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Review

The *Capsicum* industry in China: development and impact

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A B S T R A C T

Since its introduction to China in the late 16th century, *Capsicum* has transitioned from an exotic crop into a cornerstone of Chinese agriculture. This review examines the industry's historical dissemination and current landscape, which now spans over 2.25 million hectares and yields exceeding 64 million tons annually. This scale supports a vertically integrated value chain, ranging from germplasm breeding and regionalized cultivation to extensive primary and advanced processing. Furthermore, we analyze cultivation practices, consumption dynamics and socioeconomic implications, while offering a strategic outlook on the industry's global competitiveness. These findings highlight the integral role of *Capsicum* in shaping China's culinary traditions and its significance as a pivotal component of the national agricultural economy.

Keywords: *Capsicum*; China; Cultivation; Consumption; *Capsicum* industry

1. Introduction

Capsicum (Solanaceae), a genus originating in Central and South America, has been under continuous cultivation for more than 6000 years (Perry et al., 2007; Kraft et al., 2014; Qin et al., 2014; Chiou et al., 2024; Lentz and Pohl, 2025). Following its introduction to Europe by Columbus in 1493, it was disseminated across Asia, Africa, and Oceania through Portuguese trade networks (Major, 2012; Tripodi et al., 2021). In China, the earliest record of *Capsicum* dates to 1591, suggesting an introduction via maritime routes to Zhejiang province during the late 16th century (Zhang et al., 2016; Cao, 2019, 2022; Guo et al., 2023). Initially, these plants were valued primarily as ornamental plants rather than food source (Zheng, 2006). The integration of *Capsicum* into Chinese cuisine was a gradual process, culminating in widespread culinary adoption over the last 300 years and significant industrial expansion within the past two centuries (Deng et al., 2024; Yan et al., 2025).

Despite a relatively recent global dispersal spanning approximately five centuries, *Capsicum* peppers have achieved universal

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appeal due to their distinct phenotypic traits, including vibrant pigmentation, morphological diversity, and characteristic pungency derived from capsaicinoids (Kim et al., 2014; Zhu et al., 2019; Wu et al., 2023; Chen et al., 2024b; Lee et al., 2024; von Steimker et al., 2024; Ahmed et al., 2025; Du et al., 2025; Jiang et al., 2025; Mao et al., 2025; Wang et al., 2025a, 2025c). These attributes have necessitated extensive cultivation across the Americas, Africa, the Mediterranean, and Asia, serving a consumer base comprising roughly one-quarter of the world's population (Murillo-Amador et al., 2015; Parvez, 2017; Barboza et al., 2022). Furthermore, the escalating demand for spicy food, natural colorants, and capsaicin-derived pharmaceutical and industrial products continues to boost a worldwide production (Baenas et al., 2019; Naves et al., 2019; Bal et al., 2022; Wang et al., 2022; Rezazadeh et al., 2023; Zukowska et al., 2025).

China currently occupies a preeminent position in the global *Capsicum* market. Recent data from the Food and Agriculture Organization (FAO) indicate that worldwide production of chilies and peppers exceeded 44 million metric tons in 2023, with China contributing over 39% of this global total (FAOSTAT, 2025). Given this dominance, this review aims to systematically examine the developmental trajectory and contemporary landscape of China's *Capsicum* industry.

2. The development of the *Capsicum* industry in China

The dissemination of *Capsicum* in China, following its initial recorded appearance in 1591, was characterized by a prolonged period of expansion. Historical analysis of local chronicles indicates that it took over a century for the crop to appear in scattered records across Shandong, Liaoning, Hunan, and Hebei by the late 17th century (Jiang and Wang, 2005). Prior to the 18th century, the adoption of *Capsicum* remained limited, serving primarily as a substitute for traditional indigenous spices such as Sichuan pepper (*Zanthoxylum bungeanum*) in the north and black pepper (*Piper nigrum* L.) in the south (Zou and Zhu, 2020). However, the 18th century marked a pivotal turning point, catalyzed by the discovery of the crop's unique pharmacological attributes. Beyond enhancing flavor, *Capsicum* was assimilated into local practices for its use in removing dampness, dispelling cold, and alleviating depressive moods (Koenig et al., 1986; Bach and Yaksh, 1995; Ludy and Mattes, 2011; Srinivasan, 2016; Varghese et al., 2017; Crapnell and Banks, 2021; Hao et al., 2021; Chen et al., 2024a; Wang et al., 2024b; Faisal and Mustafa, 2025b). Consequently, the crop was rapidly embraced in humid regions such as Hunan, Guizhou, and Sichuan, spreading to adjacent provinces and transitioning from an ornamental novelty to an essential seasoning crop (Jiang and Wang, 2005; Ding and Hu, 2015).

