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Increasing Performance of the Cassava Industry in West and Central Africa Region (IPCI)

Mission Report for Visit to Congo Brazzaville

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1. Executive Summary

In February 2016 a team from the IPCI project (consisting of experts from NRI and SNV) made a visit to Republic of Congo to work with FIDA, PADEF and the Ministry of Agriculture to investigate two areas where IPCI might strengthen the outputs of the FIDA funded PADEF project. The first of these involved making a detailed investigation of the current status of cassava processing in the country and assessing options for improvement. This work was design to feed into the PADEF plans for demonstration centres to showcase improved technologies for gari, dried chip and chikwangue. As part of this work the IPCI team assessed the capacity and potential of machinery fabricators and availability of raw materials and components for cassava processing machines in Brazzaville. The second area of interest was to look in more detail at the current status and future potential of NG-Manioc. NG-Manioc is the only large-scale cassava processing business and has the capacity to process >7,000 tonnes of fresh cassava roots per year. It was known that the business was operating at a low level but the reasons for the problems at NG-Manioc were not well understood.

A programme of field visits were planned that would have seen the team travelling to Oyo in North Central area of the country to visit NG-Manioc and farmers supplying the factory and then to Pointe Noire and villages in the South of the country to assess the current status of gari and dry chip processing and marketing and to gather data to contribute to the design of the demonstration centres. Visits were also planned to fabricators and raw material suppliers around Brazzaville. However, on arrival the team were advised to curtail their travel plans due to potential for civil unrest in the lead up to the Presidential elections in March 2016. The team revised their plans to focus on Brazzaville, but were still able to make some field visits to villages processing chikwangue and dried cassava chips ~80km North East of Brazzaville. Interviews were held with key personnel including the Managing Director of NG-Manioc at the offices of FIDA and PADEF in Brazzaville. Some activities could not be achieved during the visit such as assessing the supply chain of NG-Manioc. However, much was achieved and the team came to the following conclusions.

Introduction of improved processing technologies from Nigeria can more than double output of gari, reduce production costs and eliminate health and safety problems associated with current gari practices used in Republic of Congo. In addition adoption of improved processing techniques will enable local gari makers to meet the quality requirements of the West African expatriate community. This in combination with lower processing costs should make the local product more competitive and attractive to customers and enable the market for local gari to expand and displace gari imported from Benin.

Nigerian processing technology can make dry chip production easier, reduce processing time from 8-18 days down to 3 to 5 days. The quality and safety of the product will also be much improved. However, further investigations are required to determine if these benefits will prove sufficiently attractive for dry chip makers to invest in improved technology.
There is potential to improve the Chikwangue process via improvements to the dough making machines and introduction of a smoke free final cooking step to eliminate the problem of smoke inhalation during steaming of the baguettes.

Most of the components for fabrication of Nigerian designed cassava processing equipment are available in Brazzaville. However, stainless steel sheet is difficult to obtain and very expensive. This could become a key constraint to local fabrication of good quality cassava processing machines.

A range of options for optimal management of groups involved in cassava processing can be offered combining experience from Nigeria and the Democratic Republic of Congo. Members of the gari and chip processing groups visiting Nigeria can gain direct experience of the options for management of processing by interacting with village processing groups. Access to microfinance can be strengthened using models for microfinance and cost sharing that have proved successful in the Democratic Republic of Congo.

NG-Manioc is not competitive under current conditions and it unsurprising that the factory has not been functional since the latter part of 2015 and was only producing on a sporadic basis for around 12 months before October of last year.
The key issue at NG-Manioc is the use of a large electrically heated tray dryer that consumes 531kWh of power (91% of the total power requirement of the factory). The dryer has a limited capacity of just 14 tonnes in 16 hours (2 batches). This equates to a massive 607kW to dry one tonne of cassava chips and a total of 628kW of energy to produce 1 tonne of flour. Power for the electrically heated dryer accounts for 97% of the US$1,218 in power costs per tonne of flour produced.

NG-Manioc faces other issues including badly sited fermentation tanks that increase fermentation time, ineffective automated peeling, problems with management of root supply, a need to separate out metering of electricity for the factory from that of the neighbouring water plant and limited access to working capital. Some improvements could be made to aspects of the current process but the key constraint will always be the power consumption of the electric tray dryer. Any plan for re-investment in NG-Manioc would need to re-think the production process (probably on similar lines to a Nigerian instant fufu powder factory) to bring down production costs. This would be expensive as large items of equipment such as the electrically heated tray dryer would have to be replaced with alternative equipment requiring a capital investment of at least US$250,000.

1. Résumé

En Février 2016, une équipe du projet IPCI (composée d'experts du NRI et de la SNV) a effectué une visite en République du Congo. Le but était, avec l'aide du FIDA, du PADEF et du Ministère de l'Agriculture, d'identifier deux aspects où IPCI pouvait renforcer les résultats du projet PADEF financé par FIDA. Le premier aspect de la mission consistait en une étude détaillée de l'état actuel de la transformation du manioc dans le pays et une évaluation des différentes possibilités de l'améliorer. Ce travail a été conçu pour faire partie des plans du PADEF qui consistent à faire des centres de démonstration, des exemples de technologies améliorées pour le gari, les cossettes de manioc et la chikwangue. Dans ce cadre, l'équipe IPCI a évalué la capacité et le potentiel des fabricants des machines et la disponibilité des matières premières et des composants pour fabriquer les machines de transformation du manioc à Brazzaville. Le deuxième aspect de la mission consistait à un examen de l'état actuel et du potentiel futur de NG-Manioc. NG-Manioc est la seule usine à grande échelle de transformation de manioc et a la capacité de traiter plus de 7.000 tonnes de racines fraîches de manioc par an. On savait que l'entreprise fonctionnait à un bas niveau, mais les raisons pour cela n'étaient pas bien comprises.

Des visites de terrain ont été planifiées pour permettre à l'équipe de rencontrer NG-Manioc et les agriculteurs qui fournissent l'usine en manioc, à Oyo, dans la région du Centre-Nord, puis à Pointe Noire et dans les villages du sud pour évaluer l'état actuel des procédés de transformation et du marketing du gari et du manioc séché puis de récolter des données afin de contribuer à la conception des centres de démonstration. Des visites des fabricants et des fournisseurs de matières premières autour de Brazzaville ont été également prévues. Cependant, dès son arrivée, l'équipe a été avisée de limiter ses déplacements en raison du risque des troubles à l'approche des élections présidentielles en Mars 2016. L'équipe a révisé ses plans pour se concentrer sur Brazzaville, mais a été quand-même en mesure de faire des visites de terrain dans des villages, à environ 80 km au nord-est de Brazzaville pour observer les procédés de transformation de la chikwangue et des cossettes de manioc séchées. Des entrevues ont eu lieu avec des personnes-clé du projet, y compris le directeur général de NG-Manioc dans les bureaux de FIDA et du PADEF à Brazzaville. Certaines activités néanmoins n'ont pas pu être effectuées, comme l'évaluation de la chaine d'approvisionnement de NG-Manioc. Malgré tout, la plus grande partie du travail a été faite et a permis à l'équipe de parvenir aux conclusions suivantes.

L'introduction des technologies améliorées de transformation du Nigeria a le potentiel de doubler la production de gari, de réduire les coûts de production, et d'éliminer les problèmes de santé liées à l'hygiène qui sont associés aux pratiques actuelles de production de gari en République du Congo. En plus, l'adoption des techniques améliorées de transformation permettra aux producteurs locaux de gari, de répondre aux exigences de qualité de la communauté expatriée d'Afrique de l'Ouest. Ceci, en combinaison avec des coûts de transformation faibles, devrait rendre le produit local plus compétitif et attrayant pour les clients et permettre au marché de gari local de se développer et de remplacer progressivement le gari importé du Bénin.

La technologie de transformation des nigérians peut permettre une production facile des cossettes séchées et une réduction de la durée de transformation de 8 -18 jours à 3 -

5 jours. La qualité et l'hygiène du produit seront aussi améliorées. Toutefois, d'autres recherches sont nécessaires pour déterminer si ces avantages se révéleront suffisamment attrayants pour que les fabricants de cossettes séchées consentent à investir dans ces technologies.
Il y a potentiel d'améliorer le procédé de transformation de la Chikwangue via l' amélioration des machines pour faire la pâte et l'introduction d'une étape de cuisson finale sans fumée pour éliminer les problèmes d'inhalation de la fumée lors de la cuisson à l'eau de la chikwangue.

La plupart des composants et matériel pour la fabrication des équipements de transformation du manioc suivant le modèle nigérian, sont disponibles à Brazzaville. Cependant, les tôles d'acier inoxydable sont difficiles à obtenir et sont très coûteuses. Cela est une contrainte majeure pour la fabrication locale des machines de transformation s du manioc de bonne qualité.

En combinant l'expérience du Nigeria avec celle de la République Démocratique du Congo, on peut proposer une gamme d'options pour une gestion optimale des groupes de transformateurs du manioc. Les transformateurs qui font du gari et des cossettes de manioc pourraient acquérir une expérience pratique de gestion de la transformation du manioc s'ils sont mis en contact avec des groupes des transformateurs villageois au Nigeria. Un meilleur accès à la microfinance pourrait être développé en utilisant des modèles de microfinance et de partage des coûts qui ont fait leurs preuves en République Démocratique du Congo.

L'entreprise NG-Manioc n'est pas compétitive dans les conditions actuelles et il n'est pas surprenant que l'usine n'ait pas été fonctionnelle depuis fin 2015 et qu'elle ait seulement produit de façon sporadique, depuis environ 12 mois, avant octobre de l'année dernière. Le problème principal de NG-Manioc est le grand séchoir électrique qui consomme 531kWh d'énergie (91% du total des besoins en puissance de l'usine). Le séchoir a une capacité limite de seulement 14 tonnes en 16 heures (2 lots). Cela équivaut à une énergie démesurée de 607kW pour sécher une tonne de cossettes de manioc et un total de 628kW pour produire 1 tonne de farine. L'alimentation du séchoir électrique à elle seule représente 97% de 1218 $ en coûts d'énergie et par tonne de farine produite.

NG-Manioc fait face à d'autres problèmes, y compris celui des bacs de fermentation mal situés dans l'usine qui augmentent le temps de fermentation, un épluchage automatique inefficace, des difficultés de gestion de l'approvisionnement en racines frais de manioc. Il y aurait besoin de séparer les compteurs d'électricité de NG-Manioc de ceux de l'usine d'eau voisine pour mieux contrôler le fond de roulement. Certaines améliorations pourraient être apportées au procédé de transformation en cours, mais la contrainte principale sera toujours la consommation d'énergie du séchoir électrique. Repenser le procédé de production sera nécessaire pour tout plan de réinvestissement pour l'entreprise NG-Manioc (ceci probablement dans le but de produire une usine de fufu instantané comme au Nigeria) pour faire baisser les coûts de production. L'investissement risque d'être coûteux puisque les grands équipements comme le séchoir électrique devraient être remplacés par des équipements nécessitant un investissement en capital d'au moins 250,000 US $.

L'équipe IPCI fait les recommandations générales suivantes:

Nous recommandons au projet PADEF de sélectionner quelques représentants des groupes de transformateurs de gari et de cossettes séchées pour une visite au Nigeria afin d'y rencontrer des fabricants d'équipements et les transformateurs de gari et de cossettes de manioc séchées. L'objectif principal de la visite sera de sélectionner les meilleurs équipements de transformation en vue de les acheter, les importer en République du Congo et les installer dans les centres de démonstration. Les modalités de passation des marchés et l'importation des équipements seront à la charge du personnel concerné de PADEF et de FIDA. Cela donnera l'opportunité aux transformateurs congolais de discuter de leurs besoins en détail, de rencontrer des utilisateurs d'équipement existants et d'essayer des équipements dans des conditions réelles en travaillant avec des groupes de transformateurs villageois nigérians. IPCI facilitera la visite par l'intermédiaire de son partenaire FUNAAB nigérian et du personnel francophone du NRI.

