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Correlates of Product Quality of Soumbala, a West African Non-timber Forest Product

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Research

Abstract

Knowledge of the correlates of product quality is a prerequisite for further commercialization of **soumbala**, a food product extracted from the leguminous tree *Parkia biglobosa* (Jacq.) G. Don. In this study qualitative and quantitative data derived from interviews of producers and expert users are used to estimate the influence of *P. biglobosa* management practices, **soumbala** product processing practices, and nutritional composition of **soumbala** on perceived **soumbala** quality. Several variables on management practices correlated with high quality **soumbala** as revealed by binary logistic regression, with quality as the dependent variable and six management related variables as independent variables. Variables relating to product processing were examined using qualitative data from group sessions, gathering all the producers in a given village. Finally the relationship between nutritional composition and **soumbala** quality was determined. The results show that local knowledge, management practices, and product processing practices are correlated with **soumbala** quality, whilst nutritional composition is a poor predictor of **soumbala** quality.

Introduction

Soumbala is a locally produced, vegetarian, protein-rich food product produced from the fermented seeds of the leguminous tree *Parkia biglobosa* (Jacq.) G. Don. *Parkia biglobosa* is widely distributed across the Sudanian and Guinean climatic zones in Africa, from Senegal in the west to Sudan in the east. It is protected by the farmers due to its resilience and high subsistence and economic value (Lamien *et al*. 1996). **Soumbala** has remarkably high protein content (Nordeide *et al*. 1996) and is consumed throughout West Africa, often in 80% of all meals (Mertz *et al*. 2001). **Soumbala** is available all year round, which makes it particularly important in periods when other food products are scarce. In south-western Burkina Faso, where this study took place, *P. biglobosa* plants easily regenerate to maintain viable populations and are managed on a sustainable basis (Ræbild *et al*. 2007) in contrast to populations in other West African countries and other parts of Burkina Faso (Hall *et al*. 1997). **Soumbala**'s nutritional qualities, economic importance, resilience, and sustainable management make it an obvious target for further research. It is an example of a traditional non-timber forest product (NTFP), which has the potential to improve economies and livelihoods of rural people.

Local consumers of **soumbala** have a clear perception of quality. Meeting the consumers' quality standards is an important prerequisite for successful commercialization.

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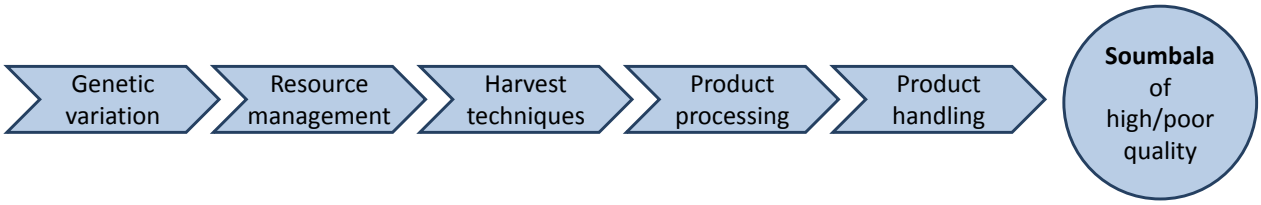

Figure 1. Flow diagram showing the most important factors controlling **soumbala** quality in Burkina Faso.

In order to do so it is obvious to take advantage of the local knowledge available on matters influencing product quality. Local knowledge on genetic variation, resource management, harvesting techniques, product processing, and product handling is crucial in the planning of **soumbala** trade (Figure 1). In this context it is particularly relevant to understand womens' perception of quality, because they are the decision makers in the household when it comes to purchase and preparation of food. The implementation of research that builds on local knowledge is more sustainable since it rests on tradition and empirically tested practices.

In this study we focus on perception of quality and the link between quality and local practices in resource management and product processing. We believe this is an important first step to further commercialize **soumbala**. It is hypothesized that local women have profound knowledge on how to manage *P. biglobosa* trees in order to produce many high quality fruits. Moreover, it is hypothesized that local women have a clear understanding of the importance of the various steps in the product processing chain and that they have an impression of what results in high quality products.

To promote food security and nutritional value it will be particularly rewarding to explore the differences in nutritional composition in what is perceived locally as high and poor quality **soumbala**, respectively. In the West African region 80% of the total consumption is based on domestic food production (USDA/ERS 2000) and 96% of agricultural activities are sensitive to rainfall patterns (World Bank 2008). Due to *P. biglobosa*'s adaptation to local climate conditions and the high protein and fat content of its seeds, **soumbala** is today a valuable NTFP. The outstanding question is whether local perception of quality correlates to high nutritional value or other attributes such as texture and flavor, providing an indication of what to focus on in future commercialization initiatives—physical characteristics or nutritional content.

