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Introduction of an SIS semolina machine in the fresh *Attiéké* manufacturing process: profitability study of a production unit in the village of Débrimou

Akely Pierre M. Thierry[1,2,*], Gnagne Heliane[2], Konan Brou Roger[2], Bouguerra Khaled[3], Coffi Rene Amand[2], N'guessan Georges Amani[2]

[1]École Normale Supérieure, 08 BP 10 Abidjan 08, Dpt. Sciences et Technologie, section SVT
[2]Université Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte D'Ivoire, UFR STA, LBTPT
[3]Institut Supérieur des Etudes technologiques de Zaghouan, Tunisie

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***Abstract*:**

A low-maintenance plant cassava contributes to addressing food crises in Africa. Cassava represents a sustainable solution for self-sufficiency among rural populations due to its ease in generating income. In the artisanal transformation of cassava into *attiéké*, a SIS semolina machine was introduced during the milling stage to alleviate the laboriousness of the process, offering a sustainable solution to enhance artisanal production conditions. To achieve this, the economic model of the *Koc'idj* women's association of Débrimou was studied, as well as the profitability of the SIS semolina machine. The classic break-even point was determined, with profits indicating a positive outcome and losses indicating a negative one. The results reveal that the association follows a standard but closed economic model. The two hundred active members, well-organized but independent artisans, produce fresh *attiéké* in their village, which they consume themselves and sell to retailers and direct consumers exclusively located in Dabou and Abidjan. They provide all the labour, operating in a circular system to involve all women. Cassava supply is facilitated by men to the women who make up various production teams. After sales, they divide the revenue based on the quantities of cassava contributed as input. The association partially relies on the revenue generated by the grinder. Furthermore, the net result of a fresh *attiéké* production unit under working conditions of the women is positive. This work has a significant impact on the production of *attiéké* and raises interest in mechanizing the fresh *attiéké* production process, a sustainable solution to alleviate the growing impoverishment of this community.

***Keywords*:** Cassava; *Attiéké*; Semolining; Profitability; Safety.

*Correspondant author:
Email address: akely_pierre@yahoo.fr *(P.M.T. Akely)*

1 Introduction

The development of post-harvest processing systems for root and tuber crops remains an effective strategy in addressing the long-standing poverty issues among sub-Saharan populations. This processing systems ensures food security by creating new opportunities for all stakeholders within the cassava industry, both upstream and downstream. In Côte d'Ivoire, cassava processing is necessary and, the output products serve as a staple food. The staple food is consumed in different forms, including fermented paste, grated cassava flour (*kokonté*), cassava mash (*fufu*), and couscous (*attiéké*) as described by [1, 2]. The potential transformation of cassava has attracted significant attention as it offers solutions to address hunger and poverty [3]. Beyond its competitive characteristics, *attiéké*, a derivative product of cassava, remains an identity food with significant cultural value. However, producers often struggle to achieve self-sufficiency and maintain consistent *attiéké* production due to the lack of adequate equipment [4, 5]. Consequently, *attiéké* is generally produced using traditional methods [6]. The traditional process involves several empirical, tedious, and complex unit operations. For instance, milling grated cassava is a labour-intensive operation that results in a heterogeneous texture of the couscous, leading to variability in quality [1, 7].

The introduction of the SIS semolina machine in the cassava transformation process holds promise for stabilizing food processing, reducing the number of artisanal producers required, and increasing profitability. Achieving profitability while maintaining acceptable organoleptic characteristics of *attiéké* remains a major challenge in the sector. This challenge is further compounded by the need to utilize the latest and improved cassava varieties [8-10].

For *attiéké* producers, the introduction of the SIS semolina machine represents a significant technological advancement, particularly for the villagers of Débrimou (Dabou). This unique technology transfer has generated considerable interest and marks the beginning of rational automation in village-based fresh *attiéké* production. To understand the impact of this innovation, this study aims to evaluate how the introduction of a mechanized grinder improves the yield in the production of village-based fresh *attiéké*. Specifically, through the economic model of the Débrimou artisan association (*Koc'idj*), this study addresses the following aspects:

- Evaluation of the production unit of the Débrimou artisan association.
- Determination of the material balance for the production of fresh *attiéké*.
- Calculation of the economic break-even point, highlighting potential profits or losses.

By addressing these points, the study aims to provide a comprehensive assessment of the profitability and feasibility of introducing the SIS semolina machine in the fresh *attiéké* manufacturing process in the village of Débrimou.

2 Material et methods

2.1 Material

2.1.1 Cassava tuberous roots

The plant's vegetative raw material primarily comprises Manioc (*Manihot Esculenta* CRANTZ) tuberous roots, specifically the Improved African Cassava variety (IAC), aged 12 months, and harvested from the fields of artisans belonging to the *Koc'idj* Association in Dabou. These roots are used in the production of fresh *attiéké*.

2.1.2 SIS Machine semolina

The grinder has been previously described by [11]. It is equipped with an input hopper used for receiving the pressed paste. This paste undergoes mechanical semolining through a rotating blade, the calibration of which is adjusted manually through a screw mechanism. The resulting couscous is collected at the output through an exit hopper. The characteristics of the grinder are provided in table 1.

2.2 Methods

2.2.1 Community investigation on village practices of the Koc'idj association

The investigation involved observing 200 artisans from the *Koc'idj* community in Débrimou, who are producers of fresh *attiéké*, regarding their economic and cultural practices. Communication with the community involved informed discussions about the availability of fresh *attiéké* and the technical aspects of production, specifically the acquisition of equipment and resource mobilization [12]. Questions about economic activities, agriculture, artisanal production and the community's income needs helped to understand the economic model and the methods of *attiéké* production, including both the traditional method and the improved traditional method involving the introduction of a semi-industrial grinder into the fresh *attiéké* production process [13]. Subsequently, the focus naturally shifted to the improved method and the availability of the primary input, which is cassava. Technical aspects related to the various methods of producing fresh *attiéké* were identified to determine the net result of a fresh *attiéké* production unit under local conditions. Finally, this last aspect allowed for the calculation of the break-even point using the standard method described by [14] in terms of both positive profit and negative loss.

