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## Socio-economic analysis of processing *Pachyrhizus erosus* (L.) Urb. tubers into gari in Benin

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### ABSTRACT

*Pachyrhizus erosus* is a legume plant that produces tubers rich in nutrients (protein, iron, zinc, etc.) that are used in various kinds of food processing. The objective of this study was to analyse producers' and processors' perception regarding processing *P. erosus* tubers into gari in on-farm conditions and its financial profitability. Kendall's concordance test was used to classify perceptions, and cost analysis was used to analyse the profitability of the product. The results showed that the mixed gari with 50% *P. erosus* was highly appreciated because of its greater fermentation ability than cassava gari. The price at which processors broke even was FCFA 340 (~ \$ 0.57) per kilogram and the sensitivity analysis revealed that when the yield of *P. erosus*-based gari increased by 30%, processors made a profit of 25% of the investment cost. So, processing of *P. erosus* is beneficial for the processors and consumers appreciate it more than cassava gari. The Benin Government needs to promote this crop in order to feed its population.

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**Keywords:** Roots and tubers, technical performance, malnutrition, Benin, population, food quality.

### INTRODUCTION

Protein-energy malnutrition and food insecurity are among the most serious problems facing tropical African countries (Bhat and Karim, 2009). It has been estimated that 800 million malnourished people live in

some of the least developed countries (Myers, 2002). Underutilization of most of the crops found in this part of the world contributes to this problem. These crops include legumes, root crops and cereals – those that have been investigated have been found to be

inexpensive and possess good nutritive value for the solution of protein-energy malnutrition (Bhat and Karim, 2009). The potential of roots and tubers for addressing the food insecurity situation in West African countries comes second only to cereals, but the utilization of these crops remains underexploited (Aye, 2013). Rather, tropical root crops such as cassava (*Manihot esculenta* Cranz, *Euphorbiaceae*), yams (*Dioscorea* L. spp., *Dioscoreaceae*), sweet potato (*Ipomoea batatas* (L.) Lam., *Convolvulaceae*) and cocoyams (*Colocasia esculenta* (L.) Schott and *Xanthosoma* Schott spp., *Araceae*) are widely grown and consumed in the tropics. All these crops are characterized by high levels of carbohydrates (starch and/or sugars) with low levels of protein. Cassava is one of the most widely consumed crops in Africa; its most popular processed product, gari, is consumed by nearly 300 million people in West Africa (Oseni, 2012). Like its raw material, a major drawback of gari as food is its low protein, and minimal essential mineral and vitamin content, a deficit in essential amino acids and resulting poor protein quality (Sanni et al., 2002; Afoakwa et al., 2010).

Benin's economy largely depends on agriculture and almost 58% of Benin's labour force works in agriculture – for a large proportion; it is their primary activity (Singbo, 2012). Roots and tubers represent one of the major crop groups grown for self-consumption. These crops were found to be particularly important in sustainable poverty control and improvement of rural households' living conditions. Thus, roots and tubers play a very important role in achieving food security. Almost 60% of the total cultivated area in Benin is used for roots and tubers. Cassava ranks first with 34% of the cultivated area and 54% of the national roots and tubers production (Djoï and Monhouanou, 2003). Thus, the cassava sector with its multiple derivatives (gari, lafun, etc.) offers an interesting frame for the introduction of *Pachyrhizus* spp. in Benin (Hibon et al., 2011).

American yam bean (*Pachyrhizus* spp.) are storage root-forming legumes of which three cultivated species are distinguished: *P. ahipa* (Wedd.) Parodi, *P. erosus* and *P. tuberosus* (Lam.) Spreng. The plants produce heavy storage roots and large seeds, but only the roots are consumed because of the toxic compound, rotenone, contained in seeds (Kisambira et al., 2014). In the frame of the yam bean project (CIP Project N° 03-13: "Enhancing the nutrient-rich Yam Bean (*Pachyrhizus* spp.) to improve food quality and availability and sustainability of farming systems in Central- and West Africa-AHIPA"), *Pachyrhizus* spp. have been introduced into Africa and are currently disseminated in five West and Central African countries, including Benin, in order to investigate its potential for food production (Heider et al., 2011).

