



Quality Analysis and Critical Control Points (QACCP) for Sustainable Value Chain of Bhutan Organic Black Tea

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Abstract— Black tea is a health drink rich in polyphenolic compounds with antioxidant properties, making it a beverage that represents the culture of both in Europe and Asia. Black tea is an economically significant product in Bhutan, as it is a community-based product under the *One Gewog One Product (OGOP)* initiative. Therefore, black tea represents the Bhutanese and reflects the process of selecting tea leaves and processing them using the Orthodox method. This research developed a system called the *Quality Analysis of Critical Control Points (QACCPs)* to control the quality of tea leaves from the plantation to be processed black tea. The study methodology was divided into three parts: 1) studying the community context, 2) studying the value chain of black tea and 3) applying QACCP based on risk analysis and screening quality to avoid potential hazards in the tea production process. The study found that the black tea produced by the Samcholing Tea Cooperation is made from an organic farming system, with the involvement of women in harvesting, withering, rolling, fermenting, and drying the tea, all of which are critical quality control points. The study also emphasized controlling hazards from physical contaminants such as stones, soil, and wood. An important value of the tea produced from this source is the promotion of women's empowerment through the development of supplementary careers in black tea processing, along with the establishment of a national tea learning center.

Keywords— Bhutan; organic black tea; value chain; sustainability; QACCP

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I. INTRODUCTION

Bhutan is a country located in the Eastern Himalayas, with an average elevation of 1,400 meters above sea level. The high altitude of the country makes it suitable for growing cold-weather crops such as apples, oranges, chillies and tea. Among these, tea is a popular beverage in Bhutan and in many other countries in Asia. Bhutan tea preparation has its unique characteristics. *Suja*, or butter tea, is a tea mixed with salt and butter. The butter, which is rich in fat, provides energy to the body during the cold winter months in the Himalayan region, where temperatures range from 9 to 22 degrees Celsius year-round. *Suja* is a staple drink at celebrations like Losar (Bhutanese New Year), weddings, or other religious events [1].

The value of Bhutan tea lies in its origin and the cultivation methods used. According to historical records, in the early 1950s, His Majesty Jigme Wangchuck (1905–1952), Bhutan's second king, planted Darjeeling tea seeds around his summer palace in Samcholing, located in the Trongsa district of Bhutan. Since 2011, the potential of this tea has been recognized, particularly for processing green tea [2] and later extending to black tea (**Figure 1**). The cultivation process in this area follows organic agricultural practices, ensuring the safety of the soil and water, benefiting both the members of the Samcholing Tea Cooperation and their customers.



Fig. 1 Bhutan organic tea products
(a) green tea and (b) black tea

Additionally, tea cultivation helps maintain the forest ecosystem sustainably, contributing to Bhutan's recognition as the world's first carbon-negative country. As a result, Bhutan is renowned globally as a leader in forest and biodiversity conservation, with nearly 70% of its land area covered by forests [3]. Tea industry promotes occupations within the community by having products sold under the name of OGOP as envisioned by Her Majesty Queen Jetsun Pema (The Queen of Bhutan)

Currently, Bhutan tea products exhibit a variety of traditional green tea production techniques, enhanced by the addition of valuable botanical ingredients such as cordyceps and shiitake mushrooms. Additionally, the tea production has been adapted to create Oolong and black tea. The black tea produced in Bhutan uses the *Camellia sinensis* var. *assamica* variety, which undergoes the orthodox production, consisting of four main steps: withering, rolling, oxidation, and drying. These steps are crucial to the final quality of the black tea, which is determined by factors such as moisture content, microorganisms (*Salmonella*, *Staphylococcus aureus*), phytochemicals (such as caffeine and catechins), including the color, aroma, flavor, and sensory characteristics [4]. Ensuring the safety of the tea from foreign contaminants such as stones, sand, plastic debris, and sharp wood is also critical. Therefore, tea standards require that small-scale tea farmers with micro-factories adopt quality control systems to ensure that their products are accepted in the international market.

QACCP is an advanced quality management system for analyzing critical control points related to quality control. It covers sensory characteristics, nutritional value, phytochemistry, and health. In the first study in European countries, this system has been developed organic carrots for use in processing baby food, starting from carrot production in the field to processing, transportation, storage, and consumption. The key points in quality control regarding the phytochemistry of carrots are lutein, alpha-carotene, and beta-carotene, as well as color values (L^* , a^* , b^*) and biomarkers of health (immune defense, antioxidant status, food bioavailability). Therefore, QACCP involves a multidisciplinary team (consumer science, agriculture, food technology, nutrition, health) [5].

QACCP integration with the HACCP system involves the analysis of critical control points for safety hazards from physical, chemical, and microbial dangers. The integration

follows the seven principles of the system: 1 Hazard (and quality) analysis and determining control measures 2 Identifying critical control points for hazard (and quality) control 3 Setting critical limits for each critical control point for hazards and quality 4 Establishing systems to monitor the control of critical points for hazards and quality 5 Defining corrective actions 6 Setting procedures for verification 7 Determining methods for document and record keeping For applying these two systems to Small and Medium Enterprises (SMEs), it is necessary to have GHPs as the basic system, which includes the following: 1 Primary production (agriculture, livestock, and fisheries) 2 Design of facilities and equipment in the workplace 3 Training and competence 4 Maintenance of the workplace 5 Cleaning, disinfection, and control of pests 6 Personal hygiene and work control 7 Product information and consumer education 8 Transportation [6-7]. The Integration of QACCP with HACCP and GMP enhances consumer trust, improves productivity, and supports sustainable agricultural practices in the organic black tea industry.

