Journal of Applied Biology & Biotechnology Vol. 11(5), pp. 133-142, Sep-Oct, 2023
Available online at http://www.jabonline.in
DOI: 10.7324/JABB.2023.11516-1

Indigenous Lakadong turmeric of Meghalaya and its future prospects

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ARTICLE INFO

Article history:
Received on: March 19, 2023
Accepted on: June 08, 2023
Available online: August 10, 2023

Key words:
Lakadong turmeric,
West Jaintia Hills,
Curcumin,
Meghalaya,
Sustainable agriculture.

ABSTRACT

Turmeric (*Curcuma longa*) has long been used in traditional Indian medicine. India accounts for 80% of total global turmeric production. Lakadong turmeric gets its name from the tiny village of Lakadong, which is located in the foothills of the Jaintia Hills in Meghalaya, India. It is known for having a high curcumin content of more than 7%, as opposed to 2 - 4% in regular varieties. The tribes of this region brought Lakadong turmeric from the forest and domesticated it for medicinal purposes centuries ago. Growth in local coal industries and a gradual decline in the market have had a significant impact on and reduced Lakadong turmeric production. To resurrect the industry, the Meghalaya government has embarked on a mission to increase production of Lakadong turmeric to 50,000 metric tons (MT) per year by 2023, up from 20,000 MT currently. However, most farmers in this region have abandoned Lakadong turmeric cultivation due to low returns. To ensure farmers' livelihoods, policymakers and the government must address future production challenges and create a viable market for such commodities. This review paper discusses the traditional history of Lakadong cultivation and its current status, challenges, and prospects. The paper also discusses the agronomic, phytochemical, and medicinal properties of turmeric.

1. BACKGROUND

The golden spice turmeric (*Curcuma longa* L.) belongs to the family Zingiberaceae and is a rhizomatous perennial herb. It has been extensively used as a culinary spice, in cosmetics, and traditional health care remedies from ancient [1]. It is cultivated throughout the world and is believed to be originated in Southeast Asian countries. Marco Polo (1280 AD) referred to turmeric as the saffron of India [1]. The documented article shows 6000 years of turmeric history in Indian culture and agriculture [2]. It was mentioned in the Atharvaveda, the Vedic scripture of Hinduism, which describes the procedures of everyday life [3,4]. It has various vernacular names such as "Haldi" in the Northern, Eastern part of India, "Manjal" in the Southern part of India [1], and "Halodi" in Assam, India [Figure 1]. According to reports, from the Latin word *Terra Merita* (meaning: meritorious earth), the word turmeric was derived from referring to the turmeric color [1,5].

In India, turmeric covers almost 6% of the total area under spices and condiments cultivation. It can be cultivated in diverse tropical conditions, up to an altitude of 1600 m, with temperatures varying from 20 to 40°C and rainfall above 1500 mm. The ideal soil pH for growth is between 4.5 and 7.5. It is a 9-month crop, generally sown in late March to early April, when the monsoon (rainy) season starts. Whole or split mother rhizomes are used for planting. The optimum spacing in furrows and ridges is between 45 and 60 cm between rows and 25 cm between the plants. The perennial herb reaches a height of about 1 m with palmate leaves. The leaves are arranged in two rows in an alternate pattern. The rhizomes are yellow to orange in color, and the segmentation is rough. Older rhizomes are scaly and brown, and young rhizomes are pale yellow to brown. Flowers are yellow-orange colors borne on the axils of waxy bracts that are pale green with tinged purple.

Carbohydrates, fibers, proteins, sugars, minerals, and vitamins are the primary constituents of turmeric [Table 1]. The rhizome of turmeric also contains significant amounts of phenolic compounds; among them, the most important one is curcuminoids, which give the yellow color to the turmeric rhizome [6]. The curcuminoid is a linear diarylheptanoid, a secondary metabolite that includes curcumin, de-methoxy-curcumin, and bis-demethoxy-curcumin [7] [Figure 2]. Curcumin is the highest (94%) among these three constituents in curcuminoid. The aroma of turmeric is related to turmerone and zingiberene [1,8]. As per the Food and Drug Administration (FDA) classification, turmeric is "Generally Recognized as Safe" (GRAS), and the daily consumption of curcumin at 0–3 mg/kg body weight is also healthy [9,10]. The curcuminoid is

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Figure 1: Lakadong turmeric, (a) Plant, (b) and (c) Rhizome. Picture credit: www.zizira.com.

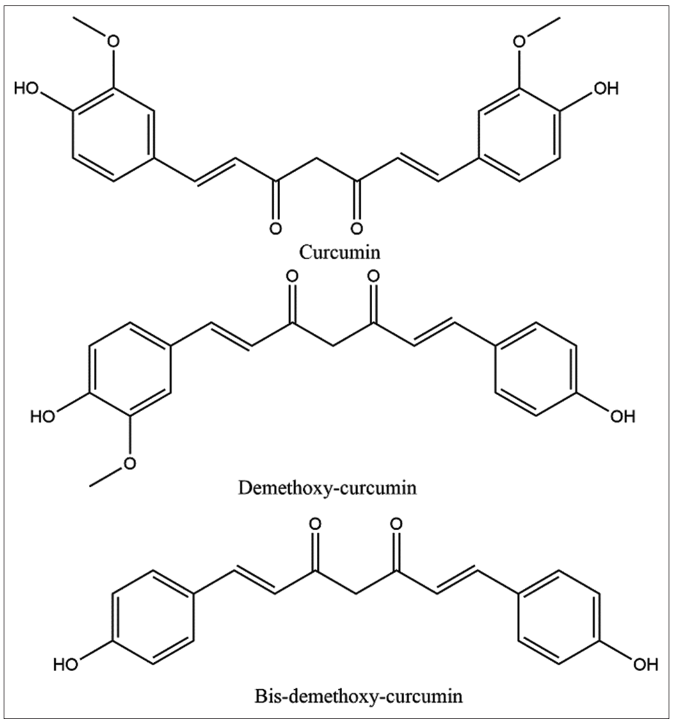

Figure 2: Chemical constituents of curcuminoid.

Table 1: Nutritional value of Turmeric#.

Components	Quantity (g 100 g^{-1})
Moisture	5.8
Protein	8.6
Fat	8.9
Carbohydrate	63.0
Fiber	6.9
Mineral matter	6.8
Calcium	0.2
Phosphorus	0.3
Iron	0.01
Sodium	0.5
Vitamin A	0.09
Vitamin B	0.09
Vitamin C	49.8
Niacin	4.8
Essential Oil	Dried rhizomes: 5–6% Fresh rhizome: 0.24%

#The table is adopted from Mission Lakadong, 2018-2023 (Supplementary file S1)

also responsible for the medicinal properties of the turmeric rhizome, including anti-hepatoxic and anti-cancerous.

In the world market, turmeric from India is considered the best because of its high curcumin content. According to the MoFPI (2021), India produces almost 80% of the world's turmeric and meets nearly 60% of the world's exports. Turmeric production in 2018-19 was 389 thousand metric tons (MT), with an area of 246 thousand hectares and productivity of 5646.34 kg per hectare, respectively. In the past year (2019-2020), the United States was the top importer of Indian turmeric, accounting for 22% of total export value, followed by Bangladesh (18%), Iran (6%), and the United Arab Emirates (5%). Other importers include Malaysia, the United Kingdom, Morocco, Germany, and Japan. The COVID-19 outbreak boosted turmeric sales significantly, both fresh and dried. The increase in sales has also increased in the international market, and the value of turmeric export has increased by 20% in the last year, compared to 6% growth in the 2016-2020 [11].