Despite **soumbala**'s great potential for improving food security and quality, a basic understanding is still lacking of the economic botany of this NTFP and the prerequisites for further commercialization. In this study we address four research questions, the answers of which will provide us with novel information on local perception of good quality, best practices in resource management, and product processing as well as nutritional composition of various grades of **soumbala**. The results will provide valuable insight on exploitation and commercialization of NTFPs in West Africa in general which is a prerequisite for inducing an ecologically and economically sustainable agricultural development in the region.

The specific research questions we addressed are: (1) How is good quality of **soumbala** perceived across households? (2) Is there a correlation between resource management and harvesting practices and good quality **soumbala**? (3) Which are the production procedures that promote good quality? and (4) Is nutritional composition of **soumbala** a strong determinant of good quality **soumbala**?

Materials and Methods

Study area

The study was carried out in south-western Burkina Faso, in the Province of Comoé, in the Cascade Region, approximately 400 km southwest of the capital Ouagadougou. The study area covers ten villages situated around a state-protected forest called Boulon-Koflandé (09°53'–10°25'N and 04°20'–04°46'W) (Figure 2). The Province of Comoé has a population density of 20.9 inhabitants/km^2 (INSD 2008), and the total population in each of the 10 villages varies between 464 and 4135 individuals (L'Inforoute Communale du Burkina Faso 2005).

The study area is situated within the South-Sudanian phytogeographic zone (Guinko 1984) and receives a mean annual precipitation of 1000–1200 mm mainly during a single rainy season from April to October, with a peak in July–August. A maximum average monthly temperature of 36°C is recorded from March through May, and a minimum average monthly temperature of 17°C is from December through February. The terrain is flat with an average elevation of 270 m asl and is located within the drainage area of Comoé River. The vegetation of the study area is a mosaic of savanna with patches of forest. The savanna has a continuous layer of perennial grass species and a more heterogeneous layer of woody species. *Parkia biglobosa* and other woody species occur abundantly in intercropping systems and fallow lands, although it is relatively rare in the savanna area (PAGEN 2005).

Human diversity is high with 14 ethnic groups present within the study area. Three of these are autochthonous:

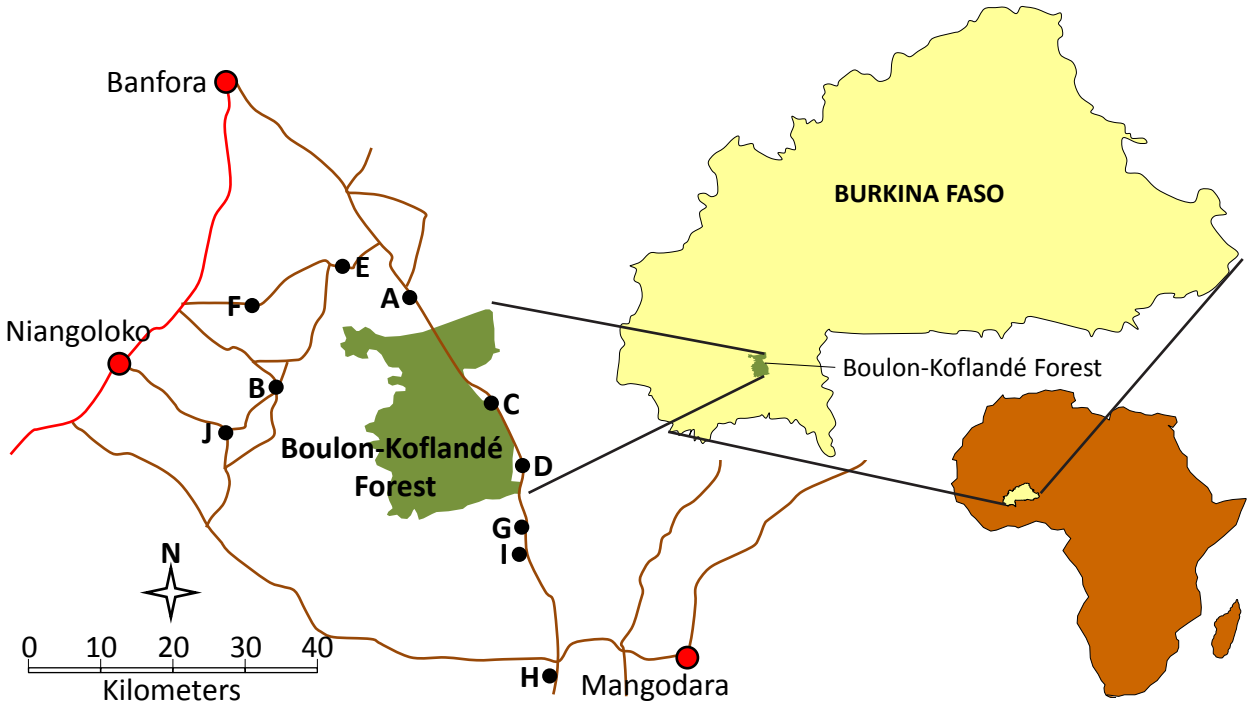

Figure 2. Location of the study area in the Province of Comoé, in the Cascade Region in southwestern Burkina Faso. The state-protected forest, Boulon-Koflandé, is shown in green, and the 10 villages visited during interviews are indicated with black dots: (**A**) Boulon, (**B**) Diéfoula, (**C**) Koflandé, (**D**) Linguèkoro, (**E**) Sakora, (**F**) Sankara, (**G**) Sokoura II, (**H**) Tomikorosso, (**I**) Torokoro, and (**J**) Toundoura.

Karaboro, Dogossè, and Gouin. Traditional subsistence farming is widespread combined with cultivation of cash crops such as cotton (*Gossypium barbadense* L.), mango (*Mangifera indica* L.), cashew (*Anacardium occidentale* L.), and the shea nut (*Vitellaria paradoxa* C.F. Gaertn.). Additional agricultural activities comprise livestock raising and extraction of NTFPs as well as rather intensive collection of firewood from the surrounding woody vegetation (PAGEN 2005).

Data collection

Collection of **soumbala** samples, interviews, and meetings were conducted in the ten villages between November and December 2010, and in November 2011. The villages and their markets were visited on the local market-day. A total of 81 **soumbala** were collected using purposive sampling. The collection constitutes a representative segment of the **soumbala** available, and the samples size is what was available, still creating a solid foundation for the analyses required. The **soumbala**-selling women were found through snowball sampling (Goodman 1961), and one **soumbala** was selected randomly from each of the women (21 for quality assessment in relation to nutritional analyses and 60 for quality assessment in relation to management practices). Structured interviews were conducted with 60 producers of the **soumbala** to gain insight into the influence of management practices (Appendix A) on **soumbala** quality (Appendix B). All interviews were performed in the language Djula. We used the same translator for all the interviews: a Burkinabé with a broad knowledge of the culture and language. A typical interview lasted approximately 10–20 minutes. Moreover, group sessions were organized with all interested **soumbala** producers (all women) in the area. Here the optimization of the various steps in the product processing was discussed (Appendix C). To assess the quality of the **soumbala** samples, both in relation to the management practices and nutritional analyses, we appointed a panel of five experts. An effort was made to minimize the bias of the panel, thus the members were not related and had no particular interest in promoting their own products. The **soumbala** experts were designated according to their qualifications in preparing and dealing with **soumbala**. Consensus among at least four out of five experts was chosen as criterion for any given quality label. The quality assessment was done by blind tasting. The questionnaire was rendered based on experience from previous ethnobotanical fieldwork in Burkina Faso.

Seven different nutritional analyses were conducted on the **soumbala**. We used the standard methods described by the Association of Official Analytical Chemists to determine the content of moisture, fat, protein, and ash (g water/100 g sample) (AOAC 1990). Moisture was determined by drying a 3 g sample at 105°C to constant weight.

Crude fat was measured by placing 5.0 g of each sample in a Soxhlet apparatus and washing it with petroleum ether (boiling point range 40–60°C). The nitrogen content was quantified and the results multiplied by a factor of 6.25 to reach an estimate of the crude protein content. Ash content was measured in a 2–3 g sample exposed to combustion in a muffle furnace at 550°C for eight hours. The content of carbohydrates was estimated by subtracting the sum of the weights of crude protein, crude fat, and ash from the total dry matter. β-carotene and vitamin E (measured in **soumbala** oil) were determined based on the column liquid chromatography method (Ake *et al*. 1998). For each of the 18 **soumbala** the seven nutritional analyses were conducted three times.

Data analysis

Local knowledge

Among the 60 respondents who were questioned about their perception of quality and management practices, we chose the 31 respondents who themselves produced high quality **soumbala** (based on the experts' quality assessment) and based the characteristics of high quality **soumbala** on the answers provided by these 31 respondents.