The production of black tea involves several key steps that determine the quality of the final product, such as tea leaf harvesting, withering, rolling, fermenting, drying, and the conditions under which the tea is stored. These steps are influenced by factors such as temperature, relative humidity, and time [8-11]. Therefore, controlling the quality of black tea through the application of the QACCP system is crucial for establishing a structured process, maintaining its premium taste and authenticity while reducing risks.

In this research, a QACCP system for organic black tea from Bhutan has been designed, linking it with the HACCP and GHPs systems. This aims to provide guidelines for controlling the black tea production, which is part of the sustainable value chain of the OGOP product.

II. MATERIAL AND METHODS

This research is a qualitative study based on a case study from the Samcholing Tea Cooperation, Drakten Gewog, Trongsa district, Bhutan (Figure 2), during the 2024-2025 period, as it is an organic tea production source for the OGOP project. The tea heritage is known as *the Valley of the Kings*. This systematic study is divided into three phases, as follows:



Fig. 2 the Samcholing Tea house, Drakten Gewog, Trongsa district, Bhutan

A. Preliminary study

Using structural questionnaires and interviews with female members of the organic tea production group regarding: 1 Responsibilities, including harvesting, tea processing, packaging, and marketing, establishing a working group to implement the QACCP system. 2 Product information 3 The black tea production 4 A layout diagram of the production site and 5 quality issues.

B. The analysis of the sustainable value chain

The community business of Bhutan tea using the framework of *The Triple Layered Business Model Canvas* [12], which consists of three layers: Economic layer, Environmental life cycle layer, and Social stakeholder layer. The QACCP team used the business model to design the sustainable value chain for Bhutan organic black tea.

C. Designing the QACCP system to connect with the HACCP and GHPs systems to produce organic black tea

The design of the organic black tea production framework integrates quality control management of black tea through QACCP (establishing, QCPs), risk reduction of hazards in black tea through HACCP (establishing, CCPs), and maintaining good hygiene practices in black tea production through GHPs (establishing SOPs), as shown in Figure 3. The process of creating criteria for screening using various systems is based on initial study data combined with previous research, as well as field studies and consultations with production teams, quality control, and assurance departments from GMP-certified tea processing enterprises (Doi Tung Top Tea) and HACCP-certified tea processing factories (Sermluk Thai Tea Co., Ltd.), with two locations in Chiang Rai, Thailand. These insights were used to screen and select the appropriate control systems for Bhutan organic black tea throughout the tea supply chain, as follows:

GHPs are a basic program used to control environmental factors in the production of black tea at the Samcholing Tea Cooperation, such as production locations, equipment and machinery, operators, transportation systems for raw materials and products, and labelling information. These factors do not directly address the quality and safety of black tea. In this study, the principles of risk analysis were adapted according to the method of Ahmad *et al.* [7], by considering the severity level of health hazards in black tea and their impact on the sensory quality of the product, based on the product sales history or consumer complaints. This is referred to as Severity (*S*), with four levels as shown in Table 1. This was then considered alongside the probability of health hazards and product quality non-acceptance, referred to as Probability (*P*), also with four levels as shown in Table 2. The result of multiplying *S* and *P* is used for an estimated method of assessment. If the *SxP* value is less than 8, it indicates that the risk is not significant to health hazards and product quality, and it can be managed through flowing SOPs.

HACCP is the most critical program for managing hazards that cannot be controlled by GHPs. This program requires identifying critical control points, control measures, critical control limits, monitoring processes, corrective actions, and responsibilities for recording the process. The classification process uses modifications from the seven logical approaches [7], where 7 variables (A-G) are assigned 3 scores (low, medium, high). The scores for all 7 variables are then totaled, and if the total score falls within the range of 17-21 points, it indicates that the hazard has a significant impact on consumer health. In this case, the hazard must be controlled using CCPs. The CCP decision tree, according to the CODEX guidelines (2023), is used to confirm that potential hazards in the organic black tea production are significant.

QACCP is a program used to manage the quality of black tea, focusing on its unique characteristics that affect sensory attributes, such as moisture, chemical compounds (caffeine, catechins), color, aroma, taste, contamination with tea stems, and small foreign objects that are not harmful to health. It also includes controlling the origin of the tea, pesticide residues not exceeding organic agriculture standards. If the producer fails to establish and control the production conditions at various stages throughout the production chain, the product will be rejected by consumers, which negatively affects the product's credibility. Therefore, the total score according to the seven logical approaches is less than 17, and it is determined to be controlled through QCPs.