There are several reports describing the use of turmeric for the treatment of diseases such as asthma, bronchial hyperactivity, rheumatism, diabetic wounds, sinusitis, smallpox, skin cancer, urinary tract infection, liver disorders, jaundice, menstrual difficulties, and abdominal pain [12,13]. Recently, turmeric has also been found effective against the pandemic COVID-19, with the potential to curb cytokine storms in patients suffering from the disease [14-25]. These finding has renewed the interest in turmeric research.

This is a narrative review that mainly focuses on the properties of Geographical Indication-tagged Lakadong turmeric [Figure 1], cultivated in the West-Jaintia Hills district of the Northeastern state of Meghalaya, India. Lakadong turmeric is famous for its high curcumin content (~7–10%) [26,27] compared to regular turmeric (~2–4%) [28]. Lakadong turmeric inherits its name from the small village Lakadong in the Meghalaya district of Northeastern India. The tribes of this area transplanted Lakadong turmeric from the forest century back and domesticated it for medicinal and traditional rituals. Growth in local coal industries and gradual decline in the market has strongly affected and reduced the production of Lakadong turmeric. This narrative literature review provides an overview of turmeric's chemical constituent and medicinal properties, especially against various inflammatory diseases. The review also highlights the current challenges in the production and farming of Lakadong turmeric, government efforts in rejuvenating the market, and its prospects.

2. METHODOLOGY

A narrative literature review has been conducted using the database of Google Scholar, Web of Science, and Connected Papers (https://www.connectedpapers.com/). The search was performed using indexed words such as, "turmeric", "Lakadong," "Lakadong turmeric," "Lakadong Meghalaya," "turmeric medicinal properties," and "curcumin Lakadong." The search was performed without any language and time filtering function. Due to the similarity of the Lakadong term with Lakadong limestone, there were several studies with Lakadong limestone in the search, and the studies discussing only Lakadong turmeric were selected. There are only a few available studies on Lakadong turmeric. A search with "Lakadong turmeric" on the web of science generated only six results. Due to the limited number of available research, all the articles generated from the search were used without any specific inclusion/exclusion parameters. For limited availability of the current status of the market of Lakadong turmeric and government policies on the indexed database, published news articles and reports were also included in this study, which was searched using the Google search engine. The chemical structure of the phytochemicals was drawn using the software Chemdraw 15.1 (PerkinElmer, USA). The location map was created in ArcGIS 10.8.2. A flow diagram of the search criteria is provided in Figure 3.

3. MEDICINAL APPLICATION OF TURMERIC

The usage of the turmeric plant for medical purposes dates back over 4000 years. The more than 3000 publications on turmeric in the past 25 years show that modern medicine has started to understand its significance [1]. Turmeric is said to provide a variety of medical benefits in Ayurvedic traditions, including boosting body energy, reducing gastrointestinal disorders, getting rid of worms, enhancing digestion, controlling menstruation, removing gallstones, alleviating arthritis, for treatment of sprains and swelling and illnesses linked to the abdominal pain [29,30]. It is antibacterial and antiseptic, used in several South Asian nations for cuts, burns, and bruises [1]. In addition to its Ayurvedic uses, turmeric is used in India to treat skin disorders and purify the blood. Turmeric has also been used for several respiratory ailments, including asthma, allergies, and bronchial hyperactivity, as well as for liver problems, anorexia, rheumatism, diabetic wounds, runny noses, coughs, and sinusitis [2,29]. Turmeric is occasionally used to treat digestive issues, colds, and sore throats by combining it with milk or water [1]. Turmeric is a powerful antioxidant, anti-inflammatory, antimutagenic, antibacterial, and anticancer agent, according to contemporary in vitro studies [2]. Turmeric has many antioxidant properties at various activity levels and is utilized in food preparation and home treatments [31]. According to studies, eating curries *in vivo* can provide enough turmeric to provide optimal antioxidant protection [32]. As an antioxidant, turmeric extracts can boost antioxidant enzymes, scavenge free radicals, and prevent lipid peroxidation [33].

In addition, kidney, heart, and neurological diseases can be treated with turmeric [20]. An ischemia and reperfusion model of myocardial injury was used to assess the impact of turmeric on myocardial apoptosis and cardiac function [34]. Significant cardio protection and functional recovery were provided by turmeric when given orally for 1 month [35]. In addition, turmeric can help with depression [36,37]. Turmeric has antiarthritic properties that prevent the destruction of periarticular joints and joint inflammation [1,38]. Curcumin and its derivatives have been shown to have various biological effects that support health promotion and illness prevention. Indeed, a bibliometric analysis conducted by Yeung *et al*. [39] revealed that the United States, China, India, Japan, and South Korea are the primary contributors to the scientific advances discovered on curcumin bioactive effects, with the most focused being their anticancer, inflammatory, and antioxidant potential, as already stated by Sharifi-Rad *et al*. [33], Xu *et al*. [40].

4. CURCUMIN AND ITS MEDICINAL PROPERTIES

Turmeric contains two key components: Curcuminoids and essential oils (primarily terpenoids), responsible for the herb's orange-yellow color and aromatic flavor [6]. These components also have a broad spectrum of bioactivities for which data has been confirmed at all levels of investigation, including *in vitro* and *in vivo* tests and human clinical trials. Curcumin, the primary and most abundant curcuminoid in turmeric, has been widely examined in pharmaceutical investigations for its bioactivity [33]. The anti-diabetic and cardioprotective properties of turmeric have piqued the interest of many researchers in learning more about the role of turmeric and related bioactive components in preventing cardiovascular diseases (CVD), a leading cause of death worldwide [41]. Curcumin, the main constituent of curcuminoids, has anti-inflammatory, antioxidant, antimalarial, anticancer, hypolipidemic, and immune enhancer properties against life-threatening viral illnesses [Figure 4] [2,42,43].

Curcumin was used to treat various inflammatory diseases in ancient Indian medicine, including sprains and swellings caused

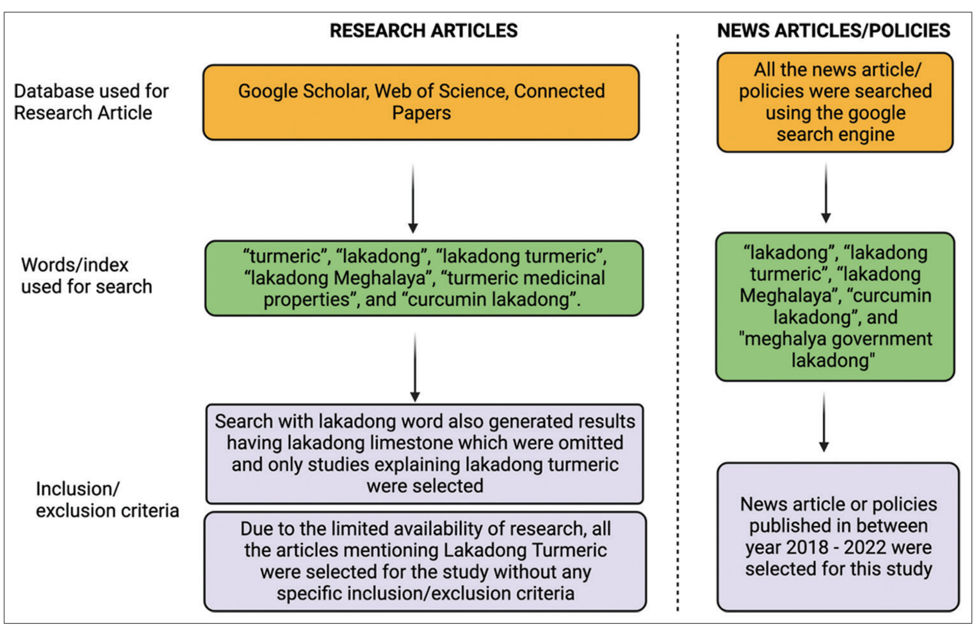

Figure 3: Search criteria for this narrative review study. Each color boxes represent one parameter of the search, orange = database, green = word/index used for the search, and purple = inclusion/exclusion criteria of the investigation.

by injury, wound healing, gastrointestinal issues, colds-cough, bronchitis, conjunctivitis, and liver disorders [44]. Ethanolic extract of turmeric and a curcumin ointment provides excellent relief in those with external malignant tumors [45-47]. Curcumin is a robust metal chelating agent and an effective free radical scavenger as an antioxidant [48,49]. Thousands of in vitro and in vivo research on its pleiotropic mechanism of action and therapeutic promise against a broad spectrum of disease conditions, including cancer, neurological disorders, and Alzheimer's disease, have been published [50-52]. Recently it has been found as a potential cure for coronavirus disease 2019 [19,23,53,54]. The oral administration of turmeric and curcumin is safe for humans and animals. They are also safe during pregnancy, but further human research is needed [55,56].

