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Sustainability and Effectiveness of Artisanal Approach to Control Mycotoxins Associated with Sorghum Grains and Sorghum Based Food in Sahelian Zone of Cameroon

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Additional information is available at the end of the chapter

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1. Introduction

In Cameroon, the production of sorghum is mostly done in the soudano-sahelian zone on approximately 300.000 hectares for an average production of 100.000 tons [1]. This places the northern region of Cameroun on the first rank for cereal production within the sub region of Central African countries. Sorghum also occupies an essential place as food for millions of Cameroonians [2]. The good image of the sorghum in the region lead to the diversification of the food and feed, in particular in urban zone, through more attractive forms at the culinary, nutritional and economic levels: flour, grits, blown products, rolled,etc [3]. Grains are harvested during the rainy season, a best period for yeast and mould which favors contamination by fungi and subsequent mycotoxin contamination. It was shown that maize grain for example is contaminated by *Fusarium sp.*, *Aspergillus sp.*, *Penicillium sp.*, *Acremonium sp.* and *Diplodia sp.* [4,5]. The contamination of maize by these fungi and their toxic metabolites has been associated with several human and animal diseases including liver and oesophageal cancer, particularly in Africa [4]. In the region, postharvest techniques for cereals are alike both for grain processing and food and feed products. It is possible that sorghum and sorghum by products are also contaminated by fungi thus potential presence of associated mycotoxins. Considering the broad use and the large quantities of sorghum produced and consumed by local population for their daily need in the soudano-sahelian region of Cameroon, it is curious that public health problems related to mycotoxins seems not relevant in the region. Are sorghum and sorghum products exempted from mycotoxin contamination or are local populations' postharvest practices quite effective against mycotoxins? The objective of this chapter is to present and discuss data from investigation

on potential mycotoxin contamination and relate them to the efficacy of local artisanal practices against mycotoxins contamination of sorghum as well as some sorghum by-products by moulds in the Sahelian zone of Cameroon.

2. Methods

2.1. Field work

Designing a research on mycotoxins for artisanal technologies with very little information on these processes is not easy. Reliability of information from the popular or unscientific methods of information is sometimes questionable. This information could be the product of preconceived notions of individual observations. The experimental study of the process was thus necessary despite the fact that it incurred significant costs, without direct effects on work. It was also difficult to objectively describe a method developed by people without reference to reliable scientific data to interpret and understand the principles related to this. In addition to the compilation of bibliographic data, data collection was completed by a cross-sectional and descriptive study including two types of surveys:

- A qualitative survey in connection with the opinions, attitudes and practices of people in terms of postharvest technologies applied to sorghum by stakeholders;
- A quantitative survey, by cluster sampling at one level, on the degree of uses of these products.
- Information on post-harvest techniques used for sorghum was collected through the organization of:
 - Focus Group (FG) with groups of sorghum processors;
 - Depth interviews (DI) with consumers, sellers and producers identified, recruited from the focus groups, in their respective activities related to transformation of sorghum grains.

The survey was conducted using pre-tested materials. Once obtained the consent of participants, the DI and FG were conducted at locations far from all external disturbances to ensure a good animation and therefore the quality of data collection.

During the survey, information was collected from households and producers, their opinions, attitudes and practices relating to mycotoxin associated with sorghum, any changes in the manufacturing processes, source of other major ingredients, improving production conditions, and storage conditions.

3. Laboratory work

3.1. Sampling

A total of 120 samples of sorghum grains from 5 varieties and 6 different locally produced artisanal sorghum by-products (Beer, flour, babies beverage, and cake) were randomly collected from traditional breweries in the cities of Garoua, Maroua and Ngaoundere in the northern part of Cameroon.

3.2. Mycotoxins extraction

Raw grains and cake were crushed and mixed with equal quantity of distilled water prior to the extraction process. Opaque beer and baby beverage were gently shake and degassed using a vacuum pump. Prepared samples were then subjected to solid phase extraction using extraction columns C18 (Perkin Elmer, Norwalk, USA), mounted on a solid-phase extraction manifold (Vacmaster®). The C18 columns were equilibrated by passing 10 ml of methanol: water (10:90) solvent. 20 ml of degassed samples was then passed through the column and the column washed by passing through 20 ml of distilled water, followed by drying with air. The mycotoxins in the column were eluted with 2 ml of methanol, which was diluted 1:10 with phosphate buffered saline (PBS) solution, before analysis by the ELISA procedure.

