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(RESEARCH ARTICLE)

Analysis of post-harvest treatment practices for kola (*Cola nitida*) using the HACCP system in three cities of Côte d'Ivoire

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Abstract

The aim of this study is to propose a revised treatment scheme for fresh kola nuts (*Cola nitida*) using Hazard Analysis Critical Control Point (HACCP). Specifically, this will involve analysing the nut processing diagram used by the stakeholders, identifying critical points and proposing corrective measures for these critical points. A survey at kola producers and traders, coupled with an on-site diagnosis, was carried out in the cities of Anyama, Bouaké and Agboville. The verification of the preconditions was based on a checklist. In addition, the kola nut processing and storage system was evaluated according to the 12 steps of the HACCP system. The diagnosis of the sector revealed an informal organization and traditional practices. A revised diagram of the cola treatment process according to the HACCP system has been developed. This diagram includes three critical control points (CCPs) at the reception, sorting and biopesticide treatment level. A HACCP plan has been drafted to better monitor and control each critical point. The technical routes for processing cola do not guarantee good quality nuts. They do not comply with good hygiene practices (GHP) during the processing and storage process. The adoption and monitoring of the HACCP system would be beneficial for the kola industry.

Keywords: *Cola nitida*; Site diagnostics; Critical control points; HACCP system

1. Introduction

The kola tree *Cola nitida* (Wind) Schott and Endlicher, (family Sterculiaceae) is a plant found in Sub-Saharan Africa where it forms a vast natural stand in the forest area [1]. Côte d'Ivoire is the world's leading producer and exporter, with a production of 260,747 tonnes of fresh kola nuts in 2016 [2]. This production is mainly used for local consumption and export to neighbouring countries, particularly Nigeria, Mali, Niger, Senegal and Burkina Faso. However, in Côte d'Ivoire, the conditions under which kola nuts are packeging and stored cause enormous losses. Indeed, kola is attacked by weevils (Balanogastris kolae, Paremydica insperata), diptera (Pterandrus colae) and fungi (*Fusarium* sp., *Penicillium* sp., *Aspergillus flavus*, *Alternaria* sp., *Aspergillus niger* and *Mucor spinosus*) which can cause 30 to 70% loss during storage [3, 4]. These insects and moulds are responsible for the deterioration of the market and sanitary qualities of the stored kola nuts. However, research on Ivorian kola is mostly focused on the agronomic aspect. Reducing production losses during handling and storage, including improving post-harvest processing systems, has been the subject of very few studies [5]. More effective control of food safety (including kola nuts) is essential to protect consumers from foodborne illness both nationally and internationally [6].

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Many studies have shown the economic and social importance of kola nuts. Indeed, Ndemen [7] reports that in the far north of Cameroon, 89% of wholesale traders involved in the marketing of kola derive most of their income from the sale of this product. However, its marketing is still essentially an informal activity, despite the fact that nuts are used in the brewing, food, pharmaceutical and dyeing industries [8, 9].

When the nuts are packaged, they are presented to the consumer with a precarious concern for hygiene, good presentation or adequate packaging. Thus, because of the difficulties in meeting the criteria of quality and the health requirements of developed countries related to food security, which is now a global concern (because of its importance for public health, but also because of its impact on international trade), effective food security systems must therefore manage and ensure the safety and security of food. It is in this sense that the deployment of a HACCP system fully plays this role.

The objective of this study is to propose a revised treatment scheme for fresh kola nuts (*Cola nitida*) using HACCP system. Specifically, this will involve analysing the nut processing diagram used by the stakeholders, identifying critical points and proposing corrective measures for these critical points.

2. Material and methods

2.1. Study material

The biological material consists of mature kola nuts of the species *Cola nitida.*

2.2. Study sites

The analysis of post-harvest kola treatment practices required surveys and field visits to three cities in Côte d'Ivoire. These are the cities of Anyama, Bouaké and Agboville. A pilot store for the treatment and storage of kola nuts has been made available to us by the National Federation of Kola Professionals of Côte d'Ivoire (FENAPROCO-CI) for the implementation of the HACCP method.