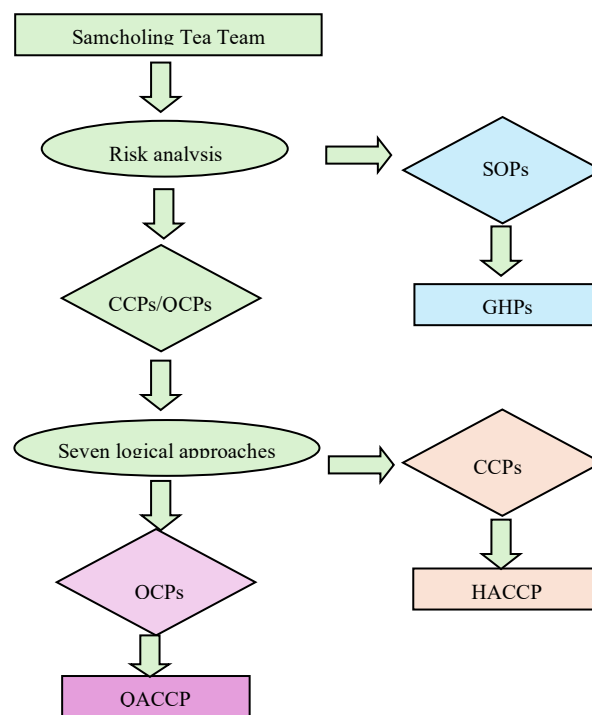


Fig. 3 Integration systems of organic black tea through QACCP, HACCP and GHPs

TABLE 1
 EVALUATION OF THE SEVERITY LEVEL (S) OF HEALTH HAZARDS AND QUALITY REJECTION OF BLACK TEA

Category	Criteria	Score
Limited	The control of the production environment does not meet standards and has never had a history of causing serious health risks or impacts on black tea quality.	1
Moderate	The control of the production environment meets standards and has a history of causing serious health issues, such as reported illnesses by consumers, or black tea quality impacts, such as sensory acceptability or contamination with foreign materials that do not affect health but are still accepted by consumers without complaints.	2
Serious	The control of the production environment meets standards and has an impact on health, affecting the immune system, causing allergies, medical visits, or illnesses that require rest and treatment. It may also lead to product quality issues, such as falling tea standards, consumer complaints about quality, or product returns.	3
Very serious	The control of the production environment meets standards and impacts health, affecting the immune system to the extent that medical treatment and rest are required, causing chronic diseases, disability, or even death. It may also affect product quality, such as falling tea safety standards, leading to lawsuits between consumers and producers, which may result in both temporary and permanent cessation of production.	4

TABLE 2
 EVALUATION OF THE PROBABILITY LEVEL (P) OF HEALTH HAZARDS AND QUALITY REJECTION OF BLACK TEA

Category	Criteria	Score
Very small	The risk of harm is very minimal, and if any hazards exist, there are subsequent steps in production to reduce the risks to a level that does not impact health, with a minimal effect on quality during production or on the final product.	1
Small	Health hazards may occur 1-2 times within a year, or there may be changes in product quality during production that deviate from the standards or scientific/research references, but these can still be corrected and adjusted back to the original standards.	2
Medium	Health hazards may occur 1-2 times within a 6-month period, or there may be a noticeable change in quality during production that deviates from the standards, requiring the product to be withheld from distribution because production cannot be corrected or adjusted to meet the original standards. However, the final product may be blended with other tea products for sale.	3
High	Health hazards occur frequently, almost every time during production. If production is not strictly controlled, it will significantly degrade the quality during processing, to the point where it cannot proceed to the next stage. As a result, the final product will not meet standards, and consumers will be affected.	4

TABLE 3
 VARIABLES OF SEVEN LOGICAL APPROACHES FOR CLASSIFICATION HACCP AND QACCP [7]

Variable	Criteria
A	The impact of the identified food safety hazards in relation to the level of control applied
B	The practicality of monitoring, such as the ability to track it promptly to allow for immediate corrective actions
C	The position of the control measure within the overall system compared to other measures
D	The likelihood of failure in the control measure or considerable variations in the processing
E	The serious consequences if the control measure fails
F	Whether the control measure is specifically designed and implemented to eliminate or significantly reduce the hazard level
G	Synergistic effects, meaning the interaction between two or more measures that results in a combined effect greater than the sum of their individual effects

The information for evaluating the risks of black tea (consumer safety and quality acceptance according to manufacturer standards) is based on the calculated scores from the severity of health impact on consumers and the frequency of occurrence in the product. These scores are then integrated into control systems, including the basic GHPs system, hazard risk control, and quality loss management systems, using HACCP and QACCP, respectively.

III. RESULT AND DISCUSSION

D. Preliminary study

This study at the Samcholing Tea Cooperation discusses three main issues: the cooperation members, the products, and the process as follows:

The group consists of 35 female members, aged between 25 and 65. Their responsibilities include: harvesting tea leaves and applying organic fertilizers to nourish the tea plants, processing the harvested tea leaves into black tea, packaging the processed black tea and labeling it, displaying the products at local festivals and in OGOP shops. The key needs identified from the group include training in proper hygiene and food safety practices, improving the quality and safety of the processed tea, procuring machinery and equipment for tea production, acquiring expertise from OGOP in quality and safety systems to establish an international standard tea production.

The black tea produced at Samcholing consists of dry tea leaves, which are black in color and free from visible mold. Laboratory tests revealed that the tea contains 8.52% tea stems (an adulteration), 5.86% moisture, 12.16% caffeine and no physical impurities. The tea is packaged in plastic zip-lock bags, with a weight of 60 grams. It should be stored in a dry place, away from light and moisture, at an ambient temperature. For brewing, 10 grams of black tea should be weighed, and 150 milliliters of hot water at 90°C should be added, then wait for 2-3 mins. The tea leaves should then be strained, and the tea can be consumed for enjoyment. The target consumer age range is 18 to 80 years. The product is transported by truck to be sold at OGOP shops in Paro Airport and Thimphu.

The process of Samcholing black tea begins with the harvesting of tea leaves during the appropriate season, which is from March to October. This is the period when the daytime temperature in Trongsa city ranges from 10-18°C. Harvesting is done by the labor of handpicking members before noon. The young tea buds and leaves 1 and 2 are collected (sometimes up to 3rd and 4th leaves), placed into baskets, and quickly weighed as fresh tea leaves. The fresh leaves are then left to reduce moisture for 16 hours overnight. After that, the leaves are rolled for 4 hours. Afterward, the tea is withered again for an additional 2 hours until the leaves are turned reddish and then they are roasted in a pan at a temperature of 200°C for 20

minutes. Additional roasting is done according to the moisture level. The tea is then left to wither for the third time for 2-3 hours. It is then oxidized in plastic bags with the tops tightly sealed for 2 days. After oxidation, the tea leaves are dried in a dehydrator at 110°C for 30 minutes. The dried leaves are visually sorted for foreign objects, weighed at 60 grams, and then packed into sealed bags for storage and transport.