By the 19th century, *Capsicum* had achieved comprehensive culinary integration. Processing techniques emerged during the Jiaqing reign, and by the late Qing Dynasty, the pepper had solidified its status as a primary condiment in Hunan and Sichuan cuisines (Lan, 2000; Ding and Hu, 2015). This three-century process of adoption culminated in the stratification of Chinese cuisine into distinct spiciness zones by the late 19th century. These zones included a high-intensity spice belt in the middle and upper Yangtze River basin (e.g., Hunan, Guizhou, Sichuan); a moderate-intensity zone extending towards the Korean Peninsula (e.g., Beijing, Shanxi, Ningxia, and Qinghai); and a low-intensity zone along the southeastern coast (e.g., Jiangsu, Shanghai, Zhejiang, Fujian, and Guangdong) (Lan, 2001; Lin et al., 2023).

Following this culinary establishment, the early 20th century witnessed a shift from local product to bulk commodity, driven by the development of domestic trade networks (Zhou et al., 2022). This led to the expansion of its cultivation into regions where it was not traditionally consumed, most notably North China. For instance, a chronicle from Shanxi province reported over 1260 ha dedicated to *Capsicum* cultivation, yielding more than 3 million kilograms (Zou et al., 2020). Despite the expansion, national production remained relatively low during this period, with estimated average yields between 2000–2500 kg · hm^{-2} (Table 1).

The *Capsicum* industry underwent a period of substantial development following the establishment of the People's Republic of China. By the 1950s, *Capsicum* had become an important agricultural export, prompting the establishment of production bases in northern and northwestern provinces, including Shandong, Hebei, Shanxi, Inner Mongolia, and Shaanxi. These bases played a crucial role in economic development and propelled the expansion of the national *Capsicum* industry. Between the 1960s and 1980s, commercial production became organized into renowned hubs, such as Chengdu, Wangdu, Yidu, and Jize, each noted for unique product features (Zou et al., 2020).

A period of explosive growth commenced in the mid-1980s and accelerated through the 1990s, expanding from under 200 000 ha to over 500 000 ha by 2000 – a nearly threefold increase compared to the 1960s average (Fig. 1, A). FAO statistics for 2000 indicated a total production of 9 648 452 tons with a yield of 24 809.3 kg · hm^{-2}, representing 41.3% of the global *Capsicum* output (FAOSTAT, 2025). However, official statistics from China's Ministry of Agriculture and Rural Affairs reported considerably higher figures. By 2000, the Ministry indicated a cultivation area exceeding 1.33 million hectares, a figure that ranked second only to Chinese cabbage and constituted 7.4% of the national's total vegetable planting area (Zou et al., 2020). During this period, total production reached 28 million tons with an average yield of 21 000 kg · hm^{-2}, generating a total industry value of 80 billion yuan and contributing 16.67% of China's total vegetable industry value (Zou et al., 2020).

This modern industrial expansion was underpinned by macroeconomic growth, enhanced transportation infrastructure, and a strategic optimization of production regions

Table 1 Historical *Capsicum* production in Shandong, Hebei, Anhui and Zhejiang (1932)

Province	Area planted (hm^2)	Production quantity (kg)	Yield (kg · hm^{-2})
Shandong	168.4	494 465	2936.2
Hebei	485.3	364 250	750.5
Anhui	533.3	1 606 500	3012.3
Zhejiang	715.0	1 720 700	2406.5

Note: Data source: Shanxi general chronicles (in Chinese) (Compilation Committee of Local Chronicles of Shanxi Province, 1994).