Curcumin has been shown to target multiple signaling molecules and function at the cellular level, supporting its various medicinal benefits [42]. Curcumin has anti-inflammatory and antioxidant properties, which supports its potential health benefits [42,57-59]. Curcumin inhibits lipoxygenase 5, peroxisome proliferator-activated receptor, interleukin 6 (IL-6), IL-8, IL-12, cyclooxygenase-2, tumor necrosis factor-alpha, mitogen-activated protein kinase, adaptor protein-1 (AP-1), and nuclear factor-kappa B (NF-B) [60,61], which are important anticancer properties. Curcumin inhibits inflammatory atherogenic cytokines such as IL-1, IL-6, and TNF- by inhibiting the anti-inflammatory enzyme heme oxygenase-1 and suppressing the transcription factors NF-B and AP-1 [62]. Curcumin is accessible in various medicinal forms, including energy drinks, ointments, tablets, capsules, cosmetics, and soaps [57]. Recent pH-sensitive curcumin formulations allow more specific and effective targeting of inflammation locations, especially in the gastrointestinal system [63]. Curcuminoids have been authorized by the US FDA as "GRAS" or GRAS [42].

CVD is one of the leading causes of death worldwide. Similarly, age and obesity, two of the main risk factors for many diseases, are also widespread issues. Aging, or the slow deterioration of bodily processes, cannot be changed. Type 2 diabetes, predisposed to obesity, is a modifiable risk factor for CVDs [41]. In addition, it influences certain fat depots in the heart and vasculature, significantly impacting the onset and progression of CVDs. Oxidative stress, mitochondrial dysfunction, metabolic abnormalities such as altered lipid profiles and glucose metabolism, and inflammation are common causes of aging, obesity, diabetes, and CVDs. Numerous plant compounds, including curcumin, the primary ingredient in turmeric rhizome, have long been employed in traditional medicine to treat CVDs [33]. Curcumin has pleiotropic effects and attenuates several factors that enhance the risk of CVDs in aging and obesity, according to a newer mechanistic, animal, and human research [64]. Both senescence-related oxidative stress and cellular senescence can be delayed and reduced by curcumin, which results in vascular dysfunction [65-67]. An *in vitro* study showed that pre-treatment with curcumin for 24 h prevented hydrogen peroxide-induced premature senescence in endothelial cells, along with a reduction in ROS production and a rise in eNOS activation and NO production [64,68].

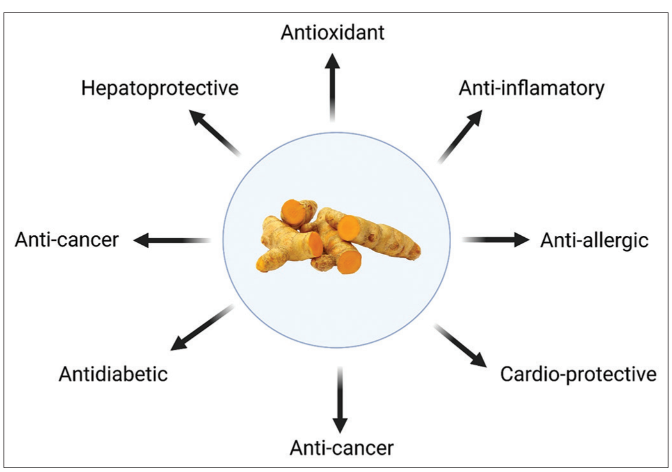

Figure 4: Medicinal properties of turmeric.

An aortic aneurysm is a potentially fatal ailment that can result in mortality in the event of rupture or dissection. Chronic inflammation, damaging connective tissue remodeling, and the loss of smooth muscle cells in the aorta wall are significant factors in forming aortic aneurysms [69]. By inhibiting the activation of NF-B and activator protein-1, curcumin treatment (100 mg/kg/day, for 14 days) along with transient elastase perfusion of the abdominal aorta, decreased the rise in aortic diameter, improved the structural integrity of medial elastin, and repressed the expression of pro-inflammatory molecules (AP-1) [70]. Curcumin has been shown to have hypolipidemic properties, which, combined with its antioxidant and anti-inflammatory activity, can help lower atherosclerosis prevalence. Curcumin's antioxidant properties lessen lipid peroxidation and the production of oxLDL, reducing the inflammatory response and the development of atherosclerosis [70,71]. Curcumin is a well-known p300 inhibitor with suppressive effects in heart failure and cardiac hypertrophy [72-74]. Numerous studies have shown the vital participation in inhibiting GATA binding protein 4 (GATA4), a crucial transcription factor for heart development and disease, to further illustrate the potential pathways. In addition to inhibiting GATA4's nuclear localization [73], curcumin also blocked the interaction between p300 and GATA4 [72]. This reduced GATA4 acetylation and gave curcumin its protective impact against cardiac hypertrophy [70]. By influencing calcium-associated molecules, curcumin was able to inhibit cardiac hypertrophy and heart failure. These effects include upregulating SR Ca2+-ATPase mRNA and protein expression [75], increasing expression and altering localization of Na+/Ca2+ exchanger, stabilizing the amplitude of oscillation and the Ca2+ content of SR, and deactivating calcium/calmodulin [70,76].

Diabetes is a chronic condition affecting people worldwide [77]. The mortality of diabetes is primarily caused by CVDs, such as diabetic cardiomyopathy, myocardial infarction (MI), and stroke [78]. More and more evidence suggest that curcumin could prevent CVDs from occurring in the first place or lessen their severity both *in vitro* and *in vivo* [79]. Curcumin might also prevent the death of cardiomyocytes, fibroblasts' growth, and collagen deposition in the infarct area. In addition, curcumin's protective impact on MI was influenced by its antiplatelet action [80]. Stroke, like MI, is caused by vascular or microvascular illnesses that block cerebral blood flow, which leads to brain dysfunction [81]. Four pathways might be used to explain how curcumin prevents strokes. First, the antioxidant enzymes SOD, catalase, and GPx activity were not downregulated by curcumin, which activated NF-E2-related factor 2 [78,82,83]. Nitric oxide (NO) production rose, lipid peroxidation was inhibited, and endothelial function in arteries improved due to less ROS being created and OS being suppressed [84,85]. Second, curcumin prevented the inflammatory responses in the ischemic region, as seen by lower NF-B activity and pro-inflammatory cytokine levels [78,86]. Third, as shown by increased Bcl-2 protein level and decreased Bax and caspase 3 protein, mitochondrial function was restored, and apoptosis was inhibited [85,87,88]. Last but not least, various signaling pathways have been linked to the protective effects of curcumin in cerebral ischemia, including p38 [86], ERK1/2 [89], and PI3K/Akt [83]. When used in combination, curcumin may lessen neurobehavioral impairments and prevent stroke through various pathways [70].