2.3. Methods

2.3.1. Prerequisite programs

We have established an inventory of the kola nut processing and storage stores and their activities and we have assessed their situation before our intervention. To this end, we have inspected all the basic activities necessary to implement good hygiene and processing practices and HACCP. We have continued with the actual implementation of good hygiene and treatment practices that are not being applied or are being partially applied. Finally, we have implemented the HACCP method, which includes the analysis of hazards and critical points defined using a decision tree recommended by the Codex Alimentarius [10].

2.3.2. Analysis by the HACCP system

The impact of post-harvest processing practices on kola nut quality was assessed using the HACCP method as described by FAO [11].

2.3.3. Building a multidisciplinary team

The HACCP team was multidisciplinary and composed of 7 peoples led by a Coordinator (HACCP manager). It was made up of food technologists, toxicologists, quality experts and food microbiologists. The mission of this team was to evaluate processing practices from the receipt kola nuts with pulp to pre-sale storage. The identification of hazards associated with the processing, packaging and storage of cola nuts, as well as the assessment of their severity and frequency of occurrence, were carried out. Then the necessary means to control them and ensure their effectiveness were proposed and implemented. The analysis by the HACCP system was based on the product description until corrective action plans were established.

2.3.4. Product description

This description focused on information on the name, physico-chemical characteristics of kola, types of packaging, packaging and storage methods, target consumer population and expected use.

2.3.5. Construction and on-site verification of the kola nut processing diagram

A detailed examination of the product flow and each step of the treatment and preservation process was carried out in order to establish a nut treatment diagram around which the HACCP analysis plan could be structured. The multidisciplinary team, after having constructed the manufacturing diagram and before starting operations, verified on site that the nut processing diagram and the plant plan corresponded to reality and that they allowed the hygienic operating conditions to be respected. All the new layouts of the treatment diagram were confronted with the traditional diagram.

2.3.6. Hazard analysis

The hazard listing consisted in identifying all biological, chemical and physical hazards that may occur during the unit operations of the kola treatment diagram. Therefore, preventive measures have been identified and proposed to prevent hazards from appearing or eliminating them to ensure the quality of the kola nut.

2.3.7. Identification of critical points

The identification of critical control points (CCPs) was based on the "decision tree" proposed by the Codex Alimentarius [12]. After analysing the hazards, identifying their levels of occurrence and causes, the HACCP team evaluated each step of the treatment diagram using the decision tree below (Figure 1) to identify the critical points.

2.3.8. Establishment of critical limit

The critical limits for each CCP identified, were established by a value; specified or inviolable maximum standard or condition that ensures that the CCP eliminates the identified hazard.

2.3.9. Establishment of a monitoring and control system for each critical point

For the various control parameters, a monitoring and control protocol allowing the respect of the critical limits or to take appropriate corrective measures has been defined.

2.3.10. Establishment of a corrective action plan

A monitoring system has been defined with measures to be observed at each critical point. This corrective action plan clearly indicates the persons responsible for the execution of the various corrective measures but also the actions to be taken regarding the products treated during the out-of-control periods.

