencur, cardamom, and others with various different processes. In the previous study, it focused more on turmeric alone with sterilization technology using the PEF and HTST approaches. Although, PEF and HTST have been applied to strawberry (Kumar et al., 2021), apple (Lee et al., 2024), and orange juice (Li, 2011), but

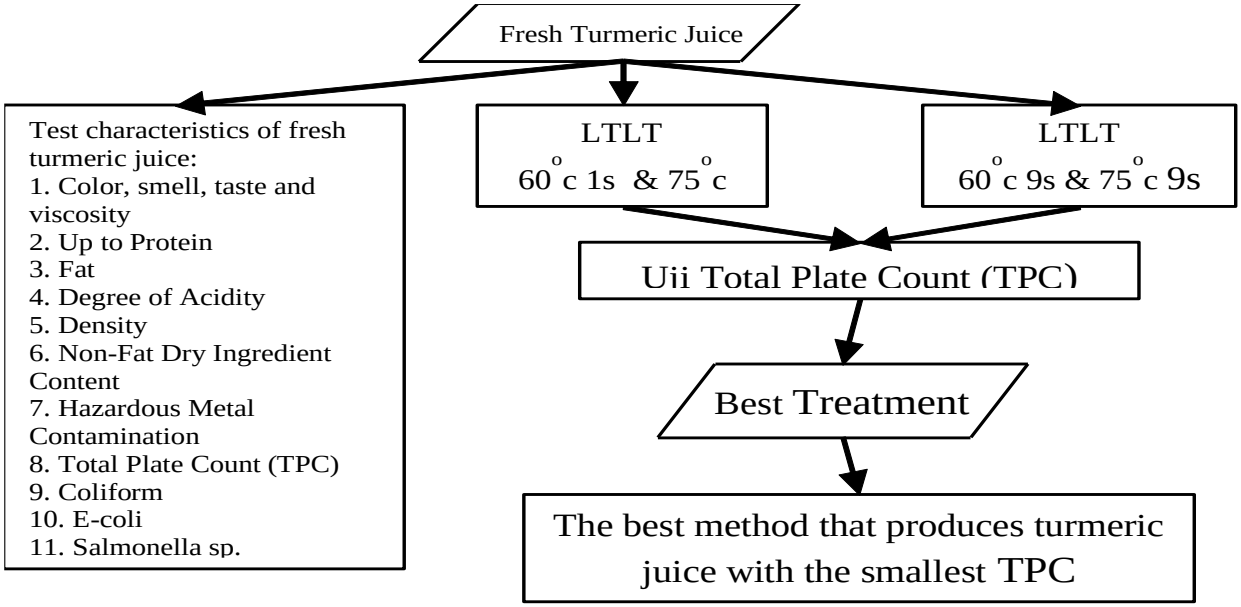


Figure 1. Research Flow Diagram

are still rarely found in turmeric juice. This study was designed to evaluate on a commercial scale. Recent research on turmeric, particularly its active compound curcumin, reveals significant gaps in understanding its mechanism of action that hinder its full therapeutic potential. Addressing this gap is essential to optimize the therapeutic application of turmeric. Curcumin interacts with various signaling pathways, including NF-κB, MAPK, and PI3K/AKT, but the exact molecular interactions are still not adequately defined [6]. Despite its promising effects, curcumin's low bioavailability limits its clinical efficacy. Research to increase uptake through new delivery systems is urgently needed (Eka N. et al., 2011).

The application of Internet of Things (IoT) technology in industrial equipment such as HTST and pulsed electric field (PEF) pasteurization machines offers significant advantages in terms of operational ease and remote access. Drawing on the Universal IoT System developed by BBPPMPV BOE Malang, the integration of hardware components such as the Raspberry Pi 4 with sensors, relays, and web-based control interfaces

enables flexible, real-time monitoring and control of machinery. Through such a system, operators can adjust machine parameters, monitor performance, and perform diagnostics without being physically present. This capability not only facilitates ease of machine operation, but also allows for remote control, enhancing efficiency, safety, and reducing operational downtime (Subiyantoro, 2020). In this study, the machine in question is an HTST and electric shock (PEF) pasteurization system specifically applied to turmeric juice sterilization (BPOM, 1989).

