Ginger processing and applications in Vietnam's food industry:a comprehensive review

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Abstract: Ginger (*Zingiber officinale* Roscoe), a perennial herbaceous plant belonging to the Zingiberaceae family, has been used for centuries in various industries, such as foods, cosmetics, and pharmaceuticals, due to its health-beneficial and aroma compounds. Vietnam plays a significant role in the global ginger market, ranking 4th in terms of ginger cultivation area and contributing approximately 5% of worldwide production Click or tap here to enter text.The present review focused on the preliminary processing of ginger, as well as different processing techniques like drying dried ginger powder and ginger starch), distillation (essential oil), extraction (oleoresin, wine and liquor), and fermentation (pickle and candied). A comparison is drawn between the traditional and modern methods to achieve a higher yield of ginger essential oil and ginger oleoresin. Additionally, other applications of ginger in food preservation (seafood and post-harvest products), food flavoring (instant ginger tea, jelly, beer, and liqueur) and the utilization of ginger residue are also discussed. This study provides an overview that highlights the diverse production processes of ginger products while emphasizing the utilization of semi-finished or by-products of ginger for other food-related purposes.

Keyword: Vietnam ginger, ginger procesing, ginger production chain

Citation: Minh Tu, N. T., D. T. Giang, and N. M. Quan. 2025. Ginger processing and applications in Vietnam's food industry:A comprehensive review. Agricultural Engineering International: CIGR Journal, 27(2): 195-211.

1 Introduction

Ginger (*Zingiber officinale* Roscoe) has a widespread history in tropical Asian countries, originating in India and spreading to Europe, East Africa, and the Americas by the 13th centuries. Taxonomically, it belongs to the Zingiberaceae family in the Zingiberales order (Do et al., 2006.). In Vietnam, ginger, an herbaceous perennial plant measuring around 40-100 cm tall with horizontally growing rhizomes, is typically cultivated in spring, with an 8 to 10-month growth cycle.

Fresh ginger contains 80%-85% moisture, 12%-15% dry matter including 2.3% protein, 0.9% fat, 1.2% minerals, 2.4% fiber, 12.3% carbohydrate, and more than 20 inorganic elements (Do, 2004). Almost all ginger plant parts from Vietnam contain essential oils (2%-3%), with the highest concentration in rhizomes and 5% resin.

Ginger is widely used for flavoring in various cuisines in Vietnam in both savory and sweet recipes, including curries, stir-fries, marinades, baked goods, teas, and beverages. Beyond its culinary function, ginger is also known for its potential health benefits. It contains bioactive compounds, including gingerols, shogaols and other antioxidants, which have been

Received date: 2024-01-05 **Accepted date:** 2025-04-06

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studied for their anti-inflammatory, digestive, and immune-boosting properties and often used as a natural remedy for digestive issues, such as nausea, indigestion, and bloating (Crichton et al., 2019; Kiyama, 2020; Li et al., 2019; Huệ et al., 2012; Dai et al., 2020).

Figure 1 Ginger (Zingiber officinale) ((TDTU(TDTU, 2022)

The global ginger market size reached US$ 3.4 billion in 2024; the market is expected to reach US$ 6.1 Billion by 2033, exhibiting a CAGR of 6.7% during 2025 - 2033 (IMARC, 2024). The ginger growing area in Vietnam reached more than 95,500 hectares (2022), with an output of about 1.61 million tons, accounting for about 5% of world ginger production. In 2019, Vietnam is one of the countries with the largest ginger growing area in the world, ranking 11th in the list of largest ginger producing countries (World Integrated Trade Solution, 2022). While the Vietnamese ginger industry possesses significant potential, it faces notable challenges. Adherence to stricter import standards regarding pesticide residues and the imperative of addressing sustainability concerns are critical. Moreover, the global ginger market is highly competitive, with established producers such as China holding substantial market share. To improve Vietnam's competitive position and appeal to environmentally aware consumers, a strategic emphasis on organic production, sustainable agricultural practices, and the enhancement of production techniques to ensure consistent product quality is essential (6Wresearch. 6Wresearch. 6Wresearch. .*错误!未找到引用源。* 2022).

As an abundant cultivation in Vietnam, novel products and applications in food industry are being researched to enhance the economic value of ginger market. Consequently, this addresses output issues for farmers, increases their income, and reduces the need for importing ginger products.

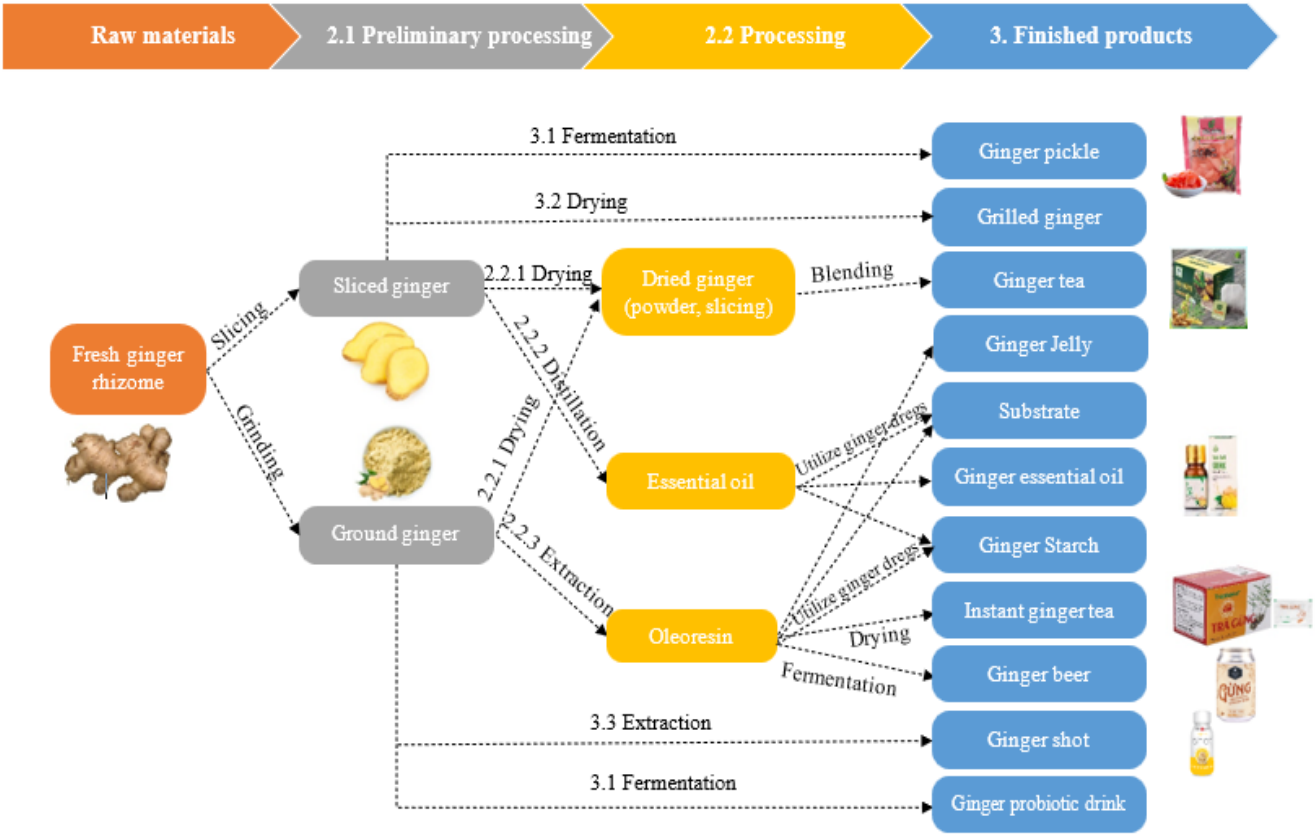

Figure 2 Ginger production chain

2 Materials and methods

Ginger has been gradually spreading in various provinces of Vietnam from North to South, there are two main varieties (Do, 2004; La et al., 2003).

