

















Varietal impact on women's labour, workload and related drudgery in processing root, tuber and banana crops: focus on cassava in sub-Saharan Africa

Alexandre Bouniol,^{a,b,c†*}  Hernan Ceballos,^d  Abolore Bello,^e 
Béla Teeken,^e  Deborah Olamide Olaosebikan,^e  Durodola Owoade,^e 
Agbona Afolabi,^{e,f}  Apollin Fotso Kuate,^g  Tessy Madu,^h  Benjamin Okoye,^h 
Miriam Ofoeze,^h  Solomon Nwafor,^h  Nnaemeka Onyemauwa,^h 
Laurent Adinsi,^a  Lora Forsytheⁱ  and Dominique Dufour^{c,j†*} 



Abstract

Roots, tubers and cooking bananas are bulky and highly perishable. In Africa, except for yams, their consumption is mainly after transport, peeling and cooking in the form of boiled pieces or dough, a few days after harvest. To stabilize and better preserve the products and, in the case of cassava, release toxic cyanogenic glucosides, a range of intermediate products have been developed, mainly for cassava, related to fermentation and drying after numerous processing operations. This review highlights, for the first time, the impact of genotypes on labour requirements, productivity and the associated drudgery in processing operations primarily carried out by women processors. Peeling, soaking/grinding/fermentation, dewatering, sieving and toasting steps were evaluated on a wide range of new hybrids and traditional landraces. The review highlights case studies of gari production from cassava. The results show that, depending on the genotypes used, women's required labour can be more than doubled and even the sum of the weights transported along the process can be up to four times higher for the same quantity of end product. Productivity and loads carried between each processing operation are highly influenced by root shape, ease of peeling, dry matter content and/or fiber content. Productivity and the often related experienced drudgery are key factors to be considered for a better acceptance of new genotypes by actors in the value-addition chain, leading to enhanced adoption and ultimately to improved livelihoods for women processors. © 2023 The Authors. *Journal of The Science of Food and Agriculture* published by John Wiley & Sons Ltd on behalf of Society of Chemical Industry.

Supporting information may be found in the online version of this article.

* Correspondence to: A Bouniol, Laboratoire de Sciences des Aliments, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, Jéricho 03 BP 2819, Benin. E-mail: alexandre.bouniol@cirad.fr or D Dufour, QualiSud, Univ Montpellier, Avignon Université, CIRAD, Institut Agro, IRD, Université de La Réunion, Montpellier, France. E-mail: dominique.dufour@cirad.fr

† These authors contributed equally to the work.

a Laboratoire de Sciences des Aliments, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, Jéricho, Benin

b CIRAD, UMR QUALISUD, Cotonou, Benin

c QualiSud, Univ Montpellier, Avignon Université, CIRAD, Institut Agro, IRD, Université de La Réunion, Montpellier, France

d International Consultant, Malaga, Spain

e International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

f Department of Soil and Crop Science, Molecular & Environmental Plant Sciences, Texas A & M University, College Station, TX, USA

g International Institute of Tropical Agriculture, Yaoundé, Cameroon

h International National Root Crops Research Institute (NRCRI), Umuahia, Nigeria

i Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Kent, UK

j CIRAD, UMR QualiSud, Montpellier, France

Keywords: breeding pipeline; gender; varietal adoption; technological characteristics; food product profile; end-product productivity; value chain; market segment

INTRODUCTION

Drudgery in processing of root, tuber and banana crops (RTBs) has been recognized as a major, complex social, economic and health problem.¹ However, little attention has been paid to the influence of varietal differences on drudgery, and the potential to exploit breeding of appropriate varieties (genotypes) as a partial solution. Although it can have a significant impact on the livelihoods and wellbeing of women (who perform the majority of processing labour), addressing labour requirements, productivity and related drudgery in food processing is often ignored in the development of improved RTB genotypes. Throughout sub-Saharan Africa, women play a vitally important role in agriculture and post-harvest activities and some 50% of agricultural work is done by women, with significant variations within and among regions and countries.² Agri-food processing at artisanal or small scale is mainly carried out by women with the help of family labour (often young and/or elderly people and neighbors). For processing of RTBs, these operations are often carried out entirely by women, from the peeling to the elaboration of the end-products ready to be marketed or consumed at the household level.^{3–7} The Collaborative Study of Cassava in Africa (COSCA), conducted in six African countries, showed that women lead in root transportation (68%) and processing operations (76%).⁸ On average, cassava processing was carried out mostly by women in about 75% of the surveyed villages, mostly by men in less than 5%, and by both equally in about 20%.¹ Women in sub-Saharan Africa have the highest average agricultural labour-force participation rates in the world.⁹

Assessment of processing productivity and the drudgery associated with processing RTB-based foods is limited. Genotype acceptability and drudgery in processing appear to be strongly linked (i.e. women are more likely to prefer RTB varieties with traits that reduce the drudgery of processing).^{10–13} Furthermore, cassava processing, for example, is associated with challenging working conditions and serious health hazards^{14–16} that increase the likelihood that such operations are perceived as drudgery. Prolonged labour associated with all the operations significantly impinges on the productivity and wellbeing of the (mostly) women operators.^{17,18} Drudgery has been defined as the dissatisfactory experiences that constrain work performance in any activity¹⁹ and is often related to time-consuming, repetitive and menial work. Physical and mental strain, agony, monotony and hardship have been linked to the drudgery often experienced in farm operations.²⁰

Whether a task is experienced as drudgery depends on many different factors, including specific working conditions (which include the quality and type of tools used), the extent of the task and also how the work is culturally validated and looked upon, which in turn determines the type of meaning executors of the task attribute to the task.²¹

RTBs have several important features of note in relation to labour input. They tend to be bulky and perishable, making them difficult to transport and, as a result, most are often eaten fresh, after cooking, soon after harvest. Alternatively, RTBs are processed soon after harvest to convert them into less perishable and more easily transported products. Cassava, in particular, is extremely sensitive (3–5 days) to post-harvest deterioration.²² Post-harvest

handling and storage offer many challenges for RTBs, eliciting development of a wide variety of food products.^{23–26}

Cassava is by far the most widely grown and consumed root in sub-Saharan Africa.²⁷ The starchy roots contain toxic cyanogenic compounds at various levels.^{28,29} Typically, consumers perceive bitterness from cyanogens beyond a cyanogenic potential of about 80–100 ppm.³⁰ These toxic compounds are only very partially (20%) removed by boiling or frying³¹ and so genotypes below 50 ppm are recommended for consumption as boiled or fried pieces (genotypes above 100 ppm become toxic for mammals and must be detoxified to avoid health risks.³² The detoxification is mainly performed by grinding or rasping, often with fermentation before or after that process. Fermentation is performed either by soaking the whole or peeled roots in containers (retting), or by resting the pulp in sacks or containers for several days. During these operations, the volatile cyanogenic compounds are released.³³ These double-purpose operations of fermentation (detoxification and softening) of the roots in water are essential for the fiber removal and preparation of safe traditional staple foods in Africa: fufu, lafun, batôn, Chikwangué, agbelima, gari and attieke.³⁴ Varying the length of fermentation allows formulation of products according to the preferred tastes of consumers, which are very diversified for a range of products, are specific to production zones of origin, and may vary according to availability in the market.^{35,36}

The present study is an output of the project *Breeding RTB products for end user preferences* (RTBfoods; <https://rtbfoods.cirad.fr>). This project developed a new five-step methodology for developing food product profiles, through mobilizing a multidisciplinary team of breeders, social scientists and food technologists to capture the preferred traits of farmers, end-users and consumers.^{37,38} The data were produced following a standardized participatory processing diagnosis procedure common to all RTBs^{39,40} and mainly published in 2021 as a special issue of the *International Journal of Food Science and Technology*.⁴¹

The main objectives of the present study were (i) to dissect the individual processing steps involved in different RTB food products; (ii) to evaluate effects of genetic differences among varieties on processor workload, particularly comparing improved and traditional varieties; and (iii) to guide breeders by highlighting the traits responsible for varietal differences in required labour inputs, which in turn influence acceptability of new varieties.

This review does not directly evaluate the level of drudgery experienced based on different genotypes, but rather examines the impact of varieties on productivity and the associated labour requirements in processing operations. Regardless of how an operation is perceived, a decrease in productivity or an increase in labour requirements can potentially contribute to the drudgery experienced by processors. Therefore, this review examined the influence of different varieties on the productivity of processors individually for various processing operations. The study measured processing operator productivity by the amount of mass produced per unit of time per operator within each operation. Additionally, as a secondary measure related to productivity, we evaluated the weights of products that processors had to transport between operations. This assessment served as an indicator,

albeit productivity-related, to quantify the labour involved in processing different varieties.

MATERIALS AND METHODS

In rural or peri-urban areas of East and West Africa, RTB processing sites were selected according to a predefined sampling methodology. The processing trials were participatory and carried out with experienced champion processors. Both preferred (locally commonly used/popular varieties) and non-preferred genotypes (locally known as non-adequate for expected product profile) were included to provide a wide range of technological and physico-chemical characteristics (fixed effects from the statistical point of view). Processors provided feedback on the varieties before, during each step and after processing to identify relevant characteristics of the crop and product. Processing parameters were measured at each step. The specific traits related to the processing ability were included in the different Food Product Profiles.

Proper and representative quantity of product was harvested from at least four genotypes (more if possible). Each processing step was conducted in duplicate or triplicate (averages of two or three women, who collaborated by processing half of each batch of material for each genotype).

- Processors were invited to observe each raw genotype and give their views, as an operation unit, on its quality characteristics.
- Dry matter content (DMC) of all the collected samples was measured.
- The processing was carried out in real/normal conditions in processors' own communities.
- Each processor started with the first operation unit stage, processing one variety at a time.

For boiled or pounded products (cassava, plantain, yam), the process is relatively simple, including steps such as peeling, washing, boiling, steaming or frying and, in some cases, mashing and pounding. The parameters measured were: peeling yield, duration of peeling, cooking (or pounding) and productivity of each operation unit. These products were processed by only two or three operation units.

Processing operations of fermented products, on the other hand, are more complex and involve more steps. To standardize the data collected in different countries and on different production lines, all the data were scaled to obtain 1000 kg of the end product. Each process was broken down into separate operation units.

- *Gari* (granulated product): peeling; grating; washing; fermentation and draining; mechanical dewatering; wet pulp sieving; mash toasting; and dry *gari* sieving.⁴²
- *Dry fufu* (soaked cassava product: couscous, lafun): peeling; washing; soaking; fiber and non-softened material removal; draining in bags; sun drying; and dry *fufu* grinding.⁴³

A representative sample of approximately 20–50 kg of roots from each genotype was processed to perform the technological diagnosis and then used to measure the yield/productivity of each operation unit (the coding used for each genotype is available in the Supporting information, Table S1).^{44,45} All trials were replicated twice. For each operation unit the average weight was measured before and after processing. The yields of each operation unit were thus calculated according to the genotypes

studied and reported as Yield by operation unit (%). The time needed to perform each operation, on all the available material, was measured with a chronometer. Operator productivity by operation unit (kg h⁻¹ per operator) was calculated for each operation and per genotype studied. The calculation table allowed to visualize the incoming and outgoing quantities for each operation unit for 1000 kg of final product: Processed material by operation unit (kg /1000 kg final product); Operator time by operation (h) and Time distribution by operation unit (%) were thus obtained. Three global values allowed characterizing genotypes by:

- *Gari* yield (%) expressed by weight of initial root/weight of finished product.
- Operator time by kg of final product (h/kg), is the time needed to produce 1 kg of end product per genotype. It is calculated as the sum of the time spent to finalize each operation unit, reported to 1 kg of final product.
- Weight carried by operator per kg of final product (kg) calculated as the sum of all intermediate products carried or moved between each operation unit to obtain 1 kg of final product.

