Federal Ministry
of Food
and Agriculture

PROCESSING

Innovative approaches to process local food in Sub-Saharan Africa and Southeast Asia, which contribute to improved nutrition, as well as qualitative and quantitative reduction of losses

Project Acronym: *Quality improvement and more efficient utilization of products derived from the baobab tree (Adansonia digitata L.) to enhance food security and nutrition in Sub-Saharan Africa (BAOQUALITY)*

country/countries	Kenya, Malawi, Sudan
funding agency	Federal Ministry of Food and Agriculture - BMEL
project management	Federal Office for Agriculture and Food – BLE
project coordinator	Rhine-Waal University of Applied Sciences (HSRW)
project partner(s)	The Fraunhofer Institute for Process Engineering and Packaging (IVV), Freising, Germany Humboldt University of Berlin (HU), Berlin, Germany Mzuzu University (MU), Mzuzu, Malawi Lilongwe University of Agriculture & Natural Resources (LUANAR), Lilongwe, Malawi University of Khartoum (UKHART), Khartoum, Sudan Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya Wild Living Resources (WLR), Kilifi, Kenya Zankhalango Association (ZA), Mangochi, Malawi Associated partners: Justus-Liebig-Universität Gießen (JLU), Gießen, Germany

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project budget	932,076.51€ + 401,866.13€ (IVV) + €339,935.97 (HU)
project duration	01.09.2019 – 31.12.2022 (HU until 28.02.2023)
key words	Baobab (*Adansonia digitata* L.), indigenous fruit tree, food security, food quality, value chains
background	The baobab (*Adansonia digitata* L.) is a naturally occurring tree species in semi-arid parts of sub-Saharan Africa, which are also focal points of food insecurity and socio-economic marginalization. Because many parts of the tree can be used for food, the baobab has traditionally played an important role in food security and income generation, especially for marginalized rural communities. The rapid growth of the baobab processing sector, particularly in Malawi, has led to significant challenges that severely limit the benefits of baobab utilization, such as poor and inconsistent raw material quality, quality, safety and shelf-life issues in processed products, nutrient losses and waste streams during processing, or the prevalence of largely informal processing enterprises with low economic performance.
objective	The BAOQUALITY project aimed at improving the quality and safety of baobab products, optimizing local processing technologies, and increasing resource efficiency in the processing process in cooperation with partners from science and practice. This should help baobab producers and processors to improve their products and processing technologies and to diversify their sources of income. Ultimately, this should improve the supply of nutritious, safe and affordable baobab food, thus contributing to food security.
results	The main results of the project can be summarized as follows, taking into account the different work packages: **Work package 1: QUALITY ASSESSMENT OF BAOBAB PULP AND SEEDS ALONG THE SUPPLY CHAIN AND STORAGE** Since baobab, like many other fruits, is a seasonal product, much of the baobab pulp and seed obtained during harvesting is stored for an extended period of time. During storage, it is important to maintain the quality and safety of the products. Therefore, in Work Package 1, the quality change of bao-

bab pulp under different conditions was considered. Since expensive, time-consuming, invasive methods are usually used to determine the quality of baobab pulp, the use of a low-cost and rapid method can improve quality and safety within the value chain. As a possible alternative, the potential of near-infrared (NIR) spectroscopy for rapid and non-invasive determination of baobab fruit quality and authenticity was investigated.

The moisture content was identified as a particularly critical factor during storage. With increasing humidity during storage, a more pronounced change in quality (vitamin loss, colour changes) and a more rapid occurrence of mould infestation were observed. Without protective packaging, storage at 75% relative humidity already resulted in a significant loss of quality.

Oxygen is the critical variable for baobab oil with regard to its shelf life. Since suitable packaging materials (e.g. glass or metal) are already used, the storage of baobab oil is in principle less critical. However, a closer look at the value chain showed that unfavourable conditions exist in the extraction of the oil, or more precisely in the intermediate storage. Due to the low yield, it takes a relatively long time to fill the vessels for storage and they are therefore frequently opened again. This results in intensive access to oxygen despite suitable packaging materials.

For the application of NIR spectroscopy for quality determination, the stored samples were measured with a compact NIR handheld device. By mathematical correlation of the NIR spectra and the measured reference values of the product quality, models for the determination of the quality, safety and authenticity of baobab pulp could be established. NIR spectrometry was particularly suitable for determining the water content of baobab pulp. This allowed a rapid and non-destructive assessment of the microbial safety of baobab pulp.

Work package 2: QUALITY AND PROCESSING TECHNOLOGY IMPROVEMENT

A fundamental problem of quality and food safety of baobab products is contamination with microorganisms and mould toxins (e.g., aflatoxins). Therefore, contamination levels were investigated in ready-to-eat baobab products (baobab powder and sweets) obtained from selected formal and informal Kenyan processing plants. At baseline, baobab fruit powder from the informal sector had significantly higher microbial contamination than that from the formal sector. The research showed that measures such as the use of aprons and hairnets throughout production and clean workplaces can improve product quality and safety. Conducting training on good practices for harvesting, storing, transporting and processing baobab fruit and fruit powder, hazard analysis and critical control points can also effectively mitigate food safety risks in the future.