- "Ginger trâu": Large, low-fiber roots are well-suited for export and predominantly grown in lower mountain regions, such as Cao Bang, Lang Son, Thai Nguyen, Bac Can, and Tuyen Quang.

- "Ginger gié": This variety (small, fiber-rich root) is mainly for domestic consumption with a spicier taste. There are two sub-varieties: one with purplish-pink young tubers, frequently cultivated by ethnic minorities in highland areas like Ha Giang, Sin Ho (Lai Chau), Sapa, and Bat Xat (Lao Cai); and the other with small ivory-yellow roots, widely grown in the Northern Delta provinces and southern regions of Vietnam.

Ginger is typically planted during the early stages of spring as the weather begins to warm up, around January to April, harvest season for ginger typically falls towards the end of the year. There are three important criteria to evaluate the quality of ginger root based on the purpose of processing: fiber content, essential oils and spiciness (La et al., 2005).

Ginger harvesting time can be divided as follows based on intended use:

Table 1 Appropriate harvest time of ginger by application

End use	Stage of harvest (Months after planting)	The quality of ginger
Vegetable candy, soft drinks, pickles, and alcoholic beverages purpose	5 – 7 months	Negligible fiber content Mild spicy taste.
Dried ginger ginger oil, oleoresin	8 – 10 months	Max content of essential oil and pungent content

2.1 Preliminary processing

After harvesting, ginger is preliminarily processed through the following steps:

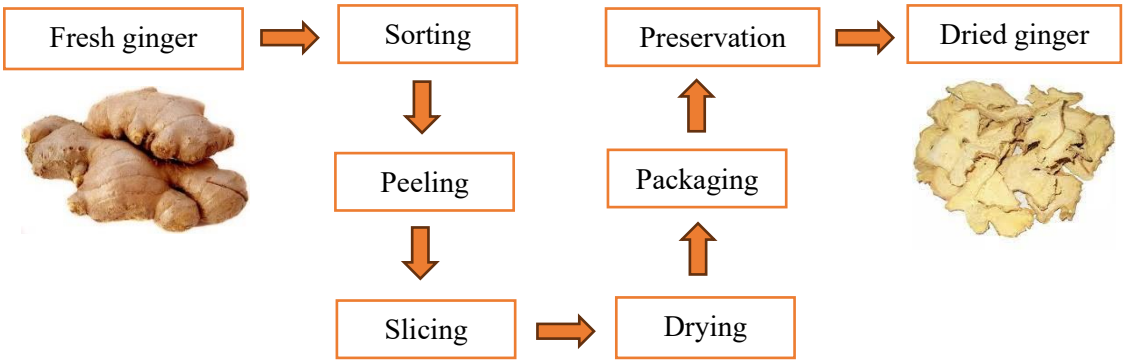

Figure 3 Ginger preliminary processing

Washing: After harvesting, fresh ginger is washed to remove dirt, dust residue, foreign objects…. In small - scale production, ginger is cleaned manually. For large - scale production, a high-pressure nozzle is used to soak the ginger in still water overnight before utilizing a high – pressure water jet. The water used is clean and disinfected with 150ppm hypochlorous acid, pH = 6.5.

Sorting: Ginger is sorted according to size, shape, weight, and color. All tubers that are damaged, broken, spotted, infected with bacteria or fungi are separated. Ginger roots that are yellow-brown and bright in color are often preferred.

Peeling: Removing ginger skin uses bamboo splinters or wooden knives. This process is often performed before drying to reduce mold growth, and fermentation. Unpeeled and peeled ginger is known as black ginger or green ginger and white ginger, respectively.

Slicing: The whole ginger is cut into pieces irregular in shapes and size not less than 20 mm in length or in small cut pieces.

Drying: This is an extremely important step in the

ginger processing. Drying makes transportation easier and reduces waste. The most common drying method is sun drying. For peeled ginger, it typically takes 7-9 days to reach a moisture content of 7.8% - 8.8%, while sliced ginger only requires 5-6 hours and whole ginger takes up to 16-18 hours.

Packaging: Finally, ginger is packed according to uniformity in size and quality. Ideally, ginger should be packaged in cardboard cartons.

Preservation: Under regular conditions, the amount of oleoresin decreases by 20% after 3 months and the gingerol content also decreases. To avoid stillness and fermentation, flakes, pieces or sliced is stored in cold (10^{o}C – 15^{o}C) and dark conditions. In addition, dried ginger can be preserved by treating with γ-Co radiation at an intensity of about 10 kGy (Gray, J kg^{-1}) to remove dust and dirt from microorganisms without compromising its quality.

2.2 Processing

2.2.1 Drying

Ginger is preliminary processed as mentioned in 2.1 the hot air-drying technique is applied to produce ginger powder with high quality. These modern mechanical dryers provide a more controlled alternative, which reduces the risk of contamination. While this approach demands higher energy consumption and initial investment, it ensures consistent quality and quicker processing times (Jayashree et al., 2014; https://www.imarcgroup.com/ginger-market. Accessed 21 May 2025.

Havigo, 2024).

The initial moisture content of freshly harvested ginger ranges from 80%-82%, but it must be reduced to 10% to ensure preservation. The dry ginger yield is contingent upon various factors, such as the ginger variety and climate, typically ranging from approximately 19 to 25 percent of the fresh ginger yield. Utilizing a mechanical drying method is associated various types of dryers, such as tray driers, cross flow air tunnels, solar driers, and cabinet driers. With hot air drying, sliced ginger pieces can be dried in just 5-6 hours. However, the temperature of hot air can affect the quality of ginger powder, particularly in terms of decreasing essential oil content (Quang et al., 2016). On the other hand, drying ginger powder at a higher temperature resulted in a significant oxidation process of fats, while also in reducing the levels of proteins and carbohydrates. The highest antioxidant activities of ginger powder are obtained by drying in 4 hours at 60ºC -70ºC (Thuy et al., 2018).

2.2.2 Distillation

Among ginger varieties, ginger "Gié" has a relatively high oil content (2.8% - 3.5%), while ginger "Trâu" typically has lower oil content (1.5% - 2.5%). Over 60 components have been identified in Vietnamese ginger essential oil, with the main groups being monoterpenoids (β-phellandrene, (+)-camphene, cineole, geraniol, curcumene, citral, terpineol, borneol) and sesquiterpenoids (α-zingiberene (30%-70%), β-sesquiphellandrene (15%-20%), β-bisabolene (10%-15%), (*E*-*E*)-α-farnesene) (La et al., 2003).

