



Cereal Science and Technology
Southern Africa



RURAL INDUSTRIES PROMOTIONS
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BOTSWANA AGRICULTURAL MARKETING BOARD

ALTERNATIVE CEREAL PROCESSING TECHNOLOGIES

LOBATSE, BOTSWANA
NOVEMBER 4-6, 2008





Group picture of the workshop participants

Sponsored by: National Food Technology Research Centre (NFTRC), International Sorghum and Millet Collaborative Research Support Program (INTSORMIL-CRSP) and Cereal Science and Technology – South Africa (CST-SA)

Co-hosted by: NFTRC, Botswana Confederation of Mill Owners (BCMO), Rural Industries Innovation Centre (RIIC), Botswana Agricultural Marketing Board (BAMB), and the Department of Agricultural Research (DAR)

Organising Committee: Dr Martin Kebakile (Chairperson, NFTRC), Ms Agatha Ellwood (BCMO), Dr Zeundjua Tjiparuro (RIIC), Dr Edward Dintwa (NFTRC), Mr Jones Proctor (BAMB), Ms Boikhutso Nyatshane (BAMB), Dr Lewis Ezeogu (NFTRC), Mr Selalelo Mpotokwane (NFTRC), Dr Stephen Chite (DAR), Ms Kemelo Ookeditse (NFTRC), Dr Gyebi Duodu (CST-SA) and Prof Gary Peterson (INTSORMIL)

Editors: Dr Martin Kebakile and Ms Kemelo Ookeditse

WORKSHOP PROGRAMME

Tuesday 4th November 2008 (Cumberland Hotel)

<u>TIME</u>	<u>TOPIC</u>	<u>SPEAKER</u>
08:00 – 08:30	Registration	
08:30-08:35	Chairperson / Introduction of VIPs	Dr Martin Kebakile (NFTRC)
08:35 – 08:50	Welcome	Dr Charity Kerapeletswe – MD - NFTRC
08:50 – 09:20	Key note address: Enabling SMMEs to benefit from research – a move towards employment creation, poverty reduction and economic growth	Mr Masego Mphathi (CEO – BAMB)
09:20 – 09:40	Food security in Africa – The future role of sorghum and millets	Prof John Taylor (University of Pretoria)
0940 – 10:00	Government policy on cereals production in Botswana	Mr Babati Moji (Dept of Crops, MoA)
10:00 – 10:30	Outputs of the sorghum and pearl millet breeding program in Botswana	Dr Stephen Chite (Dept of Agric Research)
10:20 – 10:40	Tea and Coffee	
10:40 – 10:45	Chair	Mr Daniel Gareebine (RIIC)
10:45 – 11:05	Sorghum and millets consumption patterns in Botswana	Mr Selalelo Mpotokwane (NFTRC)
11:05 – 11:35	Constraints and opportunities in the sorghum and millets milling industry in Botswana	Ms Agatha Ellwood (BCMO)
11:35 – 12:05	Recent improvements on the RIIC milling technology	Dr Zeundjua Tjiparuro (RIIC)
12:05 – 12:25	Roller milling – an alternative milling process for sorghum and pearl millet	Dr Martin Kebakile (NFTRC)
12:25 – 12:45	Why fortify sorghum and pearl millet meal?	Ms Motlalepula Mokotedi (NFTRC)
12:45 – 13:30	Lunch	
13:30 – 13:35	Chair	Dr Gyebi Duodu (CST-SA)
13:35 – 14:30	Supply chain management and utilization of sorghum and millet	Prof Lloyd Rooney (Texas A&M University)
14:30 – 15:00	Sorghum Malting	Dr Lewis Ezeogu (NFTRC)
15:00 – 15:15	Tea and Coffee	
15:15 – 15:20	Chair	Mr Chris Boikanyo (BCMO)
15:20 – 16:00	From prototype to reality – sorghum product development and entrepreneurship	Dr David Jackson (University of Nebraska)
16:00 – 16:40	From farm to products – Marketing strategies for farmers (Senegal case study)	

16:40 – 17:00	Strategies to ensure grain supply to processors in Botswana	Mr Jones Proctor (BAMB)
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Wednesday 5th November 2008 : Field Visits

08:30 – Bus leaves Cumberland Hotel
09:15 – Honey Guide Mill - Automated Sorghum Mill in Pitsane
11:00 – Rural Industries Innovations Centre
13:00 – Lunch (Motse Lodge)
14:30 – National Food Technology Research Centre
16:00 – Bus leaves NFTRC to Cumberland Hotel

Thursday 6th November 2008 : Practical demonstrations

<u>TIME</u>	<u>TOPIC</u>	<u>SPEAKER</u>
Cumberland Hotel		
08:00 – 08:30	Arrival	
08:30 – 08:35	Chair	Dr Stephen Chite (DAR)
08:35 – 08:55	Simple grain quality evaluation procedures	Dr Janet Taylor (Dept Food Sci/UP)
08:55 – 09:30	Mycotoxins associated with cereal crops in Southern Africa	Dr Gert Marais (FABI/UP)
09:30 – 09:50	Implications of the BOS ISO 22000 and Sorghum Standards on the cereal industry	Mr Molefe Bannyaditse (BOBS)
09:50 – 10:00	Introduction of practical sessions	Dr Edward Dintwa (NFTRC)
10:00 – 10:15	Tea and Coffee	
10:20	Bus leaves Hotel to NFTRC (Kanye)	
11:00 – 13:00	Practical sessions 1) Sorghum grain evaluation procedures 2) Extrusion of corn and sorghum snacks 3) Production of instant flours 4) Fortification trials and evaluation of fortified meals 5) Composite flours and evaluation of composite breads 6) Extrusion of sorghum/soy blends	
13:00 – 14:00	Lunch (NFTRC)	
14:00 – 14:05	Chair	Dr Bernard Bulawayo (NFTRC)

14:05 – 14:45	Plenary session	
14:45 – 15:00	Introduction of CST-SA	Dr Gyebi Duodu – Chairperson – CST-SA
15:00 – 15:15	Brief about INTSORMIL activities	Prof Gary Peterson (INTSORMIL)
15:15 – 15:30	Tea and Coffee	
15:30 – 16:20	Summary of workshop and Presentation of Certificates	
16:20 – 16:30	Vote of thanks	Prof Afam Israel Jideani (NFTRC)
16:40	Bus leaves NFTRC to Motse Lodge	
17:00 – 19:30	Cocktail party (Motse Lodge)	Hosted by Hon Leach Tlhomelang (NFTRC)
19:40	Bus leaves Motse Lodge to Cumberland Hotel	

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KEY NOTE ADDRESS

Mr Masego Mphathi
CEO – Botswana Agricultural Marketing Board

Director of Ceremonies.
The Chairperson of NFTRC Board
NFTRC Board members here present
NFTRC Managing Director – Dr Kerapeletswe-Kruger
Coordinator of the International Sorghum and Millet Collaborative Research Support Program (INTSORMIL) activities in Africa – Prof Gary Peterson
Chairperson of Cereal Science and Technology – South Africa (CST-SA) – Dr Gyebi Duodu
Agro processors
Farmers
Distinguished guests
Ladies and gentlemen

Good morning.

I am delighted to have been invited to give a keynote address at the official opening of this important workshop on Alternative Cereal Processing Technologies, which is jointly organized by the National Food Technology Research Centre (NFTRC), Cereal Science and Technology – South Africa (CST-SA) and the International Sorghum and Millet Collaborative Research Support Program (INTSORMIL). My interest in this workshop derives from the fact that the Botswana Agricultural Marketing Board (BAMB), the organization I work for, is a major player in the grain supply chain, and is a potential beneficiary of any advances made in milling technology. I am also pleased to note that the workshop programme includes a paper to be presented by one of our staff, as this will obviate the need for me to go into details about the role that BAMB plays in the grain industry. More importantly, I believe the paper will generate discussions which should help BAMB to improve its contribution to this important venture.

The objectives of this workshop I am informed are:

- To review the current status of local cereals production and processing explore opportunities for growing the cereal industry.
- To promote diversification of cereal processing by sensitizing all players and stakeholders in the cereals industry about readily available alternative cereals processing technologies which have commercial potential.
- To promote and strengthen collaboration between local and international researchers, as well as fostering strategic partnerships between researchers and users of technologies to develop customer tailored processing technologies.

A quick look at the workshop programme shows that for three days participants and resource people alike will be treated to a rich exchange of ideas. The theme of my address **“Enabling SMMEs to benefit from research – a move towards employment creation, poverty reduction and economic growth”** is only a preamble for the interesting things ahead.

At independence most new governments in Africa embraced mega projects, particularly in mining and other resource extraction sectors. However it soon became clear that some of these ventures although they had their positive contribution, they did not create as much employment as had been hoped for. Prior to increasing local beneficiation, our diamond industry was one such example. The greatest challenge still faced by most African countries today, Botswana included, is to create a diversity of jobs and alleviate poverty. It has lately dawned upon us that the effect of small, micro and medium enterprise (SMMEs) cannot be underrated, and in fact, they do play a vital role in creating employment and wealth, thus have immense potential to alleviate poverty, contribute to economic growth as well as advance innovation and competitiveness.

SMMEs are however, commonly hampered by low skills levels, lack of access to information and shortage of effective supportive institutions, among others. The adoption of appropriate technologies can level the playing field between big and small businesses. I need not emphasise that for SMMEs to derive maximum benefit, they should not be passive recipients of new ideas generated through research, but should be proactive in providing feedback into such research programmes. In this way, research institutions would ensure that research programmes target their operational needs. I therefore commend NFTRC and co-organizers for bringing stakeholders together to facilitate such an exchange.

Elsewhere in the world countries are participating in and benefit from new technological innovations. Outputs of scientific and technological research offer immense possibilities for solving many of the complex problems that currently impede economic and social development in Africa. Such outputs are basic and essential to the economic growth and industrial growth of any nation. Perhaps we should take a leaf from newly industrialized nations such as India. In technological innovation and industrialization, India has performed well. For instance before 1947 India was a net importer of most finished products. Today India is a major manufacturer of every item of consumer goods that one can buy in the open market. The country is self-sufficient in consumer items, and exports more than 150 different categories of finished products. This great achievement was driven by SMMEs and a strong and close collaboration between scientific research and industry.

The importance of research cannot be over emphasized as in Botswana examples of what scientific research output can do to transform the socioeconomic status of the nation are also abundant. Before the introduction of the sorghum milling technology by Rural Industries Innovation Centre (RIIC), in partnership with IDRC of Canada, sorghum milling was a drudgery endured by women and children. As a result of the arduous labour required for their processing, it was also already evident that the consumption of sorghum and millet was declining at the time. Since the introduction of the current milling

technology, the consumption of sorghum and millet products has picked up, and as we speak today there are more than 234 sorghum mills throughout the country. These milling plants have created several thousand jobs for Batswana. Due to the increase in demand for sorghum and millet products further jobs continue to be created at primary production level. In our context, the improvement in milling technology further validates efforts and investment being put into the commercialization of arable farming through programmes such as the newly introduced Integrated Support Programme for Arable Agriculture Development (ISPAAD). This is just but one example that shows that by sharpening our ability to harness scientific and technological outputs we can diversify our economy for all of us to prosper.