*Pachyrhizus erosus* and its closely related species *P. ahipa* and *P. tuberosus* produce tubers containing greater amounts of crude proteins than cassava, reaching levels of 11–18% (Kale, 2006; Zanklan et al., 2007) and iron up to 130 mg.kg<sup>-1</sup> (Kale, 2006). The physicochemical characteristics of proteins and starch from *Pachyrhizus* sp. have been investigated for potential agro-industrial uses (Forsyth and Shewry, 2002; Forsyth et al., 2002; López et al., 2010). Its exceptional agronomic and nutritional properties suggest that it could be adopted by consumers as well as by farming households, due to the mitigation of potential risks (Hibon et al., 2011). According to Hibon et al. (2011), *P. erosus* tubers can be used to produce 'gari' and 'flour'. It therefore has great potential to improve the staple food of rural populations in Benin, both quantitatively and qualitatively. It has been introduced in Benin with the purpose of processing it into gari and thereby meeting the food needs of the population. Gari from *P. erosus* contains five times more proteins than gari from cassava and, most likely, *P. erosus* gari has higher iron and zinc concentrations (Zanklan et al., 2007). According to Padonou

et al. (2013), gari from *P. erosus* contains 4.77% proteins, 1.74% ash and 0.35% lipids.

In previous studies, Zanklan et al. (2007), Wassens (2011) and Padonou et al. (2013) demonstrated the suitability of *Pachyrhizus* spp. roots for gari production in West Africa. However, there is a lack of economic analysis of *P. erosus* processing and its perception among consumers. The present study aimed at analysing the profitability of *P. erosus* processing and evaluating the perception of processors and consumers of gari from *P. erosus* in an area of major gari consumption in Benin.

## MATERIALS AND METHODS

### Study zone

The study was carried out in the following departments: Ouémé, Plateau, Atlantique, Zou and Collines, located in the southern and central part of Benin (Figure 1). It covered one or two village(s) in each department, in which roots and tubers are traditional and common crops and cassava is often processed into gari. The villages were: Wovimè in Ouémé, Mowodani in Plateau, Bossouvi in Atlantique, Togbadji and Hounvi in Zou and Gbanlin in Collines.

### Materials

The material comprised tubers from two *P. erosus* accessions (EC-533 or CIP 209018 and EC-KEW or CIP 209019) and cassava roots. *P. erosus* tubers were provided by farmers who tried in each village the cultivation of this new crop while cassava roots were either also harvested from their farm or purchased in local market.

