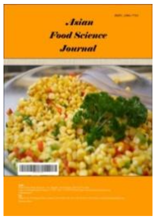

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HACCP Plan and Adoption of HACCP Metasystem in the Tea Industries of Bangladesh

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Authors' contributions

The work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

HACCP (Hazard Analysis and Critical Control Points) metasystem is a concept not much familiar to the tea industries of Bangladesh. This study was conducted to investigate the issue of food safety through HACCP metasystem and conduct a hazard analysis to make a comprehensive model of HACCP plan for the tea industries of Bangladesh. Both qualitative and quantitative data analysis was used to determine the CCPs (Critical Control Points) or OPRPs (Operational Pre-Requisite Programs) and design a HACCP plan through risk assessment and seven logical approaches. Two OPRPs and CCPs were determined. The derived CCPs were the biological hazard in the cultivation stage and the physical hazard in the processing step namely CTC (Crush, Tear and Curl) and Googy shifter step. The biological hazard in the cultivation stage can be controlled by proper application of GAP (Good Agricultural Practice) while the physical hazard can be controlled in the processing step by proper maintenance of the magnetic arrestor. Considering the benefits and constraints, standard processing procedures and guarantees of food safety of tea as well as to stay in the competitive global market the tea industries should adopt HACCP metasystem.

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Keywords: Tea industry; food safety; HACCP metasystem; CCPs; OPRPs.

1. INTRODUCTION

Tea is one of the most popularly consumed and the cheapest beverages in the world and ranks following to water [1]. This safe, mildly stimulating and delicately flavored brew is prepared from the young, tender leaves of a heterogeneous self-incompatible and cross-pollinated evergreen shrub *Camellia sinensis* [2,3].

For the time being, tea has been spread all over the world and become a leading cash crop in modern world agriculture with boosting production and of cultivating area [4] and today, Bangladesh has 166 commercial tea estates, including many of the world's largest plantations [5].

Few years back, Bangladesh was a leading tea producing and exporting country. But currently, it is stumbling in the global market to compete because of the poor quality of black tea. Significant growth of internal demand, lack of high yield varieties, backdated knowledge, poor technology, and uncertain hazardous processing units, etc. are the major findings concerning the loss of the potential tea industries of Bangladesh [6,7].

During the past two decades, public awareness and concern regarding food safety have increased both in developed and developing countries and as a result, the governments as well as respective food processing industries, are currently intensifying their efforts to improve the levels of food safety [8-11].

With respect to hazard and safety concern, HACCP is a systematic approach to food safety which identifies, evaluates and controls significant hazards throughout the whole chain of food production [12-16]. It is recognized essential for Food Safety Management System (FSMS) and necessary to concretize the GMP (Good Manufacturing Practices) and PRP (Pre-requisite Programs) measures on one hand and to look for additional hazards assessment and implementation of control measures through a company specific on the other hand [17-20].

Metasystem technique which defined as the process to assure quality on an ongoing process with periodic verification and certification by an unbiased third party has been increasingly adopted to assess the overall effectiveness of HACCP based FSM systems addressing a broad range of research questions with regard to food safety, presence of microbial contamination in foods, risk assessment of foodborne pathogens, occurrence of foodborne diseases, and barriers to implementation of FSM systems [21-25].

So to hold on the competitive international market and to meet the increasing demand as well as pressure created by various local (both private & public) and international institutions to ensure higher standard of food safety and quality and nutritional safety of the consumers there is no alternative to adopt and initialize a food safety management metasystem of HACCP in tea industries of Bangladesh [17,26].

As there having a less available information about physical, chemical and biological safety hazard analysis in all the processing steps from cultivation to storage as well as lack of sufficient research work on HACCP in tea Industries of Bangladesh therefore, present research work was intended to investigate the issue of food safety through HACCP meta system and conduct hazard analysis to make a comprehensive model of HACCP plan for the tea industries of Bangladesh.

2. MATERIALS AND METHODS

A systematic approach was carried out for hazard identification, assessment, and adoption of control measures for the tea industries of Bangladesh in 2016. Six different tea industries (Two governments and semi-government, two private national, two private multinational) were selected in this connection. These three types of industries were selected to get the overall idea about the status and the effectiveness of HACCP based FSM systems in tea industries of Bangladesh.