METHOD

The fresh turmeric juice was prepared by blending turmeric with water, followed by pressing and filtration to extract the juice.

Tools and materials for sterilization and electric shock treatment

1. Pasteurization machines are equipped with electric shock features, the specifications are as follows:
    a. Capacity: 10 liters
    b. Tube material: 304 stainless steel, Frame material: 201 stainless steel
    c. Heater Power: 1000 watts
2. The additional tools required include cables, containers, timers, and notebooks.

Tools and materials used in TPC testing for each treatment

The material used for TPC analysis consists of PCA media.

The tools used in this test consisted of umbrella paper, sterile gauze, distilled water, 70% alcohol, spirtus, autoclave, Erlenmeyer, cups, stirrer, electric stove, thermometer, electric sterilization unit, incubator, bunsen burner, round flask, vortex, water bath, volume pipette, Petri dish, and colony counter.

This research was conducted using two temperature levels and two electric shock durations. Phase I involved sterilizing turmeric juice using Low Temperature Long Time (LTLT) combined with Pulsed Electric Field (PEF) at temperatures of 60°C and 75°C. Phase II focused on sterilization of turmeric juice using LTLT and PEF combination, at the electric shock durations of 1 second and 9 seconds. Both phases used a steep climbing method with two treatment factors: sterilization temperature and the contact time of the turmeric juice with electric shock. The observed response was the Total Plate Count (TPC). The study consisted of five treatments based on the design of the steep climbing method, as shown in Table 3. The first (linear) design is used for initial repairs until further response does not occur. Subsequent observations between the variable and the response used a second (quadratic) approach to capture additional reductions

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Table 1 Research Design to Build a First Order Function Model

Temperature Sterilization (^{O}c)	Time Contact (s)	Response TPC (cfu/ml)
60	1	
60	9	
75	1	
75	9	

This research is an experimental investigation aimed at evaluating the effectiveness of thermal treatment using pasteurization in ensuring the microbial safety and preserving the quality of turmeric juice. The experiment was conducted at PT METROMESIN MENDUNIA, a company specializing in food processing machinery. The research took place in March 2025, utilizing the company's pasteurization machine as the primary equipment for applying controlled thermal treatment. This setting provided a practical environment to simulate real-world processing conditions and assess the impact of pasteurization parameters on the turmeric juice.

Sample Preparation and Treatment

A total of 2 kilograms of fresh turmeric rhizomes were processed to extract juice. The turmeric was blended with water, squeezed, and filtered using a fine mesh strainer, yielding approximately 3 liters of fresh turmeric juice. A 50 mL aliquot of this unprocessed juice was collected and labeled "Turmeric Juice (Without Pasteurization)", which served as the untreated control sample.

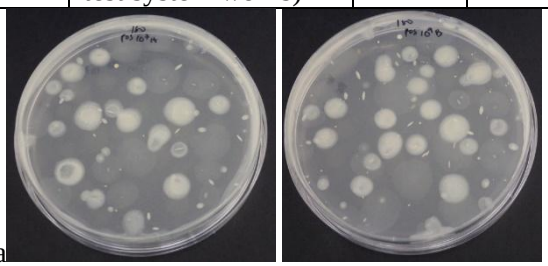
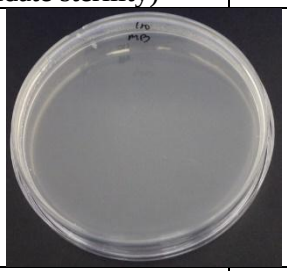
Two separate 500 mL portions of the turmeric juice were then subjected to thermal pasteurization using a pasteurization machine. In the first treatment, the juice was heated to 60 °C for 30 minutes. Upon reaching the