Nous recommandons que l'équipe IPCI soit impliquée dans la préparation des plans détaillés des centres de démonstration. Nous croyons qu'un centre de démonstration pour mettre en valeur les techniques améliorées de transformation du gari pourrait être construit pour un coût compris entre 50,000 US $ et 60,000 US $. Ce coût est très inférieur par rapport à celui de 1,000,000 $ cité dans les propositions initiales du centre d'affaires mais, les équipements et l'infrastructure correspondent mieux aux besoins d'un groupement de transformateurs villageois qu'à une usine de transformation à grande échelle comme NG-Manioc.

Nous recommandons que des ingénieurs nigérians et anglais de l'équipe IPCI viennent en République du Congo pour aider à l'installation et à la mise en service des nouveaux équipements, ainsi qu'à la formation des transformateurs dans les centres de démonstration, le cas échéant.

IPCI propose d'organiser avec PADEF et FIDA la visite d'un fabricant d'équipements expérimenté du Nigeria et d'un ingénieur du Royaume-Uni à Brazzaville et Pointe Noire (avec un traducteur français) pourconduire une formation pratique aux fabricants locaux. La formation comprendrait la construction de presses jack, broyeurs à marteaux humides, râpe/trancheuses, et foyers à gari améliorés. Une formation générale serait également proposée pour des domaines de compétences cruciaux comme le soudage. En ce qui concerne l'amélioration du procédé de transformation de la Chikwangue, l'équipe IPCI propose que les ingénieurs du NRI conçoivent une chikwangue cuite sans fumée à l'étape finale. Les ingénieurs pourraient aider à superviser la construction, l'installation et la validation de la cuisinière améliorée dans un village où la chikwangue est la plus fabriquée localement tel qu'Ignié par exemple. Les ingénieurs aideraient aussi à la conception et la construction des machines comme le pétrisseur et verraient s'ils y a possibilité d'amélioration comme par exemple, éviter les problèmes actuels de corrosion des composants internes.

Concernant NG-Manioc, il nous apparait que l'entreprise n'est pas viable dans sa forme actuelle et qu'un important investissement en capital serait nécessaire pour surmonter les problèmes actuels et construire un argument commercial solide. L'équipe IPCI serait prête à discuter de l'élaboration de propositions plus détaillées pour la réhabilitation de

NG-Manioc si PADEF et FIDA trouvent cela approprié.

Nous recommandons qu’une copie des sections pertinentes du présent rapport soit envoyée au directeur général de NG-Manioc pour ses commentaires et suggestions.

La prochaine étape pour les partenaires IPCI est de se réunir en mai 2016 pour discuter du projet de plan de travail pour 2016-2017. IPCI travaille dans plusieurs pays d'Afrique occidentale et centrale, et il sera essentiel que les partenaires conviennent de la meilleure utilisation de ces ressources qui sont limitées avant de finaliser le plan d'action pour l'année à venir. Une fois qu’un plan de travail a été convenu, l'équipe IPCI sera en mesure de discuter avec le PADEF et FIDA des actions détaillées et des plans de mise en œuvre.

IPCI préparera également les termes de référence pour la visite par les représentants des transformateurs congolais au Nigeria car cela a déjà été identifié comme action prioritaire par le PADEF, FIDA et le Ministère de l'Agriculture afin d’assurer le succès des centres de démonstration.

2. Introduction

Following on from the initial visit by members of the IPCI team (from NRI & SNV) to Brazzaville and Oyo in May 2015 (see mission report at http://projects.nri.org/cassava-ipci) terms of reference were prepared for a second mission to investigate current and future options for development of cassava processing as a business opportunity in Republic of Congo in more detail. This mission was originally scheduled for October 2015 but had to be postponed until February 2016 due to political unrest. For the mission in February 2016, the IPCI team proposed the following activities and sub-activities:

1.1 Outline of mission activities

The mission activities were divided into two:

1. Assessment of current and future options for cassava processing in Republic of Congo

- Assess current practices for cassava chip processing and recommend improvements;
- Assess current practices for gari production & recommend improvements;
- Evaluate plans for the proposed business centres and make recommendations;
- Assess current practices for Chikwangue production and determine if the process can be improved;
- Examine potential for procurement of sample sets of equipment from Nigeria and capacity building for fabricators in Republic of Congo.

2. Assessment of NG-Manioc & raw material supply chain

- Raid assessment of technical and economic aspects of the NG-Manioc factory;
- Assessment of current and potential markets & competing products;
- Investigation of current procurement practices and current and future role of smallholders in supplying the factory

This information was intended to form the basis of a business case for re-investment in NG-Manioc with recommendations for further action if appropriate.

To deliver these activities a programme of field visits was drawn up for implementation in the period from 8th to 19th February 2016. It was intended that the IPCI team should visit NG-Manioc in Oyo and suppliers of NG-Manioc in the area around Oyo over a 3 day period. The team also planned to travel to the Southern part of the country to visit villages involved in gari and chip processing. Visits were planned to investigate cassava marketing in Brazzaville and Pointe Noire and also to look at availability of raw materials and components for agro-processing machinery in Brazzaville and Pointe Noire.

The IPCI team arrived in Brazzaville on Monday 8th February 2016, security clearance for travel was obtained from the UN Security Adviser and the team planned to travel to Oyo on Tuesday 9th February. However, the proposed travel programme had to be curtailed on the advice of the Ministry of Agriculture who were concerned over possible civil unrest in the lead up to the Presidential elections scheduled for March 2016. The proposed visits to Oyo and the South of Congo could not take place, but the team did agree to continue with activities in Brazzaville and to make short excursions to chikwangue and chip producing areas approximately 80-90km north east of Brazzaville. Arrangements were made to have a discussion with the Managing Director of NG-Manioc at the FIDA offices in Brazzaville.

The disruption of the proposed travel programme had implications for delivery of the activities. Investigation of the NG-Manioc supply chain and in depth technical investigations at the factory could not take place. However, sufficient information was gathered during the interview with the Managing Director that combined with data from last years' visit to Oyo enabled the team to reach a conclusion about the likely viability of the factory in its present form.

The loss of the opportunity to visit the gari processors was most unfortunate but the team was able to gather information through interviews with PADEF and Ministry of Agriculture staff familiar with gari processing in Republic of Congo. Visits were also made to gari sellers in Brazzaville who provided an insight into the gari market and customer preferences. Members of the IPCI team have extensive experience of gari processing in West Africa and this proved invaluable for developing recommendations as to how to improve gari processing in Republic of Congo.

Field visits were made to chikwangue and chip processors, and to cassava product markets and fabricators of machinery in Brazzaville. Visits were also made to various businesses to determine the availability of raw materials and components required for the long term sustainability of any improved cassava processing technologies introduced into Republic of Congo.

3. Assessment of current & future potential for cassava processing in Republic of Congo

This section of the report looks at the current status of processing techniques for chips, gari and chikwangue in the Republic of Congo with recommendations for improvements that could be made by introducing better processing technologies from Nigeria. We also look at fabrication of cassava processing machines in Republic of Congo and what should be done to improve the capacity of the fabricators.

3.1 Gari processing

Current status of gari processing in Republic of Congo

Gari is the name given to a cassava-based product consisting of small granules of fermented, fried and dried cassava mash. Gari granules have a moisture content of 10-14% and range in size from ~<0.25mm (Extra fine gari) to 1.25-2.0mm (Extra coarse gari). The gari process has the advantage of removing cyanogenic glucosides and converting highly perishable and bulky fresh cassava roots into a compact convenience food with a long shelf life (~1 year if stored under dry conditions). Gari is a convenience food as it can be mixed with a variety of combinations of milk/water, sugar and groundnuts and eaten directly without any further cooking. Alternatively it can be ground into a flour, mixed with hot water to form a paste and then cooked to form a thick dough known in Nigeria as Eba. Gari is believed to have originated in Latin America and is a very popular product across West Africa (especially Nigeria, Benin, Cameroon and Ghana).

Gari is not a traditional food for most people in Republic of Congo, its production is believed to be restricted to two villages Ndounga and Ntebele in the South of the country. Gari production is thought to have been introduced to the villagers of Ndounga about 20-25 years ago by a trader from Benin. Most production is still restricted to 50-60 families in Ndounga village. Gari imported from Benin is sold to the West African expatriates in Brazzaville and Pointe Noire, locally produced gari is marketed mainly in Pointe Noire. There appears to be potential to increase sales of locally produced gari to the West African community. There is also a chance that gari might be popularised as a convenience food for people in Republic of Congo especially as consumers are already familiar with the taste of fermented products such as chikwangue and fufu.

The IPCI team were not able to travel to the gari producing area of the country in February 2016 and had to rely of discussions with staff from the Ministry of Agriculture and the PADEF project who have experience of gari processing in Republic of Congo.

According to these sources the major constraints all relate to the method used for gari processing which has the following steps:

- Peel and wash fresh cassava roots;
- Manually grate the peeled cassava using a hand held grater;
- Pack the grated mash into a sack, place the sack in a basket (some producers do not use a basket to contain the sack of mash) and cover with heavy rocks and leave to ferment for 2-3 days to form a fermented wet cake;
- Sieve the fermented wet cake to form fine granules;

- Fry the wet granules in a metal pan over an open fire;
- Sun dry the fried granules on a mat and then bag for sale.

This version of the gari process has the following major constraints:

- Manual grating is time consuming, one person can only grate ~20kg of peeled cassava roots per hour. Using a manual grater is potentially dangerous with a high risk of cuts to the fingers and hands. It is also difficult to produce a consistent finely grated mash;
- Using heavy rocks to reduce the water content of the mash is inefficient, initial moisture contents of 65-70% only reduce to 55-60%. This has implications for the sieving and frying steps. Sieving of mash with a high moisture content is more difficult and granule sizes tend to be large, it is almost impossible to produce the finer grades of gari. Frying takes longer due to the high moisture content and there is a risk that the final product will contain too high a moisture content reducing shelf-life. Handling heavy rocks is a hazardous occupation and can lead to internal injuries;
- Frying gari over an open fire is a hazardous occupation as the operator inhales large quantities of wood smoke and volatiles driven off from the hot granules in the pan;

This approach to producing gari is still used in some part of West Africa (Niger State in North Central Nigeria for example) but is known to be very labour intensive and inefficient and has gradually fallen out of favour in South Western Nigeria, Ghana and Benin over the last 25-30 years.

Improved gari processing
Various improvements to the gari process have been introduced to reduce drudgery, improve quality and make the process more efficient. The following gives a description of some of the improvements that could be made to the gari process currently used in Republic of Congo.

Manual peeling – Much effort has been devoted to attempts to develop automated means of peeling cassava over the last 25 years. Unfortunately cassava roots present problems due to their irregular shapes and wide range of sizes. The IPCI team have never seen a truly successful cassava peeling machine. Some machines do not completely peel the roots resulting in the need to complete peeling manually. Others remove all of the bark and peel along with significant amounts of the valuable white flesh. We do not recommend investment in mechanical peeling because of the limitations associated with current peeling technologies. Manual peeling remains the only effective approach for a small-scale gari processing group.

Mechanised grating/crushing – Two options are available for small-scale gari processing. The first involves using a mechanised grater (see figure 1). These graters consist of a rotating drum covered in a stainless steel grating surface contained within a metal housing with a feed hopper. Peeled roots are dropped into the hopper and forced to pass through a narrow gap between the wall of the grater housing and the rotating drum which grates the surface of the roots producing a fine mash. Power can be provided by either a 3-phase electric motor or petrol engine with an output of ~4kW (5.5HP). Graters sold in Nigeria cost ~US$900 (including engine or motor) and can grate ~500kg of peeled cassava roots/hour of operation. The 4kW petrol engine will consume ~1 litre of petrol per hour of operation. Mechanised graters offer a massive advantage over manual grating due to the high output, fine quality of the mash and reduction in time and labour inputs and removal of hazards associated with manual grating. Mechanised graters have the disadvantage that the grating surface needs replacing after ~200 hours of operation. As the cutting surface becomes worn and blunt output will fall to ~200kg and efficiency of grating will decrease until 45-50% of cassava flesh fed into the grater will fail to grate properly. Replacement of the grating surface is not difficult under normal circumstances but could present issues in Republic of Congo where stainless steel sheet is expensive and difficult to obtain.