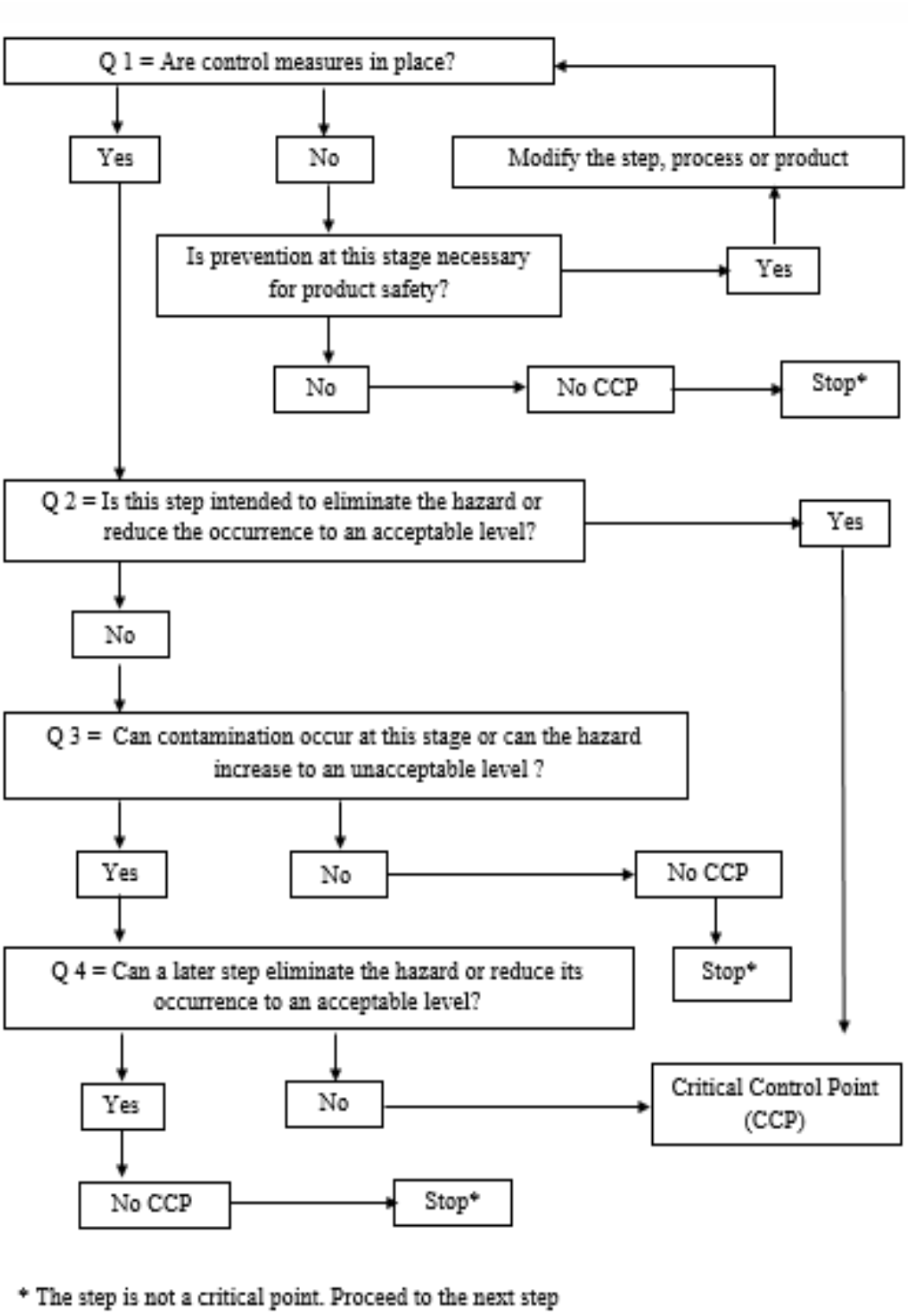

Figure 1 Decision tree for the identification of critical control points (CCPs)

3. Results

3.1. Summary of the diagnosis of the cola sector

Table 1 presents the assessment of the practices of treatments, storing kola nuts and the organization of the industry in the various cities surveyed according to the recommendations of the Prerequisite Program (PRP).

Table 1 Diagnosis of the sector according to the recommendations of the good hygiene practices (GHP)

Sr. No.	Requirements	Surveyed cities		
		Anyama	Agboville	Bouaké
1	Premises	Not satisfying	Not satisfying	Not satisfying
2	Facilities and workspace	Not satisfying	Not satisfying	Not satisfying
3	Air, water and energy supply	Not satisfying	Not satisfying	Not satisfying
4	Waste and wastewater disposal	Absent	Absent	Absent
5	Appropriate equipment	Absent	Absent	Absent
6	Management of purchased products	Absent	Absent	Absent
7	Measures to prevent cross-contamination	Absent	Absent	Absent
8	Cleaning and disinfection	Absent	Absent	Absent
9	Pest control	Absent	Absent	Absent
10	Hygiene of staff members	Not satisfying	Not satisfying	Not satisfying
11	Staff training	Absent	Absent	Absent
12	PRP Management	Absent	Absent	Absent
13	Staff health policy	Absent	Absent	Absent
14	Contractual relationship with suppliers and product management.	Not satisfying	Not satisfying	Not satisfying
15	Organization and commitment of the Management	Not satisfying	Not satisfying	Not satisfying

3.2. Drafting of the HACCP plan

3.2.1. Description of the product and its intended use

Table 2 presents the description of the product and its intended use.