2.2.2 Procedure for calculating the Break-even Point

The break-even point was determined in terms of profit if it is positive and loss if it is negative. It is important to note that technical measurements were conducted on the production site over a six-month period, and general data collection was performed. The analysis of the financial profitability of introducing the grinder into the traditional process was based on this data and conducted over a one-year period. A material balance was established for a daily production of one ton of fresh *attiéké*. The cassava used for this material balance is the Improved African Cassava (IAC), with a dry matter content of approximately 44% and a yield of 41% after cooking. The entire profitability study was carried out using the method described by [15] based on the material balance (Figure 4).

Table 1
Experimental characteristics of the grinder.

Characteristics	Parameters
Space (H x l x L)*	1500 mm x 650 mm x 1250 mm
Electric engine	3 CV, 1500 rpm
Axis speed	750 rpm
Productivity	250 kg/h

*H x l x L = stands for "Height x Width x Length"

2.2.3 Physico-chemical analyses

The starch, moisture, ash, fat, protein content and pH analyses were carried out according to the standard procedures described by AOAC [16]. Mineral content was determined by the emission flame photometric method [17]. The granularity of semolina was determined according to [18]. The energy value was calculated in relation to the dry matter (DM) according to [17]. The total dietary fibre was determined according to [19]. The determination of sugar and organic acids was performed using high-performance liquid chromatography (HPL, Merck Hitachi) according to the method described by [20]. All analyses were performed in triplicate to ensure accuracy and consistency.

2.2.4 Data monitoring and statistical analysis

Questionnaire, quantitative and qualitative data analysis software (Sphinx iQ2, 1995 [X]) were performed to process and analyses the survey data. Conventional method for profitability studies was applied to the financial analysis of the production of one ton of fresh *attiéké* per day (1 t/day) derived from the Improved African Cassava (IAC) variety. The management balances taken into account are: (1) - Revenue; (2) - Production; (3) - Gross Margin on Material Consumption; (4) - Value Added; (5) - Personnel Remuneration; (6) - Gross Operating Surplus (EBE); (8) - Operating Result.

That allowed for the calculation of several significant management balances to assess the need for the introduction of a grinder (SIS) into the *attiéké* manufacturing process. Statistical analyses were carried out using Minitab software (1998) with a significance level of 5%. All data were performed in triplicate.

3 Results and discussion

3.1 Evaluation of the production unit of the Débrimou artisan association

- **Description of the economic model and availability of cassava and fresh *attiéké***

Economic model of the association can be described as a village community of the Adioukrou ethnic group, primarily composed of 100,000 individuals, including men, women, young and children. They represent nearly 99% of the indigenous population. The remaining 1% consists of non-indigenous people who come from neighbouring countries or are children of immigrants who have converted or been naturalized. The Adioukrou people are characterized by their traditional socio-cultural and economic practices, to which they remain attached. They primarily rely on cassava agriculture, accounting for 90% of their livelihood, along with other starchy staples (10%) rich in starch, such as yam (5%) and plantain (5%) for the less privileged members (representing 90% of the community). Due to the advent of intensive farming, the entire community has shifted towards rubber and oil palm cultivation (covering 40-60% of cultivable land). According to the villagers, this has led to a local cassava shortage and consequently a national one. In response to the supply shortage, 200 women from Débrimou and Adissagne formed an association (*Koc'idj*) to produce *attiéké* for sale and direct consumption.

The survey also revealed the existence of a diverse range of dishes derived from the production of *attiéké*. These include: *Popori*: Hand-made fermented cassava balls, prepared in salted boiling water, enriched with dried fish particles and dried chili; *Préprécou*: Large hand-made fermented cassava balls, prepared in combination with palm nut sauce; *Akraro*: Cassava paste for *placali*, hand-made and grilled with red palm oil; *Pkôtê*: Residue from milling, dried through smoking over several months, prepared in combination with palm nut sauce; *Magne-offoun*: Fermented cassava paste flattened in *Stomatococcus daniellis* leaves, smoked gently over a metal grill, and consumed with dried coconut; *Placali*: Well-known as the fermented cassava paste used in *attiéké* production, soaked in water, sifted and gelatinized at 100°C ; *Ebge-placali* or *attiéké-placali:* A lesser-known variant of *placali* or *foutou,* made from cooked or dried *attiéké*, soaked in boiling water, then combined with ripe plantain and pounded in a mortar. It should be noted that another type of *attiéké-placali* is obtained from partially or completely altered *attiéké*. The preparation of this dish is more rigorous, as the *attiéké* is first dried, crushed, washed, soaked in boiling water, cleaned and then combined with ripe plantain and pounded in a mortar.

Considering the introduction of the semi-industrial grinder (SIS) by LBATPT, the women of the *Koc'idj* association provide all the labour. They operate in a rotational system on the semi-industrial grinder (SIS) to involve all the women. While waiting for their turn in rotation, the women are free to engage in their personal activities. This makes the activity entirely flexible, with a desire for collaboration and mutual support among the members. Cassava supply is managed individually by the association members organized into production teams. The workers are primarily composed of young women aged 18-45 (approximately 80%) and older mothers aged 45-90 (approximately 20%). After sales, they share the revenue (CA) in proportion to the quantities of cassava brought in as input. The association partially sustains itself through the proceeds from the integrated grinder in the production process. The women follow a traditional circular economy, based on an extract-produce-consume-dispose-revalorize model (Figure 1).