The methodology described above became a processing diagnostics and mass balances for the main RTBs consumed in subtropical Africa: Yam in Benin and Nigeria; Sweetpotato and Potato in Uganda; Plantain in Cameroon; Matooke in Uganda; and Cassava in Benin, Cameroon, Nigeria and Uganda.

RESULTS

Productivity and peeling yields of RTBs strongly influence the labour required from the processors. Specifically for cassava processing, multiple operation units and teamwork make it difficult to evaluate the labour required to produce 1 kg of end-product. New data on cassava, sweetpotato, yam, potato and cooking bananas (plantain and matooke) collected in accordance with the methodology of Fliedel *et al.*³⁹ were used. The data collected allowed estimating the average productivity of each operation according to the genotypes used.

RTB peeling yield related to shape and ease of peeling

Table 1 reports the RTB peeling data (available in open access) in each RTB processing diagnostic summary for the main product profiles. The flowsheet of each RTB final product has been established and is fully available in each crop report as indicated in Table 1.

The lowest yields were for bananas, with 55% yield measured for the matooke peeling operation and a productivity of 28 kg h⁻¹ per operator. For plantains a yield of 50% was observed and a productivity of 43 kg h⁻¹ per operator of pulp obtained after peeling. These results are in general agreement with previous reports,^{46,47} although yields were slightly lower. For potatoes 75% of peeling yield and 9 kg h⁻¹ per operator were found for manual peeling in Uganda. In the industry, using steam peeling for potato, losses range from 6% to 10% of fresh weight.^{48,49} In Uganda, sweetpotato studies reported a peeling yield of 79% and a peeling productivity of 14 kg h⁻¹ per operator. In India, losses ranged from 3% to 21% among 18 sweetpotato genotypes studied, with an average peel loss of 11%.⁵⁰ Yam peeling yield of 80% has been reported in Nigeria and Benin, with an average productivity of 34 kg h⁻¹ per operator.

Table 1. Peeling yield and productivity and RTB shape reported on RTBfoods RTB processing diagnostic summary. [Correction added after first online publication on 11 December 2023. Table 1 has been updated.]

Product by institution and country	Link to published flowsheets	Mean ± SD										Age of plants at harvest (months)
		RTB Shape					Peeling yield (% wb)	Productivity (kg h ⁻¹ operator)	Number of genotypes			
		Weight (g)	Girth (cm)	Length (cm)	Landraces	Improved						
Boiled yam, UAC-FSA-Bénin ⁵²	http://agritrop.cirad.fr/602027	1441 ± 589	***	35 ± 9	75 ± 11	39 ± 23	6	0	9			
Boiled yam, NRCRI-Nigeria ⁵³	https://agritrop.cirad.fr/602029	***	***	***	87 ± 3	38 ± 9	0	4	***			
Pounded yam, Bowen Univ.-Nigeria ⁵⁴	https://agritrop.cirad.fr/602042	978 ± 340	31 ± 6	36 ± 5	79 ± 10	24 ± 11	10	***	***			
Boiled sweetpotato, CIP-Uganda ⁵⁵	https://agritrop.cirad.fr/602026	184 ± 95	***	***	79 ± 5	14 ± 3	6	1	***			
Boiled potato, NARL-CIP-Uganda ⁵⁶	https://agritrop.cirad.fr/602025	68 ± 42	***	***	75 ± 6	9 ± 4	4	2	***			
Boiled plantain, CARBAP-Cameroon ⁵⁷	https://agritrop.cirad.fr/602023	222 ± 57	13,7 ± 1,3	24,3 ± 4,5	50 ± 5	43 ± 4	3	1	***			
Matooke, NARL-Uganda ²⁵	https://agritrop.cirad.fr/602041	26 ± 9	13,7 ± 1,4	19,3 ± 1,4	55 ± 4	28 ± 5	3	3	4			
Bâton, CIRAD/IITA-Cameroon ⁵⁸	https://agritrop.cirad.fr/595635	875 ± 482	21 ± 6	27 ± 4	70 ± 5	54 ± 13	0	8	13			
Gari, CIRAD/UAC-FSA-Benin ⁵⁹	https://agritrop.cirad.fr/597596	509 ± 178	19 ± 7	28 ± 3	66 ± 3	66 ± 18	2	13	12			
Dry Fufu, CIRAD/IITA-Cameroon ⁶⁰	https://agritrop.cirad.fr/597597	***	***	***	73 ± 6	40 ± 10	3	18	13			
Dry fufu, CIRAD/UAC-FSA-Benin ⁶¹	https://agritrop.cirad.fr/597594	1068 ± 707	23 ± 6	34 ± 11	73 ± 3	64 ± 13	3	13	12			
Boiled cassava, NaCRRRI-Uganda ⁶²	https://agritrop.cirad.fr/602019	***	***	***	70 ± 8	60 ± 27	4	5	*			
Boiled cassava, UAC-FSA-Bénin ⁶³	https://agritrop.cirad.fr/602013	388 ± 345	16 ± 5	29 ± 9	77 ± 6	16 ± 8	6	0	12			
Water fufu, IITA-Nigeria ⁶⁴	https://doi.org/10.1111/ijfs.14862	577 ± 585	22 ± 6	26 ± 9	80 ± 3	54 ± 7	5	15	13			
Gari/eba, IITA-Nigeria ⁶⁵	https://doi.org/10.1111/ijfs.14862	581 ± 453	25 ± 9	21 ± 8	78 ± 3	63 ± 12	5	15	13			
Gari/eba, NRCRI-Nigeria ⁶⁵	https://agritrop.cirad.fr/602035	***	***	***	75 ± 3	***	***	***	***			
Water fufu, NRCRI-Nigeria ⁶⁶	https://agritrop.cirad.fr/602033	***	***	***	83 ± 7	23 ± 4	1	3	12			
Attieke, CNRA-Cote d'Ivoire ⁶⁷	https://agritrop.cirad.fr/603470	1254 ± 559	24 ± 4	37 ± 10	70 ± 5	34 ± 7	2	4	15			

*** Not evaluated.

For cassava, for which the largest number of trials were conducted, the average peeling yield was 74% and the productivity 57 kg h⁻¹ per operator. However, there was a high variability among locations and end products (Table 1). The physical characteristics of the peel could influence both peeling labour and the amount of product lost at the peeling stage. These differences in the properties of the peel can include variation in thickness, texture and strength of adhesion to the root flesh.⁵¹ The peel consists of two basic components: the phelloderm (i.e. the bark) is the thin, usually rough, outer layer; the cortex is the fibrous layer that

attaches directly to the pulp. Low peel adhesion strength to cassava flesh allow easy removal of the external phelloderm by making an incision within the cortex with a knife, followed by pulling and removing the peel around the flesh or by rubbing it off in mechanized systems (Fig. 1). Cassava genotypes with easy peel removal reduce product waste and labour.

Roots of the majority of existing cassava genotypes in Africa can only be peeled (with current technologies) by slashing it off the flesh of the root with a sharp knife or machete, increasing the losses enormously in addition to processor fatigue.⁶⁸ Some



Figure 1. Peeling cassava roots. (A) The occurrence of constrictions (left) and variation of root shape and size (right). (B) Traditional peeling by slashing in Africa. (C) Roots where the peel can be easily removed.

studies used a large number of cassava genotypes in Colombia,⁶⁹ Uganda⁷⁰ or India⁷¹ for evaluating phelloderm and root cortex thickness: (0.79–5.14 mm in Colombia on 64 genotypes; 0.3–4.9 mm in East Africa on 825 genotypes; 0.2–0.5 mm in India on 10 genotypes, with cortex thickness at the proximal, middle, and distal varying from 1.2–3.1 mm). This large genetic variation in peel thickness is associated with the difficulty of peeling, which strongly affects peeling yields and productivity. Industrial or small-scale processors prefer genotypes that are easier to peel and for which labour and drudgery are reduced. For hand peeling, mainly in Africa, yield and productivity are also strongly related to the size and shape of the roots and the presence of constrictions.^{72,73}

The data collected by the RTBfoods project teams allowed visualization of the peeling yield and productivity as a function of root girth, root weight and root length (Fig. 2). Although there was a strong increase in peeling yields as a function of increasing root diameter, weight and length, the dispersion of the data highlights other factors such as irregular shape, peel thickness and/or the presence of constrictions affecting peeling efficiency. Processors know how to predict accurately the ease of peeling. It is mainly the women processors who set the purchase prices of the genotypes to be processed and thereby contribute directly through their processing preferences to the varietal adoption by cassava farmers. These gendered decisions are primarily influenced by the labor-intensive nature of the tasks, particularly in relation to product yield, processing productivity and the perceived level of drudgery.

Gari processing: diagnosis and genotype differences

Gari processing experiments were conducted by three different institutes in three different locations: Savalou, Colline, UAC/FSA, Benin (see Supporting information, Table S2), IITA, Osun State, Nigeria (see Supporting information, Table S3) and Umudike, Imo State, NRCRI, Nigeria (see Supporting information, Table S4). A varying number of genotypes was evaluated in each location (see Supporting information, Table S1). The Genotypes TME B419 (codified as I-N-U-TME), TMS IBA010040 (codified as I, N, U10), TMS IBA980505 (codified as I, N, U12), and TMS IBA980581 (codified as I, N, U13), were evaluated in all three locations.

Figure 3 illustrates the entire process to produce 1 ton of gari and the relative losses through the different stages. Yields were obtained for each operation unit on three different sites: UAC/FSA in Benin, and NRCRI (Umudike) and IITA (Osun State) in Nigeria. There were large differences in the average tons of fresh roots required to produce 1 ton of gari: 12.9 ton (NRCRI), 7.0 ton (UAC/FSA) and 5.1 ton (IITA). To a large extent, as illustrated later, the variation in the amounts of roots required was closely related to the average DMC of the genotypes processed in each location (31.4%, 37.4% and 39.2%, respectively).

Root peeling is the first stage (operation unit) in gari processing. About 30–35% of the initial root weight is lost in the (manual) peeling. Although the shape and size of the roots play an important role in defining the losses during peeling (as noted above), the present study did not characterize those parameters. As will be shown later, there is also a remarkably variable required labour from the female processors, depending on each genotype and location. The average time to obtain 100 kg of peeled roots was 3.3 ± 2.0 h by operator, but the variation was very large, ranging from 1.3 h (easy to peel and high DMC) to 11.5 h for the most difficult genotypes (small size, very adherent peel and/or low DMC).

A second stage in which weights are drastically reduced (by about 40%) is during the fermentation, draining and

mechanical dewatering (Fig. 3). The third important reduction in weights (around 50%) takes place during pulp toasting.^{74–76}

For each processing site, the operators (mainly women) must carry fresh roots and the residual material after each operation unit to be able to proceed to the next one. For the three trials, depending on the genotypes used, to obtain 1000 kg of gari, a woman operator had to carry the accumulated weight of 25.7, 48.0 and 19.3 tons, respectively, in UAC/FSA, NRCRI and IITA.

