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# Cassava in Central and Western Africa: Postharvest Constraints and Prospects for Research and Market Development

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## Abstract

Cassava, one of the main components of the diets of the populations of Central and West Africa, conveys an image of the culture of the poor, due to structural and technological constraints that inhibit its industrial and commercial expansion. Technological constraints are reviewed in the context of food uses of the tuber. They mainly focus on the diversity of processing practices, the low technological level of the processing tools and/or their inadequacy, the lack of standardization of processes, and the quality of the products. Removing these constraints calls for technological research for which research and innovation tracks are raised. These mainly concern the characterization and control of existing or potential markets and the optimization of processing processes, in relation with the quality requirements of the products. This optimization approach must take into account the cultural diversity of the actors of the systems, which could be essential, if not crucial, in defining the forms and modes of perception and definition of the quality of cassava products.

**Keywords:** cassava, postharvest system, processes, quality, market, actors

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## 1. Introduction

Cassava (*Manihot esculenta* Crantz), native in Brazil, is one of the main root and tuber crops grown in the world. The white and milky pulp of the tuberous root occupies an important place in the diet of several people of Africa, especially in Central Africa. In this regard, cassava is the third most important food production in the tropics after rice and maize [1]. Africa is the largest producer, accounting for more than 50% of the world production.

The strong expansion of cassava in the tropics, particularly in Africa, is due to the simplicity of its cultivation; its ability to grow on marginal lands that are difficult to use for other crops; its resistance to drought conditions, which, moreover, justifies its extension in the Sahelian zones; and the possibility of leaving it in the ground and harvesting it progressively, thus allowing for extensive management of its food consumption. As the main component of the food ratio of more than 25% of the African population for an average annual consumption of 100 kg of roots per inhabitant, cassava is, in Central and Western Africa, a crop destined totally and exclusively for human food. However, in emerging economies and cassava producers, as it happens in Brazil, Malaysia, Thailand, and South Africa, the development of cassava cultivation is supported by a process of upgrading the tuber in various food and nonfood industrial systems (animal feed, starches, sugar derivatives, glues, etc.), with highly significant capital gains [2]. In Central and Western Africa, only Nigeria has embarked on a policy of industrial valorization of cassava.

In addition, the nutritional importance of cassava is limited by nutritional and toxicological constraints. The tuber only supplies energy because of its high starch content but is deficient in lipids and proteins—which, in fact, are of poor quality, because they contain very few essential amino acids, minerals, and vitamins [3]. This deficiency also justifies the fact that maps of protein malnutrition (kwashiorkor) coincide with those where cassava predominates in the diet of children [1]. Another limitation of the tuber is the toxicity of certain varieties containing cyanogenic compounds.

Finally, in the countries of Central and Western Africa, cassava is closely linked to rural poverty, although it is not the cause of it; the tuber is sociologically perceived as the culture of the poor, because the marginal areas where cassava is grown are those where poor people generally live [4]. Moreover, the narrowness of individual crop areas, the isolation of production areas, and the low technological level of the processing system are all constraints which limit the productivity of the root and its access to the market and contribute to reducing the level of its industrial valorization.

The above observations have justified a series of reflections on the promotion of cassava development strategies, such as the forum on the Global Cassava Development Strategy (Rome, April 2000), which proposed an approach to make cassava more competitive on the market. This approach is based on identifying and developing the potential markets for cassava and its products and improving varieties and yields to supply these markets with quality tubers and, at competitive prices, technological valorization of the tuber in response to the needs of consumers. In fact, it is a matter of integrating cassava into the lucrative market of starch products, through the development of finished and semifinished products likely to contribute to the agricultural development and economic growth of the producing countries. The great variability of cassava peasant processing systems and products constitutes a foundation whose mastery of practices and associated constraints is the key element for the development of markets and the quality of products.

## **2. Cassava and its uses in Africa**

The food use of cassava incorporates two main forms of consumption, the peeled and cooked tuber, which absorbs about 30% of the African cassava production, and then the remaining

70% is processed into various derived products (chips, flour, cooked pasta, gari, etc.) whose processes and denominations differ from one region to another, even within the same region [1] (Table 1 and Figure 1). Fermented products are the main form of cassava use in Africa, accounting for almost 75% of the cassava-based foods [5]. The microorganisms of cassava fermentation are predominantly lactic bacteria (*Lactobacillus plantarum*, *Streptococcus faecium*, *Leuconostoc mesenteroides*) and bacilli [1, 6–8]. Their activity results in the reduction of cyanogenic compounds and in the production of pectinolytic enzymes which promote the softening of the pulp, thus facilitating subsequent manipulations of pressing, crumbling, and conditioning. At the same time, they develop characteristic flavors conferring an organoleptic typology to the cassava fermentation products.