Table 2 Product description

Parameters	Characteristic values
Product name(s)	**Kola**
Important product features	Bright colour (White, red and pink) Crunchy texture, Odourless, Bitter taste, weight = 18±4 g, 8.58% protein, 2.24% fat, 2.46% fibre, 2.8% caffeine and 0.05% theobromine, 0 pathogens.
Intended use of the product	Direct consumption, production of energy drinks and pharmaceutical drugs.
Packaging	Polyethylene bag, Rattan basket lined with Thaumatococcus daniellii leaves, polystyrene trays
Duration of the conversation	6 months at room temperature (29±1°C)
Place where the product is sold	Retail market in Côte d'Ivoire (neighbourhood), Wholesale market and to export to countries such as Nigeria, Mali, Senegal and Burkina Faso
Labelling instructions	Origin of the kola (production area), type of nut (tamed or wild plant), Name of buyer, Place of destination, Color of nuts
Special control devices during distribution	Visual and manual verification of quality criteria, sorting, washing and reconditioning

3.2.2. Diagram of post-harvest treatment practices for kola nuts

The diagram in Figure 2 shows the treatment of kola nuts from receipt of pulped nuts to storage. It includes improvements to the traditional diagram used by producers and traders. Indeed, new steps (soaking in the biopesticide ...) and a new input (polystyrene trays) have been added to the treatment diagram.