Figure 3 presents the information for each location, dissecting the losses through the individual processing operations in the gari production. The graphs demonstrate the great influence of the location and edaphoclimatic parameters on the quantity of roots necessary to produce 1 ton of gari. There were large genetic differences in the losses at different stages of gari production by location. The DMCs of local varieties, as well as the new hybrids tested in NRCRI, were much lower than those observed in UAC/FSA or IITA ($31.4\% \pm 2.3\%$; $37.4\% \pm 5.9\%$ and $39.2\% \pm 2.9\%$ respectively).

The weight of discarded peel was much lower at IITA (954 kg) compared to NRCRI and UAC/FSA (2732 and 1879 kg, respectively). The low DMC of the trial at NRCRI would explain the important losses observed during the dewatering operation in that trial. In this region, locally grown genotypes (Agric, Nwacho and Mgboto) on the right of the plot Fig. 4 have a higher overall processing yield than the new hybrids evaluated. For the IITA and UAC/FSA trials, on the other hand, many of the new hybrids introduced showed higher gari yields than the locally grown landraces.

The SDs provided in Fig. 3 demonstrate important differences among genotypes at the different stages of gari production. The coefficient of variation ($\sigma/\mu \times 100$) can provide an insight into these stages during gari production where there is relatively more variation among genotypes regarding losses (see Supporting information, Table S5).

Influence of root DMC on the amount of raw cassava roots required to produce 1000 kg of gari

Figure 5 depicts the relationship between DMC of raw roots from 38 cassava genotypes (57 datapoints across three locations) and the respective amounts of raw roots required to produce 1 ton of gari. There was a clear negative correlation between DMC and the amount of fresh roots required (tons of fresh roots = $26\,078 - 0.525 \times \text{DMC}$; $r^2 = 0.674$). The red dots identify commercial checks often used to produce gari in the regions: K 195, NR8082, TME B1, TME B2, TME B7, TMS 30572 Dale, Kati Kati, Salome, AGRIC, Nwageri, Chigazu, Durungwo, Nwocha, Mgboto Umuahia, Honourable 1 and 2, Omoh Local 1 and 2 and Akpu (refer to Supporting information, Table S1 for the codes used). Commercial checks are scattered from the top left down to the bottom right. TMS IBA010040, TMS IBA980505 and TMS IBA980581 (I-, N- and U-10; -12; and -13, respectively) and TME B419 codified as I-N-U-TME in green were processed in all of the three trials. (See also table S1). From this it is clear that the same variety but evaluated in different environments occurs in extremely different locations on the graph stressing the enormous influence of the environment and/or harvesting time on root dry matter. The NRCRI and UAC Trials were harvested in June, in the peak of the rainy season while the IITA trial was harvested in September after the peak of the rainy season which can be a large part of the explanation of these results.

Three groups of clones showing large deviation from the regression line (more than 2 tons difference between expected values based on the DMC and the actual amount of fresh roots required to produce 1 ton of gari) are highlighted in Fig. 5. Below the regression line, there is a single group (within a

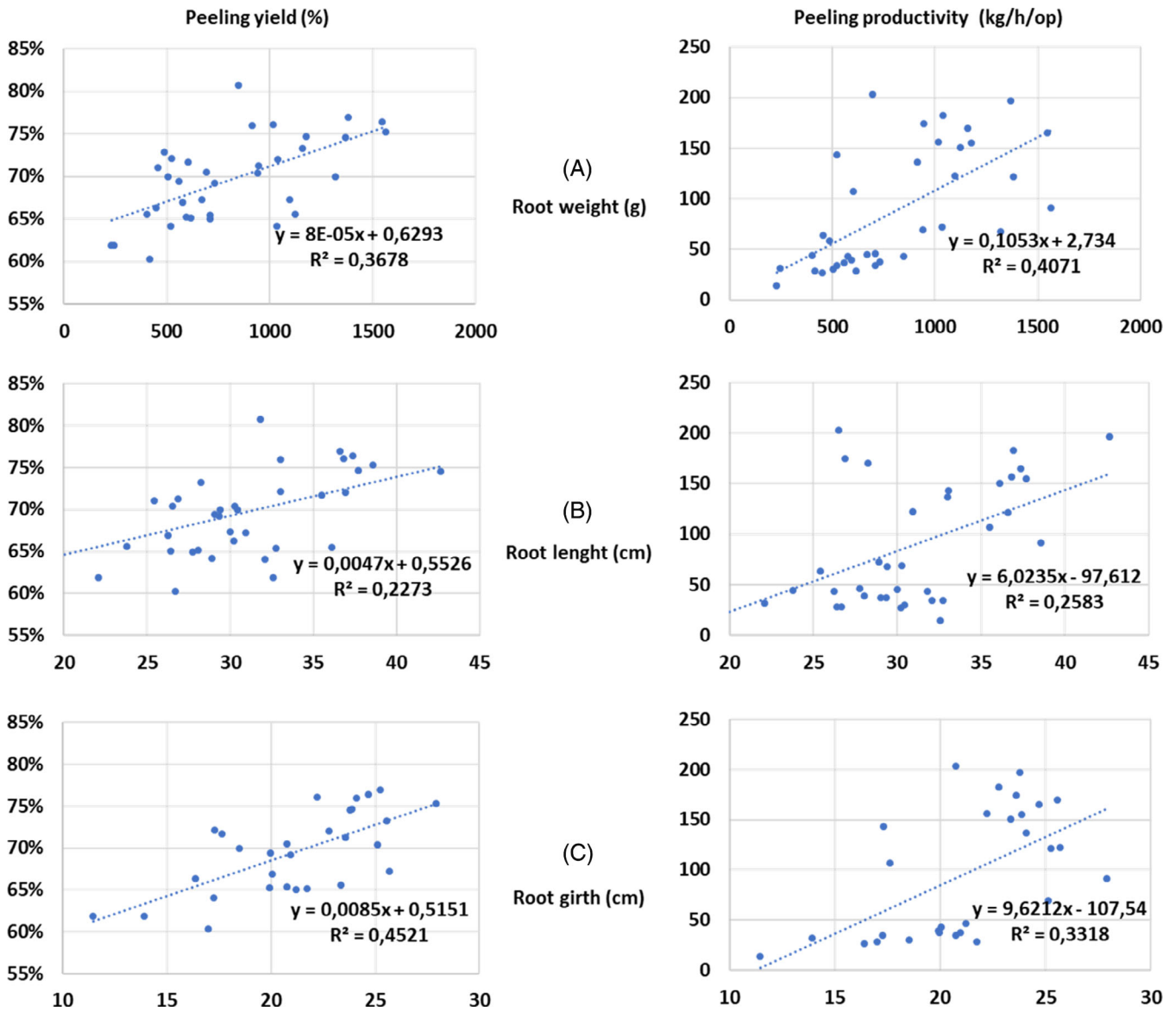


Figure 2. The impact of root morphology on peeling yield (%) and productivity (kg/h/operator) in cassava. (A) Root weight (g). (B) Root length (cm). (C) Root girth (cm). Based on gari UAC/FSA,⁵⁹ Iafun UAC/FSA⁶¹ and Bâton IITA-Cirad Cameroun⁵⁸ data.

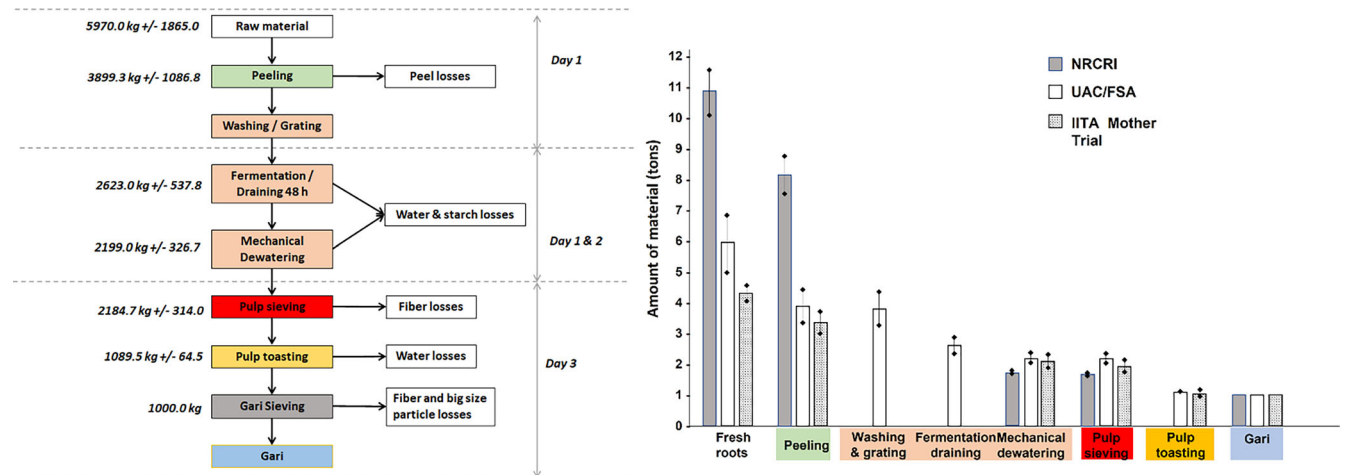


Figure 3. General description of the process to produce gari and average amounts of roots and intermediate products involved in the production of 1 ton of dry gari in three different regions of West Africa represented by the three different institutes that lead the work in the different regions. Lines on top of each rectangle represent the respective SDs.

green-dotted triangle). This group includes only improved clones. On average, these genotypes required 5.27 tons of fresh roots to produce 1 ton of gari. However, based on the DMC, the model expected that these genotypes should have required up to 8.54 tons of roots. On average, these genotypes had intermediate

levels of DMC (average of 33.4%) and the contrast between their expected and observed performances would suggest that they were efficient gari producers.