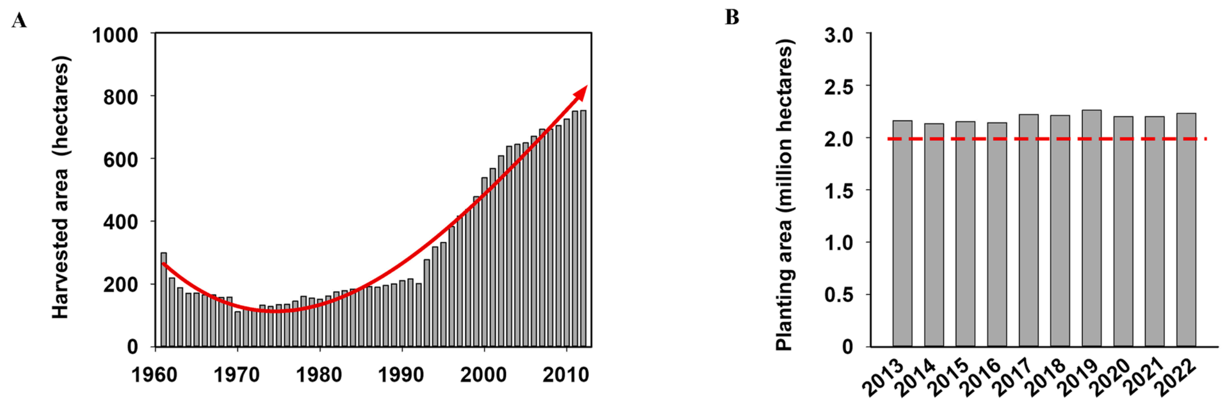

Fig. 1 Changes in *Capsicum* cultivation area in China

A. Harvested area from the 1960s–2010s. B. Planting area from 2013 to 2022.

(Zou et al., 2025). This transition alleviated chronic undersupply, achieving market balance or even oversupply. Furthermore, critical advancements in cultivation science were crucial for extending the supply window (Song et al., 2020; Li et al., 2022; Yang and Zou, 2024). For instance, refined cultivation methods in the middle and lower reaches of the Yangtze River enabled a prolonged supply period stretching from early spring to late autumn (Zou et al., 2020). The adoption of diverse cultivation models, such as protected cultivation, combined with the use of light and heat resources in tropical regions during winter, facilitated year-round production (Nieto-Garibay et al., 2022; Manjunatha et al., 2023; Hossain et al., 2025). Collectively, these technological and logistical innovations successfully alleviated chronic seasonal shortages, enabling a consistent, year-round nationwide supply of fresh *Capsicum* fruits.

3. Status of the *Capsicum* industry in China

3.1. *Industry scale and cultivation trends*

The 21st century has marked a period of significant expansion for the *Capsicum* industry in China. Since 2013, the national cultivation area has stabilized at over two million hectares annually (Fig. 1, B), establishing *Capsicum* as the country's largest vegetable crop by acreage (Zou et al., 2020; Qiao et al., 2023). This extensive cultivation supports an annual production volume exceeding 64 million tons, with average yields approaching 30 000 kg · hm^{-2} (Qiao et al., 2023). Economically, the primary agricultural output of this sector is valued at approximately 250 billion yuan. The crop's significance is further underscored by its contribution to the nation vegetable sector, accounting for 9.28% of total cultivation area, 7.76% of total production volume, and 11.36% of the total output value (Zou et al., 2020).

Production is increasingly spatially concentrated, as twelve provinces now maintain cultivation areas exceeding 66 700 ha (1 million mu). Guizhou and Henan have emerged as the primary production hubs, followed closely by Yunnan, Shandong and Jiangsu (Zhao et al., 2020; Zou et al., 2020, 2025). This geographical spread is underpinned by technological advancements in protected cultivation, which have enhanced cultivation standards and expanded the production footprint across the entire country, spanning from Hainan in the south to Heilongjiang in the north. In terms of germplasm, the industry is overwhelmingly dominated by *Capsicum annuum* cultivars, which constitutes over 95% of total production (Zhang et al., 2016; Guo et al., 2023). While other species, such as *Capsicum frutescens* and *Capsicum chinense* are cultivated on a limited scale in southern regions like Hainan, Yunnan, and Sichuan, species such as *Capsicum baccatum* and *Capsicum pubescens* remain rare in Chinese commercial production (Deng et al., 2009; Zhang et al., 2016; Wang et al., 2024a; Wu et al., 2024a, 2024b).