Extraction of ginger oil in Vietnam is commonly carried out by hydro distillation method. Ultrasonic waves, which facilitate the disruption of plant cells and tissues, thereby allowing for easier release of essential oils during subsequent distillation (Yusoff et al., 2022). With the ultrasonic power of 225 W, the distillation time is 180 minutes the highest yield reached 2.19% (Nguyen et al., 2022).

Hydro distillation for ginger oil extraction in Vietnam requires significant water and energy inputs and generates considerable biomass waste, posing environmental concerns that necessitate improved waste management strategies. To address this issue, ginger residues are repurposed as biofertilizers or animal feed, contributing to waste reduction and the promotion of circular agriculture (Nguyen et al., 2022). Additionally, integrating renewable energy sources, such as solar

heating, into the distillation process has the potential to reduce its carbon footprint and enhance sustainability (Yusoff et al., 2022).

Table 2 Vietnam ginger essential oil compositions

No.	Compounds	Composition (%)						
		Vietnam					China (Al-Dhahli et al., 2020)	Chenmai, India (Raina et al., 2005)
		Can Tho (Huệ et al., 2012)	Nghe An (Le, 2018b)	Thua Thien Hue (Le et al., 2018a)	Phu Yen (Nguyen, 2022)	Binh Duong (Nguyen, 2022)		
	α-Pinene	-	-	-	1.52	1.28	2.57	1.9
	Camphene	4.04	12.80	11.52	5.46	3.62	7.26	6.6
	β-Phellandrene	0.16	7.80	-	3.95	-	10.81	4.2
	Pseudolimonen	-	-	12.31	-	-	-	-
	Geraniol	5.28	4.60	-	0.60	3.61	0.61	1.2
	Geranial	-	-	-	6.66	10.83	-	-
	(Z) -Citral	4.84	30.60	0.61	-	-	6.62	5.3
	Borneol	0.79	-	1,52	-	-	2.18	0,1
	Zingiberene	16.75	4.0	32.52	34.54	25.15	17.94	15,2
	β-Sesquiphellandrene	6.26	1.70	11.37	3.95	-	7.69	7,2
	β-Bisabolene	0.30	1.80	5.54	-	-	7.59	-
	Eucalyptol	5.92	-	4.94	3.46	2,78	-	-
	ar-Curcumenen	2.60	1.00	5.61	3.57	3.04	-	5,4
	α -famesene	11.5	-	3.92	-	-	-	-

2.2.3 Extraction

Ginger oleoresin, a significant ginger product, comprises 15%-25% essential oils (e.g., zingiberene, zingiberol, d-β-phellandrene, n-decylaldehyde, n-nonylaldehyde), and 20%-30% pungent compounds featuring the 3-methoxy-4-hydroxyphenyl functional group, whereas the key components included gingerol, shogaol, paradol, zingerone, gingerdione, and gingerdiol groups. Notably, 6-gingerol and 6-shogaol are pivotal pungent compounds responsible for ginger oleoresin's characteristic spiciness, indicative of its quality. Additionally, ginger oleoresin contains colorants, fatty oils, resins, and carbohydrates. Do (2020) published differences in the 6-gingerol content in ginger oleoresin from various provinces and cities in Vietnam. Among them, ginger samples from Kì Sơn, Đà Nẵng had the highest 6-gingerol content, reaching 5.7%, while ginger samples harvested in Hải Dương had the lowest 6-gingerol content at 0.64%. Other ginger samples in the market had 6-gingerol content ranging from 1.13% to 1.98% (Do, 2020).

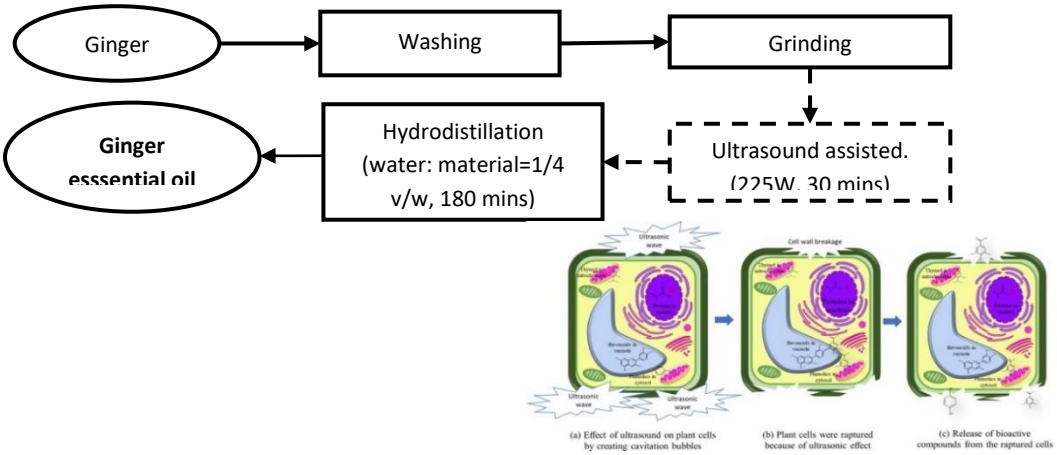

Figure 4 Ultrasound-assisted hydro distillation processing and effects to plant cells

Traditional maceration resulted in a higher yield of 16.36% ginger oleoresin, compared to the non-heating mechanical stirring method (10.97%) and ultrasound-assisted extraction (11.23%), but it required a much longer extraction time of 3 days compared to only 60 - 75 minutes for other methods These traditional methods exhibit specific drawbacks, including lengthy extraction times and low yields (Duc et al., 2015).

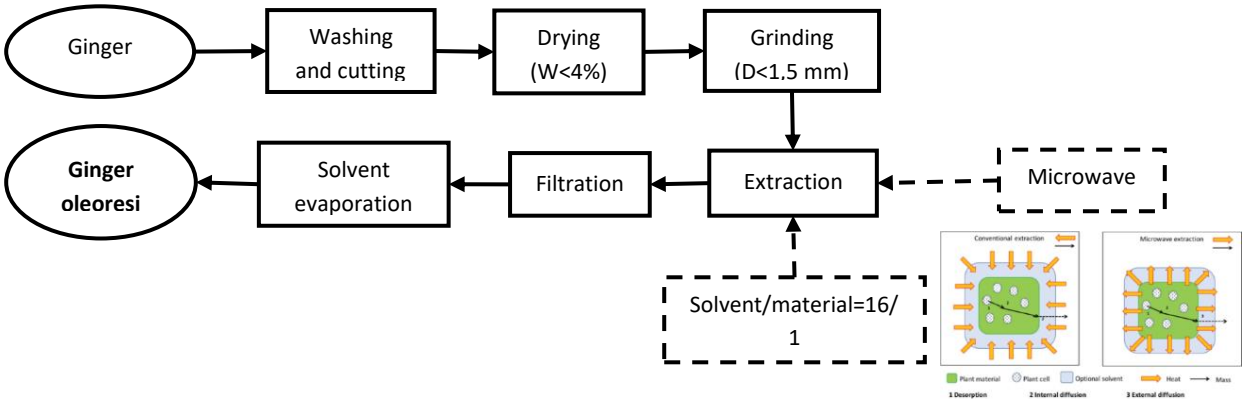

Figure 5 Microwave-assisted ginger extraction

Advanced extraction methods that have been developed are highly efficient, economically viable, environmentally friendly, and aligned with sustainable development goals (Samota et al., 2024). Microwave-assisted extraction (MAE) was employed to optimize ginger oleoresin from fresh ginger (Nguyen et al., 2018, Rosa et al., 2018). Fresh ginger pieces (1-2 mm) were undergoing MAE with a mixture of ethanol and water as solvent. The resulting solution was then filtered to remove solid particles and evaporated in a rotary concentrator. The yield of ginger oleoresin extracted by MAE was 10.2% and higher than maceration extraction (7.5%). Although the yield obtained by Soxhlet extraction methods was 12.5%, it requires longer extraction time and energy consumption. Supercritical fluid extraction (SFE) is an advanced method that preserves the natural flavor and quality of valuable bioactive compounds like gingerol and shogaol. It also offers advantages in transportation costs, preservation, and environmental handling (Samota et al., 2024).