3.3. Mycotoxin analysis

All analyses were performed using direct competitive microplate enzyme-linked immunosorbent assays (ELISA) as previously described by Usleber, *et al.*[6,7]. The microtitre plate wells were coated with antimycotoxin antibody solution in 0.1M sodium bicarbonate buffer and incubated 18hours at room temperature. The wells were then washed three times with NaCl-Tween (8.5 g NaCl and 250 µL of Tween-20 in 1 litre of water) solution after the free protein binding sites were coated with 3% fetal calf serum in phosphate buffer solution (200 µL/well) for 20 min. Aliquots (50 µL) of diluted sample extracts (sorghum grain, sorghum beer, sorghum based food) and respective mycotoxin standards were added into the well, followed by addition of aliquots (50 µL) of the respective mycotoxin horse radish peroxidase conjugate. The plates were incubated for two hours at room temperature, washed, and an enzyme substrate solution (100 µL) added. The absorbance was read at 450 nm using an ELISA reader reaction after the reaction was stopped by addition of 1M sulfuric acid (100 µL). Absorbance values were analyzed with competitive ELISA software [8], and the data statistically analyzed for variability and association using the SPlus 2000.

4. Results and discussion

4.1. Mycotoxins in raw sorghum grains

In northern Cameroon, there are two types of sorghum production: the rainy season production and the dry season production. Sorghum varieties are thus classified according to season. This includes:

- The *muskuwaari* group which is composed of dry season varieties namely *safraari*, *majeeri*, *burguuri* and *ajagamaari*, *Muskuwaari* in fulfuldé. The fulani language is used to describe all dry season varieties which are sow at the end of the wet season on argils soils called karal. Those varieties have the ability to accomplish their vegetative cycle during drying season from water reserve of those argils soils. The seedlings are prepared in August and sown in the field from September to November (winter). They're generally harvested few months later from April to March.

- The raining season varieties *Madjeri* with two principal groups: *Damougari* and *Djigari*.

All analyzed samples presented no evidence of Aflatoxin B₁, Ochratoxin, Deoxynivalenol (DON) and Fumonisin B₁ contamination in muskwari group while some raining season varieties were contaminated only by Aflatoxin B₁ (Table 1). This indicates clearly that there is no incidence of mycotoxins in collected and analyzed muskwari group grains. This may be due primarily to the nature of different varieties and their vegetative cycle which includes development phase in dry season. We can also mention their relatively low moisture content [9] and the availability of grain storages and adequate facilities in rural zone [10].

	<i>Sorghum varieties cultivated in raining season</i>				<i>Sorghum varieties cultivated in dry season (Muskwari group)</i>					
<i>Variety</i>	<i>Damugari</i>		<i>Djigari</i>		<i>safraari</i>		<i>majeeri</i>		<i>burguuri</i>	
	Inci- dence	levels	Inci- dence	levels	Inci- dence	levels	Inci- dence	levels	Inci- dence	levels
Aflatoxin B ₁	75%	0.0-230 ng/g	45%	0.0-145 ng/g	0%	nd	0%	nd	0%	nd
Ochratoxin A	0%	nd	nd	nd	0%	nd	0%	nd	0%	nd
Deoxynivalenol (DON)	0%	nd	nd	nd	0%	nd	0%	nd	0%	nd
Fumonisin B ₁ (FB ₁)	0%	nd	nd	nd	0%	nd	0%	nd	0%	nd

nd: not detected

Table 1. Mycotoxins in Sorghum grains varieties from Savannah zones of Cameroon

4.2. Influence of artisanal harvesting on mycotoxin contamination

As mentioned earlier harvesting period and harvesting method may have impact on sorghum quality. In fact depending on season and scale of production most farmers use artisanal hand harvesting methods. The sorghum panicles are cut from the stalks either by hand or using a knife, placed into sacks and taken to the threshing platform where they are placed on racks or spread on the platform for drying. Proper drying is considered to be one of the greatest factors in determining whether grains will be effectively stored without damage, thus avoiding mycotoxins associated mold to growth. In the rainy season when there's not enough sun, the grains are piled on racks or heaps to dry. In this way there is lack of air movement, leading to sprouting, discoloration and microbial damage. This may explain the presence of Aflatoxin B₁ in some analyzed samples (Table1). In addition

mycotoxin contamination may occur due to rats, birds, insects etc. To avoid this, dry grains are stored in granaries till they're pounded. Abarca *et al.* [12] indicate that ochratoxin A contaminates a variety of plant and animal products but is most often found in stored cereal grains. But as shown in table 1, no traces of Ochratoxin A were recorded during our study in all samples. The absence of mycotoxins in grains maybe linked to good postharvest techniques applied by local populations like mastering of the agri-calendar leading to harvesting of grains at right time[1], availability of artisanal granaries and finally agro climatic conditions which are favorable for grains storage (hot and dry air, sandy soils...). As mentioned by Van Egmon [13] mycotoxin contamination of foods and feeds depends highly on environmental conditions that lead to mould growth and toxin production. Moore-Landecker, [14]; Wilson and Payne, [15] notice that environmental conditions and some key factors such as moisture, temperature, rats, insects, human manipulation of crops are particularly important factors determining the occurrence of mycotoxins within the seeds or grains.

