



# Traceability Strategy for Dried Mango Production Units: A Study in Côte d'Ivoire

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## **Authors' contributions**

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

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## **ABSTRACT**

**Background:** Defined as a tool for quality management, traceability is succeeding in boosting the performance of agro-industrial production systems. However, in Côte d'Ivoire, certain industries such as food processing units do not have a traceability system.

**Aims:** A study was therefore carried out in the Korhogo commune at two dried mango production units, "coop-ca Gninnangnon" and "Ivoire organics" selected for their production capacity. The overall aim of the study is to help improve the quality and competitiveness of dried mango processing units.

**Methods and Results:** Firstly, levels of satisfaction with the general principles of traceability were determined using an evaluation grid. Radar and Pareto diagrams were then used to analyze the system using the 0, 1, 2, 3 rating method. It is worth noting the difference in fruit loss during

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ripening, with each company using different methods. As far as coding procedures are concerned, the traceability elements implemented by the two structures through the traceability registration and identification registers enabled codes to be determined according to the organization of each company. However, this coding led to the proposal of a traceability scheme adapted to the realities of the companies in terms of all the parameters specific to the units. It should be noted here that COOP-CA GNINNANGNON's drying unit achieved an overall satisfaction rate of 62.74% with respect to traceability requirements, while IVOIRE ORGANICS achieved an overall satisfaction rate of 74.47%.

**Conclusion:** The establishment of a coherent traceability system will contribute to the competitiveness of mango processing companies.

*Keywords:* Traceability system; management; quality; dried mangoes; performance tools; company.

## 1. INTRODUCTION

The mango tree, *Mangifera indica*, is native to northern India, and belongs to the Anacardiaceae family, comprising 60 tree species. The mango tree is thought to comprise 1,000 varieties and over 70 cultivars (grafted) found on various continents (Michel R and Jean-Michel M. 2009). Mango, the fruit of the mango tree, now plays an important role in Côte d'Ivoire's economy. Côte d'Ivoire's economy is based on agriculture, and the country's many natural assets are ideal for farming, enabling it to adopt a policy of diversifying agricultural production. These include the mango (GSAC 2015). With annual world production approaching 34 million tons, mango is currently the 5th most produced and marketed fruit worldwide, after bananas, grapes, oranges and apples (FAO 2010). The main mango production areas are in northern Côte d'Ivoire, where this crop currently remains one of the main sources of income for the population after cotton (FIRCA 2014). More than 1.5 million people live directly or indirectly from this crop. Mango orchards, mostly dominated by village plantations, cover an area of around 20,000 hectares. Côte d'Ivoire produces around 100,000 tons of mangoes a year, with exports accounting for between 10,000 and 15,000 t, a tiny fraction of its total production (Kouassi 2012). Over 95% of the mangoes exported by Côte d'Ivoire are destined for the European market, where they face competition from mangoes produced in Brazil and Peru. The mango industry provides a livelihood for over 100,000 people in Côte d'Ivoire and distributes substantial income, helping to reduce poverty in production areas (Soungari 2022).

Côte d'Ivoire is a major player in the fresh mango market. However, its supply of processed mangoes is still limited. Juice and dried mango are the main products of mango processing,

representing only 4,500 and 170 tons respectively. Processed mango products are rarely exported and are mainly destined for the local market (COLEACP 2021). Dried mango is a product made from healthy, ripe fruit of certain varieties. It is obtained by drying and is a means of preserving the fruit. Mango can be dried in the sun or by other recognized dehydration methods, such as tunnel drying or the ATESTA oven. Depending on product specifications, dried mango can be produced with or without added sugar (Rosalie et al. 2018, Muñoz-Redondo et al. 2021, Nguyen et al. 2024). Dried mango processing is a recent phenomenon in Côte d'Ivoire. Around 1998, there were small rudimentary processing units encouraged by processors from Burkina. But the actual production of dried mango began and experienced its evolution from the year 2016. Since then, there has been rapid growth even if, compared with fresh mango production, this processing rate remains low (Soungari 2022), giving new added value to the original product and providing a means of combating post-harvest losses. However, these small production companies are faced with a real problem that hinders their development. This is the problem of company performance. Faced with this situation, a quality tool could be a solution to alleviate this problem. The implementation of a Sanitary Quality Management System is necessary for any agri-food processing company, as it is a tool for ensuring product traceability in order to guarantee competitiveness. Today, traceability makes it possible to improve business productivity and efficiency by identifying and correcting any faults that may occur, and to boost the competitiveness of small and medium-sized enterprises (SMEs) in the agri-food processing sector (CCA 2019). In the agri-food sector, it has now become a component of the COLEACP food safety guarantee (COLEACP 2021). Despite these assets, very few small and medium-sized

businesses in northern Cote d'Ivoire have a traceability system. With a view to promoting this tool, the present study was carried out in two agri-food companies in the north of Côte d'Ivoire on the theme "strategy for implementing a traceability approach in two dried mango production units: Entreprises "Ivoire Organics and Coop CA Gninnangnon de Korhogo", with the aim of contributing to improving the quality and competitiveness of processing units. Specifically, the aim is to

- describe the functional organization of the production unit, from procurement to marketing.
- define coding procedures for production system inputs and products.
- propose a traceability scheme adapted to the realities of the company: information flows, form, media.