### Data

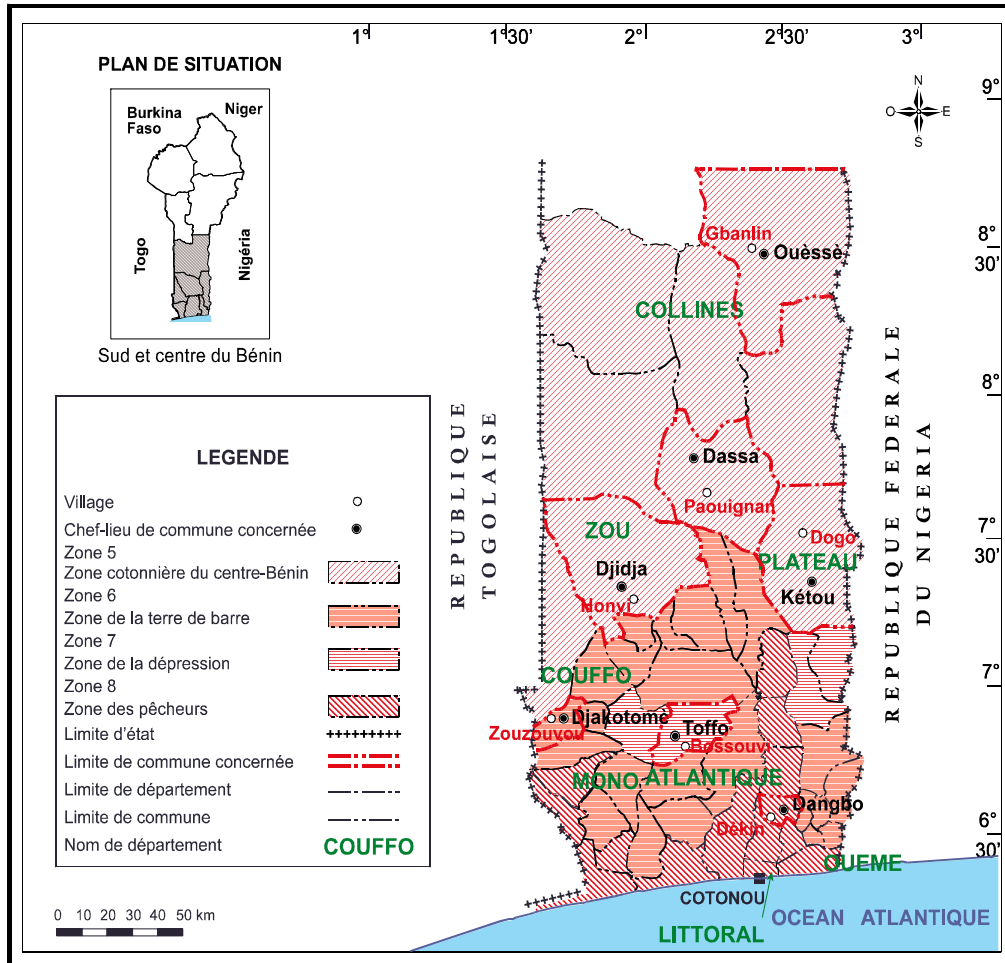
Since women are the major actors in gari production, the experimental units consisted of women's organizations in villages where experimental *P. erosus* cultivation occurred.

The experiment was designed following the on-station trials approach reported by Padonou et al. (2013). This involved producing gari from 100% cassava (in all the sites), gari from 50% cassava + 50% *P. erosus* (in all the sites), and gari from 75% cassava + 25% *P. erosus* (Affamè and Bossouvi villages only). The processing method, and the operations and equipment used were the same in all villages.

Both conventional survey method and rural participatory appraisal (PRA) were used. The conventional survey involved the use of a structured questionnaire with more emphasis on quantitative information on cost and benefits of *P. erosus* processing options. With the PRA, a semi-structured questionnaire-cum-checklist addressing the issues raised in the objectives was used to gather informal qualitative data and information in a more interactive manner (Quaye et al., 2009). The PRA involved individual interviews with key informants, focus group discussions with processors, and personal observations. The PRA generated supplementary information on the suitability of the various cassava processing options as well as group-based information to cross-check individual data on costs and benefits.

### Statistical analysis

Quantitative data were analysed using Statistical Package for Social Scientists (SPSS) version 16.0 and MS Excel. Descriptive statistics generated from SPSS was used to present results. Data on average costs, marginal cost and benefits for the various *P. erosus* processing technologies were also generated from SPSS analysis and used in Excel for benefit-cost ratio and simulation analysis. Nonparametric test of Kendall was used in SPSS to analyse processors' and consumers' perceptions of the advantages and disadvantages of processing *P. erosus* into gari and of consumption of *P. erosus* gari.



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Figure 1: Map of study area.

## RESULTS

### Analysis of constraints related to the processing of *P. erosus* into gari

Processing *P. erosus* tubers into gari in real conditions entailed the same operations required in processing cassava roots into gari. According to processors, washing and cooking were quite easy. Peeled *P. erosus* tubers were easy to wash because of their soft pulp that does not retain too much dirt. Likewise, *P. erosus*-based gari cooks like cassava-based gari and it can even be made crusty. Kendall's test results (Table 1) classified the difficulties met by women during the processing.