To further improve the quality and safety of baobab products, the results from work package 1 were applied to implement suitable measures to extend shelf life. Based on the knowledge of the influence of humidity on baobab pulp, various packaging materials were tested for their influence on shelf life in both laboratory tests and mathematical simulations. Packaging

materials with a high water vapor barrier, such as PP or PE, were particularly suitable for baobab pulp. With these packaging materials, a shelf life up to ten times longer could be achieved than with comparable packaging materials with a low water vapor barrier (e.g. PLA).

To extend the shelf life of baobab oil, the packaging concept was adapted using simulation models. The use of small packaging containers in which the air content is minimal leads to stable storage conditions within a very short time. If these are retained and not reopened, the shelf life is significantly extended. On the basis of the results obtained, the previously critical intermediate storage can thus be improved enormously.

The measures for optimizing the packaging of baobab pulp and baobab oil were communicated directly to stakeholders during workshops in Kenya and Malawi. For further dissemination of the measures, these were clearly recorded in written form as recommendations for action for the stakeholders.

In addition to optimizing the processing and packaging technology, the NIR spectrometer used in work package 1 was further optimized. Thus, NIR spectrometry was successfully applied to determine the water content through different packaging materials. The calibration models created were still able to determine the water content of baobab pulp despite different packaging materials and packaging thickness.

Work Package 3: VALUE CHAIN, POST-HARVEST LOSSES AND PRODUCER ASSOCIATIONS

Work package 3 explored collection and marketing patterns, post-harvest losses along supply chains, traders' awareness and attitudes towards baobab products, and the intra-household dynamics of decision-making in baobab activities. The study was conducted in three countries (Malawi, Kenya, Sudan), with a different focus in each country.

In **Kenya**, 352 baobab traders were surveyed on awareness of various baobab products. The variety of potential baobab products was rather low in rural and urban markets; overall, it was slightly higher among urban traders. The most popular products included porridge, juice, and sweets made from baobab, as well as processed and unprocessed fruit pulp. The local population saw baobab products primarily as a profitable source of income and related employment opportunities. Results showed that factors such as access to training and business registration positively influenced the technical efficiency of candy enterprises, while gender, distance to the market, and income from other sources had a negative influence.

In **Malawi**, data from 864 baobab collectors revealed that male baobab managers collected more baobab fruit and received a higher selling price for baobab fruit than female baobab managers. The men also received a seven percent higher price per kilogram of baobab fruit pulp than the women. This is equivalent to about nine euros per season. These differences can be explained by women's reproductive and household responsibilities (e.g., childcare, food provision). Therefore, women often have fewer opportunities to

visit more distant markets where better prices could be obtained.

We found that cooperative membership increased baobab income and household food security. Most commonly used selling outlets by baobab collectors were farmgate, rural market, and urban market. We showed that participation in off-farm market channels (rural and urban market) relative to farmgate, was associated with increases in baobab income and food security.

Analyses of postharvest losses showed that the greatest losses to whole baobab fruit and fruit pulp occurred during storage. Rot, mould, and microbial infestation, as well as fruit scavenging by insects and rodents, were found to be the major causes. In addition, 50% of baobab collectors surveyed cited inadequate drying, poor storage conditions (19%), and lack of knowledge about handling the product (17%) as other causes of losses.

In **Sudan**, the majority of baobab collectors and traders participate in domestic market. Urban markets (32%), local markets (29%), and processing plants (25%) served as the main channels for marketing, while small percentage of collectors and traders participate in export market outlet (an estimated 26% of traders exported baobab).

Analyses of intra-household dynamics showed that men were the main decision makers in baobab activities compared to women. For example, compared to women, men made the most decisions regarding the source of credit (53% vs. 39%), the amount of baobab fruit to sell (51% vs. 38%), and the timing of baobab collection (48% vs. 36%).

Work Package 4: PRODUCT INNOVATION CAPABILITIES AND SYSTEM-LEVEL SUPPORT

In work package 4, we developed an innovative energy source from baobab shells, conducted a characterization of the informal baobab sector, and created a valid model to support innovation.

Innovative energy source: Due to the high demand for firewood and charcoal in Malawi, forest resources are threatened in many areas. Alternative, environmentally friendly energy sources are of great importance. Therefore, the suitability of baobab fruit shells, currently a waste product from baobab fruit production, as a renewable energy source was investigated. Due to their high lignin and cellulose content, they have a high calorific value and are suitable as a fuel. Since their irregular shape and low density make handling and transport difficult, the project produced briquettes from baobab shells, also in different mixtures with other agricultural wastes. Analytical results of the physicochemical properties of the different briquettes showed that pure baobab briquettes have the most favourable technological properties.

Characterization of the informal baobab sector: From our studies of the baobab sector, three types of baobab enterprises were identified: Highly profitable enterprises with growth (type 1, 13% of the sample), profitable enterprises (type 2, 29%), and enterprises in survival mode (type 3, 55%).