5. LAKADONG VILLAGE AND LAKADONG TURMERIC

Meghalaya is home to numerous spices, including the well-known turmeric (*C. Longa* L.). Meghalaya's Jaintia hills districts are home to the Lakadong variety of turmeric, which is regarded as one of the best in the world due to its higher curcumin content. It is known as shynrai or shyrmit Lakadong in Khasi. The tiny community of Lakadong, situated in the foothills of the Jaintia Hills (25°11' N, 92°17' E, Meghalaya, India), is named after the valuable spice Lakadong turmeric [Figure 5]. It has a curcumin content of >7% [90-93], compared to 2–4% in typical turmeric varieties available in the market. It has a significantly darker color compared to other turmeric varieties in India.

Lakadong turmeric has the potential to transform the livelihoods of thousands of Meghalaya's small and marginal farmers if effectively marketed. Although turmeric is now grown almost everywhere in the state, the Jaintia Hills still has the most land under cultivation and produces more than half of the total turmeric produced in the state. Lakadong turmeric farming is mostly practiced in Sumer, Lakadong, Shangpung, Looksi, Nongtyngkoh, Khoushnong, Umdeanglin, Umchalait, and Saphai. The most common varieties grown in these areas are Lakadong, Lashien, Ladaw, Lakachain, and Yangau [92]. Lakadong turmeric has been domesticated by the people of this region for over a century. According to reports, Lakadong is also associated with the "Thanksgiving" and "Children's Naming" ceremonies among the *Pnar* community of Jaintia Hills. During the ceremony shortly after the child's birth, turmeric is held on a bronze plate with dry fish. It was cut into a square shape and tied around the baby's hands to keep them safe from potentially hazardous falls, accidents, or injuries [94].

Recognizing the need to maximize the potential of this variety, the Directorate of Horticulture, Department of Agriculture, Government of Meghalaya has launched the "Lakadong Mission (2018-2023)" to increase Lakadong turmeric production, post-harvest management, processing, and other related activities in Meghalaya's Janita hills districts [95]. AgNext Technologies, in collaboration with the Spices Board of India, has used its cutting-edge curcumin testing technique to examine the Lakadong turmeric of Jaintia Hills. According to a press release by the company, AI-based technology is being deployed for the first time in Meghalaya for rapid quality testing of Lakadong turmeric [96]. The Spices Board and turmeric producers will also have access to the AI-enabled SaaS (Software as a Service or SaaS) platform "Qualix," which will help digitize quality, generate vital insights, and enable supply chain traceability.

6. PROBLEM AND CHALLENGES WITH LAKADONG TURMERIC PRODUCTION

Unawareness of the varietal differences is a significant issue in Lakadong production. Farmers are currently uninterested in learning about the variety they are cultivating and are ignorant of its distinctive qualities. The West Jaintia Hills Districts of Meghalaya cultivate three varieties of turmeric: Lachein, Lasyein, and Lakadong. The Lakadong possesses the highest curcumin content (7–10%). However, farmers are unaware of this information and are not incentivized to cultivate varieties with higher curcumin content by higher market returns. Due to this misconception, the Lachein variety has the largest proportion of cultivated land in the West Jaintia Hills district, despite having a lower curcumin concentration (4–5%) [11]. Since the Lakadong variety is not available in significant quantities, market participants who are aware of the types and curcumin content are faced with the

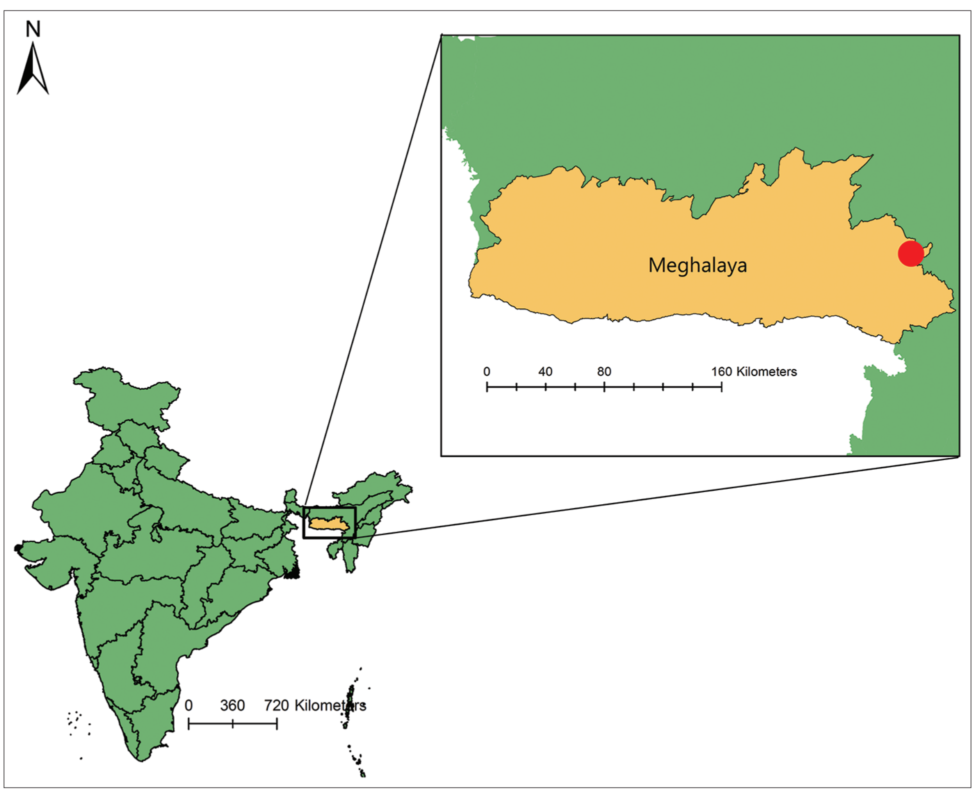

Figure 5: Map of the Lakadong village, Meghalaya, India. The red marker shows the location of Lakadong village.

problem of diminished economies of scale. To take advantage of Lakadong's high curcumin content, farmers must be educated on the significance of Lakadong and its Geographic Indication (GI) status. It is necessary to develop a niche market for these commodities. Farmers should be able to make an informed decision about switching to Lakadong production, and efforts should be made to provide them with price realization incentives. Farmers must also have access to the necessary planting materials, such as turmeric rhizomes and seeds, for this massive transformation. Tissue culture and other methods of mass multiplication can help produce more plant materials. Due to the region's lack of facilities for handling, processing, value addition, packing, and even structured marketing, post-harvest losses of virtually all agricultural products are extremely high. Despite producing turmeric and other foods of the highest quality, the region has few facilities for processing these commodities.

Turmeric is practically grown in every family in Lakadong village. Cultivation of this turmeric type has now relocated from Lakadong to its neighboring villages, owing to large-scale coal mining and greater market returns from ginger cultivation [92]. The absence of appropriate processing capacities to exploit the marketable surplus is a common flaw discovered when the issue of commodity processing is typically analyzed [97]. The problem with Lakadong turmeric is that while processing units have been created, the supply chain is so inadequate that there is no backward link to provide a year-round stable raw material supply to these processing units.

7. PROSPECT AND MARKET

Turmeric is known as the "golden spice" due to its widespread use in the cooking and pharmaceutical industries, as discussed in this narrative review. Curcumin has been shown in studies over the last few decades to have greater antioxidant properties than a-tocopherol [98]. This characteristic is widely used as a chemopreventive medication for a variety of cancers, including colon, breast, prostate, esophageal, lung, and oral cancers, as well as an inhibitor of atherosclerosis, viral, and bacterial growth [42]. Other curcuminoids, such as desmethoxycurcumin and bisdemethoxycurcumin, have been shown in cancer cell lines to be cytotoxic, antioxidants, and anti-inflammatory [99]. The pharmaceutical industry benefits greatly from the contents of such medicinally significant substances.