The approach required proper planning which started with the formation of a HACCP team [27]. In this study the HACCP team was formed with a number of HACCP experts and tea experts who conducted a series of face to face interviews based on a questionnaire reported by [28] with some modification with the managerial of the industries regarding quality assurance, which helped to justify the scenarios of the present condition of the industries to initialize HACCP meatsystem.

According to the approach hazard assessment, strategy to control hazard by combining PRPs, OPRPs and HACCP plan (By establishing CCPs) was established to construct a comprehensive HACCP metasystem model for tea industries of Bangladesh. The overall activities under the approach can be summarized as (Fig. 1).

2.1 Risk Assessment

The team assessed the risks of physical and chemical hazards after visiting, inspecting and interviewing with the managerial of different tea industries whereas the risk of potential biological hazards was assessed in both tea samples and ambiance of different processing steps (from cultivation to storage) by commencing necessary laboratory works at a microbiology laboratory. PDA (Potato Dextrose Agar) and SDA (Sabouraud Dextrose Agar) were used for microbial growth and the CFU (Colony Forming Unit) was determined in the both media.

The risk identified was assessed by the severity or the effect of the hazard in relation to the probability in which the hazard can occur in the end product if the considered specific control measures are not present or are failing to take into consideration the next steps in the process where an elimination or reduction to an acceptable level is possible and taking into consideration the existing correct implemented Pre-requisite Programs (PRPs). The risk was assessed by an estimated method reported by [29,30] with some modification by setting different levels of severity/effect and different levels of likelihood/probability, and by assigning a value to each level. The likelihood was evaluated based on the company's experience (historical background, customers' and consumers' claims and non-conformities) by establishing the following criteria (Table 1) whereas the severity was evaluated in response to human health according to (Table 2).

A hazard was considered significant if the probability (P) value by the severity (S) value ($P \times S$) was over 8. The hazards that were non-significant ($P \times S \leq 8$) did not move on to the next step in this study, and these hazards could be managed by the PRPs.

The Risks which were significant, the control measures were classified according to whether they could be managed through OPRPs or by the HACCP plan (by establishing CCPs). According to ISO 22000 the OPRPs contain the food safety hazard, control measure, monitoring procedures, corrective actions, responsibilities and monitoring records while the HACCP plan contains the identification of critical control points (CCPs), control measures, determination of critical limits for CCPs, monitoring procedures,

Table 1. Evaluation of probability (P) with their assigned value

Category	Criteria	Value
Very Small	Next step in the production process may eliminate or reduce the hazard to an acceptable level and limited and local contamination	1
Small	Absence of the general measures and the chance of hazard occurrence in the end product is very limited	2
Real	Failing or lacking of the specific control measure and hazard occurrence in the end product is in a certain percentage in the associated batch	3
High	Failing or lacking of the specific control measure result in a systematical error and high probability of hazard occurrence in all end products of the associated batch	4

Table 2. Evaluation of severity (S) with their assigned value

Category	Criteria	Value
Limited	The hazard can never reach a dangerous concentration	1
Moderate	The hazard can provoke only minor health problems	2
Serious	The hazard may provoke some health problems in immune-compromised/allergic individuals, or may involve medical consultation and has long term effect	3
Very Serious	The hazard may provoke significant problems, not only in immune-compromised/allergic individuals, but also in healthy people, which may involve hospitalization or potential chronic disease	4