The value of Kendall's W was 0.456 – significant at the threshold of 5%. Thus, the major constraints were related to peeling, pressing, fermentation and breaking. Compared with cassava roots, peeling tubers was difficult and required lot of effort due to their sticky and strong skins. According to the processors from the different women organizations, pressing and grating were more difficult for *P. erosus* than for cassava. This is probably due to the fact that the grated pulp of *P. erosus* was softer and it took longer to expel water from the pulp. Fermentation duration of *P. erosus* grated pulp was relatively longer (about 1 extra hour) than cassava. Draining of *P. erosus* grated pulp,

during which fermentation takes place, was longer than that of cassava because of the greater quantity of water in the grated pulp. Finally, breaking the pulp cake of *P. erosus* was more difficult compared to that of cassava, because the fibres of *P. erosus* seemed to be more flexible and therefore not easily breakable.

#### **Perception of the quality of *P. erosus*-based gari**

Colour, granule size, aroma, texture during chewing and commercialization of 50% *P. erosus* gari were positively appreciated. According to the consumers, *P. erosus*-based gari was of very good quality: it was more fermentable than cassava gari, had the same granulometry, good flavour, and was very easy to chew and as easy to market as cassava gari, especially in the areas where fermented gari is favoured.

Criteria like taste, ability to make by products and weight of *P. erosus* gari were less well appreciated by the consumers compared to those of 100% cassava gari. The reasons were that *P. erosus* gari tasted slightly more sour than cassava gari.

#### **Yields during processing of *P. erosus* gari**

Data in Table 2 show that processing yields differed from one operational unit to another. Regarding the peeling, differences observed for processing 100 kg of cassava, 75 kg of cassava + 25 kg of *P. erosus*, and 50 kg of cassava + 50 kg of *P. erosus* were as expected because the skin of cassava roots is thicker than that of *P. erosus* tubers. Thus, peels of *P. erosus* weigh less than those of cassava. For grating, the differences were quite small and depended on the grater. With regard to pressing, the differences observed could be explained by the fact that the grated pulp of *P. erosus* contains a lot of water compared to cassava so that, after pressing, the amount of effluent obtained was heavy compared to the small quantity of pulp. Yield gaps observed for breaking and sifting operations were related to the greater quantity

of fibres contained in *P. erosus* tubers. Differences in gari yields at the end of the process were overall a result of the greater amount of water contained in *P. erosus* tubers. The yield of 100% cassava gari was higher than that of gari from 50% *P. erosus*. The ratios obtained for gari from 25% *P. erosus* were closer to those of 100% cassava gari because of the smaller quantity of *P. erosus* tubers used in the processing. Based on these results, the economic analyses focused on mixed gari with 50% *P. erosus*.

#### **Duration of the unit operations during the processing of cassava and *P. erosus* into gari**

Analysis of results showed a big difference between the durations of unit operations to produce cassava gari and *P. erosus* gari (Table 3). The operations to process *P. erosus* gari took longer than operations to process cassava gari, except for grating, breaking and toasting. The longest durations were observed for peeling and pressing. Regarding peeling, this difference could be explained by the fact that tubers of *P. erosus* were more difficult to peel because of their sticky and hard skin. Also, these tubers have a round shape that does not make peeling easy. Moreover, women had not mastered the technique of peeling *P. erosus* tubers. The long duration of washing *P. erosus* is due to the fact that *P. erosus* was a new product for processors; thus, they spend more time washing it with a lot of care because of its shape. Since the tubers of *P. erosus* contain much more water, grating them was quicker.

#### **Production cost analysis**

Cost analysis (Table 4) showed that the production cost of gari obtained from 100 kg of raw product (50% cassava, 50% *P. erosus*) was about FCFA 7916 (~ \$ 13.35). The purchase price of *P. erosus* represented 44% of the production costs. Cooking represented 12% and the purchase price of cassava represented 11% of mixed-gari production costs.

The analysis of by products (gari, peels, residue after breaking, and residue after sifting) obtained from mixing 50% *P. erosus* and 50% cassava revealed a revenue of about FCFA 1795 (~ \$ 3.02). Gari represented 77% of this revenue. So, among these by products, gari is the main product in terms of revenue obtained from processing. This shows that *P. erosus* tubers can be used in the production of gari.