Fig. 4 The 15 stages of Samcholing black tea processing

E. The analysis of the sustainable value chain

In summary, this black tea process is adapted from the Orthodox method, with added steps of rolling the tea leaves and withering them twice, along with roasting the tea to reduce moisture and mold growth before withering and oxidation. The

entire process, from harvesting to packaging the black tea, takes about 3 days. However, if a withering machine is used, which blows air to dehydrate during the withering process and speeds up drying, the tea can then be oxidized. The process is overviewed in **Figure 4**.

The value chain of black tea production in Bhutan explains the overall process at the Samcholing Tea Cooperation, starting from tea planting to the final step of delivering the product to customers. The analysis is classified into primary activities, starting with 1) inbound logistics, which is the importation of organic tea leaves, followed by 2) operations, which involve processing the black tea leaves as detailed, and 3) outbound logistics, where the finished products are delivered to OGOP shops. This is followed by 4) marketing and sales, which involve selling to tourists, and 5) service, which provides product information. Activities 1-3 use the QACCP system to maintain the quality of the black tea. Additionally, black tea production includes four supporting activities: 1) sourcing production materials, such as packaging, 2) developing technology and research for black tea quality control, 3) human resource management related to the implementation of the QACCP system among tea producers, and 4) developing producer groups, such as managing accounting and fairly distributing income to group members.

Community-based businesses are not only intended to generate income for members participating in various activities but also need to consider the sustainability of both the environment and society. The Triple Layered Business Model Canvas is an innovative tool used to manage the Samcholing Tea Cooperation, aligning with Bhutan's philosophy of Gross National Happiness (GNH). This includes the four pillars of GNH: sustainable and equitable socio-economic development, environmental conservation, preservation and promotion of culture, and good governance [13].

The business model of the Samcholing Tea Cooperation offers a value proposition of delivering high-quality black tea sourced

from Bhutan's organic production areas. The production activities are supported by the OGOP project, which provides the necessary resources for production, such as machinery and food standard training. The OGOP project acts as a community representative, marketing the products to customers under the concept of value addition to local products. Information is provided to customers through the website <https://ogop.bt/>, with the primary target audience being international tourists and foreign executives who visit Bhutan for government or business purposes.

The social model of the Samcholing Tea Cooperation brings social value to consumers by empowering women and farmers in the Samdrupcholing community. The group is led by a female chairperson and consists of more than 30 women members involved in the tea production process on an 80-hectare farm located at 1,800 meters near the Himalayan Mountain range. The tea farming activities contribute to improved livelihoods by providing women with income, serving as an example of opportunity for women in Bhutan to learn entrepreneurship and promote gender equality [14]. The progress of this women-driven business is communicated through the official website <https://samcholingteabhutan.com/>, which serves as a channel for customer engagement by sharing the story of the tea-growing area, activities at the tea learning center, and introducing the unique characteristics of the locally produced black tea. This tea is distinguished by its rich, full-bodied flavor, complex aromas of honey, dried fruits, and a delicate hint of spices, offering a warming and refined tea experience. Supporting the purchase or distribution of practices with systems like QACCP/GHPs, the community business benefits both sellers and buyers sustainably [15]. Community products promote women, elders, youths and farmers, as well as others in the community, such as students, young women, and tourists who visit to learn about Samcholing tea, its production, and quality control.

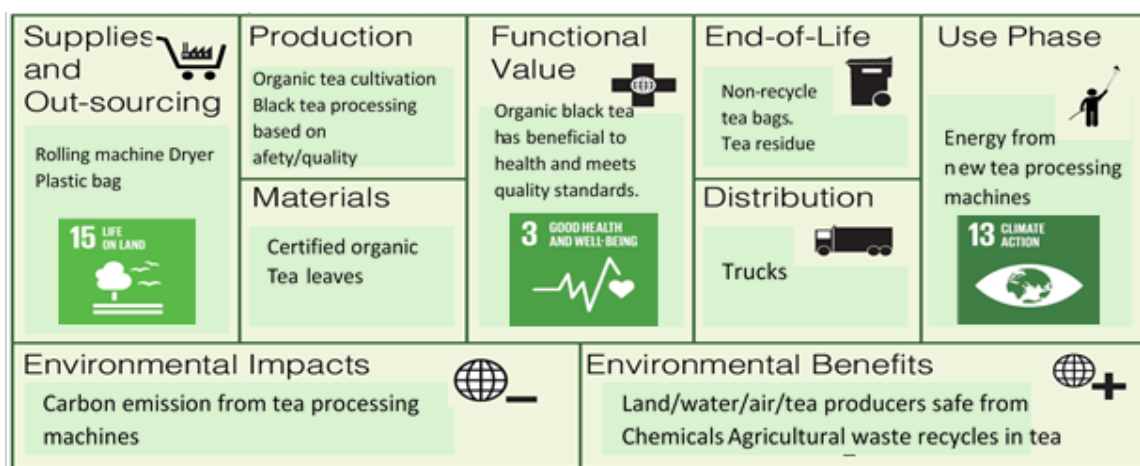


Fig. 5 Environmental life cycle Business Model Canvas of the Samcholing Tea Cooperation, Trongsa, Bhutan