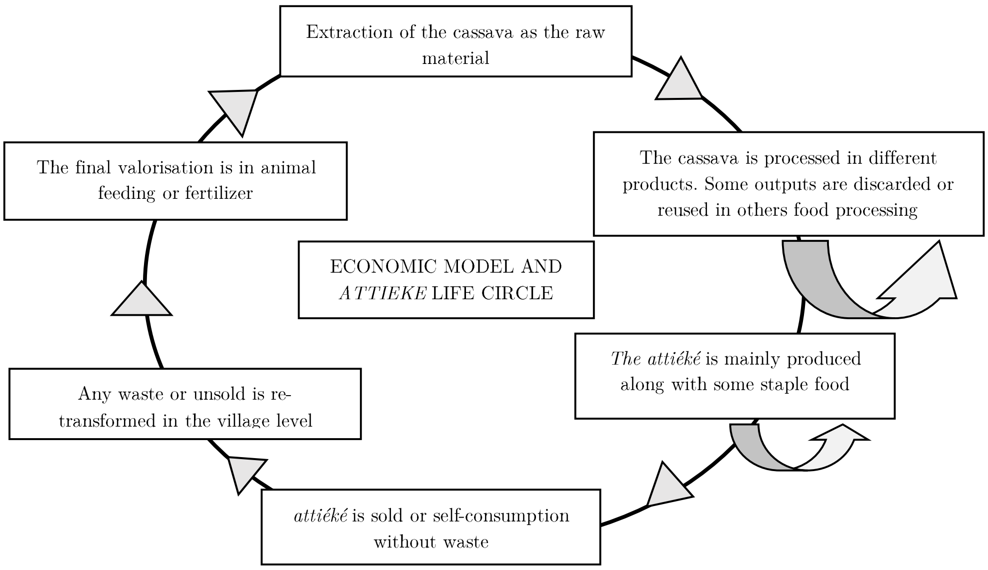

Fig. 1. The economic model of *Koc'idj's attiéké* production.

The economic model can be summarized as follows: cassava production, its transformation into *attiéké*, local market commercialization, and its value addition as a local dish. As noted, this local model incurred no cost because non-food residues are utilized as animal feed for pigs or as fertilizer for cassava crops. The cassava production of Débrimou (village located 5 km from Dabou), is estimated at 18,000 tons per year. That biggest village alone contributes 50% of the *Leboutou* production, primarily with varieties like *Yacé,* [21] *Yavo, Bonoua, Zoglo* and other introduced varieties such as *TMS* [22]. Débrimou alone supplies the city of Abidjan, accounting for 40% of the production. This performance significantly surpasses the production of the *Gbêkê* region (North-Central) at 18%, the *Marahoué* region (West-Central) and the *Comoé* region (East) at 11% and 9% of national production, respectively. It's worth noting that cassava production yields have declined due to poor arable land quality and the emergence of rubber tree cultivation.

- **Technical aspect of the physico-chemical and nutritional qualities and the production method of *attiéké***

In general, it is well-known that the physico-chemical and nutritional qualities of the village attiéké are the best [9, 21, 22]. The physico-chemical composition and nutritional value of the *attiéké* are presented in the table 2. The results aligned with the physico-chemical and nutritional qualities of attiéké reported elsewhere by [23-25]. It is worth noting that *attiéké* is a highly caloric food, rich in carbohydrates (as indicated by the starch content, approximately 70-80%) and minerals. This makes it a highly sought-after food consumed in various forms, such as *placali,* cassava pieces, flour, fresh semolina, starch, etc. Fresh *attiéké* remains the most well-known format, as opposed to dehydrated *attiéké.* Its production is carried out by several small-scale family-based artisanal or semi-artisanal units, which are more significant than industrial production. Additionally, fresh *attiéké* is easily characterized by a high starch content ranging from 71.5% to 80% on a dry matter basis, this value falls 10 for the dry *attiéké*. The dry matter content ranged from 50 to 54%, and 90% for the dry *attiéké*, with a crude protein content ranging from 1.50% to 2.89%. This value slightly falls to 1.46% for the dry *attiéké*. However, the pH value of fresh *attiéké* after cooking ranges between 4 and 4.50, which may increase to 5.03 [24, 26, 27]. This variation depends on the generally hetero-lactic fermentation [28] and others microbiotas naturally present in the products [29]. Furthermore, the ash content (total minerals) is 0.45% on a dry matter basis (see Table 2). The protein content ranged from 1.5 to 2.89%, and 1.46 for the dry *attiéké*. The cyanide content is ranging to 0 to 10 mg/kg lower than recommended level (10 mg/kg) reported by [24].

It is noted that *attiéké* (fresh or dry) also contains cellulose (1.30%) and lactic acid (2.12%) as well as sugars and organic acid such as sucrose, glucose, fructose, maltose, and organic acids like acetate, formate, lactic acid, acetic acid, and ethanol [24] and minerals [27]. This is due to lactic fermentation, which imparts an acidic flavour [28, 29]. The quality of *attiéké* is assessed in urban markets by its non-fibrous appearance, sticky texture, light yellow, glossy, creamy colour, pleasant odour, and slightly acidic taste [30-32]. *Attiéké* is characterized by varying minerals and, granulometry, consisting of grains ranging from fine to coarse, with an average size between 0.1 and 3 mm [33], close to the indicative values in the table 2 (approximately 0.8 – 0.2 µm). The production techniques of *attiéké* proceed as follows.

- **The traditional process of fresh *attiéké* production**

The main steps of *attiéké* production are as follows:

a) Pre-fermenting of inoculum (three-day cassava ferment).

b) Peeling and slicing the cassava into pieces.

c) Washing and cleaning the cassava pieces and the ferment.

d) Mixing the ferment with heated palm oil until it turns colourless.

e) Grinding or grating fresh cassava piece along with the ferment mixed with saturated oil.

f) Fermenting of the ground cassava (with specified addition rates and time).

g) Pressing the fermented dough with solid bricks or an artisanal press.

h) Crumbling and sieving.

i) Milling with a bowl.

j) Solar pre-drying of the semolina.

k) Defibrillation and winnowing to remove fibres.

l) Steaming the semolina with boiling water vapour

m) Cooling the product (*attiéké*).

n) Packaging using *Stomatococcus daniellis* or *Musa acuminata* leaves.

Table 2
The standard physico-chemical composition and nutritional qualities of the *attiéké* (fresh and dry).