The cost of producing mixed gari (50% *P. erosus*) was FCFA 340 (~ \$ 0.57) per kilogram. If a kilogram of mixed gari were to be sold at FCFA 340 (~ \$ 0.57), processors would breakeven. It seems, therefore, that a sensitivity analysis needs to be conducted to identify the selling price of mixed gari of *P. erosus* that could be suitable for consumers and also provide some profit to processors. Simulations should also be done by taking in account the yield of gari in order to analyse its impact on the make-up of the processors.

#### Economic performance

Results of labour productivity and of the gross margin are given in Table 5. These results are calculated on the basis of the cost price in order to analyse the remuneration of household labour. Analyses showed that the gross profit was FCFA 1245.51 (~ \$ 2.10) for 100 kg of the processed mixture of 50% *P. erosus* + 50% cassava. Labour productivity was FCFA 303.78 (~ \$ 0.51) per hour. Considering that a person works for eight (8) hours a day, the productivity in days was FCFA 2430.24 (~ \$ 4.10). This value is higher than wage labour, which was about FCFA 1800 (~ \$ 3.04) in the study zones. This

showed that processing *P. erosus* remunerates household labour well.

#### Sensitivity analysis

Analysis of technical performance revealed low yield of mixed gari of *P. erosus*. This can be mainly explained by the abundance of water in the tubers. Improving the yield by introducing varieties with higher dry-matter content could improve the revenue of women processors and thereby the cost price, the latter being linked to the quantity produced. The sensitivity analysis is based on the yield and the cost price from the scenarios used in order to identify the different possibilities of mixed gari of *P. erosus* production to satisfy processors and consumers. The different scenarios are:

- 1<sup>st</sup> scenario: Keep the cost price constant and change the yield
- 2<sup>nd</sup> scenario: Change the yield and the cost price.

The results given in Table 6 show the evolution of the profit in the production cost. These results showed that a yield increase up to 30% would achieve a level of profit that represents about a quarter of the production cost of gari, i.e. 25% of the cost invested in gari processing. The yield of gari corresponding to the 30% increase was 23.4 kg. At this increase rate, the cost price of mixed gari of *P. erosus* is estimated at FCFA 261.50 (~ \$ 0.44) per kg. Moreover, when the price and the yield were increased by 15%, the profit reached 25% of the invested cost, i.e. a yield level of 20.7 kg and a kilogram selling price of FCFA 391 (~ \$ 0.66).

**Table 1:** Classification of difficulties related to *P. erosus* processing.

Criteria	Average rank	Rank
Difficult peeling	1.68	1
Difficult pressing	1.85	2
Long fermentation duration	2.47	3
Difficult breaking	2.90	4
Kendall's W	0.456**	

\*\* Significant at the threshold of 5%.

**Table 2:** Average yield per unit operation during the processing of gari (kg).

Operations	Average yield		
	Pure cassava gari	Gari from 25% <i>P. erosus</i> + 75% Cassava	Gari from 50% <i>P. erosus</i> + 50% Cassava
Fresh non-peeled cassava/ <i>P. erosus</i>	100	100	100
Peeling-Washing	73	74	77
Grating	98	98	99
Pressing	74	67	44
Breaking	95	94	93
Sifting	94	92	87
<b>Cooked gari</b>	<b>23.15</b>	<b>20.95</b>	<b>14.34</b>

**Table 3:** Quantity of labor for 100 kg of raw materials (m-h)<sup>†</sup>.

Operations	Quantity of labor		
	Pure cassava gari	Gari from 25% <i>P. erosus</i> + 75% Cassava	Gari from 50% <i>P. erosus</i> + 50% Cassava
Peeling	2.94	3.55	5.40
Washing	0.23	0.38	0.55
Grating	0.20	0.18	0.13
Bagging/Pressing	1.21	2.40	3,22
Breaking	0.54	0.52	0.51
Toasting	5.65	5.29	4.25
Sifting	0.13	0.13	0.16
Total duration	10.90	12.45	14.22