The environmental life cycle of the Samcholing Tea Cooperation emphasizes its functional value, offering high-quality black tea with natural color, aroma, taste, and phytochemical properties, ensuring safety for both health and the environment. The government supports the production factors, including tea leaf rolling machines, drying cabinets, trainers who provide knowledge, and development of the production process based on QACCP/HACCP/GHPs principles. The OGOP project serves as the marketplace for community products, utilizing organic tea leaves from the community, which are grown according to *The Bhutan Organic Standard (BOS 02.2022)* [16]. The tea-growing areas are certified under national organic standards by *Bhutan Food and Drug Authority (BFDA)*. The production process minimizes environmental impact on soil, water, and air, with efforts to reduce energy consumption and carbon emissions during processing and transportation [17]. Additionally, promoting zero waste to prevent the triple planetary crisis of climate change, biodiversity loss, and pollution [18], while supporting the sustainable consumption of products through recycling and reuse [19]. This aligns with Bhutan's goal of achieving a carbon-neutral, environmentally benign, and high-performance food system by 2030, as summarized in **Figure 5**.

F. Designing the QACCP system to connect with the HACCP and GHPs systems to produce organic black tea

The Samcholing Tea Team collaborated to review the process of producing black tea (**Figure 4**) by comparing actual production and the flow of fresh tea leaves to dried tea leaves packaged in bags. In each of the 15 steps, control measures can be defined using three systems: GHPs, HACCP, and QACCP, respectively, using three tools (risk assessment, CCP decision tree, and 7-logical approaches). The results of the analysis are as follows:

The risk assessment of health hazards and quality rejection is the primary tool used to classify activities related to GHPs. The $S \times P$ value (less than 8) is used for this classification.

According to SOPs in **Table 4**, tea cultivation must not involve genetic modification, and the area should not use chemicals. The maintenance of tea plants should use natural products such as cow manure. Tea should be planted in areas interspersed with forests. An SOP for pest surveillance and record keeping should be established, with pest and weed control carried out through integrated pest management (IPM). Irrigation should be performed, and the tea plants should be pruned to a height of approximately 50 cm above the ground. The process of harvesting tea leaves includes transporting them to the processing facility, weighing the fresh leaves, inspecting foreign contaminants, and sorting out damaged leaves. The harvesting equipment, such as baskets, bags, and clean scales, should be used. The scales must be calibration to standard specifications once a year, and records should be kept.

Handwashing areas should be designated both in the tea garden and in the production building. Annual training should be conducted for the team responsible for maintaining the tea garden and harvesting the tea. Workers should wash their hands thoroughly. Wage considerations should align with working hours, and biodiversity should be preserved [19], with proper waste management from the tea garden.

In addition, *BFDA* has established the Bhutan general standard for food hygiene and Bhutan mandatory standard for labelling of prepackaged food [20,21] as the general standard for food production. According to the central regulations, these guidelines lead to practical implementation by checking compliance with the specific requirements for tea production [22]. The five critical steps in the tea production process include: withering, rolling, roasting, fermenting, and drying tea leaves. These steps must adhere to GHPs to reduce two main risks: microorganisms and foreign contaminants.

Microorganisms: Contamination can arise from production workers, machinery, and equipment that are not clean. Therefore, it is essential to clean areas such as the tea leaf withering area, fermenting area, rolling machines, drying machines, roasting pans, and bamboo trays. This includes washing floors, conveyor belts, and equipment.

Prevention of Foreign Contaminants: Measures should be in place to prevent foreign contaminants from machinery and equipment. This involves creating records for the usage of tools, monitoring conditions during use, and ensuring equipment maintenance to avoid malfunctions. Equipment must be functional and not pose risks to workers. Food-grade lubricants should be used. Regular calibration of moisture meters, relative humidity, temperature, and time monitoring should also be implemented.

Additionally, proper training in good hygiene practices should be provided, with a cleaning log for the production facility (including floors, walls, doors, ceilings, ventilation systems, and tables) and production equipment. Systematic training is essential, and clean, functional restrooms should be available, with access to clean water, handwashing agents, hand-drying equipment, and waste bins. After the production process, steps like sorting, weighing, and packaging should ensure appropriate lighting and calibrated scales. During storage and transportation, the products must be preserved properly to avoid degradation or damage of the finished tea product.