Management practices

Forty-five of the 60 **soumbala** were classified by the experts as either of high quality (31) or poor quality (14). Binary logistic regression analyses were conducted to determine the importance of various variables as determinants of **soumbala** quality. Eleven independent variables were chosen for the logistic regression analyses that were all more or less management related. Only six of these showed sufficient variation among the samples to be included: pruning, burning, weeding, fencing, sowing, and fallow (Appendix D). The performance of 64 models that comprised all combinations of these six variables was tested. Akaike's information criterion corrected for small sample sizes (AICc) was calculated to assess each model, together with their appertaining delta values (the difference in AIC from the best model, ∆AIC). Models having a delta value ≤ 2 where among the models regarded as having profound support (top models) (Burnham & Anderson 2002). Akaike weights (w) for each of the 64 models were computed to give insight in model performance (probability that a given model is best). The relative importance of the independent variables was calculated as the sum of their respective Akaike weights across all models. Finally, we computed the correlations between quality and each of the independent variables as averaged parameter estimates. These were weighted according to the Akaike weights of the respective models. Parameter estimates give an indication of the direction of the correlation (Burnham & Anderson 2002, Grueber *et al*. 2011). Statistical analyzes were performed using the MuMIn package in R (R 2.14.2, R Development Core Team 2012).

Nutritional composition

Eighteen out of the 21 **soumbala** samples used to explore the link between quality assessment and nutritional analyses were classified by the experts to be either of high (9) or poor quality (9). For each **soumbala** a mean was calculated based on the three replicates for each of the analyses. Subsequently, these numbers were used to calculate the overall mean and the appertaining standard error for the two qualities in each of the seven analyses. Finally, differences in means for the two qualities were compared using student's t-test. Statistical analyses were performed using JMP 9.0 (SAS Institute Inc. 2010).

Results

Local knowledge

The 31 respondents answered relatively unanimously when asked about their perception of **soumbala** quality. Within the predefined categories of the four **soumbala** characteristics — seed size, seed color, smell, and texture — the majority of respondents cited the following indicators of representatives for high quality: mixed sized seeds, brown black seeds, strong smell, and dry texture (Figure 3).

Management practices

No variation was found in the variables fertilizer, harvest, intercropping, irrigation, and livestock. All respondents cultivated crops in combination with *P. biglobosa* and having livestock on their fields, and they were all harvesting fruits sustainably. No respondents fertilized trees directly, and none used irrigation.

Models with a ∆AICc > 2 were discarded, leaving only four variables to constitute the top models (pruning and fencing were omitted). The AIC value and relative importance of the variables clearly showed that the models including the weeding and fallow variables performed best (Tables 1, 2). Based on a parsimony principle we chose to continue with the FW model as best model since it explains a high amount of variation with a minimum number of predictor variables.

The direction of the correlation between quality and the variables in the best model is computed in the parameter estimates. From Table 2 it can be seen that fallow is negatively correlated and weeding is positively correlated with **soumbala** quality.

Production procedures

Product processing methods that, according to local knowledge, are associated with good quality **soumbala** are shown in Table 3. There was general consensus among the informants on the production methods which