There is a second group of six genotypes (within a red-dotted triangle), well above the regression line. This group included five

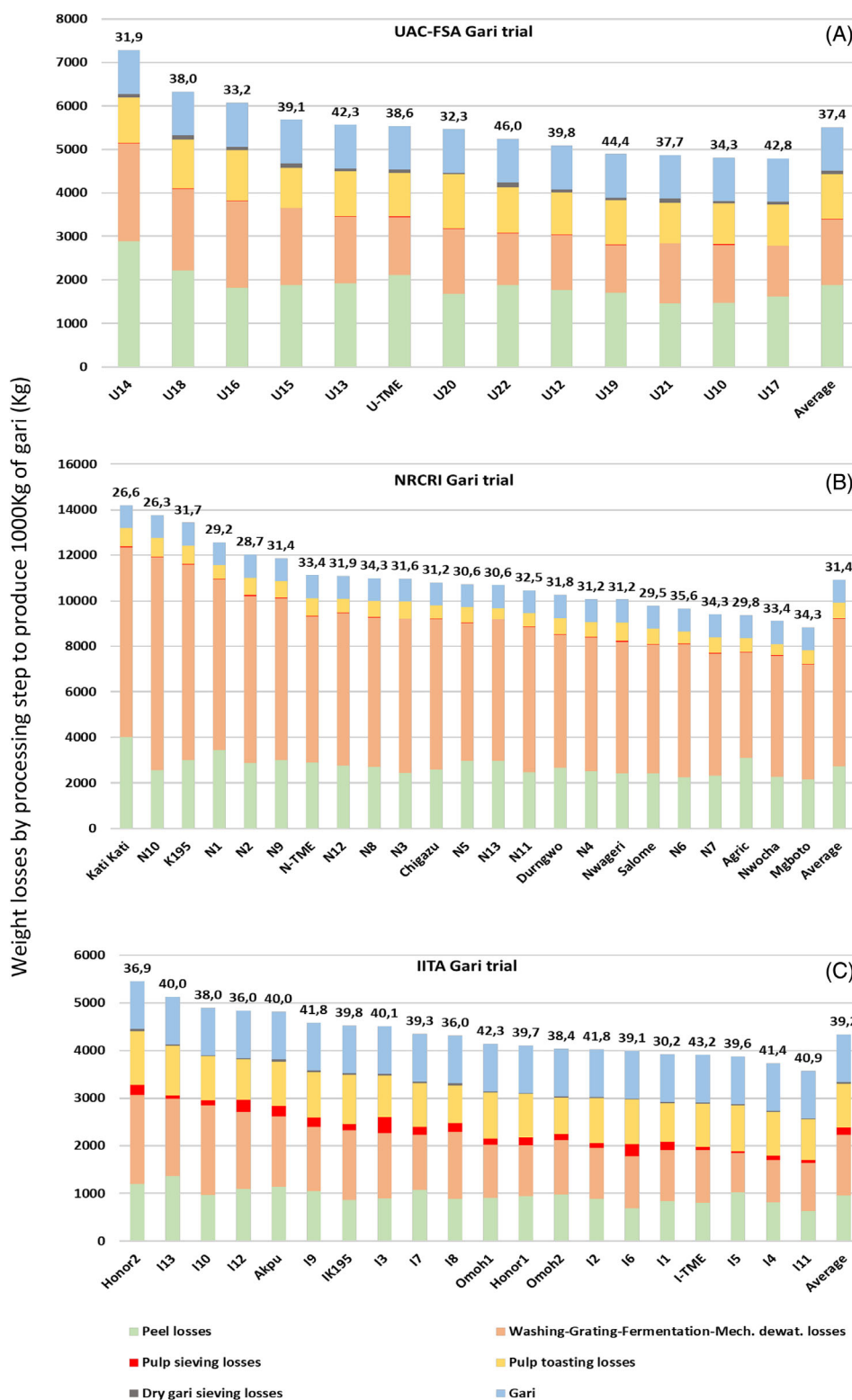


Figure 4. Individual losses through the different stages of gari production of several cassava genotypes evaluated at (A) Savalou, Colline, (UAC/FSA) Benin; (B) Umudike, Abia State, (NRCRI) Nigeria; and (C) Osun state, (IITA) Nigeria. DMC values (%) are depicted on top of the respective bar.

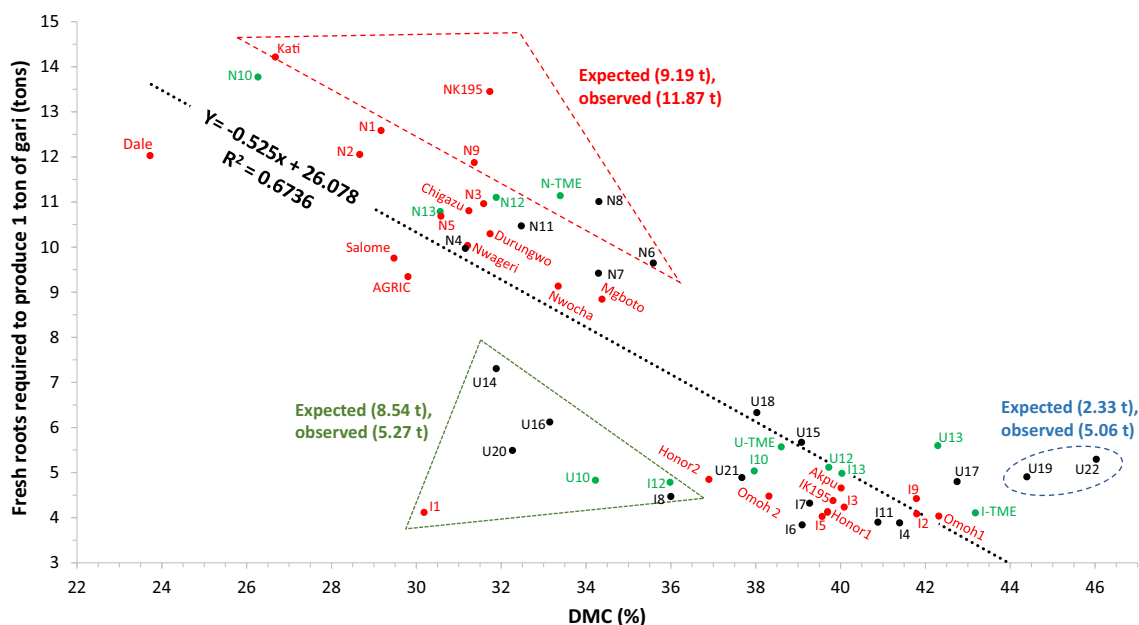


Figure 5. Relationship between dry matter content (%) of roots and the amounts of roots required to produce 1 ton of gari.

bred clones and only one landrace check (Kati Kati). DMC in Kati Kati was very low (26.6%). The other five clones had intermediate DMC levels (average = 33.3%). The amounts of roots required to produce 1 ton of gari (11.87 ton) for these clones were considerably higher than the expected (9.19 ton) based on their DMC levels. Finally, as shown in Fig. 5 (oval, red-dotted figure, bottom right), there was a third group (two bred genotypes) that required 5.06 tons of fresh roots to produce 1 ton of gari. This is considerably more than the amount expected by the model (2.33 ton). These last two groups are inefficient genotypes (above the regression line). They required considerably more fresh roots than expected based on the DMC regression model. These two groups differed considerably in their DMC averages.

The efficiency of gari production is clearly related to DMC as shown in Fig. 5. However, other characteristics (e.g. thin peel; easy to peel; reduced fiber content; less starch loss during the dewatering process, etc.) may explain the occurrence of large deviations from the expected values determined by the regression line.

Partitioning the total labour into the different activities

Figure 6 shows the data generated at Savalou, Colline, UAC/FSA, Benin and Osun state, IITA Nigeria on the time required to complete each key step of the process for the gari production for 1000 kg of final gari. By far the most time-demanding activities in the production of gari are pulp toasting (53.5%) and root peeling (31.0%). Other activities remained relatively minor in terms of labour demand (6% for pulp sieving, and root washing and dry gari sieving with about 3.7% each). The SDs indicate that there is considerable variation among genotypes in relation of their demand of labour to produce 1 ton of gari. The graph reveals that toasting was less efficient at IITA but, on the other hand, peeling was less time-consuming there as compared with UAC/FSA (Fig. 6A).

The variety Dale has been ignored in Fig. 6 because of its outlying performance. As indicated, there were marked differences in the time invested for each operation among the genotypes evaluated, as suggested by the SDs in Fig. 6(A). The plots in Fig. 6(B,C)

confirm large genetic variation for labour requirements to produce 1 ton of gari.

The coefficients of variation ($CV = \sigma/\mu \times 100$) from UAC/FSA data, for the different operations, were: overall time (hours required to produce 1 ton of gari): 19.3%; peeling: 22.7%; washing: 33.2%; grating: 18.0%; dewatering: 6.8%; pulp sieving: 22.9%; pulp toasting: 23.6%; and dry gari sieving: 27.2%. In the case of IITA trials CVs were: overall time: 16.0%; peeling = 15.6%; dewatering: 7.4%; pulp sieving: 27.3%; and pulp toasting: 19.7%.

The CVs provide a general appreciation of where variation among genotypes is particularly important for a given activity and point out results that require further exploration. For example, in the IITA trial (Fig. 6B), root peeling was relatively more uniform ($CV = 15.6\%$) than pulp sieving ($CV = 27.3\%$). I10 and Honor 2 required more than 40 h in pulp sieving, whereas Akpu and I7 required less than 20 h. Understanding why these genotypes are so contrasting for pulp sieving would help breeders to use more efficient selection approaches.

Figure 6(B,C) also provide information on DMC for each genotype. U14 has low DMC and requires considerable labour input. U22 had the highest DMC and was the second lowest clone with respect to labour requirements (Fig. 6C). There is some association between DMC and labour requirements. On the other hand, U21 with an intermediate DMC (37.7%), required considerably less labour than U13, which had excellent DMC (42.3%). This last clone required an additional 80 h compared to the average of 523 h (excluding Dale) for UAC/FSA.

Influence of DMC on workload to process 1 ton of gari

Labour hours required to produce 1 ton of gari versus DMC of raw roots (UAC/FSA data) are plotted in Fig. 7. Dale is a locally grown variety in Benin with low DMC and small roots. If this genotype (clearly outlying) is included, the regression analysis comparing DMC and labour hours results in $r^2 = 0.55$. However, when Dale was ignored, the coefficient of determination was drastically reduced ($r^2 = 0.26$). Even when Dale is overlooked, there is a large range of variation in