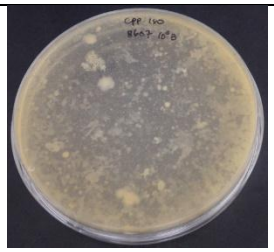
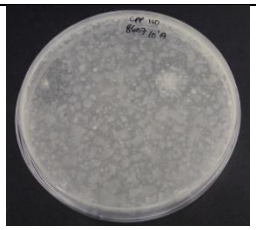
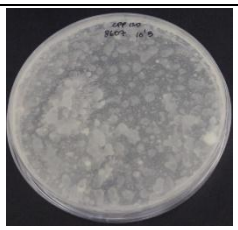
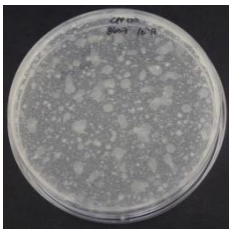
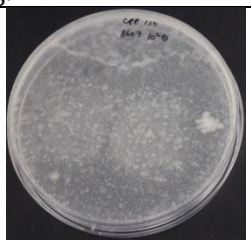
target temperature at the 20th minute, the electric shock feature of the pasteurizer was activated for 1 second. A 50 mL sample was immediately collected and labeled "Pasteurized Turmeric Juice 60 °C 1 Second." The electric shock was then reapplied for an additional 8 seconds, followed by the collection of another 50 ml sample labeled "Pasteurized Turmeric Juice 60 °C 9 Seconds."
In a second thermal treatment, another 500 mL portion of turmeric juice was heated to 75 °C for 33 minutes. At the 23rd minute, when the juice reached 75 °C, the electric shock was applied for 1 second, and a 50 mL sample was taken and labeled "Pasteurized Turmeric Juice 75 °C 1 Second." The electric shock was again applied for an additional 8 seconds, and another 50 mL sample was collected and labeled "Pasteurized Turmeric Juice 75 °C 9 Seconds."

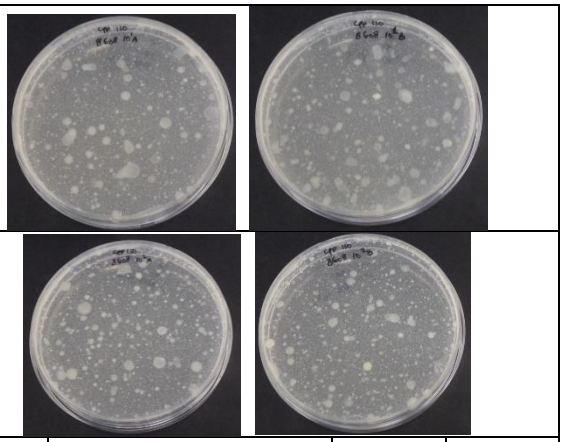
RESULT AND DISCUSSION

The samples obtained from each treatment were analyzed to assess the impact of thermal processing and electric shock duration on the characteristics of turmeric juice. By comparing untreated juice with samples subjected to different pasteurization conditions (i.e., 60 °C vs. 75 °C and 1-second vs. 9-second electric shock exposure), the effectiveness of combined thermal-electric pasteurization methods can be evaluated.
These comparisons aim to identify potential changes in juice properties such as microbial load reduction, color, aroma, or active compound retention (e.g., curcumin), though specific results and measurements are discussed in subsequent sections. This setup provides a systematic basis for understanding how temperature and electric shock interact to influence turmeric juice quality and safety.

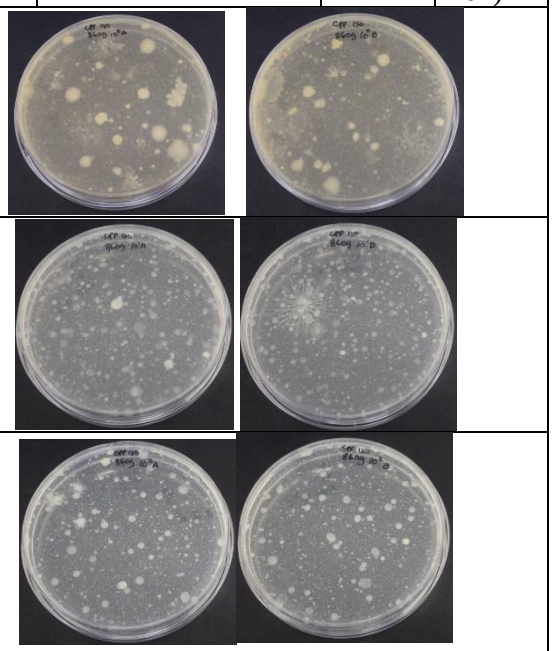
Table 2 Bacterial Culture Plate of each Sample