TABLE 4
 GHPs SCREENING DURING SAMCHOLING BLACK TEA PROCESSING FROM CULTIVATION TO DELIVERY TO OGOP SHOPS

Step	Health hazards and quality rejection	Form	Severity level (S)	Probability level (P)	SxP	GHP (YES/NO)	SOP
0 Tea cultivation	-Pesticide residue, heavy metals	-Physical hazard	2	1	2	YES	Organic farming and certification
	-Plant disease and insect infections	-Biological hazard	2	2	4	YES	Organic farming and certification
1 Plucking tea shoots	-Gravel, snails	-Physical hazard	2	2	4	YES	Inspection of fresh tea leaves
	-Caterpillars, human pathogens	-Biological hazard	1	2	2	YES	Personal hygiene control/pest surveillance
	-Plunk only bud, 1 st , 2 nd and 3 red leaves affects liqre colour, taste, flavour, and aroma	-Sensory characteristics	3	3	9	NO	
2 Transportation from garden to factory	-Damage of the plucked leaves by excessive pressing	-Physical damage	1	1	1	YES	Inspection of fresh tea leaves Tea container cleaning
3 Fresh tea weighting	-Foreign objects e.g. dust, stone	-Physical hazard	1	2	2	YES	Inspection of fresh tea leaves Tea container cleaning
	-Human pathogens	-Biological hazard	1	2	2	YES	Personal hygiene control
4 1st Withering	-Time and temperature are not suitable.to develop liqre colour, taste, flavour, arome	-Sensory characteristics	3	3	9	NO	
	-Foreign bodies (dust and stones)	-Physical hazard	2	2	4	YES	Inspection of dried tea leaves Floor/ceiling cleaning
	-Human pathogens and formation of mold due to inadequate drying	-Biological hazard	3	2	6	YES	Personal hygiene control
5 Rolling	-Metallic contamination	-Physical hazard	2	2	4	YES	Inspection of dried tea leaves/ Machine cleaning
	-Microbial growth, human pathogens	-Biological hazard	3	2	6	YES	Personal hygiene control
	-Rolling technique are not suitable.to develop liqre colour, taste, flavour, and aroma	-Sensory characteristics	3	3	9	NO	
6 2 nd Withering	-Time and temperature are not suitable.to develop liqre colour, taste, flavour, and aroma.	-Sensory characteristics	3	3	9	NO	
	-Foreign bodies (dust)	-Physical hazard	2	2	4	YES	Inspection of dried tea leaves Floor/ceiling cleaning
	-Human pathogens	-Biological hazard	1	1	1	YES	Personal hygiene control
7 Roasting (pan frying)	-Time and temperature are not suitable.to develop liqre colour, taste, flavour, and aroma.	-Sensory characteristics	3	3	9	NO	
	-Foreign bodies (dust)	-Physical hazard	2	1	2	YES	Inspection of dried tea leaves Machine cleaning
	-Human pathogens	-Biological hazard	2	1	2	YES	Personal hygiene control
8 3 rd Withering	-Time and temperature are not suitable.to develop liqre colour, taste, flavour, and aroma.	-Sensory characteristics	3	3	9	NO	
	-Foreign bodies (dust)	-Physical hazard	2	2	4	YES	Inspection of dried tea leaves Floor/ceiling cleaning
	-Human pathogens	-Biological hazard	1	1	1	YES	Personal hygiene control
9 Oxidation	-Time, temperature, and relative humidity are not suitable to oxidize polyphenolic compounds.	-Sensory characteristics	4	3	12	NO	
	-High moisture of oxidized tea, microbial growth,	-Biological hazard	3	2	6	YES	Inspection of dried tea leaves

Step	Health hazards and quality rejection	Form	Severity level (S)	Probability level (P)	SxP	GHP (YES/NO)	SOP
10 Drying	human pathogens						Floor/ceiling cleaning
	-Gravel, sand, sharp wood splinters, heavy metal	-Physical hazard	2	2	4	YES	Inspection of oxidized tea leaves
	-Time and temperature are not suitable to reduce moisture from tea leaves	-Mold growth	3	3	9	NO	
	-Foreign bodies (dust, iron rust)	-Physical hazard	2	2	4	YES	Inspection of dried tea leaves
11 Sorting	-Human pathogens	-Biological hazard	2	2	4	YES	Machine cleaning Personal hygiene control Pest control
	-Gravel, sand, sharp wood splinters, heavy metal Tea stalks	-Physical hazard -Adulteration	3	4	12	NO	
12 Weighting	-Human pathogens	-Biological hazard	2	2	4	YES	Personal hygiene control
	-The weight does not match the label.	-Deceiving buyers	4	2	8	NO	
13 Packing	-Human pathogens	-Biological hazard	1	1	1	YES	Personal hygiene control
	-Packing not sealed properly or leaked,	-Increased moisture	3	2	6	YES	Inspection of finished product
	-Incorrect or missing product information, such as the production date and expiration date	-Deceiving buyers	4	2	8	NO	Inspection of product labelling Recall procedure/consumer complaints
	-Contamination by migration of packaging objects	-Physical hazard	1	1	1	YES	Inspection of finished product
14 Storage	-Human pathogens	-Biological hazard	2	2	4	YES	Personal hygiene control
	-Proliferation of microorganisms	-Biological hazard	3	2	6	YES	Inspection of finished product
15 Transportation from Trongsa to OGOP	-Damage of the packaging by excessive pressing	-Physical damage	2	2	4	YES	Inspection of finished product Transportation control

TABLE 5

CCPs/QCPs SCREENING DURING SAMCHOLING BLACK TEA PROCESSING FROM CULTIVATION TO DELIVERY TO OGOP SHOPS

Step	Health hazards and quality rejection	Form	Seven logical approaches							Total score	CCP (YES)	QCP (Yes/No)
			A	B	C	D	E	F	G			
Plucking tea shoots	Plunk only bud, 1 st , 2 nd and 3 red leaves affects liqre colour, taste, flavour, and aroma	Sensory characteristics	1	2	2	2	1	1	1	10	NO	YES
Withering	Time and temperature are not suitable.to develop liqre colour, taste, flavour, arome	Sensory characteristics	1	3	1	2	3	1	3	14	NO	YES
Rolling	Rolling technique are not suitable.to develop liqre colour, taste, flavour, and aroma	Sensory characteristics	1	3	1	2	1	1	3	12	NO	YES
Roasting	Time and temperature are not suitable.to develop liqre colour, taste, flavour, and aroma	Sensory characteristics	1	2	1	2	1	1	3	11	NO	YES
Oxidation	Time, temperature, and relative humidity are not suitable to oxidize polyphenolic compounds		1	2	3	3	3	1	2	15	NO	YES
Drying	Time and temperature are not suitable to reduce moisture from tea leaves	Sensory characteristics	1	2	3	3	3	1	3	16	NO	YES
Sorting	Gravel, sand, sharp wood splinters, heavy metal	Physical hazard	3	3	3	3	3	3	1	19	YES	NO