Global food consumption trends as shown by FAO Statistics indicate that there is an increase in the dietary energy intake globally. The share of dietary energy supplied by cereals, however, seems to have remained relatively stagnant over time globally, and has declined slightly in developing countries, where it fell from 60% to 54% over a period of 10 years. This decline has been attributed to cereals such as wheat and rice gradually becoming less preferred foods. Given the health promoting benefits associated with the consumption of cereals, such as the reduction of cardiac related diseases, it is necessary to reverse the downward trend in cereal consumption. Perhaps this is an opportunity to focus efforts towards promoting consumption of the hitherto less utilized traditional grains, such as sorghum and millets, which for a long time were overlooked by the global market. However, in turning to the sorghum and millet grains we must be mindful of the fact that we are still lagging behind in the area of value adding processing technologies. We therefore urgently need to explore opportunities to develop attractive value-added products from sorghum and millets in order to widen their consumption, since doing this is synonymous with increasing jobs.

Being part of the grain value chain NFTRC is, among others, mandated to conduct research, develop and promote adoption of food processing technologies which have commercial potential. I wish to commend the NFTRC as the lead organizer and members of the organizing committee of this workshop, which I was informed, comprised members of NFTRC, RIIC, BAMB, Botswana Confederation of Mill Owners (BCMO) and Department of Agricultural Research, for making this workshop possible. Of course this would not have happened without the kind sponsorship and guidance of INTSORMIL and CST-SA, which we very much appreciate.

I would like to pay special tribute to all the presenters, especially those of you who have travelled from far afield, for having agreed to come to share their professional knowledge with us here. We realize that we cannot walk this path alone, but rather need to establish and intensify cooperation between us in the region and internationally. This kind of collaboration is particularly important for us in Africa, given that resources like the Human Resource capacity, modern equipment and scientific literature needed for research are in short supply and need to be shared. I believe going forward Botswana will continue to provide an excellent platform for these exchanges and therefore can serve as a model of other developing countries.

Director of Ceremonies, ladies, and gentlemen, I wish participants fruitful discussions over the next three days, and I now have the pleasure to declare this workshop officially open.

PULA!!!

WELCOME REMARKS

Dr Charity Kerapeletswe-Kruger
Managing Director - NFTRC

The CEO of the Botswana Agricultural Marketing Board, Rre Mphathi
The Chairperson of NFTRC Board, Rre Tlhomelang
Distinguished workshop participants and experts in Food Processing
Directors of NFTRC Board here present
Senior officials from government, parastatals and non-governmental organizations
The entrepreneurs from the food processing industry
Representatives of farmer's organizations
Ladies and gentlemen

Good morning (Ke a dumedisa). It is a great honour and pleasure for me to be given this opportunity to welcome you to this first **Alternative Cereal Processing Technologies Workshop**. I believe this workshop marks the beginning of many workshops of this nature that will come in the future.

Before I proceed with my welcome remarks, I just want to know this, did anyone have sorghum porridge this morning? Well, sorghum is the staple food for Botswana. It is usually served as breakfast cereal. If you missed having sorghum porridge for breakfast, all is not lost, you can still have it later for lunch or for dinner. Oh yes, we eat sorghum porridge all day long. So there is no reason why anyone of you should go back without tasting a little bit of Botswana, our porridge!

Ladies and gentlemen, I note that this workshop has brought together participants from Botswana, South Africa, United States of America and other countries to share information and exchange experiences on alternative cereal processing technologies.

This workshop is most appropriate, as cereal constitute a major source of dietary nutrients all over the world. Sorghum in particular, is a staple food in many parts of Africa, Asia and parts of the Middle East.

It is also used as animal feed in many other countries such as the USA. Being Motswana, it was a big challenge for me to live in the USA, with plenty of milo (sorghum) growing even on the university grounds, and yet I did not have access to it. You can imagine how home sick I felt!

This workshop came at the right time when institutions such as ours are faced with a number of challenges, one being enhancing food security, nutrition and health of the nation, and the other being adding economic and nutritional value to food material through product and process development.

Distinguished guests, we are late starter in food processing. In the past not much effort was made to harvest research products. The food manufacturing industry in Botswana also did not taken keen interest as most of the foods we consume locally are imported from South Africa. Now applied research, especially in food processing, is taking centre stage in Botswana. At NFTRC we have gone a step further to align our research work with government development

policy objectives of economic diversification, job creation, poverty alleviation and the fight against HIV/AIDS, etc.

We see our Centre as a critical link in the food value chain. We provide both forward and backward linkages through generation of food technologies. We promote the establishment of food manufacturing industries, which in turn promote agricultural production through increased demand for raw materials. To date we provided outstanding technical support to government and food enterprises in the country.

To sustain our research, however, we need both financial and technical support. With this kind of support, we will be better placed to develop programs that can better the lives of many. In a nutshell, there is still need to adequately address the resource constraints that the Centre faces.

Just to highlight some of the serious constraints that we are faced with; Presently, the Centre is not adequately funded to cater for all its activities and optimal operation. The Centre has the necessary equipment but lacks skilled scientists to wholly utilize the physical resources.

To conclude, our hopes are high that you will in the course of time, assist us in our endeavor, which I believe is also your endeavor, to achieve our research objectives. My job is to welcome you to this occasion, which marks the commencement of an event that will now be taking place annually, I hope. Let me take this opportunity to thank scientists from USA, South Africa and other countries for showing interest in participating in the deliberations of this workshop on Alternative Cereal Processing Technologies. This occasion provides the scientists from Botswana and the rest of the world an opportunity to establish linkages, which will be beneficial for collaboration in regional research programmes, and to our food manufacturing industry. To the American scientists here present, may I encourage you not to use milo as animal feed, it is human food in this part of the world. To the South Africans, I encourage you to eat less pap and more sorghum.

Distinguished guests, ladies and gentlemen let me end by wishing you successful deliberations and implementable resolutions at the end of the workshop. Once again I welcome you all to the workshop. I am thrilled to see that so many people have come out for this workshop. We thought the theme of the workshop was an interesting and important topic, but we were not anticipating this many people, so this is really terrific. **Thank you.**

FOOD SECURITY IN AFRICA – THE FUTURE ROLE OF SORGHUM AND MILLETS

John R.N. Taylor

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INTRODUCTION

The term Food Security means many different things to different people. Most definitions are narrow, encompassing the concept of “access to adequate food” especially for subsistence farmers. I have a somewhat broader view. To me, “Food security is where a person has a livelihood that provides him/her and his/her dependents with access to safe water, adequate food, shelter, healthcare and education.”

TABLE 1: Sorghum and millet (pearl millet and finger millet) production in African countries where it exceeds 10% of their total cereal production (data from FAO, 2008)

Country	Sorghum		Millets	
	Production (thousands of tons)	Percentage of total cereal production	Production (thousands of tons)	Percentage of total cereal production
Angola			147	20.1
Benin	200	16.4		
Botswana	33	69.4		
Burkina Faso	1620	43.3	1104	29.5
Burundi	75	26.9		
Cameroon	540	34.5		
Central African Republic	43	21.4		
Chad	700	22.7	550	17.8
Eritrea	130	73.4	20	11.3
Ethiopia	2300	16.8		
Gambia	40	14.3	160	57.0
Ghana	350	18.9		
Guinea	38	14.5	323	12.4
Guinea-Bissau	25	12.3	50	24.7
Lesotho	11	15.3		
Mali	908	25.9	1074	30.6
Mauritania	58	37.4		
Mozambique	350	16.1		
Namibia			58	50.9
Niger	975	25.4	2782	72.4
Nigeria	10500	34.0	7700	25.0
Rwanda	187	54.8		
Senegal	120	13.6	363	41.0
Somalia	80	40.8		
Sudan	5048	76.8	792	12.1
Tanzania	900	15.3		
Togo	200	24.7		
Uganda	456	17.3	732	27.8

Sorghum and millet (pearl millet (*Pennisetum glaucum*) and Finger millet (*Eleusine coracana*) are important cereals in Africa, with 27.2 and 17.2 million tons being produced in 2007, respectively (FAO, 2008). These figures represent 18.7 and 11.7% of total African cereal production, respectively. Their importance to food security, however, varies greatly

from country to country (Table 1). As can be seen, the countries with the highest proportion of sorghum and millet production are in the Sahel region and North Africa around the Sahara Desert, the Horn of Africa, in South-west Africa around the Kalahari and Namib Deserts and in East Africa. Generally, these are areas of very low rainfall, less than 500 mm per year. In these areas sorghum and pearl millet predominate as food crops for subsistence farmers on account of their unique ability to produce a crop under conditions of low rainfall and because in the case of sorghum it is drought-tolerant (INTSORMIL and ICRISAT, 1997).

Since in Africa sorghum and the millets are used solely for producing foods and beverages and for animal feed, this paper will primarily examine their nutritional and other qualities with respect to food security as defined above, with the emphasis on potential opportunities for farmers and food and beverage processing entrepreneurs.

NUTRIENT COMPOSITION OF SORGHUM AND THE MILLETS

Neither sorghum, pearl millet nor finger millet are exceptional in nutritional quality, when compared to other cereals (Table 2). Thus, while they are important starchy staples, they do not constitute a complete diet. Here only their apparently more unusual nutrient compositions will be considered. With regard to sorghum, its lipid content at around 3.4% is relatively high for cereals, on account of its proportionally large germ, around 8% of the kernel.

TABLE 2: Nutrient composition of sorghum, pearl millet and finger millet compared to hard wheat (adapted from Taylor and Emmambux, 2008a). Data expressed on a 12% moisture basis

Nutrient	Sorghum	Pearl millet	Finger millet	Wheat (hard red spring)
Energy (kJ)	1374	1443	1396	1389
Protein (g)	11.6	11.5	7.3	15.9
Lysine (g)	0.24	0.36	0.19	0.41
Lipid (g)	3.4	4.7	1.3	1.9
Ash (minerals) (g)	1.6	2.3	2.6	1.9
Carbohydrate (g)	77.0	71.6	74.0	68.6
Dietary fibre (g)	6.3 (white sorghum 9.1-11.5 (others))	9.7	3.2 (crude fibre)	12.3
Ca (mg)	29	36	358	25
Fe (mg)	4.5	9.6	9.9	3.6
Mg (mg)	135 ¹	111	140	125
P (mg)	296	332	250	335
K (mg)	361	498	314	343
Na (mg)	6	15	49	2
Zn (mg)	1.4	2.0	1.5	2.8
Cu (mg)	1.7	0.5	0.5	0.4
Mn (mg)	No Data	0.8	1.9	4.1
Se (µg)	No Data	No Data	No Data	71.3
Thiamin (mg)	0.24	0.30	0.24	0.51
Riboflavin (mg)	0.15	0.19	0.11	0.11
Niacin (mg)	3.0	2.5	1.0	5.8
Vitamin B6 (mg)	0.18-0.48	No Data	No Data	0.34
Folate (µg)	84	No Data	No Data	43
Vitamin A (µg retinol equivalents)	10-20	22	6	3
Vitamin E (α-tocopherol) (mg)	1.2	1.9	2.2?	1.0

? = questionable data

In sorghum, the content of the essential amino acid lysine is only around 2.0 g/100 g protein and data suggests that sorghum has somewhat lower lysine amino acid scores than other major cereals (Klopfenstein and Hosney, 1995). However, the range of values is very wide

and probably the real differences are marginal. An apparently unique feature of sorghum protein is that its digestibility is substantially reduced when the flour is wet cooked to make a food product such as a porridge or bread (Duodu et al., 2003). This seems to be primarily due to cross-linking by disulphide bonding of the major proteins in sorghum grain, the kafirins. A reduction in protein digestibility is clearly disadvantageous for people whose protein intake is limited.