Figure 1 Mechanised grater used in gari production in Nigeria

Figure 2 Wet hammer mill used in gari production in Nigeria

The alternative to the mechanised grater is a wet hammer mill (see figure 2). Wet hammer mills are similar in construction to conventional hammer mills having a set of stainless steel hammers rotating on a shaft enclosed within a metal housing fitted with a feed hopper. Peeled cassava roots are pulverised by the rotating hammers forming a fine mash. Power is supplied by a 10.5kW (14HP) 3-phase electric motor or petrol/diesel engine. The petrol/diesel engine option will consume ~1.2 litres of fuel per hour of operation. Wet hammer mills sold in Nigeria cost ~US$1,500 and can crush 900kg of peeled cassava roots per hour of operation. Wet hammer mills are more expensive than a mechanised grater but have the advantage of higher output, more efficient crushing of the roots and lower levels of maintenance as unlike the grater the hammers do not need replacing every 200 hours. A single wet hammer mill in private or shared/community ownership could easily provide daily crushing services for a group of 60 processors.

Fermentation & mechanical de-watering of cassava mash – Two alternatives to the traditional rock method of pressing. These are the screw type and hydraulic jack presses. Screw presses (see figure 3) are available with either a single central screw or twin screws placed at the ends of the pressure plate. Cassava mash is packed into sacks and placed in the press. Pressure is applied by winding the screw to force the pressure plate against the sack of mash. Once pressure has been applied the press is left for 2-3 days to allow for fermentation (to remove cyanogenic glucosides) and reduction in water content. Screw presses with a capacity of ~500kg of mash per batch are available in Nigeria for ~US$250-300. Screw presses require considerable afford to apply enough pressure to reduce water content of the mash to 50-55%. Most of the screw presses are old designs lacking a proper supporting structure and this tends to reduce the efficiency pressing.

Figure 3 Screw press (left) and jack press with 20 tonne jack (right) used in gari production in Nigeria

The hydraulic jack press option relies on a hydraulic truck jack to apply pressure to the pressure plate of the press (see figure 3). For gari production a 20 tonne truck jack will give good results reducing moisture content to ~45%. The hydraulic jack press has advantages in giving a better reduction in moisture content and being easy to use. Suitable presses sold in Nigeria have a capacity of ~750kg of mash per batch and range in price from US$339 for a press with a low quality Chinese made truck jack to US$679 for a press supplied with a high quality Italian made truck jack. The cheaper Chinese jacks are low priced but tend to leak oil and break easily when used for gari processing. The Italian jacks may appear expensive but they are far more robust and durable when used for gari processing and will last much longer.

Re-crushing of pressed wet cake – Pressing produces a compact cake, this cake must be broken into fine granules before it can be fried. This is easily achieved by passing the cake back through the wet hammer mill or mechanised grater. The resulting output will be a fine granular material ready for sieving and frying. Before frying the wet granules are sifted through a traditional sieve made from interwoven strips of plant material. Sieving helps to ensure a supply of small granules for frying. Sieving can be done before frying but some gari producers arrange their work area so that they can carry out sieving and frying at the same time (see figure 4).

Figure 4 Sieving of wet gari granules using a traditional sieve, note operator is also frying gari at the same time

Frying & drying – Traditional gari processing involves frying the wet granules in a circular metal pan over an open fire (see figure 5). This approach has several disadvantages. Firstly the size of the pan limits frying to 6kg of gari per batch. Frying takes approximately 30 minutes, as a result a gari fryer using a traditional pan is limited to about 50kg of gari in 8 hours. During frying the operator is exposed to smoke from the open fire under the pan. This makes gari frying a hazardous and unpleasant occupation. Smoke problems are increased if the fryers are installed indoors as the frying room tends to fill with toxic wood smoke and the walls and ceilings become coated with soot and resinous material created as by-products of burning wood. In addition fried gari removed from the pan is still moist and must be sun dried on a mat for 4-6 hours before packing into bags (see figure 5).

Figure 5 Traditional frying over an open fire (left) and sun drying of gari on a mat as seen in Nigeria

Figure 6 Improved smoke free combination gari fryer and dryer used in Nigeria

Nigeria has developed improved gari fryers that solve the smoke problem, increase output and allow for drying as part of the frying process. A typical improved gari fryer consists of 1.2x1m rectangular pan (see figure 6) made from 3mm thick stainless steel sheet. Stainless steel is essential for the frying pan as mild steel will rust and contaminate the gari with iron oxides and fragments of rusty metal. The stainless steel frying pan is backed underneath the frying surface with a 3mm thick sheet of mild steel. The mild steel backing sheet (not visible in figure 6) protects the stainless steel from heat damage from the fire burning under the pan. The fire is contained within a 60cm high insulated firebox. The firebox has a double wall made from sheets of 2mm thick mild steel. The space between the two walls is filled with a 10cm thick layer of fibre glass insulation. Insulating the firebox ensures maximum heat transfer to the frying surface. This has the advantage of reducing frying time to 20 minutes per batch and reducing fuel consumption by 40-45% when compared to traditional gari fryers. Some improved fryers in Nigeria have fire boxes made from mud bricks but this is a false economy as it reduces fuel efficiency and increases frying times.

Improved gari fryers are designed to be used inside a building with the entry to the firebox situated in the outer wall of the building (see figure 6). At the far end of the pan furthest away from the entry to the firebox is a galvanised steel chimney that serves to remove smoke from the firebox for safe discharge above the roof line of the gari frying house. This design eliminates the problem of smoke inhalation from gari frying.

The hot end of the frying pan located nearest the entry point to the firebox is used for frying the wet granules. The capacity of the frying pan is 20kg of gari with a frying time of 20 minutes. On this basis an operator could produce ~500kg of gari in 8 hours but in practice few operators would work at this intensity, in real life outputs of 250-300kg per day are often achieved. Once the granules have completed frying (turned a golden yellow colour) the operator pushes the fried granules down to the chimney end of the frying pan. This area of the pan is much cooler but is still hot enough to dry the granules. Dried granules are removed from the fryer and spread on a raised mat for 30minutes to cool before final sieving and bagging.

In Nigeria a high quality improved fryer can be purchased for ~US$543. Much cheaper pans are available but these should be avoided as the pan is normally made from mild steel and will rust after just day of frying. Cheap pans normally have badly made fireboxes that are energy inefficient and leak smoke into the frying room.

Improved gari fryers represent a considerable initial investment for small-scale operators especially as the fryer requires a simple building to contain the fryer. This type of fryer is best suited for communal use whereby the community shares a communal facility consisting of a building with 5 to 10 improved fryers.

Automated gari fryers – Nigeria also produces automated gari fryers (see figure 7). These machines are designed for larger-scale operators and reduce the labour required to produce larger quantities of gari. The fryer consists of a circular stainless steel frying pan (~2m in diameter) fitted with rotating paddles to move the gari around on the frying surface. The paddles are driven by a 1.5kW (2HP) 3-phase electric motor. Heat energy can be provided by a wood fuelled firebox under the frying pan but many are fitted with a pressure jet burner (PJB) running on kerosene or diesel. The PJB will use 6 litres of fuel per hour of operation. The output of an automated gari fryer is 500kg per 8 hours of operation, this equates to a fuel consumption of 96 litres of diesel or kerosene per tonne of gari produced. A good quality automated gari fryer will cost US$5,430 with a wood furnace or US$6,787 with a pressure jet burner. Automated gari fryers are designed for larger-scale factory production of gari. They are not well suited for village operation due to the need for electricity and issues of fuel and maintenance for the pressure jet burner. The IPCI team does **NOT** recommend purchase of automated gari fryers for use by village processing groups in Republic of Congo.

Figure 7 Automatic gari fryer with electrically powered paddles & heat provided by a diesel pressure jet burner as used by some large-scale gari makers in Nigeria

Sieving of final product – Granule size is one of the key quality attributes for gari. Some consumers like large particles (coarse gari) whereas others prefer small particles (fine gari). In general gari is usually classified into 4 grades based on particle size, these are:

- Extra coarse – particle size range 1.25-2.0mm
- Coarse – particle size range 1.0-1.25mm
- Fine – particle size range 0.5-1.0mm
- Extra fine – particle size range 0.25-0.5mm

Traditional manual sieves made from plant materials produce mainly coarse and fine gari particles. For better control of particle size metal sieves can be used. Mechanical sifters are available but these are not common as most gari makers prefer to sieve manually. The IPCI team visited gari vendors in Brazzaville and were informed that most customers prefer fine or extra fine gari. Nearly all of the gari on sale was of extra fine or fine quality although one stall was selling a few containers of coarse grade gari. Vendors commented that locally made gari was too coarse to appeal to their customers. Current processing techniques make it difficult to produce fine grades of gari but this could easily be solved if fine metal mesh sieves (0.25 to 0.5mm aperture) were introduced.

Recommendations for improved gari processing in Republic of Congo

The IPCI team understands that the PADEF project wishes to establish 1-2 demonstration centres for improved gari processing. If two centres can be supported these could be located at Ndounga and Ntebele villages as these are the two villages already involved in gari processing. If only centre can be supported it would make sense to locate the demonstration centre at Ndounga village as this place has the highest concentration (~50-60 households) of households involved in gari processing. We have provided an outline of our recommendations for one demonstration centre, some details will require further elaboration and a field visit to the potential site of the demonstration centre.

For improved gari production we recommend continuing with manual peeling and washing of cassava roots as this is the most effective method for village level processing.

Crushing of roots should be automated, for a group of 60 people working 6 days per week in two shifts of 30 (morning & afternoon shifts) a 900kg/hour wet hammer mill would be sufficient (assuming a peeling rate of 40kg per person per hour). The wet hammer mill could be in communal ownership (owned by the gari producers group) or owned by an individual service provider in the same way that petrisseurs are owned by individual entrepreneurs in villages producing chikwangue. The wet hammer mill would be in a fixed location (not mobile). This could be within the frying house at the gari demonstration centre (for security) or in a separate building if owned by an individual. The demonstration centre will need a secure place to store fuel for the wet hammer mill and trucks when not in use.

For a single days production ten jack presses of 750kg capacity fitted with 20 tonne jacks would be needed. However, as fermentation takes two to three days a second set of presses would be needed making a total of 20 presses. Presses should be mounted on a 20cm thick concrete base (1x1m per press) with drainage channels leading to a soakaway. This is essential to avoid contaminating the environment with liquid effluent discharged during pressing. Fermentation takes 2-3 days (choose either 2 or 3 days depending on the strength of flavour in the final product and desired output). Given the fermentation time it will not be possible to use the same presses every day. In reality a rota will have to be established to make optimal use of the available presses.

For a two day fermentation (assuming that Sunday is a holiday) root crushing and press loading can take place on Monday to Thursday and on Saturday but not on Friday. Frying of gari can take place on Wednesday to Saturday and on Monday but not on Tuesday. The maximum output for 60 people (assuming a peeling rate of 40kg/person/hour) will be 14.6 tonnes of gari per week.

For a three day fermentation (assuming that Sunday is a holiday) root crushing and press loading can take place on Friday & Saturday and Monday & Tuesday but not on Wednesday & Thursday. Frying of gari can take place on Thursday & Friday and on Monday & Tuesday but not on Wednesday and Saturday. The maximum output for 60 people (assuming a peeling rate of 40kg/person/hour) will be 11.7 tonnes of gari per week.