## 2. MATERIALS AND METHODS

### 2.1 Biological Material

The biological material used in this study is dried mango pulp from the Kent, keitt and brooks varieties. These varieties are regularly used in Korhogo drying units.

### 2.2 Survey

This consisted in gathering information from production managers at the two production units. In the field, the question-and-answer technique was used to fill in the questionnaire.

### 2.3 Evaluation of the Traceability System

#### 2.3.1 Questionnaire design

To carry out this study, a questionnaire was drawn up for production managers of dried mango units. The questionnaire was designed according to the traceability systems in place, i.e. from fruit reception through processing to packaging and the various traceability tools in use. This enabled us to gather important information on both production units. This information concerned the organization of the place to produce dried mango and, above all, quality management in the drying units.

#### 2.3.2 Drawing up an evaluation grid

The evaluation grid is a tool to help implement improvement actions relating to the quality

management system. In this study, the grid was drawn up based on the general principles of traceability set out in the Codex Alimentarius. It consisted of the prerequisites for setting up a traceability system, based on the manufacturing diagram, and finally the rating of satisfaction with the requirements.

Firstly, information was gathered during the administration of the questionnaire and interview guides. In addition, observations were made, recorded during guided visits to the exterior and interior of the two production units. This observed data was then used to inform our evaluation grid. Gaps between actual practices and the requirements of the standard were measured using the scoring method.

#### 2.3.3 Rating method

Scoring was primarily of type 0, 1, 2 or 3, and was based on the tools in place (traceability prerequisite programs). When a question was not applicable, it was noted, and the reason given. Ratings 0, 1, 2, 3 corresponded respectively to:

- A rating: 0 "Nothing is done".
- B rating: 1 "Some elements exist".
- C rating: 2 "Most elements are in place".
- D rating: 3 "Relevance and suitability checked".

### 2.4 Analysis of Traceability Systems

The results obtained were processed with SPHINX version 15 software, which was used to draw up our questionnaire, with a view to showing the performance level of the company's arrangements, using the data collected. Excel was also used for comparison tests. The graphs show the different quantities of product losses during ripening, and the data is presented in the form of a Radar diagram and a Pareto chart.

## 3. RESULTS

### 3.1 Description of Coding Procedures for Production System Inputs and Products

#### 3.1.1 Description of the organization of the two production units

Data describing the organization of the two dried mango production units are recorded in Table 1.

**Supply Organization:** The various production units work in partnership with different mango

growers. The Ivoire Organics company, which is a limited liability company (SARL), obtains its supplies from suppliers located in the villages and towns around Korhogo, who are recorded in a register according to an order based on several elements of traceability.

The Gninnangnon company, being a cooperative society, is supplied mainly by these member producers and by other individuals located in the surrounding villages and towns and has a delivery contract.

After each delivery, the two units record information on the product delivered until it is processed.

**Fruit Reception:** Fruit is received by the units in different ways. Ivoire Organics receives fruit in bulk. Once received, the fruit is placed under a shed and undergoes an initial sorting to eliminate any foreign bodies, injured fruit and fruit at an advanced stage of ripeness, before being sent to the ripening room for ripening. This prevents fruit loss due to contamination. The batch of fruit is then recorded in a notebook, based on several elements: the batch number, the code assigned to the producer (IOP) and the date of arrival. The Gninnangnon cooperative company takes delivery of the produce, which is unloaded and stored in the ripening room, coded and recorded in a delivery register book containing the following information: date of arrival, variety, producer's name or code, batch number in the order of arrival (Fig. 1).

**Sorting Ripe Mangoes for Processing:** The mangoes are sorted, weighed and then washed before entering processing, accompanied by a document showing the sorting date, variety and weight. At Ivoire Organics, ripening takes place over 2 days to reduce the amount of fruit loss, at which point the fruit is sorted a second time to

remove any damaged fruit. It should be noted that the Gninnangnon cooperative records a loss rate of 5% for Stocker products, compared with 2% for Ivoire Organics; this can be seen in the image (Fig. 1).

Sorting enables us to select mangoes that have reached the right degree of ripeness. The aim is to create homogeneous batches of mangoes with the same degree of ripeness, and to eliminate suspect fruit (fruit with spots). Spots on fruit are often due to the action of micro-organisms, and it's best to eliminate the offending ones. Over-ripe mangoes should also be discarded to avoid compromising the homogeneity of the product after drying. The management of sorting operations is fundamental to the profitability of drying operations, guaranteeing the availability of the quantities of raw materials required for daily processing operations, and significantly reducing raw material losses due to over-ripening.