Name	Positive Control (To ensure reagents are active, To verify the test system works)	Sample Code	POST
a 			
Name	Negative Control (To check for contamination, To validate sterility)	Sample Code	MB
			
Name	Turmeric juice (without pasteurization)	Sample Code	8607 (100; 101; 102)

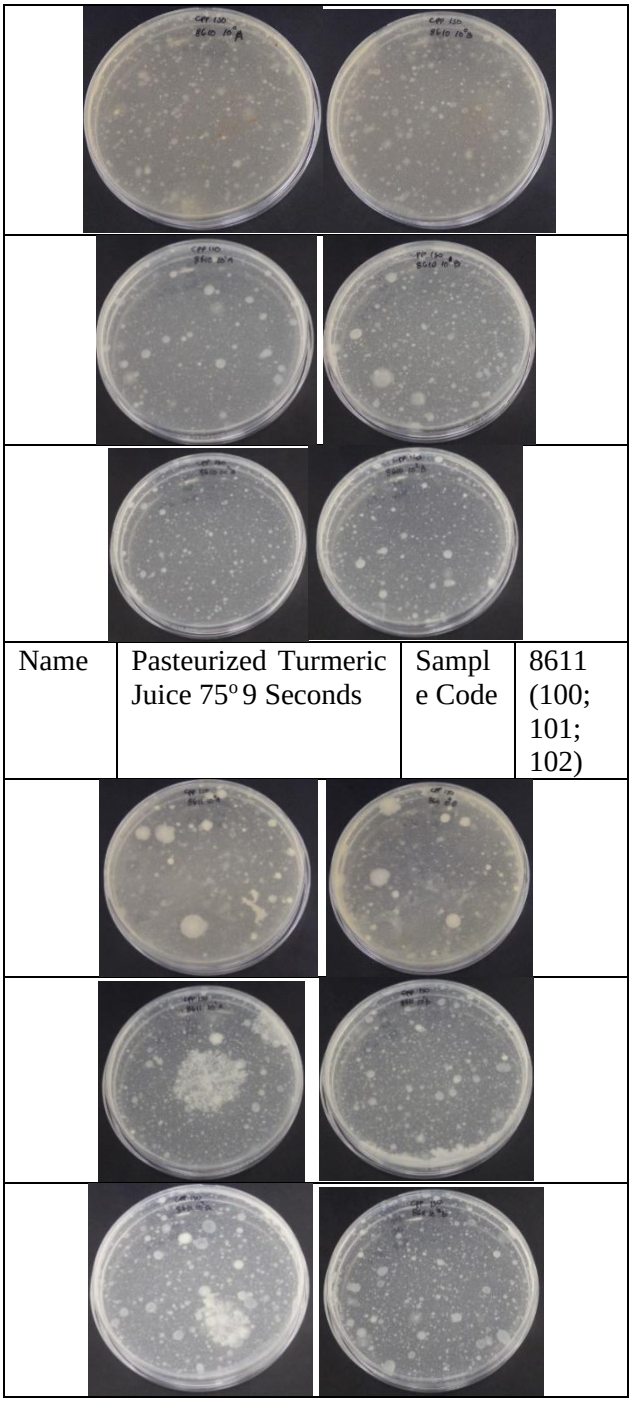
d.  e. 			
f.  g. 			
h.  i. 			
Name	Pasteurized Turmeric Juice 60° 1 Second	Sample Code	8608 (100; 101; 102)
 			



Name	Pasteurized Turmeric Juice 60° 9 Seconds	Sample Code	8609 (100; 101; 102)



Name	Pasteurized Turmeric Juice 75° 1 Second	Sample Code	8610 (100; 101; 102)



Name	Pasteurized Turmeric Juice 75° 9 Seconds	Sample Code	8611 (100; 101; 102)

This activity was conducted on turmeric juice in April 2025 Kepanjen where the pasteurization machine is located. The aim of this finding was to evaluate the microbial safety of turmeric juice before it iscommercialized to the general public. The activity was carried out offline in collaboration with a team from Metro Machine. The method used is a learning by doing system or direct practice carried out by introducing a modern PEF (pulsed electric field) pasteurization machine. Furthermore, the results of modern pasteurization are brought to the lab to find out how many bacteria are contained in it without being given preservatives. The last activity is to analyze the results from the lab to be compared before and after before being commercialized, which can later be useful for the community in processing turmeric juice.