With regard to micronutrients, the bioavailability of the minerals in sorghum is probably more adversely affected than most cereals, due to its high levels of phenolics, and particularly tannins where present (Serna-Saldivar and Rooney, 1995). To alleviate the problem of the poor protein quality, digestibility and micronutrient availability in sorghum a research project, the Africa Biofortified Sorghum (ABS) project is being undertaken the auspices of the Gates Foundation Grand Challenges in Global Health. Using genetic engineering and conventional breeding new lines of sorghum are being developed with substantially increased levels of lysine, pro-Vitamin A, and improved mineral and protein bioavailability (ABS Consortium, 2008). This Biofortified Sorghum will not only be valuable in improving sorghum consumers' nutrient and health status but also as feed for monogastric animals and for industrial uses such as brewing.

As indicated, a very important nutritional feature of sorghum grain is that many varieties contain substantial quantities of phenolic compounds. The phenolic compounds can be categorised into three groups: simple phenolic acids, monomeric polyphenolic flavonoids and complex polymeric polyphenolic condensed tannins (also called proanthocyanidins or procyanidins) (Awika and Rooney, 2004). It is important to understand that condensed tannins are only present in some sorghum varieties, the tannin sorghums. Tannin sorghums have somewhat lower nutritional value than tannin free sorghums and other non-tannin containing cereals. There are numerous animal studies that show lower weight gain for animals fed tannin sorghums (Hancock, 2001). The mechanisms involved are incompletely understood. Tannins form complexes with food proteins and carbohydrates. Tannins also bind with and inactivate digestive enzymes such as proteases and amylases.

Regarding pearl millet, the grain has a high energy content for a cereal grain, approx. 1443 kJ/100 g. This is on account of the high fat content of the grain (approx. 4.7%), resulting from its large germ. Because of its high fat content, pearl millet is a probably a good source of tocopherols (Vitamin E), located mainly in the germ. The protein content is also relatively high, 11.5% or higher, again due to the large germ. The proteins in the germ are of the albumin and globulin type, which are rich in essential amino acids (Serna-Saldivar and Rooney, 1995). Its protein therefore has high lysine content for a cereal grain (2.8-3.2 g/100 g). The high energy content and level of lysine make pearl millet particularly valuable as poultry feed.

Like sorghum, pearl millet can contain flavonoid phenolics in the pericarp, which are responsible for brown/grey pigmentation of the grain and have antioxidant activity. There is evidence that some of these can act as antinutrients, specifically as goitrogens. The causal agents seem to be C-glycosyl flavones: vitexin, glucosyl vitexin and glucosyl orientin (Birzer and Klopfenstein, 1988). These compounds apparently inhibit the deiodination of the hormone thyroxine to its more active form triiodothyronine. As they are concentrated in the pericarp, they are considerably reduced when the grain is "dehulled" during milling. However, the nutritional significance of the goitrogens in pearl millet should not be overstated. Although some rural people in the Sudan who consume pearl millet as a staple

have been found to suffer from goitre, it is probable that this is because their diet is very restricted and hence deficient in iodine.

With regard to finger millet, perhaps its most significant nutritional characteristic is its low fat content, only about 1.6%. This undoubtedly contributes to the good storability of the grain. In terms of fatty acid composition, finger millet seems to be unusual for cereals in that nearly half is oleic acid (C18:1) (Serna-Saldivar and Rooney, 1995), the monounsaturated fatty acid for which olive oil is famed. The protein content of finger is low, but it has been reported that it is particularly rich in the essential amino acid methionine (National Research Council, 1996). This is not supported by data presented by Serna-Saldivar and Rooney (1995), which show a normal methionine content. Table 2 indicates that the overall mineral (ash) content of finger millet is high and that some particular minerals such as calcium and sodium are very high. However, these data are very likely misleading due to contamination with earth, which is particular problem with small sized grains like finger millet.

Finger millet is a rich source of phenolics. It contains flavone type flavonoids, which are undoubtedly responsible for the red/brown colour of many varieties. Finger millet foods are also strongly flavoured, so it is possible that these compounds are also responsible. Some finger millet varieties also contain tannins; levels up to 2% have been found (Siwela et al., 2007). These levels are somewhat lower than those reported for tannin sorghums.

The basic production and nutritional data do not tell the full story with respect to sorghum and millets for food security in Africa. For example, in South Africa commercial companies make an excellent living growing sorghum and processing it into food and beverage products such as porridge flour and sorghum beer, and in Kenya finger millet is highly valued for uji (soft porridge) making. In fact, when traded in Kenya, finger millet is five times the cost of maize. Hence, the remainder of this paper will concentrate on the food and beverage quality aspects of sorghum and pearl and finger millet with respect to their current and future commercial use, and their potential to provide livelihoods.

CURRENT AND FUTURE COMMERCIAL USES

Exploiting the health-promoting aspects of sorghum and millets

Sorghum and the millets have some very useful health-promoting components that should be exploited to increase their marketability.

As discussed, sorghum and the millets are generally rich in phenolics. Phenolic compounds have high antioxidant activity. There is evidence that the consumption of foods rich in antioxidant phenolics is highly beneficial in terms of the prevention of diseases such as cardiovascular disease and cancer (Awika and Rooney, 2004). Products such as fruits and teas are already being marketed on the basis of them being rich in antioxidant phenolics. In this respect, sorghum and millets are lagging far behind.

People who eat both sorghum and maize frequently refer to sorghum “filling the stomach” more than maize and giving one energy all through the day. This is well-supported by scientific evidence. It has been shown *in vitro* that the rate and extent of digestion of starch is sorghum, particularly cooked sorghum is low (Ezeogu et al., 2005). This *in vitro* work is supported by animal feeding studies, mainly using raw grain, which have consistently shown that sorghum has a lower metabolisable energy content than maize. The advantage of slower starch breakdown is that sorghum seems to be more sustained source of energy than, for example, maize. For this reason, many doctors in Africa recommend that people who are at

risk from Type II diabetes consume sorghum on account of its slower starch digestibility. In Europe, the USA and Australia, the rates of obesity and Type II diabetes are so high as to constitute a health crisis. The potential of sorghum to prevent these conditions should be investigated in more depth, as positive evidence could greatly increase the demand for sorghum.

The wax of sorghum, which is on the pericarp surface of the grain, may also have some unique health-promoting properties. Of specific interest are the primary long chained alcohols in the wax, which are called policosanols. Policosanols are reportedly effective in lowering the amount of low-density lipoprotein (LDL) cholesterol and raising the amount of high-density lipoprotein (HDL) cholesterol, thus improving the LDL/HDL ratio (Hargrove et al., 2004).

It is becoming evident that a substantial proportion of people, perhaps as many as one in 150, should not consume food and beverage products made from wheat, barley and rye, as consumption makes them ill. The most well-known condition is coeliac disease, where the proteins of these grains, the so-called “gluten-like proteins” are toxic to sufferers. The proteins of sorghum do not cause this condition (Ciacci et al., 2007), and the same is undoubtedly true for the millets. In Europe and the USA there is a rapidly growing market for “gluten-free” cereal products, such as bread and cakes and even beer.

Commercial Products

Of major importance is that across Africa, sorghum is becoming the grain of choice for lager and stout beer brewing by major international companies (Taylor et al., 2006). This is because of its competitive price and availability compared to barley and its intrinsic good brewing properties in terms of starch content and malting quality.

In Africa, sorghum and millets are also used to produce a very wide of range of traditional food and beverage products (Taylor and Emmambux, 2008a,b). Some of these of have been exploited commercially, most notably opaque beer which is brewed industrially on a large scale in several southern African countries (Daiber and Taylor, 1995). With the rapidly increasing urbanisation in Africa and growth of the middle class, who demand convenient and healthy foods, there is much scope for commercialisation of other traditional African sorghum and millet products. The examples of couscous, injera and pito beer will be discussed.

Couscous comprises pieces of cereal meal have been pre-cooked by steaming and is generally made from wheat semolina. However, in the Sahel region, couscous is traditionally made from pearl millet and sorghum flour. Repeating steaming steps partially gelatinise the starch on surface of the flour particles, gluing them together to form the couscous. Today, this couscous is beginning to be manufactured for both the local middle-class market and also for export to Europe as a gluten-free food.

In Ethiopia and Eritrea, sorghum, finger millet and tef (a cereal very like finger millet) are used to make injera, the staple cereal food product in these countries. Injera is a large (approx. 50 cm diameter), spongy textured leavened pancake about 5 mm thick. A key step in the process of making injera involves pre-cooking part of the dough. This gelatinises the starch making the dough viscous, allowing the injera to hold gas and rise during baking (Taylor and Emmambux, 2008b). Injera is what is today referred to as a “wrap”, a very popular convenience food for eating a balanced meal of starch, meat and vegetables in a hurry.

In Ghana and Nigeria, women brew on a small commercial scale a traditional beer called pito or burukutu. Although slightly sour in taste, it more closely resembles lager beer than southern African opaque beer, both in terms of its brewing process and that that is mainly clear. The process of pito beer brewing is extremely clever. Steps include preparation of an enzyme extract, separate gelatinisation of the starch and clarification of the wort by flocculation. Pito type beer could exploit a gap in the market between lager beer and opaque beer, and even appeal to the gluten-free market.

CONCLUSIONS

Sorghum and the millets are not just important crops for food security in Africa in its narrow sense, they also have great potential to provide livelihoods through commercial farming and food and beverage manufacture. To exploit their potential, there needs to be a partnership in southern Africa of all stakeholders, including government, scientists, educators, farmers, entrepreneurs and non-governmental organisations.

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GOVERNMENT POLICY ON CEREALS PRODUCTION IN BOTSWANA

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INTRODUCTION

The baseline area for the communal sub-sector for cereal production is about 600,00 ha, however, the average area planted for the past seven (7) years was 66,646ha ranging from 17,000ha to 123,838ha in 2001/02 to 2005/06 respectively, planted by about 83,000 small scale farmers.