	Fresh*	Dry*
Moisture (%MS)	36 - 55	10.00± 0.01
Dry Matter (%)	50 - 54.1	90.00± 0.01
pH	4 - 4.5	
HCN (mg/kg)	0 - 10	-
Ash (mg/100 g)	0.45 - 1.40	0.67± 0.01
Starch	71 - 80.4	87.10± 0.01
Fat (mg/100 g)	0.45 – 0.80	0.20± 0.01
Protein (mg/100 g)	1.50 - 2.89	1.46± 0.01
Carbohydrate	39± 0.01	-
Bulk Density	0.8 - 1.1	-
Semolina (µm)	0.8 – 0.2	≤ 0.63± 0.01
Cellulose (mg/100)	1.30± 0.01	1.30± 0.01
Crude fibre (%)	1.9 ± 0.1	-
lactic Acid (%)	2.1 ± 0.2	-
Phosphorus (mg/100)	60.00 ± 0.01	60.00± 0.01
Calcium (mg/100 g)	60.00± 0.01	60.00± 0.01
Potassium (mg/100 g)	1.40± 0.01	1.40± 0.01
Fer (mg/100 g)	2.72± 0.01	2.62± 0.01
Cu (mg/100 g)	0.50± 0.01	0.36 ± 0.01
Energy value (kcal)	170.00± 0.01	-

*Value in column followed by ± standard deviation; (-) trace value.

- **The improved process for producing fresh *attiéké***

The main steps of the improved *attiéké* production process are as follows:
a) Preparation of the ferment.
b) Weighing the cassava roots.
c) Peeling (defibrating and slicing) the cassava roots into pieces with knife.
d) Washing the cassava pieces three times with fresh water.
e) Weighing the washed pieces and grinding them with the addition of starter culture and refined palm oil.
f) Fermenting in closed bins for 45 minutes to 1 hour.
g) Placing the obtained paste in sacks for fermentation for 15 to 23 hours.
h) Draining the fermented paste.
i) Granulating using SIS machine semolina.
j) Pre-drying the semolina and cooking with steam.
k) Cooling the product (*attiéké*) with steamer.
l) Packaging.

The manufacturing processes in traditional and semi-industrial environments are summarized in figure 2. There is a noticeable difference between the two processes. that partial drying, the double crumble-sieve operation, as well as winnowing-defibrillation, are non-existent in the semi-industrial process. However, the two processes have in common the operations of peeling, slicing, washing, grating (or grinding), fermentation, pressing (or centrifugation), granulation and steam cooking. In the first group of operations, the cassava root is completely peeled, ground, and fermented in one day of work. In the second group of operations, the fermented cassava is pressed, crumbled, semolinaed, sieved-winnowed, dried, and steamed, which can be done in one or two days of work.

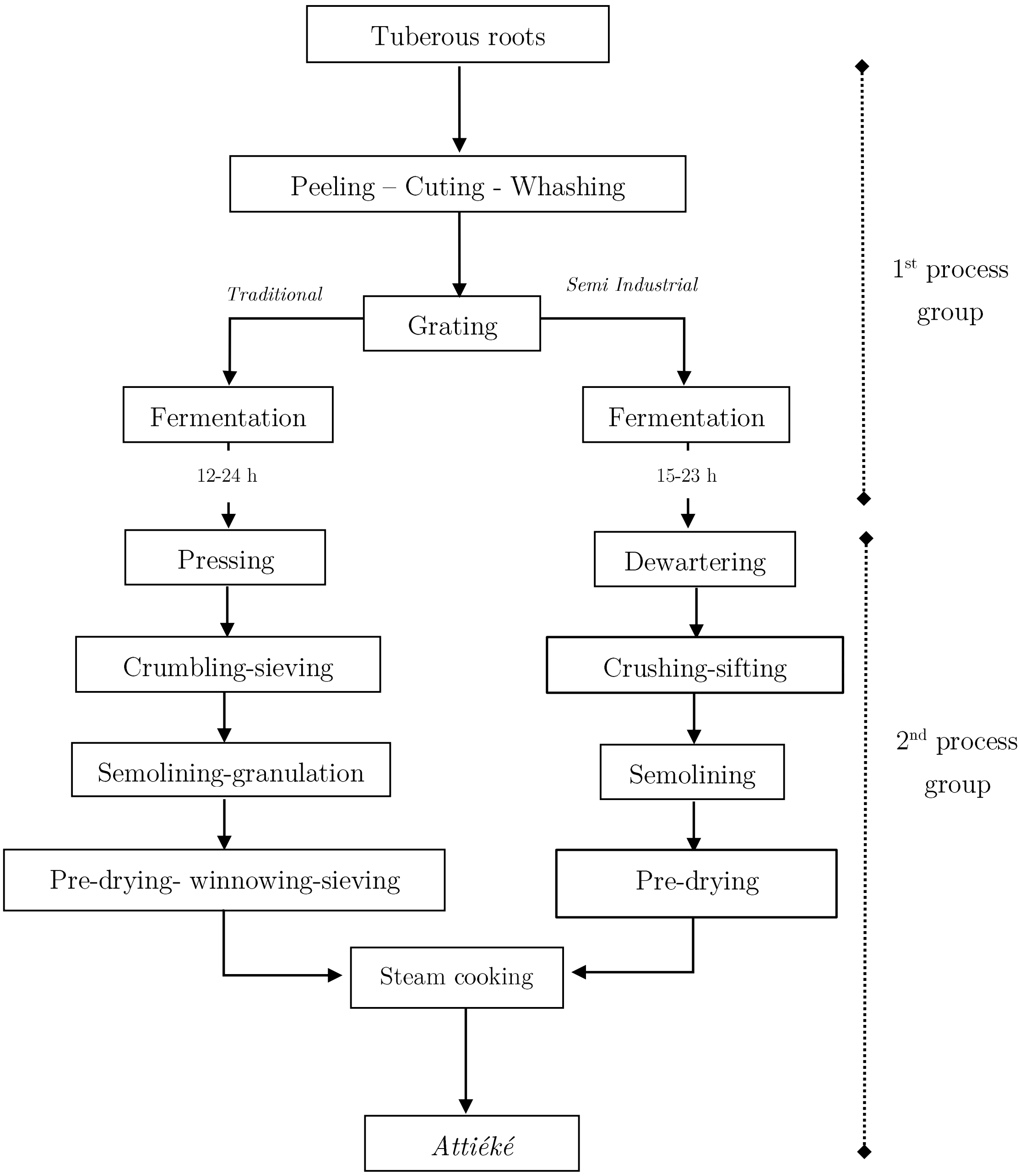

Fig. 2. Semi industrial versus traditional process for the *attiéké* production.