3.2. *Economic segmentation and the value chain*

The Chinese *Capsicum* industry operates within a highly integrated value chain that encompasses seed and seedling production, cultivation, processing, and related tertiary sectors such as catering and tourism (Zhao et al., 2020). The foundation of this chain is the seed and seedling sector (Cvetković et al., 2022; Lozada et al., 2022; Jankauskienė and Laužikė, 2023; Dobón-Suárez et al., 2025). The annual market demand for *Capsicum* seeds is valued between 8 and 10 billion Yuan, with seed costs varying significantly - ranging from 3000–4500 Yuan · hm^{-2} for domestic cultivars to 22 500–30 000 Yuan · hm^{-2} for imported ones. The seedling market is even more substantial, with an estimated value of 16 to 25 billion yuan, based on average costs of 7500–12 000 Yuan · hm^{-2}. Consequently, the aggregated annual value of the upstream seed and seedling sector is estimated at 24 to 35 billion yuan. Following this is the cultivation sector, which generates an estimated market value of 120 to 130 billion yuan annually, driven by the consistent producing of over 64 million tons of fresh peppers (Zou and Zou, 2021).

Beyond primary agricultural output, the processing and tertiary sectors add significant economic value. The processing sector is stratified into three categories: primary processing, which includes products such as chopped chili, chili sauce, and pickled chili, accounting for a market share exceeding 40 billion yuan (Zhao et al., 2020); secondary processing, focusing on chili-flavored snack foods with an annual value of over 1 billion yuan (Zhao et al., 2020); and advanced processing, which yields high-value bioactive extracts like capsaicin and capsanthin for pharmaceutical and industrial applications, creating a multi-billion yuan market (Sharma et al., 2013; Arimboor et al., 2015; Kennedy et al., 2021; Tang et al., 2024; Wang et al., 2025b). Finally, the tertiary sector leverages the cultural significance of the crop. Specialized tourism, including 'chili towns' and agricultural parks, generates an estimated 20 to 30 billion yuan. Furthermore, *Capsicum* serves as an indispensable ingredient in high-value reginal cuisines, particularly those of Hunan and Sichuan. These regional food industries boast annual output values exceeding 100 billion yuan respectively (Zhao et al., 2020), highlighting the profound indirect economic impact of the *Capsicum* industry on the broader Chinese economy.

4. Practices of *Capsicum* cultivation in China

4.1. *Suitable cultivation areas for cultivated pepper*

Temperature serve as the primary limiting factor for *Capsicum* cultivation, dictating the crop's physiological performance and geographical suitability (Khaitov, 2019; Xu et al., 2021; Mou et al., 2024; Zhang et al., 2024a; Bulle et al., 2025; Jang et al., 2025). Optimal vegetative growth occurs between 20 °C and 30 °C, with a narrower thermal window of 20 °C–25 °C required for robust flowering and fruit set (Zou, 2009; Zhang et al., 2024b). Physiological activity typically ceases below 15 °C, and temperatures below 0 °C are lethal (Zou, 2009; Zhang et al., 2024b). Beyond basic survival, thermal conditions profoundly influence fruit quality (Arce-Rodríguez and Ochoa-Alejo, 2019); higher temperatures during seed maturation correlate with capsaicin content (Lee et al., 2001; Murakami et al., 2006; Kim et al., 2009; Antonio et al., 2018), while substantial diurnal temperature variations during ripening enhance capsanthin accumulation (Zou, 2009). These agro-climatic requirements drive the regional suitability of production across China. Although southern regions-such as the Yangtze River basin, South China, and Southwest China-are capable of cultivating *Capsicum*, their high humidity and sustained heat often exacerbate pest and disease pressure, thereby compromising yield and quality (Velásquez et al., 2018; Yang et al., 2022; Yang et al., 2023). Conversely, the drier, more temperate climates of North, Northwest, and Northeast China provide more superior phytosanitary conditions (Gong et al., 2022), resulting in lower disease prevalence and higher-quality produce. Consequently, these northern territories, alongside the vast Southwest region (Wang et al., 2018), have emerged as the nation's primary cultivation zones (Zou et al., 2020), while the tropical climates of Hainan and Yunnan offer unique comparative advantage for off-season winter production (Hou and Wang, 2024).