The total area planted to cereal crops in Botswana varies with seasons following the rainfall pattern. The area planted increased when there is good rainfall and is reduced when the rainfall is limited. The major cereal crops include maize, sorghum, millet and cowpeas.

Under the commercial sub sector, the total hectareage planted is about 25,000ha, cultivated by 20 Enterprises. The area planted also fluctuates depending on the rainfall situation. The average production per unit area ranges from 0.1mt/ha to 2mt/ha for the small scale and commercial farmers respectively.

On average, while the national annual demand is around 200,000mt the national annual production is only around 40,000mt, which makes a supply gap of 160,000mt, which has to be met by importation from other countries.

GOVERNMENT POLICY ON CEREAL PRODUCTION

As the Arable Land Development Programmes (ALDEP) I, II, and III have not improved food situation in the country, the government has replaced it with the **Integrated Support Programme for Arable Agriculture Development (ISPAAD)**. This is a government assistance programme aimed at helping all categories of farmers to improve on their production per unit area.

ISPAAD Has the Following Packages

- Free seed for 16 ha and 50% payment for extra hectares.
- Free fertilizer for 5 ha and 50% payment for additional fertilizers required.
- Free ploughing/planting for 5 ha and payment of 50% of additional hectares ploughed/planted.
- Cluster fencing, where a group of farmers with a minimum of 150 ha will be fenced by one perimeter fence by the government to reduce on the fencing costs.
- Establishment of 15 Pilot Agricultural Service Centres that will sell agricultural inputs nearer to farmers. They will also provide mechanical draught power and associated

implements at a cost to the farming community. These Agricultural Services Centres will be extended to the rest of the country if they can be proved to be effective.

LIMITATIONS

The majority of our farmers are small scale, most of whom have not adopted improved crop production technologies. Most of them harvest very little crops per unit area because they never analyze their soils to establish their fertility levels. They only work on soils they do not know their fertility levels, as a result always harvest very little per unit area as the soil nutrients are always very low.

Our commercial farming sub sector is only composed of 20 enterprises that produce about 80% of our local cereal production.

The other most limiting factor is that most small scale farmers believe in increasing their cereal produce through ploughing/planting very extensive hectarages. They believe in extensive rather than intensive crop farming. As a result of these extensive farming practices, they are unable to carry out all the necessary cultural practices that could improve on the crop yield per unit area.

Challenges in Crop Production

There are many challenges that hinder increased cereal production and some of them are as listed below:

- Inadequate technology adoption and application.
- Lack of access to credit, thus unable to purchase required seasonal inputs.
- High cost of seasonal inputs such as fertilizers, pesticides etc, thus limiting their application.
- Lack of crop insurance, thus unable to guard against natural hazards.
- Poor agricultural infrastructure such as roads, power and telecommunication to production areas.
- Undeveloped marketing system, that becomes too expensive for farmers to market their produce.
- Shortage of farm machinery and appropriate implements to speed up timely farming operations.

STRATEGIES TO IMPROVE CEREAL PRODUCTION

In addition to the above efforts, the government will do the following in an effort to improve on Cereal Production:

- Establishment of Production and Training Farms (PTFs) that can be used as on the ground Rural Training Centres for farmer training.
- Tailor made training programme (targeted messages) for all categories of farmers.

- Establishment of production clusters with a minimum of 150ha in areas with high potential in agricultural production.
- Establishment of Agricultural Insurance Schemes to guard against natural hazards.
- Formation of Producer Associations to team up for a common purpose.
- Intensify on conducting of Farm Walks to give farmers the chance to learn on the ground.
- Extension officers should intensify on training of farmers through demonstrations.
- Extension Officers should encourage all farmers to start their agricultural business by analyzing their soils so that they can know what type of soil they are working on.
- For them to get high yield per unit area, they should add some fertilizer to their soils as per the recommendation of the soil analysis results.
- Each farmer, particularly among small scale farmers should be encouraged to work on a small hectareage they can afford to manage as required – they can be able to undertake all cultural practices.
- Training of farmers by other farmers is very effective because farmers believe in “If he did it, then why can’t I also do it”.

OUTPUTS OF THE SORGHUM AND PEARL MILLET BREEDING PROGRAMME IN BOTSWANA

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INTRODUCTION

Sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*), are important staple food crops in Botswana. Both crops are drought tolerant and hence better adapted than many other crops to the semi-arid environment in Botswana. Sorghum is the most widely cultivated and hence it is found in most of the districts in the country. It is grown annually in about 140,000 ha with a production of about 27,000 tonnes (CSO, 2004). In contrast, pearl millet cultivation is confined to the north-eastern part of country and the Okavango sub-district in the north-western part where it may account for as much as 90% of the total area planted. It is grown in area of about 14,000 ha with an annual production of about 2,100 tonnes.

A large proportion of Botswana is occupied by marginal land with poor soils and when this is coupled with the low, unpredictable and unreliable rainfall agricultural productivity is greatly reduced. Traditional varieties of these two crops are genetically diverse and this might be largely responsible for their adaptation to low moisture and high temperature conditions. In general, grains of local sorghums have a white or red pericarp, lack a subcoat or testa and possess a hard, corneous endosperm. In Botswana, sorghum is primarily used for human consumption and therefore any grain, whether with a white or red pericarp, is acceptable as long as it produces acceptable porridge. Boling and Eischer (1982) observed that texture of the meal produced by the sorghum grain appears to be more important than colour.

SORGHUM AND MILLET PRODUCTION AND CONSUMPTION IN BOTSWANA

In Botswana, the production of sorghum and millet is in the hands of small farmers and is largely derived from the traditional varieties. Sorghum is the predominant crop in terms of area planted, percent area harvested and production (Figures 1, 2 and 3). Between 1979 and 1988, the area planted to sorghum increased significantly before a downturn which led to sorghum being surpassed by maize in area planted in 1998. The area planted to millet, although very small, is also declining albeit at a slower pace. It is also useful to note that in any given year the area harvested is always lower than the area planted and in certain years there is a complete crop failure (Figure 2). Yields of sorghum and pearl millet are low, ranging from 200 – 300 kg ha⁻¹ in the traditional farms and 1000 – 2000 kg ha⁻¹ in the commercial farms. The higher productivity in the commercial sector is attributable to adoption of technologies and use of improved crop management practices. Sorghum production has remained below the national demand and therefore the shortfall is met through imports (Figure 3). Sorghum imports are the primary reason why the sorghum milling industry is still in existence. This industry has graduated sorghum from being a food security crop to a commercial crop (Rohrbach et al 2000). Despite that, commercialization of sorghum has had limited impact on domestic sorghum production.

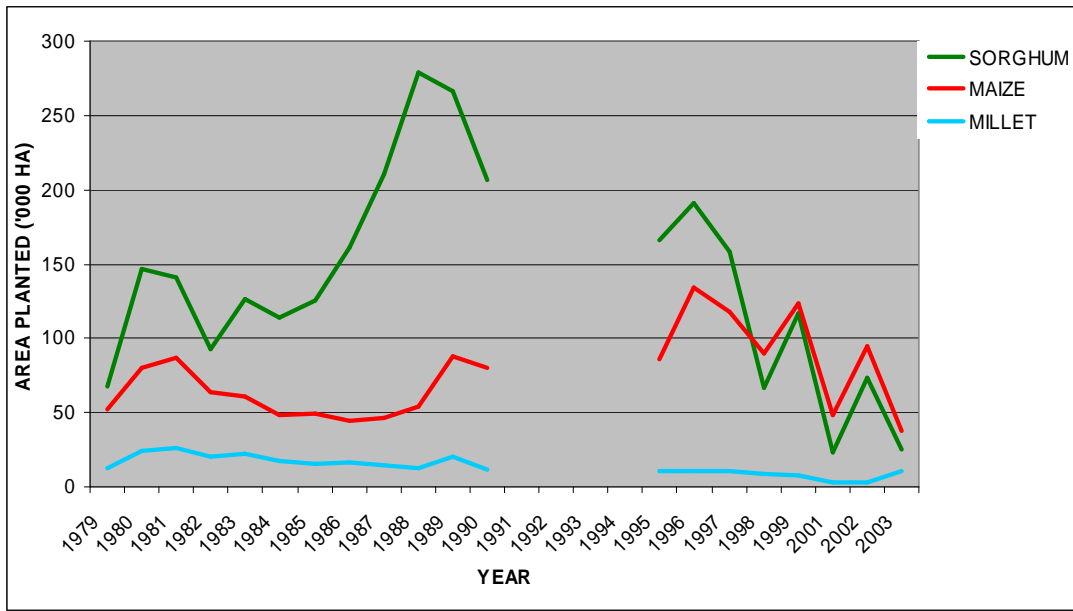


Figure 1. Total Area Planted to Sorghum, Maize and Millet in Botswana (1979-2003).
Source: Central Statistics Office Annual Report (2004)

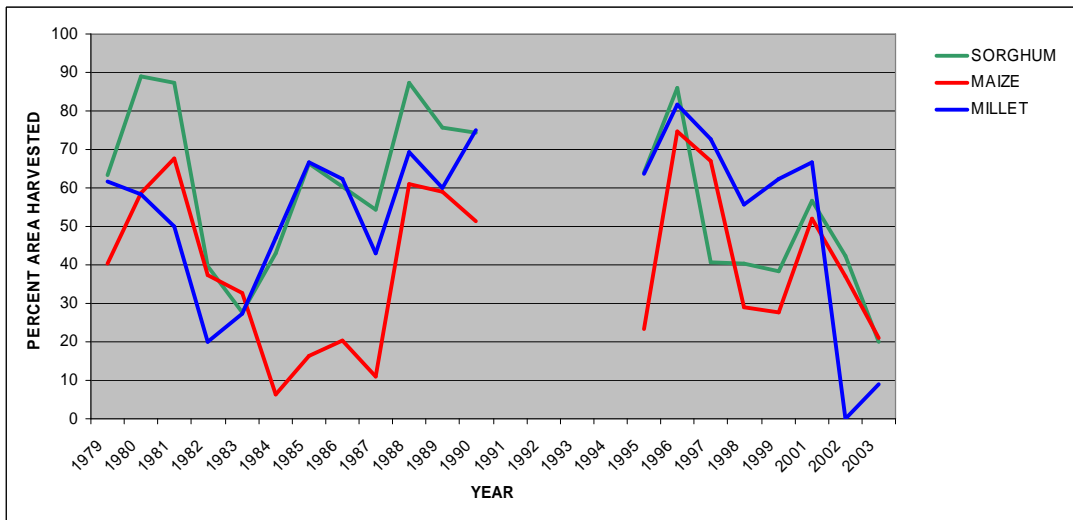


Figure 2. Percent Area Harvested for Sorghum, Maize and Millet (1979 – 2003)
Source: Central Statistics Office Annual Report (2004)