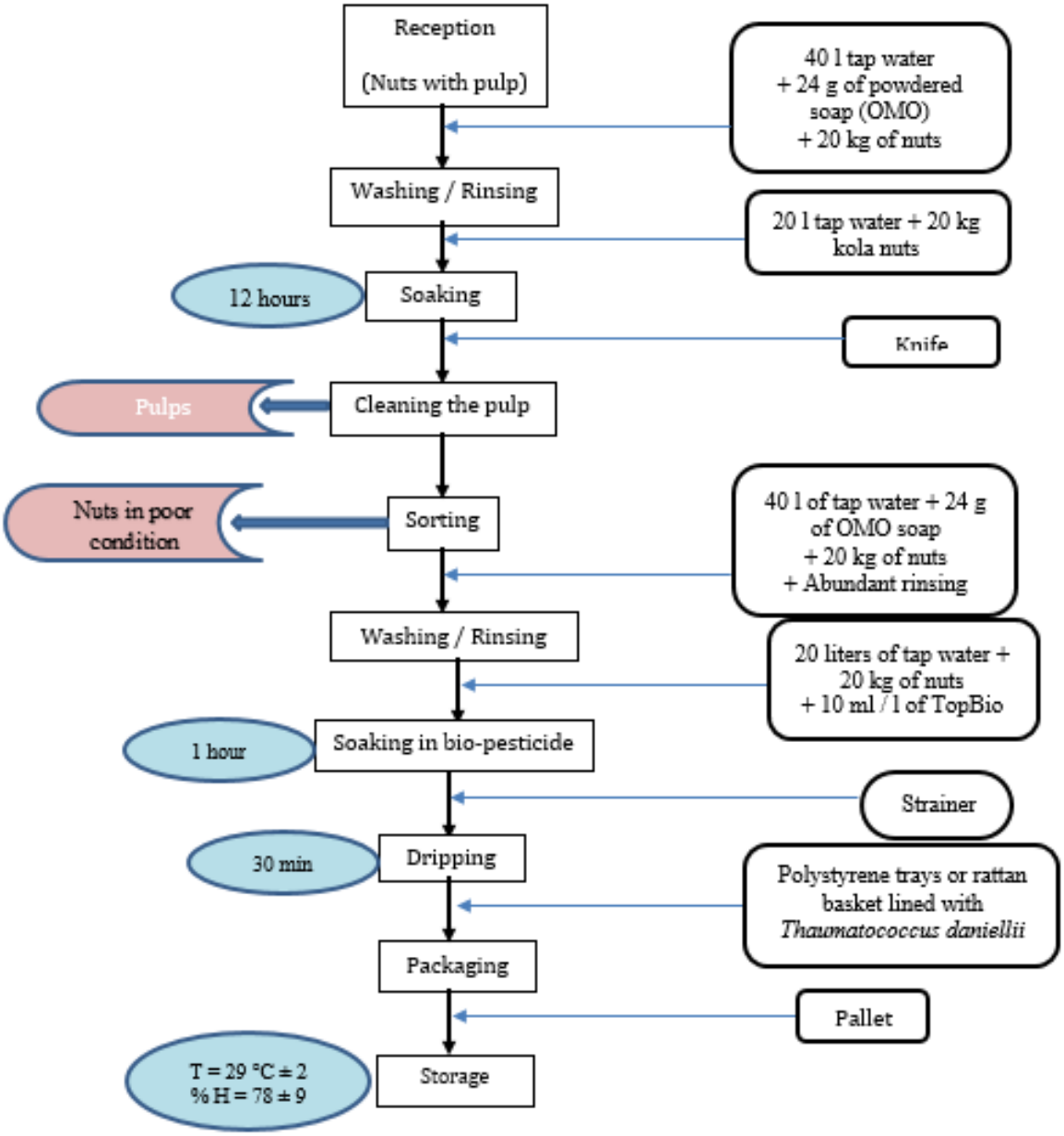

Figure 2 Diagram of post-harvest treatment of the kola nut (T = Temperature, H = Relative humidity)

3.2.3. Analysis of potential hazards

Knowledge of the product and treatment processes made it possible to list potential hazards (physical, biological or chemical) and the conditions of their presence, severity, frequency and probability of manifestation at the different stages of kola nut processing (Table 3). Biological risks arise from openings in nut wounds, the nature and humidity of the supports or storage area and the poor quality of the water used. This would encourage the development of weevils, moulds and telluric bacteria at all stages of treatment. On the other hand, chemical risks are most often related to non-registration or non-compliance with the dosage of pesticides used. As for physical risks, they are related to foreign bodies, waste and the hygiene of the premises and staff.

Table 3 Hazard analysis

Steps	Hazard	Causes of the hazard	Control measure
Reception	B1. Risks related to pests and microorganisms	B1. Opening of kola nuts during dehulling	B1. - Visual inspection, Use of disinfectant when washing or soaking in biopesticide could eliminate this risk
	C1. Risks related to pesticide residues	C1. Spraying of pods	C1. Use of registered pesticides and compliance with prescribed rates
	P1. Risks related to foreign bodies	P1. Unsorted nuts before packaging for transport	P1. Visual inspection on receipt
	P2. Risks related to shocks during transport	P2. Incorrect handling during loading and unloading of nut transport trucks	P 2 Control during loading and unloading
Washing & Rinsing	B2. Biological risk related to water quality	B2. Use of poor quality water Soaking, Human Handling and Cross-contamination	B2. Use good quality water and comply with GHPs
	C2. Chemical risk related to detergent	C2. Failure to comply with the prescribed dosage and insufficient rinsing	C2. -Comply with the requirements indicated on the labelling of detergents, -Efficient rinsing
Soaking	B3. Biological risk related to water quality	B3. Use of poor quality water Soaking, Human Handling and Cross-contamination	B3. Use good quality water
Cleaning the pulp	B4. Biological risk related to microorganisms	B4. Nut injuries and human handling	B4. The use of disinfectant during washing could eliminate this risk
	P3. Physical risks related to objects used for pulping	P3. Use of sharp objects (knife) and/or piece of wood for pulping	P3. Compliance with GHPs / Training
Sorting	P4. Physical risks related to foreign bodies and nuts in poor condition	P4. Non-compliance with GHPs	P4. Compliance with BPH, Training
Washing & Rinsing	B5. Biological risks related to cross-contamination (microorganisms) and water quality	B5. Human handling and cross-contamination	B5. Compliance with BPH, Training
	C3. Chemical risk related to detergent	C3. Failure to comply with the prescribed dosage and insufficient rinsing	C3. Respect the prescribed doses of detergent and rinse well
Soaking in biopesticide	B6. Biological risk from water quality	B6. Contact of poor quality water with nuts	B6. Use good quality water, Respect of GHPs, Training
	C4. Chemical risk related to biopesticides	C4. Failure to comply with the prescribed dosage and insufficient dripping	C4. Use the approved biopesticides and follow the prescribed doses
	P5. Physical risk related to personal belongings	P5. Non-compliance with GHPs	P5. Respect for GHPs, Training
Dripping	B7. Biological risks related to cross-contamination	B7. Human handling and cross-contamination	B7. Respect for GHPs, Training
	P6. Physical risk related to personal belongings	P6. Non-compliance with GHPs	P6. Respect for GHPs, Training
Packaging	B8. Biological risk related to pests and microorganisms	B8. Human handling and cross-contamination	B8. Respect for GHPs, Training
	P7. Physical risk related to personal belongings	P7. Non-compliance with GHPs	P7. Respect for GHPs, Training