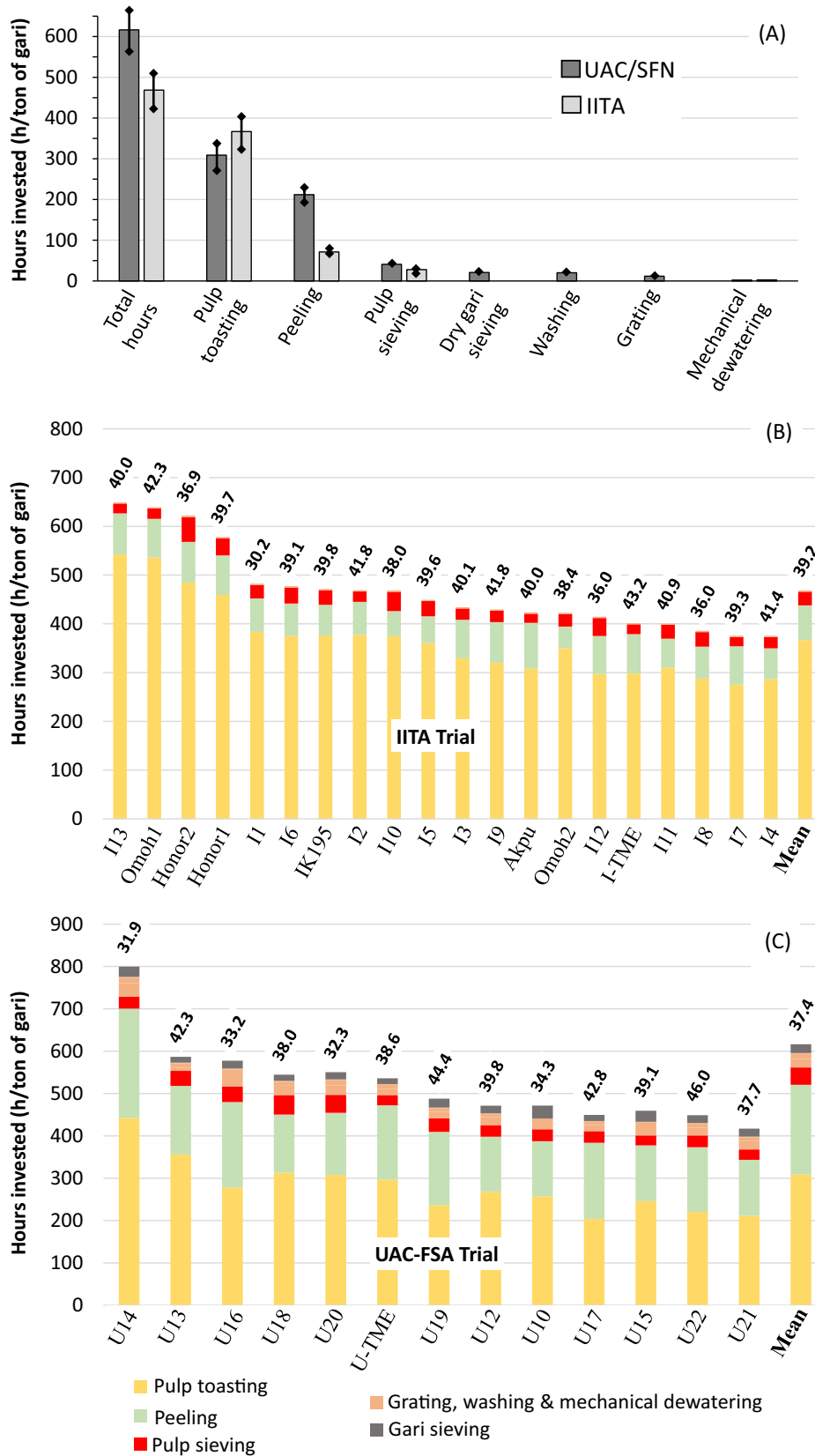


Figure 6. Time invested to produce 1 ton of gari. (A) Partitioning the total labour required to produce 1 ton of gari into the different activities of the process. Time invested to produce 1 ton of gari in (B) the UAC/FSA trial and the (C) IITA trial discriminated by genotypes and activities.

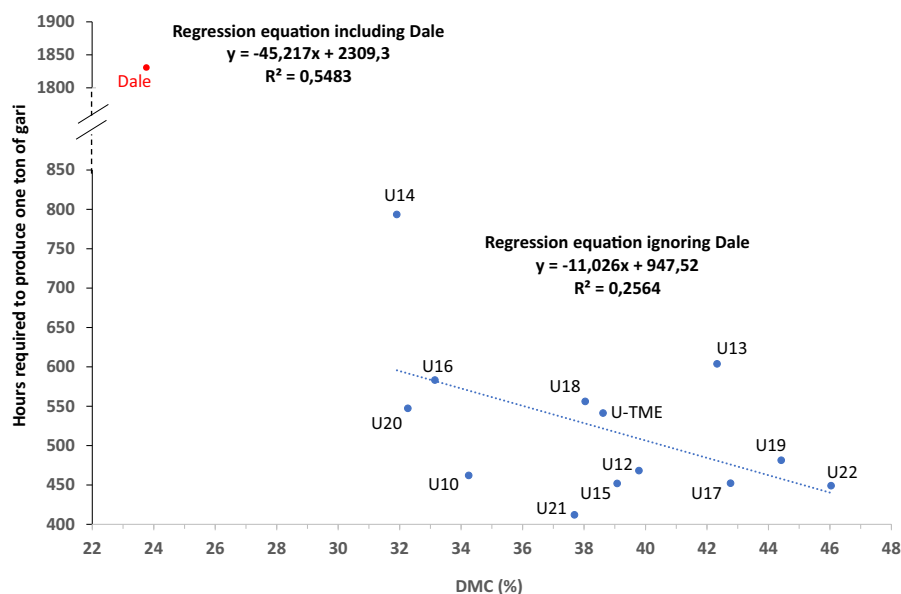


Figure 7. UAC/FSA trial relationship between dry matter content of activities (Fig. 6A) and therefore the relationship between DMC and the time required to carry the roots and the total labour requirements to produce 1 ton of gari.

the time required to process 1 ton of gari, spanning from 400 to 800 hours. Relatively little of that variation is explained by DMC, as also indicated by data from Fig. 6(B,C). There are therefore other factors that influence the variation in the labour required for processing 1 ton of gari such as shape and size of roots, which has a huge impact on the peeling operation.

Root peeling, pulp sieving and pulp toasting are the most labour-demanding out these activities was further analyzed and are depicted in the Supporting information (Fig. S1). The data included trials at UAC/FSA and IITA. The most important influence of DMC was found to be that for pulp sieving. However, there is a large dispersion of data (Supporting information, Fig S1). The negligible influence of DMC on labour requirements for pulp toasting is not surprising. Most of the effect of DMC would be on stages prior to the toasting. When the material being processed reaches that stage, they already have a much more uniform (and increased) DMC because of the mechanical de-watering that takes place after fermentation.

Summary of the influence of DMC on gari production

A summary of the relative importance of DMC in gari yield and labour requirements is provided in Fig. 8. In addition, another important parameter related to the drudgery of gari production is provided: the total amount of mass that women had to move throughout the entire process. The highest coefficient of determination was observed for the regression of kg of mass movement per kg of gari produced, on DMC ($r^2 = 0.65$).

Figure 8(A) shows a positive correlation between gari yield and the raw root dry matter content. However, the dry matter content does not impact significantly the time spent for processing (Fig. 8B). Other parameters may have to be considered for their impact on process productivity, such as root peeling ability, draining behavior during fermentation and sieving ability linked to fiber content. A clear negative correlation can be observed between mass movement and dry matter content (Fig. 8C). The dry matter content is thus an important trait to be considered in

order to reduce labour requirements and thus the often related drudgery in gari processing.

DISCUSSION

This review shows a strong genetic influence on processing yield, operators' efficiency, workload and fatigue of RTB processors (mainly women, young children and elderly). Processing yield depends not only on varieties, but also on the level of complexity of the processes. Indeed, low processing yields are the result of complicated operations with many steps to reduce water content, enhance the shelf-life of products and, in the case of cassava, detoxify it if necessary.

Thus, more complex processes tend to increase the likelihood of perceived drudgery and reduce global processing yields, but, on the other hand, lengthen the shelf life of food products. In that sense, complexity and, concomitantly, some degree of drudgery are the price to pay to increase the shelf life of the end-product originating from the same raw material.

Reduced processing yields not only have a direct negative economic impact on the value addition, but also have an indirect (but strongly correlated) effect on the accumulated weight carried through the process. By combining all the data sets for the different food product profiles, Fig. 9 illustrates the clear association between weights carried out and processing yields.

Furthermore, this review addresses a clear gender dimension because processing work is often dominated by women as a result of existing norms that often push women into monotonous and drudgery related tasks. Because social impact through social and gender inclusiveness is a particular outcome aim of RTB breeding⁷⁷ and part of the sustainable development goals, increasing productivity and limiting perceived drudgery in RTB processing is therefore crucial within the empowerment of women from below. Gender transformative approaches that aim to change gender roles are important but often slow and are not always able to address the concrete working conditions and livelihoods and their context (including the existing norms) that

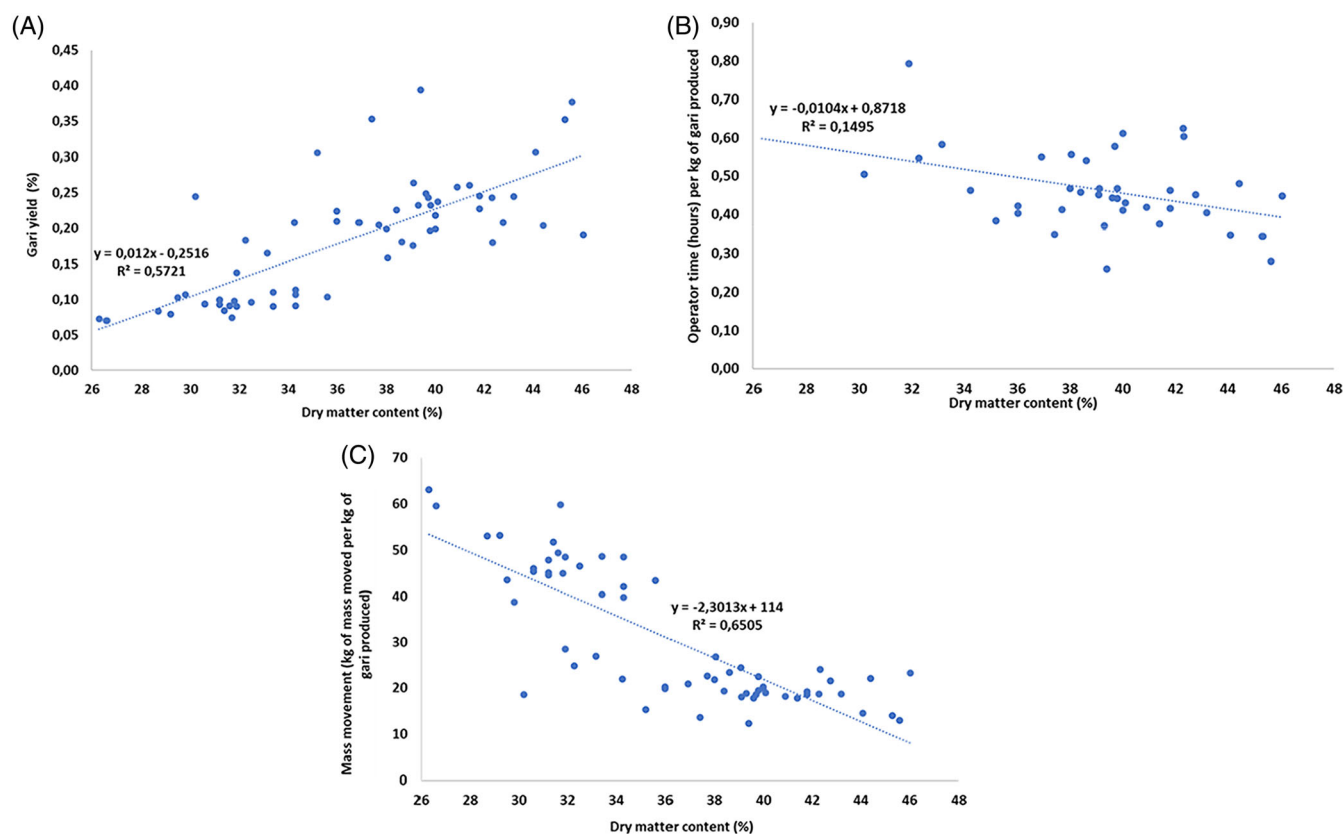


Figure 8. Impact of raw material dry matter content (%) on (A) gari yield, (B) operator time and (C) drudgery.