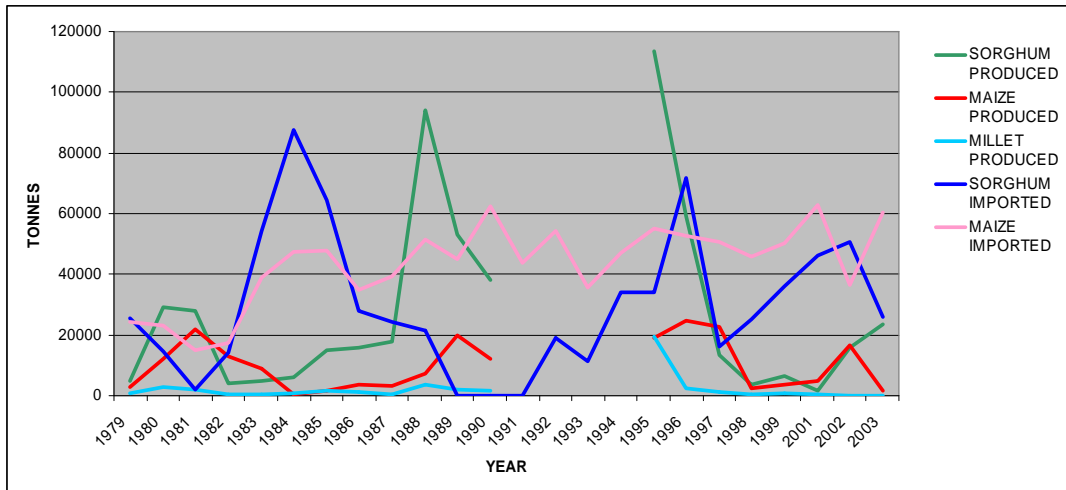


Figure 3. Total Sorghum, Maize and Millet produced and imported (1979-2003)

Source: Central Statistics Office Annual Report (2004)

Source: FAOSTAT Imports

CONSTRAINTS TO SORGHUM AND MILLET PRODUCTION

The major constraint to sorghum and millet is low productivity which occurs as a result of farmers opting to use their traditional varieties instead of improved varieties. This is so despite the fact that several improved varieties of sorghum and millet have been developed and released. The failure by farmers to adopt recommended agronomic management practices is also another constraint. Labour costs associated with sorghum and millet production are very high whereas returns for the labour invested are very low (Rohrbach et al, 2000). The susceptibility of sorghum and millet to bird damage is the major reason why many farmers are switching to maize.

SORGHUM AND MILLET BREEDING IN BOTSWANA

Sorghum and millet breeding was started 1983 in Botswana (DAR, 1984). The goal of the breeding programme was to raise productivity of sorghum and millet through the development of varieties with high and stable yields, resistance to biotic and abiotic stresses. Initially emphasis was on introducing and breeding open pollinated varieties. Recently, however, the focus is also on developing hybrids as it has been realised that hybrids perform equally well under low-input agriculture. The breeding programme benefited and is still benefiting from collaborative research efforts with ICRISAT, INTSORMIL and other initiatives in accessing enhanced genetic stocks for direct release or breeding purposes. Most of the national sorghum and millet varieties released are products of these collaborative research efforts. However, the adoption of these varieties by farmers has been very poor as farmers prefer their own varieties (Rohrbach and Makhwaje, 1999) although they have a relatively poor yield potential.

RESEARCH OUTPUTS OF SORGHUM AND MILLET

SORGHUM

Segaolane

Segaolane is an open pollinated variety of sorghum selected in Botswana. Its early growth is very vigorous and tillers profusely. Mature plants are 1.5 –1.8m in height. It normally flowers 60-65 days from date of planting. It takes 130 days to physiological maturity. The heads are of good size, ripening evenly, with medium grains that are pearly white in colour. The variety produces semi-open heads with very good exertion. Segaolane has good resistance to most leaf and stem diseases. It is however susceptible to aphid infestation and damage under very late rain conditions. The porridge made from Segaolane is slightly dark but very palatable. The variety has very good milling qualities.

Phofu

Phofu is a tan plant open-pollinated variety that was released in 1994. Its early growth is relatively vigorous, produces stout stems with large semi-erect leaves and is very poor in tillering. Mature plants are 1.5 – 1.6 m high. Flowering commences at about 68 – 70 days after planting. It produces large, compact heads with white, medium sized grains. It yields between 1.5 – 3.0 tonnes ha⁻¹, has very good milling qualities and its porridge is of excellent appearance.

Mmabaitse

Mmabaitse is a white grain variety released in 1994. This is a medium season variety flowering at about 70 days after planting. The heads are medium, semi-compact with good exertion. The plants grow to a height of 1.1 -1.2 m and the variety yields between 1.5 – 3.0 tonnes ha⁻¹.

Mahube

Mahube is an improved red seed dwarf variety released in 1994. Its early growth is slow. Mature plants are 0.9 – 1.0m high. Flowering occurs at about 55-60 days after planting and will reach physiological maturity in about 105 days. The heads are large with medium to large grains. It is recommended for mid-late season planting and yields between 1.5 – 3.0 tonnes ha⁻¹.

Botswana Sorghum Hybrid 1 (BSH-1)

The only sorghum hybrid released in Botswana, BSH-1 is a single cross hybrid released in 1994. It flowers at 68 -78 days after planting and takes 130 – 150 days to maturity. Mature plants measure 1.3-1.6 m in height. It produces large heads with bold white grains. This hybrid produces excellent flour and has very good milling qualities. The porridge is very appealing in appearance. It may yield between 3 and 6 tons ha⁻¹.

Sephala

Sephala is a tan plant variety of sorghum released in 2004. Mature plants are 1.2 -1.5 m tall and flowering is normally between 68 – 75 days from date of planting. It takes 120 -130 days

to reach physiological maturity. The heads are of medium size with white medium sized grains. The variety has excellent milling qualities. It yield between 1.5 and 3 tons ha⁻¹.

PEARL MILLET

Serere-6A

Serere 6A is an open-pollinated variety released in 1998. It flowers early at about 51 days after planting. Mature plants have a height of 1.4 m and produces long cylindrical compact heads with or without awns. The variety exhibits good resistance to drought and lodging. It has good milling qualities and produces yields between 1 and 2 tonnes ha⁻¹.

Bontle

Bontle is an open-pollinated variety released in 1998. It flowers early at about 60 days after planting. Mature plants have a height of 1.5 m and produces well-exserted medium length cylindrical compact heads with bold grey, large grains. It has good milling qualities and yields between 1 and 2 tonnes ha⁻¹. The variety is resistant to downy mildew.

Legakwe

Legakwe is an open-pollinated variety released in 1998. It flowers early at about 60 days after planting. Mature plants have a height of 1.7 m and produces long cylindrical compact heads with bold grey, medium-sized grains. It has good milling qualities. The variety has moderate resistance to important diseases. It yields between 1 and 2 tonnes ha⁻¹.

SUMMARY

Sorghum and millet are important staple food crops in Botswana. Of the two crops, sorghum is the most widely cultivated while millet is important in the Okavango sub-district and to some extent in the north eastern part of country. The area planted to sorghum is decreasing and so has been the production. Yields under the traditional farming conditions have remained low, ranging from 200 – 300 kg ha⁻¹ although improved varieties may give on average 2000 kg ha⁻¹ of grain under good management. Traditional varieties occupy most of the area planted to sorghum and millet. The Department of Agricultural Research has released sorghum and millet varieties with high yield potential. Adoption of these varieties is yet to be realized. Labour costs associated with sorghum and millet production are also very high. These factors combined have led to a yearly sorghum deficit in the country.

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SORGHUM AND MILLETS CONSUMPTION PATTERNS IN BOTSWANA

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INTRODUCTION

Sorghum (*Sorghum bicolor*) comes fifth in importance after wheat, maize, rice and barley in global cereals production, and although still prevalently grown for subsistence, sorghum is becoming increasingly important in commercial production. In Africa, sorghum is the second most important cereal, with about 20 million tonnes produced per year, which is one third of world production (Taylor, 2003). Production of millets was reported to cover 18.50 million hectares in Africa (Obilana, 2003). Sorghum and millets accounted for 23% of SADC's cereal production, while being the dominant grain crops in the SADC member countries of Botswana and Namibia, accounting for 86 and 50% of total cereal production, respectively (FAO, 1995). For Botswana, the prevailing crop between the two cereals is sorghum, while pearl millet is the more widely grown one in Namibia.

Agte *et al.* (1999) reported the superiority of pearl millet to sorghum and rice in terms of bioavailability of micronutrients, and to all the other cereals (sorghum, wheat and rice) in terms of weight gain in mice. The consumption of millet in Botswana has remained fairly high in the northern part of the country, and low in the south, mainly owing to cultural differences – in the north it is mainly grown for food, while in the south, where sorghum is more popular, pearl millet has traditionally been grown on the edges of fields, intended for birds to feed on, hence deterring them from attacking other crops that are perceived to be more valuable; this notwithstanding its high pro-vitamin A content, for example (Obilana, 2003).

Ohiokpehai and Kebakile (1996) developed prototypes of sorghum pasta, instant beer powder, health food powder, fermented sorghum (dry *ting*) powder and a nonalcoholic malt drink, which were suitable for processing in small and medium scale enterprises (SMEs). Sorghum-legume composite flours were also used to develop fried as well as steamed prototypes. Practically all of the above applications are relevant for millet as well. The study showed the potential for the use of sorghum and millet in food and beverage production in Botswana.

Kebakile *et al.* (2003) reported that attributes that were considered most important by Botswana consumers when choosing sorghum products were, for young people, nutritional and health benefits, while for older people it was mostly recognition of a traditional flavour; for both groups, light colour and a medium texture were also reported to be desirable. The researchers' findings also revealed consumers' desire for contemporary products formulated from sorghum; they expressed their need to see sorghum products such as breads, biscuits, pasta, pearled grain, breakfast flakes and fermented beverages (mageu) on the market.

According to local retailers and processors, the demand for sorghum flour is currently so high that the product simply “flies off the shelves”; for example, one miller reports sales of up to 50 tonnes/week, while one supermarket’s sales are around 1000kg/week. The distribution centre for a major supermarket chain reports sales of 750 tonnes/month. Sorghum grain is so scarce that suppliers depend largely on imported grain. There is thus clearly a large market niche for the supply of sorghum grain for processing of additional products such as *bogobe jwa lerotse*, dried *ting*, *logala*, *mosuthane*, *lehata*, malt, snacks (e.g. popped sorghum grains) and convenience foods (e.g. extruded instant meals, breakfast cereal), non-alcoholic beverages (e.g. *mageu* and malt beverages), composite flours for the baking industry, gluten-free breads, sorghum beer concentrate, etc.; most of the sorghum-based foods and beverages on this list are not commercially available, and are normally consumed at feasts, freshly prepared.

PRODUCT CONSUMPTION PATTERNS

In Botswana, sorghum is used mainly for production of flour, which in turn is used for cooking porridge. *Ting* is a very popular fermented sorghum porridge, eaten either soft (usually for breakfast, with sugar and/or milk added), or stiff (for lunch, dinner, or on special occasions, with meat and/or vegetables); households normally ferment their own; however, busy urbanized lifestyles normally mean that preparation of the fermented slurry proves to be a challenge time-wise to many busy individuals, hence the need for the development of a commercial dried product. So far the National Food Technology Research Centre (NFTRC) has had success with a couple of naturally fermented prototypes, and product development continues.