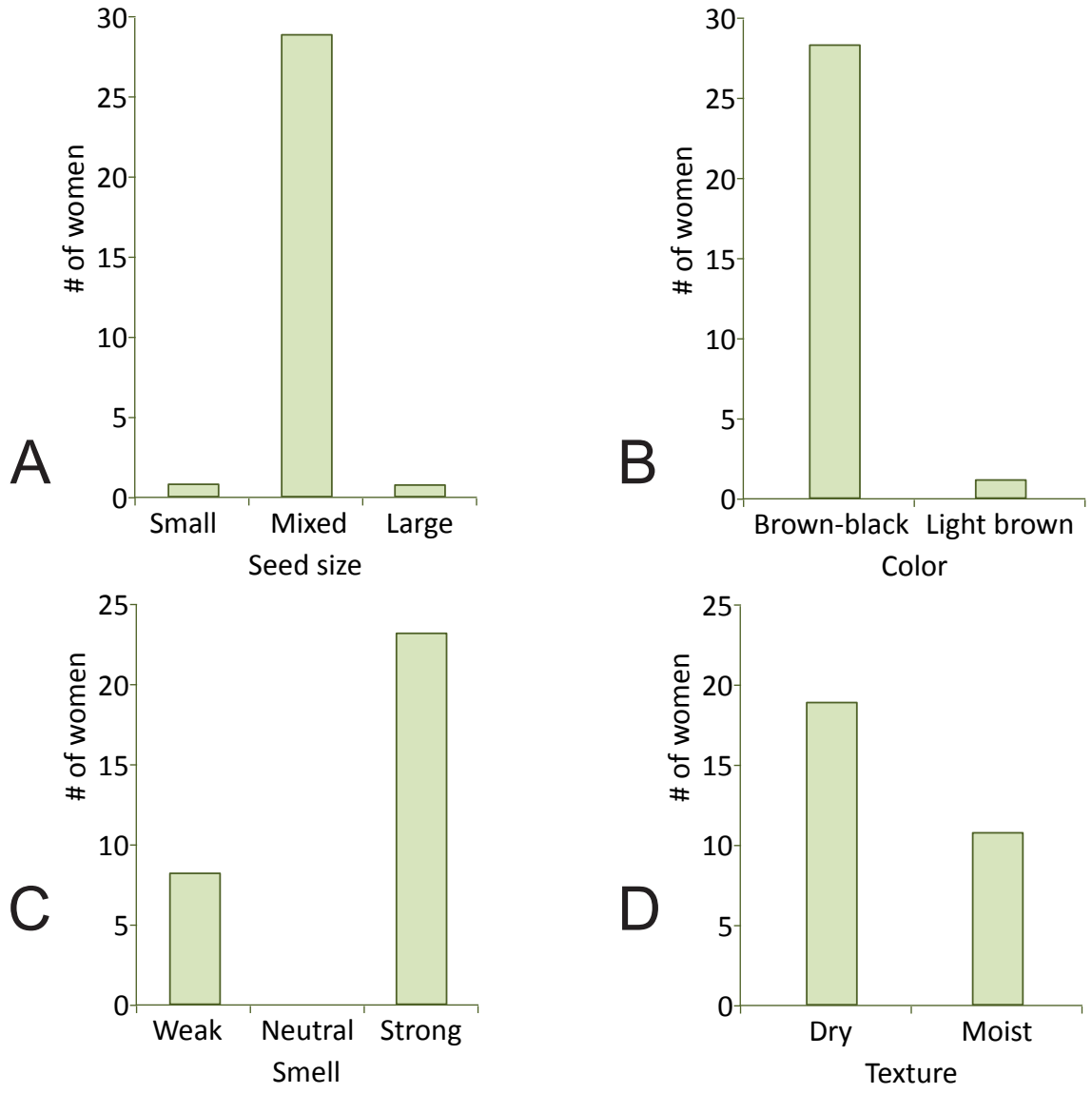

Figure 3. Number of respondents relating a certain characteristic to high **soumbala** quality in southwestern Burkina Faso (N = 31). Respondents providing the same answer are summed. The four characteristics, with subcategories, are (**A**) seed size, (**B**) color, (**C**) smell, and (**D**) texture.

Table 1. Logistic regression models of the **soumbala** quality as predicted by different character combinations (burning (B), fallow (F), sowing (S), weeding (W)) in southwestern Burkina Faso. The number of variables in each model (including the constant) is shown together with AICc, ΔAICc and the Akaike weights (w). (N = 45). Text and numbers in **bold** indicates the best model.

	# of variables	AICc	ΔAICc	w (%)
FSW	4	51.19	0.00	0.33
FW	**3**	**51.32**	**0.14**	**0.30**
BFW	4	51.96	0.78	0.22
BFSW	5	52.76	1.58	0.15

Table 2. Summary results of the logistic regression modeling of **soumbala** quality in southwestern Burkina Faso as a function of the four variables after model averaging. Parameter estimates (indicating the direction of the correlation) and their standard errors (SE) and each variable's relative importance are shown. (N = 45).

	Estimate	SE	Relative importance
Burning	-12.7510	10.9750	0.37
Fallow	-0.6195	0.3131	1.00
Sowing	-13.4950	0.9643	0.47
Weeding	21.4610	0.8999	1.00
Constant	21.9480	12.3540	-

Table 3. Schematic overview of the critical steps in the processing of high quality **soumbala** in southwestern Burkina Faso.

Activity	Duration (hours)	Processing description	Smell at end of process	Additives	Additional information
1st cooking	36	Seeds are boiled at low heat.	Weak	-	The water used should be relatively clean in order to avoid unnecessary contamination.
Dehulling	-	The seed coat of the hot seeds is removed in a mortar. Ash is added to ease removal of the seed coat.	-	Ash	
Washing	-	Seeds are washed to remove the ash.	-	-	The water used should be relatively clean.
2nd cooking	3–4	The dehulled seeds are boiled to prepare them for fermentation.	Medium	-	Seeds are boiled once more to prepare them for fermentation.
Fermentation	72	The cooled seeds are placed in a closed container to allow the seeds to ferment.	Strong	Mango leaves, maize flour, whole chilies	It is important that seeds are kept sterile since unwanted bacteria will affect the fermentation negatively. Other ingredients may be added to give flavor, but only by some producers.
Drying	50–80 (daylight hours)	Previous to shaping into balls, the fermented seeds are dried for 12–24 h. The **soumbala** is then dried additionally until it has the desired texture.	Strong	-	Proper drying in the sun is important since the **soumbala** will otherwise spoil after a short period of storage. The number of hours before sufficient drying depends on the strength of the sun.
Storage	-	The dried **soumbala** is placed in a closed container and stored in a dark place.	-	-	**Soumbala** will keep for about a year without spoilage.

lead to high quality **soumbala**. These are: harvesting of ripe seeds only, elimination of physically flawed seeds, washing and boiling of seeds in relatively clean water, fermentation under controlled conditions, and drying of the **soumbala** before storage.