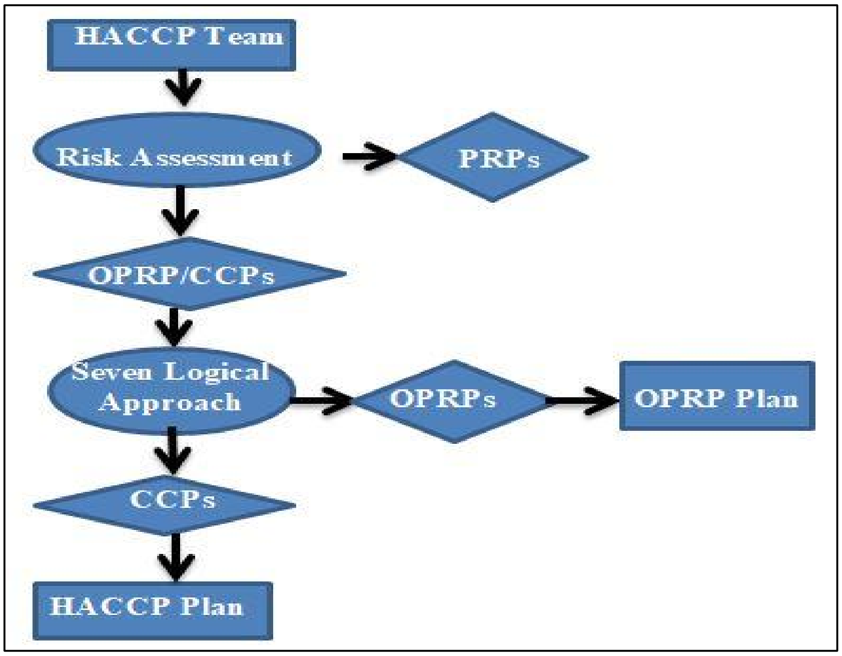

Fig. 1. A framework for collection and analysis of data to construct the HACCP plan for tea industries of Bangladesh

Table 3. Remarks of seven logical approaches according to [31]

Code	Variables/Remarks
a	Its effect on identified food safety hazards relative to the strictness applied;
b	Its feasibility for monitoring (e.g. ability to be monitored in a timely manner to enable immediate corrections);
c	Its place within the system relative to other control measures
d	The likelihood of failure in the functioning of a control measure or significant processing variability
e	The severity of the consequence(s) in the case of failure in its functioning
f	Whether the control measure is specifically established and applied to eliminate or significantly reduce the level of hazard(s);
g	Synergistic effects (i.e. interaction that occurs between two or more measures resulting in their combined effect being higher than the sum of their individual effects)

corrective actions, and responsibilities and monitoring records. The selection and categorization was carried out using the seven logical approaches that includes assessments concerning the following (Table 3).

Each control measure was scored for the seven variables. If the final score was > 17, it would be managed by the HACCP plan (by establishing CCP) and if the final score was < 17, it would be managed by OPRPs.

2.2 Statistical Analysis

Among the statistical tools of measures of dispersion, mode was used to calculate the risk assessment to identify the CCP's for the next phase of the full model of HACCP for the tea industries of Bangladesh. In the case of two or more mode values, the HACCP team preferred the maximum rating to consider every possible hazard.

3. RESULTS AND DISCUSSION

HACCP team had selected the factors according to their ideas regarding the adoption of HACCP metasystem. Then the mathematical percentage of the factors had been expressed by the HACCP team choosing in accordance with the types of benefits and constraints. Among the selected industries few industries follow their routine work which partially compliance with HACCP. Hence these were considered as partial implementers of HACCP metasystem while the rests weren't concern about similar types of activities relating to HACCP metasystem and in this regard, they were considered as non-commenced industries. The industries which had partially implemented and others were not implemented HACCP plan differed in different circumference such as in benefits, costs, market access, customer satisfaction and acceptance, income, quality, and shelf life, etc. parameters. According to the collected data, the benefits can be presented as profit oriented was 55%, technical efficiency oriented was 18% and human resource oriented was 27% (Fig. 2).

Wijayasiri and Jayaratne [32] reported that the benefits, better market access, gain of customer acceptance, reduction in waste and enhancement of efficiency increased with the implementation of HACCP metasystem in tea industries of Srilanka. Similar observation towards the improvement of overall quality performance, the efficacy of processing, recording and personnel hygiene was reported by Lokunarangodage, Wickramasinghe [33] in Srilankan tea industry.

Besides the benefits, the HACCP adopters faced various constraints. Here the utilization of the internal environment and monetary problems are found as the prominent obstacles (Fig. 3). Gajanayake, Jayasinghe-Mudalige [34] reported in case of Srilankan Tea processing Industries that training of employees conforms to HACCP plan and monetary issue and utilization of internal environment to allocate physical resources were the prime constraints faced by the HACCP adopters.