<sup>†</sup> m-h= man-hour

**Table 4:** Structure of the production cost of gari from 100 kg *P. erosus* and cassava (50:50).

Items	Gari from 50% <i>P. erosus</i> + 50% Cassava		
	Amount Franc CFA	US Dollar	Share in the total production cost (%)
Purchase price of 50 kg of cassava	900	1.52	11
Purchase price of 50 kg of <i>P. erosus</i>	3,550	5.98	44
Harvesting (a)	302.21	0.51	3
Peeling (b)	266.87	0.45	3
Washing (c)	78.75	0.13	1
Water	147.07	0.25	2
Grating (d)	317.14	0.53	4
Starch extraction (e)	229.5	0.38	3
Bagging/Pressing (f)	657.70	1.11	10
Breaking (g)	117.39	0.20	1
Toasting (h)	944.99	1.60	12
firewood	373.34	0.63	5
Sifting (i)	30.96	0.05	0.4

<b>Total production costs (1)</b>	<b>7,915.92</b>	<b>13.35</b>	<b>100</b>
<b>Cost total labor = (a+b+c+d+e+f+g+h+i)</b>	<b>2,945.51</b>	<b>4.97</b>	<b>-</b>
Income from Gari (j)	1,390	2.34	0.77
Income from peels (k)	69	0.11	0.04
Income from residue after breaking (l)	165.79	0.27	0.09
Income from residue from sifting (m)	170.53	0.28	0.1
<b>Total costs derivative products (2) =(j+k+l+m)</b>	<b>1,795.32</b>	<b>3.03</b>	<b>1</b>
Production cost to be covered with gari of <i>P. erosus</i> (3)= (1)-(2)	6,120.6	10.32	
Quantity of gari in kg	18	18	
<b>Cost price (CP)</b>	<b>340</b>	<b>0.57</b>	

**Table 5:** Labor productivity and gross margin of 100 kg mixture of 50% *P. erosus* + 50% cassava.

Items	Value		
	F CFA	US Dollar	man-hour
Paid labor	1,700	2.87	-
Quantity household labor	-	-	4.1
Total cost raw materials	4,450	7.50	-
Total cost of inputs	520.41	0.877	-
Cost of factor except household labor	6,670.41	11.25	-
Gross product	7,915.92	13.35	-
Gross margin	1,245.51	2.10	-
Labor productivity (per man-hour)	303.75	0.51	-
Capital productivity (%)		1.18	

**Table 6:** Results of simulations.

Scale	0%	5%	10%	15%	20%	25%	30%
<b>1<sup>st</sup> scenario: Maintain the cost price constant and change the yield</b>							
Gross product (US \$)	13,35	13,86	14,38	14,89	15,41	15,93	16,44
Production cost (US \$)	13,35	13,35	13,35	13,35	13,35	13,35	13,35
Cost/Benefit ratio	0	25,92	12,94	8,63	6,47	5,17	4,31
Corresponding cost price (US \$)	0,57	0,54	0,52	0,49	0,47	0,45	0,44
<b>2<sup>nd</sup> scenario: Change the yield and the cost price</b>							
Gross product (US \$)	13,35	13,86	14,38	14,89	17,89	19,15	20,47
Production cost (US \$)	13,35	13,35	13,35	13,35	13,35	13,35	13,35
Cost/Benefit ratio	0	12,6	6,2	4,01	2,94	2,3	1,87