4.2. *Geographic distribution of production and yield*

Rencent data reveals a distinct spatial concentration in the industry's production capacity. The North, Northwest, and Northeast regions collectively dominate the sector, accounting for over 33% of the national cultivation area and nearly 48% of total production. The Southwest region-encompassing Yunnan, Guizhou, Sichuan, and Chongqing-represents a significant secondary hub, comprising 29.7% of the cultivation area (659 187 hm^2) and 19% of total production. The remaining 36% of acreage and 32% of production are distributed across the Central-South, East, and South China regions (Table 2). Notably, productivity exhibits marked regional heterogeneity. The Northeast region achieves the highest efficiency with yields reaching 88 $t \cdot hm^{-2}$, attributed to favorable climatic conditions and specialized cultivation practices. The Northwest, Northeast and East China regions maintain moderate yields exceeding 30 $t \cdot hm^{-2}$. In contrast, the Southwest region records lower average yields, while the Central-South and South China regions demonstrate the lowest productivity, averaging only 9 $t \cdot hm^{-2}$ (Table 2).

4.3. *Cultivation systems and regional specialization*

To accommodate these diverse climatic conditions and market needs, China employs a multifaceted portfolio of cultivation systems (Ampim et al., 2022; Li et al., 2022; Zhou et al., 2022). Open-field cultivation remains the dominant practice, occupying 74% of the total acreage, while protected cultivation systems-comprising plastic walk-in tunnels (17%), insulated greenhouses (4%), and low tunnels (4%)-account for the remaining 26% (Zou et al., 2020; Qiao et al., 2023). The deployment of these systems is highly region-specific. Open-field cultivation is most prevalent in the Southwest, which holds 37% of the national open-field area and serves as the primary supplier of peppers for drying and processing industries (Zhao et al., 2020; Qiao et al., 2023). Conversely, protected structures are strategic assets in other regions. Insulated greenhouses are heavily concentrated in North China, representing 53% of the national total for this category. These facilities are essential for overwinter production, protecting crops from cold stress to ensure a supply of fresh *Capsicum* during winter months. Meanwhile, tunnel systems are predominant in East China and the Central-South region. These structures are utilized primarily for early-season fresh markets,

Table 2 Analysis of *Capsicum* cultivation area, yield, and consumption in China

Region	Province	Cultivation area ($\times 10^4$ hm^2)	Production quantity ($\times 10^4$ t)	Consumption ($\times 10^4$ t)
Northeast	Heilongjiang, Jilin, Liaoning	7.3	652.1	493.1
North China	Hebei, Shandong, Inner Mongolia, Shanxi, Beijing, Tianjin, Henan	50.8	1914.4	431.1
East China	Jiangsu, Anhui, Shanghai, Zhejiang, Fujian	28.0	925.9	406.4
Central-south	Hubei, Hunan, Jiangxi	29.2	692.4	1560.4
South China	Guangdong, Guangxi, Hainan	23.3	476.6	426.7
Southwest	Yunnan, Guizhou, Sichuan, Chongqing	65.9	1232.7	1382.6
Northwest	Shaanxi, Gansu, Ningxia, Xinjiang, Qinghai, Tibet	16.6	505.3	421.0

Note: Data source: research report on the development of *Capsicum* industry in China (Zhao et al., 2020).

protecting crops from adverse weather and pests to guarantee stable supply chains (Li et al., 2022).

5. Regional consumption patterns of *Capsicum* in China

5.1. *Regional disparities and consumption zones*

The consumption of *Capsicum* in China exhibits marked regional disparities, characterized by a distinct concentration along the upper and middle reaches of the Yangtze River (Zou and Zou, 2021). Approximately 30% of peppers is consumed in the Central China region, while nearly 27% is consumed in the Southwest region. Collectively, these two regions account for 57% of the national total (Table 2). In contrast, the Northeast contributes 10%, while the North, East, South, and Northwest regions each account for roughly 8% (Table 2). These quantitative differences are further explained by variations in variety preference, culinary application, and the influence of population mobility. In Northeast and North China, consumption is dominated by non-pungent or mildly pungent varieties, such as bell peppers and cowhorn peppers. Conversely, in the Northwest, preferences lean toward moderately pungent varieties like cowhorn and screw peppers, with lower-pungency dried peppers favored in parts of Shaanxi and Gansu (Zhao et al., 2020). In East and South China, coastal regions traditionally associated with non-spicy cuisines, consumption patterns have been significantly influenced by the influx of migrant workers from high-consumption inland regions (Ma and Chen, 2006; Keung Wong et al., 2007). While indigenous populations generally retain a preference for milder varieties, this demographic shift has become a primary driver of rising local demand for pungent peppers. Furthermore, consumption patterns remain heterogeneous even at the intra-provincial level. For instance, while Fujian province generally favors milder flavors, the city of Sanming, bordering Jiangxi, extensively incorporates spicy varieties into its cuisine. Similarly, in Guangdong, residents of Nanxiong demonstrate a unique preference for highly pungent dishes, diverging from the region's typically non-spicy Cantonese cuisine (Lin and Paul, 2022).

