Participatory process diagnosis on pounded yam product profile in Ivory Coast

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Ethics: The activities, which led to the production of this document, were assessed and approved by the CIRAD Ethics Committee (H2020 ethics self-assessment procedure). When relevant, samples were prepared according to good hygiene and manufacturing practices. When external participants were involved in an activity, they were priorly informed about the objective of the activity and explained that their participation was entirely voluntary, that they could stop the interview at any point and that their responses would be anonymous and securely stored by the research team for research purposes.

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Final validation by	
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ABSTRACT

This report is part of the RTBbreeding outputs collected through a participatory processing preparation. The outline of this activity is to i) describe the different steps of the preparation, and the key processing unit operations in the quality of intermediate and pounded yam products, ii) identify the quality characteristics of yam (as raw material) and pounded yam (as end product). This report aims to provide information on quality traits of raw yam, pounded yam processing steps and final pounded yam from ten varieties.

Key Words: participatory, processing, pounded yam, quality.

1 METHODOLOGY

1.1 Study area

This study was carried out in the Bingerville CNRA's station in Abidjan (Ivory Coast – Figure 1).

Figure 1: CNRA's stations involved – Ivory Coast

1.2 Raw material

Ten (10) yam varieties with contrasting characteristics were obtained from the experimental field of the Bouaké CNRA station in Ivory Coast (Figure 2). These varieties were selected in collaboration with CNRA's breeders within their yam collection. These varieties were part of the complex D. rotundata-cayennensis, and D. alata as follow:

- 4 rotundata varieties: Kponan, Krenglé, TDR 00/00380 and CIVCDR092
- 6 alata varieties: MA01-Florido, Taba #1, Taba #2, Florido, Soglan and C18

  They were harvested after nine (9) months of plantation and stored at ambient temperature before use for this study during:
  - one (1) month for the 6 following varieties: Kponan, Krenglé, MA01-Florido, CIVCDR092 and Taba#1
  - four (4) months for the 4 following varieties: Soglan, Taba#2, Florido and C18.

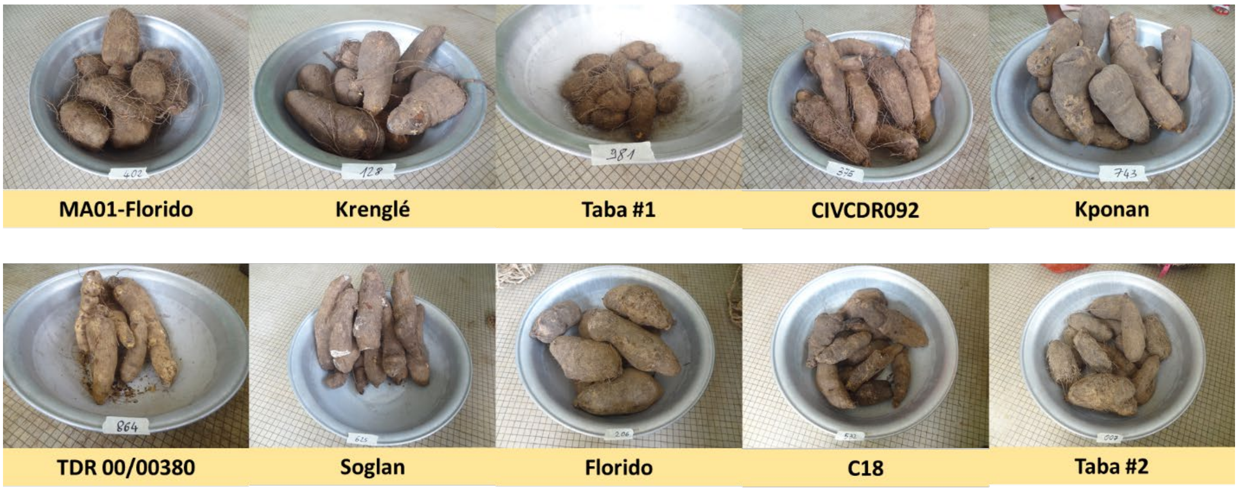

Figure 2: Overview of the variability (phenotype) of the 10 varieties used (Photo A. Bouniol)

1.3 Pounded yam processing

The ten yam varieties were coded with a random three-digit number. Five skilled workwomen processors were recruited to prepare pounded yam and then, to evaluate quality characteristics of each product along the process (at each step). Yam varieties were presented to each processor in random order. Each processor received at least one tuber of each variety, which weighed between 1.0 and 2 kg. The cooking was carried out (by usual practice of each processor) variety after variety consecutively in the random order previously obtained. During the preparation, the following data were collected by participatory approach:

- Raw Yam characteristics related to morphological aspects of tuber and boiled yam pieces (weight, length, circumference by measuring etc.)
- Unit operations of boiled yam preparation and some key technical data of each unit operation (mass balance, duration, temperature etc.)
- Quality characteristics of yam at each step of preparation into boiled yam (dry matter content); textural characterisation according LSF protocol from each sample and each variety has also been done. Nevertheless, this work contributes, as a comparative protocol, to the building of the Kieffer Dough Extensibility standard operational procedure that has been since developed. LSF results have thus been considered as non-discriminants between genotypes, so results won't be present in this report.

2 RESULTS

2.1 Yam tuber characteristics

2.1.1 Variability in the weight of tubers and shape characteristics (length and circumference)

The average weight of yam tuber from varieties varied between 261.2 and 1814.2 g (range of 0.137 to 3.590 Kg). The average length of yam tuber varied between14.3 and 43.0 cm (range of 10 to 54.2 cm). The average of the maximum circumference of yam tuber varied between 19.3 to 35.3 cm (range of 15.0 to 51.0 cm); see figure 3 below.

Except for the Taba #1 variety, no significant difference could be observed I terms of weight and length. This variety, Taba #1, presented such characteristics probably due to delayed development at field level.