Nutritional composition

Except for moisture and ash value, all nutritional variables showed insignificant differences between the high and poor quality **soumbala** respectively (Table 4).

Table 4. Nutritional composition of **soumbala** in southwestern Burkina Faso. Means and standard errors (SE) are given for each of the two qualities based on duplicate or triplicate analyses (N = 18). The p-values from a comparison of the means for the two qualities are shown. Significant values are indicated with an asterisk (α = 0.05, student's t-test). [a]Calculated by difference.

	Quality				
	High (N = 9)		Poor (N = 9)		
	Mean	SE	Mean	SE	p-value
Moisture (g/100g)	11.00	±0.96	13.60	±0.69	0.0370*
Lipid (g/100g)	21.63	±1.06	22.68	±1.89	0.6065
Protein (g/100g)	37.25	±0.77	36.62	±1.58	0.7016
Ash (g/100g)	3.14	±0.08	3.56	±0.18	0.0345*
Carbohydrate[a] (g/100g)	37.98	±1.35	37.14	±2.17	0.7292
β-carotene (µg/100g)	8.36	±1.36	8.95	±0.71	0.7010
Vitamin E (µg/100g in **soumbala** oil)	433.20	±27.66	461.85	±21.04	0.4058

Discussion

Local knowledge

Our results reveal that a consensus existed among the respondents on what defines high quality **soumbala**. The characteristics are (1) mixed seed size, (2) brown-black seeds, (3) strongly smelling end product, and (4) dry texture of end product. This consensus on quality criteria is an important foundation for development of future commercialization plans.

Interestingly respondents did not prefer uniform seeds but rather a mixture of sizes. Seeds constitute less than 20% of the total pod weight with pulp comprising the major part (Oni 1997). Future breeding programes should focus on an increased numbers of seeds versus high pulp content, since income from **soumbala** sale exceeds that of pulp.

According to respondents brown-black seeds will give a better quality of **soumbala** as opposed to light-brown seeds. The color is genetically determined (Teklehaimanot 1997) and may change through the various steps in the product processing. Cooking of seeds and fermentation affect the color of the seeds towards a darker color (Sadiku 2010).

Respondents claim that high quality **soumbala** have a characteristic strong smell, which is the result of proper fermentation. Beaumont (2002) and Sarkar *et al*. (1994) revealed a correlation between smell and fermentation as well and demonstrated that the conversion of proteins into free amino acids and derived metabolites gives rise to the very distinct smell associated with **soumbala** and other products fermented by *Bacillus* species. Good quality **soumbala** is furthermore characterized by being dry. Sun exposure is used to bring down the water content (Beaumont 2002). The drier the **soumbala**, the better its storage capability. Figure 3D shows that **soumbala** sold for immediate consumption may be moist but still considered of a high quality. In some cases this “fresh” **soumbala** is further dried by the customer for storage.

Management practices

Management practices influence the quality of **soumbala**. Providing optimal conditions for trees will not only increase the survival of the critical saplings and juvenile plants but also result in higher quality seeds. If the basis material is good, there is a good chance that the end-product is of high quality if processed correctly. Our results show that it is both possible and relevant to develop management plans with the aim of promoting high quality **soumbala**.

Two management variables correlated with **soumbala** quality: weeding and fallow (Tables 1, 2). Weeding around the stems of smaller trees has the added benefit that risk of death by wildfires is minimized. Since wildfires are frequent in the study area it is crucial to protect seedlings by removal of the surrounding flammable weeds. The negative correlation between fallow periods and **soumbala** quality is the result of a complex interaction of soil-related factors. Plowing will in general allow water to infiltrate more easily in the soil in comparison to untreated fields. The roots of *P. biglobosa* are distributed in the upper layers of the soil and extend more than 10 m away from the trunk (Tomlinson *et al*. 1998). This implies that although the crops are not grown in immediate proximity of the trees these will still benefit from the fertilization of the fields. This is in contrast to the fallows where trees will rely on nutrients released from the manure of freely roaming livestock. Odebiyi *et al*. (2004) noted that the pressure from pests that may affect fruit quality may be lower in cultivated fields than in fallows. This may be a result of pest control practices, but more research is needed before a conclusion can be drawn on the subject.