Cassava leaves are also integrated into the diets of several African regions, particularly in Central and Eastern Africa. The young leaves are, depending on the case, fermented or not

Products	Processing
Chips/flour	Peeling roots, cutting into pieces, retting (optional), and drying
Gari	Pre-gelatinized cassava granules obtained by root peeling, grating, pressing/fermentation, flaking, and pre-gelatinization by roasting in wood fires in large stoves with the addition of palm oil
Attiéké (Côte d'Ivoire)	Cassava semolina obtained as a result of operations analogous to those of the preparation of gari, except that pre-gelatinization is carried out by steam cooking
Fufu (Central Africa) Foo foo (Ghana) Ugali (East Africa)	Paste cooked from fresh roots (foo foo) or chips flour (ugali), or from fresh fermented (water fufu) or dried (fufu) pulp
Chikwangue or Kwanga (Congo), Miondo, Bobolo, Mintoumba (Cameroon) Mboung (Gabon) Mangbele (Central Africa Republic)	Fermented cassava paste cooked in vegetable leaves (banana, ginger). The different local names differ in terms of the fermentation conditions of the tubers during the retting and of the possible addition of other ingredients (palm oil in the case of Mintoumba)
Melongo or Medua-membong (Cameroon) Cassadan (Gabon) Mpataka or jiboh or iwaukpu (Nigeria)	Household conservation form of cooked cassava. Cooked roots are diced or sliced and, then soaked in water with daily change of the soaking water. The product is consumed as snack.
Buward or mapala or ipoti (Gabon)	Steaming of retted roots in Marantaceae or banana leaves. Conservation by drying or smoking. For consumption, the dried product is soaked in water, followed by a new steaming.
Mahiac (Gabon)	Slurry prepared from retted cassava flour into which grilled peanut paste is added. This preparation is comparable to corn gruel prepared with unroasted peanut paste in savanna regions. Interest: improvement of the nutritional value of the slurry by addition of fat
Nkonda (Cameroon)	Retted cassava paste mixed with groundnut peanut, and possibly crayfish, and then packaged and cooked under the same conditions as miondo, bobolo, and chikwangue.
Ntoba mbodi (Congo)	Sliced and fermented cassava leaves.

**Table 1.** Some forms of cassava food use in Africa.



**Figure 1.** Pictures of some traditional cassava products.

and then crushed and cooked in sauce with various condiments. Unlike roots, cassava leaves are characterized by a better nutritional value, with in particular nearly 30% of the proteins. In the Democratic Republic of Congo, cassava leaves have a better market value than roots [9] and account for almost 68% of the leafy vegetables produced in the country [10].

The diversity of forms of cassava use is integrated into the cultural diversity of the producing populations. The unit operations involved in their preparation constitute, regarding the conditions, tools, and means of their implementation, the framework of the constraints to be lifted in order to improve the use and market value of cassava products.

### **3. Constraints of the cassava production system in Africa**

Production and processing constraints of cassava can be perceived both in relation to the modes and conditions of production and to the biological nature of the product and the limits of the processing system.

#### **3.1. Postharvest constraints**

Transport of roots from the field to markets and to processing workshops is the first bottleneck in the cassava sector. The bagged roots are transported on the head or on wheelbarrows and carts. Due to the remoteness of the markets and the isolation of production areas, only 15% of the root production arrives on the market or in processing structures [1], unless the latter are close to the fields or if the fields are in peri-urban areas.