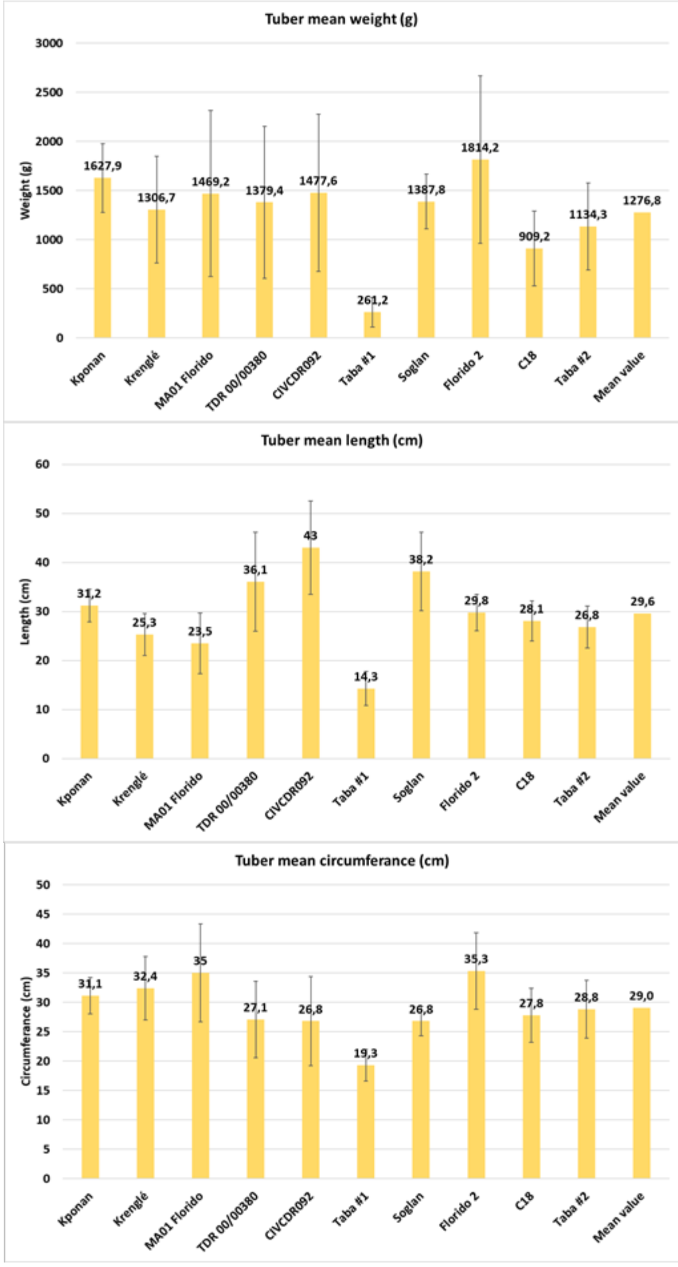

Figure 3: Physiological characteristics of assessed varieties

2.1.2 Variance in dry matter content of raw yam

The dry matter content of yam tubers ranged between 27.3 and 46.4%. Figure 4 allowed to observe that 2 groups can be defined:

- A group of 3 varieties (*Taba #1, Kponan and Taba#2*) with high dry matter content above 39.6%
- A second group gathering the other 7 varieties (*MA01 Florido, Krenglé, CIVCDR092, TDR 00/00380, Soglan, C18 and Florido*) with dry matter content comprised between 27.3 and 34.4%.

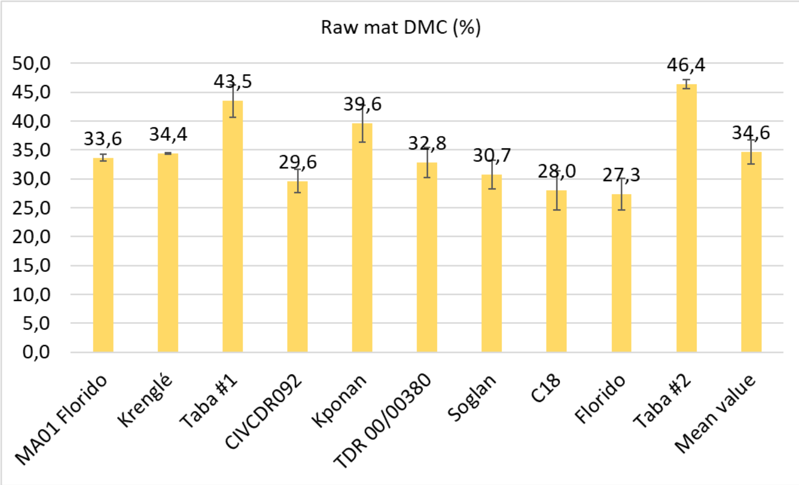

Figure 4: Physiological characteristics of assessed varieties

2.2 Pounded yam process description

The main unit operations of pounded yam productions were the peeling, washing, cutting, cooking and pounding. Peeling unit operation is carried out manually using simple kitchen knives. This operation is important because it allows processors to get a more precise idea of the quality of the yam and thus to make decisions for the rest of the process: definition of the size of the pieces of yam to cook (cf below), the quantity ratio of water and yam to cook as well as the cooking time (these last 2 parameters being linked).

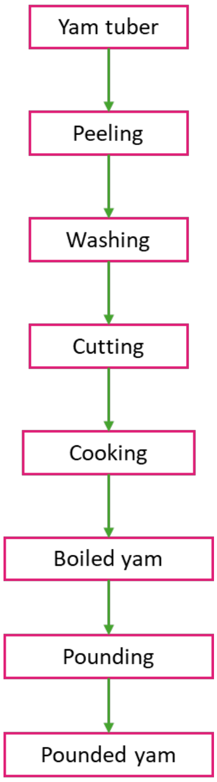

Figure 5: Flow diagram of pounded yam process

2.2.1 Peeling

Peeling unit operation was characterized by the processing yield (%w.b) and productivity (kg/h/processor). The peeling yield varied from 60.1 to 82.3% (w.b), with no significant difference between the 10 varieties (Figure 6).

The productivity varied from 23.9 to 70.8 kg/h/operator, with a mean value of 52.6 kg/h/operator. Except for the variety *Taba #1,* no significant differences were found between yam varieties (Figure 7). The figure 8 allowed to observed that the small size of *Taba #1* tuber impact negatively the productivity. It can be considered that a minimum tuber size of 900g could recommended in order to maintain a correct productivity and to reduce the drudgery of this manual unit operation.