Step	Health hazards and quality rejection	Form	Seven logical approaches							Total score	CCP (YES)	QCP (Yes/No)
			A	B	C	D	E	F	G			
	Tea stalks	Adulteration										
Weighting	The weight does not match the label.	Deceiving buyers	1	3	3	1	3	1	1	13	NO	YES
Packing	Incorrect or missing product information, such as the production date and expiration date	Deceiving buyers	1	3	3	1	2	1	1	12	NO	YES

TABLE 6
 QCPS/CCPs PLAN FOR SAMCHOLING BLACK TEA PROCESSING, TRONGSA, BHUTAN

Step	Quality	Critical limit	Monitoring procedure				Correction	Corrective action
			What	When	How	Who		
Plucking tea shoots	Sensory aspect	Plunk Bud and 1 st -3 rd leaves	Tea leaf picking	8.00 am-12.00 pm March to October	Hand picking	Harvesting team	Visual inspection	Sorting out, Instructions to Harvesting team
Withering	Sensory aspect	14-16 hrs./ 15-18 °C	Temp./time record	5-hours interval	Use a thermocouple/ a digital watch	Processing team	Withering conditions	Adjust time/temp.
Rolling	Sensory aspect	4 hrs./ 45 rpm/min. 15-22 °C	Time record	2-hours interval	Use a digital watch	Processing team	Rolling conditions	Adjust time/ Rolling time/temp.
Roasting	Sensory aspect	200°C/ 20 mins	Temp./time record	a batch interval	Use a thermocouple/ a digital watch	Processing team	Roasting conditions	Adjust time/ Rolling time/temp.
Oxidation	Sensory aspect	2 days/ 25 °C/ 95% RH No air leakage/ No mold	Time/temp./ RH record	a day interval	Use a digital watch/ a thermocouple/ an RH probe Visual inspection	Processing team	Oxidation conditions	Adjust time /temp/RH
Drying	Sensory aspect Moisture/caffeine/ Microbial standard	110°C/ 30 mins.	Temp./time record	a batch interval	Use a thermocouple/ a digital watch	Processing team	Drying condition Visual inspection	Adjust time/temp Re-dry, sorting out
Weighting	Food labelling standard	60+1 gram	Dried black tea weighting	Periodic inspection at each bag	Use a 1-digit digital balance	QC team	Weigh and repackage	Check the weight and calibrate the scale every year.
Packing	Food packaging Standard	No leakage	Dried black tea packing	Periodic inspection at each bag	Turning the bag upside down	QC team	Test by flipping the packaging to check for leaks	Inspect the packaging, such as for leakage, and the labeling before use
Step	Safety	Critical limit	Monitoring procedure				Correction	Corrective action
			What	When	How	Who		
Sorting	Physical hazard	No metal, gravel, or	Separate foreign contaminants	Periodic inspection at	Spread the dried black tea leaves	QC team	Visual inspection/ metal detection	Sorting out, instructions to processing team

Step	Quality	Critical limit	Monitoring procedure				Correction	Corrective action
			What	When	How	Who		
		tea stalk fragments were found		each batch	on a white table and then sort them Use a magnetic bar			



Fig. 6 Example of the information provided on a Bhutanese black tea pouch

As seen in **Table 5**, The Seven Logical Approaches is a tool used to classify steps that may pose risks of contamination in products, which are identified with CCPs, and distinguish them from steps that might deteriorate in product quality, identified with QCPs. It was found that the main hazard in black tea production in Bhutan is physical contaminants, such as gravel, metal fragments, large woodpieces, and sharp-ended tea stalks, which could be introduced from the planting fields through to the drying process. Therefore, sorting is identified as a critical step for removing these foreign contaminants. According to the CCP decision tree, this step is designed to screen and remove contaminants before the tea leaves are weighed and packaged. The Somchering team is responsible for inspecting every batch produced. Each batch, which weighs between 10-20 kilograms, undergoes sorting on a clean white table in a well-lit area beneath the packaging room. If larger production volumes are involved, a metal detector is used to enhance this CCP. This process ensures the removal of contaminants and confirms that tea leaves meet safety standards before further processing.

Table 6 shows QCPs, with 8 steps directly related to the quality of Bhutanese black tea. Previous research has indicated that product quality may be lost if not properly controlled by the QACCP team [5]. This could result in black tea not meeting sensory standards or leading to misleading product information provided to consumers. These steps can be divided into 3 groups as follows: Tea Leaf Harvesting, Orthodox Process, and Weighing and Packaging. This approach ensures that all critical quality points are monitored to maintain the high standards of the product. Details of these steps are as follows:

1. *Tea Leaf Harvesting*

Tea leaf harvesting is an important step that directly affects black tea taste and flavour. The tea variety, altitude, soil, water, and temperature all impact on the quality of tea leaves. Reports [11,23] show that the levels of caffeine, theaflavins, and thearubigins tend to increase in the bud, first and second young leaves, while the levels in older leaves (third to fifth leaves) decrease, which are important compounds that affect the flavour and aroma of black tea. In the plucking rounds during a 7-day period, the caffeine content reaches its peak and decreases when the round period is extended to 11 days. However, the levels of theaflavins and thearubigins increase. Therefore, to reduce the bitterness of black tea leaves of The Samcholing Tea Corporation, it is recommended to harvest the buds and leaves 1 to 3 and extend the harvesting round to 9-11 days, using hand plucking and collecting the leaves during temperatures between 18-24°C in May-August to prevent the leaves from wilting or getting damaged. To maintain the quality of fresh tea leaves, QCP by random checks harvested tea leaves must be conducted to ensure that they are not mixed with older leaves. If such leaves are found, they must be discarded, and the harvesting team should be trained to identify

the aroma and taste differences between fresh and aged black tea leaves for the Samcholing harvesting standard.