The highly perishable character of cassava, due to its water load, limits its consumption period to a few days after harvest. Postharvest degradation of cassava can occur into physiological and microbial forms. Physiological degradation, characterized by internal discoloration of the tuber and known as vascular striatum, is manifested in bluish or brownish streaks along vascular vessels [11]. It is easily induced by mechanical lesions inherent to the conditions of harvesting and handling of the tubers [12]. These lesions serve as a gateway for microorganisms that initiate secondary degradation leading to fermentation phenomena. Various scientific studies dealing with the biochemical mechanisms of physiological and microbial deterioration of cassava highlight the enzymatic processes involved in reactions [13], their association with starch conversion and the accumulation of cyanogenic glycosides [14], as well as differentiation of degradation velocity and the intensity with cassava variety and/or cultivar [12, 15]. These studies provide indications to understand some secular practices of storage, such as the burial of tubers in trenches covered with earth [1], or the relatively recent fact of pruning the plant 2–3 weeks before the harvest [16]. The ancestral landfill practices of fresh cassava have been enhanced by technological research which has proposed stacking fresh tubers in bags, cartons, baskets, or crates filled with sand or sawdust [17, 18], in order to facilitate the transport and conservation of the product. The sand or the sawdust serves as an absorbent material, which helps to regulate the humidity of the medium, a critical parameter of conservation. This practice allows tubers to be kept for up to 2 months, which may be extended by the use of fungicides. Other more elaborate and efficient techniques, such as tuber refrigeration and freezing, have been successfully tested [18] but have the disadvantage of having a high cost of production for a low-cost farmers' system such as cassava, particularly in Africa.

The presence of cyanogenic compounds (linamarin and lotaustralin) in cassava may also be considered as postharvest stress, since these compounds, which may be hydrolyzed to cyanide, limit the food use of certain varieties of cassava, because of its toxicity. The manifestations of this toxicity, combined with a continuous consumption of cassava, concern the degradation of hemoglobin [19], goiter and cretinism [20], and konzo (paralytic disease) [21, 22]. Cassava varieties are arbitrarily classified according to their cyanogenic content [23] and in relation to their toxicity [24, 25]. However, there are still discrepancies in the toxicity threshold: Bolhuis [24] sets the toxicity threshold around 50 mg of HCN/kg fresh tuber, while Rosling [25] proposes 20 mg/kg. The bitter or sweet taste of cassava is also associated with its content of cyanogenic glycosides, bitter cassava being toxic, as it is rich in cyanogens, while sweet cassava is considered healthy. While this is generally true, it should be noted that no scientific cause-and-effect relationship has been established between the organoleptic flavor of cassava and its toxicity, especially since certain varieties of sweet cassava contain cyanogenic glycosides [26, 27], apparently resulting from their environmental conditions of cultivation. In addition, a bitter compound, different from cyanogenic glycosides, has been isolated from cassava [28].

The constraints inherent in the toxicity and perishability of cassava certainly justify the development of peasant farming practices which, for the most part, have higher health and conservation potential with limits at a different level.

### 3.2. Constraints of the processing system

The unit processing operations of cassava, as applied in peasant practices (**Figure 2**), reveal two main types of constraints, inherent in the induced work load and in the control of processes for the quality of products on the markets.

Most of the postharvest operations at the peasant scale are carried out manually, due to the lack or inadequacy of high-performance processing tools. In a case study of the cassava production and processing processes in Tanzania, Van Oirschot et al. [29] found that manual labor loads are mainly related to harvesting and transport (28%), peeling (35%), and grating (13%). In general, the postharvest workload of cassava is higher than that of other staple foods. The harvest and processing of 10 tons of cassava (average production of 1 hectare of plantation) require about 721 man-hours of work, of which 212 man-hours for harvesting, 156 man-hours for handling operations, and 353 man-hours for processing operations [1, 30]. Moreover, this workload is handled at almost 92% by women [1, 31], since men are involved only when the opportunities for mechanization and commercialization are established [32].

The manual workload induced by postharvest cassava operations results in as many losses during the various operations. The most important losses are induced by the various processing operations (23.2%), harvesting (13.6%), and handling operations (8.5%) [1]. This finding justifies the efforts made in recent years to develop equipment and protocols adapted to the postharvest system of cassava by various research and development institutes, with the aim of both reducing the hardship and improving process and product quality. In this respect,