5.2. *Culinary application in primary consumption hubs*

Within the two dominant consumption centers, Central and Southwest China, culinary applications of *Capsicum* diverge fundamentally. In Central China, exemplified by Hunan cuisine, fresh *Capsicum* is utilized predominantly as a primary vegetable ingredient rather than merely a seasoning. Although historically reliant on dried peppers, modern cultivation techniques now allow Hunan cuisine to overwhelmingly favor fresh peppers due to the year-round availability, leading to the proliferation of dishes where the pepper is the central component, such as chopped chili condiments, and stir-fried pork with chili (Li et al., 2024). In contrast, the culinary traditions of Southwest China rely heavily on dried *Capsicum* as a core seasoning agent (Zhou and Liu, 2024). In Sichuan cuisine, dried peppers are used abundantly to create its signature pungent flavor profile, often paired with Sichuan pepper to produce a distinctive 'numbing-spicy' sensation (Zhang et al., 2021), as seen in iconic dishes like spicy chicken and Sichuan hot pot (Wang et al., 2023). In neighboring Guizhou, the flavor profile is distinguished by a unique blend of sour and spicy notes (Li et al., 2019), further highlighting the diversity of applications within the Yangtze belt.

5.3. *Contemporary trends and industrial implications*

A comparative analysis of China's *Capsicum* industry reveals a significant spatial divergence. The primary production bases are concentrated in the north, while major consumption centers are located in the Central and Southwest regions. This geographical separation underscores the complexity of consumption trends. In recent decades, three pivotal trends have reshaped this landscape.

First, *Capsicum* consumption has transitioned from being localized to one of nationwide prevalence. Since 2000, large-scale internal migration has facilitated the diffusion of spicy culinary traditions beyond their historical holds in Central and Southwest China (Ma and Chen, 2006). Migrant populations have introduced these habits to developed coastal areas, promoting broader acceptance and integrating spicy foods into the national culinary mainstream (Zou et al., 2025). Second, overall consumption volume has surged, driven by urbanization and physiological factors. The fast-paced urban lifestyle has increased reliance on pre-packaged meals where *Capsicum* is frequently used for flavor enhancement. Additionally, capsaicin stimulates the production of endorphin (Koenig et al., 1986; Bach and Yaksh, 1995), creating a pleasurable sensation that reinforces habitual consumption (Byrnes and Hayes, 2016; Siebert et al., 2022).

Third, the industry has undergone rapid industrialization, with processed products now utilizing approximately 50% of the total cultivation area. Traditional artisanal products, such as chopped chili, fried chili in oil, and blanched chili pepper, are now manufactured at an industrial scale (Zou et al., 2022), fostering the emerge of regional processing clusters. Prominent enterprises include Laoganma in Guizhou (fried chili in oil), Junjie and Lameizi in Hunan (chopped chili), and various producers of spicy bean paste in Sichuan (Zou et al., 2020; Lin et al., 2023). Concurrently, the high-value extraction has become a critical sub-sector. Enterprises like Chen Guang Biotechnology Group in Hebei now control over 80% of the market share for extracts such as capsanthin (Zhao et al., 2020). These evolving demand dynamics are restructuring the agricultural foundation of the industry. To meet the specific needs of the processing sector, cultivation-particularly for dried peppers, is strategically shifting toward advantageous production zones in the northwest (Zou et al., 2025). Furthermore, as the sector transitions from smallholder farming to large-scale cultivation, producers faces dual pressures to increase yields and reduce labor costs, thereby accelerating the adoption of mechanization (Zou et al., 2025). Collectively, these shifts are propelling China's *Capsicum* industry toward a more sustainable, efficient and industrialized future.

6. Socioeconomic impacts of *Capsicum* in China

The introduction and subsequent widespread adoption of *Capsicum* in China have catalyzed profound transformations in both the nation's culinary landscape and its agricultural economy. As the world's leading producer, China has evolved its engagement with *Capsicum* from the cultivation of a novel exotic species into the management of a vital economic and cultural asset (Zhang et al., 2016; Wang et al., 2018; Du et al., 2019; Wang et al., 2021).