The observed low incidence levels of mycotoxins in raw dry sorghum grains from northern Cameroon could be link to a pre- and post-harvest strategies to prevent crop contamination which include yearly crop rotation, irrigation in hot and dry weather, use of pesticides to reduce insect population, drying crops to a safe moisture level, and providing protective storage are mastered by local rural population, managing sorghum grains in the field. Makun *et al.*, [16] indicate that although the optimum temperature and moisture content for growth and toxin production for the various aflatoxigenic fungi varies, and considering that these conditions approximate the ambient climatic conditions in most parts of Africa, this author predicts that climate change might exacerbate the aflatoxin crisis in Africa. Although this assumption seems verified for East Africa, the situation may be different in the northern Cameroon which has a hot and dry sudano sahelian climate compared to the hot and humid climate of eastern African regions. This can also be one of the key factors associated to the high quality of sorghum from Northern Cameroon. In addition to this, the broad use of pesticides to reduce insect population, the mastering of agricultural calendar leading to right harvesting time and availability of artisanal storage facilities in rural area may explain the non-detection of targeted mycotoxins in the analyzed samples despite the none application of complicated HACCP methods.

4.3. Mycotoxins in some commonly used Sorghum derived products from the savannah zones of Cameroon

As shown in table 2 and 3, some sorghum by products, contrary to sorghum grains are contaminated by either one or more types of mycotoxin. Sorghum beer is contaminated by aflatoxin B₁, ochratoxin A and deoxynivalenol. No fumonisin were detected in beer. Sorghum balls were contaminated by ochratoxin only. Three of the fourth types of mycotoxin checked, were recorded in Sorghum porridge namely: aflatoxin B₁, ochratoxin and deoxynivalenol (DON). Aflatoxin B₁ and deoxynivalenol were detected in *dakkere*, a mixture of sorghum and maize flour baked in hot water and sundried.

	<i>Sorghum derived product</i>			
	<i>Bil-Bil</i>	<i>Sorghum porridge</i>	<i>dakkere</i>	<i>naakia</i>
Aflatoxin B ₁	86%	73%	82%	nd
Ochratoxin	27%	nd	nd	76%
Deoxynivalenol (DON)	12%	16%	45%	55%
Fumonisin B ₁ (FB ₁)	nd	nd	nd	nd

Table 2. Incidence of mycotoxins in some commonly used Sorghum derived product of the savannah zones of Cameroon

	<i>Sorghum derived product</i>			
	<i>Bil-Bil</i>	<i>Sorghum porridge</i>	<i>dakkere</i>	<i>naakia</i>
Aflatoxin B ₁ (mg/kg)	0.0-245	0.0-250	0.0-178	nd
Ochratoxin A (mg/kg)	0.0-45	nd	nd	0.0-33
Deoxynivalenol (DON) (µg/kg)	0.0-120	0.00-500	0.00-423	0.0-538
Fumonisin B ₁ (FB ₁)(µg/kg)	nd	nd	nd	nd

Table 3. Levels of mycotoxins in some commonly used Sorghum derived product of the savannah zones of Cameroon

It is obvious from the results that despite the good quality of sorghum grains as shown in table 1, most of processed sorghum based foods are contaminated (Table 2 and 3). It is thus likely that processing may be one of the key factor in favor of mycotoxins occurrence in sorghum products. Most of the analyzed derived products contain mycotoxins at levels far above accepted values in foods and feeds.