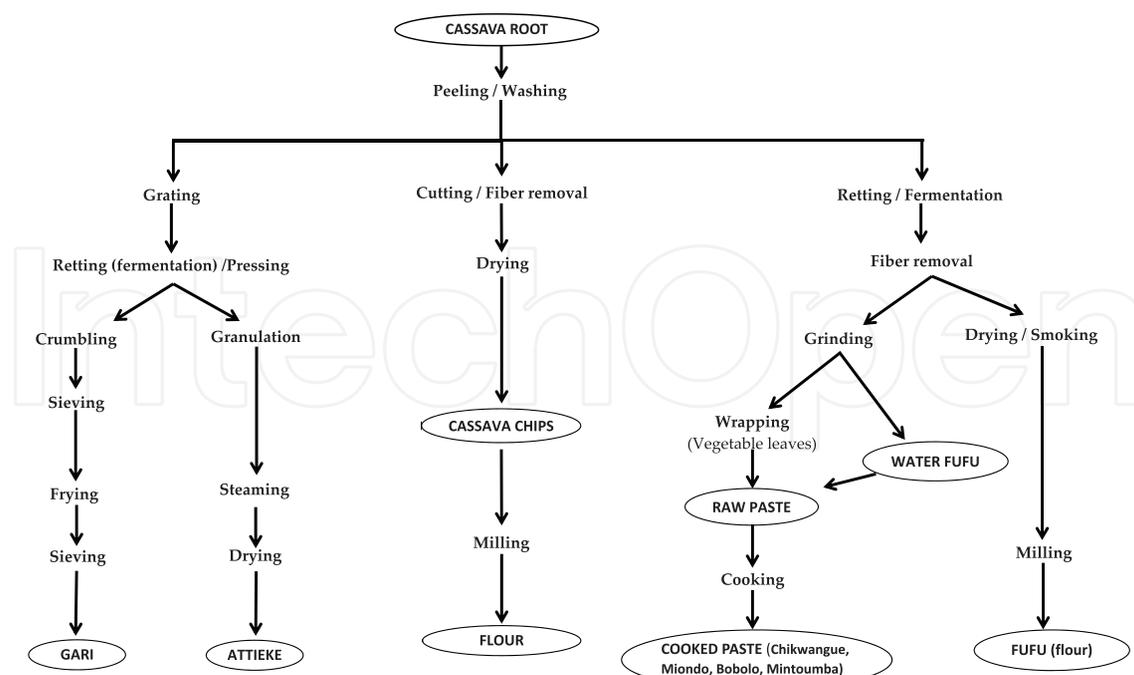
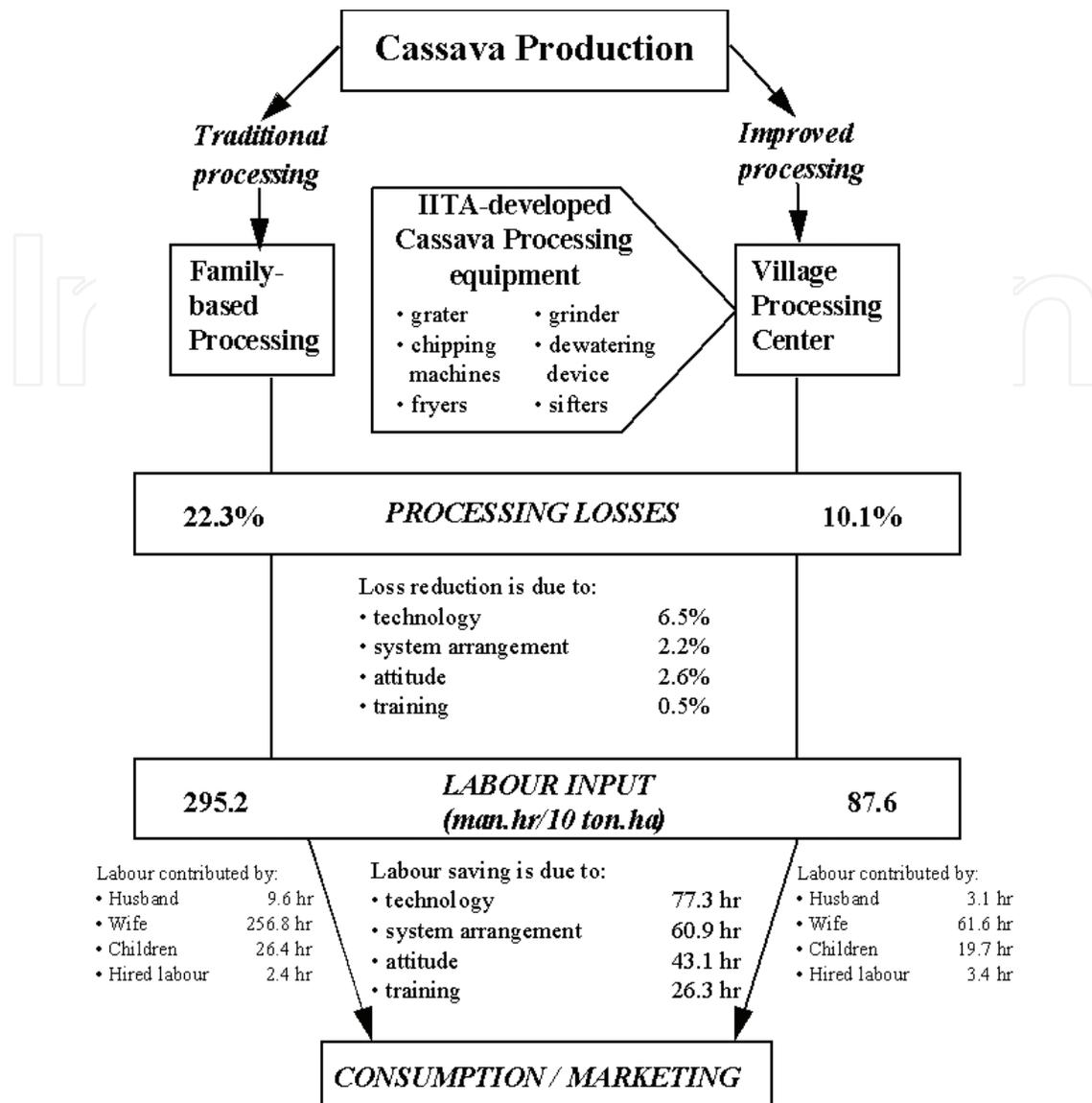