Table 4 CCPs identified by step of the kola nut processing process

Process step	Hazard	Q1	Q2	Q3	Q4	Conclusion
Reception	B1. Risks related to pests and microorganisms : - Weevils: *Balanogastris kolae*, *Sophorhimis sp*, *Paemydica insperata.* - Mold : *Aspergilus* and *Penicillium* - Telluric bacteria: *Bacillus cereus* and *Clostridium botulinum*.	Yes	No	No	-	Not a CCP; because washing and treatment with biopesticide can eliminate the hazard or reduce it to an acceptable level.
	C1. Risks related to pesticide residues	Yes	No	Yes	No	CCP 1
	P1. Risks related to foreign bodies (stones, pieces of wood, jewellery, and packaging fragments).	Yes	No	Yes	Yes	Not a CCP; because triage can eliminate the hazard.
	P2. Risks related to mechanical shocks during transport	Yes	No	No	-	Not a CCP; because triage can eliminate the hazard or reduce it to an acceptable level.
Washing & Rinsing	B2. Biological risk related to water quality (rainwater, marigot and well water),	Yes	No	Yes	Yes	Not a CCP; because treatment with the biopesticide can eliminate the hazard or reduce it to an acceptable level.
	C2. Chemical risk related to detergent	Yes	No	No	-	Not a CCP; The danger cannot increase to an unacceptable level.
Soaking	B3. Biological risk related to water quality (rainwater, marigot and well water),	Yes	No	No	-	Not a CCP; because treatment with the biopesticide can eliminate the hazard or reduce it to an acceptable level.
Cleaning the pulp	B4. Biological risk related to microorganisms (*E. coli* and *S. aureus*)	Yes	No	Yes	Yes	Not a CCP; because treatment with the biopesticide can eliminate the hazard or reduce it to an acceptable level.
	P3. Physical risks related to objects used for cleaning the pulp	Yes	No	Yes	Yes	Not a CCP; because sorting can eliminate the danger.

Q 1 = Are control measures in place?
Q 2 = Is this step intended to eliminate the hazard or reduce the occurrence to an acceptable level?
Q 3 = Can contamination occur at this stage or can the hazard increase to an unacceptable level?
Q 4 = Can a subsequent step eliminate the hazard or reduce its occurrence to an acceptable level?

Table 4 Continuation of the table of CCPs identified by step of the processing process of kola nut