In the current situation, one of the future challenges is to produce turmeric in a sustainable manner. Plant growth-promoting rhizobacterial treatments protect plants and soil from the harmful effects of synthetic chemicals and promote an environmentally friendly habitat for plants and bacteria. Ongoing research into plant-microbe interactions is gaining traction. High-throughput technologies, such as next-generation sequencing, can be used to investigate complex microbiomes, allowing for in-depth studies of Lakadong turmeric's unique characteristics and complex ecology.

Marketing of any agricultural product is a major concern because the price fluctuates every year, which is similar to the case of turmeric. The turmeric-producing community faced serious issues, such as a lack of price to cover production costs, which is one of the major reasons for trader domination in the pricing [100,101]. According to an industrial report, in 2020, the curcumin market size exceeded USD 70 million, which is an estimated hike of 11% from 2021 to 2027 [102]. The main focus of the Key companies operating in the global turmeric market is introducing new products with multiple industrial applications to maintain their market importance. A few key companies performing in the global curcumin market are Sabinsa Corporation, Synthite Industries Ltd., and The Green Labs LLC [103]. There is an international platform (https://www.diasporaco.com/products/lakadong-turmeric?variant=40973996425387) which is selling Lakadong turmeric for $12/50 g, and the reviewers comment greatly emphasized on how the use of Lakadong turmeric has helped in curing knee pain. This indicates there is a potential market for this variety if production and marketing can be done in a more appropriate way.

As reported in the English Daily, about 150 kg of Lakadong turmeric was recently shipped to the Netherlands, and another 210 kg of the same turmeric is bound for the UK [96]. Despite the highest curcumin content and excellent domestic sales and export potential, Lakadong turmeric faces severe market access issues due to the location, topography, and terrain remoteness. Application of drone/Unmanned Aerial Vehicle-based technology was recently demonstrated in West Jaintia Hills of Meghalaya to overcome these problems, which could serve as a model for solving the transportation issues for Lakadong turmeric farmers from remote villages [104].

Moreover, this Lakadong turmeric variety has also been recognized under "One District, One Product Initiative" of DPIIT, Ministry of Commerce and Industry, as a product with excellent potential for growth and export for West Jaintia Hills [105]. Since 2018, the Meghalaya government has been on a mission to grow Lakadong turmeric, with a goal of increasing production to 50,000 MT per year by 2023 from the current 20,000 MT. This will necessitate ongoing capacity development for potential entrepreneurs. The mission will take a much more focused approach, leveraging Lakadong's existing brand equity and increasing demand, primarily from the pharmaceutical industry, to ensure better returns for farmers by streamlining and facilitating the demand-supply chain. In addition to the Directorate of Horticulture, there are already a number of organizations and agencies. Private entities like Zizira (https://www.zizira.com/collections/zizira-lakadong-turmeric-products) have been tied up with farmers with a cooperative agreement to buy turmeric from them, process and sell to different clients. The mission would strive to bring them all into a convergent and enabling platform that would ensure fair returns to farmers and establishing the market by facilitating the growth of these local enterprises and leaving them to big institutional buyers.

8. CONCLUSION

Turmeric (*C. Longa*) has long been used in traditional Indian medicine. India accounts for 80% of total global turmeric production. Lakadong turmeric gets its name from the tiny village of Lakadong, which is located in the foothills of the Jaintia Hills in Meghalaya, India. It is known for having a high curcumin content of more than 7%, as opposed to 2–4% in regular varieties. Turmeric production used to be higher and more extensive in this region, according to local farmers, but due to coal mining in the area for the past 20–30 years, cultivation has decreased significantly [94]. A sharp price drop followed by an increase in production in recent years has also resulted in poor market demand for the produce. As a result, farmers have been unable to profit from turmeric production for the past three to 4 years. Total production and the land area given to farmers for cultivation are both rapidly declining. Due to increased demand, nearly all resourceful impoverished farmers in the Lakadong area are abandoning turmeric cultivation in favor of producing *Zingiber officinale* [94]. Farmers claim that growing turmeric commercially is risky because there is no market assurance based on an agreed-upon price.

Thousands of small and marginal farmers in Meghalaya could have their lives transformed if the Lakadong variety is effectively taken advantage. Farmers can play a crucial role in formulating policies designed to increase product consumption. They will likely be motivated by the potential for greater financial rewards. To ensure a year-round variety of safe crops, farmers must be empowered by policies that enable diversification and cost-effectiveness in their production methods, harvest scheduling, and harvest management.

The bioactivity and therapeutic properties of turmeric have been intensively studied. For the long-term use and socioeconomic advancement of the Lakadong population, it is necessary to study these abundant bioresources in terms of their vital bioactive molecules. The Northeastern region of India has great potential for turmeric production on a large scale [92]. Current productivity in the region is only 1.5 tonnes per hectare, compared to the national average of 3.9 tonnes per hectare [106], which can be significantly increased through the implementation of various regenerative agricultural practices. Since rhizome multiplication is slow, plant tissue culture technology has replaced traditional seed rhizome propagation over the past four decades. Conventional propagation methods are incapable of meeting the demand for large quantities of genetically superior varieties, necessitating cultivar improvement projects. In conjunction with traditional breeding techniques, tissue culture can accelerate the production of Lakadong species cultivars.

Due to historical, political, and geopolitical factors, it has been challenging for northeastern Indian states like Meghalaya to successfully promote local businesses outside their borders. The documentation of traditional knowledge pertaining to food, medicine, and other necessities will significantly increase the market due to the improvement of lifestyle necessities and benefits. Farmers may play a crucial role in policies intended to increase production and consumption. They will be motivated by the promised greater economic benefits. Policies must empower farmers so that diversification and cost-effectiveness in their production systems become a reality, and harvests can be planned and managed to ensure a year-round supply of a variety of safe goods. This study is a representative sample of a larger body of work. Nonetheless, it is of great importance for comprehending resources, their effects, and the possibility and application of incentives and subsidies to increase the supply growth and effectiveness of turmeric. Exploration of these abundant bioresources' significant active principles or bioactive compounds is required for their long-term use and the socioeconomic development of the local populace.

9. AUTHORS CONTRIBUTIONS

MKR conceived the idea, MKR, SD, DS, and PKM wrote the draft, reviewed it, and finalized it.

10. FUNDING

There is no funding to report.

11. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

12. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

13. DATA AVAILABILITY

All the data is available with the authors and shall be provided upon request.

14. PUBLISHER'S NOTE

This journal remains neutral with regard to jurisdictional claims in published institutional affiliation.