## DISCUSSION

Studies have been carried out to improve the nutrient content of gari through enrichment of cassava mash with protein and/or mineral-rich sources during the processing (Eke et al., 2008; Kolapo and Sanni, 2009). So, the processing of *P. erosus* tubers into the widely consumed gari would make the introduction of this new crop into West African cropping systems of interest. Adegbola et al. (2011) stated that roots of *P. erosus* can be used to produce 'gari' and 'bakery flour'. According to consumers, mixed gari with 50% *P. erosus* was of very good quality, i.e. more fermentable than pure cassava gari, with the same granulometry, good flavour, very easy to chew and as easy to market as cassava gari, especially in the areas where fermented gari is more popular. This confirms the results of Padonou et al. (2013) who found that mixed gari with 50% *P. erosus* had better quality than pure cassava gari. From their evaluation of the quality of *P. erosus* gari and *P. erosus* fortified gari, Padonou et al. (2013) concluded that the protein content increased by more than 30% when 50% *P. erosus* was included in the processing with cassava, and the gari was whiter in colour and panellists scored it well. The yield of 100% cassava gari was higher than that of the 50% *P. erosus*-based gari, due to the greater amount of water contained in *P. erosus* tubers. According to Grüneberg et al. (2003), Balbin et al. (2005), and Zanklan et al. (2007), with a view to improving the yield of garification, there is a need to evaluate the potential of making gari from yam bean Chuin type (*P. tuberosus*), which has high dry-matter content, combined with high protein content. The lower yield of mixed gari of *P. erosus* could also explain its cost price estimated at FCFA 340 (~\$ 0.57) per kg. This price is greater than cassava gari's price which was about FCFA 150 (~\$ 0.25) per kg. By taking into account the nutrient characteristics of mixed gari, consumers would be better off health-wise consuming mixed gari with 50% *P. erosus*. The major problem was the

decrease of the yield of gari obtained by mixing 50% *P. erosus* with cassava. Improving the yield by introducing varieties with high dry-matter content could improve the revenue of women processors and thereby the cost price, the latter being linked to the quantity produced.

## Conclusion

The present study and the results obtained allowed identifying difficulties related to the processing of mixed gari made with 50% *P. erosus*. Technical and financial results and the appreciation of processors showed that mixed gari of 50% *P. erosus* is edible and can be commercialized. However, the high water content of *P. erosus* makes the gari yielded quite low, preventing those processing these tubers into gari from making more profit. Sensitivity analyses showed that increase in yield of mixed gari of 50% *P. erosus* improves processors' profit, giving producers the opportunity to reduce unit sale price and thereby improve marketability. Research on gari processing should therefore be directed to other varieties with tubers containing less water.

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## REFERENCES

- Adegbola YP, Djenontin INS, Sossou CH, Hinnou CL, Thiele G, Mensah GA. 2011. Etude Diagnostique Participative pour le Projet Ahipa au Bénin. CIP/INRAB ; p. 170.

