RUFORUM Working Document Series (ISSN 1607-9345), 2018, No. 17 (2): 316-323.
Available from http://repository.ruforum.org

Research Application Summary

Scaling up African baobab food products valuation through enhancement of their safety and value chains for food and nutritional security in Benin, West-Africa

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Abstract

The African Baobab is a strategic indigenous tree species of sub-Saharan Africa. Its pulp is highly nutraceutical and is used as a food ingredient and dietary supplement. Locally, the pulp is used for several products. Leaves are also highly nutritious and nutraceutical with increasing demand too. As a result, pulp and leaves are overharvested in the wild, jeopardizing the species natural stands. Domestication of baobab has become urgent and several researches have been carried out to speed this process, though several aspects are still uncovered. With the growing local/global market around baobab products, it becomes imperative to structure/upgrade its value chain which yet has been so far disregarded in national State agenda, in spite of its demonstrated potential to promote pro-poor growth, especially for women who often specialize in baobab products related activities. Taking advantage of knowledge and products generated by two recent (2015-2017) RUFORUM-GRG projects (125 & 135) projects in Benin, the aim of this project is to develop a sustainable and competitive baobab value chain in Benin. The project is built around six work-packages and will facilitate university-TVET and community linkages to upgrade baobab products value chain while contributing to improve farmers' livelihoods and baobab conservation.

Key words: Baobab value chain, Benin, domestication, experiments, promising doses

Résumé

Le baobab africain est une espèce d'arbre indigène stratégique de l'Afrique subsaharienne. Sa pulpe est très nutraceutique et est utilisée comme ingrédient et complément alimentaire en Afrique, en Europe et en Amérique. Sur le plan local, la pulpe est utilisée dans plusieurs produits. Les feuilles sont également très nutritives et nutraceutiques et fortement demandées. En conséquence, la pulpe et les feuilles sont surexploitées dans la nature, mettant en péril les peuplements naturels de l'espèce. La domestication du baobab est devenue urgente et plusieurs recherches ont été menées pour accélérer ce processus, toutefois, plusieurs aspects sont toujours non élucidés. Avec le florissant marché local

/ mondial autour des produits du baobab, il devient impératif de structurer / améliorer sa chaîne de valeurs qui a été jusqu'ici ignorée dans l'agenda national, malgré son potentiel démontré de promouvoir une croissance favorable aux pauvres, en particulier les femmes spécialisées dans les activités relatives aux produits du baobab. En se basant sur les évidences techniques et les résultats générés par deux projets récents (2015-2017) du RUFORUM-GRG (125 et 135) au Bénin, ce projet vise à développer une filière de baobab durable et compétitive au Bénin. Le projet s'articule autour de six paquets de travail et facilitera les liens entre l'université et les Institutions d'enseignement et de formation techniques (TVET) et les communautés afin d'améliorer les produits de la chaine de valeurs du baobab tout en contribuant à l'amélioration des moyens de subsistance des agriculteurs et la conservation du baobab.