The two management correlates of **soumbala** quality that were identified in this study should be considered when developing management plans and making recommendations to the stakeholders. Caution should be taken not to disregard the other four management variables (pruning, burning, fencing, and sowing) despite the fact that no correlation with **soumbala** quality was demonstrated, nor the five initial management variables that lacked enough variability among the samples to warrant further testing (fertilizer, livestock, irrigation, harvest method, and intercropping). These are still interesting from a socio-economic perspective and should not be overlooked when developing management plans. Management plans developed to improve **soumbala** quality should take a starting point in farming traditions and only suggest socio-economically sustainable changes.

Production procedures

The main purpose of the processing of **soumbala** is to transform a plant part that is basically indigestible for humans into a nutritionally rich and tasty food product. The results revealed a consensus among the respondents concerning which steps in harvesting and processing are critical for obtaining a high quality product: harvest of ripe seeds only, elimination of flawed seeds, washing and boiling of seeds in clean water, fermentation under controlled, non-contaminated condition, and efficient drying of the end product before storage. These critical steps in the production of **soumbala** correspond well with those mentioned in previous reports on the subject (Gernah *et al*. 2007, Odunfa *et al*. 1985a, 1985b, 1986).

Not all the critical steps in the processing of good quality **soumbala** are easily fulfilled. Producers are generally skilled when it comes to elimination of flawed seeds. However, obtaining mature seeds is often difficult due to competition from various animal species that eat both unripe

and ripe fruits (Kunz & Linsenmair 2007). A common practice is to cover the trees with nets during the months that lead up to the harvest.

It is important with a set of minimum standards to assure a consistently high **soumbala** quality. Current practices are rather uniform, and the producers share an awareness of the pitfalls associated with production of **soumbala** as summarized in Table 3. Nevertheless certain steps in the processing need reconsideration. Thus the respondents repeatedly indicated the importance of using clean water for boiling and washing of the seeds, e.g., newly collected groundwater. This is a critical point since access to clean water is restricted in many rural areas and contamination may occur in various ways shortly after it has been collected at the well or tap (Wright *et al*. 2004). Whereas it may be difficult to put in more taps in the villages, it seems more feasible to train the producers of **soumbala** to correctly handle the water used in the processing. It is particularly important to avoid microbial contamination prior to or during fermentation, since this may impact the **soumbala** quality negatively. To meet the demand for a stable supply of good quality **soumbala** additional research on optimization of the production is needed.

Nutritional composition

Our results show that the nutritional value of both high and poor quality **soumbala** is high in accordance with previous studies (Gernah *et al*. 2007, Nordeide *et al*. 1996, Sadiku 2010). This is important in developing countries where animal sources of protein are in low supply and expensive and vegetable alternatives often are used daily. The protein content of **soumbala** is equal to or even higher than most types of meat and as found by Nordeide *et al*. (1996) includes several essential amino acids. Since **soumbala** also has a high content of fat it supplements the staple food and thereby fulfils the dietary needs even in small amounts. Only ash and moisture content showed significant differences between qualities, with poor quality **soumbala** containing both most ash and most water. Ash is used here as the collective term for inorganic materials such as metals, salts, and trace minerals. In terms of nutritional value the difference in ash seems of less importance. Food products with high fat content and relatively low water content such as **soumbala** have a high energy density, a property that is crucial in developing countries struggling with food security (Prentice & Paul 2000). Still, a minor difference, although significant, in moisture seems not to be relevant in a broader context.

The nutritional content in high and poor quality is, as discussed above, relatively identical, implying that respondents' perception of quality is based on other aspects than nutritive ones. It could be assumed that there would be a correlation between nutritional content and a woman's choice of **soumbala**, unconsciously choosing **soumbala** with a higher nutritional content. However, this seems not to be the case in the present study. Instead it is the physical characters of **soumbala** which seem to be the criterions under scrutiny by consumers. Since the nutritional value of high and poor qualities of **soumbala** are not significantly different, future commercialization efforts should focus on aligning the physical characteristics of the end product with consumer demands, hence promoting a product comprised of mixed sized, brown-black seeds with a strong smell and dry texture.

Conclusions and Further Research

This study provides novel information on household perception of the physical characteristics of high quality **soumbala** produced in rural areas. It makes a case for improvement through both management practices and production procedures. Finally it shows how perception of quality is primarily determined by physical characteristics and not so much by differences in the nutritional composition. **Soumbala** has a key role in developing rural livelihoods through food security and improved income generation, and baseline information like this is crucial for the commercialization of **soumbala**.