The mentioned above advanced ginger oleoresin extraction methods enhance some aspects of traditional extraction in term of sustainability.

The cost-benefit comparison of MAE, supercritical CO_2 extraction (SCO_2E) and traditional extraction for ginger extraction is presented in the Table 4.

Table 3 Sustainable issues and comparison

Sustainable aspect	Traditional methods (maceration, Soxhlet, mechanical stirring)	Advanced methods (MAE, SFE)
Energy & time efficiency	Maceration requires 3 days; Soxhlet consumes high energy	MAE completes in 60–75 min, reducing energy use (Nguyen et al., 2018)
Yield & resource optimization	Maceration yield: 7.5%; Soxhlet: 12.5%	MAE yield: 10.2%, higher than maceration; uses ethanol-water, reducing solvent waste (Duc et al., 2015)
Environmental impact	Uses large amounts of organic solvents, contributing to pollution	SFE eliminates toxic solvents, preserving bioactive compounds (Nguyen et al., 2018)
Sustainable waste management	Generates significant biomass waste	Residual biomass can be repurposed into biofertilizers or animal feed (Rosa et al., 2018)
Carbon footprint	Higher due to long extraction time and solvent use	Lower due to efficient extraction and reduced solvent consumption (Duc et al., 2015)

Table 4 Cost-benefit comparison of MAE, SCO_2 and traditional extraction

Factor	Microwave-assisted extraction (MAE)	Supercritical CO_2 extraction (SCO_2E)	Traditional solvent extraction
Extraction efficiency	High for phenolic compounds (e.g., gingerol, shogaol (Teng et al., 2019)	Selective for non-polar compounds (e.g., essential oils) (Hu et al., 2011)	Moderate, can extract a wide range of compounds but with impurities (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)
Processing time	Fast (minutes) (Liu et al., 2014)	Moderate (hours) (Hu et al., 2011)	Long (several hours to days) (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)
Solvent use	Requires ethanol/water (environmentally friendly) (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)	CO_2 (green technology, but high pressure required) (Garza-Cadena et al., 2023)	Uses organic solvents (e.g., ethanol, methanol, acetone), possible toxic residues (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)
Cost of equipment	Lower initial cost (~$50,000-$200,000) (Liu et al., 2014)	High cost (~$250,000-$500,000) (Hu et al., 2011)	Low cost (~$5,000-$50,000) (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-

			gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)
Operational cost	Low (energy-efficient) (Teng et al., 2019)	High (CO_2 compression, high pressure maintenance) (Garza-Cadena et al., 2023)	Moderate (solvent cost, evaporation, waste disposal) (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)
Yield & purity	High yield but potential degradation at high temperatures (Liu et al., 2014)	High purity with minimal thermal degradation (Hu et al., 2011)	Lower purity, may require additional purification steps (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)
Scalability	Easily adaptable for industrial use (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)	Requires specialized equipment and process control (Garza-Cadena et al., 2023)	Simple to scale but requires more processing steps (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)
Environmental impact	Uses organic solvents, some residue left (Teng et al., 2019)	Eco-friendly (no solvent waste) (Garza-Cadena et al., 2023)	High solvent waste, potential environmental pollution (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)
Safety	Safe at controlled temperatures (Liu et al., 2014)	Requires high-pressure operation, potential hazards (Hu et al., 2011)	Flammable/toxic solvents require handling precautions (Ministry of Industry and Trade of the Socialist Republic of Vietnam. 2022. Successful production of fermented ginger beer 'Made in Vietnam. Available at: http://moit.gov.vn/khoa-hoc-va-cong-nghe/san-xuat-thanh-cong-bia-gung-len-men-made-in-vietnam-.html. Accessed 4 November 2023. Nagendra Chari et al., 2013)

3 Ginger in food product

Vietnamese ginger is renowned for its exceptional quality, largely due to its tropical climate. Currently, ginger is primarily consumed and sold in its fresh form,

which engenders several challenges on the market due to its limited shelf life, high transportation costs, and considerable seasonal price fluctuations. Farmers frequently encounter a cycle of good harvests paired with low prices. There are instances when traders drive down domestic ginger prices, resulting in substantial losses for producers, leading some to abandon cultivation altogether. To tackle this issue, numerous studies have been conducted on the development of post-harvest processed ginger products, aimed at decreasing the reliance on fresh consumption and gradually stabilizing ginger output. Furthermore, these initiatives represent a dedication to sustainable agriculture and high-quality product development which are critical for enhancing the international reputation of Vietnamese agricultural products (Van, 2024).

3.1 Fermentation product

Lactic fermentation brings many advantages to ginger production, increasing the quality and nutritional value of the product (Ebahbah et al., 2019). Beyond preservation, lactic fermentation imparts a rich and complex flavor profile to ginger, elevating its taste and aroma. This not only enhances the culinary experience but also holds potential health benefits. The proliferation of beneficial bacteria, particularly Lactobacillus, in fermented ginger introduces probiotics, supporting digestive health (Zhang et al., 2023). Two main products of ginger are ginger pickle and ginger probiotic drink.

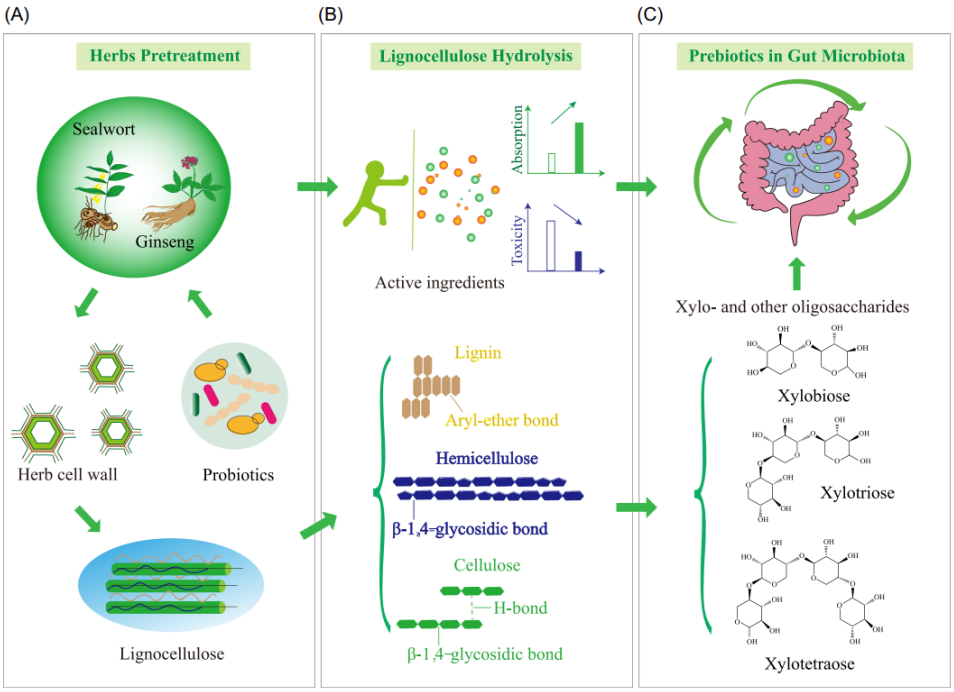

Figure 6 Mechanism of lactic fermentation process (Zhang et al., 2023)