### 3.1.2 Organization of dried mango processing

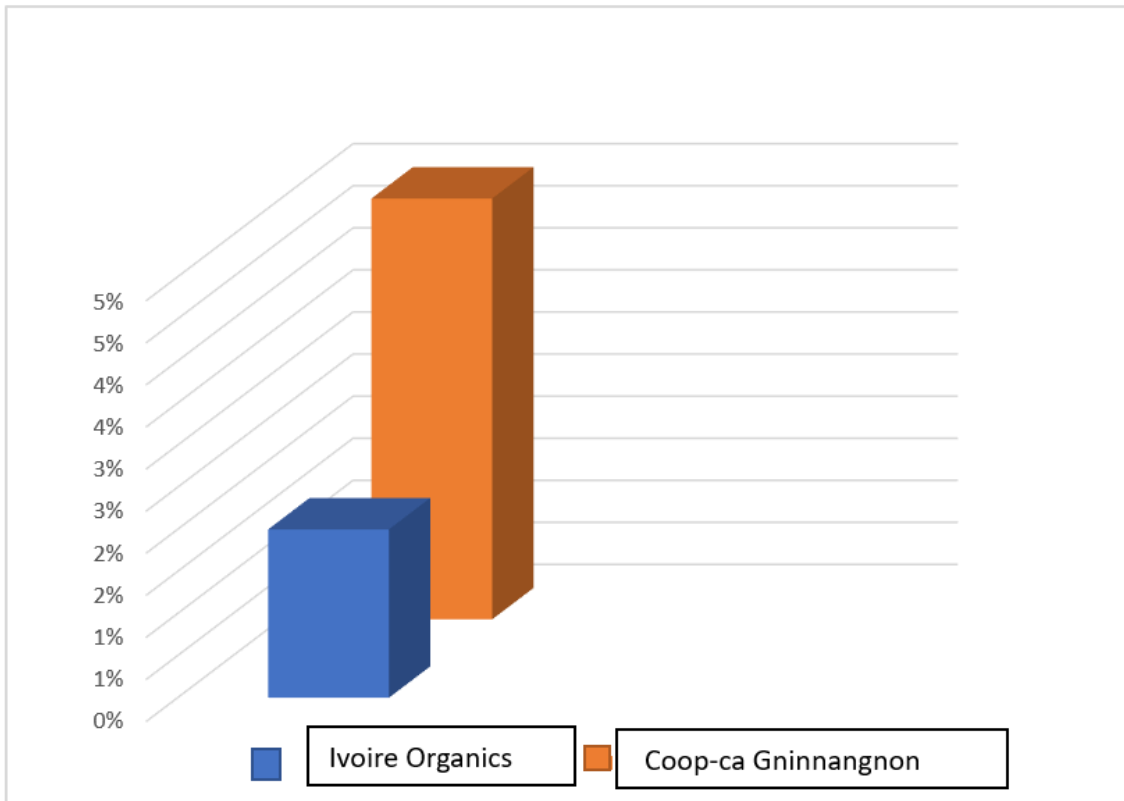
**Peeling:** Peeling removes the skin from the fruit and is usually carried out manually using a knife or peeler. In any case, it is important to avoid losing too much pulp during the peeling operation, which could compromise the profitability of drying operations. Both companies have a single production line, with different numbers of peeling staff: 25 women for the cooperative and 35 for Ivoire Organics.

**Weighing Cut Pulp:** For the Gninnangnon cooperative, the cut pulp is weighed and divided into 5 kg batches. They are then immersed in a solution of meta-bisulfite, a preservative, before being placed on a rack in a South African CD1500 tunnel kiln. In contrast, Ivoire Organics produces organic preservative-free products with a mass of 6 kg per rack in a Sri Lankan ATESTA model oven.

**Table 1. Comparison of the existence of traceability parameters**

Traceability parameters (Supply and reception))	COOP-CA Gninnangnon	Ivoire organics
Parcel identification	-	+
Lot identification	+	+
Delivery vehicle code	-	+
Delivery date	+	+
Weight of delivered product	-	+
Maturing time	+	+
Sorting	+	++
Receipt slip	-	+
Register of receipt	+	+
Lot coding	-	+

- : no indicator; +: present indicator; ++: accentuated indicator



**Fig. 1. Distribution of fruit loss after ripening**

**Drying, Time/Temperature Pairing:** Once the mango slices have been placed on trays, the trays are placed in the dryer. The drying process can last from 18 to 24 hours, depending on the technology used, the drying period, the mango variety and the operator's skill. For this operation to be a success, it is important to: monitor the time/temperature relationship; rotate the trays from top to bottom and front to back, to ensure even drying; fill in the traceability tools. Thermal efficiency values for mango dryers using natural convection are known, with a maximum of 35%, whereas recirculating air dryers achieve 60% to 70%.

**Cooling and Decanting of Dried Pieces:** The dried mango slices are taken out of the dryer and cooled, then the water content of the slices is homogenized (maturation takes place in the barrels for 24 hours). Then, within the hour, the mango slices and pieces are peeled off so that the surface-dried juice doesn't have time to harden. During this operation, only those pieces that are too moist are removed, so that they can be dried again. The rest of the product is placed in bulk in 50-liter watertight drums and transferred to the packing room to protect it from insects.

### 3.1.3 Grading dried mangoes

Dried mangoes are sorted on a stainless-steel table (recommended) and classified into two (02) categories (1st and 2nd choice) according to customer choice. Using pairs of scissors, the dried strips are cut or trimmed to remove imperfections. The characteristics of the dried mango category commonly used for 1st choice are orange to yellow color, good texture, accentuated fragrance, slice size and thickness to be defined according to the customer. The 2nd choice category comprises dried slices of smaller size, but of the same taste quality as those of the 1st choice.

### 3.1.4 Organization of dried mango packaging

The function of packaging is to protect the finished product from external attack (pests, physical and chemical factors). For both production units, packaging is carried out in two phases: primary packaging (bagging) and secondary packaging (boxing). Product packaging depends on the customer's specifications, which are drawn up before the start of the campaign (Figs. 2 and 3).