Mots clés : Baobab, Bénin, domestication, dosage, expérimentation

Introduction

Despite its relatively stable democratic system, Benin republic remains one of the poorest countries in the world, with almost 40 % of its population living below the poverty line (UNDP, 2016). In this country, food and nutrition security is still challenging and is expected to worsen as the population rises. The country relies heavily on agriculture for food security and economic development. However, agricultural production is limited by factors including a lack of modern farming technologies, poor soils, inadequate storage and food processing facilities (FAO, 2015). In these conditions, inhabitants and particularly children (0-5 years) and women in reproductive age face major threats such as micronutrient deficiencies. For example, high anaemia rates (78.1 % in children under five years and 61.3 % in women of reproductive age) are due to iron deficiency (INSAE & Macro International Inc. 2007). With such an alarming picture, improvement of food and nutrition security becomes a must. To efficiently address these issues, wild edible plants and their derived foods are worth exploring. These resources often rich in micronutrients can be used in food-to-food fortification. Then, if well structured, their value chains can strategically contribute to improving farmers' revenues and hence improve their livelihoods. These resources are also hands-on and local people use them raw, or partially processed. Among them, is the African baobab (*Adansonia digitata* L.). Several studies in different African countries have shown the need to domesticate and expand the use of this indigenous fruit tree (Gebauer *et al*., 2016). In many countries in West Africa including Benin, its leaves, and fruit pulp are the main ingredients in sauces, porridges and beverages preparation (Chadare *et al*., 2009). Recently, baobab has been referred to as a "superfruit" based on its nutritional profile (e.g. vitamin, fatty acid, mineral) (Gruenwald, 2009). For example, the consumption of 40 g of baobab pulp provides 100% of the recommended daily intake of vitamin C in pregnant women (19– 30 years) (Chadare *et al*., 2009). Its fruit pulp has a very high vitamin C content (up to 500 mg/100g dw, ~ ten times more than that of orange, and three times that of chocolate milk), hence high anti-oxidant properties. Its leaves contain important amounts iron, calcium and vitamins such as pro Vitamin A (Chadare *et al*., 2009; Chadare *et al*., 2014). Due to this exceptional nutritional value, baobab was in 2008 acknowledged as a novel food by the European Union (Regulation EC N°258/97 of the European Parliament) and also accepted as a food ingredient in the US.

Despite the huge nutritious and economic importance of the species pulp, leaves and derived products, their value chains (VC) in sub-Saharan Africa are still under-developed. Indeed, the species food products are still facing some challenges namely: (i) low competitiveness of actors along the entire value chains, (ii) safety of post-harvest leaves and pulp handling making it necessary to develop a

Hazard Analysis and Critical Control Point (HACCP) plan for these products , (iii) lack of or limited knowledge of private and public service providers for appropriate technology packages to promote baobab products, (iv) inappropriate rural development policies and programmes focusing on baobab, and (v) widespread mistrust between value chain operators, as well as between private and public stakeholders, making it necessary to establish an operating platform involving all stakeholders. Though pulp production is seasonal, techniques are being developed for its sounds storage to have adequate pulp throughout the year. For that, several studies and initiatives focused on baobab, and the project team members have substantially contributed to these efforts (Assogbadjo *et al*., 2009, Chadare *et al*., 2009, 2014, Hounsou-Dindin *et al*., 2016). These studies showed the potential of baobab for entering broader value-chains with a valuable contribution to sustainable agribusiness. However, over-exploitation of fruits have caused decline of the species population due to lack of natural regeneration (Sanchez *et al*., 2010). In addition, repetitive harvest of leaves from reproductive wild trees gives rise to reduced and late fruit production and ultimately to population decline. Therefore, to ensure sustainability it is necessary for farmers to engage in the production of both leaves and fruit, hence baobab cultivation. While baobab leaves are produced after three months of planting, fruits are produced after about 12 years. Recent studies conducted in Kenya showed that baobab can be successfully grafted. With this method baobab can start fruiting after about three years, a period significantly earlier than in the wild (Anjarwalla *et al*., 2017). Grafting of baobab has not been tested in Benin, and thus not accessible to farmers. In addition, performance of such techniques may be affected by biotic (pests, competition, etc.) and abiotic conditions (precipitation, temperature, humidity, soil etc.) which greatly vary across countries. It is therefore necessary to engage research for science-based advice and guidance of farmers and nurture the existing value-chains.

Based on the above demonstrated challenges, the project aims to combine both participatory research and capacity building actions to set a long lasting valorization scheme for the African baobab at a national scale in Benin. Specifically, the project will [i] diagnose baobab leaves and fruit pulp value chains, [ii] organize actors involved in baobab leaves and fruit pulp value chains (VC) into a platform and networks to ensure long lasting connections, [iii] develop market driven technological packages for baobab leaves and fruit pulp and derived-products to allow baobab cultivation and supply the market with safe and quality baobab derived-products, [iv] establish pilot incubators for baobab leaves and fruit pulp valorization in the project areas, [v] scale-up added-value novel technologies at country level, and [vi] develop an advocacy plan for better integration of baobab products in food and nutrition security strategies but also as agro-business opportunity at national level.