Further research focusing especially on seed quality and storage conditions is needed before high throughput facilities producing high quality **soumbala** can be achieved. In addition, it is obvious that less healthy substitutes for **soumbala** are bought when the supply of **soumbala** is low and the price consequently high. One solution is to focus future research on investigating opportunities for increased production and other value chain initiatives in order to provide a more stable supply at a competitive price. Moreover, **soumbala** substitutes are bought if quality of **soumbala** is poor, stressing the value of standardizing management and production procedures in order to improve quality, and to produce a product corresponding to consumer demands.

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Appendix A. Questionnaire used during interviews of 60 informants examining the management of *Parkia biglobosa* (Jacq.) Benth. in southwestern Burkina Faso.

Questions		Responses
Do you use fertilizer around your *P. biglobosa* trees?		Yes/No
Do you burn your fields?		Yes/No
Do you prune the tree during harvest of the fruits?		Yes/No
Do you harvest the fruits sustainably?		Yes/No
Do you cultivate crops together with *Parkia* trees?		Yes/No
Do you sow seeds of *P. biglobosa*?		Yes/No
	Why do you sow the seeds?	Open
Do you practice shifting cultivation?		Yes/No
	How long is the fallow period?	Open
Do you have livestock grazing on your fields?		Yes/No
Do you nurse your *P. biglobosa* trees?		Yes/No
	Do you weed around seedlings?	Yes/No
	Do you irrigate the trees?	Yes/No
	Do you fence the trees?	Yes/No

Appendix B. Questionnaire used during interviews of 60 informants examining their perception of high quality **soumbala** in southwestern Burkina Faso.

Questions		Responses
How do you define high quality **soumbala**?		Open
	What are the key characteristics of high quality?	Open
How does high quality **soumbala** smell?		Open
	What is the strength of the smell?	Weak/neutral/strong
Is high quality **soumbala** moist or dry?		Moist/dry
What does high quality **soumbala** look like physically?		Open
	What size of seeds?	Mix/small/large
	What color of seeds?	Open

Appendix C. Questionnaire used during group meetings examining the production procedures applied to ensure high quality **soumbala** in southwestern Burkina Faso.

Questions		**Responses**
First cooking		
	For how long do you cook the seeds?	Open
	Can you describe the process?	Open
	How does it smell at the end of cooking?	Open
	Is anything added? And why?	Open
	What is important during this process?	Open
Dehulling		
	Can you describe the process?	Open
	Is anything added? And why?	Open
	What is important during this process?	Open
Washing		
	Can you describe the process?	Open
	What is important during this process?	Open
Second cooking		
	For how long do you cook the seeds?	Open
	Can you describe the process?	Open
	How does it smell at the end of cooking?	Open
	Is anything added? And why?	Open
	What is important during this process?	Open
Fermentation		
	For how long do you ferment the seeds?	Open
	Can you describe the process?	Open
	How does it smell at the end of fermentation?	Open
	Is anything added? And why?	Open
	What is important during this process?	Open
Drying		
	For how long do you dry the fermented seeds?	Open
	Can you describe the process?	Open
	How does it smell at the end of drying?	Open
	Is anything added? And why?	Open
	What is important during this process?	Open
Storage		
	Can you describe the process?	Open
	What is important during this process?	Open
Are there any other steps in the processing of **soumbala**?		Open

Appendix D. Variables in the binary logistic regression analysis of **soumbala** in southwestern Burkina Faso

Variables	**Definitions**
Burning	Categorical variable; taking the value 1 if the informant does not practice burning.
Fallow	Continuous variable; taking the value equal to the number of years the field lies fallow.
Fencing	Categorical variable; taking the value 1 if the informant fences the trees.
Fertilizer	Categorical variable; taking the value 1 if the informant uses fertilizer.
Harvest	Categorical variable; taking the value 1 if the informant harvests in a sustainable way.
Intercropping	Categorical variable; taking the value 1 if the informant practices intercropping systems.
Irrigation	Categorical variable; taking the value 1 if the informant irrigates the trees.
Livestock	Categorical variable; taking the value 1 if the informant lets livestock graze on and around the trees.
Pruning	Categorical variable; taking the value 1 if the informant prunes the trees.
Quality	Categorical variable; taking the value 1 if the **soumbala** quality is high, and 0 if the quality is poor.
Sowing	Categorical variable; taking the value 1 if the informant sows seeds.
Weeding	Categorical variable; taking the value 1 if the informant weeds around seedlings.