For a group of 60 people working 6 days per week in two shifts of 30 (morning & afternoon shifts) a set of ten improved gari fryers is needed for maximum output to be achieved. The gari fryers should be installed within a simple but secure building. A structure suitable for 10 gari pans & a wet hammer mill would have a 20x5x0.3m concrete base (30m^3 of concrete equivalent to 1,278 bags of concrete) and a 21x5m (81m^2) corrugated metal sheet roof with a 30° pitch constructed from 2x1m x0.4mm thick corrugated metal sheets (~156 sheets). The height of the walls would be 4m consisting of a 2m high lower half made from concrete blocks and an upper half made of heavy duty metal mesh. The roof would be supported on 12 vertical (80x80mm) treated posts spaced a maximum of 2.4m apart. The roof structure and purlins would be made from 45x45mm treated timber. The roof would need a minimum of 32 purlins spaced 1.2m apart to hold the roofing sheets. The building should have wooden lockable doors at each end to make the premises secure. Each gari fryer will have a 5m high galvanised steel chimney emerging above the roof line for discharge of smoke from the frying units.

Preliminary estimate of costs for a gari demonstration centre

A rough estimate of the cost for a gari demonstration centre with sufficient equipment to allow 60 people to produce the maximum possible weekly output of gari working a 6 day week is given in table 1 below. All costs are quoted in US$, and do not include costs for labour local transport of building materials or shipping and import costs for machines purchased in Nigeria. Costs for building materials have been derived from prices collected by the IPCI team from vendors of building supplies in Brazzaville in February 2016.

Gari producers should have access to a clean water supply. If the target villages lack a suitable water supply we would recommend that the PADEF project consider supporting installation of a tube well in the village. This investment would also have benefit in terms of health and wellbeing of all households in village by offering a supply of clean water in the village.

Table 1 Estimated cost for a gari demonstration centre for use by 60 people in Ndounga village

Item	**Unit cost US$**	**No**	**Cost US$**
Wet hammer mill 900kg/hr capacity	1,500	1	1,500
Jack press with 20 tonne truck jack	679	20	13,580
Improved gari fryer	543	10	5,430
Metal sieves (0.25 & 0.5mm)	20	60	1,200
Sub total for equipment			**21,710**
Concrete base for jack presses (1x1mx20)	10	170	**1,700**
Gari frying house			
Concrete base	10	1,278	12,780
Roof sheets (2x1m 0.4mm thick)	12.5	156	1,950
Concrete blocks	0.55	960	528
Wood for roof structure (45x45mm)	1	200	200
Wooden posts (6m long, 80x80mm)	12.5	12	150
Metal security ,mesh	10.76	96	1,033
Wooden doors with locks	100	2	200
Sub total for gari frying house			**16,841**
Overall total for gari demonstration centre			**40,251**

Costs could be reduced by reducing the number of jack presses and improved gari frying units. The size of the gari frying house would also be reduced if fewer fryers were purchased. However, this would restrict gari production in the village for a relatively small saving in cost to the PADEF project.

3.2 Dried cassava processing

Current status of dry chip processing in Republic of Congo

Fresh cassava roots deteriorate rapidly and become virtually unusable within 4 days of harvest. A simple way to prevent this deterioration is to peel the roots and dry them to form dried cassava chips. If the roots are of a bitter variety containing high levels of cyanogenic glucosides a soaking step is added before drying to reduce cyanide concentrations to a safe level. In Republic of Congo, traditional chipping is one of the simplest and cheapest forms of cassava processing and is widely practiced even in remote rural areas. The IPCI team visited a cassava chip processor in an area ~80km north east of Brazzaville.

The method used for cassava chipping was as follows:

- Peel fresh roots in the field using straight knives and then transport to the processing area close to the field edge;
- Dig a pit 4m long by 2m wide and 1m deep, line with a heavy duty plastic sheet and fill with 750 litres of water;
- Place peeled whole roots in the pit and leave for 3 days to ferment;
- Remove roots from the pit and place on a drying rack made from old cassava stems covered with layer of dried grass (rack dimensions 20m long, 2m wide and 1m high). Roots will require ~5 days to dry during the dry season and ~10 days to dry during the wet season. Heavy duty plastic sheets are required to cover the roots in the event of bad weather;
- Dried roots are bagged in sacks for transport to the main road for local sales and transport to markets in Brazzaville.

Other than labour, the only investments are for the heavy duty plastic sheets costing ~US$17 per sheet (require 3 sheets for a processing site) and thirty x 25 litres cans of water at a cost of US$15. The water can be re-used for upto 7 batches of roots but water quality will deteriorate as acidity levels increase. The processor identified water quality, long processing times and variable quality of the end product as major constraints. Chip quality is compromised by the long drying times resulting in mould growth. The chips seen by the IPCI team were discoloured with grey and brown patches.

The growth of mould on the dried cassava creates issues with off flavours but can also represent a food safety risk especially during the rainy season. Studies carried out by NRI on cassava chip drying in rural Ghana showed that during the rainy season moulds growing on the chips produced 4 different mycotoxins at levels hazardous to human health. These toxins were carried through into the flour and being heat stable were present in the final cooked food product.

Improved chip processing

Processing of fermented chips is popular in Nigeria, Ghana, Benin and several other West African Countries. Manual peeling is used but chipping has been automated with machines that not only decrease labour requirements but also produce much smaller chips that ferment and dry more quickly. Some processors use drying racks to reduce drying times.

Two types of chipping machines are available, one cuts the roots into 1-2cm thick transverse and longitudinal slices. The other cuts the cassava roots into fine strips that resemble spaghetti; this type of machine is commonly referred to as a "mini-chipper". Mini-chippers (see figure 8) are ideal for processing of sweet varieties of cassava that do not require fermentation as the mini-chips have a large surface area and will dry in the sun within 4-6 hours. Unfortunately this rapid drying gives no chance for removal of cyanide, the chips cannot really be soaked as they tend to breakdown leading to product losses. The IPCI team does not recommend using mini-chipping machines for processing in Republic of Congo.

Figure 8 Mini-chipper used for production of quick drying mini-chips. Note this type of chipper must only be used with sweet cassava roots

Cassava slicing machines (see figure 9) have a lot more potential for use in Republic of Congo. The 1-2cm thick slices are robust enough to be soaked in water and soaking times can be reduced to 2 days as the slices have a greater surface area for removal of cyanogenic glucosides. After soaking, raised drying racks can be used to reduce drying time.

Suitable drying racks (see figure 10) can be made from double layers of fine plastic mesh (such as untreated mosquito netting) stretched over a 3x1m wooden frame with wooden cross supports to prevent the mash sagging under the weight of the chips. A 1m high wooden rail is needed to raise the racks at an angle of $\sim 30^\circ$ (see figure 10). The combination of the raised racks and holes in the mesh improves air circulation and thus increases the rate of drying. Chips placed on this type of rack will dry within 1-2 days depending on the weather. The drying racks are portable and can be taken inside to avoid bad weather or covered with plastic sheeting during bad weather. Drying racks have a capacity of 10kg of wet chips per m^2 of drying area, on this basis a 3x1m rack can be used to dry 30kg of wet chips.

Figure 9 Cassava slicer used for production of fermented and dried cassava chips in Nigeria.

Figure 10 Wooden framed plastic mesh racks for drying cassava chips, placed at a 30 angle to improve air flow and reduce drying time

Recommendations for improved chip processing in Republic of Congo

Introduction of mechanised chipping and mesh type drying racks would dramatically reduce processing times from 8-18 days down to 3-4 days. Rapid drying would improve product quality and eliminate the risk of mycotoxin formation in the dried chips. However, introduction of these improvements would have a cost implication. At the present time processors in Republic of Congo need only to purchase some plastic sheets and cans of water for processing. The initial investment will be around US$65 to start processing. Cassava chipping machines (of the slicing type) can be purchased in Nigeria with or without and engine. A fully mechanised slicing machine with a 4kW (5.5HP) petrol engine will cost ~US$900. This type of machine can slice 500kg of peeled cassava roots per hour and will consume 1 litre of petrol per hour of operation. Manual versions of the cassava slicing machines are also available at a cost of ~US$350. The manual chipping machines have the advantage of lower purchase cost and lower operating costs as they do not require petrol and oil or engine maintenance. However, they can be hard to operate and it is worth making sure that the chipper has good bearings to ensure easy rotation of the chipping disc. Cassava chipping machines are quite portable and thus could potentially be operated by mobile service providers in much the same way as the petrisseur machines seen in Chikwangue production. The drying racks can be made locally and should not cost more than about US$20 per rack (for the wooden frame and plastic mesh). A set of ten racks would cost ~US$200.

There is no real need for specialised structures for improved chip processing so a demonstration of improved chip processing could be established for around US$1,100 (excluding shipping and import costs). The IPCI team recommends that representatives from cassava chipping communities have the opportunity to join representatives from the gari processing villages in a visit to Nigeria to evaluate processing technologies prior to making any decision to invest in improved technologies for chip processing. The technological benefits are clear but given the investment cost it is not clear to the IPCI team whether or not investment in chipping machines and drying racks will be attractive to those involved in cassava chipping in Republic of Congo.

In order to further develop the method for assessment of small and medium enterprises (SMEs) and village processing groups (VPGs), the NRI/FUNAAB team in collaboration with VCDP interviewed two VPGs and one SME , thereby using (components of) the checklist. The full checklist can be found in Annex 1 of this report. The three assessed organisations were: :

3.3 Chikwangue processing

Current status of chikwangue processing in Republic of Congo

Chikwangue is a popular high-value fermented product produced from cassava roots. The production process is complex and labour intensive involving the following steps:

- Peel and wash fresh cassava roots;
- Ferment peeled roots in water for 2-4 days;
- Sieve roots to form a mash and remove fibrous material;
- Allow water to drain from the mash for 6-10 hours;
- Form mash into a wet dough, this was traditionally done using a wooden board and rolling pin but nowadays most processors make use of a petrol engine powered dough making (petrisseur) machine;
- Partially cook the dough over a fire outdoors for 1 hour;
- Allow the hot dough to cool for ~30 minutes and then form the dough into baguettes on a wooden board whilst the dough is still warm;
- Wrap baguettes in two types of leaves and tie with string to form a neat package;

- Steam the wrapped baguettes over a fire indoors for 1-2 hours;
- After cooling baguettes are ready for sale.

The IPCI team visited several Chikwangue processors living around the village of Ignie ~80km north of Brazzaville to discuss any problems or constraints associated with chikwangue processing. Processors raised concerns over two issues, namely the quality of the petrisseur machines used for dough making and smoke inhalation during the final cooking step of the process.

The mobile petrisseur machines (see figure 11) are a great labour saving innovation but problems with the construction of the machines leads to contamination of the wet dough with rust and fragments of corroded metal. This contamination is due mainly to the use of mild steel in the construction of most parts of the machine that come into contact with the food product. The cassava dough is acidic and causes the mild steel to rust and corrode quite quickly (see figure 11). In many cases the machines are rusty even before their first use in the village. All parts should be made from stainless steel but local fabricators only use stainless steel for the main hopper, even this steel sometimes rusts due to damage to the surface of the steel by poor quality welding. Visits to two petrisseur fabricators in Brazzaville showed that the fabricators have difficulty with obtaining stainless steel sheet, lack any formal training and have limited tools for fabricating machinery.

Figure 11 Chikwangue dough making machine and view of feed screw and hopper showing corrosion and poor quality welding (seen in Ignie village, Republic of Congo)

The final step of the chikwangue process involves steaming the baguettes of dough over an open fire for 1-2 hours. The fire is kept indoors to prevent draughts from interfering with the cooking process. Unlike gari frying the operator does not have to be present at all times, but the processor must still make frequent checks on the status of cooking. As a result the processor is exposed to smoke and inhales toxic particulates generated by the combustion of wood in the open hearth (see figure 12).