Mageu is a fermented, non-alcoholic beverage, processed through fermentation of porridge. Currently, the only type that is available on the market is made from fermented maize porridge. Botswana have traditionally been known to make *mageu* even from sorghum porridge hence this niche remains completely untouched.

The per capita consumption of clear beer in Botswana is 33.5 litres (vs. 49.4L for RSA, and 38.6L for France). Kgalagadi Breweries, a 60:40 partnership between Botswana Development Corporation and SAB-Miller (RSA), is owned by the Sechaba Group, which does consistently well on the Botswana Stock Exchange. In 2004, the Group was reported to contribute BWP1.6 Billion to Botswana’s GDP, and expressed that opportunities still existed in the supply of malt, sorghum and barley. The Sechaba Group also owns Botswana Breweries Limited (BBL), which brews the opaque beer known as *Chibuku*. In 2005, Sechaba reported a 3.3% decline in opaque beer consumption, which was however compensated for by an ‘upgrade’ to clear beer; this further buttresses the point that sorghum still has a lot of potential for utilization in the industry. In fact, this traditional beer still comprised 47% of Sechaba’s annual sales. BBL’s total sales for *Chibuku*, clear beer and *mageu* were in excess of 1.6 million litres, distributed as 64% *Chibuku*-, 34% clear beer- and about 1.5% *mageu* sales (Stockbrokers Botswana, 2005). Taylor (2003) estimates that home-brewed beer accounts for about twice the amount produced industrially. In Botswana, the brewing industry has clearly been doing well; recently though, it is experiencing somewhat turbulent times since government wishes to apply significant tariffs (30% levy) on alcoholic beverages. There is also to be a clampdown on ungazetted traditional brews.

Bogobe jwa lerotse is a porridge made from sorghum flour and melon pulp. The product is now highly popular in restaurants – for example, at the cultural night held in honour of delegates to the World Trade Organization for Africa workshop held in Gaborone, Botswana in 2005, *bogobe jwa lerotse* was the mainstay of a traditional menu that also had traditional sorghum opaque beer as a dessert option. The highly successful Motswana-Motho traditional cuisine restaurant at the Gaborone Station's Morula Food Court, *bogobe jwa lerotse* is reported to be so popular that 60L (170-200 plates) of it is sold on a busy day; this, accompanied by sales of 20-40L plain *bogobe jwa mabele* and 20L *ting*, proves that sorghum dishes are highly popular. It suggests potential for products made from mixing sorghum or millet flour with other fruit pulps e.g. porridges made with morula- and mmilo pulp, as well as pumpkin, traditionally exist.

Logala is porridge made from cooking cereal flour with milk; it thus has enhanced protein levels. This is also a highly popular product – the Management of Motswana-Motho easily substitute this product for *bogobe jwa lerotse* in cases where melons are in short supply. Similar products may be processed using liquid resulting from extraction of protein from crushed melon (e.g. *sesoswane*) seeds.

Tsabana and *Tsabolthe* are extruded sorghum-soy blends produced by Foods Botswana. *Tsabana*, intended for children (as the Setswana name suggests) as a weaning food has enjoyed much popularity even with the adult population. However, *Tsabolthe*, despite having a very similar taste, has not had that much success, mainly because people associated the type of product with alleviation of nutritional deficiencies, hence being given for free at government health centres across the country.

Morvite, a South African product, is pre-cooked sorghum flour that has been enriched with vitamins. Taylor reported that between the years 2000 and 2003, production had increased by 20% (going up to 12,000 tonnes a year, 15-20% of South Africa's entire commercial sorghum milling production. This product has enjoyed popularity in Botswana; Kebakile *et al.* (2003) reported preference for these products as being dependant on age, place of origin, household size, educational level, the type of suburb as well as gender.

The Botswana Agricultural Marketing Board (BAMB) is one of the very few commercial places from where *mosuthane* may be sourced. *Mosuthane* is dehulled sorghum. This product is part of a traditional cuisine that-, as BAMB puts it, got lost with the influx of foreign foods. Some millers were reported to have tried packaging and selling this product in the past, but it failed to win a share of the market, and this was largely blamed on poor/unappealing presentation of the product to the consumer (Kebakile *et al.*, 1997). *Lehata* is the whole grain (not dehulled) version. BAMB also sells a product known as *ntlatlwane*, which is sorghum flour that has some amount of bran (traditionally it could be whole bran).

Even though BAMB's monopoly to import grain was lifted as far back as 1992, a major challenge that local importers of grain are faced with is the fact that the quality of imported grain is usually lower than that of local grain, hence significantly offsetting their profits; this in some cases is due to the fact that where it originates, such grain is normally intended for

animal consumption and/or malting. Ultimately therefore, the sorghum that finds its way to processing plants practically all goes towards making flour, a basic product, requiring very minimal value addition in order to obtain significant mark-ups, and for which demand far outstrips supply. Therefore, for as long as the gap in the supply of this basic sorghum product remains largely unfilled, it will be a challenge to diversify the product supplies much further than the currently available products. There is a major need to stimulate sorghum production, which for the current harvest season stands at only 26,000 Mt (MoA, 2008), despite the fact that rains had been reasonable, compared to the previous year, where only about 11,700 Mt were harvested. BAMB's latest reports indicate that of the total sales of agricultural produce realized this year, sorghum contributed about 64%, being in excess of P46 million; pulses took a distant second position, at 25%. Largely due to drought, BAMB had purchased only 10,335 Mt of sorghum grain, being 88% of the scheduled local produce.

Millet dishes or products include dumplings, fat cakes, different porridges made by mixing the flour with- sweet melon, pumpkin, beans, and groundnuts, as well as composite flours made by mixing millet flour with wheat-, sorghum or maize flour.

Emphasis on traditional foods is the latest health consciousness trend in Botswana, with many fora stressing the need for the nation to go back to consuming such foods, since they are healthy. Examples of recent interventions include efforts by NFTRC, University of Botswana, and BAMB (the latter two in conjunction with the Botswana Heart Foundation). There has been a clear shift from demand for overly refined cereal flours, to those containing significant amounts of bran, for consumers to benefit from both naturally-occurring micronutrients, as well fibre, antioxidants, etc.; in that regard then, the cereals industry in Botswana has seen a shift from the need for aesthetics in food, to functional properties. With cardiovascular diseases (CVDs) and other lifestyle morbidity conditions coming second in importance after HIV/AIDS, attributes of sorghum and millet that were once almost exclusively considered from the point of view of them being anti-nutritional (e.g. tannins), are now experiencing a totally new significance, in positive light, at the centre of people's well-being. Many patients with CVDs are increasingly being advised by medical personnel to shift from refined starchy foods, to sorghum-, and, to some extent, millet (largely depending on whether the patient's cultural background favours such a shift). Management at the Motswana-Motho traditional cuisine restaurant reports that major customer profile categories are the health conscious (including the ailing, such as diabetics), tourists, and the youth – for the latter group, reasons for purchase are mainly cultural pride, especially that in recent times a lot of them grow up with practically no exposure to such traditional foods. Nutritional benefits of these foods, apart from their antioxidant potential, also include low glycaemic indices.

The highly acclaimed Letlhafula Festival, held annually by the Botswana Craft, has been instrumental in promoting traditional foods, quite a number of which are made from sorghum and millet. Quite a number of restaurants also set themselves ahead of the competition by making sure to have such dishes on their menus, daily.

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CONSTRAINTS AND OPPORTUNITIES IN SORGHUM AND MILLET MILLING INDUSTRY IN BOTSWANA

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INTRODUCTION

Grain sorghum is the most important cereal grown in Botswana. It is also grown in other African countries namely South Africa, Zambia, Nigeria, Eritrea where it is exported. It ranks as fifth most important cereal crop grown in the world. In the USA it is the third most important cereal crop grown and the United States is the world's largest producer of grain sorghum followed by India and Nigeria in metric tons. In Africa sorghum is a leading cereal grain produced and is an important food source also in India. The leading world exporters are the United States, Australia and Argentina.

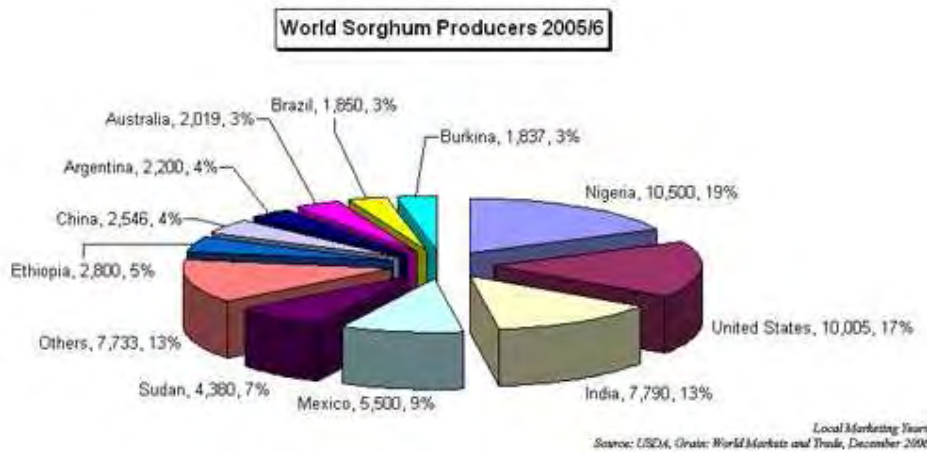


Figure 1. Global sorghum production statistics

CONSTRAINTS IN THE BOTSWANA SORGHUM INDUSTRY

Botswana is blessed with a lot of land with a small population of 1.7 million people. Although most of the habitable and arable land is mostly along the eastern part of the country there is more than sufficient land for its population size.

Botswana is a very dry country with extremely unreliable rainfall. Sorghum is thus the best crop to be grown in Botswana along with Millet. Before independence millet was the cereal most eaten by Botswana and for some unknown reason sorghum took over. It may have to do with the harvesting of millet since it grows much taller than sorghum and therefore making it tedious to harvest in relation to grain sorghum. There are many grain sorghum varieties grown in Botswana from the north part of the country to the south. Millet on the other hand is primarily grown in the northern part of the country but in very small quantities.

It is unfortunate that at the time of independence 73% of Botswana's GDP was generated from agriculture and it now stands at less than 3%.

With the discovery of diamond and quick cash revenue, Botswana stopped farming as it became cheaper to import mostly from South Africa than to produce food locally.

There are constraints that are faced by the sorghum milling industry that will be highlighted.

Poor and Unreliable Rainfall

The rainfall in Botswana is most unreliable. The rainy season is supposed to start around October through to April but this is not reliable at all. The amount it rains differs from very little to nothing at all. There was a long drought that only broke in 2007 when we had more rain than was necessary to sustain the sorghum crop. This led to a lot of farmers losing out due to crop rot from too much water. Before that, Southern Africa as a whole was hit by a terrible drought that also left some farmers with no crop at all.