Steam cooking is sometimes delayed in case of agglomeration of *attiéké* semolina obtained during cooking. This implies poor fermentation at the base. In this case, the cassava semolina is completely covered and stored in an anaerobic environment for one or two full days to restart the deficient lactic fermentation process before proceeding with the final cooking process. It should be noted that the quality of *attiéké* is highly dependent on the fermentation and pressing stages. To obtain a qualitative finished product, there must be a balance between hetero-lactic ferments and an optimal amount of residual water during pressing. In conclusion, for both processes, the *attiéké* manufacturing time is long, justifying a single weekly production of fresh *attiéké*. In this fundamental aspect, there is no difference between the two processes, except for the use of pH sticks to control fermentation. Both techniques last half a day of work (approximately 12 hours), which can extend to a full 24-hour day of work. This makes it impractical for industrial production [25, 26]. A comparison of the unit operations and equipment used in traditional and semi-industrial techniques is presented in table 3.

Table 3

Contrast of traditional and semi-industrial *attiéké* manufacturing processes.

Processing step	Processes methods	
	Traditional	Semi-industrial
Peeling, cutting, washing	Manual defibration with knives	Motorized defibration
Grinding	Grating, manual grater, perforated plate (Mortar)	Mechanical grater for speed and time efficiency (800 kg/h)
Fermenting	Inoculum from an old jute bag, Uncontrolled fermentation in utensils	Controlled fermentation with pH and inoculum rate monitoring
Pressing	Manual pressing with large stones, Uncontrolled Manual Twisting	Screw pressing, centrifuge spinner with known quantity of extracted water
Granulating	Manual granulation using wooden bowls, Sieving and winnowing, uncontrolled	Automatic semolining (200 to 250 kg/h) for time efficiency
Drying	Manual sun drying and ground-level winnowing	Tray drying on metal racks
Steaming cooking	Pottery pot, wood fuel, empirical cooking	Automatic cooker, gas or electric; controlled cooking
Packaging	Wooden and banana leaf	Food packaging, polyester bag

3.2 Material balance of a one-ton daily production unit of fresh *attiéké*

Figure 3 highlights the operational process and material balance for the production of fresh *attiéké*. It shows that the conversion yield of cassava is 85% for peeled roots, 40% for wet *attiéké* and 30% for dehydrated *attiéké* with 10% moisture content. This means that one ton of cassava tuber roots produces an average of 300 kg of dehydrated *attiéké* and 400 kg of wet *attiéké* ready for consumption. In projection, approximately 4.8 tons of wet *attiéké* can be obtained per hectare of cultivation with a yield of 12 t/ha of cassava tuber roots. Since the price of fresh *attiéké* is approximately 500 XOF per kilogram at retail, the production cost is approximately 960,000 XOF. However, it should be noted that this price may need to be adjusted due to the constant fluctuations in the market. This income is obtained after a long manufacturing process, which takes at least a week of work.

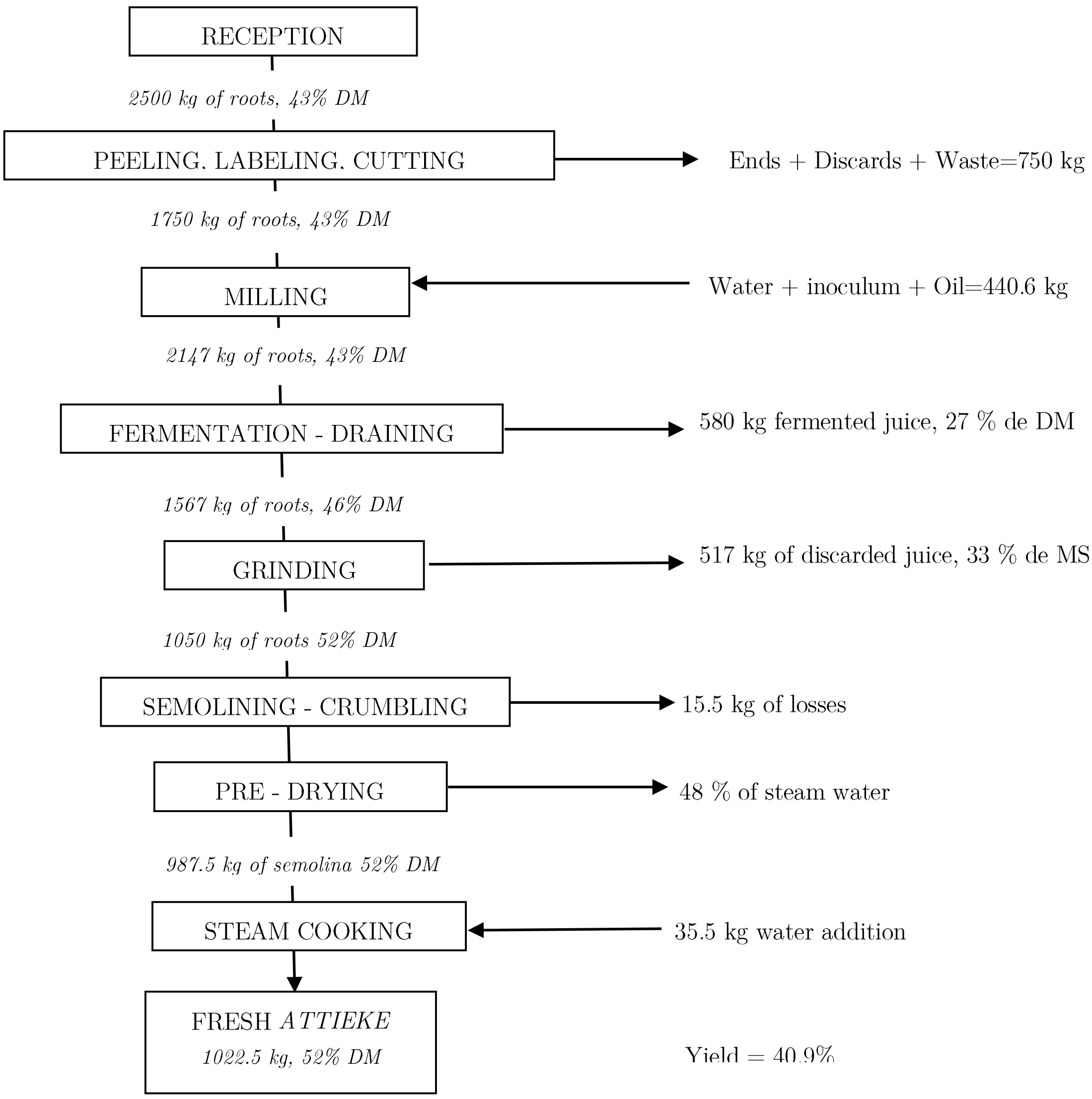

Fig. 3. Material balance for a one-ton fresh *attiéké* production unit per day.