Figure 2. Main operations of traditional cassava processing in Africa.

the technological package proposed and tested by IITA, containing various improved equipments (peeler, rasping, press, mill, gari fryer, sieve), allows significant improvements both in terms of ease of operations and productivity (Figure 3). The development of processing equipment is therefore a priority issue for the improvement of the productivity of the cassava system. In this respect, various equipments more or less adapted are offered on the market, with various efficiencies [33], relating to cost, maintenance, and ease of use. Research needs therefore remain important and call for the development of operational approaches and tools to diagnose processing techniques and evaluate the effectiveness of the equipments proposed or to be developed [34–36]. In this logic, peeling, drying, and fermentation processes remain among the most common technological constraints of the cassava system and deserve special attention in terms of both improving and standardizing processes and the development or adaptation of equipment.

Processes for the processing of cassava incorporate, for a given product, unit operations which are substantially comparable from one region to another. However, many variants exist, on the one hand, in the conduct of these unit operations and on the other hand in the nature and the mode of use of the equipment involved. Although this variability in technical practices can be a wealth in terms of specification of product representative of the image of the terroirs, it nevertheless incorporates limits relating to a lack of standardization of techniques and/or products in a given space. Indeed, the same product, processed under comparable technical conditions between two space, or even on the same space with different actors, can present a variation of quality according to space or actors. This lack of standardization can be considered as a constraint whose lifting is likely to create conditions for the emergence of the postharvest cassava system for markets.



**Figure 3.** Impact of improved processes and equipments on workload and postharvest losses of the cassava processing system (source: [1, 30]).

The practice of fermentation constitutes one of the operations common to all practices of food processing of cassava. Three variants of this practice are common in Africa:

- Fermentation of the grated tuber in bag, carried out by lactic bacteria [37–39] and used in the production of gari and attiéké.
- Fermentation by soaking the tuber in water for 3–6 days depending on the practices and products concerned. This practice, used for the production of fufu and cooked cassava paste (chikwangue, bobolo, miondo, mintoumba), starts with a combined action of various bacteria (*Bacillus*, *Leuconostoc*, *Klebsiella*, *Corynebacterium*, *Lactobacillus*, *Aspergillus*, *Candida*, *Geotrichum*) and ends by a dominant action of lactic acid bacteria and yeasts [40].

- c. The fungal fermentation obtained by piling up of fresh tubers. This practice, common in Tanzania, Uganda, and Mozambique [41, 42], involves microorganisms of the genus *Rhizopus*, *Mucor*, *Penicillium*, and *Fusarium* [43].