Figure 12 Final stage of Chikwangue process involves cooking over an open hearth indoors, note deposits of soot on the walls of the cooking house (seen in Ignie village, Republic of Congo)

Recommendations for improved chikwangue processing in Republic of Congo

The problem with the petrisseur machines is due to a combination of difficulties with getting supplies of stainless steel, lack of training and insufficient skills in key areas such as welding and lack of access to essential equipment for casting and machining. The IPCI team recommends support be extended to the fabricators in the following areas:

- Improve access to supplies of stainless steel sheet;

- Support practical training workshops in basic techniques such as welding and production of processing machinery in Brazzaville by a master fabricator from Nigeria;

To solve the problem of smoke inhalation during the final cooking step it will be necessary to produce a smoke free cooking system along the same lines as the improved gari fryer developed in West Africa. Such systems are not available off the shelf in Nigeria where chikwangue processing is not practiced. However, the engineering principles are straightforward and have historical precedents in old fashioned water boilers used in Europe in the past. In these systems a metal container was set into a brick hearth (see figure 13) with a fire underneath. The feed point for the hearth would be placed outside and the hearth of the water boiler provided with a chimney to extract smoke. NRI as a partner in the NRI project could provide an engineer to design and supervise fabrication of a suitable smoke free chikwangue cooker. Such a cooker would be simple consisting of an enclosed hearth with a metal pan for boiling the water. The hearth would have an access point and chimney to remove the smoke outside the cooking house. The smoke free chikwangue cooker could be built in a chikwangue processing area such as Ignie to serve a demonstration of the benefits of a smoke free cooker.

Figure 13 Traditional wood fired water boiler (seen in a historic house in New Zealand), note water container is made from copper a modern version for chikwangue cooking would use an aluminium alloy cooking pot

3.4 Fabrication of cassava processing equipment in Republic of Congo

Technology for processing of cassava into fermented chips/flour, gari and chikwangue is not well developed in Republic of Congo. At the present time mechanisation is limited to hammer mills for milling dry chips into flour and mobile petrisseur machines for mechanised production of chikwangue dough. There is considerable potential to improve production of fermented chips and gari via the introduction of machines and techniques from Nigeria. In the short-term PADEF can rely on machines imported from Nigeria. However, to make real progress it will be essential to manufacture and maintain the cassava processing machines locally in Republic of Congo. For this reason the IPCI team made visits to fabricators of processing equipment and component suppliers in Brazzaville.

The IPCI team was not able to determine how many fabricators are active in Brazzaville but we were informed of the existence of at least 4 small fabricator workshops in Brazzaville that make petrisseur machines and hammer mills. Visits were made to two of these fabricators. The first fabricator was involved in production of petrisseurs, hammer mills, metal gates and auto repairs. The workshop was relatively well equipped with 2 engineers lathes, bench and hand held grinders, a drill stand, circular saw, arc welder and hand tools including hacksaws, hammers, metal shears and an engineers' vice. The manager of the workshop said that in the past they had facilities for making metal castings but the blower unit had broken so they were no longer able to make castings. The fabricator had a stock of new and used mild steel metal bars, rods and sheets. There was also some second-hand stainless steel sheet recovered from an old sugar refinery.

An example of a completed petrisseur machine was examined at the premises of the first fabricator. The petrisseur machine was made mainly from mild steel with the exception of the feed hopper which was constructed from stainless steel. The feed screw was quite crudely made from mild steel rod with a stainless steel sheet screw welded onto the shaft. The feed screw had a bearing unit that appeared to have come from a motor vehicle. Power for the machine was supplied by a 4.1kW petrol engine. The cost for the machine plus engine was US$583 (XAF350,000). The cost of the engine alone was given as US$316 (XAF190,000). Externally the machine looked quite well made. However, although brand new the interior of the barrel and shaft of the feed-screw were already rusting. There were also areas of corrosion in the stainless steel hopper, this was due to damage to the hopper by poor quality welding.

The second fabricator was also involved in making petrisseur machines and hammer mills but had very limited equipment consisting of an arc welder, hand held grinder and basic hand tools including hacksaws and hammers. There was a small stock of mild steel and several sheets of second-hand stainless steel obtained from the same source as the first fabricator. Examples were seen of a hammer mill with an 11kW motor and a petrisseur machine (intended to be fitted with 3.7kW petrol engine). Construction of both machines was crude and of low quality when compared to the machines seen at the premises of the first fabricator. The second fabricators petrisseur was priced at US$533 (XAF320,000) inclusive of engine.

Both fabricators shared common problems that limited their ability to produce a good quality product. Neither had any formal training, and raw materials such as stainless steel were expensive and difficult to obtain. The first fabricator had access to a reasonable selection of machine tools but the absence of casting and milling facilities made it impossible to produce certain components such as feed-screws for the petrisseurs. The second fabricator lacked access to most of the tools needed to produce good quality processing equipment. Poor quality welding was a major issue that reduced the quality of surfaces in contact with the food product and increased corrosion problems.

3.5 Availability of raw materials and components suitable for use in cassava processing machines

If new types of processing technology are introduced into Republic of Congo from NIgeria by PADEF it will be necessary to encourage local fabrication of the machines to ensure longer term sustainability of technology without relying on imports from Nigeria. To produce jack presses, cassava chippers, wet hammer mills and improved cassava fryers it will be necessary to have local access to mild steel sheet, angle and rod, stainless steel sheet, jack presses and engines and motors with a capacity of 4-10kW.

Visits to shops around Brazzaville indicated no problem with purchase of mild steel in any form. Prices were quite reasonable with 45x45mm angle iron selling for US$3.33/m and 8mm mild steel rod for US$3.06. Stainless steel was not readily available. The IPCI did not see any vendor selling unused stainless steel sheet. The only material available was second-hand sheeting recovered from an old Sugar refinery close to Pointe Noire. Stainless steel from this source was being sold at US$33.33 per m^2. This is expensive and will make it difficult to manufacture machines locally at an affordable price.

Motors and engines were readily available the team saw Chinese made 4kW motors similar to those used in Nigeria selling for US$467. A 4kW petrol engine retailed for US$334 whereas a larger 7.5kW engine was priced at US$750. Truck jacks with a capacity of 20 tonnes were widely available from vendors of auto-parts. Prices ranged from US$58 for a Chinese jack imported via the UAE to US$238 and US$335 for Spanish and Italian made jacks respectively. Although cheap the Chinese jacks looked to be of poor quality and would not last long if used for gari processing. The Italian jack appeared to be of the highest quality but the cheaper Spanish made jack should be suitable for use in gari processing.

The IPCI team visited two fabricators with very different levels of capacity. The fabricator with the lowest level of capacity will struggle to make good quality versions of processing machines introduced into Nigeria. This fabricator and others like him would need extensive support to upgrade equipment and skills to meet the challenge.

The better equipped fabricator was more promising. There should be no difficulty in this fabricator making jack presses from Nigerian designs. This fabricator has the capacity in house to make wet hammer mills, graters and improved gari fryers but to be successful access to supplies of stainless steel will have be improved and the fabricator will require practical training both in how to make the specific machines but also in ways to improve basic skills such as welding.

In our experience the best approach will be to bring in a joint training team of engineers from Nigeria and UK to organise practical training for groups of fabricators in Brazzaville and Pointe Noire. The lead trainer from Nigeria will be a master fabricator with extensive experience of making and selling all types of cassava processing equipment. NRI will provide an engineer with experience in cassava processing to assist in design and delivery of the training programme. Ideally this training should take place after machines have been delivered from Nigeria to the PADEF demonstration centres as this will enable the fabricators to see examples of properly constructed equipment in use. A translator will be required as none of the Nigerian fabricators is able to speak French. It will also be necessary for the NRI engineer to visit Congo in advance of the training to select a suitable venue and ensure that all materials and equipment required for the training will be available when the training team arrives.

4. Marketing of selected cassava products in Brazzaville

According to the FAO Pocketbook World Food and Agriculture (2015), Congo's population was 4.6 million in 2014 (up from 2.4 million in 1990, and 3.1 million in 2000). The population employed in agriculture was 35.4% for the total population and 39.3 for the female population. Dietary energy supply was 2 121 kcal/per capita/day in 2014, which was considered 97% of the average dietary energy supply adequacy. GDP per capita was US$ 5,680 (Purchasing Power Parities) in 2014.

Cassava is the main staple food for about 90% of Congolese. It is more or less everywhere produced in the country and production was estimated at 1.2 million tonnes in 2010 according to a study by the World Bank. At the same time, based on active farming population and assuming that each one of them cultivates 0.5 hectares, Ntsouanva et al (2013) estimate that annual tuber root (cassava?) production is 2.673 million tonnes.

Average cassava consumption is estimated at 425 kilograms per capita per annum in rural areas, and 175 kilograms per capita per annum in urban areas. (Ntsouanva et al, 2013).

Chikwangue (steamed cassava batons), fermented cassava paste (la pâte rouie), and dried cassava chips (cossettes) are the main cassava products processed for commercial use. In addition, leaves are often consumed, in particular in the form of saka-saka (milled and cooked). The cassava value chain is a major source of income in rural areas. Chikwangue is considered more profitable in terms of income earner than the other products, despite the drudgery/painfulness (pénibilité) during processing. At the same time, gari is considered to gain market shares in southern parts of the country (Bouenza) (Ntsouanva et al, ibid).

4.1 Marketing of Chikwangue

Chikwangue processing takes place in most parts of Congo. In this report, the information is based on a field trip North of Brazzaville on 10/02/2016 (near Ignié).

Processors (mostly female) purchase cassava near roadside in wheelbarrows from suppliers. Table 2 shows the profitability of chikwangue making near Brazzaville. It is estimated that a processor can prepare approximately 200 pieces of chikwangue (bâtons de manioc) per week, thereby earning about XAF62,000 (US$103) net. It is understood that this covers the labour of herself and helpers (e.g. younger family members, female or male). For comparison, the daily labour rate for labourers working on cassava fields is XAF3,000 (US$5), plus food.

Table 2: Profitability of chikwangue Processing near Brazzaville

Items	Cost (FCFA)
Purchase of 1 wheelbarrow of cassava roots	6,000.00
Water	2,000.00
Leaves	5,000.00
Wood	3,000.00
Dough-making (petrisage, service provider)	2,400.00
Opportunity cost of capital (3%)	552.00
Total costs	**18,952.00**
Sales value (100 batons @ 500Fcfa)	**50,000.00**
Profit margin	**31,048.00**

Figure 14 Selected steps in chikwangue making

Cassava in wheelbarrow ready for sale	Grading and peeling of fresh roots
Pétrisseur and owner	Pétrisseur used for dough-making
Processor cooking chikwangue	Board used for chikwangue making

Even when the opportunity cost of labour is deducted, the calculations in Table 2 show that processors can earn a relatively good income from chikwangue making. At the same time, one needs to take into account the drudgery/painfulness (pénibilité) of chikwangue making (e.g. exposure to heat and smoke during cooking/steaming of the product).

chikwange processing has been partly mechanised during the last decade in that pétrisseurs (dough-making machines; the fermented paste is processed into an easy to handle and form cassava dough from which chikwangue is made) are increasingly used in that service provides (mostly men) offer their services in villages or small rural towns. For example, three to four service providers have been encountered in a village near Ignié north of Brazzaville. The age of the machines seen varies between about seven years and new.

The mechanised machines (pétrisseurs) are hired out to chikwangue makers. The owner of the equipment usually comes with the machine to facilitate production. The fee paid for dough-making is XAF800 (US$1.33) per basin. The daily capacity of a pétrisseur is about 30 basins, hence the gross daily income is approximately XAF24,000 (US$ 40). Apart from depreciation and capital costs, the main input is fuel (about 5 litres of petrol per day, costing US$1.33 per litre in rural areas). One litre of oil is also needed per month (costing US$3.33).