Legal limits for aflatoxins require that food for human consumption should contain less than 10 µg/kg (parts per billion) of which only 5 ppb may be Aflatoxin B₁ and these limits are based largely on research results [17]. Legal limits for fumonisins have not yet been introduced locally and vary from one region to another. Locally a provisional tolerance level of 100-200 ppb total fumonisins has been suggested for maize/sorghum and maize/sorghum based products intended for human consumption. This lower tolerance level is based on the high human consumption of cereal within the northern part of Cameroon. Limits for deoxynivalenol have been implemented locally by some foreign non-governmental organisation (NGO) especially for trade purpose and vary from 500 to 1 000 ppb in foods and 1 000 ppb to 10 000 ppb in animal feed. Although there are no yet legal limits in Cameroon for ochratoxins in food some international NGOs working in the area have proposed a maximum limit of 5µg/kg in sorghum based products for direct human consumption. The local regional health adviser has therefore advised withdrawal of sorghum found to contain more than 1000µg/kg. At present there is no requirement to recall product, and the local government considers that occasional consumption of affected sorghum meal is unlikely to pose a risk to the consumer. However retailers and manufacturers are advised to withdraw affected batches from shelves. Despite efforts to

implement these regulatory measures, there are no adequate facilities for mycotoxins detection as the ones for universities are only for educational and research purposes. We thus think that the best way to tackle the problem is to avoid contaminations during processing. In the following paragraph, we will discuss the risk of mycotoxins occurrence in relation to the processing methods applied to sorghum.

4.4. Artisanal postharvest techniques and risk of mycotoxin contamination of Sorghum grain

Data on local post-harvest techniques used for handling grains by local rural populations were collected during the survey. Processing methods for first transformation product were also screened to determine mycotoxins critical control points in the process. Collected data from focus group discussions following information were drawn from sorghum postharvest techniques to sorghum grain transformation.

4.5. Primary processing

Sorghum grain requires the removal of the outer layer before any further processing could be done. The outer layers of some sorghum varieties contain tannins, which have a bitter taste. For this reason it is normally dehulled and then pounded into flour [3]. Traditionally the processing of sorghum in northern Cameroon is carried out by pounding grain using a pestle and mortar. Grain are then winnowed to remove the bran. Pounding and winnowing are repeated several times before good quality flour is obtained. The objective of hand pounding is thus twofold, the first is to remove the bran and the second is to produce the flour, but this is time consuming and backbreaking. The removal of the bran is one of the key factors reducing the risk of mycotoxin occurrence. The processing of sorghum grain into quality flour is presented in fig 1.

4.6. Dehusking and grinding grains

Grinding and husking are essential steps for sorghum processing in rural sahelian zone of Cameroon. First, grains are spread on mats, plastic sheets or on the floor in monolayer form for sun drying with constant spreading. Dried grains are then stored in paddy forms inside granaries. At this level we had critical points which are laying and threshing. These two steps of the processing which allowed hot air to flow easily through grains may have an effect by avoiding potential mold contamination. Sometimes plastic sheets are colored black to absorb more heat, and the constant stirring contributes to distribute heat in between grains thus may reduce water activity which is an important factor for mycotoxin occurrence [5, 18].

Artisanal grain processing operations for polishing sorghum paddy are generally performed by women and usually start with cleaning of coarse paddy grain using screens. The one with large mesh is used to remove larger particles (straws, other grains ...) and a second with smaller mesh is used to remove dust, dirt or immature grains. At this level risk of

contamination of sorghum by mold is reduce by about 20% as it's likely that most strains of mold originate from those larger particles.