2. *Orthodox Process*

Withering affects the moisture content of fresh tea leaves, reducing it from 70-80% to 60-70%, and takes 12-14 hours. Withering enhances the aroma and flavor of the tea, including compounds like geraniol and linalool. The ideal temperature is around 22°C, and 14 hours is the optimal time. However, withering should not exceed 20 hours [24,25], as excessively low moisture will reduce the activity of the polyphenol oxidase enzyme (PPO) and cause the tea leaves to break during the rolling process. One technique to reduce moisture more quickly is using a fan to blow air or flipping the tea leaves to allow the moisture from the bottom of the leaves to evaporate more easily [26,27]. Therefore, the QCP must continuously monitor and record the time and temperature to ensure they stay within the specified range to prevent quality degradation.

Rolling the tea leaves to break the plant cells and increase the surface area results in the release of PPO, peroxidase, and catechins, which react during oxidation to form Theaflavins, which are associated with brightness and briskness. Meanwhile, Thearubigins contribute to the orange-brown color and flavor. The optimal temperature for rolling the tea leaves is between 10-25°C, with the first rolling process set for 4 hours and the second rolling for 2 hours. The rolling speed is set at 45 rotations per minute. Reports indicate that rolling the tea leaves twice enhances the release of enzymes and catechins[28]. Therefore, the QCP team must continuously monitor and record the time, rolling speed, and temperature to ensure that they stay within the specified range to maintain consistent aroma, color, and flavor in the black tea.

Roasting using Pan fixation of tea leaves is used to reduce excess moisture and enhance the color, aroma, and flavor of the rolled tea leaves by setting the temperature at 200°C for a short period of 20 minutes, which is higher than the typical range of 160-180°C [11]. In the case of Samcholing Black Tea, the goal is to quickly reduce the remaining moisture in the tea leaves, which can still be as high as 70% during the withering process, to minimize the risk of mold growth during oxidation. This step is crucial for quality; if the temperature and time during the pan-firing process are not controlled, prolonged exposure can inhibit the activity of the PPO enzyme, leading to incomplete oxidation of the black tea.

The oxidation process of tea leaves is a crucial step in determining the quality of black tea. The temperature is set between 20-30°C for 30-120 minutes, while maintaining the relative humidity at 95-98% and ensuring sufficient oxygen. Oxidation helps reduce the pH value from 5.5 to 4.5-4.8 [11]. By maintaining proper oxidation conditions and ensuring cleanliness during the process, the Processing team can prevent spoilage of the oxidized tea leaves. Over-oxidation can lead to undesirable sensory characteristics, such as a dull, dark color, and a lower amount of theaflavins.

Drying tea leaves helps reduce the moisture content to below 8% to prevent overoxidation during the storage of black tea. It has been reported that if the moisture content exceeds 11% (aw 0.61), there is a risk of *Escherichia coli* growth, making the tea unsafe for consumption. The QCP sets the temperature at 110 °C (usually within the range of 90-140 °C) for 25-30 minutes [11]. The temperature and drying time are monitored using a thermometer to measure the incoming air temperature of the dehydrator, and the tea leaves are dried once the temperature reaches the specified level.

An overview of the black tea process reveals that the Orthodox tea process is related to factors in quality control, including temperature, relative humidity, time, and rolling speed. These factors are involved in the changes of the PPO enzyme, which converts catechins into various aromatic and flavor compounds. Therefore, the QACCP team must monitor the processing conditions along with preventing physical hazards using HACCP and basic practical GHPs to maintain the quality of black tea according to the Samcholing tea standards.

3. Weighing and Packaging

Besides the quality of the black tea that has gone through the production process, packaging and product information are also QCPs aspects that tea producers must comply with legal requirements. For example, in here, the Bhutan mandatory standard for labelling of prepackaged food is mandated to display important information, such as the product name, ingredients, usage instructions, production location, production date, or expiration date, as well as contact information. Additionally, the net weight information must be verified to ensure it matches the label, as consumers may file complaints about quality. Similarly, the packaging that reaches the consumer must be sealed properly to prevent the black tea from deteriorating. The QACCP team must communicate any corrective actions to the production department before sending the products to wholesalers or directly to customers. Additionally, information about the health benefits of black tea [30-31] is provided by referencing academic publications to promote the marketing of community products to foreign customers.

IV. CONCLUSION

The QACCP system was designed to develop and maintain the high quality of Bhutan organic tea having the optimum nourishment, medicinal value, and wholesome taste. There are five main steps involved, starting with hand-picking the tea, tea withering, tea rolling, tea oxidation, and tea drying (and roasting). The QACCP is applied to mitigate risks in tea production under the HACCP system, with one key control point: sorting. Foreign materials must be removed from the dry tea before weighing and packaging. The system also requires adherence to basic GHPs, including SOPs for cleaning the production facility, cleanliness of equipment and machinery,

waste management, pest control, and hygiene training for staff. Additionally, QACCP is an intervention of black tea supply chain to sustain community business practices in terms of the environment by growing tea in certified organic farms and creating socially employment opportunities for women and providing learning resources for the community.

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CONFLICT OF INTEREST

Authors declare no conflict of interest to disclose. The authors confirm that no generative AI or AI-assisted tools were used in the preparation of this manuscript.

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