REFERENCES

1. Prasad S, Aggarwal BB. Turmeric, the golden spice: From traditional medicine to modern medicine. In: Herbal Medicine: Biomolecular and Clinical Aspects. 2nd ed. Boca Raton: CRC Press/Taylor and Francis; 2011. p. 1-46.
2. Lal B. Review study on medical use of turmeric. Asian J Multidimens Res 2022;10:543-9.
3. Akhila KS, Gopi S. Turmeric the miraculous herb from ancient india and its historical background. In: Thomas S, Kunnumakkara AB, Aggarwal BB, Amalraj A, editors. The Chemistry and Bioactive Components of turmeric. United Kingdom: The Royal Society of Chemistry; 2020. p. 1-29.
4. Kandwal A, Mamgain RK, Mamgain P. Comparative evaluation of turmeric gel with 2% chlorhexidine gluconate gel for treatment of plaque induced gingivitis: A randomized controlled clinical trial. Ayu 2015;36:145-50.
5. Paramasivam M, Poi R, Banerjee H, Bandyopadhyay A. High-performance thin layer chromatographic method for quantitative determination of curcuminoids in *Curcuma longa* germplasm. Food Chem 2009;113:640-4.
6. Kocaadam B, Şanlier N. Curcumin, an active component of turmeric (*Curcuma longa*), and its effects on health. Crit Rev Food Sci Nutr 2017;57:2889-95.
7. Niranjan A, Prakash D. Chemical constituents and biological activities of turmeric (*Curcuma longa* l.)-a review. J Food Sci Technol 2008;45:109-16.
8. Kumar A, Singh AK, Kaushik MS, Mishra SK, Raj P, Singh PK, *et al*. Interaction of turmeric (*Curcuma longa* L.) with beneficial microbes: A review. 3 Biotech 2017;7:357.
9. Amalraj A, Pius A, Gopi S, Gopi S. Biological activities of curcuminoids, other biomolecules from turmeric and their derivatives a review. J Tradit Complement Med 2017;7:205-33.
10. Food and Drug Administration. GRAS Notice. United States: Food and Drug Administration; 2017. p. 696.
11. Ministry of Food Processing Industries. Market Trends in Turmeric Processing. New Delhi: Ministry of Food Processing Industries; 2021.
12. Dixit V, Jain P, Joshi S. Hypolipidaemic effects of *Curcuma longa* L. and *Nardostachys jatamansi*, DC in triton-induced hyperlipidaemic rats. Indian J Physiol Pharmacol 1988;32:299-304.
13. Bundy R, Walker AF, Middleton RW, Booth J. Turmeric extract may improve irritable bowel syndrome symptomology in otherwise healthy adults: A pilot study. J Altern Complement Med 2004;10:1015-8.
14. Rocha FA, de Assis MR. Curcumin as a potential treatment for COVID-19. Phyther Res 2020;34:2085-7.
15. Zahedipour F, Hosseini SA, Sathyapalan T, Majeed M, Jamialahmadi T, Al-Rasadi K, *et al*. Potential effects of curcumin in the treatment of COVID-19 infection. Phyther Res 2020;34:2911-20.
16. Nemati M, Asl E, Pouya F, Rasmi Y. Curcumin, an inhibitor of PAK1, potential treatment for COVID-19. J Infect 2020;3:1-3.
17. Prabha T, Dhanabal P, Selvamani P, Latha S, Sivakumar T, Jubie S. Hydroxychloroquine and curcumin conjugates as multifunctional co drugs for the potential treatment of COVID-19: An *in-silico* based study. Int J Res Pharm Sci 2020;11:348-59.
18. Soni VK, Mehta A, Ratre YK, Tiwari AK, Amit A, Singh RP,

et al. Curcumin, a traditional spice component, can hold the promise against COVID-19? Eur J Pharmacol 2020;886:173551.
19. Babaei F, Nassiri-Asl M, Hosseinzadeh H. Curcumin (a constituent of turmeric): New treatment option against COVID-19. Food Sci Nutr 2020;8:5215-27.
20. Rattis BA, Ramos SG, Celes MR. Curcumin as a potential treatment for COVID-19. Front Pharmacol 2021;12:675287.
21. Hussain MS. Potential role of curcumin as a treatment option for Covid-19: A review. Plant Arch 2021;21:42.
22. Saber-Moghaddam N, Salari S, Hejazi S, Amini M, Taherzadeh Z, Eslami S, *et al*. Oral nano-curcumin formulation efficacy in management of mild to moderate hospitalized coronavirus disease-19 patients: An open label nonrandomized clinical trial. Phyther Res 2021;35(5), 2616-23.
23. Dourado D, Freire DT, Pereira DT, Amaral-Machado L, Alencar EN, de Barros AL, *et al*. Will curcumin nanosystems be the next promising antiviral alternatives in COVID-19 treatment trials? Biomed Pharmacother 2021;139:111578.
24. Noor H, Ikram A, Rathinavel T, Kumarasamy S, Iqbal MN, Bashir Z. Immunomodulatory and anti-cytokine therapeutic potential of curcumin and its derivatives for treating COVID-19-a computational modeling. J Biomol Struct Dyn 2022;40:5769-84.
25. Anvekar P, Kumar M, Lohana P. An abridgement on curcumin potentials for Covid-19 treatment a miracle drug? J Bahria Univ Med Dent Coll 2021;11:138-9.
26. Singh P, Banik R. Biochemical characterization and antitumor study of L-glutaminase from *Bacillus cereus* MTCC 1305. Appl Biochem Biotechnol 2013;171:522-31.
27. Verma S, Singh S, Sharma S, Tewari SK, Roy RK, Goel AK, *et al*. Assessment of genetic diversity in indigenous turmeric (*Curcuma longa*) germplasm from India using molecular markers. Physiol Mol Biol plants 2015;21:233-42.
28. Aswathi AP, Raghav SB, Prasath D. Assessment of genetic variation in turmeric (*Curcuma longa* L.) varieties based on morphological and molecular characterization. Genet Resour Crop Evol 2023;70:147-58.
29. Araújo MC, Dias FL, Takahashi CS. Potentiation by turmeric and curcumin of gamma-radiation-induced chromosome aberrations in Chinese hamster ovary cells. Teratog Carcinog Mutagen 1999;19:9-18.