- Afoakwa EO, Kongor EJ, Annor GA, Adjonu R. 2010. Acidification and starch behaviour during co-fermentation of cassava (*Manihot esculenta* Crantz) and soybean (*Glycine max* Merr) into gari, an African fermented food. *Int. J. Food Sci. Nutr.*, **61**: 449–462.
- Ayeh SE. 2013. Development and quality characteristics of yam bean (*Pachyrhizus erosus*) flour and its performance in bread. MSc thesis, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, p. 114.
- Balbin IO, Delgado-Vásquez O, Carhuanca KM, Sørensen M, Kvist LP. 2005. *El Cultivo de Chuin (Pachyrhizus tuberosus): una Alternativa Para la Seguridad Alimentaria y Recuperación de Suelos Degradados en la Amazonía Peruana*. Lima: Peru; 40.
- Bhat R, Karim AA. 2009. Exploring the nutritional potential of wild and underutilized legumes. *Compr. Rev. Food Sci. F.*, **8**(4): 305–331.
- Djoï D, Monhouanou JD. 2003. *Etude de Marché National sur les Racines et Tubercules et Produits Dérives*. MAEP/PDRT : Bénin.
- Eke UB, Owalude SO, Usman LA. 2008. Enrichment of a cassava meal (Gari) with soyabean protein extract. *Adv. Nat. Appl. Sci.*, **2**: 60–62.
- Forsyth JL, Shewry PR. 2002. Characterization of the Major Proteins of Tubers of Yam Bean (*Pachyrhizus ahipa*). *J. Agric. Food Chem.*, **50**: 1939–1944.
- Forsyth JL, Ring SG, Noel TR, Parker R, Cairns P, Findlay K, Shewry PR. 2002. Characterization of Starch from Tubers of Yam Bean (*Pachyrhizus ahipa*). *J. Agric. Food Chem.*, **50**: 361–367.
- Gruneberg WJ, Freynhagen-Leopold P, Delgado-Vaquez O. 2003. A new yam bean (*Pachyrhizus* spp.) interspecific hybrid. *Genet. Resour. Crop Evol.*, **50**: 757–766.
- Heider B, Tumwegamire S, Tukamuhabwa P, Ndirigwe J, Bouwe G, Bararyenya A, Hell K, Leclercq J, Lautié E, Wassens R, Burgos G, Zumfelde T, Thiele G, Grüneberg W. 2011. Nutritional improvement of yam bean and sustainability of farming systems in Central and West Africa. *Afr. Crop Sci. Conf. Proc.*, **10**: 93–95.
- Hibon A, Adegbola PY, Hell K, Thiele G. 2011. *Contraintes et Opportunités pour l'Introduction de Nouveaux Produits sur les Marchés Locaux des Racines et Tubercules au Bénin*. International Potato Center (CIP): Lima, Peru.
- Kale PR. 2006. Studies on nutritional and processing properties of storage roots of different yam bean (*Pachyrhizus* spp.) and wild mung bean (*Vigna vexillata*) species. PhD. thesis, Universitat Gottingen, Cuvillier Verlag, Gottingen, Germany.
- Kisambira A, Muyonga JH, Byaruhanga YB, Tukamuhabwa P, Tumwegamire S, Gruenberg W. 2014. Physicochemical Characteristics of Yam Bean (*Pachyrhizus erosus*) Seed Proteins. *J. Food Res.*, **3**(6): 887–895.
- Kolapo AL, Sanni MO. 2009. A comparative evaluation of the macronutrient and micronutrient profiles of soybean fortified gari and gari. *Food Nutr. Bull.*, **30**: 90–94.
- López OV, Viña SZ, Pachas ANA, Sisterna MN, Rohatsch PH, Mugridge A, Fassola HE, García MA. 2010. Composition and food properties of *Pachyrhizus ahipa* roots and starch. *Int. J. Food Sci. Technol.*, **45**: 223–233.
- Myers W. 2002. In Sustainable food security for all by 2020. Proceedings of the International Conference on Food Security, Bonn (Germany), September 4–6, 2001, Washington DC, IFPRI, p. 100.
- Oseni AL. 2012. Empowerment initiatives: Garri processing empowers women. *West Africa Insight*, **3**(6): 3–5.

- Padonou SW, Houyèvou Klotoe A, Ahounou J-L, Houssou PA, Fandohan P, Aïhou K, Adjanohoun A, Hell K, Adégbola PY, Mensah GA, Koudandé OD. 2013. Yam bean (*Pachyrhizus erosus*) tuber processing in Benin: Production and evaluation of the quality of yam bean-gari and yam bean-fortified gari. *Int. J. Biol. Chem. Sci.*, **7**: 247–259.
- Quaye W, Yawson I, Gayin J, Plahar WA. 2009. Economic Comparison of Cassava Processing Methods in Some Selected Districts of Ghana. *Afr. J. Root Tuber Crops*, **35**(2): 211–218.
- Sanni AI, Marlon-Guyot J, Guyot JP. 2002. New efficient amylase-producing strains of *Lactobacillus plantarum* and *Lactobacillus fermentum* isolated from different Nigerian traditional fermented foods. *Int. J. Food Microbiol.*, **72**: 53–62.
- Singbo A. 2012. Analyzing efficiency of vegetable production in Benin. PhD thesis, Wageningen University, the Netherlands, p. 128.
- Wassens R. 2011. Assessment of the suitability of yam bean for the production of gari. MSc thesis, Wageningen University, the Netherlands, p. 82.
- Zanklan AS, Ahouangonou S, Becker HC, Pawelzik E, Grüneberg W. 2007. Evaluation of the storage root-forming legume yam bean (*Pachyrhizus* spp.) under West African conditions. *Crop Sci.*, **47**: 1–14.