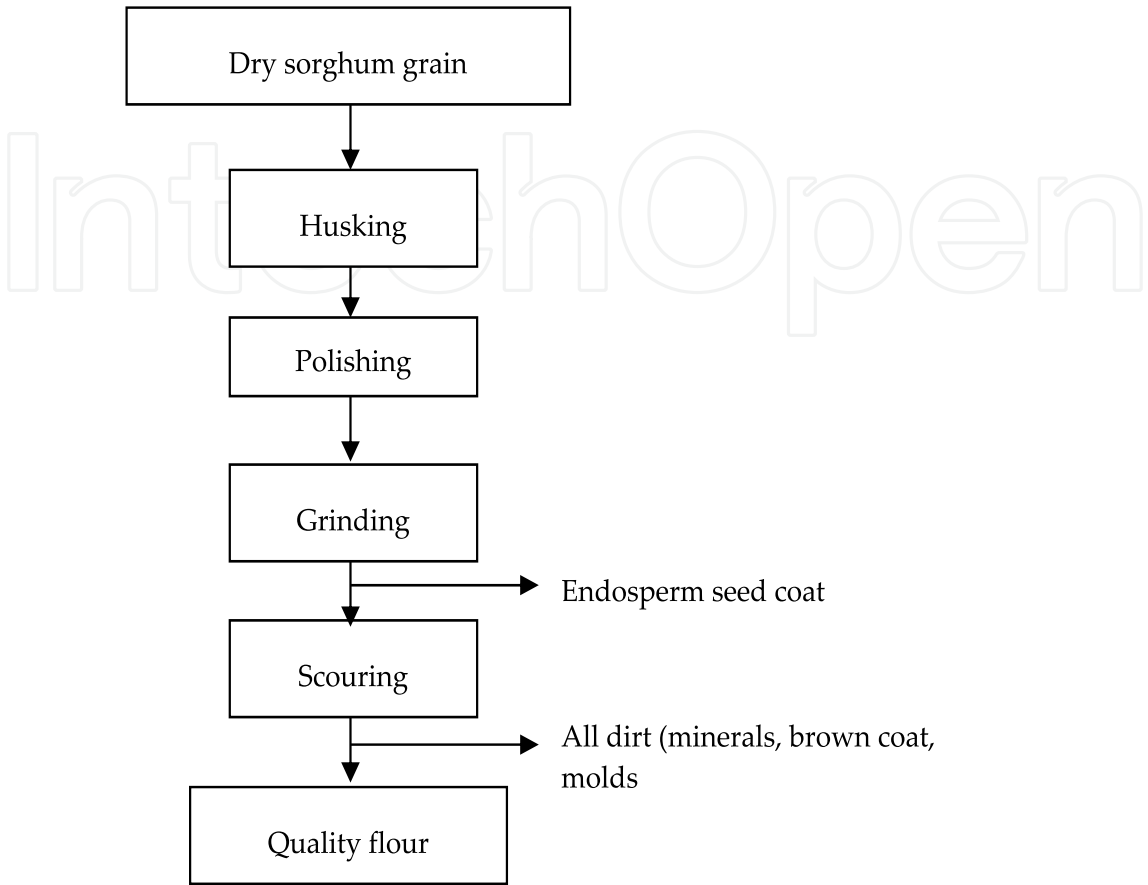


Figure 1. First transformation of sorghum grain: Quality flour production

Dehusking and polishing are carried out simultaneously in mortars and pestles. Five successive pounding, each followed by winnowing are made to separate pericarp and germ from the grain until perfect of polish. The fourth-pounding matches the winnowing stage when the grain is fed to a modern milling machine. The corresponding percentage yields of paddy are about 60-68% complete after polishing. As main mold are in pericarp we can deduce that 38-40% of contamination risk is reduced.

After the last pounding, the polished sorghum is washed. The grain are immersed in a large calabash of water and stirred by hand; dirty water containing dust and bran is continuously eliminated. This operation is repeated several times depending on the nature and color of the predominant variety (housewives often use a mixture of several varieties). Women then proceed to a step leading to removal of total sand. To do this, they dip a gourd containing the washed sorghum grain in a basin of clean water and start with slow swings to bring down gradually the grain in water until only sand settles at the bottom of the gourd. This is reproduced as many times as necessary. It can be expected at this level the removal of sand spores of yeast, and mold which are potential mycotoxins producers. Table 4 presents each operation with levels of reduction of mycotoxins contamination risk.

Step in the process	Reduce levels of risk of mycotoxin contamination
Winnowing	15%
Laying and threshing	10%
Husking and polishing	38%
cleaning of coarse paddy grain	20%
Washing	4%
Removal of sandy spores of yeast and mold, potential mycotoxins producers	5%
Grinding	20%

Table 4. Levels of mycotoxin contamination as % risk according to the steps in the sorghum artisanal processing.

Grinding is performed once the grains are washed and sometimes shelled, using a gasoline mill. When power supply is available, electric mill is used. Scouring is done to improve the quality of the flour. This is performed to remove the seed coat (bran) covering the endosperm. The operation removes all "dirt" from the pericarp (minerals, brown coat, molds ...), to give a best quality flour for preparations [3, 19]. This operation is also one of the best practices to avoid growth of molds responsible for mycotoxins production. According to interviewed women, this operation helps to reduce the bitter taste of grain, but it causes weight losses. The husking performance depends on the hardness of the grain, character related to the glassiness of the endosperm (relative importance of the vitreous and floury parts). Women also noticed poor ability to shell *muskwari* varieties. Their grain flour with brown layer mostly tends to crash during the operation and a fraction of the flour is lost in the sorghum bran. In the contrary the seed coat comes off more easily for raining season's varieties, for which vitreousness seems higher [9]. Women sometimes perform this operation manually using a mortar and pestle after moistening the grains. The operation can also be done mechanically. Nearly 75% of surveyed women, prefer to systematically wash the grains and then let the grain dry in the sun to reduce the bitterness of the grains coat before grinding. This practice may explain the observed high incidence of mycotoxins contamination of food based product (Table 2).