Process step	Hazard	Q1	Q2	Q3	Q4	Conclusion
Sorting	P4. Physical risks related to foreign bodies and damaged or injured nuts	Yes	Yes	-	-	CCP 2
Washing & Rinsing	B5. Contamination risks related to microorganisms and water quality	Yes	No	Yes	Yes	Not a CCP; because treatment with the biopesticide can eliminate the hazard or reduce it to an acceptable level.
	C3. Chemical risk related to detergents,	Yes	No	No	-	Not a CCP; The danger cannot increase to an unacceptable level.
Soaking in biopesticide	B6. Biological risk related to insects and the development of microorganisms	Yes	Yes	-	-	CCP 3
	C4. Chemical risk related to biopesticides	Yes	No	No	-	Not a CCP; The danger cannot increase to an unacceptable level.
	P5. Physical risk related to personal objects (jewellery, pen, toothpicks)	Yes	No	No	-	Not a CCP; Compliance with GHPs helps to avoid danger.
Dripping	B7. Biological risks related to cross-contamination (microorganisms)	Yes	No	No	-	Not a CCP; Compliance with GHPs helps to avoid danger.
	P6. Physical risk related to personal objects (jewellery, pen, toothpicks,)	Yes	No	No	-	Not a CCP; Compliance with GHPs helps to avoid danger.
Packaging	B8. Biological risk related to insects and the development of microorganisms	Yes	No	No	-	Not a CCP; The hazard cannot increase to an unacceptable level.
	P7. Physical risk related to personal objects (jewellery, pen, silver coin, toothpick,)	Yes	No	No	-	Not a CCP; Compliance with GHPs helps to avoid danger.
Stockage	B9. Biological risks related to pests and the development of microorganisms	Yes	No	No	-	Not a CCP; The danger cannot increase to an unacceptable level.
	C5. Chemical risks related to presence of mycotoxins	Yes	No	No	-	Not a CCP; The danger cannot increase to an unacceptable level. In addition, Compliance with GHPs helps to avoid danger.

Q 1 = Are control measures in place?
Q 2 = Is this step intended to eliminate the hazard or reduce the occurrence to an acceptable level?
Q 3 = Can contamination occur at this stage or can the hazard increase to an unacceptable level?
Q 4 = Can a subsequent step eliminate the hazard or reduce its occurrence to an acceptable level?

3.2.4. CCPs identified

The kola nut processing diagram (Figure 2) includes three Critical Control Points (CCPs). These CCPs concern the reception of the product, sorting and soaking in the biopesticide. Indeed, at the reception there is a chemical CCP related to the potential risks of pesticide residues in kola nuts. Then, a physical CCP at the sorting stage, because this stage is specifically designed to eliminate all waste, foreign bodies and mitted nuts during the treatment process. Finally, a biological CCP at the soaking stage in the biopesticide. Because this very essential step in the kola treatment process has been designed to control the possible proliferation of fungi and weevils. The other risks listed are not CCPs because they can be eliminated or reduced to an acceptable level by steps downstream of the diagram or controlled by the application of GHP (Table 4).

3.2.5. Establishment of critical limits for each CCP

The critical limits of the CCPs identified are presented in Table 5. To minimize the chemical risk related to pesticide residues upon receipt, all the chemicals used must be approved, but also the strict adherence to the dosages given by the manufacturers. If necessary, whatever the risk, adjust or stop the washing and remove the affected lot of kola nuts. The physical danger during sorting is due to the presence of foreign bodies, kola nuts stung by insects and injured nuts. Zero tolerance must be applied because of the risk of pest proliferation and rotting of nuts. As for the biological hazard related to weevils, microorganisms and the source of the water (quality), at the soaking step in the biopesticide, it is necessary to apply the limits for each microorganism but especially to be very rigorous for molds because of the danger posed by the toxins produced on health. Care must be taken to apply good hygiene practices for the bags and the storage site and to carry out frequent analyzes of the mold load (*Penicillium* and *Aspergillus*).

Table 5 Critical limits established for each CCP

Steps	Hazards	Critical limits
Reception	C1. Chemical related to pesticide residues	Regulation (EC) No 396/2005 of the European Parliament and of the Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC
Sorting	P4. Physics related to foreign bodies and nuts mitted or in bad condition	Zero tolerance (Absence)
Soaking in the biopesticide	B6. Biological related to weevils, microorganisms and water source (quality)	-Application of the limit for each microorganism in accordance with the regulations - Absence of weevils

3.2.6. Establishment of surveillance measures and corrective measures

The monitoring measures and corrective actions of the identified CCPs will be regularly evaluated by the person responsible for their control procedures who will ensure that a record of the reports is maintained (Table 6).