Fermentation practices are also applied on cassava leaves for food consumption. In Congo, the semisolid fermentation of cassava leaves results in a product called “*ntoba mbodi*.” Though the fermentation of cassava roots is a lactic fermentation with *Lactobacillus* as dominant microflora, that of cassava leaves is an alkaline fermentation where *Bacillus* constitutes the main microflora [44, 45]. The advantage of fermentation is the detoxification of cassava by the degradation of cyanogenic compounds [46]; the improvement of the protein and vitamin value of the product; the development of characteristic texture, aroma, and flavor compounds [47, 48]; and digestibility of the products. The diversity of the microorganisms involved in the fermentation process is, to some extent, indicative of the diversity of the ecosystems in which the tuber is processed, which may justify the diversification of the quality of the products. Various scientific studies have been carried out to identify both the qualitative and quantitative differential functions of the microorganisms involved in the process [49–53] and to standardize the process for a given product [7, 54, 55]. The scientific opportunities offered by these various studies focus as much on the characterization and the control of the enzymatic processes involved in the fermentation operation as on the ecogeographical typology of the microorganisms. Such mastery is likely to allow objective territorial groupings of practices and a standardization approach based on coherent indicators that take into account the tools and technological factors of fermentation, the relationship with the physicochemical and organoleptic characteristics of products, as well as the conditions for their preservation.

If the fermentation practice is decisive for the physicochemical and organoleptic characteristics of cassava processing products, they are also influenced by other factors such as the cassava variety [56–58], the soil type, the planting season [59], the method of culinary preparation [60], and the conditions and means of preserving [61] and distributing the products. These factors must be taken into account in any process of standardization and improvement of the quality of cassava food products [62].

Various research efforts are also being carried out to valorize endogenous cassava processing techniques [63, 64], improve the nutritional value of products [65, 66], develop equipment [67, 68], understand the relationship between processes and quality in order to develop new products of food and industrial interest [69–72], and to attract private sector interest in investment in this sector. However, there are weaknesses in the proposal and the adoption of technological innovations that may favor the transition from self-consumption to industrial or market products. Moreover, beyond the significant amount of work on the physicochemical properties of cassava processing products, in relation to processes, control of the quality and functionality of these products remains relatively limited; this contributes to the weakness of the development of the industrial processing of cassava in tropical Africa.

It is true that local efforts to capitalize technological knowledge through the development of cassava processing SMEs have met with inadequate raw material in most countries, the latter being intended primarily for self-consumption. This fact has justified the implementation of

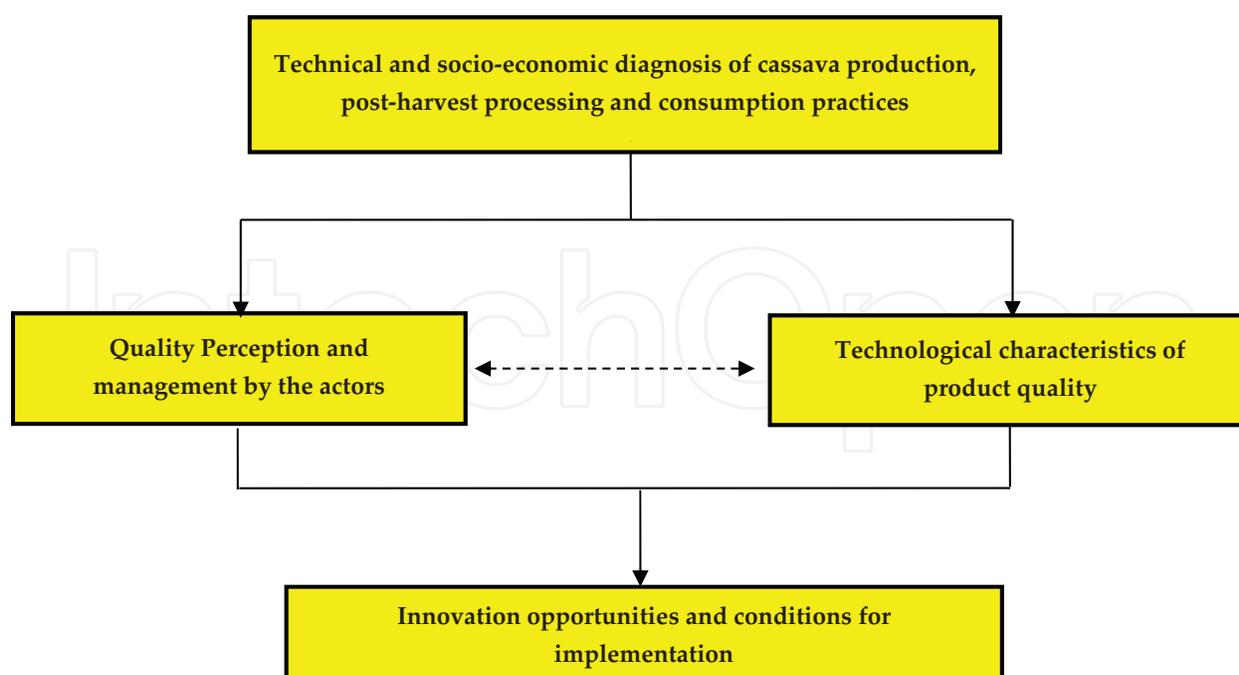
the global cassava development strategy in various African countries, carried out by various international organizations (IFAD, FAO, CIAT, CIRAD, IITA, NRI). This involves not only developing cassava cultivation and improving yields but also exploring and capitalizing on all the technological and market opportunities likely to favor the industrial emergence of the postharvest system.