The main hypothesis underlying this research project is that "strengthening the baobab value chain with the adaptation of improved production technologies and their adoption by rural gatherers, farmers and agri-entrepreneurs will enhance nutrition, food security and livelihoods in Benin". Subsequent hypotheses are as follow: (i) Baobab value chain is non-structured with disconnected stakeholders, under-performing; (ii) Baobab reproductive performances vary across study sites; (iii) Length of stem cutting and number of nodes of cuttings positively affect their rooting and leafing abilities of the species; (iv) There is a lack of safety during post-harvest handling of baobab leaves and pulp as well baobab pulp packaging; and (v) Developed technologies are profitable with profitability differing for leaves or pulp.

The project is prepared such that it shifts from traditional conservation and poverty alleviation approaches to the use of a business-oriented approach with pro-poor growth strategy. Partners of the project include public research institutions (LABEF, LEA, LSA), local communities, three Technical

Vocational Education and Training (TVETs) institutions, Non-Governmental Organizations (Cidev-ONG, Jura-Afrique, Oe-Benin), and one private for-profit company ("La bourgeoise").

The project focus and implementation

The project is organized in six work packages (WP): WP1 - Diagnosis and mapping of the baobab value chains; WP2 - Participative organization of actors involved in baobab value chains; WP3 - Capacity building on market driven technological packages; WP4 - Establishment of pilot incubators for baobab products valorization in each project zones; WP5 - Assessment of farmers' perceptions and adoption of the market driven technological packages and the impact on household welfare (income, food security) and establishment of baobab garden/plantation, and WP6 – Scaling-up the novel technologies at country level through an advocacy plan for better integration of baobab products in food and nutrition security strategies at national scale.

WP1: The diagnosis consists of three major activities as follows:

1. Collaborative mapping of the baobab products value chain: Through stakeholder's meetings and survey, the structure (links and actors) will be mapped and roles/ responsibilities will be analyzed.

2. Assessment of the economic potential and environment of the baobab products value chains: Using market test and economic analyses, the market and value adding potential as well as the gain distribution will be estimated at different stages of the VC; Using network analysis, the VC governance structure, functioning, and supporting institutions will be described as well as political, legal, administrative and infrastructural framework conditions.

3. Participatory assessment of opportunities/constraints for leverage points identification: SWOT analysis will be coupled with an analytic hierarchy process (AHP) to describe supporting and inhibitor factors. Using root causes analysis, the challenges and opportunities that are critical for baobab products value chain (BP-VC) development will be identified, and hence used as points of leverage to either overcome constraints or to seize opportunities.

This diagnosis will result in (1) identification of stakeholders (VC operators, VC supporters and VC enablers) and existing networks; (2) clarifying the roles and responsibilities of all stakeholders for the performance and competitiveness of the VC and understanding of the degree and structures of interdependencies between the different stakeholders; (3) economic characteristics of the VC that covers market potential, cost-benefit relations and return on investments; (4) knowledge on benefit distribution among operators along the VC; (5) knowledge of the efficiency or deficiencies of linkage management by VC operators along the VC; (6) description of the institutions supporting the VCD, including strengths, weaknesses, opportunities and threats (SWOT), as well as needs for upgrading the capacities of service providers; and (7) description of the political, legal, administrative and infrastructural framework conditions, including analysis of their impact on VCD, and need for change.

WP2: Based on the detailed knowledge of the value chain from the previous WP, this second WP through a participative approach will organize actors involved in baobab value chains with the ultimate goal of creating a platform of actors and a strong network. This WP will be organized around two main activities:

Co-creation of platform involving all actors. The platform involves farmers, farmers' associations, NGOs working with farmers, women associations working within the baobab VC, the national business institutions;

Training of actors at micro, meso and macro levels involved in the baobab value chain and linking actors horizontally and vertically to boost the value chain. This activity was achieved through a three-day workshop whereby a baobab products fair was organized and presentations made on the baobab value chain. This contributed towards attracting more attention to the project. The Ministry of Industry launched the project along with the Rector of the University of Abomey-Calavi and the Vice-Dean of the Faculty of Agronomic Sciences.