4.7. Risk of mycotoxin contamination during artisanal Sorghum grain processing

4.7.1. Porridge preparation

Sorghum flour is primarily used to prepare porridge, locally called couscous, the main staple of people in northern Cameroon. This preparation is made by mixing sorghum flour to boiling water and stirring vigorously until the dough has a firm and smooth consistency. The porridge is eaten by dipping rolled small cuts inside sauce. The surveyed indigenous peoples of the region are unanimous: *Muskwari sorghum* gives the best balls not only in regard with sensory properties, but also in technological point of view as it is said that "the porridge from those sorghum varieties take well. » This may be due to the quality of starch and low moisture content of the grains grow in dry conditions [3]. The light bitterness

observed is said to be due to the pericarp. When the grain is dehusked this bitterness disappears during storage.

Interviewed women say to rarely have opportunity to mix some varieties in order to improve the quality of the ball because the grain are opened one by one. However, used varieties may vary depending on the season. During hard field work, women cook the porridge from *safraari* varieties because *it is said to give strength*, and they keep *majeeri* for a longer time as it's mainly used during the dry season. The *majeeri* variety is said to be less subject to alteration than other varieties, thus less susceptible to carries yeast and molds. Surveys show that some flours like *majeeri* stick least to the pot than *safraari varieties*: for the same amount of water, more *majeeri* flour is added comparing to *safraari* flour for the same desired consistency. These observations must be correlated to changes in grain composition according to the types of sorghum. The composition of the endosperm (starch solubility, amylose content ...) plays a direct role on the texture of the ball [20]. This may also explain the ability of those varieties to be moistened during cooking of porridge. The cooking temperature and reduce water absorption of flour together with some key activities during processing like mixing sorghum flour to boiling water , vigorously stirring the mixture and the dough firm and smooth consistency may be correlated to observed low mycotoxin contamination of porridge

4.7.2. The slurry

Sorghum slurry is similar to sorghum porridge but with a lesser consistency. It is mainly prepared for children. The preparation of sorghum slurry is done by incorporating flour in hot water and continuously stirs the mixture until a thick and homogeneous liquid is obtained after cooking. There are different types of slurry according to the ingredients added at the end of preparation. It's locally called *gaari Kossam* when milk and sugar are added, *gaari biriji* when peanut butter is added, *gaari kilburi* when sodium powder is added ... The *kilburi* slurry look yellowish as it is made with flour from *safraari* sorghum varieties only. It is often taken to treat digestive disorders. But generally *majeeri* sorghums are favored by women for the preparation of the slurry. The *majeeri ranwanyaande* (white glumes) are the most popular, because even without shelling, grain flour gives a uniform color. During fasting (Ramadan period) Muslims eat pap, a soft porridge made from shelled and flour from *majeeri majeeri* whose grains are systematically shelled. Despite the fact that we did not analyse these types of sorghum slurry, it is predictable that since groundnuts, susceptible to be contaminated by mycotoxin the risk of mycotoxin contamination may be enhanced.

4.8. The Bil Bil (traditional beer)

Non-Muslims in villages especially in the foothills and plains of Kaélé, *muskuwaari* brew traditional sorghum beer, *bil bil*.. The process of production of *bil-bil* can be described as follows (Fig 2):