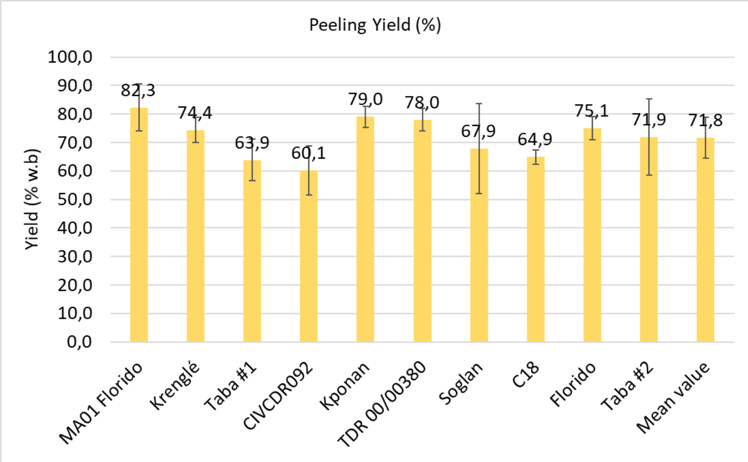

Figure 6: Peeling yield (% w.b) according varieties

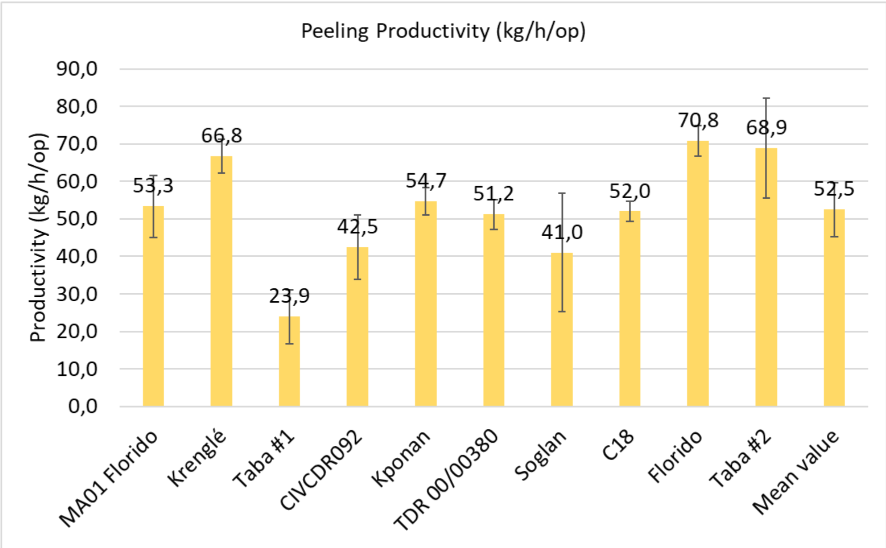

Figure 7: Peeling productivity (kg/h/op) according varieties

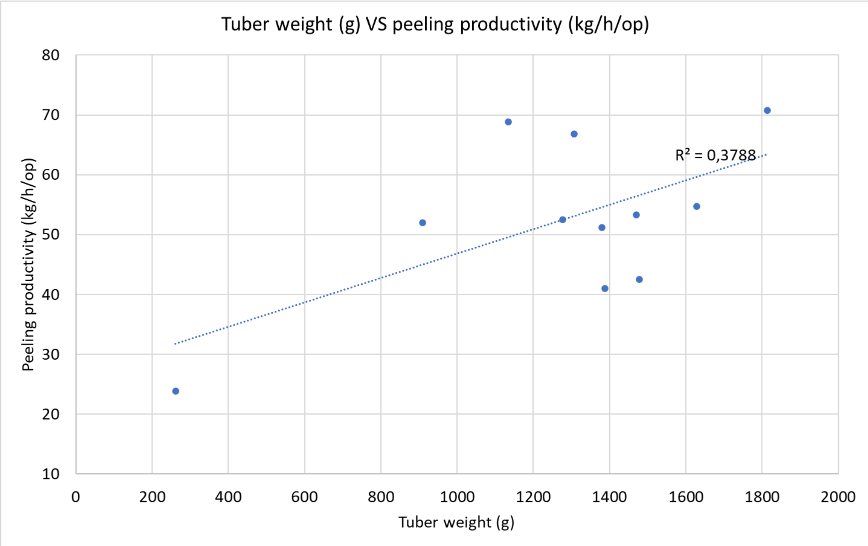

Figure 8: Tuber weight (g) VS Peeling productivity (kg/h/op)

2.2.2 Washing

This unit operation is very fast probably due to the low quantity processed (+/- 1.5 kg/operator); so, no data were collected. Nevertheless, it should be noted that the washing step of peeled yam is very carefully carried out to avoid the presence of organic and/or inorganic matters. In the case of the processing of a large quantity, processors store the peeled yam in the water until the end of the peeling operation, in order to avoid any blackening phenomenon due to oxidation.

2.2.3 Slicing/Cutting

Cutting operation was characterised by the average weigh of the yam pieces (g) and the productivity (kg/h/operator). The average weigh of a boiled yam pieces varied between 36.1 to 63.2 g (Table 1 – Annex).

A tentative of correlation between yam piece size and dry matter content of the raw material allowed to observe a trend indicating that the processors adapt the piece size according their appreciation of the dry matter content of the tuber. This point is confirmed by explanations of processors that indicate they are modulate the yam piece size according the "starch content", that they define according their own experiences/skills. Thus, in order to avoid any risk of heterogeneity within yam piece size during the cooking operation, they adapt yam piece size. They have also indicated that the shape of the yam pieces can be adapted in the same way, by cutting yam in order to obtain parallelepiped shape rather than cubic shape (a way to increase contact surface with cooking water).

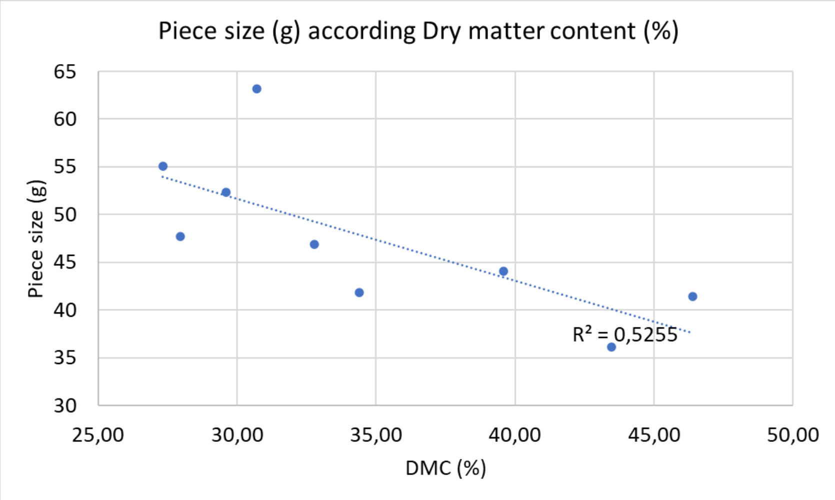

Figure 9: Physiological characteristics of assessed varieties

Concerning productivity, a tentative of correlation show a trend indicating that the productivity decreases with high dry matter content. These first data should be consolidated in order to better evaluate the drudgery of this manual operation.

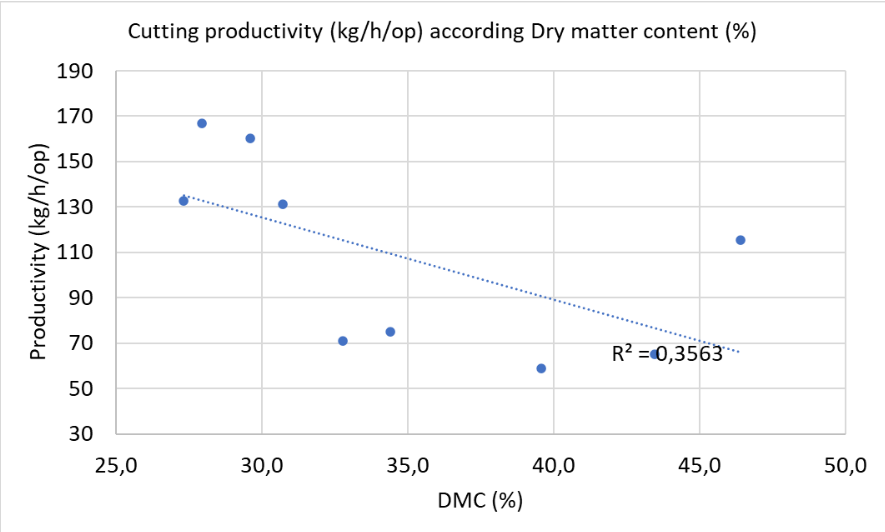

Figure 10: Cutting productivity (kg/h/op) according dry matter content (%)

2.2.4 Cooking

In the water-cooking system, processor places peeled yam pieces into a pot while cooking and add a quantity of water according their appreciation of the quality of the flesh quality and the necessary duration of cooking unit operation.