#### **4. Prospects for the development of the cassava postharvest system in Africa**

The recognition of cassava as a strategic culture in Africa, its deep set in local food traditions, and the diversity of its processing products offer so many research and development opportunities for the fight against poverty, improvement of nutritional situations, development of new products, and identification of market niches. The implication of technological research must be based primarily on steps to remove the constraints of the postharvest system and to promote the commercial emergence of products.

The overall cassava development strategy bases the emergence of the postharvest cassava system on the development of markets for agricultural production. In this regard, from the point of view of research, it is appropriate not only to characterize and control the structural and functional elements of these markets but also to correlate their requirements with the quality of cassava products. Therefore, controlling the postharvest processes, consistent with the use value of the products for the markets, constitutes a priority axis of research.

Central and Western Africa, regions with a high intensity of localized production and consumption of cassava, are characterized by relatively small national markets and processing practices of a relatively rudimentary technical level. The analysis of markets, processing processes, and the use value of products in these areas must be able to be carried out in an integrated way, taking into account, on a comparative basis, localized traditional knowledge. This include understanding the social and cultural determinants of local processing practices, the perception and management of product quality by the processing actors, and linking the indicators derived from those findings with the technological quality of the products. The correlation between social perception and management of product quality on the one hand and technological quality on the other hand may give rise to identify innovation opportunities to introduce in the system. An integrated methodology to undergo the above research and development initiative is proposed on **Figure 4**. This methodology starts with an interdisciplinary technical and socioeconomic diagnosis of the whole cassava postharvest sector, covering demand structure, market analysis, processing and consumption practices, actors' organization, processing workshops distribution, etc. Technologists, socioeconomists, geographers, sociologists, and even anthropologists are involved in this diagnosis which allows setting up the key elements for the understanding of the technical system and the boundaries of the activities to undergo further. From the results of the diagnosis, the specialists, later on, return in their specific specialties to study, on the one hand, the perception and the management practices of quality by actors and, on the other hand, the technological characteristics



**Figure 4.** Operational approach for the analysis of production systems and the identification of innovations.

of that quality. Integration can, in this case, consist in a definition of the conditions for the transfer of technological knowledge on an intra- or interregional scale. Similarly, the definition of cost-effective operating conditions for postharvest systems, adapted to the small size of internal markets, may also be an interesting issue, given the geographical isolation of most of the production and processing systems.