6.1. *Culinary integration*

Upon its introduction, the crop was rapidly integrated into regional dietary traditions, particularly within provinces such as Hunan, Sichuan, and Guizhou, where it fostered a pervasive preference for pungency (Cao, 2019). Valued for its significant nutritional profile (Song et al., 2010; Palma et al., 2015; Olatunji and Afolayan, 2018; Palma et al., 2020; Azlan et al., 2022; Jin et al., 2023; Faisal and Mustafa, 2025a), *Capsicum* is consumed extensively as a fresh vegetable. It features prominently in dishes such as stir-fried pork with chili, underscoring its centrality to Chinese gastronomy.

Beyond fresh consumption, it is the most widely used spice and flavoring agent within the food processing sector (Jarret et al., 2019; Zou et al., 2022; Islam et al., 2023; Qiao et al., 2023; Elmatsani et al., 2024; Jalgaonkar et al., 2024). Its adaptability to diverse processing techniques (Chuah et al., 2008; Zou et al., 2022; Liu et al., 2023; Jalgaonkar et al., 2024), including drying, pickling, fermentation and oil extraction, has facilitated the development of an extensive industrial chain. This industrialization has yielded a wide array of commercial products, ranging from chopped and pickled chilies, to fried chili in oil and complex sauces (Loizzo et al., 2015; Zou et al., 2020; Ye et al., 2022), cementing the crop's status as a commercially indispensable flavoring agent (Cao, 2019).

6.2. *Role in agricultural economy*

Capsicum cultivation constitutes one of the largest vegetable-growing sectors in China, with an annual planting area exceeding 2 million hectares (Wang et al., 2021). Its ubiquitous presence as both a fresh vegetable and a condiment has established it as a cornerstone of the domestic food market. Recognizing its high economic value and broad market demand (Karim et al., 2021; Zou et al., 2022), *Capsicum* has been strategically integrated into national policy frameworks aimed at poverty alleviation and rural revitalization (Wang et al., 2021). Consequently, for numerous agricultural communities, chili cultivation has transitioned from subsistence farming to a primary source of income, functioning as a critical “cash crop” that drives local economic growth (Lin et al., 2023; Deng et al., 2024).

This economic significance is particularly evident in major cultivation hubs such as Guizhou, Henan and Hebei provinces. In specific regions, such as Zunyi in Guizhou and Jize in Hebei, the *Capsicum* industry has matured into a foundational economic pillar. This regional specialization has led to the formation of national agglomeration centers for *Capsicum* cultivation and distribution, thereby contributing significantly to regional economic stability and growth (Wang et al., 2021).

7. Analysis of the global competitiveness of China's *Capsicum* industry

As the most widely cultivated pungent vegetable crop globally, chili peppers occupy a pivotal position in the international agricultural economy. According to recent statistics from the Food and Agriculture Organization, global production exhibits significant regional disparities, with China demonstrating a pronounced dominance in overall scale.

7.1. *Market share of fresh and dried peppers*

In the fresh pepper sector, China serves as both the world's largest producer and consumer. In 2023, national production reached 17.13 million tons, capturing approximately 44.7% of the global total. This volume is 4.6 to 5.6 times that of the next major producers - Mexico, Turkey, and Indonesia, highlighting its scale-based comparative advantage (Table 3). This output is largely sustained by the widespread adoption of protected cultivation technologies, which have successfully facilitated year-round supply (Jia et al., 2024).

However, the dynamics of dried pepper production differ substantially. Global production is concentrated primarily in India, Bangladesh, Thailand, and China. In 2023, China ranked fourth worldwide, accounting for 5% of the global total with production clustered in regions such as Guizhou, Henan, and Xinjiang (Qiao et al., 2023; Zou et al., 2025). Although China's dried pepper production is substantial, India leverages its unique climatic conditions and labor cost efficiencies to contribute 47% of global production, thereby establishing it as the market leader in this specific sector.