The following parameters were measured during cooking: ratio water/yam, [Quantity of water introduced in the system (Qw) / Quantity of peeled yam pieces (Qy)], duration and the yield. This ratio [Qw/Qy] varied from 0.65 to 1.69 (Figure 11).

Ratio [Quantity of water introduces in the system (Qw) / Quantity of peeled yam pieces (Qy)]

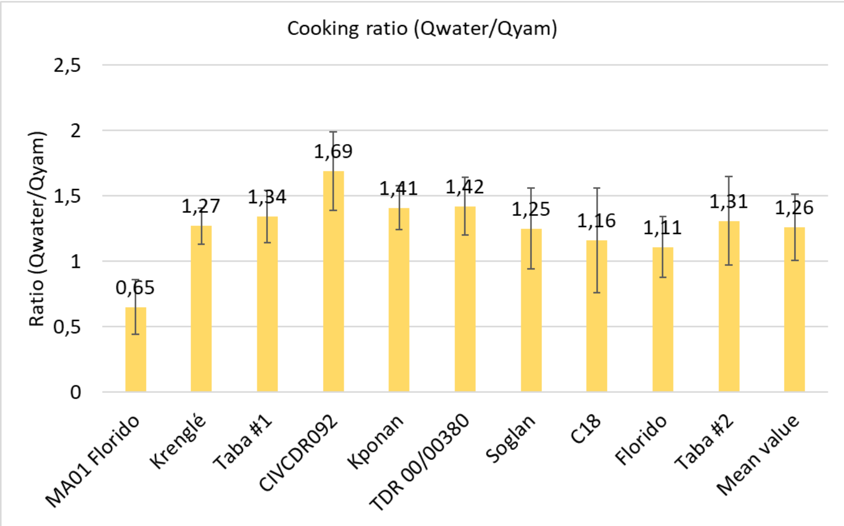

Figure 11: Ratio [Q.water/Q.yam] during cooking unit operation

In the steam-cooking mode, the processor provides a quantity of water in excess. In this case, the yam pieces do not contain too much water and are not too sticky. Conversely, to avoid this pitfall during cooking by immersion in water, the processors add the amount of water needed to cook the yam pieces, avoiding an excess of water, otherwise the yam pieces will absorb too much water and may become sticky, which is a criterion for consumers to reject the end-product.

According to processors, the cooking operation by immersion in water is the determining step to obtain a high-quality boiled yam. This step requires a highest level of expertise and know-how. In the case of steam cooking, this is not critical step. This last cooking mode significantly reduces the risk to obtain product with too much water, sticky or pasty cooked yam.

Cooking time

The cooking time is defined from the beginning of the fire until the end of cooking.

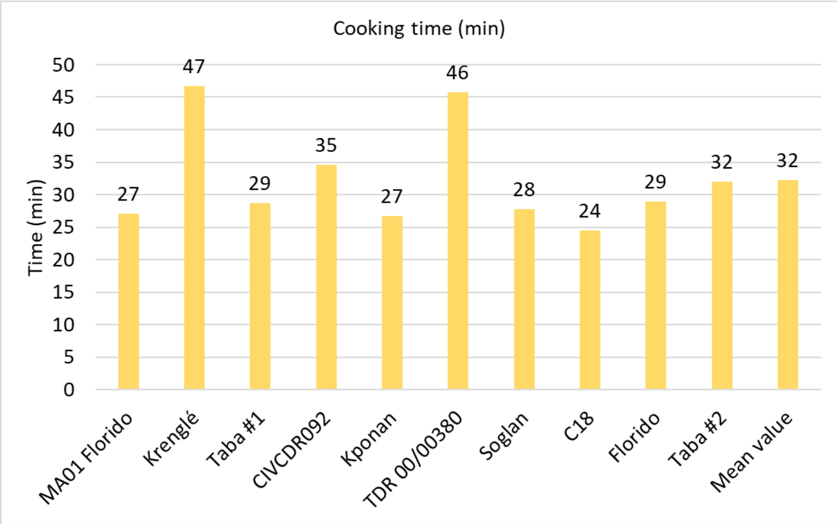

Figure 12: Cooking time (min) according varieties

The cooking duration varies from 24 to 47 min (Figure 12). The processors revealed that, according their appreciation of the raw material quality, the cooking time can be modulate in order to control the quantity of water absorbed by yam pieces. This appreciation does not only take into account dry matter content of the tuber because no correlation between dry matter content and cooking time appears.

Evaluation of the end of cooking (cooking time)

The processors used different techniques to identify the end of cooking:

- The use of fork to monitor sporadically the softness of yam pieces. The easy to reach the heart of yam piece using a fork is referred to the end of cooking.

- The viscosity of the residual cooking water is also an indicator of the degree of cooking. At the end of cooking, the residual water is supposed to be slightly viscous.

- The stickiness of yam pieces is evaluated by touching it with the back of a fork.

2.2.5 Pounding

Following cooking step processors proceed to the pounding unit operation using a traditional wood mortar and pestle. Processors indicated that this operation includes 3 main sub-steps:

- Sub-step 1: step aimed at crushing the cooked yam pieces without adding water in order to obtain a sort of yam puree; this step combines i) low-intensity pestle strokes with the uses both the pestle and a large surface of the mortar in order to increase the contact surface, which generates a mechanical shearing action to best deconstruct the matrix of the cooked yam pieces, and ii) low intensity pestle strokes that involves both the pestle and a small surface area of the mortar in order to exert a mechanical impact action on the product to finish crushing the hardest pieces of cooked yam and begin to burst the cells to release the gelatinized starch

- Sub-step 2: step aimed at pounding the crushed cooked yam with small regular additions of water in order to obtain a final texture of the product that is stretchable, sufficiently firm and with limited stickiness; this step requires higher-intensity pestle strokes than the previous one, and involves both the pestle and a small surface area of the mortar in order to exert a mechanical impact action intended to burst the cell walls of the matrix and release the gelatinized starch.
- Sub-step 3: once the correct texture has been obtained, a short step of shaping the dough is carried out by the processors using their hands in the mortar and allowing a ball of pounded yam to be obtained.