Table 6 Monitoring and control system for each CCP

Step of reception				
N° CCP / Type of hazard	CCP C1			
Hazard description	**Monitoring measures**	**Corrective actions**	**Control procedures**	**Recordings**
Pesticide residues	Analysis of pesticide residues on kola nut Respect for Good Agricultural Practice (GAP) and specifications	Removing non-compliant batches	Analysis of pesticide residues on kola nuts	- Technical data sheet of the control procedure, - Corrective action report
Step of sorting				
N° CCP / Type of hazard	CCP P4			
Hazard description	**Monitoring measures**	**Corrective actions**	**Control procedures**	**Recordings**
Foreign bodies, nuts stung by insects and injured nuts	Carefully sort the nuts	Resumption of sorting operation	The person in charge shall ensure that the monitoring measures are properly applied.	- Technical sheet of the kola nut sorting operation. - Corrective Action Report
Step of soaking in the biopesticide				
N°CCP / Type of hazard	CCP B6			
Hazard description	**Monitoring measures**	**Corrective actions**	**Control procedures**	**Recordings**
Biological hazard related to insects and microorganisms	- Research and identification of the pathogenic charge. - Search for nuts stung by insects	- Resumption of the treatment operation with the biopesticide. - If not identified, destruction of the contaminated kola batch	The person in charge shall ensure that the monitoring measures are properly applied	- Technical data sheet for treatment with biopesticide, - Corrective Action Report

4. Discussion

During this study, it was observed that the activity of production and processing of kola being in the informal, the whole of the practices of treatment of the nuts applied, to the store of storage is source of enormous losses. In addition, no kola nut processing and storage center, surveyed cities (Anyama, Bouaké and Agboville) comply with the recommendations of the Prerequisite Program (PRP). Merchants do not have a developed pest plan. During the treatment of nuts, some actors use soap powder for washing and disinfecting nuts.

The risk analysis revealed several potentials for contamination in the walnut processing process. Indeed, all the data collected shows that the treatment as applied is generally done under unhygienic conditions and often with dangerous behaviors and habits. This favors a microbial proliferation presenting a major risk due to a lack of a training program in Good Hygiene Practices for the benefit of the staff of the kola industry. Several studies have shown that employees are the source of food contamination. In fact, the hygiene of the staff is an essential point to avoid cross contamination during the process of treating nuts. Also, the hands that are most often in direct contact with foodstuffs, should be considered in this sector of activity, as the first tool. In this respect, particular attention must be paid to their cleanliness as well as to the equipment made available to the operators for washing them. According to Bonne and al. [13], if the hands are not subjected to strict hygiene rules, constitute the first vector between the germs (possibly pathogenic) carried by the organism of the operators and the food. This comes down to the application of Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) at the production sites that are essential to guarantee the quality and safety of a food. The treatment of kola nuts should begin with a first wash of the nuts with the pulp to remove the soil, followed by another wash after pulping and finally soaking in a biopesticide treatment solution. Sorting (removal of infested nuts, waste and foreign matter), washing and biopesticide treatment are essential steps, because if pathogens are not eliminated, neutralized or controlled, they can spread and contaminate the entire stock of kola.

5. Conclusion

This study made it possible to better understand and evaluate the different practices of post-harvest processing of kola nuts. The triage stage is a particular CCP to be mastered to avoid physical hazards (foreign bodies, mothed nuts and injured nuts), but also an essential control point to prevent the development of weevils. Indeed, any lot of nuts containing larvae of weevils or weevils will be destroyed under the activity of this insect during its development.

Despite the willingness of actors to have organizational sanitation at the level of the sector, they are still going through difficult times. The sector therefore remains poorly organized and informal. However, the organizational sanitation of the sector is a prerequisite for obtaining training in good practices for treating nuts, as well as obtaining financing and international markets. Thus, in the light of all these findings, a policy can be put in place to comply with the basic recommendations of the Good Hygiene Practices (GHP) before a concrete implementation of the HACCP system at the level of all producers and traders of the kola in Côte d'Ivoire.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in the publication of this manuscript.

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