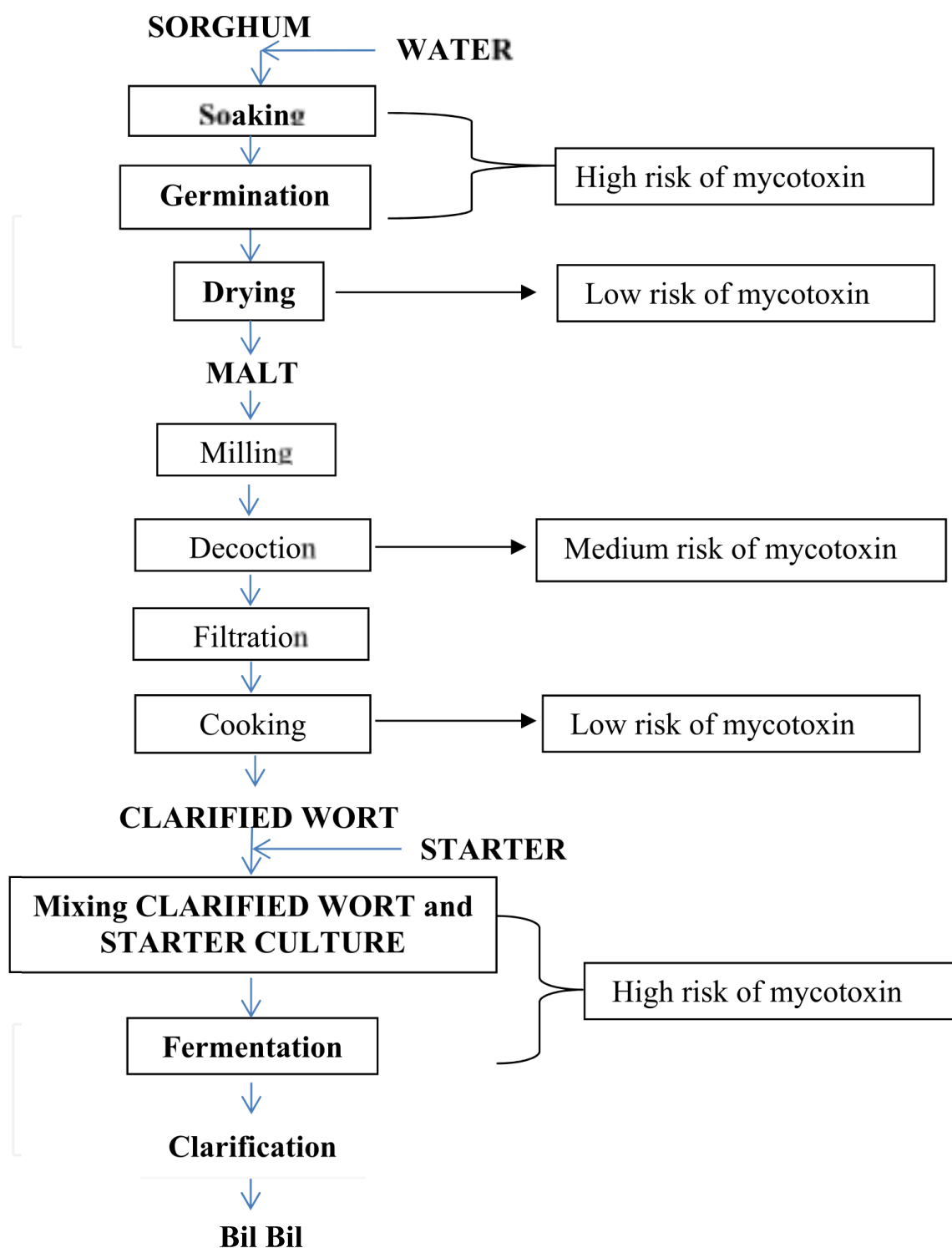


Figure 2. Mycotoxin risk assessment during the process production of *bil-bil*

This operation starts with malting. Most often populations choose a sorghum variety locally known as "mouskouari" [9]. After washing, sorghum grains are soaked in water for 72 hours to obtain a water content varying from 35% to 40 % (w/w). This soaking is required for the germination process. Information from the discussion groups revealed that water temperature is very important for soaking process. Soaking is done at high temperature so

that the soaking process is rapid (20 ± 4 hours). This high temperature close to 45°C may reduce risk of yeast and mold growth thus mycotoxin contamination. The next step is germination. Wet grains are placed on burlap bags for 24 to 36 hours or the grains are left in the tin used for soaking, usually in a container until the rootlets appear and/or grain spades. On burlap bags, the grains are sprayed with water on daily basis. At this stage the risk of yeast and mold growth is increased. The disposal of grains in heaps on burlap bags allows a rise of the temperature during the process, which facilitates the germination. This process can be the genesis of mycotoxin occurrence in the final beer.

However, many women do not follow this step, especially in the arid and hot areas and immediately after soaking, they place grains over a clean area (wood sheet, clay, rock). The grains are laid in 3 ± 0.2 cm layers, covered with leaves that keep the grains in darkness and maintain adequate humidity. All these operations are clearly favorable conditions for yeast and mold growth. Thus increase risk of mycotoxin contamination of the final beer. Sometimes women say the soaking and germination processes can be conducted in jars in the dark but emphasize that in this case, molds are more frequent and the germination process is slow. This may be explained by the low ventilation and higher humidity inside the jars. Again at this level the risk of mycotoxin production may be high.