The following parameters were measured during pounding unit operation: time, quantity of water added and a description of the different pounding sub-steps through the number of pestle strokes per unit of time obtained through video analysis.

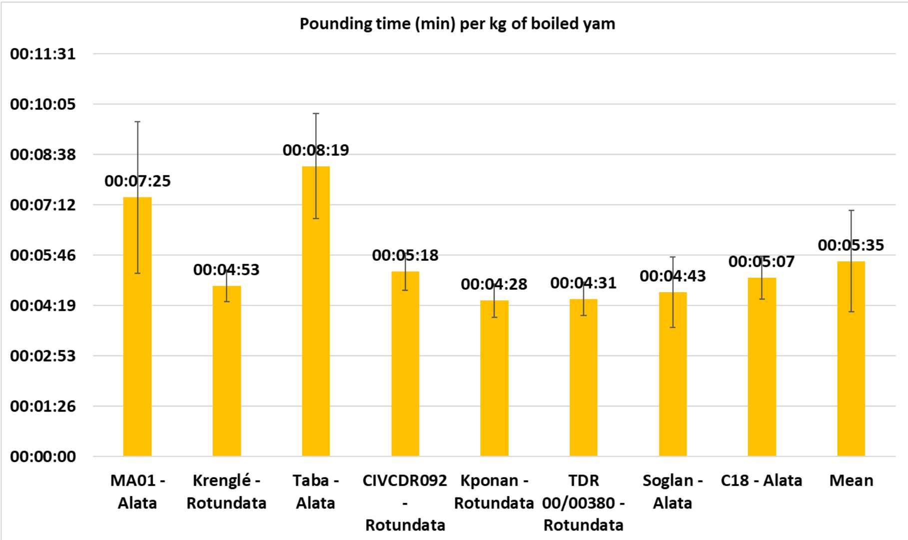

Figure 13: Pounding time (min) per kg of boiled yam according varieties

The total pounding duration per kg of boiled yam to be processed varies from 4min31 to 8min19 (Figure 13). According figure 14 it appears a trend indicating that the higher the dry matter of the raw material, the longer the pounding time.

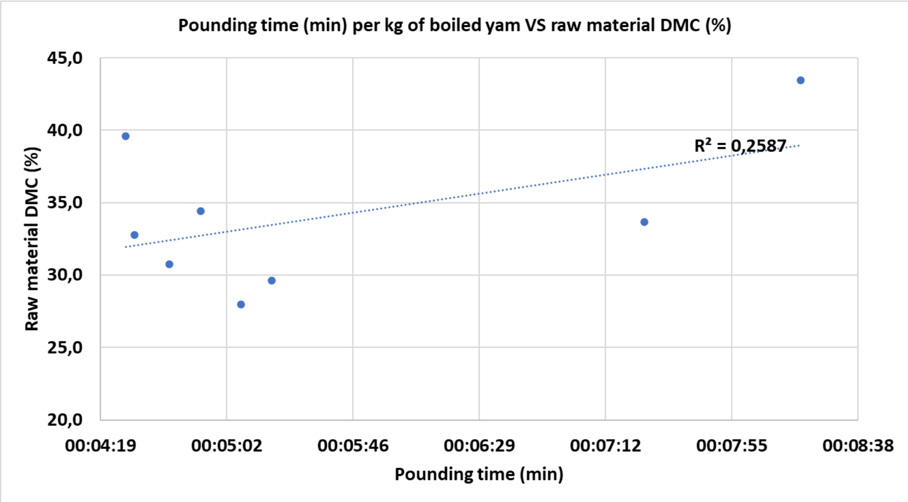

Figure 14: Pounding time (min) according raw material dry matter content (%)

In the same way figure 15 allowed to observed that the higher the dry matter, the higher the quantity of water added.

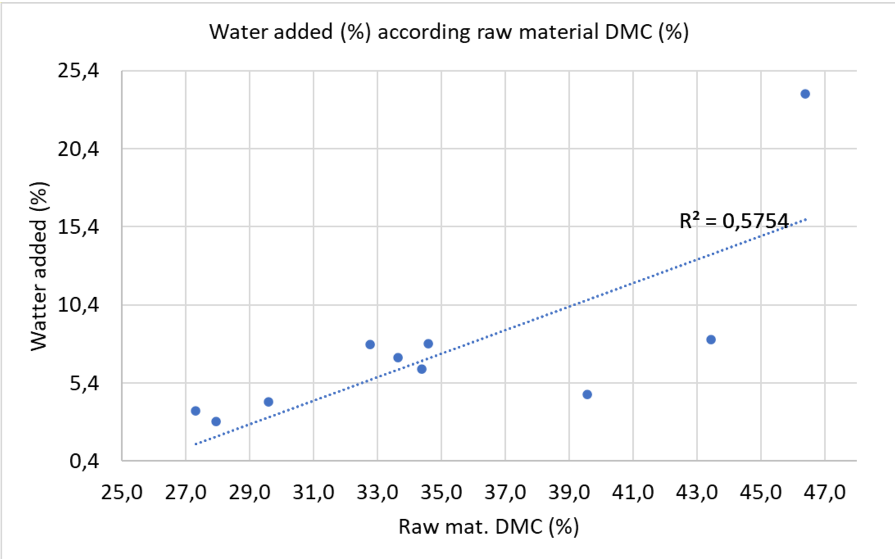

Figure 15: Percentage of added water during pounding according raw material dry matter content (%)

Regarding each of the pounding sub-stages (Figure 16), 3 types of behaviors appear depending on the varieties:

- varieties for which each of the 2 sub-stages requires the same time: *MA01 – Alata, Kренglé – Rotundata, CIVCDR092 – Rotundata, Kponan – Rotundata* and *TDR 00/00380*

- varieties requiring a longer time for the first sub-step: *Soglan – Alata* and *C18 - Alata*