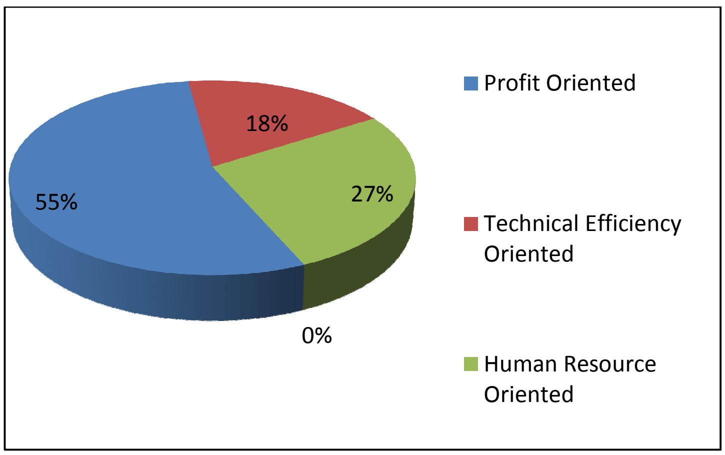

Fig. 2. Percentage of benefits by adopting HACCP in different tea industries of Bangladesh

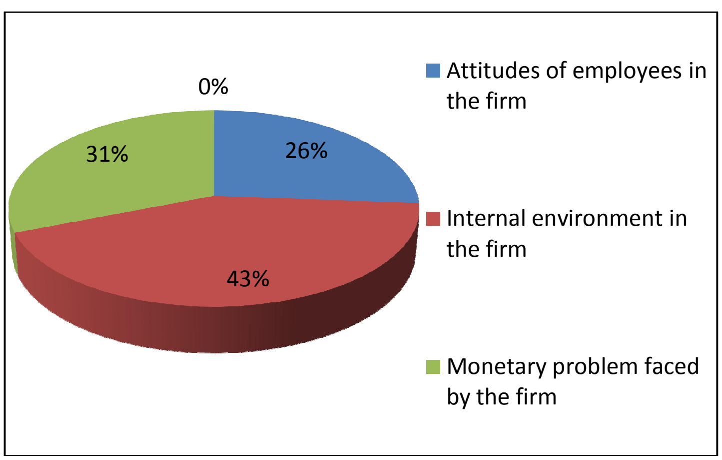

Fig. 3. Percentage of constraints faced by adopting HACCP in different tea industries of Bangladesh

3.1 Microbial Hazards in Different Steps of Tea Processing

The Graphs representing the Total Microbial load in CFU at the ambiance of the different section of tea from field to final Products (Fig. 4). It was observed that cultivation steps i.e. Nursery and Matured field possess on average 120 CFU and 115 CFU respectively hence the risk was prominent in this step. From the graphical representation (Fig. 4) it was observed that the drying and storage steps contained a lower amount in CFU. The reason might the presence of heating source and High temperature at the drying step. Whereas the outcomes were completely unsatisfactory for good quality tea as it exhibits the retention of the opportunity of the final product being contaminated by Biological hazards. The withering and rolling and fermentation step contained microbial load about 76 CFU and 81 CFU. But it was evident that for food safety purpose microorganism prevalence implies to negative impact. According to Mishra, Gautam [35] it was explored that during storage under high humidity, absorption of moisture may encourage fungal growth and result in quality loss of the product. Hence, in drying and grading as well as subsequent packaging and storage their existence should be zero. The load would be lower enough in every step of factory level, if there had adequate construction facilities, strict hygienic precautions, maintaining positive hydrostatic pressure at all times and others factors were correctly maintained according to the safety issue. Considering the necessary factors (Probability, Likelihood, occurrence and correcting action in following steps, etc.) the risk was determined by setting different values by the HACCP team and analyzed by above-mentioned strategy.

3.2 Risk Assessment and Control Strategies

The possible hazards identified in each step of the process along with their forms and P & S ratings were shown in (Table 4). Concerning the P×S value (Table 4), it was explored that at cultivation stage, to control chemical and biological hazard PRP and OPRP can be adopted respectively. In the case of the transportation stage to check chemical and biological hazard OPRP/CCP should be established. At the CTC and Googy shifter step, the biological and physical hazards can be kept in limit by establishing PRP and OPRP/CCP.

It was also clearly observed that at fermentation stage Physical and chemical hazard can be controlled by PRP while the biological hazard can be controlled by establishing OPRP/CCP. On the other hand in case of plucking of tea shoots, loading on the withering trough, withering and rolling, pre-conditioning (rolling / rotor vane), drying, shifting, grading, and packing and storage steps potential hazards can be minimized by adopting PRP as the P×S score was ≤ 8.