WP3: In this WP, capacity building mainly involves baobab raw material (leaves and pulp) producers/ collectors, baobab products processors and marketers. This WP consists of both research and training. Research experiments will be set up to *identify best vegetative propagation methods that result in early reproduction of the baobab tree*. The research team has developed through a previous RUFORUM-GRG grant, a technical manual for producing baobab leaves from seed in a time frame of three months. This was a significant contribution in domesticating baobab. While this has been achieved for the production of leaves, less was done for fruiting. Precocious baobab fruiting is necessary to support the increasing demand for baobab pulp. Vegetative propagation techniques are known to make possible precocious fruiting (Akinnifesi *et al*., 2006; Anjarwalla *et al*., 2017). Two vegetative propagation techniques will be examined in this project, namely grafting and aerial marcotting. Grafting has been recently tested successfully in Kenya (see Anjarwalla *et al*., 2017) and need to be tested in Benin conditions. To our knowledge little is known on baobab marcotting which, if successful, is also a good way to quickly reproduce baobab. One M.Sc. student will study grafting techniques while the second will work on marcotting. Each M.Sc. student will be assisted by two B.Sc. students. For the grafting experiments, baobab scions will be collected from different zones of the tree. Scions of about 20 cm length will be grafted on rootstocks of different ages (2 years, 3 years, 4 years, 5 years). These trees exist from previous projects (RUFORUM-GRG, CORAF). A factorial 3-factor experiment with two replicates of 10 scions will be used. The three factors will be: 1 = rootstock age (2 years, 3 years, 4 years, 5 years); 2=grafting method (Top cleft and side veneer grafting methods); and 3 = mother tree. The 'new shoot', first branch developing from an active bud of the scion (and bearing new leaves) will be used to assess performance of the trials. Data will be collected on grafting success and the length of tagged new shoot produced. The most promising technique will be identified and used to train farmers during training workshops to inform and sensitize local people (farmers, extensionists, NGOs, and other stakeholders) on the best vegetative propagation methods. Each of the three TVETs will collaborate in this experiment. As far as experimentation for aerial marcotting is concerned, trees of five different ages (2 years, 3 years, 4 years, 5 years, 6-10 years: such trees exist from previous projects [RUFORUM-GRG, CORAF, DADOBAT]) will be combined with two substrates (sand and sawdust) to assess success of marcotting. At this step, the watering regime will be normal. Successful marcots will be transplanted. But at the transplantation stage, water stress may become a constraint and then negatively affect the regrowth. Therefore, at transplantation stage, two water regimes (normal water requirements versus stress) will be examined to identify which tree age and substrate better respond to water stress. Findings will help to develop a technical manual for successful marcotting of baobab. Therefore, in each region, a two-day training session will be done to demonstrate to farmers how young baobab trees can be cultivated to produce leaves and how vegetative propagation of baobab can be implemented for precocious fruiting. The ultimate goal behind this activity is to increase the supply of baobab products without jeopardizing the natural baobab trees.

Also, in this WP, capacity of involved actors in BVC (farmers, processors, wholesalers and retailers) will be building for post-harvest handling. For that, a research will be implemented to develop a HACCP plan for ensuring safety of baobab leaves and pulp. This work will consist of: (i) a hazard analysis of the traditional pulp extraction, (ii) elaboration of an HACC plan for pulp extraction for women association involved in the activity. In first place, HACCP team including processors and food scientists will develop a list of ingredients, materials and equipment used in the extraction of baobab pulp. Then, a process flow diagram of the baobab pulp extraction will be developed using a participative method involving the HACCP team. From this point, a hazard and risk analysis will be performed to identify the critical points which are important to monitor and ensure safety of the pulp to be produced. The seven (7) principles of the HACCP plan will be used to develop an appropriate HACCP plan for the traditional extraction of baobab pulp: (i) conduct a hazard analysis, (ii) determine the critical control points (CCPs), (iii) establish critical limits, (iv): establish monitoring procedures, (v) establish corrective actions, (vi) establish verification procedures, (vii) establish recordkeeping and documentation procedures. Next to the development of a HACCP plan for both baobab leaves and pulp, one pilot farmers' model processing unit with the contribution of partner NGOs will be set up in each region. This pilot unit will serve for training farmers on baobab leaves and baobab pulp post-harvest handling and conditioning for optimal baobab pulp and leaves powder conditioning.