- variety requiring a longer time for the second sub-step: *Taba - Alata*

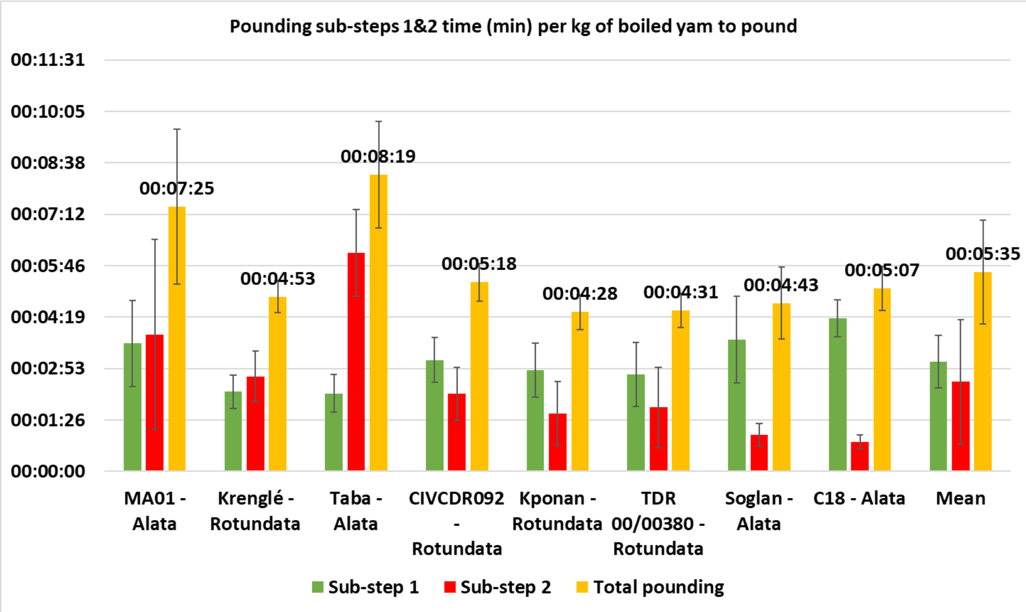

Figure 16: Time per sub-step 1 & 2 of the pounding unit operation

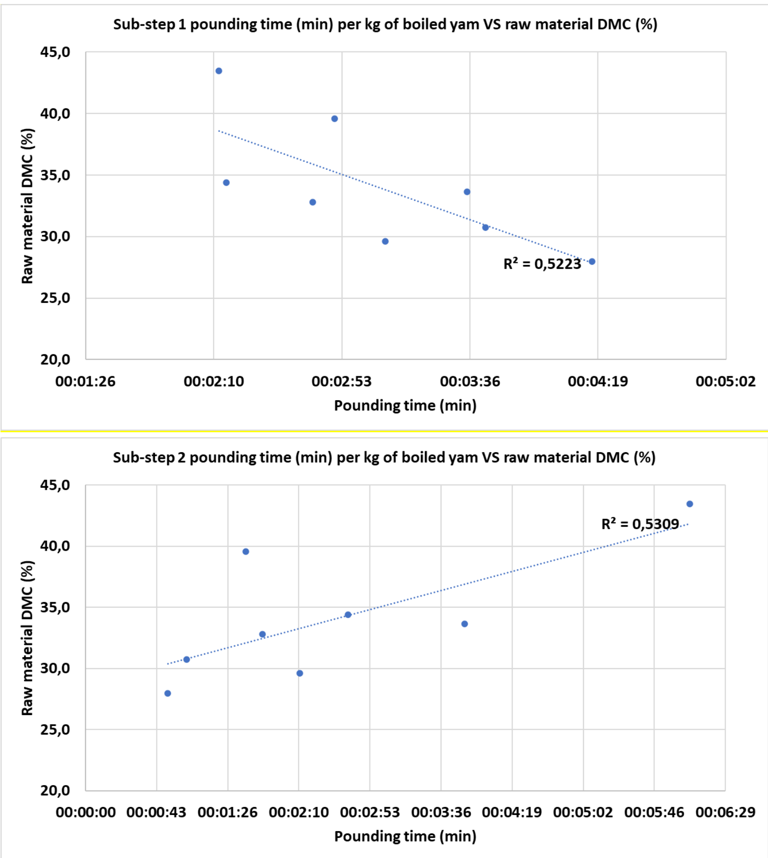

Figure 17: Pounding time per sub-step of the pounding unit operation according raw material dry matter content

Figure 17 shows a relationship between the dry matter content of the raw material and the time spent on each sub-step 1&2. It can be seen that the higher the dry matter content of the raw material, the shorter sub-step 1 and the longer sub-step 2. In other words, varieties with a high dry matter content are easier to crush during the first sub-step but require a greater crushing effort during the second sub-step with a significant mechanical impact action in order to obtain the desired final texture. This seems consistent because the higher the dry matter content, the greater the amount of gelatinized starch that must be extracted from the cells.

In order to evaluate the pounding drudgery for each of these sub-steps it can be highlighted different parameters:

- Intensity: Pounding frequency for each of these sub-steps expressed in strokes per minute
- Workload: Weight of pestle moved for each of these sub-steps expressed in weight of pestle moved (kg) per kg of boiled yam to pound.

Figure 18 allows us to observe the pounding intensity of each sub-step for each variety studied. It can be seen that on average the pounding frequency of sub-step 1 is 2 times higher than that of sub-step 2, respectively 66 strokes/min and 34 strokes/min. This can be explained by the fact that this sub-step 1 requires low intensity work force since it aims to crush the boiled yam into a puree with mechanical work combining shearing and low intensity impact. Conversely, sub-step 2, which aims to release the gelatinized starch and obtain the desired texture, requires mechanical impact work of higher intensity, which results in a reduction in the pounding frequency.