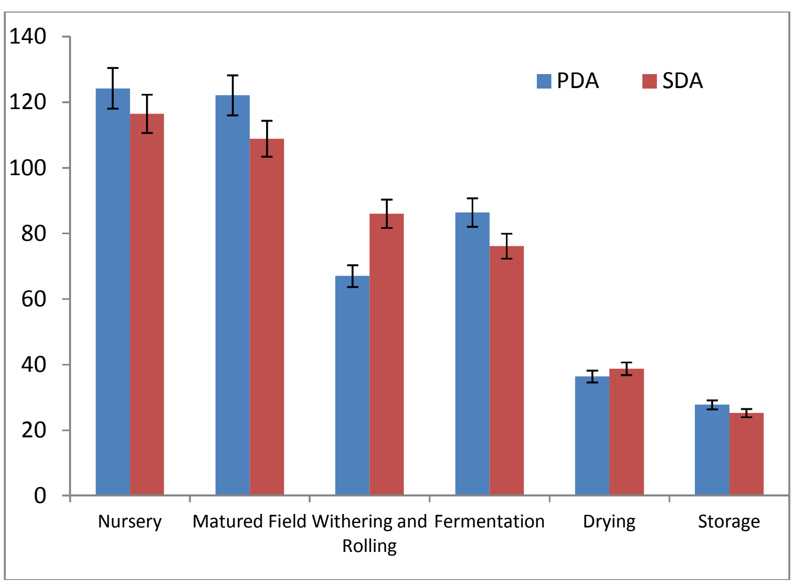

Fig. 4. Total microbial load in CFU at different steps of tea processing in different tea industries

Table 4. Risk assessment in different steps of tea processing (from cultivation to storage) with respective ratings in different tea industries of Bangladesh

Steps	Hazard	Forms of hazard	Probability rating	Severity rating	P×S	PRP Y/ N
Cultivation	Pesticide residue	Chemical	4	1	4	Y
	heavy metals		2	2	4	Y
	plant disease and insect infections	Biological	4	3	12	N
Plucking of tea shoots	Foreign objects	Physical	3	2	6	Y
	human pathogens, snails	Biological	2	1	2	Y
Transportation from garden to factory	Damage of the plucked leaves by excessive pressing	Physical	3	3	9	N
	Chemical fertilizer	Chemical	1	3	3	Y
	contamination by fuel of vehicles		3	2	6	Y
	human pathogens	Biological	1	2	2	Y
Loading on withering trough	Foreign bodies likes dust, stone etc.	Physical	2	2	4	Y
	human pathogens	Biological	2	1	2	Y
Withering	Foreign bodies (dust)	Physical	2	2	4	Y
Pre-conditioning (rolling / rotorvane)	Metallic contamination	Physical	3	2	6	Y
	Microbial growth	Biological	3	2	6	Y
CTC & Googy shifter	Metallic contamination	Physical	3	3	9	N
	Microbial growth	Biological	2	3	6	Y
Fermentation	Extraneous matter	Physical	1	1	1	Y
	contamination by washing chemicals	Chemical	2	2	4	Y
	Microbial growth	Biological	3	3	9	N
Drying	Moisture	Physical	2	3	6	Y
Sifting	Metallic contamination	Physical	2	2	4	Y
Grading	Foreign matter	Physical	2	2	4	Y
Packing	Contamination by migration of packaging component	Chemical	3	2	6	Y
Storage	Proliferation of microorganisms	Biological	2	3	6	Y

Y = Yes; N = No

Table 5. Seven logical approaches to determine CCPs or OPRPs for tea industries of Bangladesh

Steps	Hazard	Forms of hazard	Seven logical approaches							Total rating	OPRP Y/N	CCP Y/N
			a	b	c	d	e	f	g			
Cultivation	Disease and insect damage Infections	Biological	3	3	2	3	3	2	3	19	N	Y
Transportation from garden to factory	Damage of the plucked leaves	Physical	2	1	2	1	2	2	2	12	Y	N
CTC and Googy shifter	Metallic contamination	Physical	3	3	2	3	3	2	2	18	N	Y
Fermentation	Microbial growth	Biological	3	3	2	2	2	2	1	15	Y	N