From a purely technological point of view, the above market stake is accompanied by a perfect mastery of the unit operations involved in the various processing processes. This mastery goes hand in hand with that of the relationship between localized technological practices and the quality of products. In detail, this technological expertise integrates, as a priority, the optimization of fermentation processes, drying practices, types, and methods of packaging and distribution of products in relation to their physicochemical, nutritional, and functional characteristics. The search for optimization takes into account the analysis and the systematic identification of constraints and development opportunities for each segment of the sector and has as goals which are to choose or develop adapted tools (equipment, starters, etc.) for the standardization of processes. In this context, prioritization of farmers' initiatives, often driven by endogenous dynamics in response to production and processing constraints, must integrate the research approaches to be implemented. It is in fact, for research and development, to rely on the actors' perception of their production constraints, the mechanisms of endogenous reactions they implement in the face of constraints, and then to deduce from it, the opportunities for innovations which will have the advantage of being carried and better adopted by the internal dynamics of these actors. In this respect, and by way of example, a case study on the valorization of peasant retting practices in Central Africa has shown the interest of taking into account the processing initiatives of the actors [73].

The retting process, common to most root processing practices, is the basis of the organoleptic and sanitary quality of fermented cassava products and constitutes thus a critical operation of cassava processing. The primary purpose of this unit operation is to soften and detoxify the root, with softening being the main indicator of retting from the actors' point of view. For this reason, actors use different strategies to accelerate the softening of the root during retting, with regard to the high market demand of retted cassava pulp and products. Old fermented retting solution or preferably pre-retted cassava flour is used in this respect. The limit of this practice is that the result obtained varies from one actor to another and even on the productions of the same actor. Considering that this variability is the result of a non-standardization of the manufacturing process of starters, it has become necessary to characterize these peasant starters and to develop standardization functions. In a participating research with retting actors (effective activities with actors in their workshops, combined to laboratory development), the main standardization functions defined were pre-retting time, reactivation conditions of the starter microflora (reactivation solution, temperature, and time), and conditions of application of the starter (dilution conditions of the starter, starter/cassava ratio, retting temperature). This approach presented more prospects for appropriation and dissemination of the innovation by the actors of cassava processing system. In fact, actors from other cassava processing areas are asking for training on the preparation and use of retting starter, and local development projects have been set up in this respect [74]. The peasant will to optimize the retting process, though endogenous use of starter to accelerate the softening of the roots constitutes a priority axis of development both for scientific and technological mastery requirements and for economic purposes. The variability of the technical practices of retting, the diversity of the microbial strains involved in the process, the varietal diversity of the roots to be retted, or even the diversity of the finished products raises up the problem of standardization of the starter or of research for suitable formulations adapted to each case. These questions constitute converging research opportunities toward the optimization of the cassava root retting process.

It should be noted that agricultural research has developed a wide range of cassava varieties characterized mainly by yields, disease resistance, and adaptation to different ecosystems. In general, little information is available on their technological and food use values. This gap needs to be filled by technological research in view of the emergence of varieties developed for the industry and markets. Similarly, the diversity of cassava varieties, practices, and forms of processing and utilization corresponds, most of the time, to a cultural diversification of the actors, which can be associated with a diversification of perception of the quality of cassava products. In this respect, the following question can be addressed: on the basis of which criteria do the different actors (producers, processors, consumers) of the cassava production and processing system perceive the quality of the tuber and its products? It is possible, hypothetically, to envisage a territorial or cultural and even varietal differentiation of the quality of cassava and its processing products.

## 5. Conclusion

Since the development of the cassava system depends mainly on the conditions of its operational and effective integration into the market, the support initiatives related to it must take

into account the real needs of the actors involved, the majority of whom being under the weight of poverty, so that the emergence of the root does not carry the risk of an extraversion toward new moneyed class actors, to the detriment of the actors of the peasant system, who would continue to convey the false image of cassava as a culture of the poor. Much of this development relates to the need to remove the logistical and technological constraints that hamper the development of the root market and its products, notably the relationship between technical practices of cultivation and processing and quality of products for the markets.

The finalization of such a goal implies the implementation of a dynamic that is based on:

- A thorough knowledge of the existing and potential markets for cassava and its products, taking into account the different mechanisms induced and consumption habits.
- A contextualized analysis of the local systems of processing and use of the roots, as well as their actual or potential relationship with markets, i.e., the quality required by these markets.
- A reflection on the dynamics to accompany or to implement for the operational integration of African cassava production, processing, and utilization systems in a wealth-generating market. It is important to integrate in the process, an approach of ownership of support initiatives by actors involved.

These are some of the issues whose answers are likely to allow the valorization of cassava and its integration into the market. The aim of technological research for the conduct of this dynamic is therefore the development and dissemination of innovations that are relevant and adapted to the requirements of product and market quality.

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