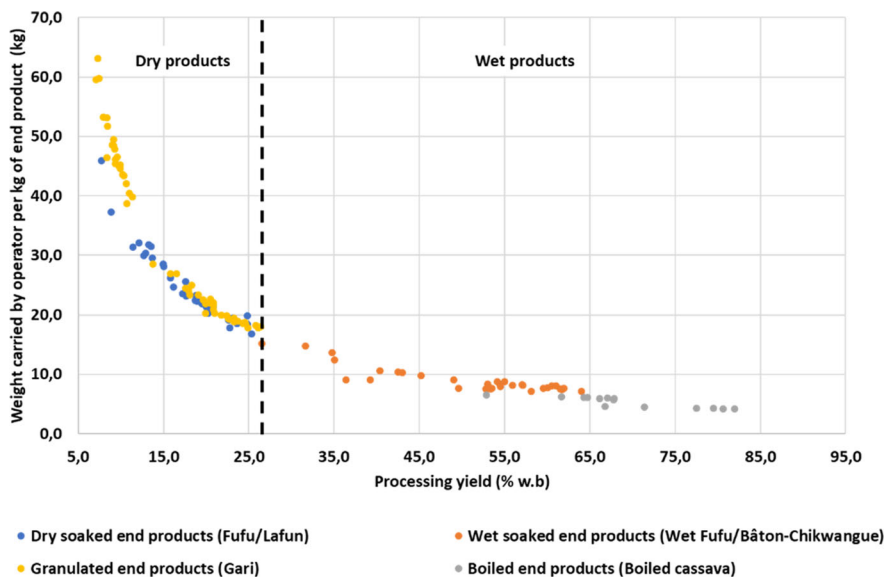


Figure 9. Weight (kg) carried out by operator per kg of end product according processing yield (% w.b.). Based on gari CIRAD/UAC-FSA,⁵⁹ gari IITA,⁶⁴ dry fufu CIRAD/UAC-FSA,⁶¹ dry fufu CIRAD/IITA,⁶⁰ Bâton CIRAD/IITA,⁵⁸ wet fufu IITA⁶⁴ and boiled cassava UAC/FSA⁶³ data.

women are largely dependent on^{78,79} to make a living and increase their income and independence.

A special effort should be made by RTB breeders to evaluate the yields of the final product and the additional fatigue that could be brought by the introduction of new genotypes. This is particularly necessary for the more complex processed products, especially those from cassava, because of the additional need to detoxify

them and to reduce the weight of the marketable product by removing water, as well as the need to increase shelf life. Moreover, addressing labour requirements and associated drudgery related to processing is not enough because breeders must also consider consumer preferences as well. There is a large diversity of requirements for granulated and soaked products on the one hand, and pasty and dough products such as pounded yam and

matooke on the other. All these products are obtained after complex processing steps.^{27,34–36}

This review also shows that cassava root dry matter is highly influenced by the location and time of harvest especially with regards to the extent harvesting takes place around the peak of the rainy season.^{80–84} This stresses the importance of selecting for dry matter stability throughout the season and not only across locations. Clones with such dry matter stability exist^{85–89} and can therefore be included in the prebreeding strategy. This would especially be beneficial for processors as they process all year round.

The processing efficiency or productivity that determines the amount of labour required from processors and the related drudgery is a key factor in the varietal adoption process. The processors, who are often the decision makers for the purchase of raw materials, strongly contribute to the creation of a market segment for new genotypes or to their rejection depending on the difficulty of processing and/or the food product yields obtained. The views of consumers, traders and growers have already been incorporated into the definition of breeding goals. This review highlights, however, the critical importance of processors in the final varietal adoption.⁹⁰ Their perception of each genotype provides relevant information that must be integrated upstream in the breeding pipeline to increase the chances of success of new varieties.

AUTHOR CONTRIBUTIONS

AB, DD, TM, FKA, GF, LF and BT were responsible for study conceptualization. HC, BA, DO, DOO, DO, AA, BO, MO, SN, NO and LA were responsible for data curation. AB, DD, HC, AB, BT, BO, SN and LA were responsible for formal analysis. AB, AB, BT, DOO, MO, SN, NO, LA and DD were responsible for investigations. AB, GF, MT, LA, LF and DD were responsible for methodology. AB, BT, TM, LA, GF, LF and DD were responsible for supervision. AB, HC and DD were responsible for writing the original draft. AB, HC, DD, LF and BT were responsible for reviewing and editing. DD was responsible for project administration.

ACKNOWLEDGEMENTS

In memoriam of our colleague and friend Geneviève Fliedel, PhD, Food technologist at CIRAD who suggested and contributed to this work and for the passion and enthusiasm that characterized her work as a researcher. We are grateful to the grant opportunity INV-008567 (formerly OPP1178942): Breeding RTB Products for End User Preferences (RTBfoods), to the French Agricultural Research Centre for International Development (CIRAD), Montpellier, France, by the Bill & Melinda Gates Foundation (BMGF) (<https://rtbfoods.cirad.fr>) and grant INV-007637 to the College of Life Science at Cornell University as part of the Nextgen cassava project (www.nextgencassava.org) also by the Bill & Melinda Gates foundation. We thank the various partner institutions of the RTBfoods project for allowing the sharing of additional data not contained in the diagnostic reports mentioned in the bibliographic list. The final proofreading of the manuscripts by Clair Hershey improved greatly the quality of this manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Agritrop at <https://agritrop.cirad.fr/>.

SUPPORTING INFORMATION

Supporting information may be found in the online version of this article.

REFERENCES

- Nweke FI and Enete A, Gender Surprises in Food Production, Processing, and Marketing with Emphasis on Cassava in Africa. COSCA – Collaborative Study of Cassava in Africa. Working Paper n°19 · International Institute of Tropical Agriculture IITA, Ibadan, Nigeria (1999). https://www.google.fr/books/edition/Gender_Surprises_in_Food_Production_Proc/wYHl6osg-ToC?hl=fr&gbpv=1&dq.
- Doss C, Meinzen-Dick R, Quisumbing A and Theis S, Women in agriculture: four myths. *Glob Food Secur* **16**:69–74 (2018). <https://doi.org/10.1016/j.gfs.2017.10.001>.
- Nweke FI, Cassava processing in sub-Saharan Africa: the implications for expanding cassava production. *Outlook Agric* **23**:197–205 (1994). <https://doi.org/10.1177/003072709402300307>.
- Curran S, Leigh-Anderson C, Gugerty MK, Cook J, Yorgey G and Gockel R, Gender and cropping: cassava in Sub-Saharan Africa. Evans School Policy Analysis and Research (EPAR). p. 6 (2009). <https://evans.uw.edu/policy-impact/epar/research/gender-cropping-sub-saharan-africa-cassava>.
- Teeken B, Olaosebikan O, Haleegoah J, Oladejo E, Madu T, Bello A et al., Cassava trait preferences of men and women farmers in Nigeria: implications for breeding. *Econ. Bot* **20**:1–15 (2018). <https://doi.org/10.1007/s12231-018-9421-7>.
- Forsythe L, Martin AM and Posthumus H, Cassava market development: a path to women's empowerment or business as usual? *Food Chain* **5**:11–27 (2015). <https://doi.org/10.3362/2046-1887.2015.003>.
- Forsythe L, Posthumus H and Martin A, A crop of one's own? Women's experiences of cassava commercialization in Nigeria and Malawi. *J gen, agric food secur* **1**:110–128 (2016). <https://doi.org/10.22004/ag.econ.246033>.
- Nweke FI, Spencer DSC and Lynam JK, *The Cassava Transformation: Africa's Best-Kept Secret*. Michigan State University Press, East Lansing, MI, p. 273 (2012) <https://msupress.org/9781609172831/the-cassava-transformation/>.
- FAO, The state of food and agriculture 2010–2011: women in agriculture: closing the gender gap for development, in *Food and Agriculture Organization of the United Nations*. FAO, Rome, Italy (2011) <https://www.fao.org/3/i2050e/i2050e.pdf>.
- Abass AB, Awoyale W, Ogundapo A, Oluwasoga O, Nwaoliwe G, Oyelekan J et al., Adoption of improved cassava varieties by processors is linked to processing characteristics and products biophysical attributes. *J Food Process Preserv* **46**:e16350 (2022). <https://doi.org/10.1111/jfpp.16350>.
- Bishop-Sambrook C, *How to Do Reducing Rural women's Domestic Workload through Labour-Saving Technologies and Practices – Gender, Targeting and Social Inclusion*. IFAD, Rome, Italy (2016) <https://www.ifad.org/documents/38714170/db859c93-9066-411a-ad40-a0204c98351c>; <https://www.ifad.org/documents/10180/c86179dd-ad6d-4622-864a-ed590016250d>.
- Polar V and Demont M, Designer crops of the future must be better tailored for women in agriculture – nutrition levels and taste should be considered along with traits such as higher yields. *Sci Am* **327** (2022) <https://www.scientificamerican.com/article/designer-crops-of-the-future-must-be-better-tailored-for-women-in-agriculture/>.
- Weltzien E, Rattunde F, Christinck A and Ashby J, Gender and farmer preferences for varietal traits: evidence and issues for crop improvement. *Plant Breed Rev* **43**:243–278 (2020). <https://doi.org/10.1002/9781119616801.ch7>.
- Adenugba AA and John P, Hazardous conditions of women in gari processing industry in Ibadan, South West, Nigeria. *J Educ Soc Res* **4**:511 (2014). <https://doi.org/10.5901/jesr.2014.v4n3p511>.
- Samuel TM, Igbeka JC and Kolawole OP, A survey of improved gari frying methods. *Int J Food Eng* **6**:1–12 (2010). <https://doi.org/10.2202/1556-3758.1473>.