	Firms of types 1 and 2 were more likely to benefit from formalization than were firms of type 3. The economic success of the firm was closely linked to start-up motives such as wealth accumulation, creation of new jobs, and adoption of certain business practices, especially in the areas of marketing, accounting, and financial planning. **Innovation promotion model**: Six factors were identified to promote innovation performance of Baobab enterprises. These are owner/manager human capital, business networking, intellectual property management, knowledge management, institutional integration, and access to finance. The model will serve as a guide for entrepreneurs and consultants to promote the innovation performance of baobab processing enterprises through targeted interventions. **Work package 5: PROJECT MANAGEMENT AND DISSEMINATION ACTIVITIES** Various measures were taken to inform relevant stakeholders about the project's results. For example, training materials on quality measures in baobab fruit processing were produced and videos for aspiring baobab entrepreneurs were developed. Project results were presented at various conferences (e.g., the Tropentag, the Baobab Conference 2020, the International Online Conference on Forests – Sustainable Forest Ecology in 2021, and the International Food and Agribusiness Management (IFAMA) Conference and the XV World Forestry Congress in 2022) and published in peer-reviewed journals. All master's students and PhD students were able to present their findings to other baobab researchers, practitioners, and policy makers at the final workshop in Lilongwe, Malawi. Based on the results of work package 4 on the production of baobab briquettes, a business plan for the districts of Mangochi and Dedza was developed together with the Malawian NGO *Zankhalango Association*. Based on the business plan, it was possible to finance a briquette press, with the help of which *Zankhalango Association* will start the production of baobab briquettes. Training was also provided to further strengthen the capacity of local baobab smallholders in Kilifi, Kenya, thereby improving the quality of the pilot plantation. In addition, quality improvement activities were carried out at the baobab pilot plant from the BAOFOOD project to increase the productivity of baobab products and establish a fully functional baobab processing plant that produces baobab fruit pulp and powder.
recommendations	Baobab makes an important contribution to food and income security in East Africa. In addition, the production of baobab briquettes has the potential to reduce local pressure on forests. To promote the sustainable development of the sector and to better and more sustainably exploit its potential, further efforts should be made, both in the value chain and at the scientific level. • NIR provides a rapid, non-destructive alternative for determining the quality and authenticity of baobab fruit that can also be implemented in

	the field by stakeholders in the value chain. • In particular, the direct purchase of baobab fruit pulp through intermediaries as opposed to closed fruit prior to processing increases the risk of microbial contamination. The risk of contamination is also higher in informal production. Training can reduce these risks. • The local population should be sensitized to the nutritional and health-promoting properties of baobab products in order to further develop the demand for baobab, especially in view of the increasing urbanization in sub-Saharan Africa. • Collective action through cooperatives in the sector of underutilized crops should be promoted through training on organizational development. • Access to rural and urban markets should be promoted, e.g. through improved access to market information and improvement of rural infrastructure to reduce transaction costs. • To reduce post-harvest losses, training to improve product handling and the introduction of standards on work instructions should be implemented. • Residues from baobab fruit processing offer various uses and can increase the efficiency of baobab processing plants. Baobab briquettes can be a sustainable alternative to firewood and charcoal. In contrast, cultivation and marketing of baobab root tubers proved less feasible and more in-depth studies on commercial potential are needed. • To identify informal enterprises that have the potential to formalize and benefit from doing so, policy makers should focus on informal baobab enterprises that generate a high annual net profit, have good business practices (e.g. financial planning, marketing), implement more formal systems and controls in their business operations, and are opportunity-driven. • To promote formalization in the baobab industry, policymakers should reduce entry costs (e.g. free registration, reduced tax burden), increase the benefits of formality (e.g. access to finance), and improve the human capital of baobab entrepreneurs (e.g. business management skills). • To improve the business performance of informal baobab enterprises and their growth potential, owners/managers should be guided by opportunity motives and adopt good business practices such as marketing, financial planning, inventory management, and accounting. • To promote innovation performance, entrepreneurs in the baobab industry should improve their human capital (e.g. transformational leadership) and build their capacity in networking, intellectual property management, knowledge management, institutional and institutional environment integration, and financing. Policy makers, on the other hand, should provide institutional support (financial and technical) for innovation. • Further research should help better understand how to sustainably use baobab resources, assessing existing baobab resources and fruit quantities that can be used sustainably, executing studies on the effects of cli-

	mate change on the future use of baobab stocks, long-term experiments on the domestication of tree individuals with superior characteristics, as well as the development of baobab agroforestry systems to adapt to climate change. • Further research is needed to improve understanding of health benefits from baobab consumption, including the underlying physiological mechanisms.
photos	 a) NIR-device with baobab powder (©Dennis Yegon).  b) Baobab tree and Baobab fruit (©Kathrin Meinhold)  c) Baobab fruit pulp and baobab juice (Left: ©Matthias Kleinke; right: ©Kathrin Meinhold)