Table 3 The production volume of *Capsicum* in major producing countries in 2023

Rank	Country	Fresh peppers		Country	Dried peppers	
		Production ($\times 10^4$ t)	Shares (%)		Production ($\times 10^4$ t)	Shares (%)
1	China	1713.44	44.69	India	278.20	47.78
2	Mexico	368.10	9.60	Bangladesh	66.28	11.38
3	Türkiye	308.10	8.03	Thailand	32.89	5.64
4	Indonesia	306.12	7.98	China	32.55	5.59
5	Spain	138.98	3.62	Ethiopia	29.82	5.12
6	Egypt	106.51	2.77	Myanmar	15.11	2.60
7	Nigeria	77.39	2.01	Benin	13.47	2.30
8	Algeria	62.49	1.63	Côte d'Ivoire	13.15	2.25
9	United States of America	57.67	1.50	Pakistan	10.96	1.88
10	Tunisia	44.49	1.16	Ghana	10.93	1.87

Note: Data source: Food and Agriculture Organization of the United Nations (FAOSTAT, 2025).

Table 4 China's annual import volume of *Capsicum* (neither crushed nor ground)

Partner	2024				2023			
	Trade value (million dollars)	Shares (%)	Net weight (× 10^4 t)	Shares (%)	Trade value (million dollars)	Shares (%)	Net weight (× 10^4 t)	Shares (%)
India	466.84	93.94	18.39	88.76	386.84	98.00	14.01	97.67
Myanmar	23.44	4.71	2.03	9.79	0.04	0.01	0.003	0.02
Viet Nam	4.50	0.90	0.17	0.86	6.72	1.70	0.28	1.96
Pakistan	1.33	0.26	0.08	0.40	0.0006	–	0.00001	–
Rwanda	0.83	0.16	0.03	0.16	1.09	0.27	0.04	0.33
Total	496.94		20.71		394.72		14.35	

Note: Data source: calculated based on the UN Comtrade database (UNTradeData, 2025), HS commodity codes 090421.

7.2. Import and export trade flows

Whereas fresh chili pepper products primarily serve the domestic market, exports of dried peppers and processed products have been steadily increasing. The trade of fresh peppers is constrained by limited shelf life, resulting in pronounced regional localization. According to FAO statistics, the major importers of fresh peppers in 2023 were predominantly Western nations, including the United States, Germany, the United Kingdom, France, and Canada (FAOSTAT, 2025). Conversely, the primary exporters were Mexico, Spain, the Netherlands, Turkey, and Canada. China's fresh pepper exports constituted only about 4% of the global total (FAOSTAT, 2025), consisting mainly of short-distance cross-border trade with neighbors such as Thailand, Russia, and Vietnam (UNTradeData, 2025).

In contrast, the dried pepper export market exhibits a clear competitive duopoly between China and India. These two nations account for 27.2% and 42.2% of global export volume, respectively, far surpassing the third-ranked Spain at 6.8% (UNTradeData, 2025). China's dried exports, along with deep-processed products are directed toward major consumer markets including the United States, Spain, Malaysia, and Thailand (UNTradeData, 2025). Notably, a sophisticated trade interdependence has materialized. While China remains a leading exporter of dried and processed chili products, it has simultaneously emerged as a major importer of unprocessed dried peppers (neither crushed nor ground). In recent years, China has imported substantial quantities of high-pungency dried peppers (such as the S17 variety) from India to support its capsaicin extraction and industrial sectors. In 2023, imports of unprocessed dried peppers totaled \$ 394 million, with \$ 386 million originating from India. This dependence remained high in 2024, with Indian imports accounting for 88.7% of the total (Table 4) (UNTradeData, 2025).

7.3. Transitioning from scale-oriented to efficiency-oriented growth

Although China remains the world's largest *Capsicum* producer in terms of total global output, it encounters intense competition from countries such as India in the dried pepper sub-sector. China's *Capsicum* industry currently faces a critical transition from scale-oriented to efficiency-oriented growth, necessitated by intense competition and internal constraints.

The industry confronts a dual challenge. First, there is a severe homogenization of domestic varieties (Wang et al., 2021). A lack of specialized cultivars tailored to industrialization undermines price competitiveness in the international market. Consequently, high-pungency dried *Capsicum* must still be imported in large quantities from India and other regions. Second, the sector is under mounting economic pressure due to rising labor costs. Manual harvesting still accounts for 20%–40% of total production expenses (Zou et al., 2025). When combined with escalating land rental rates, these labor costs have eroded net profit margins. Consequently, overcoming varietal homogenization and accelerating mechanization to mitigate labor costs have become the primary imperatives for enhancing the global competitiveness of China's *Capsicum* industry.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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