This activity was carried out to provide solutions in the community, especially for the processing, production and distribution of turmeric juice to partners or consumers Indonesia. Therefore, activities in the form of checking the public are also needed to provide information related to turmeric juice, which can help enhance its market value and optimizing its distribution. The alternative given to the community in Kepanjen was to

introduce a modern pasteurization machine PEF (pulsed electric field), which is a machine that offers the community to increase the production effiency and extending the shelf life of turmeric juice.

In addition, workshops and trainings were carried out related on the types of turmeric and their processing methods. These activities aimed to educate the community and enhance their competitiveness and marketability of turmeric-based products. Participants involved in community training/workshops on the operation of pasteurization machines from start to finish. The practical activities carried out by the community in the workshop are as follows: (1) Starilization of equipments: the pasteurization machine is sterilized first before use to ensure a contamination from other materials. (2) Preparation of ingredients: turmeric juice was prepared by by blending fresh turmeric using either a blender or other machines. (3) Pasteurization: heating is conducted to eliminate most of the bacteria present in the turmeric juice, ensuring the product remains safe for consumption while maintaining it quality. , (4) Electric shock treatment: after heating is with a certain temperature, the electric shock was applied for a few moments to eliminate heat-resistant bacteria (5) Cooling: he pasteurized turmeric juice was allowed to cool to around 30 °C with the aim that the turmeric juice ingredients are ready it for packaging and consumption.

The next activity involved training with the aim of knowing the proper use of packaging and the design of the stirrup. This is crutial for attracting public attraction and consumer purchasing power in the future. The training includ guidance on designing attractive packaging and a provide attractive design of the products, examples of packaging that can attract consumer interest are various sizes so that people can choose the right size for consumption. The next step is to estimate the consumer capabilities of each package offered, for example bottle packaging ranging from 200ml to 500ml.

In addition to the activities above, we also provide education about attractive designs and labels on turmeric juice products. Labels play the important components in the marketing and sales process, because there is information about the product that will be read by consumers. During the labeling workshop, it was explained about labels, logos, exp time, composition, and other necessary details.

Table 3 TPC Test Result

Sample Name	**Treatment**		
	Temperature (°C)	Shock Duration(s)	Result
Turmeric Juice Without Pasteurization	0	0	$3.0x10^4$
Pasteurized Turmeric Juice 60°C 1 Second	60	1	$2.6x10^4$
Pasteurized Turmeric Juice 60°C 9 Seconds	60	9	$1.3x10^4$
Pasteurized Turmeric Juice 75°C 1 Second	75	1	$2.3x10^4$
Pasteurized Turmeric Juice 75°C 9 Seconds	75	9	$0.3x10^4$

The activity was implemented and received a very positive response from the community, especially business actors in the field of turmeric juice. The public realizes how important of proper branding and and labeling by using the right logo and information, so that it can attract buyers both locally and from outside regions.

CONCLUSION

Turmeric juice is a functional product with significant potential for improvement through optimized processing and proper labeling so as to produce a healthy final product and attract the attention of other consumers. In addition to having various benefits in the health benefits, people who produce turmeric juice finally realize that there are many other things that can affect sales and public attraction. Because the area that produces the most turmeric is in East Java, people who make a living in the field of plants, especially turmeric, must be given information related to this modern pasteurization. Traditional turmeric juice products without pasteurization are often less competitive in the market compared to those processed using modern equipment like pasteurization machine. Therefore, it is expected that the proposed alternatives provided will enhance the marketability and competitiveness of the of turmeric commercialization. It is highly important to increase public understanding of

the pasteurization technology because it can also be applied to other agricultural products, contributing to improved competitiveness in both local and international markets.

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