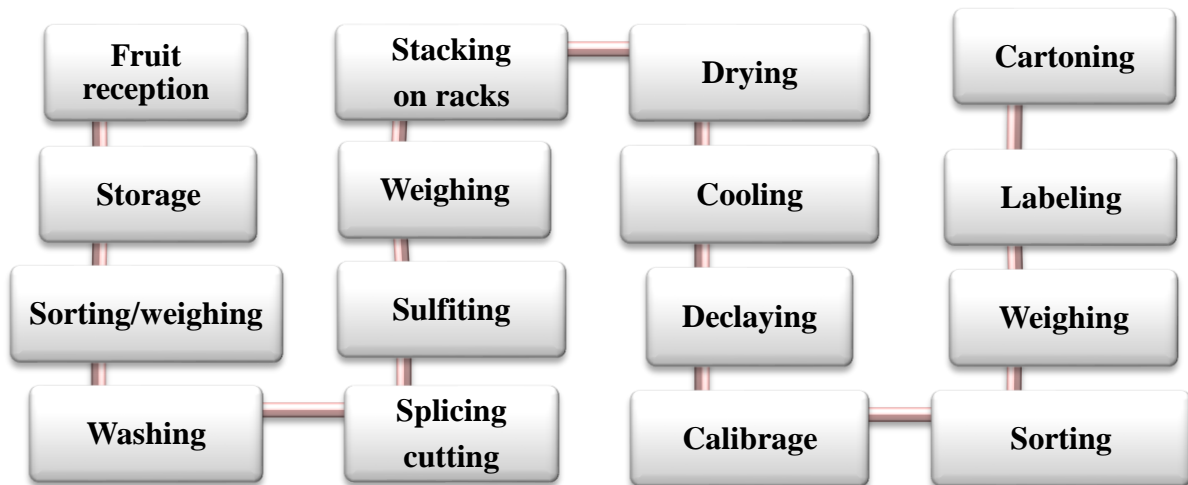


Fig. 2. Diagram of dried mango processing at coop-ca Gninanngnon

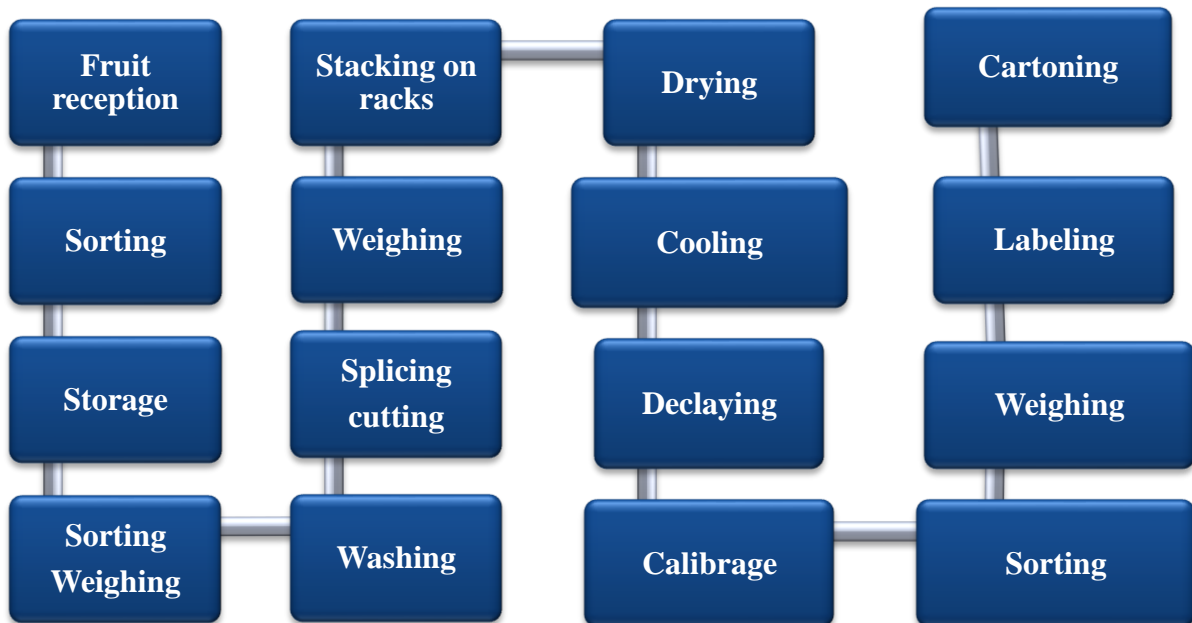


Fig. 3. Diagram of dried mango processing at Ivoire Organics

### 3.1.5 Raw material coding

This section describes and presents how products are identified and coded for the two different production units, to improve traceability.

**Reception:** On receipt, both companies identify the products they receive based on several elements. For IVOIRE ORGANICS, identification elements include the harvest slip, plot code, variety and delivery date. For COOP-CA GNINNANGNON, identification is based on delivery date, variety, lot number and grower's

name. All this information is recorded in a register book.

**Processing:** For both companies, once the products to be processed have been sorted, they are coded and processed. The Coop-ca Gninanngnon cooperative's traceability information is recorded on an individual identification sheet, including processing date, variety, mass and batch number. For Ivoire Organics, the information on the identification sheet concerns the mass of the product to be processed, and the batch codes (made up of the

plot code and a number allocated to the producer with the company's initials).