High Prices due to a Lack of locally Produced Goods

This scanty rainfall led to huge lack of supply of grain sorghum in the entire SADC region leaving millers searching for grain outside the country. In the past few years Botswana has had to import a lot of grain sorghum from South Africa due to the fact that very little was grown locally. Most of the sorghum grown in Botswana is grown in Pandamatenga, north of Botswana because of better availability of water. There are also many farms in the southern part of Botswana but little has been produced there due to lack of rainfall and loss of interest in farming.

Government policies

Government through the Ministry of Agriculture and Ministry of Trade plays a major role in the supply chain of agricultural food in this country. The Ministry of Agriculture has so far taken a back seat and played a very inactive role in encouraging the production of grain sorghum and other food crops in that a lot of schemes were set up to supposedly assist farmers financially and technically but to no fruition, as there was never a monitoring of follow through program. This led to a collapse of most schemes and a huge lack of locally produced goods.

The few farmers that have continued to grow sorghum and other crops have no storage for their crops and have had to sell to BAMB at a lower price set by BAMB. So far Pandamatenga farmers are the only commercial farmers in the country and charge whatever they wish. Their highest yield on a good year has so far been 35 000 metric tons and one of the lowest (2007) been 15000 metric tons.

Government has also condoned inflationary prices used by BAMB in procurement of grains. The produce from farmers, especially Pandamatenga farmers are purchased at a fairly low price through pre crop contracts. This same grain is then sold onto the millers at what the millers consider as extortionate prices. The same applies to grain purchased outside the country under the auspice of strategic food reserves obtained at very attractive prices using government finance and resold locally at the same high prices as the locally derived commodities.

Exportation of crop

Government has no policy on protecting local buyers by preventing exportation of food crops for Botswana. In 2007 the little grain sorghum that was produced was bought by BAMB as the local supplier and the rest exported to South Africa. This exported grain is in turn sold back to the Botswana millers from South Africa at much higher prices. It is to be noted that farmers are also in business and will sell to whoever can pay the asking price.

Botswana is not yet in a position to export any food as it does not produce enough to feed its people. This is a huge food security risk.

Botswana Agricultural Marketing Board

BAMB as it is commonly known was set up by government to assist farmers by buying farmers produce, storing it and supplying the market at affordable prices. Most millers used to buy most of their grain sorghum from BAMB. This has changed over the years because of high prices set by bamb. In the past 3 years prices of grain sorghum has gone up 200% due to factors mentioned above that led to high demand and low supply due to unavailability.

In 2006 BAMB was forced to look outside of SADC for sorghum and was able to source grain from the USA to supply local millers and some millers were able to get what they could from South Africa. The pattern of price of grain since 2005 has moved from P65 to P68 to P85 to P121 to P133. BAMB used to offer millers a discount of between 3 and 5% because they bought in large quantities but this has since stopped, so whether you buy a 50kg bag or a 32 ton truckload you pay the same per 50kg bag upfront. This has been a huge problem for millers.

On the other hand millers have also had to increase the price of their meal by 100% as consumers complained of high prices. The selling price of sorghum meal has moved from P18.95 in 2005 to between P38.00 and P44.00 in 2008.

Rebates, Early settlement, Discounts and Returns/damages

This also results in loss for the millers. Some wholesale and retail stores charge a huge rebate for keeping your stock on their floor, and charge between 5 and 10% for early settlement payment of between 30 and 60 days. A lot of stock is returned to millers (at their cost) as damages due to poor handling by the stores.

Dependance on Government Tenders

In the past most of the small millers used to mill grain for government and supply mostly primary schools and the vulnerable group (unemployed, invalids etc fed by government). This worked well as various millers would provide sorghum meal to the schools in their proximity. This policy worked very well in the past few years but has since stopped. A new tendering process has been introduced that favours large millers. (There are only really three large sorghum millers in the country). This has completely left out all small millers who have been feeding Batswana all these years. This has also resulted in a very low supply of sorghum meal because the large millers alone do not collectively have the capacity to feed the country hence a large number of imported sorghum meal to cater for the difference.

This and other actors mentioned above, has unfortunately resulted in a lot of small millers closing down.

OPPORTUNITIES

Sorghum is one of the most drought tolerant cereal crops currently under cultivation worldwide. It is recognised as the most important crop behind corn, wheat and soybeans and yet features the highest resistance to drought and high temperatures corn, soybeans, wheat and other crops. It offers farmers the ability to reduce costs on irrigation and other on-farm expenses. The International Water Management Institute (IWMI) warns that by the year 2025, 25 percent of the world's population will experience severe water scarcity. However, water productivity in both irrigated and rain-fed acres can be increased through the use of more water-use efficient crops, like sorghum.

Sorghum has a high yield potential and the highest recorded yield for the crop is 20.1 tons per hectare (320 bushels/acre). However, yield per hectare in Africa and India remains very low. In Botswana the best yield potential has been 4 tons per hectare.

Sorghum Usage

In many parts of the world sorghum has traditionally been used in food products and various food items; porridge, unleavened bread, cookies, cakes, couscous, and malted beverages are made from this versatile grain. Traditional food preparation of sorghum is quite varied. Boiled sorghum is one of the simplest uses for this type of food product. The whole grain may be ground into flour or decorticated before grinding to produce either a fine particle product or flour, which is then used in various traditional foods. In Botswana sorghum is processed manually by pounding or processed by use of machines. It is de-hulled to remove some of the outer husk and what remains is sorghum rice which can either be cooked as is or further processed to produce sorghum meal or flour.

The meal is cooked as soft porridge and eaten with milk and sugar or cooked firmer and eaten as a main meal with relish.

Sorghum has unique properties that make it well suited for food uses. Some sorghum varieties are rich in antioxidants and all sorghum varieties are gluten-free, an attractive alternative for wheat allergy sufferers.

Sorghum delivers many **nutritional benefits** including calcium, iron, potassium and phosphorous and fibre. Doctors used to prescribe sorghum to patients before the creation of multi-vitamins. Sorghum meal and flour unlike wheat flour, does not contain gluten. This makes it a suitable alternative food for people with wheat gluten allergies. The **health benefits** of sorghum are plenty. In Botswana it is still widely used in hospitals for patients. Sorghum porridge especially is used to help the ailing to speedy recovery and used by breastfeeding women to help increase milk production.

There are many other uses that are not known by the sorghum millers that can be beneficial and used to diversify the grain use.

Government farmers finance through Citizen Entrepreneurial Development Agency

There is new hope for increased farming through the newly established young farmers fund that has been set up primarily to assist and encourage young people to go into farming to try to reduce dependence on South African imports. There are already some experienced farmers who can with financial assistance produce beyond their usual yield thereby generating surplus crop which will in turn reduce the high cost of locally produced food. With good and sound management of this industry, Botswana can eventually move away from being a food

importing country to an exporting country when there is surplus. This can easily be achieved, bearing in mind that Botswana has a small population of 1.7 million. India is a great example to use as they have in 20 years moved from being an importing country to a net exporter whilst supporting and feeding a country with a population of 1.3 Billion.

Millers Association

A new association has been formed by the small sorghum millers to try and find common ground and encourage the production of grain sorghum in Botswana. Due to the weather Botswana produces the best variety of grain although in very small quantities.

Once the association can get on board most of the millers, it can speak with a bigger voice in procurement of grain and be in a better stance to negotiate better prices with farmers through contract farming and forward pricing. Buying as an association for the millers will definitely be cheaper for the millers who can in turn pass the savings on to the consumer.

The association can be owned by the member millers who can each have a stakehold in the association where they can directly benefit from a market linked dividend.

To further encourage farmers to increase their produce, a Botswana Commodities Exchange could be founded thus exposing local crops to the global market. This could also stabilise the commodity price across the country by attaching a transport differential, revolving around the location of the biggest consumer of a specific commodity. All imported commodities would also be subject to the exchange equivalent price, bringing about equity to all, farmers and millers alike.

Add Value to products

Currently all millers in Botswana process grain sorghum the same way except for one miller who processes it using the extrusion method and produces a pre cooked meal for infants and young children. The rest all produce sorghum meal, sorghum rice and flour. Millers should now look at expanding and adding value to sorghum by looking for the many opportunities in adding value to the crop. Malting, sorghum chips as a health snack, syrup as a sweetener instead of sugar etc.

Hope for the small millers

Yes, there is hope for the small millers. They have always fed the country and through a strong Association and good strong team work, they can turn the situation around and feed the country again. Statistics taken in 2005 by BIPDPA shows that with the inclusion of the two large millers at the time the statistics was collected, small millers contributed to 96% of the sorghum meal sold all over Botswana. By closing down due to factors that can be tackled, they have left a huge gap for the importation of sub-standard meal from outside Botswana.

Sorghum Millers are still protected by government in that you have to be a Botswana citizen to open up a sorghum milling plant. By closely working with the National Food and Technology Centre millers can develop new ways to improving and adding value to the grain by introducing new products to the traditional sorghum meal.

RECENT IMPROVEMENTS IN THE RIIC MILLING TECHNOLOGY

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INTRODUCTION

As is the case with the rest of post harvest technologies research, design and development of sorghum milling technologies in Botswana were meant to meet a particular need, namely, human consumption. Total world production of sorghum is estimated at around 70 million metric tonnes with USA being the largest producer at 35% (Biswas, 2004), of which Africa produces well over 9.4 million tonnes (FAO, 1977). Sixty percent is consumed by human, 35% used for animal feed and the remaining 5% for industrial use. However, research on sorghum processing was conducted more on silage, beer, starch extraction and subsequent processing for high producing dairy cows (Grant, 1999). There has therefore been a technology gap in terms of processing sorghum for human consumption. In the case of Botswana, lack of technology development drove people from their preferred staple food to maize meal which was imported from South Africa (Laswai et al, 2003).

Sorghum is a staple grain in Botswana. Traditional food uses of sorghum in Botswana comprise mainly of porridge and brewing. RIIC's participation in the sorghum processing industry has, thus, been largely confined to dehulling and milling, to support the porridge component of sorghum food uses. On this aspect, RIIC has a long history dating back as far as 1977 and since sorghum food use in Botswana has remained unchanged to date, the same processing principles have not changed. In fact, the same initial dehuller and milling modules recorded in 1977 have either been up-scaled, automated or reconfigured into high capacity plants without change to the underlying principles. RIIC dehullers use the abrasive type of dehulling involving hard stones to rub off the outer layer on the grains while the milling technology is based on hammers.

HISTORY OF RIIC MILLING TECHNOLOGIES

The need for a technology to process sorghum grains was identified by the Government of Botswana as a means of addressing gender imbalances prevailing then. The United Nations World Conference on Women held in Mexico in 1975, a period during which gender issues were gaining momentum (Carr, 1997), was a turning point for Botswana women as the Government gave attention to the difficulties women were facing in their everyday life. In the mid 1970s the Government of Botswana searched for an appropriate technology that could relieve women of the drudgery of hard stamping. This involved the pestle and mortar technology which was widely used. The method involves soaking grains in water, pounding to remove bran and tannin, manual winnowing to separate grain from bran, further pounding of the grain to produce flour and drying of the flour. Outputs rate of this method were low, with 2 to 3 people averaging about 10kg in 3 to 4 hours. Available manual technologies (known as "Lelwala" and "Kgailo" respectively) were equally labour intensive.