30. Aggarwal BB, Sundaram C, Malani N, Ichikawa H. Curcumin: The Indian solid gold. In: Surh YJ, Shishodia S, editors. The Molecular Targets and Therapeutic Uses of Curcumin in Health and Disease. Boston, MA: Springer US; 2007. p. 1-75.
31. Tanvir EM, Hossen S, Hossain F, Afroz R, Gan SH, Khalil I, *et al*. Antioxidant properties of popular turmeric (*Curcuma longa*) varieties from Bangladesh. J Food Qual 2017;2017:8471785.
32. Tilak JC, Banerjee M, Mohan H, Devasagayam TP. Antioxidant availability of turmeric in relation to its medicinal and culinary uses. Phytother Res 2004;18:798-804.
33. Sharifi-Rad J, El Rayess Y, Rizk AA, Sadaka C, Zgheib R, Zam W, *et al*. Turmeric and its major compound curcumin on health: Bioactive effects and safety profiles for food, pharmaceutical, biotechnological and medicinal applications. Front Pharmacol 2020;11:1021.
34. Liao CL, Liu Y, Huang MZ, Liu HY, Ye ZL, Su Q. Myocardial ischemia reperfusion injury is alleviated by curcumin-peptide hydrogel via upregulating autophagy and protecting mitochondrial function. Stem Cell Res Ther 2021;12:89.
35. Mohanty I, Arya DS, Gupta SK. Effect of *Curcuma longa* and *Ocimum sanctum* on myocardial apoptosis in experimentally induced myocardial ischemic-reperfusion injury. BMC Complement Altern Med 2006;6:3.
36. Yu ZF, Kong LD, Chen Y. Antidepressant activity of aqueous extracts of *Curcuma longa* in mice. J Ethnopharmacol 2002;83:161-5.
37. Xia X, Cheng G, Pan Y, Xia ZH, Kong LD. Behavioral, neurochemical and neuroendocrine effects of the ethanolic extract from *Curcuma longa* L. in the mouse forced swimming test. J Ethnopharmacol 2007;110:356-63.
38. Funk JL, Frye JB, Oyarzo NN, Kuscuoglu N, Wilson J, McCaffrey G, *et al*. Efficacy and mechanism of action of turmeric supplements in the treatment of experimental arthritis. Arthritis Rheum 2006;54:3452-64.
39. Yeung AW, Horbańczuk M, Tzvetkov NT, Mocan A, Carradori S, Maggi F, *et al*. Curcumin: Total-scale analysis of the scientific literature. Molecules 2019;24:1393.
40. Xu XY, Meng X, Li S, Gan RY, Li Y, Li HB. Bioactivity, health benefits, and related molecular mechanisms of curcumin: Current progress, challenges, and perspectives. Nutrients 2018;10:1553.
41. Pivari F, Mingione A, Brasacchio C, Soldati L. Curcumin and Type 2 diabetes mellitus: Prevention and treatment. Nutrients 2019;11:1837.
42. Gupta SC, Patchva S, Koh W, Aggarwal BB. Discovery of curcumin, a component of golden spice, and its miraculous biological activities. Clin Exp Pharmacol Physiol 2012;39:283-99.
43. Nelson KM, Dahlin JL, Bisson J, Graham J, Pauli GF, Walters MA. The essential medicinal chemistry of curcumin. J Med Chem 2017;60:1620-37.
44. Shishodia S, Chaturvedi MM, Aggarwal BB. Role of curcumin in cancer therapy. Curr Probl Cancer 2007;31:243-305.
45. Kuttan R, Sudheeran PC, Josph CD. Turmeric and curcumin as topical agents in cancer therapy. Tumori 1987;73:29-31.
46. Epstein J, Sanderson IR, Macdonald TT. Curcumin as a therapeutic agent: The evidence from *in vitro*, animal and human studies. Br J Nutr 2010;103:1545-57.
47. Wang E, Kuhn T, Lahiri C, Nguyen M, Ofotokun I, Abraham R, *et al*. 4553 An investigation into the use of curcumin, a topical herbal agent, for the treatment of cervical intraepithelial neoplasia. J Clin Transl Sci 2020;4:122-3.
48. Nardo L, Andreoni A, Masson M, Haukvik T, Tønnesen HH. Studies on curcumin and curcuminoids. XXXIX. Photophysical properties of bisdemethoxycurcumin. J Fluoresc 2011;21:627-35.
49. Mulyani S, Harsojuwono BA, Satriawan IK. Metabolite profile of ethanol extract of *Curcuma domestica* Val. variety Turina-1. J Appl Hortic 2021;23:11-4.
50. Ringman J, Frautschy S, Cole G, Masterman D, Cummings J. A potential role of the curry spice curcumin in Alzheimers Disease. Curr Alzheimer Res 2005;2:131-6.
51. Kulkarni SK, Dhir A. An overview of curcumin in neurological disorders. Indian J Pharm Sci 2010;72:149-54.
52. Abbas S, Latif MS, Shafie NS, Ghazali MI, Kormin F. Neuroprotective expression of turmeric and curcumin. Food Res 2020;4:2366-81.
53. Vahedian-Azimi A, Mohammadi SM, Banach M, Beni FH, Guest PC, Al-Rasadi K, *et al*. Improved COVID-19 outcomes following statin therapy: An updated systematic review and meta-analysis. Biomed Res Int 2021;2021:1901772.
54. Saeedi-Boroujeni A, Mahmoudian-Sani MR, Bahadoram M, Alghasi A. COVID-19: A case for inhibiting NLRP3 inflammasome, suppression of inflammation with curcumin? Basic Clin Pharmacol Toxicol 2021;128:37-45.
55. Soleimani V, Sahebkar A, Hosseinzadeh H. Turmeric (*Curcuma longa*) and its major constituent (curcumin) as nontoxic and safe substances: Review. Phyther Res 2018;32:985-95.
56. Ghaneifar Z, Yousefi Z, Tajik F, Nikfar B, Ghalibafan F, Abdollahi E, *et al*. The potential therapeutic effects of curcumin on pregnancy complications: Novel insights into reproductive medicine. IUBMB Life 2020;72:2572-83.
57. Prasad S, Tyagi AK, Aggarwal BB. Recent developments in delivery, bioavailability, absorption and metabolism of curcumin: The golden pigment from golden spice. Cancer Res Treat 2014;46:2-18.
58. Qureshi M, Al-Suhaimi EA, Wahid F, Shehzad O, Shehzad A.