Figure 15 Issues and challenges in cassava value chain

Input supply	Production	Aggregation	Processing	Marketing
• Land is widely available • Improved high yielding disease resistant cassava varieties have been released • Local cassava varieties are widely in use • Availability of machines has improved (CEMA) in parts of the country • Labour costs are relatively high • Project support exists (e.g. Farmer Field Schools) • Access to material and inputs required for the manufacturing of processing equipment needs to be improved (e.g. stainless steel)	• Cassava value chain is main source of income in rural areas • Lack of community organisation as far as cassava production is concerned • Scattered production often far away from villages requires farmers to stay in camps when cassava production takes place • Limited access to mechanised inputs (e.g. tractors) in parts of the country • Limited awareness of improved cassava production methods affecting yields • Low yields contribute to high costs of cassava roots	• Training of producer groups (GIECs) needed to strengthen their bargaining power, access to finance, access to machinery, and, as a result, improve production and aggregation of roots • Appropriate means of transport needed for transport of roots to reduce the extent of head or back-loading.	• Chikwangue, fermented cassava paste, and dried chips, are the main commercial products; cassava leaves are also consumed • Some mechanisation of processing has taken place during the last decade (e.g. pétrisseurs) • Stainless steel is short in supply to manufacture equipment • Processing related drudgery / pénibilité (Chikwangue, gari) • Improved processing equipment required: pétrisseurs using stainless steel, mechanised graters / chippers, hydraulic presses, improved ovens (less smoke).	• Gari marketing requires strengthening e.g. promotion of group marketing; improve image of locally produced gari versus imported gari); option of setting up marketing outlets for gari from Ntunga to be explored in Pointe-Noir and Brazzaville – to be discussed with processors and GIECs to determine which model is best • Image of mechanically produced Chiqwangue requires improving (related to quality, and food safety if stainless steel is used) • Better storage facilities and food safety measures needed.

4.2 Marketing of dried cassava

Production of fermented, dried cassava chips is more practiced in remote rural areas where farmers do not have easy access to sell their fresh roots to chikwangue makers or other buyers. The dried chips are sold to markets in cities such as Brazzaville, where they are milled into flour (foufou flour) using hammer mills.

Soaking of chips	Sun-drying of cassava chips

Figure 16 Processing of fermented, dried cassava chips (cossettes)

Table 3 Costs and margins of dried cassava marketing Brazzaville (purchase of chips and selling of foufou flour)

Items	Cost (FCFA)
Purchase of 1 bag of dried cassav chips, ~90kgs	30,000.00
Transport (per taxi)	1,500.00
Milling (service provider owning hammer mill)	1,000.00
Paper (packaging of flour)	2,000.00
Rental of market stand (bench)	100.00
Market fees	50.00
Cleaning of market	34.00
Opportunity cost of capital (3%)	1,040.52
Total costs	**35,724.52**
Sales value of flour (1 bag per day)	**38,000.00**
Profit margin	**2,275.48**

Figure 17 Sale of foufou flour in Brazzaville Market

4.3 Gari marketing

Only relatively small quantities of gari have been seen in the markets of Brazzaville. Traders tend to say that the gari originates from Benin. The prices quoted in February 2016 were per container (XAF500 (US$0.83) for 0.5 litre plastic bottle filled with gari, or XAF1,500 (US$2.50) for 1.5 litre bottle). It is understood that there are two different qualities of gari in the market. According to traders, the gari from Benin is white and finer, whilst the local gari from Ntounga is more yellowish and has coarser particles which are not favoured by most customers.

One trader said she would order 2 bags of gari in Benin which are then shipped per boat to Pointe-Noire and transported to Brazzaville. A bag of gari (~80kg) was quoted to cost XAF45,000 to 50,000 (US$45-83.33).

Figure 18 Gari sold in drinks bottles in Brazzaville market

4.4 Case study of gari processing and marketing in Ntounga community (Bouenza Department)

Background

Ntounga and Ntebele are the only two villages in Congo where Gari is produced. They benefit from a market which is more or less assured in Pointe-Noire amongst the West African Community (PADEF, December 2015).

The emphasis in this report is on Ndounga which is located in Mouyondzi District (Bouenza Department, about 280 kms from Brazzaville). The landscape in the area consists of a mosaic of mountain chains, hills, plains and plateaux (Source: Draft Feasibility Study to Establish Two Business Centres in Mouyondzi and Gamboma; November 2015).

Cassava production

A survey at producer level has shown that the field sizes cultivated are relatively small. More than 50% of indivudal producers have less than 0.5 hectares of manioc, 22.2% have 0.5 hectares, and 22.2% have 4 hectares (ibid, 2015). If production is undertaken by GIECs (Community Groups of Economic Interest) the surfaces cultivated often vary between 5 to 15 hectares.

Table 4 Production costs for one hectare of cassava by the GIECs of Bongui and Mayalama, Mouyondzi using mechanised ploughing

Operations	GIEC Bongui at Mayalama (Cost/ha en XAF)	GIEC Mayalama (Cost/ha en XAF)
Cost of land rental	40000	25 000
Land clearing 1 (dessouchage)		55 000
Land clearing 2 (rabattage)		30 000
Ploughing (mechanised)	90000	45 000
Harrowing (Pulvérisage)		50 000
Planting (making holes, planting of stems, etc)	110000	35 000
Weeding 1	80000	75 000
Weeding 2	80000	75 000
Weeding 3	80000	
Total	**480000**	**390000**
Cost of roots per kg, if yield is 10 tonnes/ha	**48**	**39**
Cost of roots per kg, if yield is 20 tonnes/ha	**24**	**19.5**

Source: Draft Feasibility Study to Establish Two Business Centres in Mouyondzi and Gamboma; November 2015; Page 36.
NB. Production costs do not include the cost of harvesting

Gari processing

Gari processing has been introduced in Ntounga by a person originally from Benin, who knew the technology and liked the taste of gari. As a result, he trained one or more gari processors of this community. In early 2016, it is estimated that there are about 50 – 60 households who produce gari, mainly destined for sale in Pointe-Noire where a community of West African expatriates lives.

It appears that no detailed study of gari marketing from Ntounga has been undertaken in the past, and the IPCI team did not have permission to visit the area in February 2016.

According to PADEF staff (Mr Marcel Nzemba) one household can produce about 2 – 3 bags of gari (80kg per bag) per week. This would represent about 200kg of gari produced by household per week. A bag of gari sells for Fcfa XAF50,000 (i.e. XAF625 (US$1.04)/kg) in early 2016 (personal communication, PADEF staff). This represents a gross income of about US$208 per week, which is significant for poor households. In particular, the younger households produce these quantities of gari (i.e. about 200kg per week); if household members are more aged they might produce 40 to 80 kg of gari per week).

Gari production in Ntounga is concentrated during the six-month period of May to October, when rainfall is low. November to January corresponds to the main agricultural production/planting season when less processing takes place. February to April corresponds to an intermediary period when some processing takes place, whilst crops are also being harvested.

According to PADEF staff, there are plenty of gari buyers in the area of Ndounga / Bouenza, including buyers from neighbouring countries such as Gabon.

Although gari processing in Ndounga is essentially considered a male activity, there are indications that several cassava production and gari processing activities are carried out by women, as illustrated in the following table:

Activity carried out	**Gender**
Weeding of cassava fields	Female
Harvesting	Mostly female
Transport of roots	Male
Peeling of roots	Female/male
Grating	Male
Pressing	Male
Frying	Mostly female
Selling	Female/male

Source: Survey data, discussion with PADEF staff in Brazzaville

Marketing

As for marketing, the costs per bag of gari (~80kg) and dried chips (~90kg) are similar. Table 5 illustrates the marketing costs per bag of gari between Ndounga and Pointe-Noire.

Table 5 Gari marketing costs (Ntounga to Pointe-Noire)

Item	XAF per 80kg bag	XAF per kg
Sales price: ~80kg bag of gari	50,000	625.00
Transport (to Pointe-Noire, 348km)	5000	62.50
Handling	1000	12.50
Miscellaneous other costs	1000	12.50
Total	**57,000**	**712.50**

Gari constitutes a niche product, involving only manual processing activities: peeling, grating, de-watering (pressing of bags with heavy stones; when fermentation of cassava paste takes place), sieving, and garification. (Source: PADEF, December 2015, page 59).

The sale of gari follows a particular pattern in Ndounga in that each processor stores their gari after processing and transfers the product, through group aggregation, to wholesalers from Pointe-Noire once a certain number of bags (3 – 4 on average) have been accumulated. As indicated, in Pointe-Noire it is mainly the West African community (in particular from Benin) who are the principal buyers and consumers. Sale is more or less direct to known customers.

Marketing of cassava products in Pointe Noire

The following section is mainly based on information from a short questionnaire survey carried out by e-mail with PADEF staff in Pointe-Noire in February 2016.

The following information has been obtained:

(a) The main cassava products consumed in Pointe-Noire are: "Cassava bread" (Le pain de manioc, or chikwangue), flour (from dried chips), gari, fresh roots (kaba), tapioca/starch.

(b) The demand (in Pointe-Noire) for cassava based products is increasing due to the rural exodus and despite decreasing consumer purchasing power, although supply is also increasing thanks to new, better performing varieties which have been introduced by the PRODER-Sud Programme and now by the PADEF Programme.

(c) The quantity of cassava products consumed per household per annum is about 600 Chikwangue (1.8 kg per unit), and five bags of dried cassava chips (cossettes).

(d) The main departments supplying Pointe-Noire with cassava products are the following: Bouenza, Lekoumou , Niari et le Kouilou, plus Cabinda (Angolan territory) to some extent.

(e) The means of packaging of cassava products include plant leaves (feuilles de maranthacées), jute bags, and other flour bags. Transport takes place by road vehicles and rarely by train (delay of short-distance transport).

(f) Cassava products consumed by which consumer segment:
   a. the better-off – «cassava bread» (pain de manioc) ;
   b. middle class – cassava chips;
   c. the poor – Chiqwangue pieces (le Nzenga) and flour in cups.

(g) Average prices for cassava products during the last three years:
   a. Cassava chips (1st grade): XAF 25,000 (2013); 35,000 (2014) ; and 40,000 (2015); (per bag of dried cassava chips).
   b. Cassava paste (fermented): XAF 22,000; XAF25,000; and XAF 30,000 (more available and cheaper in December and January ; and less available i.e. expensive in October, November, and February, March).
   c. Locally produced gari: XAF 35,000; XAF 40,000; and XAF 45,000 (the price tends to be lower during the dry season due to school holidays and children's involvement in production.
   d. Cassava paste from Cabinda: XAF 24,000; XAF 28,000; XAF 32,000/bag of 40 sachets.

(h) 75% to 80% of the gari consumed in Pointe-Noire is imported from Benin.

(i) The quality of the imported gari is considered to be far higher.

(j) Gari prices: Imported gari (XAF 50,000 per bag of 100kg); local gari: XAF 35,000 to XAF 45,000 per bag of 100 kg (this price is related to the supply situation and the period of the year).

(k) Imported gari is stored differently from local gari.

(l) Imported gari is trasported by boat in containers. Importation costs are not known by retailers. Only wholesale importers know them.

(m) Imported gari is more consumed than local gari, generally by the West-African community, and in particular by the community originating from Benin.

(n) It is possible that local gari processing groups (e.g. from Bouenza) could open a shop in Pointe-Noire, however this needs to be discussed with them.

(o) There are no specialised cassava storage facilities in Pointe-Noire. Hygienic conditions are low (bags of chips are stored in bulk on pallets, while cassava paste is stored directly on the ground.

(p) Storage costs (coûts de gardiennage) are as follows in these stores (dépôts de fortune): Gari – XAF 500/15days/bag; Fermented cassava paste (XAF 500/15 days/bag); Cassava chips (XAF 300/15 days/bag).

(q) Transport costs by truck
   a. Chips from Ioudima to Pointe-Noire, XAF 4500 / bag out of which XAF 1500 for handling.
   b. Fermented cassava paste: XAF 5000/bag, out of which XAF 2000 for handling.
   c. Gari from Mouyondzi: XAF 5500/bag; out of which XAF 2,500 for handling.

(Source: Pointe-Noire, le 13 février 2016, Henri MABIALA, Facilitateur du PADEF).

4.5 Challenges of cassava production and gari processing in Ndounga

It appears that mechanised production and processing of roots is not common. As for production, this is partly due to the hilly terrain, but also due to the general lack of tractors or other farm machinery. At the production stage, this involves manual soil preparation, followed by other manual operations such as planting, weeding, and harvesting.