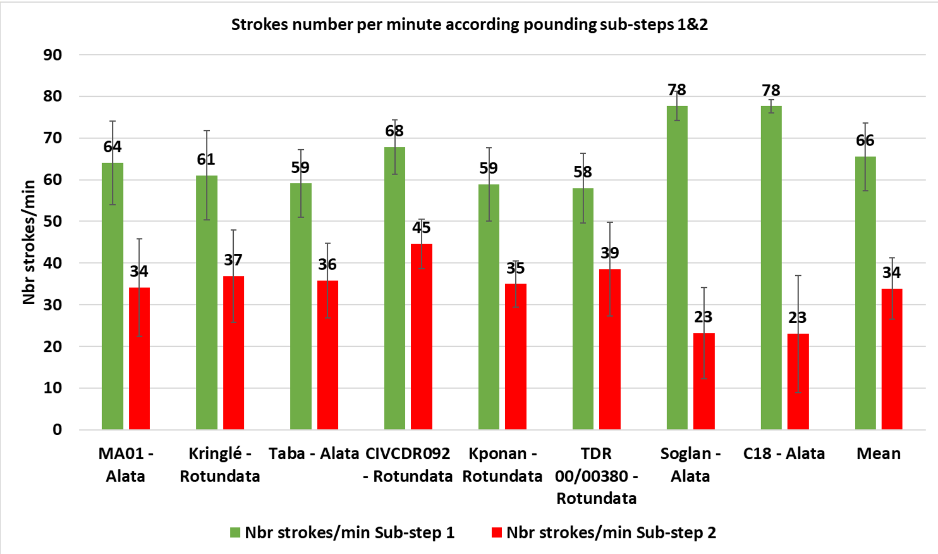

Figure 18: number of strokes per minute according pounding sub-steps 1&2

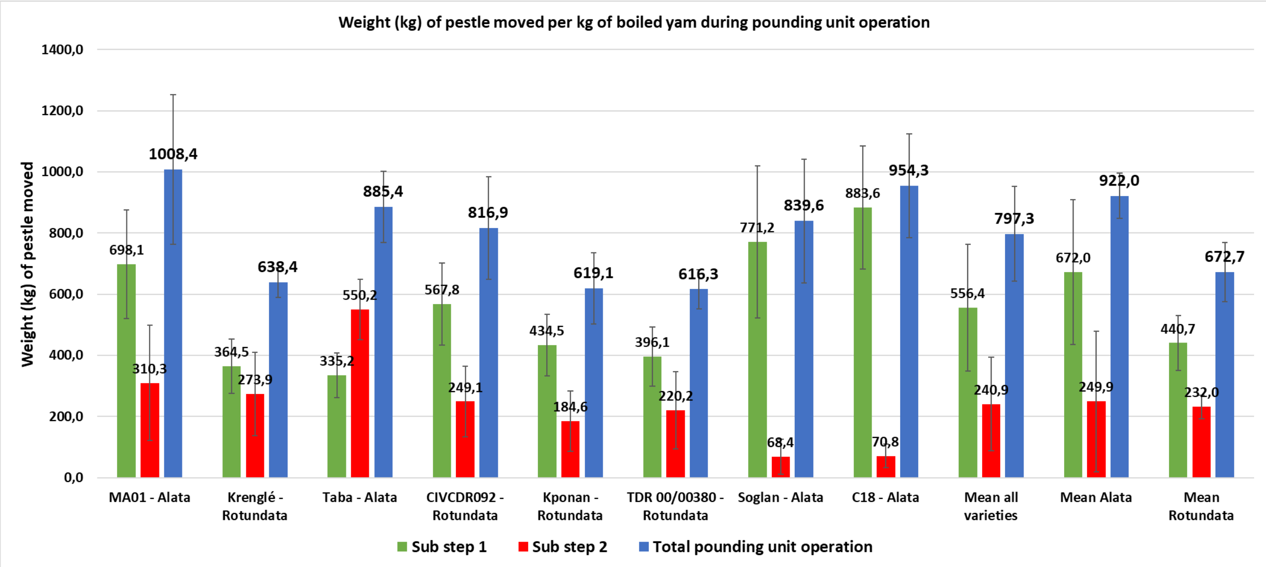

Figure 19: Weight (kg) of pestle moved per kg of boiled yam during pounding unit operation

Figure 19 shows the workload for each of the sub-steps and in total during the pounding unit operation. It can be seen that sub-step 1 is the one during which the weight of the pestle moved is greater than that moved during sub-step 2, with an average of 556.4 kg and 240.9 kg respectively. We can also observe significant differences depending on the varieties with for sub-stage 1 differences varying from 335.2 to 883.6 kg moved and for sub-stage 2 from 68.4 to 550.2 kg and in total, differences from 616.3 to 1008.4 kg of pestle moved per kg of boiled yam.

It is also worth noting a significant difference between the Alata and Rotundata type varieties with a total displaced mass of 922.0 and 672.7 kg respectively. It is interesting to note that it is sub-step 1 that requires the processors to move the pestle more than sub-step 2. We can assume that the cooking behavior of the Alata does not allow the yam matrix to be sufficiently deconstructed, which will require more shearing work for these varieties in order to obtain the yam in the form of puree. In other words, the processors compensate for the poor cooking abilities of the Alata by more shearing work during this first sub-step of the pounding unit operation.

Finally, it can be noted that the kponan variety, which is the reference variety in Ivory Coast for obtaining high-quality pounded yam, is one of the two varieties that required the lowest workload, with a total of 619.1 kg, with, compared to the TDR00/00380 variety, less impact work during sub-stage 2, which is lower.

2.3 Dry matter content and yield evolution during processing

Dry matter content evolution

The end product dry matter content varied between 25.4% and 34.9% (Figure 20), with significant differences only for the Florido variety which is also the lowest dry matter content as raw material

(25.4%). The mean value of end products dry matter content is 31.0% with a standard deviation of 3.1% while the raw material mean value dry matter content is 34.6% with a standard deviation of 6.5%.

These results indicate clearly that processors, in order to obtain the right end product quality, drive the process through the control of the dry matter content. Thus, for raw materials with high dry matter content, the cooking step allows to reduce significantly the dry matter content. During cooking step according varieties characteristics and properties of the matrix, the yam pieces absorb most of the water. In order to master the absorption of water, processors adjust the ratio of water and yam pieces to be cooked (ratio [Qw/Qy]), the size and shape of the yam pieces and the cooking duration. During pounding step, the three high dry matter content varieties (Taba#1, Kponan and Taba#2) need a complement of water addition, in order to reach the targeted end product dry matter content.

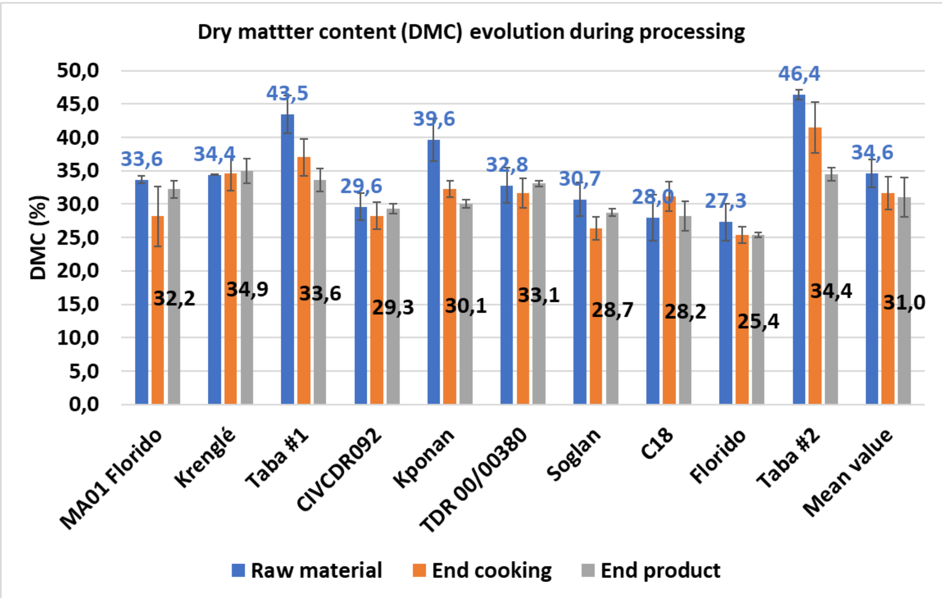

Figure 20: Dry matter content (%) evolution during processing

Evolution and global processing yield

The global processing yield of the pounded yam varied from 60.4 to 105.1 % w.b (Figure 21) with an average among varieties of 75.1%.

The global yield of pounded yam process is driven by the peeling ability of varieties and also by their ability to intake water during cooking step. The pounded unit operation doesn't impact significantly the global yield which is consistent regarding the small quantities of water added during this step.

Thus, varieties with a low yield at peeling level are also those with a low global processing yield. Even if these varieties have a good capacity to intake water under the processor's adjustments during processing, the global yield cannot be compensated (e.g CIVCDR092, Taba#1 and C18).