- 16 Okwor TJ, Ozoh OB, Okonkwo U and Osibogun A, Occupational exposure to particulate matter from biomass smoke and its relationship to respiratory symptoms and pulmonary function among rural women involved in cassava processing in Nigeria. *Open J Prev Med* **7**:41–54 (2017). <https://doi.org/10.4236/ojpm.2017.73004>.
- 17 Vemireddy V and Choudhary A, Labor-saving technologies designed for women can reduce their drudgery, in *CGIAR Gender Platform Evidence Explainer*. CGIAR GENDER Platform, Nairobi, Kenya (2021) <https://hdl.handle.net/10568/114807>.
- 18 Bello A, Agbona A, Olaosebikan O, Edughaen G, Dufour D and Bouniol A, Genetic and environmental effects on processing productivity and food product yield: drudgery of women's work. *J. Sci. Food Agric* **104**:4758–4769 (2024). <https://doi.org/10.1002/jsfa.13079>.
- 19 Mrunalini A and Snehalatha C, Drudgery experiences of gender in crop production activities. *J Agric Sci* **1**:49–51 (2010). <https://doi.org/10.1080/09766898.2010.11884654>.
- 20 Bal SK, Shivani S and Kaur H, Assessment of drudgery experience of rural women while performing different farm operations. *Adv Res J Soc Sci* **4**:68–71 (2013) http://researchjournal.co.in/upload/assignments/4_68-71.pdf.
- 21 Isaksen J, Constructing meaning despite the drudgery of repetitive work. *J Humanist Psychol* **40**:84–107 (2000). <https://doi.org/10.1177/00221678000403008>.
- 22 Luna J, Dufour D, Tran T, Pizarro M, Calle F, García Domínguez M *et al.*, Post-harvest physiological deterioration in several cassava genotypes over sequential harvests and effect of pruning prior to harvest. *Int J Food Sci Technol* **56**:1322–1332 (2021). <https://doi.org/10.1111/ijfs.14711>.
- 23 Ravi V, Aked J and Balagopalan C, Review on tropical root and tuber crops I. storage methods and quality changes. *Crit Rev Food Sci Nutr* **36**:661–709 (1996). <https://doi.org/10.1080/10408399609527744>.
- 24 Kouamé AC, Kouassi KN, N'dri YD and Amani NG, Glycaemic index and load values tested in normoglycemic adults for five staple foodstuffs: pounded yam, pounded cassava-plantain, placcali, attiéke and maize meal stiff porridge. *Nutrients* **7**:1267–1281 (2015). <https://doi.org/10.3390/nu7021267>.
- 25 Marimo P, Akankwasa K, Khamila S, Tinyoro SE, Bouniol A, Ndagire L *et al.*, *RTBfoods Participatory Processing Diagnosis of Matooke in Uganda*. RTBfoods/CIRAD, Kampala, Uganda, p. 38 (2021). <https://doi.org/10.18167/agritrop/00615>.
- 26 Otegbayo B, Madu T, Oroniran O, Chijioke U, Fawehinmi O, Okoye B *et al.*, End-user preferences for pounded yam and implications for food product profile development. *Int J Food Sci Technol* **56**:1458–1472 (2021). <https://doi.org/10.1111/ijfs.14770>.
- 27 Dufour D, Hershey C, Hamaker BR and Lorenzen J, Integrating end-user preferences into breeding programmes for cassava, tubers and bananas. *Int J Food Sci Technol* **56**:1071–1075 (2021). <https://doi.org/10.1111/ijfs.14911>.
- 28 Bokanga M, Distribution of cyanogenic potential in cassava germplasm, in *International Workshop on Cassava Safety*, Vol. **375**, ed. by Bokanga M, Essers AJA, Poulter N, Rosling H and Tewe O. WOCAS/ISHS /ISTRIC, The Netherlands, Acta Hort, pp. 117–124 (1994) https://www.actahort.org/books/375/375_9.htm.
- 29 Sánchez T, Salcedo E, Ceballos H, Dufour D, Mafía G, Morante N *et al.*, Screening of starch quality traits in cassava (*Manihot esculenta* Crantz). *Starch/Stärke. Erratum: Starch/Stärke* **61**:12–19 (2009). <https://doi.org/10.1002/star.200800058>.
- 30 Chiwona-Karlton L, Brimer L, Kalenga Saka JD, Mhone AR, Mkumbira J, Johansson L *et al.*, Bitter taste in cassava roots correlates with cyanogenic glucoside levels. *J Sci Food Agric* **84**:581–590 (2004). <https://doi.org/10.1002/jsfa.1699>.
- 31 Nambisan B, Strategies for elimination of cyanogens from cassava for reducing toxicity and improving food safety. *Food Chem Toxicol* **49**:690–693 (2011). <https://doi.org/10.1016/j.fct.2010.10.035>.
- 32 FAO/WHO, Maximum levels for hydrocyanic acid in cassava and cassava products. Food standards programme codex committee on contaminants in foods, Seventh session, Moscow, Russian Federation, 8–12 April 2013. Agenda Item 10, CX/CF 13/7/10 (2013). https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?Ink=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252Fshared%2BDocuments%252FArchive%252FMeetings%252FFCCCF%252Fcccf%252Fcf07_11e.pdf.
- 33 Montagnac JA, Davis CR and Tanumihardjo SA, Processing techniques to reduce toxicity and Antinutrients of cassava for use as a staple food. *Compr Rev Food Sci Food Saf* **8**:17–27 (2009). <https://doi.org/10.1111/j.1541-4337.2008.00064.x>.
- 34 Béchoff A, Tomlins K, Fliedel G, Becerra Lopez-lavalle LA, Westby A, Hershey C *et al.*, Cassava traits and end-user preference: relating traits to consumer liking, sensory perception, and genetics. *Crit Rev Food Sci Nutr* **58**:547–567 (2018). <https://doi.org/10.1080/10408398.2016.1202888>.
- 35 Lancaster PA, Ingram JS, Lira MY and Coursey DG, Traditional cassava-based foods: survey of processing techniques. *Econ Bot* **36**:12–45 (1982). <https://doi.org/10.1007/BF02858697>.
- 36 Westby A, Cassava utilization, storage and small-scale processing, in *Cassava: Biology, Production and Utilization*, ed. by Hillocks RJ, Thresh JM and Bellotti AC. CABI Publ, New York, pp. 281–300 (2002) http://ciat-library.ciat.cgiar.org/articulos_ciat/cabi_17ch14.pdf.
- 37 Forsythe L, Tufan H, Bouniol A, Kleih U and Fliedel G, An interdisciplinary and participatory methodology to improve user acceptability of root, tuber and banana varieties. *Int J Food Sci Technol* **56**:1115–1123 (2021). <https://doi.org/10.1111/ijfs.14680>.
- 38 Forsythe L, Olaosebikan O, Teeken B, Newilah GN, Mayanja S, Nanyonjo AR *et al.*, A case of transdisciplinarity and collaborative decision making: the co-construction of Gendered Food Product Profiles. *J Sci Food Agric* **104**:4485–4497 (2024).
- 39 Fliedel G, Bouniol A, Kleih U, Tufan H and Forsythe L, *RTBfoods Step 3: Participatory Processing Diagnosis and Quality Characteristics, RTBfoods/CIRAD*. CIRAD, Montpellier, France, p. 29 (2018). <https://doi.org/10.18167/agritrop/00570>.
- 40 Ngho NG, Teeken B, Bouniol A, Bugaud C, *A participatory methodology to evaluate processing ability and food product quality to increase acceptability of new root, tuber & banana genotypes. Gender equitable positioning, promotion and performance, WP5*. Njombé : RTBfoods Project-CIRAD, p. 29 (2022). <https://doi.org/10.18167/agritrop/00584>.
- 41 International Journal of Food Science and Technology, Special Issue: Consumers have their say: assessing preferred quality traits of roots, tubers and cooking bananas, and implications for breeding. *International Journal of Food Science and Technology* **56**:1071–1501 (2021). <https://doi.org/10.1111/ijfs.14636>.
- 42 Ndjouenkeu R, Ngoualem KF, Teeken B, Okoye B, Madu T, Olaosebikan OD *et al.*, From cassava to garri: mapping of quality characteristics and end-user preferences in Cameroon and Nigeria. *Int J Food Sci Technol* **56**:1223–1238 (2021). <https://doi.org/10.1111/ijfs.14790>.
- 43 Chijioke U, Madu T, Okoye B, Ogunka AP, Ejechi M, Ofoeze M *et al.*, Quality attributes of fufu in south-East Nigeria: guide for cassava breeders. *Int J Food Sci Technol* **56**:1247–1257 (2021). <https://doi.org/10.1111/ijfs.14875>.
- 44 Wossen T, Tessema G, Abdoulaye T, Rabbi I, Olanrewaju A, Alene A *et al.*, The cassava monitoring survey in Nigeria Final report. IITA, Ibadan, Nigeria. 66 pp (2017). <https://hdl.handle.net/10568/80706>.
- 45 Oiza Enesi R, Hauser S, Pypers P, Kreye C, Tariku M and Six J, Understanding changes in cassava root dry matter yield by different planting dates, crop ages at harvest, fertilizer application and varieties. *European Journal of Agronomy* **133**:e126448 (2022). <https://doi.org/10.1016/j.eja.2021.126448>.
- 46 Ferris RSB, Ortiz R and Vuylsteke D, Fruit quality evaluation of plantains, plantain hybrids, and cooking bananas. *Postharvest Biol Technol* **15**: 73–81 (1999). [https://doi.org/10.1016/S0925-5214\(98\)00067-2](https://doi.org/10.1016/S0925-5214(98)00067-2).
- 47 Gibert O, Dufour D, Giraldo A, Sánchez T, Reynes M, Pain JP *et al.*, Differentiation between cooking bananas and dessert bananas. 1. Morphological and compositional characterization of cultivated Colombian Musaceae (*Musa* sp.) in relation to consumer preferences. *J Agric Food Chem* **57**:7857–7869 (2009). <https://doi.org/10.1021/jf901788x>.
- 48 Mäder J, Rawel H and Kroh LW, Composition of phenolic compounds and Glycoalkaloids α -Solanine and α -Chaconine during commercial potato processing. *J Agric Food Chem* **57**:6292–6297 (2009). <https://doi.org/10.1021/jf901066k>.
- 49 Pathak PD, Mandavgane SA, Puranik NM, Jambhulkar SJ and Kulkarni BD, Valorization of potato peel: a biorefinery approach. *Crit Rev Biotechnol* **38**:218–230 (2018). <https://doi.org/10.1080/07388551.2017.1331337>.
- 50 Visalakshi C, Anil SR, Sheela MN, Hegde V, Jyothi AN and Sreekumar J, Genetic variation for important processing traits and identification of potential parents for developing hybrid clones suitable for processing in sweet potato (*Ipomoea batatas* L lam). *S Afr J Bot* **141**: 255–264 (2021). <https://doi.org/10.1016/j.sajb.2021.04.005>.