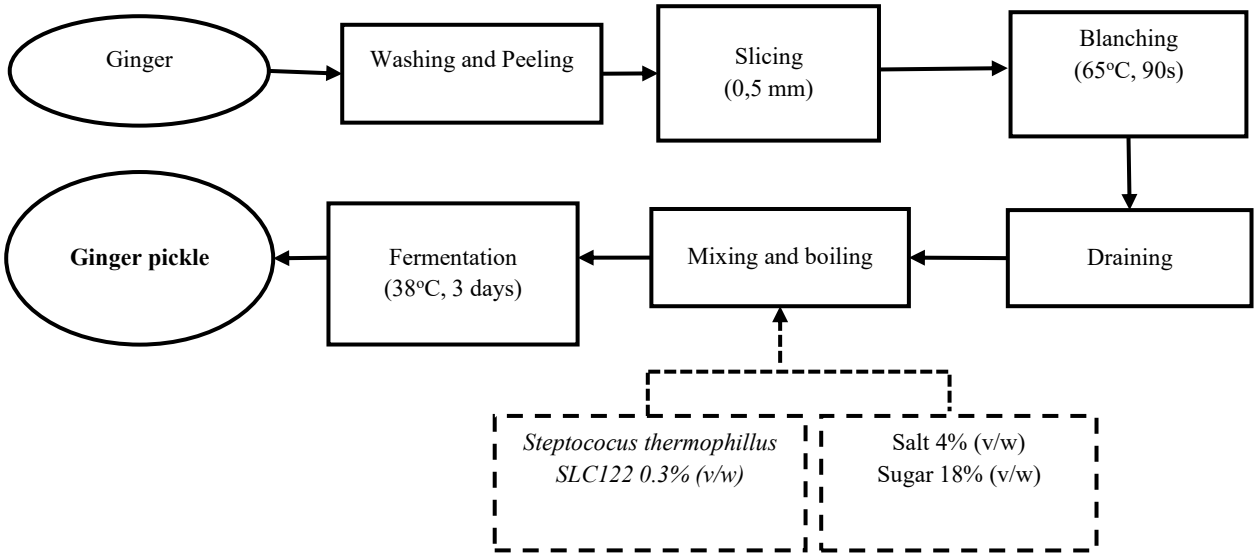

Figure 7 Ginger pickle processing

According to Volza's Vietnam Export data, Vietnam exported 129 shipments of ginger pickle from August 2023 to July 2024, reflecting a growth rate of 158% compared to the previous twelve months. The majority of these exports are sent to Japan, United States, and France (Robinson, 2025).

Steptococus thermophilus are lactic fermentation bacteria, which are commonly found in dairy products, meat, and fermented fruits and vegetables. The utilization of these bacteria in the fermentation process offers the advantage of stabilizing the quality, reducing spoilage rates, and fermentation time in fermented ginger products. Furthermore, their incorporation aids in preserving the original flavors of the ingredients, while also providing support for the digestive process (Nguyen et al., 2020).

3.2 Dried product

There are many dried products available in Vietnam: ginger starch, instant ginger tea (spray drying), ginger tea bag (sublimation drying), and ginger jam.

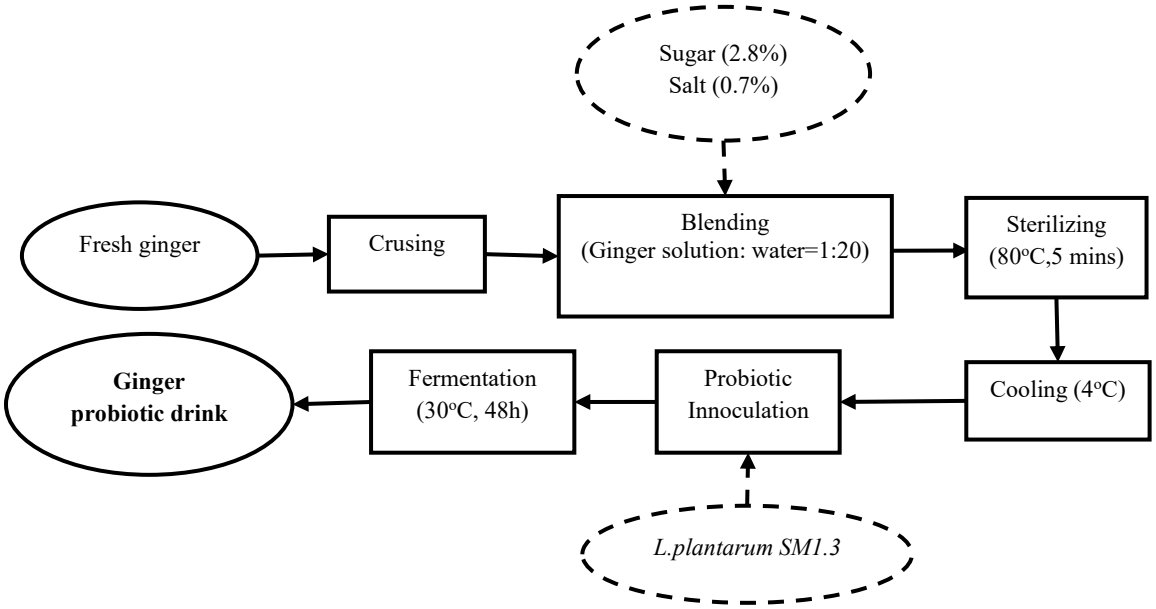

Figure 8 Ginger probiotic drink processing (Vu et al., 2022)