One of the constraints of artisanal and semi-industrial processing is the lack of profitability due to a lack of control over unit operations and equipment. Thus, the yield in transforming cassava into *attiéké* is 85% for peeled roots, 32% for dried chips, 30% for flour and 30% for *attiéké* dehydrated to 10% moisture content. This means that one ton of tuberous roots will yield 300 kg of dehydrated *attiéké* and 400 kg of moist *attiéké* ready for consumption. Approximately 4.8 tons of moist *attiéké* can be obtained from one hectare of cultivation, assuming a yield of 12 tons/ha of tuberous roots.

3.3 Outcome of the profitability of the improved fresh *attiéké* production process

This financial study focused on the daily production of one ton of fresh *attiéké* using the bitter variety of cassava namely IAC. This part is crucial because it is logical that if, with the introduction of the SIS semolina machine into the process, the women of Débrimou cannot sell their *attiéké* for a higher price than it costs to produce, then the introduction of the semolina machine would have been a failure, potentially leading to their disappearance. Therefore, this financial study will aim to practically determine some theoretically significant management balances to assess the necessity of introducing the SIS semolina machine into the *gari* production process.

3.3.1 Revenue

All the production generated by the women from Débrimou for the purpose of selling is successfully marketed. This data proved to be invaluable for the analysis of the *Koc'idj* association's production unit. The current market price for one kilogram of fresh *attiéké* stands at 500 XOF (Figure 4). This price has remained constant since 2010 [34]. Nevertheless, it is susceptible to fluctuations depending on cassava availability, underscoring the significance of conducting a comprehensive supply study prior to entering the sector. Therefore, for the purposes of this study, the adopted selling price aligns with the prevailing market rate of 500 XOF per kilogram in the Ivorian market:

(1) SELLING PRICE = 500 XOF/kg (Figure 4).

The investigation results show that the annual quantity produced is the product of the daily quantity and the number of days of annual *attiéké* production, resulting in 20 days/month × 12 months, giving an annual production period of 240 days/year. The daily quantity of *attiéké* is determined to be 1,000 kg/day, which equals 1,000 kg/day × 240 days/year, resulting in an annual quantity of 240,000 kg per year. Thus,

(2) QUANTITY SOLD/YEAR = 240,000 kg/year.

According to the survey, it is observed that the entire production is sold, leading to the calculation of revenue by simply multiplying the production quantity (1) by the selling price (2). Hence, the revenue is equal to 240,000 kg/year × 500 XOF/kg. Therefore,

(3) REVENUE = 120,000,000 XOF/year.

Fig. 4. Market price evolution of *attiéké*.

3.3.2 Production

The production analysis reveals that the *Koc'idj* association in Débrimou does not maintain a significant inventory of their output. Consequently, the inventory level is insignificant. However, another factor must be considered: non-commercialized production. Non-commercialized production refers to the quantity of *attiéké* consumed locally by the artisan women. It's important to note that *attiéké* is a staple food in this region [35-37]. Therefore, the total production consists of the sum of sold production, inventory, and the quantity used for domestic consumption. Specifically, the annual production sold amounts to 240,000 kg, there is no inventory (0 kg), and the annual domestic consumption is 10,000 kg. This adds up to a total annual production of 250,000 kg/year.

Furthermore, the 10,000 kg of *attiéké* consumed domestically cannot be priced at 500 XOF per kilogram due to the absence of packaging and distribution costs. After calculations, these costs were valued at 430 XOF per kilogram. Consequently, the annual production intended for domestic consumption is calculated to be equal to 10,000 kg × 430 XOF, resulting in an annual domestic consumption production of 4,300,000 XOF.

In summary, production is determined as the total sum of revenue (3) added to production for domestic consumption (3'), resulting in 120,000,000 XOF + 4,300,000 XOF. This leads to:

(4) PRODUCTION = 124,300,000 XOF.

3.3.3 Gross material consumption margin

The gross material consumption margin, also referred to as gross margin in consolidated accounts, is a significant balance for a production unit. The gross material consumption margin is determined as the production subtracted from material consumption. Material consumption is essential in the sense that it takes into account variations in stock levels. In this context, the artisans do not stock either the starter culture, palm oil, or cassava. This practice has the consequence of reducing material consumption to the purchase of raw materials and other supplies because there is no stock variation (0).

In summary, material consumption equals the sum of raw material purchases plus other supplies minus the stock variation, determined as follows (see Table 4).

Purchase of IAC cassava for the production of 250,000 kg of fresh *attiéké* per year: For the production of 250,000 kg of fresh *attiéké* per year, 625,000 kg of IAC cassava roots are required (cf. material balance; Table 4).

Purchase of starter culture (10% of the weight of cassava pulp): The starter culture used to improve and direct the fermentation of the *attiéké* is 175 kg for 1,750 kg of cassava pulp, which corresponds to 437,500 kg of dough (cf. material balance, Table 4). These proportions correspond to the production of 250,000 kg of fresh *attiéké* per year.

Purchase of palm oil (0.2% of the weight of cassava pulp): Decolorized and deodorized palm oil acts as a binder, giving *attiéké* its consistency and cohesion, and maintaining the shape of the grains during cooking. In the absence or incorrect dosage of oil, *attiéké* may become lumpy during cooking. It also imparts a unique creamy-yellow colour to *attiéké*. For 437,500 kg of dough, 0.2% equals 875 L of palm oil. The total material consumption for the production of 250,000 kg of fresh *attiéké* is the sum of the material consumption of all inputs. This results in the consumption of IAC cassava (*YACE*) equal to 40,125,000 XOF, the consumption of yeast (*MAGNAN*) equal to 2,253,125 XOF, and the consumption of palm oil equal to 721,000 XOF. Therefore, the determined total material consumption is:

(5) MATERIAL CONSUMPTION = 43,100,000 XOF. Hence, the margin on material consumption is equal to the production (124,300,000 XOF) minus the material consumption (43,100,000 XOF), resulting in 81,200,000 XOF:

(6) MARGIN ON MATERIAL CONSUMPTION = 81,200,000 XOF.