WP4: This WP consists of two main activities: (i) Establishment of demonstration plots for baobab leaves and pulp production to train actors of the value chain. This demonstration plot will be a 3 ha garden per region. A local management community will be set up and farmers willing to establish a plot will be supported. TVET of each of the three regions will lead the management of this garden in collaboration with local authorities. The 30 students from the TVETs will be trained in writing business plans and applying for funding at the national youth business fund. (ii) Establishment of units for baobab pulp and leaves post-harvest handling to guarantee food safety, increase their competitiveness and to train actors of the value chains: A processing unit will consist of installing equipment for packaging dried baobab leaves and baobab pulp.

WP5: This WP stands is an impact assessment of all research and capacity building activities that have been done so far (from the first year of the project to now) before scaling out the novel technologies at country level. Indicators of success will include (but not limited to): (i) number of baobab seedlings or young trees per farmers, (ii) number and proportion of farmers with baobab young trees on their farms, (iii) number and proportion of farmers who have tried planting baobab trees, (iv) number and proportion of women with baobab young trees on their farms/gardens, (v) number and proportion of women who have used the fortified food-to-food formula, (vi) number and proportion of infant-children malnutrition, etc. The study design will be as follows: two types of village will be considered in each region, *control village* where no activity of the project has been implemented and *intervention village* (where all activities of the project have been conducted). In each village, baseline and endline surveys (6 months before the end of the) will be conducted and data collected on the above indicators of success. Difference-in-difference (D.i.D) approach (Abadie, 2005) will be used for data analysis.

WP6: Involves (i) developing advocacy plan toward policy makers at national, departmental and municipal to sustain functioning baobab value chain in Benin, (ii) enhancing market penetration and market access for the actors, (iii) creating an institutional framework including all stakeholders and connect it with other institutions of interests (private and public), and (iv) formalize the governance structure of the value chain.

Expected outputs and impacts of the project

The expected outputs include: [i] baobab leaves and fruit pulp value chains diagnosed and mapped in Benin, [ii] operating platform and networks actors of baobab leaves and fruit pulp value chains, [iii] market driven technological packages developed for baobab leaves and fruit pulp and derived-products, and stakeholders capacitated on these technologies, [iv] operating pilot start-up incubators for baobab products valorization in the project areas, [v] added-value novel technologies for baobab leaves and fruit pulp and derived-products scaled up country level, [vi] 1 PhD, 5 M.Sc., and 30 TVET students trained for impact-oriented research, and [vii] maintenance of collaborative working relations among researchers, farmers, market actors, national agricultural research and advocacy institutions, and government, TVETs.

The direct impact of the project will reach 300 farmers, 60 small and medium-sized enterprises involved in baobab leaves, fruit pulp and derived-products value chains, and 36 students. The targets groups include young, women, farmers' associations, TVETs, NGOs, students, and researchers. The project seeks to promote and nurture long term partnership between public research institutions, local communities, TVETs, NGOs, and private for-profit companies. The project envisages to improve actors' revenue through better organization of the value chains while contributing to food security and nutrition of households as well as sustainable conservation of baobab trees. Accordingly, through the development of the baobab value chains, this project is expected to stimulate the local economy through the development of business aspects of farming, postharvest handling and processing of baobab products. Some expected development milestones include: [i] stakeholders along the baobab value chains in Benin are connected, [ii] supply of raw materials (baobab leaves and pulp) is increased while pressure on wild population of the species is reduced, [iii] the safety and standard of baobab pulp and leaves are improved, [iv] new enterprises for valuing baobab products were created, [v] maximum of the add value generated by the chain benefits the local people (smallholders' and processors), and [vi] livelihood of baobab smallholders' farmers and processors is improved. Through its objectives, the project will strategically contribute to the fulfilment of the RUFORUM's vision since it aligns with its vision as well as the MasterCard Foundation mission. By contributing to agricultural diversification, safety baobab products, and improving farmers' revenues with emphasis on youth and women, the project also aligns with the Malabo declaration of African Union on accelerated agricultural growth but also the UN-SDGs (end poverty, zero hunger, good health and well-being, and gender equality).