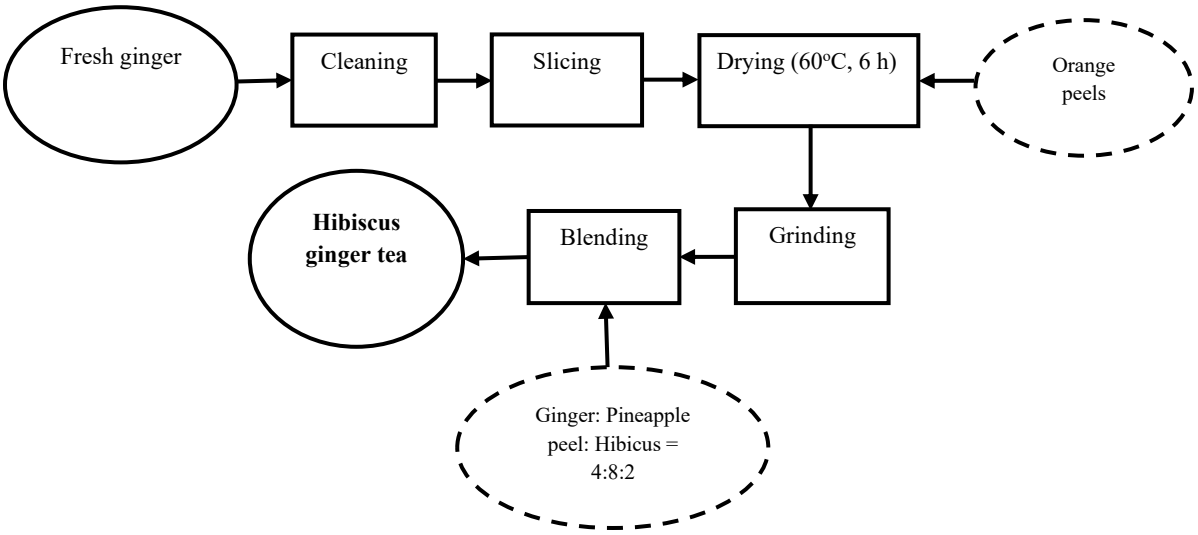

Figure 9 Ginger and hibiscus tea processing (Van et al., 2022)

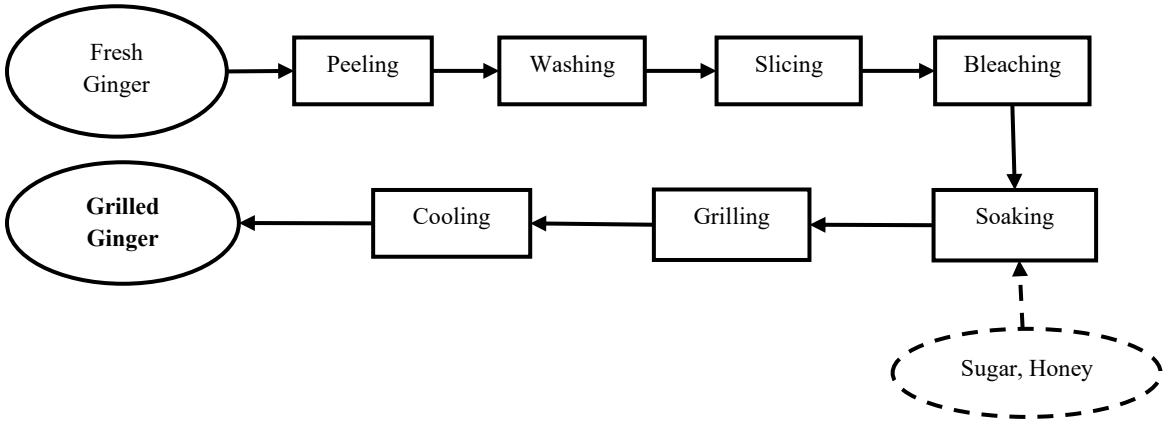

Figure 10 Grilled ginger processing (Le et al., 2022)

3.3 Extraction product

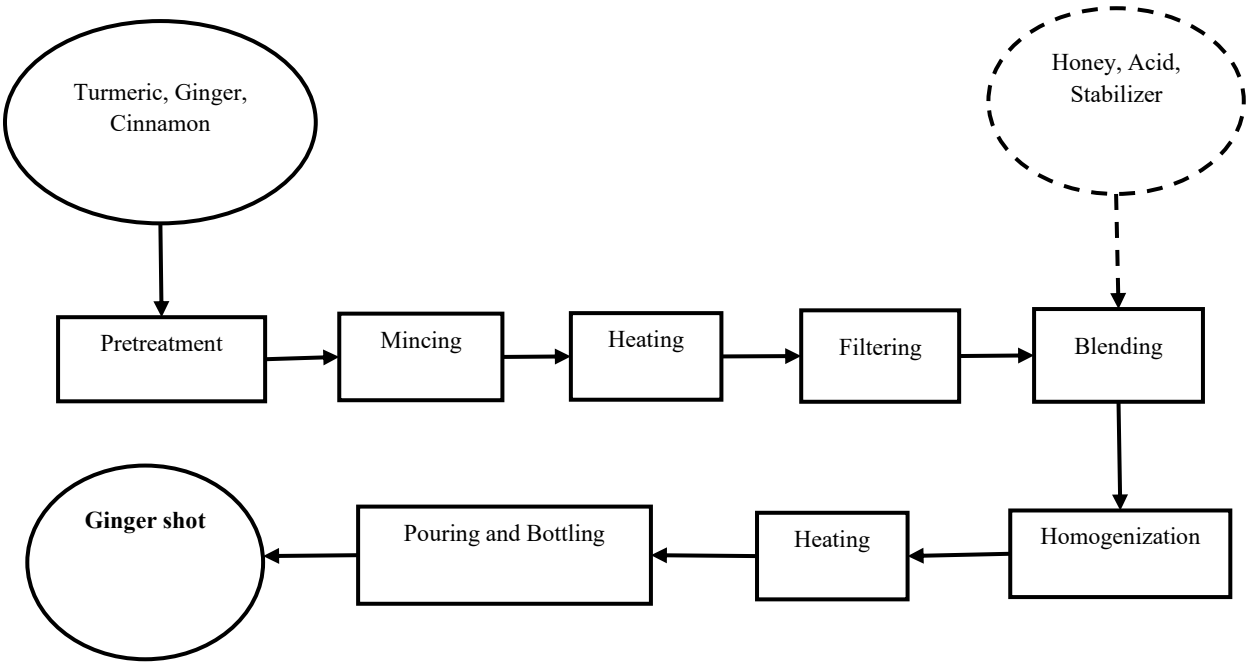

Figure 11 Ginger shot processing (Nguyen et al., 2019)

4 Other applications of ginger products in food industry

4.1 Application of ginger essential oil in food preservation

Besides being used as food flavor, ginger is utilized as a food preservative in Vietnam. Antimicrobial and antioxidative activities of ginger are studied widely to apply in agriculture and food processing.

Ginger oil extracted from *Zingiber officinalis* in Thua Thien Hue by hydro distillation method had a high content of α -zingerberene (Le et al., 2018a) and demonstrated antibacterial activity against *S. aureus* and *B. subtilis,* with a MIC value of 43.8 mg ml^{-1}.

Another research assessed ginger's extracts from Hai Duong, Bac Ninh, Nghe An, Tay Nguyen and Quang Nam (Phan et al., 2016). Antibacterial ability against *Vibrio parahaemolyticus* indicator strains was quite good, the diameter of inhibition zone of the extracts in ethanol/water reached 31 – 35 mm. Mixture of ginger and galangal was studied to preserve White-leg shrimp (*Litopenaeus vannamei*) (Phan and Nguyen, 2019). The optimal mixture consisted of ginger extract in 50% ethanol/water (G50) and galangal extract in 60% ethanol/water (R60), along with 0.5% chitosan and 200 ppm nisin. The wet dipping method using this mixture has extended the preservation time to 10 days at 0°C - 2°C, ensuring good quality and food safety. The evaluated criteria, such as NH3 < 35 mg/100 g and total microbial count < 6.0 log CFU/g, along with sensory assessments related to color, texture, and taste.