Processors have their own cassava farms (about 1 ha), and are also cultivating intercrops such as maize, groundnuts, legumes, courges, oseille, gombo (ladyfingers).

Transport of roots takes place on back-load (by women in hilly terrain, up to 60kg per load), and on motorcycles or tricycles (operated by men). The distance between farm and processing site can be 10km.

Although it has been mentioned that improved cassava varieties are needed, it is understood that in addition to the local varieties some improved varieties from IITA are in use in the Ndounga area. While, according to PADEF staff, the local varieties may yield 15 – 20 t/ha, yields from improved varieties are of the order of 25-30 t/ha.

Cassava production costs in the Ndounga area are estimated to be of the order of XAF 600,000 – 650,000 (US$1,000-US$1,083/ha (Source: PADEF staff, February 2016). It is understood that this is based on the use of a tractor for ploughing, but does not include the cost for harvesting. If production costs are US$1,000(XAF

600,000) and the yields are 20 tonnes per hectare then the production costs per tonne of fresh cassava roots are XAF 30,000 (US$50).

According to PADEF staff, after harvest peeled roots are put in 200 litre drums which are filled with water. The harvester will receive XAF2,500 per drum filled with cassava (wage for harvest and peeling). One hectare of cassava can yield 120 – 130 drums of cassava, which in turn will result in 70 bags (80 – 100kg/bag) of dried cassava chips (cossettes). The latter cost XAF25,000 (during dry season) to XAF40,000 per bag of approximately 90kg (during rainy season).

If 70 bags of dried cassava chips can be produced per hectare and each bag costs XAF30,000 then the gross income is XAF 2.1 million per hectare (US$ 3,500). Labour costs for harvesting and peeling are XAF312,500 per hectare (US$ 520), based on the cost of harvesting and peeling cassava roots to fill 125 drums.

It is understood that gari processing is mainly manually done. This involves:

- peeling of roots with knives,
- manual grating on grating boards,
- pressing/de-watering of grated cassava mash using heavy stones,
- sieving using locally made sieves,
- frying of dewatered mash using frying pans on open fires.

The absence of mechanisation during processing has two consequences:

(a) Injuries, including hernia as a result of carrying heavy stones needed for pressing, cut fingers or hands as a consequence of manual grating, and smoke inhalation as a result of using open fires during frying.
(b) Low capacity in terms of quantities of gari that can be produced, plus high processing costs (per unit produced). Both of these effects limit the turn-over such a micro- or small-scale enterprise can achieve.

5. Assessment of NG Manioc factory (Oyo)

Introduction NG-Manioc is the only large-scale cassava processing business in the Republic of Congo. The factory was established in the industrial processing zone in Oyo in 2004, the present Managing Director Dr Sam Kasu has been running the factory since 2011. The factory is designed for large-scale production of fermented flour. There are also provisions for processing of fresh cassava leaves (saka saka) and starch. The factory has a theoretical capacity to produce three batches of 14 tonnes during the course of a week thus giving a stated capacity of 42 tonnes of flour per week or 2,184 tonnes of fermented flour per annum. The concept of three weekly batches is based on three sets of fermentation being started every week and three completing each week with an average fermentation time of 3 days per batch. However, in reality fermentation time is often 6 days cutting production to 2 runs per week. Production in 2015 was sporadic in nature with a total output of 90 tonnes which equates to 4.1% of capacity. There has been no production since October 2015, this was attributed to delays in importation of a special coating from France that is essential for re-coating the fermentation tanks. However, as will be seen later there are other factors that contribute largely to the lack of production.

Products & markets – The main product is fermented cassava flour produced by milling fermented and dried cassava chips. The factories stated conversion ratio is 3:1 this is very low for cassava flour and implies a high fibre content, absence of sieving of the flour and the likelihood of a certain amount of peel fragments in the final product. Fermented flour is milled to provide a particle size of ~0.5mm and packed into 25kg and 5kg bags. Most sales were made through two supermarkets in Brazzaville. The wholesale price for fermented flour was set at US$1 per kg, the retail price was US$1.33per kg of flour. In comparison traditional fermented flour is available retail in Brazzaville markets at US$0.70 per kg. Flour from NG-Manioc is almost twice the price of flour sold on the open market. This indicates that the NG-Manioc product is uncompetitive and it is unsurprising that production and sales volumes very small and made via the niche area of supermarkets patronised by people with higher levels of income.

Cassava starch is a by-product prepared by settling out starch from the waste water in the peeling section of the factory. Water is run into basins allowed to settle for 24 hours and sun-dried for 1-2 days. Fifty tonnes of cassava roots have to pass through the peeler to produce 1 tonne of starch. On this basis the theoretical output of the factory would be ~131 tonnes of starch per annum. In 2015 starch production would not have exceeded 5.4 tonnes per annum. The starch was packed into 1kg packs for sale at US$1.17/kg. This makes the starch very expensive at US$1,170 per tonne. In addition starch produced by this method would be of inferior quality (partly fermented with some granule damage and reduction in paste viscosity). There was no information available on any markets or sales of starch from NG-Manioc.

The factory was equipped with a machine for blanching and packaging of fresh cassava leaves. Fresh cassava leaves known as "saka saka" are a popular vegetable in Congo. Unfortunately the packaged leaves required refrigeration and the factory has no access to a cold chain so production had to be stopped.

Technical description of the NG-Manioc process –Fresh cassava roots are passed through an abrasive peeling machine supplied by the German company Dornow. This machine is supposed to remove all of the bark and peel. However, factory personnel complained that the peeler was not peeling properly and an expert from the IPCI team visiting the factory in May 2015 observed that dried chips in the milling area still had significant amounts of peel in place. After peeling the roots are passed through a chopper to cut them into chunks and then fed via a conveyor belt into one of three fermentation tanks filled with water. Fermentation is supposed to take 3 days which would be the normal time for fermentation in a traditional village process in Republic of Congo. However, fermentation periods were often extending to 6 days. This is probably due to the tanks being located indoors away from the heat of the sun. Fermentation time and temperature have a direct correlation and the siting of the tanks indoors was clearly a mistake. After fermentation the water is drained away and the fermented chunks of peeled cassava are laid out on plastic mesh trays for transfer to the drying section.

The factory was originally equipped with two small tray dryers with a total capacity of 3 tonnes of dry chips per batch. Drying time was 18 hours and the chips needed to be turned three times during drying. The tray dryers required 48kWh of electrical power plus 15 litres of diesel oil per hour to heat the air stream circulating within the drying chambers. This gives as a power requirement of 288kW per tonne of dry chips and a diesel consumption of 90 litres per tonne of dry chips. The cost of the energy for heating the air stream would be US$71.25/tonne of dry chips. Electrical power would have cost US$558.72/tonne giving a total cost for drying of US$629.97. This is a very high cost for drying and it is unsurprising that the factory deemed the tray dryers uneconomic and decided to replace them with a different system.

The replacement for the small diesel electric tray dryers is a massive tray electric tray dryer 20m in length, 4m wide and 3m high with two chambers. This dryer is capable of drying 14 tonnes (in 2 batches of 7 tonnes each) over a 16 hour period. Chips need to be turned twice during the drying process. The dryer has a much greater capacity than the old diesel electric dryer and eliminates the need for diesel to heat the air stream as heating is provided by electric elements. However, the power consumption of the electric tray dryer is 531kWh. The energy consumption per tonne of dry chips is 607kW giving a cost of US$1,177 to dry one tonne of chips. This is obviously uneconomic given that the wholesale price of one tonne of flour was quoted as US$1,000. This cost only takes the drying part of the process into account, the total cost of energy for production is discussed in the next section of this report.

After drying the chips are passed through a hammer mill fitted with a 0.5mm screen and a 35kW motor. Flour is bagged in either 25kg or 5kg sacks with an inner liner to prevent water absorption by the flour. It is interesting to note that the milling section of NG-Manioc was equipped with a larger range of milling and blending equipment (with a power rating of 126kWh) intended for production of fortified flour but this equipment has never been used due to the absence of any market for fortified flour.

Power consumption at NG-Manioc – The total rated power of the NG-Manioc factory is a massive 738kW. This is broken down as follows:

- Cassava peeler and root chopper (14.2kW);
- Conveyor belts (3.0kW);
- ***Small diesel electric tray dryers (48.2kW)***
- Large electric tray dryer (531kW)
- ***Saka saka machine (14.1kW)***
- ***Milling equipment (126kW)*** but only 35kW is used
- Other requirements (2.0kW)

The figure of 738kW is used by the electricity board in calculating the monthly bill for power at NG-Manioc. In addition NG-Manioc shares a common connection with the neighbouring bottled water factory. This is unfortunate as the higher the rating of the factory the higher the price for electricity (based on the electricity boards' large user HT tariff system). The monthly charge per kWh could be reduced if NG manioc and the bottled water factory had separate lines and if unused equipment at NG Manioc was disconnected and removed from the factories rating statement. The unused excess items are highlighted in bold and italics above. If these items were removed the factories true rating would be 585kW. The electricity board have quoted NG-Manioc US$33,698 to separate the metering of the two factories. Unfortunately NG-Manioc lacks the resources to pay for the separation of the electrical lines.

Given that the true power rating of NG-Manioc is 585kW this means that the large electric tray dryer accounts for 91% of the rated power of the factory. Given the capacity of the known throughput of the peeling and milling sections we can estimate a total power consumption of 628kWper tonne of flour. The total cost for power would be US$1,218 with the large electric dryer accounting for 97% of the total cost of power for production of 1 tonne of flour. As stated earlier these costs (which do not take into account of other costs such as labour) are completely unrealistic and the factories product can never hope to compete with traditionally produced flour.

Constraints faced by NG-Manioc – The Managing Director of NG-Manioc, identified lack of working capital as his major constraint as this prevented him from purchasing regular supplies of cassava roots from local farmers. He was also concerned about the price quoted by the electricity board for electricity which he considered too high. He was also concerned about the cost of separating the factories electrical supply from that of the neighbouring bottled water factory. Problems with the peeling machine and delays in obtaining paint for re-coating the fermentation bins and long fermentation times were also seen as constraints.

The IPCI team agree with all of the constraints raised by the Managing Director of NG-Manioc. However, the key constraint is clearly the massively energy inefficient electric tray dryer. As long as this dryer remains in operation there is no business case for NG-Manioc to produce cassava flour.

Possible ways forward – The current design of NG-Manioc attempts to copy the typical rural process of producing fermented dry chips and flour on a large-scale. Unfortunately the design is fundamentally flawed. Fermenting whole roots is a time consuming process (especially indoors) due to the poor surface area to volume ratio of whole roots and integrity of the intact tissue. Artificial drying of roots direct from the fermentation tank without mechanical de-watering increasing the amount of water to be removed by the dryer and thus increases costs. Using an extremely inefficient system such as an electrically heated tray dryer ensures an uneconomic process.

A possible solution could be arrived from an adaptation of the Nigerian instant fufu process. Traditional wet fufu processing is not similar to anything seen in Republic of Congo. However, over the last 20 years a process has been developed for production of a dried fufu flour often marketed as “instant fufu”. “Instant” fufu is a fermented flour with product characteristics almost identical to the fermented flours seen in Republic of Congo (texture, taste and final use to prepare a fermented dough). However, the production process has some significant differences. The basic steps for production of Nigerian “instant” fufu are as follows:

- Peel roots and wash roots;
- Crush roots into a pulp using a rasper or wet hammer mill;
- Ferment the pulp in tanks for 2-3 days (no water added);
- Press pulp (with a hydraulic press) for 2 hours to reduce water content from 65 to 40%;
- Artificially dry the pulp using a flash dryer;
- Mill dried product using a hammer mill fitted with a 0.5mm screen

Nigeria has a number of commercial producers of “instant” fufu flour, NRI (a member of the IPCI team) has conducted detailed engineering assessments of factories producing “instant” fufu flour. Total production costs range from US$443 to US$450/tonne of flour. Energy for heating the air in the flash dryer accounts for 9% of the total cost of production, whilst electrical power accounts for 11% of the total production cost. Given the larger-scale of NG-Maniocs operations it would not be possible to copy all aspects of the Nigerian process. For a factory such as NG-Manioc it would be necessary to use a larger more efficient rasping unit (see figure 19) and the hydraulic pressing of the fermented pulp would be replaced with a rotary vacuum filter (see figure 20) and feed tank to provide a continuous feed of de-watered pulp to the flash dryer (see figure 21). The flash dryer uses a heated air stream for continuous drying of the fermented cassava pulp. Flash dryers are the most energy efficient system available for drying of cassava pulp to form a dry flour (10-12% moisture content).