Acknowledgement

Authors are grateful to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) and to MasterCard Foundation for funding this research through the RUFORUM Community Action Research Program PLUS (CARP+). This paper is a contribution to the Sixth Africa Higher Education Week and RUFORUM 2018 Biennial Conference.

References

Abadie, A. 2005. Semiparametric Difference-in-Differences Estimators. *The Review of Economic Studies* 72 (1): 1–19. DOI: 10.1111/0034-6527.00321

Akinnifesi, F.K., Kwesiga, F., Mhango, J., Chilanga, T., Mkonda, A., Kadu, C.A.C. and Ramadhani, T. 2006. Towards the development of miombo fruit trees as commercial tree crops in southern Africa. *Forests, Trees and Livelihoods* 16 (1): 103-121.

Assogbadjo, A.E., Kyndt, T., Chadare, F., Sinsin, B., Gheysen, G., Eyog-Matig, O. and Van Damme, P. 2009. Genetic fingerprinting using AFLP cannot distinguish traditionally classified baobab morphotypes. *Agroforestry Systems* 75: 157-165.

Chadare, F. J., Hooiveld, G.J.E.J., Linnemann, A.R., Nout, M.J.R. and Hounhouigan, D.J. 2014. Effect of cooking on *in vitro* on solubility of minerals and carotenoids in *Adansonia digitata*. *Annales des Sciences Agronomiques* 18: 1-19.

Chadare, F.J., Linnemann, A.R., Hounhouigan, J.D., Nout, M.J.R. and van Boekel, M.A.J.S. 2009. Baobab food products: a review on their composition and nutritional value. *Critical Reviews in Food Science and Nutrition* 49: 254-274.

FAO 2015. Regional overview of food insecurity in Africa. African food security prospects brighter than ever. Accra, FAO.

Gebauer, J., Adam, Y.O. and Sanchez, A.C. 2016. Africa's wooden elephant: the baobab tree (*Adansonia digitata* L.) in Sudan and Kenya: A review. *Genet Resour Crop Evol* 63 (3): 377–399. DOI: 10.1007/s10722-015-0360-1

Gruenwald, J. 2009. Novel botanical ingredients for beverages. *Clinics in Dermatology* 27 (2): 210–216, DOI: 10.1016/j.clindermatol.2008.11.003

Hounsou-Dindin, G., Assogbadjo, A.E., Idohou, R., Salako, V.K. and Glèlè Kakaï, R. 2016. Morphological variation of baobab fruits and seeds traits in smallholders farming systems in Benin: a preliminary study on baobab leaves production. *RUFORUM Working Document Series* 14 (2): 979 - 985.

Institut National de la statistique et de l'analyse économique (INSAE) [Bénin] et Macro International Inc. 2007. Enquête démographique et de santé (EDSB-III)-Bénin 2006. Institut National de la statistique et de l'analyse économique Bénin et Macro International Inc., Claverton, Maryland, USA. 492pp.

Anjarwalla, P., Ofori, D., Owino, A., Matuku, D., Adika, W., Njogu, K. and Kehlenbeck, K. 2017. Testing different grafting methods for vegetative propagation of baobab (*Adansonia digitata* L.) in Kenya to assist its domestication and promote cultivation. *Forests, Trees and Livelihoods* 26 (2): 85-95, DOI: 10.1080/14728028.2016.1202791

Sanchez, A.C., Osborne, P.E. and Haq, N. 2010. Identifying the global potential for baobab tree cultivation using ecological niche modelling. *Agroforest. Syst* 80 (2):191–201. DOI: 10.1007/s10457-010-9282-2

UNDP 2016. Human development report. New York, USA. 286pp.