Table 4

The purchase cost of IAC cassava, yeast, and palm oil.

Designation	Quantity	Unit Price (XOF/kg)	Amount (XOF)
IAC cassava Purchase for the production of 250,000 kg of fresh *attiéké* per year			
Cassava root (kg)	625,000	60	37,500,000
	37,500,000	0.07	2,625,000
Sum			40,125,000
Inoculum purchase (10% of the weight of the cassava dough)			
Inoculum (kg)	4,3750	50	2,187,500
	2,187,500	0.03	65,625
Sum			2,253,125
Palm oil purchase (0.2% of the weight of the cassava dough)			
Palm oil (L)	875	800	700,000
	700,000	0.03	21,000
Sum			721,000

3.3.4 Value Added

Value added reflects the additional value brought by the artisans in their production of fresh *attiéké* to the goods and services from third parties. For purists, the women of Débrimou do not generate a commercial margin because they are a transformation enterprise, not a trading or distribution enterprise, although this may not necessarily be evident in observed facts. This observation led to the calculation of their value added as the difference between their margin on material consumption and the consumption of goods and services from third parties. Other external expenses include subcontractors (such as grinding), rent, and non-storable material purchases and supplies. Therefore, the value added is determined as equal to the margin on material consumption minus other external expenses.

Grinding (subcontracted): It is the third stage of the process. The artisans subcontract this stage. If fifty kg of cassava pulp is ground at 250 XOF in Débrimou, with 437,500 kg of cassava pulp and 43,750 kg of yeast to be ground, the total mass to be processed is 481,250 kg.

Rent: The artisans of the association operate under wooden shelters they constructed themselves. Only the SIS processor is located in a separate building. This means they are not protected from the weather. However, for sustainability reasons, their annual rent has been set at 120,000 XOF, which includes the rent for the space housing the SIS processor and symbolic rents for the spaces they occupy in the village for *attiéké* production.

Non-storable material purchases and supplies:

* **Non-storable - Water**: The women of Débrimou do not use the water sold by Côte d'Ivoire Water Distribution Company for *attiéké* production. They use a village potable water well maintained by Côte d'Ivoire Water distribution company. For this expense category, an amount of 60,000 XOF per year has been determined for well maintenance.

* **Non-storable - Electricity**: The SIS processor has a power of 3 kW and a nominal capacity for processing 250 kg of squeezed dough per hour. Based on empirical measurements, it has a mass yield of 93%, calculated as the ratio of the final mass to the initial mass, which is equal to 0.93. According to the material balance of the IAC variety (see Figure 3 above), to produce 250,000 kg of fresh *attiéké* per year, 255,000 kg of semolina is required before pre-drying. Considering the mass yield of the SIS processor, the initial mass is equal to 274,200 kg of squeezed dough. This value, when related to the capacity of the SIS processor (250 kg/h), gives the annual working time of the SIS processor, which is approximately 1100 hours per year. Its power is 3 kW, so the annual electrical energy consumption is determined by the product of power (3 kW) and time (1,100 h), resulting in 3,300 kWh per year. Furthermore, the type of Ivoirian Electricity Company network subscription for the women of Débrimou is indicated in Table 5 (Non-storable - Electricity).

* **Non-storable - Firewood**: Firewood is the primary source of energy used for cooking fresh *attiéké*. However, women collect it themselves from cassava or

surrounding forest plantations. It should be noted that women do not hire any services (such as loggers or bundle gatherers) for either deforestation or cultivation. They primarily use dead trees collected from the forest. At this vital expense category, an amount of 120,000 XOF per year corresponding to potential purchases of collected firewood has been allocated. Other external expenses for the production of 250,000 kg of fresh *attiéké* are determined in table 5 (Other external expenses), which is:

(7) OTHER EXTERNAL EXPENSES = 3,050,000 XOF per year.

The value added is determined as (6) the margin on material consumption (81,200,000 XOF) minus (7) other external expenses (3,050,000 XOF), resulting in 78150000 XOF, i.e., (8) VALUE ADDED = 78,150,000 XOF.

Table 5

The cost of grinding, electricity, and other external expenses.

Designation	Quantity (kg or kWh)	Unit Price (XOF/kg or h/work)	Amount (XOF)
Grinding (subcontracted)			
Milling + Inoculum	481,250	5 XOF/kg	2,406,250
Sum			2,406,250
Non-storable purchase			
Consumption	3,300 kWh	9,258 (XOF incl. taxes)	305,525
Rural electrification fees (months)	6	1,170	7,020
Municipal Tax (months)	6	1,070	6,420
Ivoirian radio TV fees (months)	6	2,000	12,000
State stamp duty (months)	6	500	3,000
Sum			334,000
Non-storable firewood purchase			
Milling fees			2,406,250
Rent			120,000
Water			60,000
Electricity			334,000
Firewood			120,000
Sum			3,050,000
Personal income: salary			
Peeling (h/month)	31,250	300	9,375,000
Semolina operators (months)	12	80,000	960,000
Producers (h/month)	19,200	300	5,760,000
Sum			1,6100,000

3.3.5 Personal remuneration

As a reminder, to produce 250,000 kg of fresh *attiéké* per year, 625,000 kg of cassava roots would be required annually. A woman can peel and wash 20 kg of roots per hour. This ratio implies that it would take 31,250 hours of work to peel and wash 625,000 kg of cassava roots. They perform all production tasks themselves. The women of the association distribute the revenue proportionally to the quantities of cassava roots they bring as input. This economic model, which works well in a village environment, is somewhat complex to analyse. For financial analysis reasons, salaries (correlated with their production based on the 2013 Ivorian minimum wage) are defined. In reality, these are production costs that they intentionally ignore due to their association model [12]. After sharing the revenue directly related to production, only the revenue from service provision remains in the association's treasury. These service provision sales are limited to the milling of cassava paste owned by non-members of their village association.