Y=Yes; N = No

Table 6. Operational pre-requisite programs (OPRPs) plan for tea industries of Bangladesh

Steps	Hazard	Monitoring procedure				Correction	Corrective action
		What	When	How	Who		
OPRP-1 Transportation from garden to factory	Physical damage of the plucked leaves	Condition of the leaves	Each transportation from garden to factory	-Proper monitoring -Visual Supervision	Managerial level staff from garden operations	-Checking - Avoid pressing the leaves	-Regular training and proper direction to the managerial -Turn over the leaves to avoid heat generation or turn the green leaves into burn.
OPRP-2 Fermentation	Microbial growth	Monitoring fermentation time , temperature relative humidity and etc.	Periodic inspection at each operation	By using thermistor and hygrometer	Process operator or supervisor	-Follow proper hygienic practices; - Maintain optimum condition	-Adjust the time -Control the temperature below 72°F

Table 7. Critical control points (CCPs) plan for tea industries of Bangladesh

Steps	Hazard	Critical limit	Monitoring procedure				Correction	Corrective action
			What	When	How	Who		
CCP-1 Cultivation	Plant disease and insect infections	Maximum allowable damage by quality control department or according to regulation	Health of the plants and leaves	-Periodic and timely inspection	- Proper monitoring - Visual supervision	Managerial level staff from garden operation	Adoption of GAP	-Allowed pesticides and insecticides should be used
CCP-2 CTC and Googy shifter	Physical; Metallic contamination	No metal component detected	Metals component at metal detector	Hourly interval or operational batch wise interval.	-Visual inspection - By using correct magnet	Process operator	- Proper monitoring - Scheduled testing of the all metal detectors - Evaluate the record of metal detector inspection	- Check the efficiency of the metal detector - Adjust distance between production line and magnet - Informs the quality officer - Rejection of the product

Among the 4 significant hazards studied in this step (Table 5), only the control measures of 2 hazards scored values of over 17. Therefore these hazards were managed by the HACCP plan (by establishing CCPs) while rest 2 were controlled with OPRPs as shown in (Table 6) and (Table 7) respectively. Earlier based on the processing technology by analyzing the Hazards LIN, LI [36] determined 5 CCPs in application of HACCP on Tartary buckwheat healthful tea in China.

It was observed that OPRP must be established for physical hazard in transportation and biological hazards for Fermentation steps. In the transportation step, the hazard can be controlled by adopting Regular training and proper direction to the managerial and by avoiding pressing and filing the leaves on the vehicles. In the fermentation step, the microbial attack can be controlled by maintaining proper air composition, optimum fermentation time and temperature. According to Choudhury [37] it was explored that the fermentation temperature must be controlled within 72°F and raise of temperature above this facilitate the growth of different microorganisms as well as unwanted secondary reaction which resulting in quality deterioration of black tea.

The determined 2 CCP were related to both the cultivation and processing steps. The reason and significance of determining these two CCP might be due to the unavailability of prerequisite programs (PRP) and unconsciousness to the food safety issue in the tea industries.

At the cultivation step tea plants face different pests and diseases attack due to the agro-ecological environment of Bangladesh Good agricultural practice, good hygiene practice and proper wastage disposal will be effective to control them. Therefore the identification of cultivation step as CCP will ensure the introduction of HACCP along optimum quality of tea from the initial stage of tea production. Another CCP was determined at the very beginning steps of machinery i.e. CTC and Googy shifter step to control the physical hazard, i.e. metal component or other foreign materials. Therefore this determined CCP will be very fruitful to maintain the quality of the final tea.

4. CONCLUSION

The HACCP metasystem process is very important to assure quality which possesses periodic verification on an ongoing basis by an unbiased third party that certifies the industry. This study sets out a systematic approach to adopting HACCP metasystem that is applied practically to conduct hazard and control measures assessment. Four significant hazards have been identified. After assessing the control measures, CCPs were determined in Cultivation Step (to control biological hazard) and CTC and Googy shifter step (to control physical hazard) while the rest two hazards were managed by establishing OPRPs. Thus the tea industry by adopting HACCP metasystem can provide a guarantee of food safety of tea which may contribute to increase its acceptability and to enter new markets. Besides, the developed HACCP metasystem model of this study can be conveniently conducted in any tea industry of Bangladesh to become compliance in quality and safety.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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