For bananas and chilies ginger extract also showed positive result in preserving with antifungal activity against *Colletotrichum musae* and *Colletotrichum gloeosporioides.*

4.2 Application of ginger in food flavoring

In addition to products directly derived from ginger rhizomes, ginger-flavored products using ginger extract and ginger oleoresin are also gaining popularity in Vietnam. These products are favored for their simple, cost-effective production processes, offering consumers unique and novel flavor experiences.

Ginger instant tea is a convenient beverage that captures the distinct taste and potential health benefits of ginger. Typically, it contains dried ginger extracts, sweeteners, and additional spices or tea (Ifood, 2022).

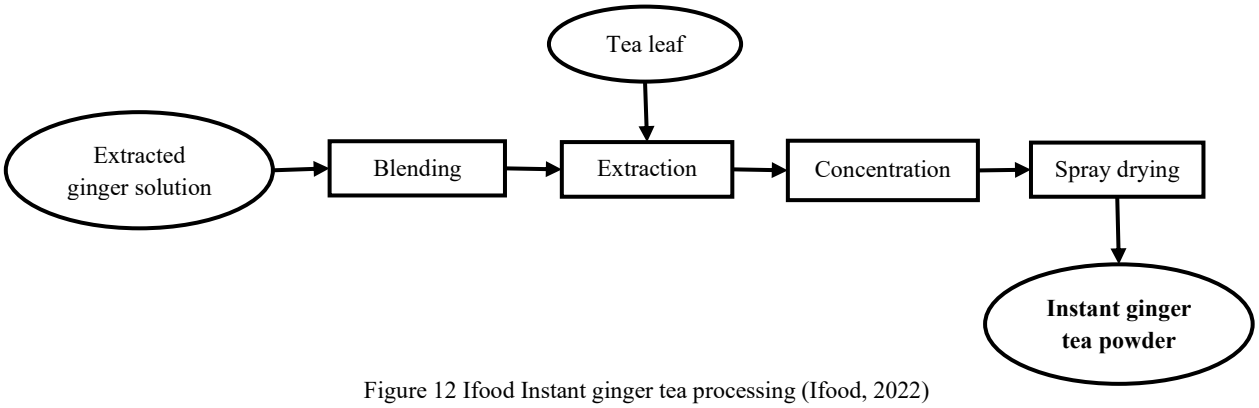

Figure 12 Ifood Instant ginger tea processing (Ifood, 2022)

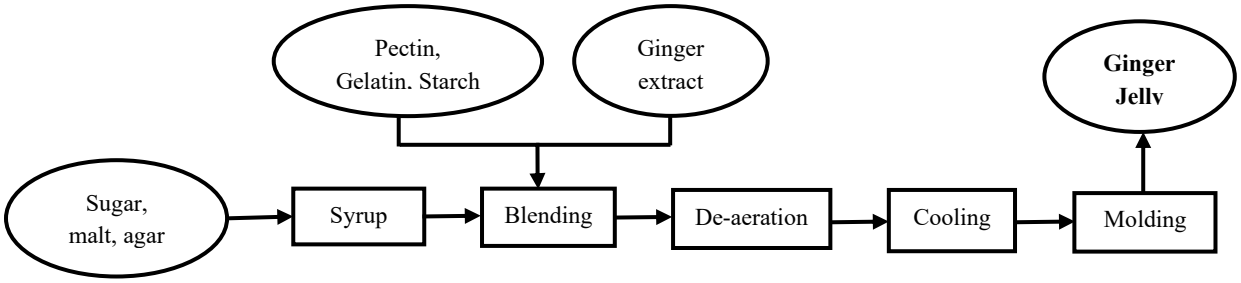

Figure 13 Ginger Jelly processing (Nguyen, 2008)

A ginger beer technology and production equipment model with an optimal capacity of 2000 liters per batch was developed and will be completed in 2022. At the Saigon-Phu Tho Beer Joint Stock Company, the team pilot-produced over 10,000 liters of ginger beer using the established technological process. Ginger beer is bright yellow and tastes like ginger (Ministry of Industry and Trade of the Socialist Republic of Vietnam, 2022). Ginger beer is usually consumed at festivals, parties, or in specialty stores.

4.3 Ginger residue

- For sequential extraction after distillation to recover both 6-gingerol and 6-shogaol

6-Gingerol, the main bioactive compound in fresh ginger (*Zingiber officinale*), is known for its antioxidant, anti-inflammatory, and anticancer properties. Under high temperatures it undergoes dehydration via the aldol reaction mechanism, converting into 6-shogaol, a compound with enhanced bioactivity. Studies suggest that 6-shogaol exhibits stronger anti-inflammatory, neuroprotective, and anticancer effects compared to 6-gingerol (Ali et al., 2008; Dugasani et al., 2010; Zick et al., 2008; Chen et al., 2019).

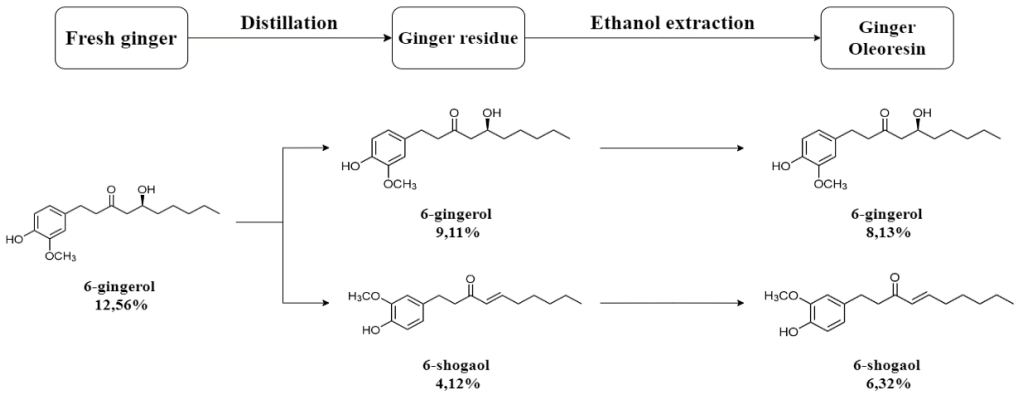

Figure 14 Change of 6-gingerol and 6-shogaol during the sequential extraction from ginger

The ginger residue after distillation is used to extract ginger oleoresin by maceration with 96% ethanol at a solvent/material ratio of 30/1 and extraction time of 21 hours. The ginger oleoresin and 6-gingerol content is determined to be 1.38% and 8.13%, respectively. This process not only saves raw ginger material but also has high applicability, making it easily implementable and scalable to larger scales (Nguyen et al., 2024).

-For starch and mushroom substrate re-placement Starch can also be recovered from ginger residue to reach content up to 31.03%. After extracting the starch, ginger residue is subjected to drying. The additives of urea, phosphate, lime powder, $MgSO_4$, $CaCO_3$ were mixed with the residue to prepare mushroom substrate and then incubated for 30 days to facilitate the absorption of nutrients on the sawdust (Le et al., 2018b).