### 3.1.6 Finished product coding

Finished products are coded at packaging department level. It considers the different elements of the process. At the request of certain customers, barcodes are often included. This coding is provided by the customer for inventory management or repackaging purposes.

As for COOP-CA GNINNANGNON, its coding is done on a manual record according to the following elements, the production year (XX), the day of the production year (XXX), the zone code assigned to the company (5), the company code (13), the variety code (numbers are assigned to each variety), the production machine code (numbers are assigned to each tunnel) (Fig. 4).

At IVOIRE ORGANICS, coding is based on the following information: company acronym (IOP), plot code (a series of three digits), variety (brooks for BR), reception date (DD/MM/YY), production date (DD/MM/YY) (Fig. 5).

### 3.2 Analysis of the Drying Units' Traceability Systems

This section presents the traceability systems implemented by the two production units. It includes the traceability requirements, the degree

to which the units meet these requirements, and the rating assigned to this degree.

### 3.2.1 Level of satisfaction with traceability requirements

The percentage of satisfaction with the 5 prerequisite programs (PRP) of the indicators and standards relating to traceability according to the codex alimentarius are recorded in Table 2. According to this table, the COOP-CA GNINNANGNON drying unit scored 32 points out of a total of 51, i.e. 62.74% overall satisfaction with traceability requirements. IVOIRE ORGANICS scored 39 points out of a total of 51, for an overall satisfaction rate of 74.47%. The program where the percentage of satisfaction is below 50% for both units is the document management organization program, with a satisfaction rate of 33.33%. For the other programs, i.e. Defining the context, defining the general objectives and identifying the existing situation, COOP-CA GNINNANGNON recorded a rate of over 75%, 91.66%, 66.66%, unlike IVOIRE ORGANICS, which recorded a rate of over 83%, 83%, 50%.

### 3.2.2 Visualization of satisfaction points on the Radar diagram

The Radar diagrams (Figs. 6 & 7) show the prerequisite programs where satisfaction percentages were low for both production units. These were the document management organization programs, with a rate of 33.33%.



Fig. 4. Bag coded by the Gninnangnon cooperative society





Fig. 5. Ivory Organics coded satchet

Table 2. Percentage of compliance with traceability requirements

PRP	Prerequisite programs	Total points	Points obtained	Satisfaction rate
PRP 1	Define the context	12	9	75%
PRP2	Define general objectives	12	11	91.66%
PRP 3	Identify existing	6	4	66.66%
PRP 4	Define procedures (action plan)	18	16	88.89%
PRP 5	Organize document management	3	1	33.33%
TOTAL	Total	51	32	62.74%
<b>Ivoire organics</b>				
PRP	Prerequisite programs	Total points	Points obtained	Satisfaction rate
PRP 1	Define the context	12	10	83%
PRP2	Define general objectives	12	10	83.00%
PRP 3	Identify existing	6	3	50.00%
PRP 4	Define procedures (action plan)	18	15	83.33%
PRP 5	Organize document management	3	1	33.33%
TOTAL	Total	51	39	76.47%

### 3.2.3 Evaluation of critical prerequisite programs

Evaluation results are illustrated by Pareto diagrams. Non-satisfaction with the program is significant when it is greater than or equal to 25%. According to these results, the first three prerequisite programs in terms of requirements to the principles of traceability at COOP-CA GNINNANGNON are not satisfied; these are programs: PR5, PR3, PR1 (Fig. 8). These are the following prerequisite programs: Organize document management (documentation), Define the context, Identify existing systems (data collection and transmission systems). Non-compliance with traceability principles was

66.67%, 33.3% and 25% respectively. For IVOIRE ORGANICS, the results show the first two programs to be unsatisfactory. These are: PR5, PR3 (Fig. 9). Non-satisfaction with traceability principles is 66.67% and 50%.

### 3.2.4 Main causes of non-satisfaction with the general principles of traceability

The assessment of the prerequisite programs for the two production units shows that non-satisfaction with the contribution of traceability is to be found in program PR5, which concerns the organization of documentation. It should be noted that for these dried mango production units, traceability is provided by the company's



main customer. In fact, these companies do not have their own traceability system, and this is an obstacle to a possible partnership with another external customer. They also lack tracking sheets for each stage in the product's life cycle.

All traceability data must be recorded on log sheets and filed by the person in charge. To improve traceability efficiency, paper can be coupled with a computer system to store and process data.