After germination, the grains are piled: the temperature rises, the amylase levels increase and eventually stop increasing when the temperature is too high. The next step is drying. This operation corresponds to kilning and brings moisture of the malt to $18 \pm 5\%$ [10] to prevent from the growth of molds. The malt is dried in the sun for one day or more, sometimes less before it goes straight to the brewing. If at this stage the growth of mold is reduce, mycotoxin eventually produced during previous stages may not be destroyed. Then we have the brewing stage. The malt is crushed in a mortar or on a flat stone. In urban areas, malt is ground in a motorized mill to obtain coarse flour. The ground malt is mixed with water with a gelatinous or mucilaginous agent (okra or sap of various trees, especially *Triumfetta* sp., which is said by women to enhance flocculation and filtration of insoluble materials. This step is like "bonding" for clarification in "high gravity" fermentation beer process [21]. At this stage there is risk of yeast and mold contamination as the use of *Triumfetta* sp. leaves are susceptible to bring spores of molds. The next stage is decoction. Here the lower phase containing the undissolved malt flour is cooked slowly to boil in order to obtain a "cooked starch" with porridge consistency. The cooking process can be extended over an hour but the upper phase liquid is then mixed with the slurry to be saccharified more easily than if it had not been cooked [22]. Cooking of the mixture is around 65°C to 70°C which is close to the destruction temperature of some mycotoxin and mold. Thus the risk of mycotoxin production is low. At the brewing stage of "bil-bil" production, some women add a mucilaginous agent to promote emulsion. This action can also enable yeast and mold contamination. The next step is fermentation. The wort is cooled either spontaneously or by successive decanting operations. When the temperature of wort is around 30°C it is mixed with an ongoing "affouk" fermentation used as starter culture. It is also common to use an old fermentation tank containing remaining beer from previous fermentation. This operation can bring some natural pathogenic molds. Some women said,

that the starter culture can also be recovered from the bottom of fermentation tanks. The cake is sun dried and kept as starter culture for new production. The risk of contamination by pathogenic mold may rise here.

According to some women Mofu Mowo, beer brewed only with *njiigari* gives headaches. Good *bil bil* is obtained by mixing in equal proportion *muskawaari* (*safraari*, *mandoweyri yaawu* and preferentially) and rained sorghum but the proportions depend especially on the types available and the market prices. In mundangs and guizigas communities, some women also use a *corn-muskawaari* in their preparation. The proportion is then quite variable, ranging from less than 1/6 to 1/3 corn.

4.9. Other sorghum derived product

The donuts: There are other Sorghum by product often prepared from flour of white *majeeri*, *tolo tolo balwanyaande*, *ajagamaari*, and sometimes skinned *safraari*. The main ingredients used for this are: sorghum flour, wheat flour, sugar, oil, eggs, orange, raisins, ground fennel seeds, honey, baking powder, sesame seeds, blanched almonds, baking soda. Even most of the used fruits may be source of mold contamination thus mycotoxin contamination

The *dakkere*. Typically Fulani, this is a dish prepared with the *majeeri* varieties only. The flour is moistened in a gourd into small balls. These are then steamed and eaten with yogurt. The main risk here is that during fermentation and conservation of final product pathogenic yeast and mold can grow with concomitant mycotoxin contamination. As shown in table 3 mycotoxins were detected in some of the analyzed samples

The *naakia* or *ndondooje* is a delicacy prepared by Fulani or similar. Women melt sugar in oil, and then add flour *safraari*, *suukkataari usuku* or *allah*. This mixture is rolled into a ball consumed especially during festivals. Again most of the steps of the production process may present risk as mycotoxins were detected in some of analyzed samples.

4.10. Social implication and sustainability

In socio economic point of view, this work involved collaboration amongst stakeholders, professionals, women, community health and other opinion leaders in the community. Thus there increased a chance capacity building for sorghum post-harvest handling techniques. The work was implemented at community level and project research assistants, community members were trained and developed HACCP practices to avoid mycotoxin in sorghum grain and by products. They may continue to train Community members or peer volunteers and other collaborating organizations, without help of trainers and thus remaining sustainable. The multi-sectoral team/ task force and community members that participated in the project, based on evidences found across the main results of the project, facilitate development of a sustainable program integrating sorghum post handling techniques in the existing community based development/health programs through participatory approaches. Promotional campaigns at the community, district, and provincial levels during the project, based on evidences found across the main results of the project, facilitate widespread

acceptance of improved post-harvest practices centred on the use of locally developed HACCP.

5. Conclusion

Enduring food-safety solutions to sorghum generates good health and improved productivity within the region. Mycotoxins associated consequences, acute intoxication and cancer development which causes irreparable damage to livelihoods in the area, thereby reducing self-sufficiency of local rural population, can be reduced by relying on local artisanal approach to control mycotoxins associated with sorghum grains and sorghum based food. As this is part of the process leading to food security. This will directly contribute to livelihoods amelioration in the long term.

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