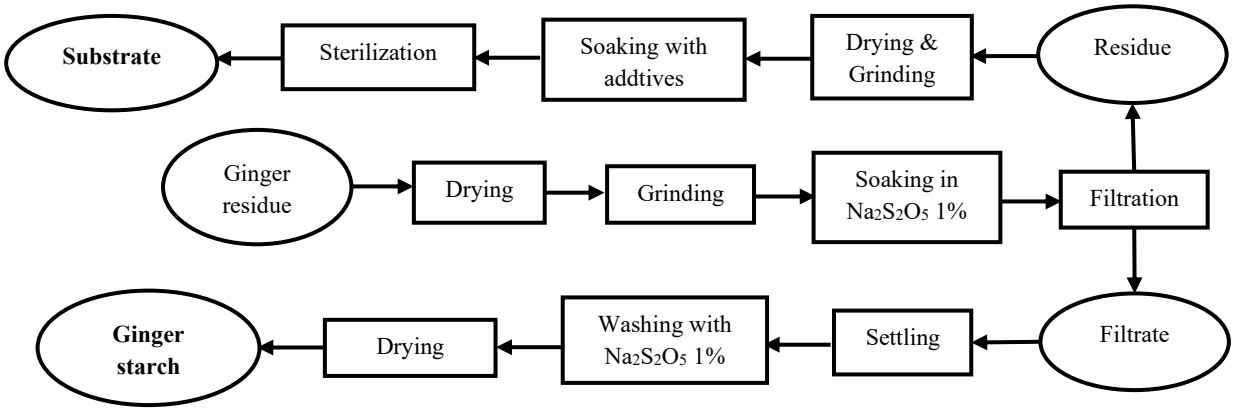

Figure 15 Utilize ginger residue for mushroom substrate replacement, starch

5 Vietnam's ginger processing chain: Challenges and opportunities from farm to market

5.1 Challenges faced by ginger growers in Vietnam

Ginger growers in Vietnam face significant challenges that impact their productivity and profitability. Limited market access forces farmers to rely on intermediaries, leading to lower prices, while poor marketing infrastructure and high distribution costs, particularly in the Central Highlands and Northern regions, further reduce earnings (Tran, 2025). Infrastructural limitations, such as poor road access, increase transportation costs and post-harvest losses, and the lack of modern storage and processing facilities prevents farmers from engaging in value-added production (Doan, 2023; Tuyet, 2021). Additionally, technological barriers, including limited access to advanced agricultural techniques and pest-resistant varieties, contribute to low yields. Many farmers depend on traditional methods due to insufficient training and financial constraints, restricting their ability to invest in improved farming practices. Addressing these issues through policy reforms, infrastructure investments, and enhanced access to modern agricultural technology is essential to strengthening Vietnam’s ginger industry and improving the livelihoods of farmers (Borbaruah and Barman, 2023a, 2023b).

5.2 Vietnam's ginger market and trade

Vietnam has emerged as a competitive player in the global ginger market, producing approximately 250,000 metric tons in 2023 (Vietnam Ministry of Agriculture & Rural Development, 2023). Despite lower production than China (2.5 million metric tons) and India (1.8 million metric tons), Vietnam’s emphasis on quality, cost efficiency, and adherence to food safety standards has driven a 30% annual export growth (Food and Agriculture Organization 2023). Major shipments are directed to China (50%), India (15%), the Middle East (10%), and Western markets such as Europe and

Australia (10%) (Vietnam Customs, 2023). With export prices ranging from $0.40 to $0.80 per kg—lower than Chinese ($0.70–$1.20) and Indian ($0.50–$1.00) ginger—Vietnam benefits from cost-effective production while maintaining strong demand in organic and premium markets (World Integrated Trade Solution. 2022 Spices: ginger exports by country 2019. Available at: https://wits.worldbank.org/trade/comtrade/en/country/All/year/2019/tradeflow/Exports/partner/WLD/product/091010. Accessed 4 November 2023.

World Trade Organization, 2023). Its ginger is highly valued for its aroma, pungency, and low pesticide residue, making it a preferred choice in the EU, USA, and Australia due to stringent food safety regulations (European Food Safety Authority , 2023). Brief comparison is presented in Table 4.

Table 5 Market comparison

Factor	Vietnam	China	India
Production volume (2023)	250,000 MT	2,500,000 MT	1,800,000 MT
Export volume (2023)	120,000 MT	1,200,000 MT	650,000 MT
Export value (2023)	$49.3 million	$2.1 billion	$840 million
Average export price per kg	$0.40 - $0.80	$0.70 - $1.20	$0.50 - $1.00
Key export markets	China, India, Middle East, EU, Australia…	USA, EU, Middle East, Japan…	Middle East, Bangladesh, Malaysia, UK…

5.3 Global contextualization and recommendation

Ginger has become a significant player in the global spice market, driven by increasing consumer demand, international trade, and advancements in agricultural practices. As of 2021, the global ginger market was valued at approximately $4.2 billion, and it is projected to reach around $5.9 billion by 2028, growing at a compound annual growth rate (CAGR) of about 5.8%. The largest producers of ginger include India, China, Nigeria, and Indonesia, with India alone contributing around 33% of the total global production (The Science Agriculture. , 2024).

Globalization has facilitated the integration of ginger into various international markets, enhancing trade opportunities. The growing trend towards organic foods has led to an increase in organic ginger cultivation, with areas under organic ginger cultivation in India expanding to around 4,500 hectares as of 2021 (The Science Agriculture. , 2024).

Advancements in agricultural technology, such as precision farming and biotechnology, have allowed producers to enhance yield and quality. For example, genetic improvements and integrated pest management strategies have led to higher disease resistance in ginger crops, ensuring consistent production despite environmental challenges. Additionally, the rise of e-commerce has further globalized ginger distribution, allowing smaller producers to reach international consumers directly. Overall, the globalization of ginger production reflects a complex interplay of market dynamics, agricultural innovation, and consumer preferences for health-oriented products. This interconnectedness not only boosts economic opportunities for farmers but also highlights the importance of sustainable practices to meet the global demand for ginger while minimizing environmental impacts.

As the demand for ginger continues to grow domestically and internationally due to its varied uses, agricultural innovations and product diversification have become crucial for maintaining competitiveness in the market in the context of globalization (**错误!未找到引用源。**, 2024a, 2024b).

1) Precision farming: The integration of sensors, drones, and satellite imagery allows farmers to gather real-time data on soil moisture, nutrient levels, and plant health. This information helps in making informed decisions on irrigation, fertilization, and pest

management, ultimately leading to higher yields and better-quality ginger.

2) Tissue culture: This technique enhances the propagation of disease-free ginger plants, ensuring a healthy crop and increasing production capacity in a shorter time frame.

3) Genetic improvement: Breeding programs focusing on disease resistance, higher yields, and improved quality are essential in developing new ginger varieties that can thrive in varying climatic conditions.

4) Sustainable practices: Emphasizing organic cultivation not only addresses consumer preferences for natural products but also promotes soil health and biodiversity.

5) Value-added products: The global demand for ginger essential oil and extracts in the food, pharmaceutical, and cosmetics industries is growing, leading to opportunities for value addition. Moreover, ginger powder and dried products enhance shelf-life and opens marketing opportunities in both domestic and export markets.

6 Conclusion

Ginger is a traditional Vietnamese crop suitable for tropical climate and soil conditions. Growing ginger is quite easy, does not require much care like other vegetable crops and has few pests, helping Vietnamese farming households to develop economically from ginger. Vietnam aims to develop its pharmaceutical economy and master plan for pharmaceutical development to 2030 of the Prime Minister has emphasized, with the orientation of prioritizing the development of Vietnam's medicinal plants, of which ginger is one of them, therefore the ginger plant, the ginger production, and application process are increasingly receiving attention.

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