### COOP-CA GNINNANGNON

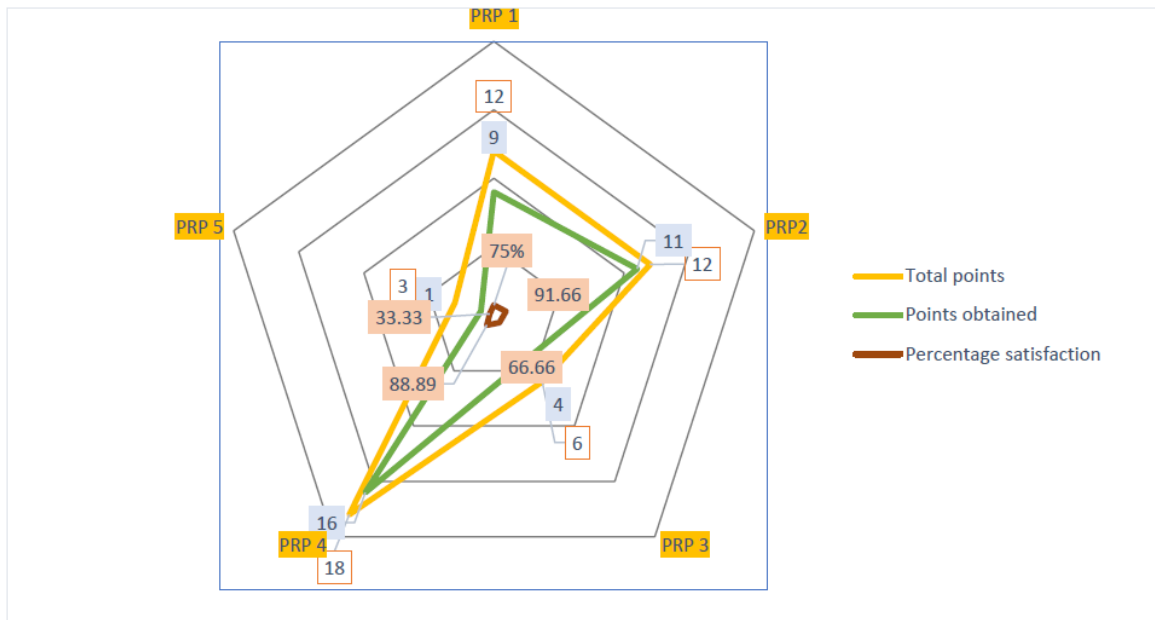


Fig. 6. Radar diagram of satisfaction with the principles of traceability at coop-ca Gninnangnon