Therapeutic potential of curcumin for multiple sclerosis. Neurol Sci 2018;39:207-14.

59. Davis BM, Pahlitzsch M, Guo L, Balendra S, Shah P, Ravindran N, *et al*. Topical curcumin nanocarriers are neuroprotective in eye disease. Sci Rep 2018;8:11066.
60. Kohli K, Ali J, Ansari MJ, Raheman Z. Curcumin: A natural antiinflammatory agent. Indian J Pharmacol 2005;37:141-7.
61. Fan C, Song Q, Wang P, Li Y, Yang M, Yu SY. Neuroprotective effects of curcumin on IL-1β-induced neuronal apoptosis and depression-like behaviors caused by chronic stress in rats. Front Cell Neurosci 2018;12:516.
62. Mohammadian M, Moghaddam AD, Almasi L, Bohlooli S, Sharifan A. The enrichment of emergency food rations with complexes made of curcumin/quercetin-whey protein nanofibrils to improve their antioxidant activity. J Food Bioprocess Eng 2021;4:63-8.
63. Li G, De Clercq E. Therapeutic options for the 2019 novel coronavirus (2019-nCoV). Nat Rev Drug Discov 2020;19:149-50.
64. Cox FF, Misiou A, Vierkant A, Ale-Agha N, Grandoch M, Haendeler J, *et al*. protective effects of curcumin in cardiovascular diseases-impact on oxidative stress and mitochondria. Cells 2022;11:342.
65. Grabowska W, Kucharewicz K, Wnuk M, Lewinska A, Suszek M, Przybylska D, *et al*. Curcumin induces senescence of primary human cells building the vasculature in a DNA damage and ATM-independent manner. Age (Dordr) 2015;37:9744.
66. Grabowska W, Mosieniak G, Achtabowska N, Czochara R, Litwinienko G, Bojko A, *et al*. Curcumin induces multiple signaling pathways leading to vascular smooth muscle cell senescence. Biogerontology 2019;20:783-98.
67. Yang L, Shi J, Wang X, Zhang R. Curcumin alleviates d-galactose-induced cardiomyocyte senescence by promoting autophagy via the SIRT1/AMPK/mTOR pathway. Evid Based Complement Alternat Med 2022;2022:2990843.
68. Powell-Wiley TM, Poirier P, Burke LE, Després JP, Gordon-Larsen P, Lavie CJ, *et al*. Obesity and cardiovascular disease: A Scientific statement from the American Heart Association. Circulation 2021;143:e984-1010.
69. Guo S, Long M, Li X, Zhu S, Zhang M, Yang Z. Curcumin activates autophagy and attenuates oxidative damage in EA.hy926 cells via the Akt/mTOR pathway. Mol Med Rep 2016;13:2187-93.
70. Li H, Sureda A, Devkota HP, Pittalà V, Barreca D, Silva AS, *et al*. Curcumin, the golden spice in treating cardiovascular diseases. Biotechnol Adv 2020;38:107343.
71. Panahi Y, Kianpour P, Mohtashami R, Jafari R, Simental-Mendía LE, Sahebkar A. Curcumin lowers serum lipids and uric acid in subjects with nonalcoholic fatty liver disease: A randomized controlled trial. J Cardiovasc Pharmacol 2016;68:223-9.
72. Morimoto T, Sunagawa Y, Kawamura T, Takaya T, Wada H, Nagasawa A, *et al*. The dietary compound curcumin inhibits p300 histone acetyltransferase activity and prevents heart failure in rats. J Clin Invest 2008;118:868-78.
73. Ahuja S, Kohli S, Krishnan S, Dogra D, Sharma D, Rani V. Curcumin: A potential therapeutic polyphenol, prevents noradrenaline-induced hypertrophy in rat cardiac myocytes. J Pharm Pharmacol 2011;63:1604-12.
74. Chowdhury R, Nimmanapalli R, Graham T, Reddy G. Curcumin attenuation of lipopolysaccharide induced cardiac hypertrophy in rodents. ISRN Inflamm 2013;2013:539305.
75. Zhang HA, Kitts D. Turmeric and its bioactive constituents trigger cell signaling mechanisms that protect against diabetes and cardiovascular diseases. Mol Cell Biochem 2021;476:3785-814.
76. Ghosh S, Banerjee S, Sil PC. The beneficial role of curcumin on inflammation, diabetes and neurodegenerative disease: A recent update. Food Chem Toxicol 2015;83:111-24.
77. Ray A, Rana S, Banerjee D, Mitra A, Datta R, Naskar S, *et al*. Improved bioavailability of targeted Curcumin delivery efficiently regressed cardiac hypertrophy by modulating apoptotic load within cardiac microenvironment. Toxicol Appl Pharmacol 2016;290:54-65.
78. Li X, Fang Q, Tian X, Wang X, Ao Q, Hou W, *et al*. Curcumin attenuates the development of thoracic aortic aneurysm by inhibiting VEGF expression and inflammation. Mol Med Rep 2017;16:4455-62.
79. Karuppagounder V, Arumugam S, Giridharan VV, Sreedhar R, Bose RJ, Vanama J, *et al*. Tiny molecule, big power: Multi-target approach for curcumin in diabetic cardiomyopathy. Nutrition 2017;34:47-54.
80. Tabeshpour J, Hashemzaei N, Sahebkar A. The regulatory role of curcumin on platelet functions. J Cell Biochem 2018;119:8713-22.
81. Kalani A, Kamat PK, Kalani K, Tyagi N. Epigenetic impact of curcumin on stroke prevention. Metab Brain Dis 2015;30:427-35.
82. Yang C, Zhang X, Fan H, Liu Y. Curcumin upregulates transcription factor Nrf2, HO-1 expression and protects rat brains against focal ischemia. Brain Res 2009;1282:133-41.
83. Wu J, Li Q, Wang X, Yu S, Li L, Wu X, *et al*. Neuroprotection by curcumin in ischemic brain injury involves the Akt/Nrf2 pathway. PLoS One 2013;8:e59843.
84. Kuhad A, Chopra K. Curcumin attenuates diabetic encephalopathy in rats: Behavioral and biochemical evidences. Eur J Pharmacol 2007;576:34-42.
85. Lan C, Chen X, Zhang Y, Wang W, Wang WE, Liu Y, *et al*. Curcumin prevents strokes in stroke-prone spontaneously hypertensive rats by improving vascular endothelial function. BMC Cardiovasc Disord 2018;18:43.
86. Dong HJ, Shang CZ, Peng DW, Xu J, Xu PX, Zhan L, *et al*. Curcumin attenuates ischemia-like injury induced IL-1β elevation in brain microvascular endothelial cells via inhibiting MAPK pathways and nuclear factor-κB activation. Neurol Sci 2014;35:1387-92.
87. Miao Y, Zhao S, Gao Y, Wang R, Wu Q, Wu H, *et al*. Curcumin pretreatment attenuates inflammation and mitochondrial dysfunction in experimental stroke: The possible role of Sirt1 signaling. Brain Res Bull 2016;121:9-15.
88. Xie CJ, Gu AP, Cai J, Wu Y, Chen RC. Curcumin protects neural cells against ischemic injury in N2a cells and mouse brain with ischemic stroke. Brain Behav 2018;8:e00921.
89. Lu Z, Liu Y, Shi Y, Shi X, Wang X, Xu C, *et al*. Curcumin protects cortical neurons against oxygen and glucose deprivation/reoxygenation injury through flotillin-1 and extracellular signal-regulated kinase1/2 pathway. Biochem Biophys Res Commun 2018;496:515-22.
90. Ranjan S. SHG Federation to Cultivate Lakadong Turmeric. Quarterly Newsletter on SHG Movement in Meghalaya. Meghalaya: Govt. of Meghalaya; 2006. p. 1-2.
91. Jha AK, Deka BC. Present Status and Prospects of Ginger and Turmeric in the NE States. Meghalaya: ICAR Research Complex for NEH Region; 2012.
92. Ram S, Dympep A, Passsah S, Feroze SM, Choudhury A, Kumar S, *et al.* Value chain analysis of Lakadong turmeric in Meghalaya: A micro-level study. Agric Econ Res Rev 2020;33:239-49.
93. Ghosal S. Agri Tech Firm AgNext to Assess Lakadong Turmeric using Curcumin Testing Technology. India: The Economic Times; 2021.
94. Daimei P, Kumar Y, Sheikh N, Paduna NL, Pfoze P. The finest Lakadong variety of turmeric from the Jaintia Hills of Meghalaya, India. Pleione 2012;6:141-8.
95. Janani P, Devi MB, Devi B, Divya P. Lakadong turmeric the golden spice of Meghalaya. Kerala Karshakan 2019;1:286-8.
96. The Economic Times. Meghalaya Exports Turmeric, Ginger Powder to Netherlands, UK. India: The Economic Times; 2021.
97. FAO. Addressing Marketing and Processing Constraints that Inhibit Agrifood Exports: A Guide for Policy Analysts and Planners. Rome, Italy: FAO; 2005. p. 1-129.

98. Abd El-Hack ME, El-Saadony MT, Swelum AA, Arif M, Abo Ghanima MM, Shukry M, *et al*. Curcumin, the active substance of turmeric: Its effects on health and ways to improve its bioavailability. J Sci Food Agric 2021;101:5747-62.
99. Jyotirmayee B, Mahalik G. A review on selected pharmacological activities of *Curcuma longa* L. Int J Food Prop 2022;25:1377-98.
100. Baral S, Luitel G, Shrestha A, Basnet B. Production and marketing of turmeric (*Curcuma longa*) in Sunsari District, Nepal. Arch Agric Environ Sci 2021;6:556-62.
101. Chhetri GB, Devkota D, Sharma B. Value chain analysis of turmeric subsector in Surkhet district of Nepal. Int J Agric Invent 2020;5:16-24.
102. Industry Report. Curcumin Market Share Forecasts; 2021. Curcumin Market Size, By Application (Pharmaceutical, Food, Cosmetics), Industry Analysis Report, Regional Outlook, Application Development Potential, Covid-19 Impact Analysis, Price Trend, Competitive Market Share & Forecast, 2021 – 2027. Report ID: GMI788. p. 160. Available from: https://www.gminsights.com/industry-analysis/curcumin-market
103. Industry Report. Curcumin Market Size, Share, Industry and Forecast 2029; 2021. Report ID: 978-1-68038-431-4. p. 120. Available from: https://www.grandviewresearch.com/industry-analysis/turmeric-extract-curcumin-market.
104. Mohd M. With Drone Payload Delivery, Meghalaya's Lakadong Turmeric's Market Linkage Gets Afi Llip; 2022. Available from: https://ruralmarketing.in/stories/with-drone-payload-delivery-meghalayas-lakadong-turmerics-market-linkage-gets-a-fillip/
105. Ministry of Commerce and Industry. One District One Product (ODOP) Mission of Centre takes a Giant Technology Boost. Delhi: PIB; 2022.
106. Ngachan SV. Huge Potential for Turmeric in North East. India: The Hindu; 2011.

How to cite this article:
Ray MK, Santra DK, Mishra PK, Das S. Indigenous Lakadong turmeric of Meghalaya and its future prospects. J App Biol Biotech. 2023;11(5):133-142. DOI: 10.7324/JABB.2023.11516-1