The variety *MA01 Florido* has a behaviour clearly very different from others. Indeed, its yield is finally positive which can be explain through a better yield at peeling level (the easiness of peeling of this variety could be linked to his shape: short variety with a great circumference) and a very good ability to absorb water during cooking step. Regarding its raw material dry matter content that is average compared to the others (33%), its relatively short cooking time (27min) and the few quantities of water added during cooking step (ratio [Qw/Qy] = 0.65), this global yield ability seems also linked to its very specificity properties of the matrix compared to other varieties.

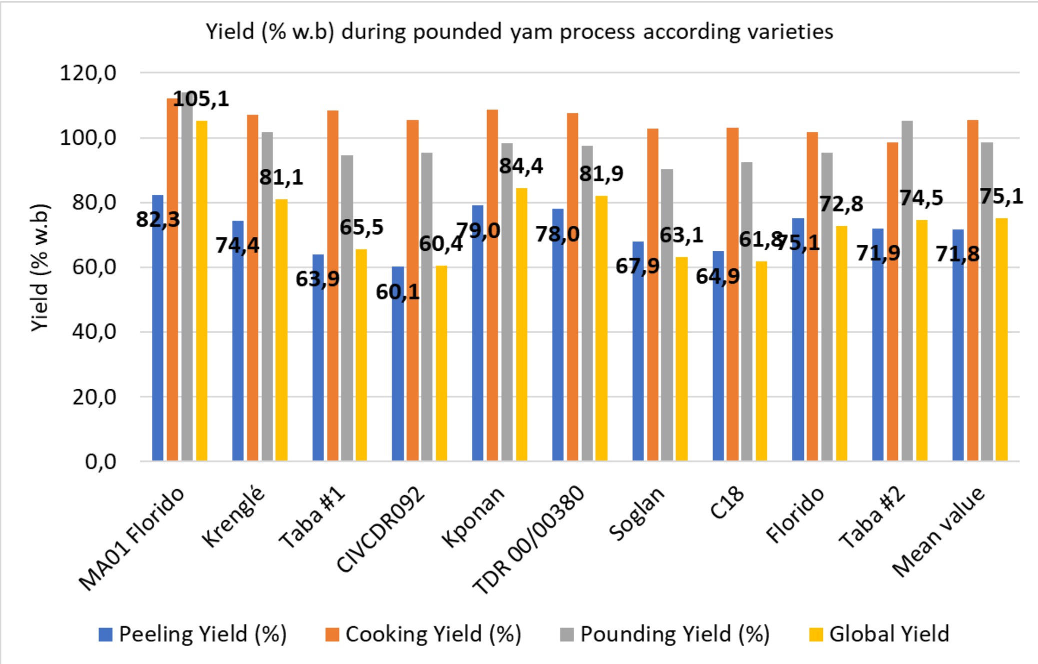

Figure 21: Evolution and global processing yield (% w.b)

3 SYNTHESIS AND CONCLUSION

The findings from the participatory processing with well skilled processors were summarized in table 1. Concerning **the yam tuber choice,** the external morphologic observation of the phenotype of tubers together with flesh characteristics can help to predict the final quality of pounded yam.

With regard to the **peeling unit operation**, two main observations should be noted:

- In terms of the final quality of the product, it is important that the peeled yam do not change colour.
- In terms of productivity, it is important to identify tubers with a shape facilitating their peeling, ie a not too long and with big circumference.

Regarding the **cooking unit operation**, the data collected revealed that:

- For the control of the [Qw/Qy] ratio is important for processors in order to control the water intake of yam pieces.
- The definition of cooking time is done in different ways. It's sometimes evaluated by the ability of fork to pick the boiled yam or by the viscosity of cooking water. The definition of the cooking duration is a parameter that allowed processors to control the yam pieces water intake.

Concerning the **pounding unit operation**, the data collected allowed to:

- Describe the 3 main sub-steps carried out by processors: crushing the cooked yam pieces, pounding crushed yam and shaping final end-product.
- Measure the pounding intensity during each step through the frequencies, expressed in strokes per minute, and the type of pestle movement (crushing vs impact), and observe differences of behaviors according varieties.

This assessment needs to be completed in the next RTBbreeding phase in order to test new sets of varieties. This will allow to consolidate these first findings and also to conduct deeper analysis on the pounding unit operation drudgery integrating qualitative and quantitative data. In the same way, the other studies conducted within this RTBbreeding project on the development of an extensibility measurement of end-products through the Kieffer Dough SOP will allow in the next phase to link process ability of varieties and end product quality.

With regard to the teams associated to this study, it is important to remember that the initial choice of the variety set is decisive for obtaining good results. The choice made here proved to be relevant by providing excellent variability in tuber characteristics and behaviours. We can underline here the interest to work in close collaboration with breeders involved in breeding programs (CNRA).

Appendix

Table 1: Synthesis of main quantitative data collected

	Raw material characteristics				Processing quantitative data								
					Peeling unit operation		Cutting unit operation		Cooking unit operation			End-products	Global process yield
Varieties	Weight (g)	Circumference (cm)	Length (cm)	Dry matter (%)	Yield (% w.b)	Productivity (kg/h/op)	Piece size (g)	Productivity (kg/h/op)	Ratio [Qw/Qy]	Cooking time (min)	Yield (% w.b)	Dry matter (%)	Yield (% w.b)
Kponan	1627,9	31,1	31,2	33,6	82,3	53,3	77,7	261,5	0,65	27	112,2	32,2	105,1
Krenglé	1306,7	32,4	25,3	34,4	74,4	66,8	41,8	75,0	1,27	47	107,1	34,9	81,1
MA01	1469,2	35,0	23,5	43,5	63,9	23,9	36,1	65,2	1,34	29	108,4	33,6	65,5
TDR 00/00380	1379,4	27,1	36,1	29,6	60,1	42,5	52,3	160,3	1,69	35	105,3	29,3	60,4
CIVCDR092	1477,6	26,8	43,0	39,6	79,0	54,7	44,1	58,8	1,41	27	108,7	30,1	84,4
Taba#1	261,2	19,3	14,3	32,8	78,0	51,2	46,9	71,1	1,42	46	107,7	33,1	81,9
Soglan	1387,8	26,8	38,2	30,7	67,9	41,0	63,2	131,2	1,25	28	102,9	28,7	63,1
C18	1814,2	35,3	29,8	28,0	64,9	52,0	47,7	166,9	1,16	24	103,0	28,2	61,8
Florido	909,2	27,8	28,1	27,3	75,1	70,8	55,1	132,8	1,11	29	101,7	25,4	72,8
Taba#2	1134,3	28,8	26,8	46,4	71,9	68,9	41,4	115,3	1,31	32	98,4	34,4	74,5
Mean Value	*1276,8*	*29,0*	*29,6*	*34,6*	*71,8*	*52,5*	*50,6*	*123,8*	*1,3*	*32*	*105,5*	*31,0*	*75,1*