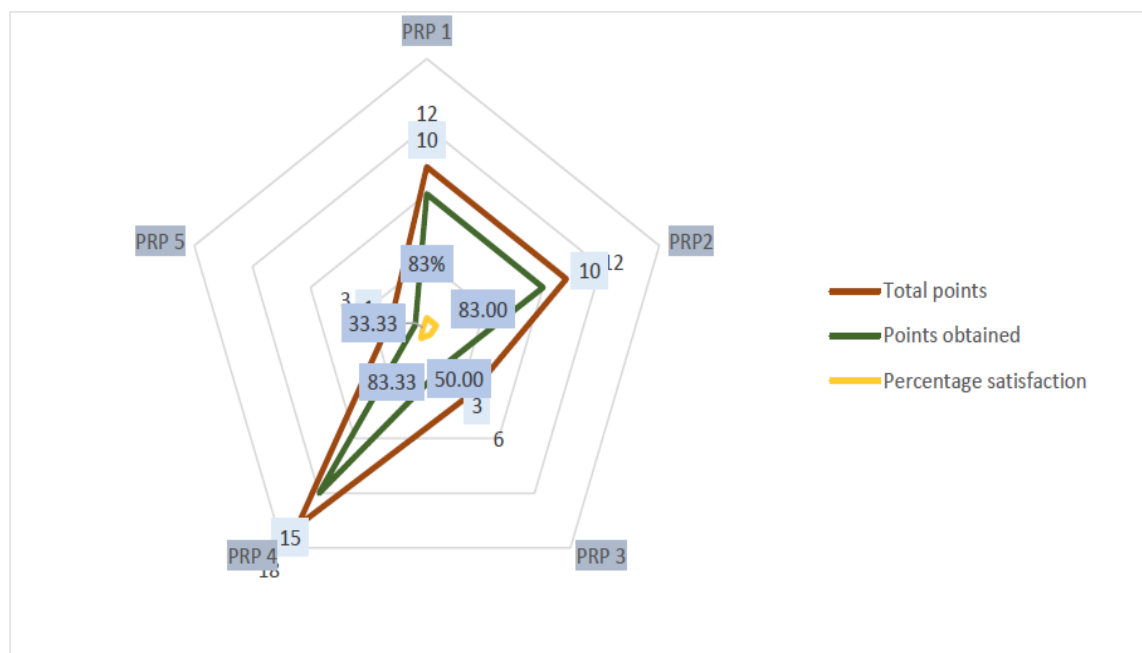


Fig. 7. Radar diagram of compliance with Ivoire Organics traceability principles

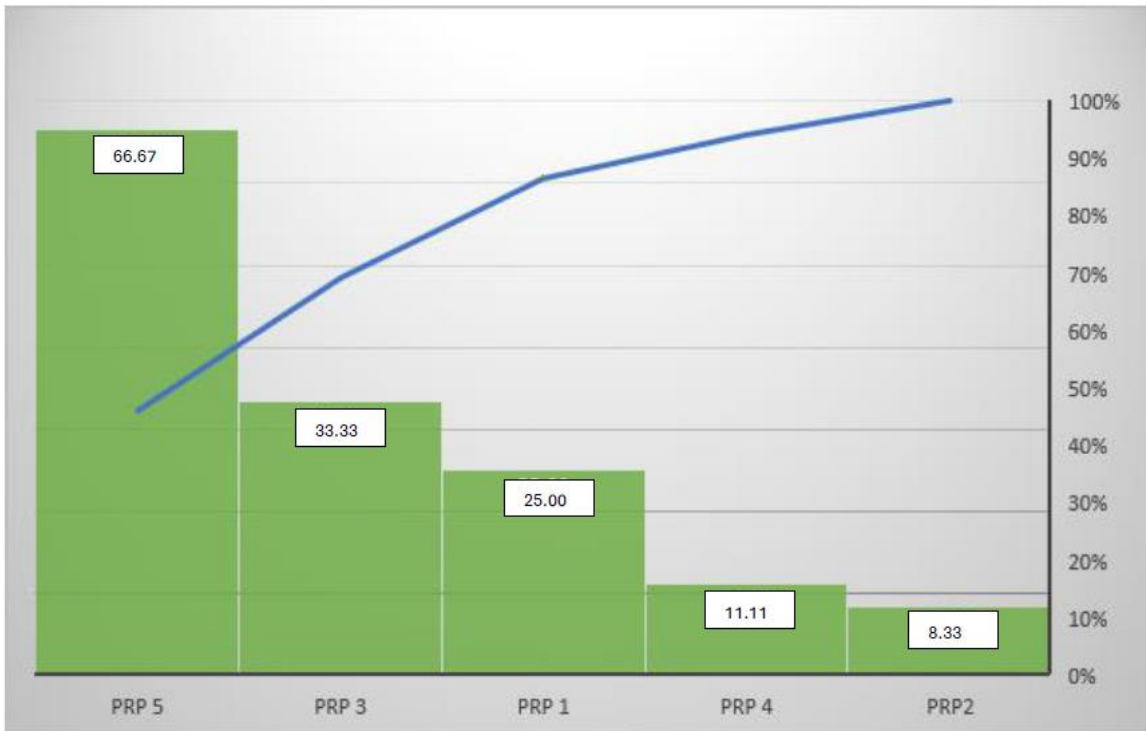


Fig. 8. Pareto chart of contribution to overall satisfaction with Gninnganon's general traceability principles

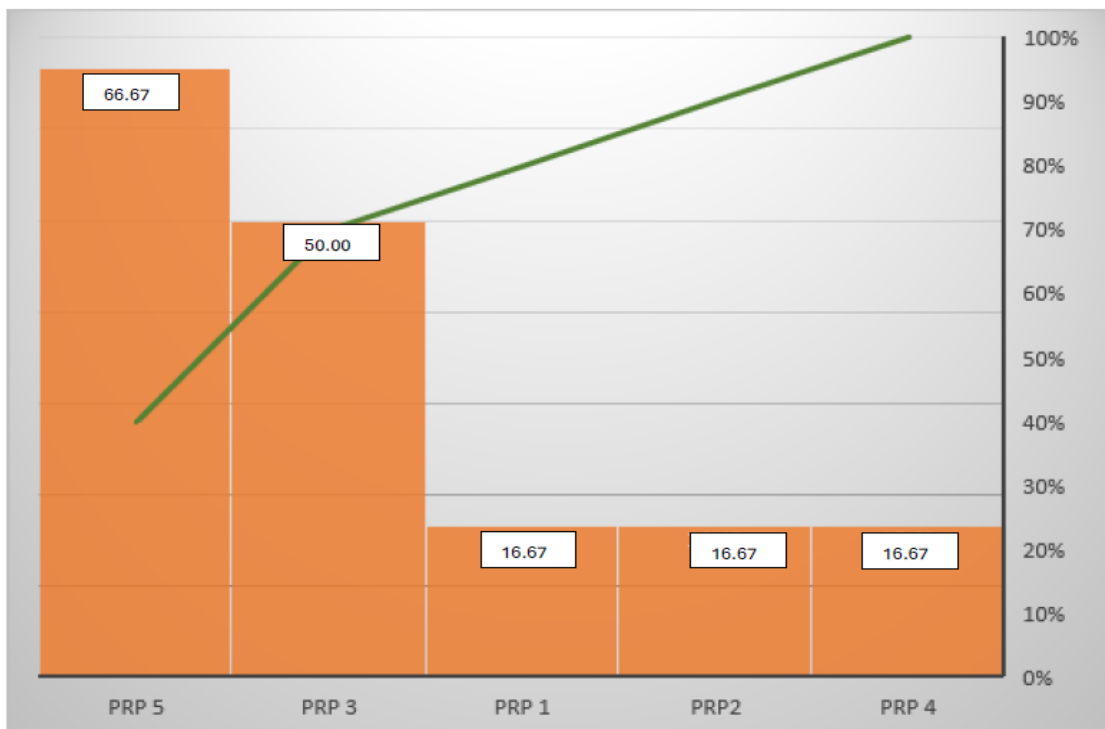


Fig. 9. Pareto chart of contribution to overall satisfaction with Ivoire Organics' general traceability principles

### 3.3 Proposal of a Traceability Scheme Adapted to the Company's Reality

The implementation of an efficient traceability system is essentially based on a diagram defining the different stages in the life of dried mango. For the Gninangnon cooperative and Ivoire Organics, the traceability system will reassure trading partners and help position dried mango on the national and international markets, giving the product a new dimension. The proposed scheme gives all the information for the various stages of the process, from receipt of fresh mangoes to processing, packaging and marketing of dried mangoes to customers. For the Gninangnon Cooperative and Ivoire Organics organization, the proposed scheme calls for all those involved in each stage of the process to set up a documentation system that covers all operations, from raw materials to final products. To this end, all levels should have the means to record data enabling the relationships between fresh and dried mangoes to be established at all stages of the process. To achieve this, it is necessary to establish a step-by-step diagram of the mango life cycle and the links between each stage. Data and information on the inputs and practices relating to each stage, and the succession of stages from raw material purchase to delivery of the finished product, must be collected and recorded.