Figure 19 Large-scale industrial rasper (12tonnes roots per hour) used to crush peeled cassava roots into a pulp

Figure 20 Rotary vacuum filter used for mechanically de-watering the fermented pulp (65% down to 45%) prior to artificial drying

It is clear from the figures above that an adaption of the instant fufu process has technical potential to solve the problems at NG-Manioc. NG-Manioc could retain the current peeling machine, root chopper, conveyor units, fermentation tanks and hammer mill but there would be a cost implication for replacement of the existing drying equipment with a flash dryer, rotary vacuum filtration unit, feed tank, “Jain” type rasper and associated pumps and pipe work. As a very rough estimate this would involve at least US$250,000 in capital investment. This figure is a very rough approximation that would require detailed refinement if NG-Manioc wished to develop a business case for re-investment along the lines described above.

Figure 20 Nigerian made 6 cyclone flash dryer with an output of 500kg per hour of dried product

Overall conclusions, recommendations & next steps

Overall conclusions

The overall conclusions of the IPCI team are as follows:

Introduction of improved processing technologies from Nigeria can more than double output of gari, reduce production costs and eliminate health and safety problems associated with current gari practices used in Republic of Congo. In addition adoption of improved processing techniques will enable local gari makers to meet the quality requirements of the West African expatriate community. This in combination with lower processing costs should make the local product more competitive and attractive to customers and enable the market for local gari to expand and displace gari imported from Benin.

Nigerian processing technology can make dry chip production easier, reduce processing time from 8-18 days down to 3 to 5 days. The quality and safety of the product will also be much improved. However, further investigations are required to determine if these benefits will prove sufficiently attractive for dry chip makers to invest in improved technology.

There is potential to improve the Chikwangue process via improvements to the dough making machines and introduction of a smoke free final cooking step to eliminate the problem of smoke inhalation during steaming of the baguettes.
Most of the components for fabrication of Nigerian designed cassava processing equipment are available in Brazzaville. However, stainless steel sheet is difficult to obtain and very expensive. This could become a key constraint to local fabrication of good quality cassava processing machines.

A range of options for optimal management of groups involved in cassava processing can be offered combining experience from Nigeria and the Democratic Republic of Congo. Members of the gari and chip processing groups visiting Nigeria can gain direct experience of the options for management of processing by interacting with village processing groups.

Access to microfinance can be strengthened using models for microfinance and cost sharing that have proved successful in the Democratic Republic of Congo.
NG-Manioc is not competitive under current conditions and it unsurprising that the factory has not been functional since the latter part of 2015 and was only producing on a sporadic basis for around 12 months before October of last year.
The key issue at NG-Manioc is the use of a large electrically heated tray dryer that consumes 531kWh of power (91% of the total power requirement of the factory). The dryer has a limited capacity of just 14 tonnes in 16 hours (2 batches). This equates to a massive 607kW to dry one tonne of cassava chips and a total of 628kW of energy to produce 1 tonne of flour. Power for the electrically heated dryer accounts for 97% of the US$1,218 in power costs per tonne of flour produced.

NG-Manioc faces other issues including badly sited fermentation tanks that increase fermentation time, ineffective automated peeling, problems with management of root supply, a need to separate out metering of electricity for the factory from that of the neighbouring water plant and limited access to working capital. Some improvements could be made to aspects of the current process but the key constraint will always be the power consumption of the electric tray dryer. Any plan for re-investment in NG-Manioc would need to re-think the production process (probably on similar lines to a Nigerian instant fufu powder factory) to bring down production costs. This would be expensive as large items of equipment such as the electrically heated tray dryer would have to be replaced with alternative equipment requiring a capital investment of at least US$250,000.

Overall recommendations

The overall recommendations of the IPCI team are as follows:

We recommend the PADEF project supports representatives from gari and dry chip processing groups to visit Nigeria to meet with equipment fabricators and processors of gari and dried cassava chips. The main objective of the visit will be to choose improved equipment to be purchased and imported into the Republic of Congo for installation at the demonstration centres. The arrangements for procurement and importation of the equipment will be the responsibility of relevant staff from PADEF and FIDA. The representatives from the Republic of Congo will have the opportunity to discuss their requirements in detail, to meet with existing users and to try out items of equipment under real-life conditions by working with Nigerian village processing groups. IPCI will facilitate the visit via staff from our Nigerian partner FUNAAB and French speaking from NRI.

We recommend that the IPCI team be involved in preparing more detailed designs for the demonstration centres. We believe that a gari demonstration centre to showcase improved techniques for production could be built for ~US$50,000 to US$60,000. Ths is very much lower than the US$1,000,000 quoted in the original proposals for business centres as we have gone for equipment and infrastructure that more closely matches the needs of village scale processing rather than trying to design a large-scale factory resembling NG-Manioc.

We recommend that Nigerian and UK engineers from the IPCI team come to Republic of Congo to assist with the installation and commissioning of the new equipment and provision of training for processors at the demonstration centres as appropriate.

IPCI proposes working with PADEF and FIDA to arrange for a master fabricator from Nigeria and an engineer from the UK to visit Brazzaville and Pointe Noire (with a French language translator) to conduct practical training for local fabricators. The training will include construction of jack presses, wet hammer mills, chipper/slicers and improved gari fryers. Some general training will also be provided to improve fabricators capacity in key skill areas such as welding.

With regard to improving the Chikwangue process, the IPCI team proposes using engineers from NRI to design a smoke-free chikwangue cooker for the final step of the chikwangue process. The engineer would then supervise construction, installation and validation of the improved cooker at a Chikwangue processors premises in a village such as Ignie. The engineer will also look at the design and construction of the petrisseur machines to see if these can be improved so as to avoid the current problems with corrosion of internal components.

With regard to NG-Manioc we have concluded that the business is not viable in its present form and would require a substantial capital investment to overcome the current problems and build a sensible business case. The IPCI team would be happy to discuss drafting more detailed proposals for rehabilitation of NG-Manioc if PADEF and FIDA decide this is the most appropriate course of action.
We recommend that a copy of the relevant sections of this report be sent to the Managing Director of NG-Manioc for his comments and suggestions.

Next steps
The IPCI partners will meet in May 2016 to discuss the project work-plan for 2016-2017. IPCI works across several countries in West and Central Africa and it will be essential for the partners to agree the best use of the limited resources before finalising the action plan for the coming year. Once a work-plan has been agreed the IPCI team will be in a position to discuss with PADEF and FIDA detailed actions and plans for implementation.

IPCI will also prepare TOR for the visit by the representatives from Republic of Congo to Nigeria as this has already been identified by PADEF, FIDA and Ministry of Agriculture to be a priority action essential for the success of the demonstration centres.

Annex 1. References

FAO Pocketbook World Food and Agriculture (2015); Food and Agriculture Organization of the United Nations, Rome, 2015.

SÉRIE TECHNIQUE, Document synthèse du Bilan diagnostic DE LA FILIÈRE MANIOC EN RÉPUBLIQUE DU CONGO, TCP/PRC/3302, « Appui à l'élaboration d'une stratégie de développement de la filière manioc au Congo »; Par : L'équipe du projet (Ntsouanva, B., et al).

RÉPUBLIQUE DU CONGO / MINISTÈRE DE L'AGRICULTURE ET DE L'ÉLEVAGE ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE AVRIL 2013.

Draft Feasibility Study to Establish Two Business Centres in Mouyondzi and Gamboma; November 2015.

PADEF (Programme d'Appui au Développement des Filières Agricoles); Revue à Mi-Parcours - Rapport Technique Détaillé; Dates de la mission: 9 nov. – 14 déc. 2015

Annex 2. Persons met & work programme

Date	Name	Position	Organisation/Location
08/02/2016	Arrival Dr A Graffham and Mr U Kleih in Brazzaville; met by IFAD Driver Mr Jean-Claude Ngoma		
08/02/2016	Mr Richard Bouka	Focal Point IFAD West and Central Africa Division	International Fund for Agricultural Development (IFAD), Brazzaville
08/02/2016	Mr Gaetan Nsoumbidi	Country Programme Assistant	IFAD, Brazzaville
09/02/2016	Mr Alouna Mféré	Security Assistant	IFAD, Brazzaville
09/02/2016	Mr Jean Fulgence Mduangou; plus colleagues	Director of Cabinet	Ministry of Agriculture and Livestock, Brazzaville
09/02/2016	Mr Jean Pascal Kabore	Programme Officer	IFAD, Kinshasa
10/02/2016	Mr Bienvenu Ntsouanva	National Project Coordinator / Director of National Centre of Plant Diseases	FAO Value Chain / Farmer Field Schools Project; Ministry of Agriculture and Livestock, Brazzaville
10/02/2016	Cassava farmers, processors, and service providers (owners of pétrsseurs)	Private sector participants in cassava value chain	Ignié (North of Brazzaville)
11/2/2016	Mr Richard Bouka	Focal Point IFAD West and Central Africa Division	International Fund for Agricultural Development (IFAD), Brazzaville
11/2/2016	Mr Henri Mabiala	PADEF Facilitator	Pointe-Noire (E-mail contact)
11/2/2016	Fabricators of cassava processing equipment; Cassava mill owner; Owner of market/ dried cassava storage	Private sector/ workshop owners	Brazzaville
12/2/2016	Dr Many Manyonga Kennes	Associate Advisor	SNV Netherlands Development Organisation; Kinshasa
12/2/2016	Mr Jean Fulgence	Director of Cabinet	Ministry of Agriculture and Livestock,

	Mduangou, plus colleagues		Brazzaville
13/2/2016	Ms Judith Ipara	M&E Specialist	PADEF Programme Brazzaville
13/2/2016	Mr Arnaud Mboungou	M&E Project Officer	PADEF Programme Brazzaville
13/2/2016	Equipment suppliers	Shop owners	Brazzaville
15/2/2016	Dr Graffham, Dr Kennes, Mr Kleih	Team work; preparation of checklists/programme	IFAD Office Brazzaville
16/2/2016	Dr Kasu Sam	Director	NG Enterprise, Oyo (met in Brazzaville)
16/02/2016	Mr Bienvenu Ntsouanva	National Project Coordinator /	FAO Value Chain / FFS; Ministry of Agriculture and Livestock
16/02/2016		Electricity Board, SNE	Brazzaville
16/02/2016	Various shop owners	Input suppliers (engines, jacks, generators).	Brazzaville, commercial centre
17/02/2016	Administrators	Electricity Board, SNE	Brazzaville
17/02/2016	Market stall owners	Markets (e.g. Poto Poto)	Brazzaville
17/2/2016	Mr Marcel Nzemba	Project Officer (discussion about gari processing in Ntounga)	PADEF Programme Brazzaville
17/2/2016	Mr Arnaud Mboungou	M&E Project Officer	PADEF Programme Brazzaville
17/2/2016		Communication Officer	PADEF Programme Brazzaville
18/2/2016	Mr Jean Fulgence Mduangou, plus colleagues	Director of Cabinet	Ministry of Agriculture and Livestock, Brazzaville
18/2/2016	Mr Dira Benjamin	Director	PADEF Programme Brazzaville
19/2/2016	Departure Dr A Graffham and Mr U Kleih, to United Kingdom; Departure Dr Many Manyonga Kennes, to Kinshasa, DRC		