Salaries: In the sector, labour costs are approximately 300 XOF per hour of work. In addition to the hours required for peeling, the salary of the two permanent operators of the SIS processor must be added. These operators have a total annual salary of 960,000 XOF, which is 80,000 XOF per month for both operators. Furthermore, it takes ten women to produce one ton of fresh *attiéké* per day. Considering that a woman works 8 hours per day and 20 days per month, this results in 19,200 hours of work per year to produce 250,000 kg of fresh *attiéké* per year.

Social charges: They are non-existent in the economic model practiced by the women; there are no officially registered employees in any social contribution institution. Typically, at the end of each production day, each worker is compensated for their quantity of work. In the future, this expense should not be neglected for the improvement of working conditions. Thus, personnel expenses are limited solely to the remuneration for hours worked. In this case, these are genuine variable costs.
(9) PERSONNEL REMUNERATION = 16,100,000 XOF.

3.3.6 Gross Operating Surplus (EBE)

Other Operating Income: It primarily consists of revenue from the milling of squeezed dough owned by women who are not members of the *Koc'idj* association. These revenues average 240,000 XOF per year, which is 1,000 XOF per day. The milling machine is primarily used for the production of *attiéké* by the women of Débrimou. Due to its high processing capacity (250 kg/hour), it is often available, and the women have decided to make it available to other asso-ciations and neighbouring villages for a fee.
(10) OTHER OPERATING INCOME = 240,000 XOF per year.

Other Operating Expenses: Other operating expenses intentionally encompass packaging costs, travel expenses, office supplies, telephone expenses, and any other charges. They are estimated at 100,000 XOF per month, which is 1,200,000 XOF per year. The maintenance costs of the milling machine (greasing, calibration, etc.)

will amount to 7,500 XOF per month, which is 90,000 XOF per year.

(11) OTHER OPERATING EXPENSES = 1,290,000 XOF per year.

The Gross Operating Surplus (EBE), which is the microeconomic indicator, has been calculated by adding Value Added and Other Operating Income and subtracting Personnel Remuneration and Social Charges, minus Other Operating Expenses. This equals (8) 78,150,000 XOF + (10) 240,000 XOF - (9) 16,100,000 XOF - (11) 1,200,000 XOF = 61,790,000 XOF.

(12) GROSS OPERATING SURPLUS = 61,790,000 XOF.

3.3.7 Operating Result

In order to ensure the sustainability of the economic production activity, it was appropriate to take into account the wear and obsolescence of various production tools. In the case of the women of the Débrimou association, only the SIS Semolina machine will be subject to depreciation. Additionally, this is justified by the fact that certain stages of their *attiéké* production process were outsourced. It should be noted that the SIS machine will be depreciated over three years on a straight-line basis, meaning it will lose 1/3 of its original value each year, as shown in the depreciation table 6.

(13) DEPRECIATION ALLOWANCES = 1000000 XOF per year.

The operating result is a correction of the gross operating surplus. It is equal to the latter, from which depreciation allowances should be deducted. Depreciation allowances are calculated expenses but not disbursed. Thus, the Operating Result equals (12) Gross Operating Surplus minus (13) Depreciation Allowances. This results in an Operating Result = 61,000,000 XOF (12) – 1,000,000 XOF (13), which is (14) OPERATING RESULT = 60,000,000 XOF.

Note: In the specific case of the women of the *Koc'idj* association in Débrimou, at this time, which is the end of the first year of operation, this operating result is also the net result. This can be easily explained by three reasons. The first reason is that there is no financial result because they do not hold any securities and have made no investments. The women of the *Koc'idj* association in Débrimou have not taken out any loans [32, 36, 37]. Therefore, their financial result is zero. The second reason is that the exceptional result is also zero because it is their first year of operation. They will not pay any income taxes in the first year. It is this third point, and not the least, that justifies the fact that the operating result of the women of Débrimou is also their net result.

(15) NET RESULT YEAR 1 = 60,000,000 XOF.

The Net Result, also called the profit of the women of the *Koc'idj* association in Débrimou, can be related to one month (1/12) and to one woman (1/200) according to the subscription principle. For this, it is necessary to assume equal contributions in input. According to the women's economic model, the revenue (CA) is distributed in proportion to the quantity of cassava brought in. There are approximately 200 women in the association. With equal input, hence equal gain, we have: $60{,}000{,}000 \times 1/12 \times 1/200$, which is equivalent to 25,000 XOF per month per woman member of the Débrimou women's association. It can be deduced that each member of the Débrimou women's association has a profit of about 25,000 XOF monthly.

Table 6
SIS Semolina machine damping.

Accounting period	Original value	Depreciation	Cumulated depreciation	Net book value (NBV)
1	3,000,000	1,000,000	1,000,000	2,000,000
2	3,000,000	1,000,000	2,000,000	1,000,000
2	3,000,000	1,000,000	3,000,000	0
Sum		3,000,000		3,000,000

In addition, there is an improvement in working conditions due to the mechanization of the SIS semolina machine. The study has demonstrated that the economic model of the women is economically workable at all levels of management. The production of *attiéké* with the introduction of the SIS mill by the women of the *Koc'idj* association is economically and environmentally sustainable. Their production method follows a respectful product lifecycle. It is also environmentally and socially viable, as the association adheres to the production cycle, thereby avoiding any destruction of flora and fauna. Lastly, it is socially and economically equitable by ensuring a fair profit-sharing without exclusion [6].

4 Conclusion

In the face of the high cost of rice, the local valorisation of roots and tubers would provide households with economic and social solutions given the relatively low production costs. These production costs do not exceed 325 XOF/kg, making fresh *attiéké* a competitive product in the Ivorian market. The introduction of the SIS semolina machine improves the working conditions of the women of the association and the quality of their outputs. This experience should be replicated in other villages in Côte d'Ivoire, and the unique economic model of the women of Débrimou is a factor of social cohesion. This study cannot be concluded without drawing attention to the use of firewood for cooking. The women of *koc'idj* association must consider the transition to the use of renewable energy sources. Production costs will be slightly higher, but the health of women and the environment will improve sustainably and to a much greater extent.

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