## 4. DISCUSSION

The study carried out on the implementation of a traceability system in two dried mango units showed the existence of traceability elements, in other words, traceability tools for the two production units. Standard elements such as customer and supplier identification are notified and recorded as soon as the product and customer order are received. According to Article 18 of Regulation (EC) No. 178/2002, each operator must establish upstream (supplier identification) and downstream (customer identification) traceability for the products he places on the market. However, the results of the study revealed the non-existence in these companies of real traceability systems issued by standards organizations.

The results revealed the various elements or tools in place to trace the origin of products through to marketing, but the two production units do not have a system as such. In addition, the management of the production process is recorded in different registers used by the two

units according to the elements available to them, which are transcribed into code when labelling the finished products. This result corroborates that of (Ouedraogo et al. 2017), which shows in a study carried out in Burkina that Labeling is to be considered at bag level and after cardboard packaging for reasons of traceability. It makes it possible to find all the information relating to a finished product (raw materials, processing conditions, storage and transport conditions).

Each of the two mango-drying units has the resources and technology it needs to improve production. During the ripening process at Ivoire Organics, the mangoes are received in large quantities, and then sorted before being stored in the ripening room for 2 days, thereby reducing the rate of mango loss. It records a loss rate of 2%, while at the coop-ca Gninangnon drying unit, products are stored unsorted in the ripening room for 3 to 5 days, recording a loss rate of 5%. This result differs from that of (Traoré et al. 2017), who show in a study carried out in Burkina, in a mango drying unit, that mango ripening lasts an average of 6.60 days. They practice accelerated ripening using chemicals that are either calcium carbide or ethephon in order to be able to produce and satisfy their demand on time.

The COOP-CA GNINNANGNON drying unit achieved 62.74% overall satisfaction with traceability requirements, while IVOIRE ORGANICS achieved 74.47% overall satisfaction with traceability requirements. The program with a satisfaction rate below 50% for both units is the document management organization program, with a satisfaction rate of 33.33%. This is explained by the fact that they do not have sufficient tools and qualified personnel for the computerized and automatic management of information and documentation relating to a traceability system.

The results showed that a procedure for coding company products was carried out according to the different stages of dried mango processing. To implement a traceability strategy, it was necessary to establish and define codes to identify the various products within the processing units. The coding system preceded by the definition of the scope of application shows that the raw material and the finished product are monitored and controlled at every level. Thus, the involvement of a traceability system has improved the management of dried

mango production units. This result corroborates that of (Rakansou 2009) who, in a study carried out in Senegal in a fishing industry, showed coding based on different fields of application. The "Pirogue Bleue" fishing company uses a batch number made up of numbers and letters that highlight the date of manufacture, the nature of the product and the origin of the fish. Unlike the coding system used by "Amerger Casamance", another fishing industry, which has ten digits, the first six represent the date the product was received, the next two the origin, and the last two the delivery number to the factory. In a dried plum production unit, the batch number is inscribed on each finished product, providing access to the item's identity card (Rakansou 2009). To meet the objectives of the various units and improve their performance, it is essential to draw up a traceability diagram, which is a genuine management tool that enables all unit activities to be tracked. In the context of our study, the proposed traceability diagram takes account of information flows, useful forms and necessary supports. All these details were designed to control products from upstream to downstream, with the aim of building customer loyalty and gaining advantages in the consumer market. This finding is like that of (Rosalie et al. 2018), which shows in a study carried out in Côte d'Ivoire in the cashew sector that a traceability system must enable products to be identified and traced as quickly as possible in the event of recrimination, which may come from the competent authorities, a trading partner or a consumer. The implementation of a high-performance traceability system is essential to reassure trading partners and thus contribute to the positioning of Ivorian origin on the international market. According to regulations, the processor should be able to ensure the targeted withdrawal of products likely to represent a health risk for consumers. Withdrawal operations must be precise and proportionate to the risks involved. To achieve this, a system for documenting and recording data and information must be in place throughout the process, enabling the relationship between incoming and outgoing products to be established.

Once the concept of traceability had been established, product traceability was often associated with the management of crisis situations requiring the withdrawal or recall of products likely to be harmful to consumer health. The contribution of a traceability system in this type of context can be summed up as providing

its beneficiaries with a set of information enabling them to manage crisis situations effectively.

## 5. CONCLUSION

At the end of this study, it was found that the Gninagnon cooperative and Ivoire Organics in the Korhogo commune are dried mango processing units. These companies do not have a traceability system within their dried mango production units, but they do have traceability tools for each stage of the process, from procurement to product delivery, as well as a coding system for finished products. This study was used to define the traceability scheme for these two production units. Traceability is an essential tool for food safety, particularly for preventing risks in the event of a crisis. In general terms, it should be seen as a quality asset. This asset plays an important role in commercial relations, including on an international level, by providing a selling point in relation to competitors who do not implement it.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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