- 51 Adetan DA, Adekoya LO and Aluko OB, Theory of a mechanical method of peeling cassava tubers with knives. *Int Agrophys* **20**:269–276 (2006). <http://www.international-agrophysics.org/pdf-106611-37453?filename=Theory%20of%20a%20mechanical.pdf>.
- 52 Bouniol A, Adinsi L, Honfozo L, Hounhouigan J, Fliedel G and Akissoe N, *RTBfoods Participatory Processing Diagnosis of Boiled Yam in Benin*. RTBfoods/CIRAD, Cotonou, Benin, 27 (2021). <https://doi.org/10.18167/agritrop/00627>.
- 53 Madu T, Ofoeze M, Onyemauwa N and Okoye B, RTBfoods participatory processing diagnosis of boiled yam in Nigeria. *RTBfoods/CIRAD, Umudike, Nigeria*:17 (2021). <https://doi.org/10.18167/agritrop/00619>.
- 54 Otegbayo B, Oroniran O, Fawehinmi O and Tanimola A, *RTBfoods Participatory Processing Diagnosis of Pounded Yam in Nigeria*. RTBfoods/CIRAD, Iwo, Nigeria, p. 22 (2021). <https://doi.org/10.18167/agritrop/00616>.
- 55 Tinyiro SE, Nakitto M, Kisakye S, Bamwirire D, Mirembe A, Okonya J et al., *RTBfoods Participatory Processing Diagnosis of Boiled Sweetpotato in Uganda*. RTBfoods/CIRAD, Kampala, Uganda, p. 25 (2021). <https://doi.org/10.18167/agritrop/00623>.
- 56 Nakitto M, Tinyiro SE, Kisakye S, Bamwirire D, Mirembe A, Okonya J et al., *RTBfoods Participatory Processing Diagnosis for Boiled Potato in Uganda*. RTBfoods/CIRAD, Kampala, Uganda, p. 21 (2021). <https://doi.org/10.18167/agritrop/00622>.
- 57 Ngho Newilah G, Kendine Vepowo C and Takam Ngouno A, *RTBfoods Participatory Processing Diagnosis for Boiled Plantain in Cameroon*. RTBfoods/CIRAD, Yaoundé, Cameroon, p. 27 (2021). <https://doi.org/10.18167/agritrop/00626>.
- 58 Bouniol A, Prin L, Hanna R, Fosto A and Fliedel G, Assessment of the processability of improved cassava varieties into a traditional food product (“baton” or “chikwangué”) in Cameroon. RTB Working Paper n°2012–1, CGIAR research program on Roots, Tubers and Bananas (RTB), 28 p (2017). <http://agritrop.cirad.fr/595635/>.
- 59 Bouniol A, Adinsi L, Hotegni F, Delpech A, Akissoé N, Fliedel G et al., Assessment of the processing ability of improved cassava varieties into a traditional food product (Gari) in Benin. Savalou. RTB Working Paper n°2012–1, CGIAR research program on Roots Tubers & Bananas (RTB), 34 p (2020). <https://agritrop.cirad.fr/597596/>.
- 60 Bouniol A, Ospina MA, Fosto A, Hanna R and Dufour D, Assessment of the processing ability of improved cassava varieties into a traditional food product (FuFu) in Cameroon. Bertoua, RTB Working Paper n° 2012–1, CGIAR Research Program on Roots, Tubers and Bananas (RTB), 24 p (2017). <https://agritrop.cirad.fr/597597/>.
- 61 Bouniol A, Adinsi L, Padonou SW, Hotegni F, Gnanvossou D, Akissoé N et al., Assessment of the processing ability of improved cassava varieties into a traditional food product (Lafun) in Benin. Kérou. RTB Working Paper n°2012–1, CGIAR Research Program on Roots, Tubers and Bananas (RTB), 29 p. (RTB Working Paper, 2012–1) (2019). <https://agritrop.cirad.fr/597594/>.
- 62 Hamba S, Nanyonjo AR, Kanaabi M and Kawuki RS, *RTBfoods Participatory Processing Diagnosis of Boiled Cassava in Uganda*. RTBfoods/CIRAD, Kampala, Uganda, 25 (2021). <https://doi.org/10.18167/agritrop/00625>.
- 63 Bouniol A, Adinsi L, Honfozo L, Hounhouigan J and Akissoe N, *RTBfoods Participatory Processing Diagnosis of Boiled Cassava in Benin*. RTBfoods/CIRAD, Cotonou, Benin, 24 (2021). <https://doi.org/10.18167/agritrop/00624>.
- 64 Teeken B, Agbona A, Bello A, Olaosebikan O, Alamu E, Adesokan M et al., Understanding cassava varietal preferences through pairwise ranking of gari-eba and fufu prepared by local farmer–processors. *Int J Food Sci Technol* **56**:1258–1277 (2021). <https://doi.org/10.1111/ijfs.14862>.
- 65 Madu T, Okoye B, Onyemauwa N and Ofoeze M, *RTBfoods participatory processing diagnosis of Gari/Eba in Nigeria*. RTBfoods/CIRAD, Umudike, Nigeria, p. 21 (2021). <https://doi.org/10.18167/agritrop/00614>.
- 66 Madu T, Okoye B, Onyemauwa N and Ofoeze M, *RTBfoods Participatory Processing Diagnosis of Fufu in Nigeria*. RTBfoods/CIRAD, Umudike, Nigeria, p. 18 (2021). <https://doi.org/10.18167/agritrop/00620>.
- 67 Diby NN, Ebah Djedji C, Kanon L, Yapi E, Bouniol A, Bechoff A et al., *Participatory Processing Diagnosis for Attieke in Cote d'Ivoire. Surveys on Trait Preferences, WP1 – Activity 4. Abidjan*. RTBfoods Project-CIRAD, Montpellier, France, p. 26 (2021). <https://doi.org/10.18167/agritrop/00724>.
- 68 Nweke FI, Lutete D, Dixon AGO, Ugwu BO, Ajobo O and Kalombo N, Cassava production and processing in the Democratic Republic of Congo. Collaborative Study on Cassava in Africa (COSCA) Working Paper N°22, 87–93 (2000). https://books.google.fr/books?id=A4VY_jli7kAC&lpg=PP1&hl=fr&pg=PP1#v=onepage&q&f=false.
- 69 Pérez JC, Lenis JI, Calle F, Morante N, Sánchez T, Debouck D et al., Genetic variability of root peel thickness and its influence in extractable starch from cassava (*Manihot esculenta* Crantz) roots. *Plant Breed* **130**:688–693 (2011). <https://doi.org/10.1111/j.1439-0523.2011.01873.x>.
- 70 Kawuki RS, Ferguson M, Labuschagne MT, Herselman L, Orone J, Ralimanana I et al., Variation in qualitative and quantitative traits of cassava germplasm from selected national breeding programmes in sub-Saharan Africa. *Field Crops Res* **122**:151–156 (2011). <https://doi.org/10.1016/j.fcr.2011.03.006>.
- 71 Krishnakumar T, Sajeev MS, Pradeepika C, Namrata AG, Sanket JM, Jeevarathinam G et al., Physical and mechanical properties of cassava (*Manihot esculenta* Crantz) cultivars: implications for the design of mechanical peeling machines. *J Food Process Eng* **45**:e13923 (2022). <https://doi.org/10.1111/jfpe.13923>.
- 72 Hauser S, Bakelana TZ, Bungu D and Mwangi M, Cassava root yield losses caused by root shape, rot and peeling and cut-off for processing of four cassava varieties on different soils in DR Congo. *Advances in Nutrition and Food Science* **5**:1–10 (2020) <https://cgspage.cgiar.org/handle/10568/119338>.
- 73 Bello A, Olaosebikan O, Osunbgbade A, Teeken B and Bouniol A, *Participatory Processing Diagnosis for Gari/Eba in Nigeria. Understanding the Drivers of Trait Preferences and the Development of Multi-User RTB Product Profiles, WP1, Step 3*. RTBfoods Project-CIRAD, Ibadan, p. 34 (2020). <https://doi.org/10.18167/agritrop/00621>.
- 74 Ezeocha CV, Ihesie LC and Kanu AN, Comparative evaluation of toasting variables and the quality of gari produced by different women in Ikwuano LGA, Abia state, Nigeria. *J Food Process Preserv* **43**:e14060 (2019). <https://doi.org/10.1111/jfpp.14060>.
- 75 Dahdouh L, Escobar A, Rondet E, Ricci J, Fliedel G, Adinsi L et al., Role of waterlogging and roasting parameters on the quality of handmade gari. *Int J Food Sci Technol* **56**:1298–1310 (2021). <https://doi.org/10.1111/ijfs.14745>.
- 76 Escobar A, Rondet E, Dahdouh L, Ricci J, Akissoé N, Dufour D et al., Identification of robust versus critical unit operations in the elaboration of gari quality. *Int J Food Sci Technol* **56**:1311–1321 (2021). <https://doi.org/10.1111/ijfs.14857>.
- 77 Polar V, Teeken B, Mwende J, Marimo P, Tufan HA, Ashby JA et al., Building demand-led and gender-responsive breeding programs, in *Root, Tuber and Banana Food System Innovations*, ed. by Thiele G, Friedmann M, Campos H, Polar V and Bentley JW. Springer, Cham (2022). https://doi.org/10.1007/978-3-030-92022-7_16.
- 78 Adams R, *Empowerment, Participation and Social Work*, 4th edition. (4 ed.) edn (Practical social work series). Palgrave Macmillan, Basingstoke (2008).
- 79 Njuki J, Eissler S, Malapit H, Meinzen-Dick R, Bryan E and Quisumbing A, A review of evidence on gender equality, Women's empowerment, and food systems, in *Science and Innovations for Food Systems Transformation*, ed. by von Braun J, Afsana K, Fresco LO and Hassan MHA. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-15703-5_9.
- 80 Koundinya AVV, Ajeesh BR, Hegde V, Sheela MN, Mohan C and Asha KI, Genetic parameters, stability and selection of cassava genotypes between rainy and water stress conditions using AMMI, WAAS, BLUP and MTSI. *Scientia Horticulturae* **281**:e109949 (2021). <https://doi.org/10.1016/j.scienta.2021.109949>.
- 81 Masinde EA, Mkamillo G, Ogendo JO, Hillocks R, Mulwa RMS, Kimatac B et al., Genotype by environment interactions in identifying cassava (*Manihot esculenta* Crantz) resistant to cassava brown streak disease. *Field Crops Research* **215**:39–48 (2018). <https://doi.org/10.1016/j.fcr.2017.10.001>.
- 82 Moreno LP and Gourdji SM, Cassava starch content and its relationship with rainfall. CCAFS Info Brief. CGIAR Research Program on Climate Change, Agriculture and Food Security (CAAFS). Copenhagen (Denmark). www.ccafs.cgiar.org and <https://hdl.handle.net/10568/58319> 2014
- 83 Adjebeng-Danquah J, Manu-Aduening J, Gracen VE, Asante IK and Offei SK, AMMI Stability Analysis and Estimation of Genetic Parameters for Growth and Yield Components in Cassava in the Forest and Guinea Savannah Ecologies of Ghana. *International Journal of Agronomy* **2017**:e8075846 (2017). <https://doi.org/10.1155/2017/8075846>.

- 84 Amelework AB, Bairu MW, Marx R, Laing M and Venter SL, Genotype × Environment interaction and Stability Analysis of Selected Cassava Cultivars in South Africa. *Plants* **12**:e2490 (2023). <https://doi.org/10.3390/plants12132490>.
- 85 Bakare MA, Kayondo SI, Aghogho CI, Wolfe MD, Parkes EY, Kulakow P *et al.*, Exploring genotype by environment interaction on cassava yield and yield related traits using classical statistical methods. *PLoS ONE* **17**:e0268189 (2022). <https://doi.org/10.1371/journal.pone.0268189>.
- 86 Ceballos H, Hershey C, Iglesias C and Zhang X, Fifty years of a public cassava breeding program: evolution of breeding objectives, methods, and decision-making processes. *Theoretical and Applied Genetics* **134**:2335–2353 (2021). <https://doi.org/10.1007/s00122-021-03852-9>.
- 87 León R, Rosero A, García JL, Morelo J, Orozco A, Silva G *et al.*, Multi-Trait Selection Indices for Identifying New Cassava Varieties Adapted to the Caribbean Region of Colombia. *Agronomy* **11**:e1694. <https://doi.org/10.3390/agronomy11091694>.
- 88 N'Zué B, Cissé B, Djédji BC, Kouakou AM, Dibi KEB, N'guetta APS *et al.*, Stability study of some cassava (*Manihot esculenta* Crantz) varieties relative to the harvest period in Côte d'Ivoire. *Journal of Global Agriculture and Ecology* **7**:16–24 (2017) <https://www.ikppress.org/index.php/JOGAE/article/view/2515>.
- 89 Gu B, Yao Q, Li K and Chen S, Change in physicochemical traits of cassava roots and starches associated with genotypes and environmental factors. *Starch/Stärke*, **65**:253–263 (2013). <https://doi.org/10.1002/star.201200028>.
- 90 Thiele G, Dufour D, Vernier P, Mwanga ROM, Parker M, Schulte Geldermann E *et al.*, Review of varietal change in roots, tubers and bananas: consumer preferences and other drivers of adoption and implications for breeding. *In. J Food Sci Technol* **56**:1076–1092 (2021). <https://doi.org/10.1111/jifs.14684>.