As a result, Botswana Agricultural Marketing Board (BAMB) was requested by the Botswana government to identify an acceptable mechanised system of processing sorghum grains. In collaboration with the Canadian based International Development Research Centre (IDRC),

BAMB was able to put in place Botswana's first commercial sorghum milling operation in Pitsane in 1977. (Eisener, 1979)

Replication of the Pitsane processing plant in the supplied configuration proved to be ineffective. It became very necessary to work on a technology that will suit the needs of rural communities. Moreover, development of local manufacturing skills of the machinery was necessary to ensure support and sustainability.

To that end, RIIC's approach was for adaptation of existing technologies. A decorticating machine was developed based on a machine put up by the Prairie Regional Laboratory of Canada (Eastman, 1980). Almost with the same approach, the hammer mill was also developed and incorporated as a standalone item for final processing of the decorticated sorghum, thus making what is today commonly known as the milling package. A working model of a small scale sorghum mill, known as BORIIC, was put into operation at RIIC as a demonstration model to prove a business case for the project. The plant was tried and yielded positive results. It employed twelve people and operated in two eight hour shifts. Each shift produced six tonnes of flour and was packaged under the brand name "NGWAO" which established itself as a household name throughout Botswana. Entrepreneurs were encouraged to take the benefit of the technology to the people. This was done through the provision of consumer service milling where consumers brought their sorghum grains to be processed for a fee and commercial milling where millers stock piled sorghum that was purchased from various outlets and processed, packaged and dispatched to selling points or retailers. Thus these two technologies were successful and uptake was good.

However, as demand for sorghum flour grew, the millers in turn started demanding high capacity machinery. The output of these machines was between 170 kg/hr and 250 kg/hr when the market demanded twice as much. In 2000, the RIIC dehuller underwent improvement to turn it into a double barrel dehulling module with a capacity of 500 kg/hr. So did the hammermill, whose milling chamber and prime mover were significantly up-scaled to deliver 500 kg/hr of flour. The two improved technologies were installed at Palapye and semi-automated to take care of material handling problems associated with the previous designs. For the first time, it was now fit to talk about a milling package, one where human intervention at the interfaces of the technologies was brought to a bare minimum. Performance of the plant was monitored was good on milling, while the double-barrel dehuller proved to be very sensitive to small variations. Thus, optimisation of the dehuller was a topical matter for sometimes until the Honey Guide high capacity plant was designed in 2007 (see below).

In 2006, Honey Guide placed an order for a high capacity (2 ton per hour of flour) and fully automated plant to be installed at their warehouse at Pitsane. The results of this enquiry were two-fold. The first was that a break from the old approach based on up-scaling of existing machines made, ushering in a new approach based on running modules in parallel. The other was that the overly sensitive double barrel dehuller was jettisoned and now permanently replaced by the robust, tried and tested RIIC dehuller. It is this system and configuration of milling that is likely to transform, profoundly, the milling landscape as more and more enquiries on the same are being processed almost on daily basis.

RIIC Milling Plant Use Statistics and Feedback

In Botswana alone, 234 units were distributed, creating about 2000 jobs, mostly for women. The milling package has also been distributed to ten (10) other African countries, namely, Lesotho, Malawi, Mali, Namibia, Tanzania, Senegal, South Africa, Swaziland, Zambia and Zimbabwe. (Maleke, 1993). Results obtained in Botswana painted a success story in as far as commercialisation was concerned. A report from Tanzania highlighted the problems of backup in terms of spare parts particularly the carborandum stones or abrasive wheels. Laswai et al (2003).

Other concerns from millers in Botswana include the following:

- Excessive dust
- Sorghum not being readily available locally
- Processing is limited to sorghum and millet only.

CONCLUSIONS

The dissemination and take up of the dehulling technology in Botswana, the SADC region and other African countries demonstrated the success of research and development in agro processing for producing sorghum flour for human consumption. It has also proven a business case for entrepreneurs who saw an opportunity in the technology.

The newly designed automated milling plant has also shown good results solving almost, all the problems previously associated with RIIC milling package. However, data will still need to be collected on a continuous basis to assess its effectiveness.

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ROLLER MILLING – AN ALTERNATIVE DRY MILLING PROCESS FOR SORGHUM

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INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is an important cereal crop in the developing countries of Africa and Asia (Dendy, 1995). In Africa, it ranks second in production, after maize. Despite its importance, the sorghum food industry is non vibrant, constrained partly by the lack of efficient milling technology (Taylor, 2003). Today, sorghum milling is commonly done using abrasive decorticators and hammer mills, in small- and medium-scale commercial mills (Bassey and Schmidt, 1989; Rohrbach, 2003). However, the abrasive decorticators used are limited in terms of production throughput and control of meal quality, and are also associated with high milling losses (Gomez, 1993; Taylor and Dewar, 2001).

A recent development in Southern Africa has been the introduction of simple roller mills with two to three pairs of rolls and vibrating sieving screens (Taylor and Dewar, 2001). These roller mills have attracted attention as a potential alternative for sorghum milling (Gomez, 1993; Kebakile et al, 2007). However, information is scanty on their sorghum milling performance. This paper therefore draws comparisons between existing commercial abrasive milling technology and the newly introduced simplified roller mill, focusing on the quality of the meals produced.

COMPARISON OF MILLING PROCESSES

Production of the meals

Twelve sorghum types with varied kernel characteristics were used (Table 1).

Abrasive decortication and hammer milling

A commercial mill that used Rural Industries Innovation Centre (RIIC, Kanye, Botswana) PRL type dehuller and hammer mill (ADHM) (Fig. 1) was engaged to produce the meals. Ten kg batches of sorghum were used. Using the dehuller, the bran was progressively abraded off and removed by means of a cyclone fan. Decortication was done to the operator's satisfaction. The grain was then milled using a hammer mill fitted with a 2.0 mm opening screen. Bran and meal were weighed to determine extraction rates.

Roller milling

A commercial roller mill (RM) (Maximill, Kroonstad, South Africa) (Fig. 2) with two pairs of fluted rolls and rated throughput of 500 kg/hr was used. The top rolls (coarse break rolls) had 8 flutes per 25 mm and the bottom rolls (fine break rolls) had 22 flutes per 25 mm. All roll

pairs operated at differentials of 1.5:1. Five kg batches of clean grain were tempered to 16% moisture for 15 min in sealed plastic buckets at ambient conditions, stirring at intervals of 5 min to uniformly distribute added water. The tempered grain was roller milled immediately using top and bottom roller gaps of 0.80 mm and 0.30 mm, respectively. The milled stock was separated on vibrating sieves of mesh sizes 1.00 mm, 0.850 mm, 0.710 mm and 0.710 mm arranged in descending order. The first two sieves retained the bran, while the last two separated the meal. Meal quality was evaluated on the basis of colour, ash and oil content, and particle size.

TABLE 1. Physical Characteristics of Kernels of 12 Sorghum Types used to Compare Abrasive Decortication & Hammer-Milling and Roller Milling

Sorghum type	Grain Size (mm) ¹	Pericarp	V H S ²	TADD	Grain colour ⁴
	3.35 <%>2.80			Yield at 4 min (g/100 g)	
BSH1	50.0c	Medium	1.7b C	87.5f	White
Kanye std	30.5b	Thick	3.7h I	79.3b	White, mottled
LARSVYT	86.1j	Thin	2.1c C	85.4d	White
Lekgeberwa	82.9hi	Thick	1.3a C	86.4de	White
Buster	55.1d	Thick	3.2fg I	87.5f	Red
Marupantsi	59.9e	Thick	2.9ef I	81.3c	Reddish-white
Mmabaitse	79.4fg	Thick	3.7h I	73.2a	White, mottled
Phofu	82.6gh	Medium	2.3c C	86.4de	White
Sefofu	21.4 a	Medium	2.2c C	87.3ef	White
Segaolane	89.3 j	Thin	2.5cd I	88.1f	white, mottled
SNK	78.8 f	Thick	3.4gh I	82.0c	Red
Town	82.9hi	Thin	2.7de I	86.4de	Red

Figures in columns with different letter notations are significantly different at P <0.05; ¹All classified as medium-size ²Visual hardness score - scale 1-5, with 1 denoting corneous (hard) and 5 representing floury (soft) endosperm; C – corneous endosperm and I – intermediate



Figure 1. PRL-type Abrasive decorticator (a) and hammer mill (b) similar to those used to produce abrasive decortication-hammer mill meal samples.



Figure 2. Two roll roller mill used to produce roller milled meal samples.

Differences between the milling systems

TABLE 2. Effects of Abrasive Decortication & Hammer Milling (ADHM) and Roller Milling (RM) on the Extraction Rate of Sorghum Meal

Sorghum type	Meal extraction (g /100 g)	
	ADHM	RM
BSH1	83.1cd	81.6ab
Kanye Std	70.9ab	85.6gh
LARSVYT	79.6bcd	82.2bc
Lekgeberwa	80.0bcd	85.5gh
Buster	74.4abc	84.3efg
Marupantsi	73.2abc	83.9def
Mmabaitse	67.9a	83.2cde
Phofu	81.4cd	80.7a
Sefofu	77.2a-d	84.8fg
Segaolane	84.8d	86.8h
SNK	67.5a	83.2cde
Town	68.5a	82.6bcd
Mean	75.7a	83.7b

Extraction rate

RM performed substantially better, giving an 11% (7.8 g/100 g) yield advantage over ADHM (Table 2). Interestingly, RM extraction rates did not correlate significantly with grain hardness, indicating that grain hardness is not important for achievement of good extraction rates with RM. In contrast to RM, there were significant correlations between ADHM extraction rate and grain hardness. The highest extraction rates were achieved with the relatively harder sorghum types, while the softer types gave the lowest extraction rates. This confirmed earlier reports that with abrasive decortication, hard endosperm grains give higher flour yields than those with softer endosperms (Bassey and Schmidt, 1989).

Meal colour

ADHM producing the lightest meals, while RM produced slightly darker meals (Table 3). The dark colour was presumably caused by the dark coloured pigments of bran, indicating higher bran contamination of meals obtained with RM. Higher bran levels in the latter were presumably caused by the friable sorghum pericarp, even after tempering (Kebakile et al, 2007).

TABLE 3. Effects of Abrasive Decortication & Hammer Milling (ADHM) and Roller Milling (RM) on the Colour Properties (L*, C*_{ab} and H*_{ab}) of Sorghum Meal

Sorghum type	ADHM			RM		
	L*	C* _{ab}	h* _{ab}	L*	C* _{ab}	h* _a
BSH1	87.6gh	11.6g	80.2g	87.2i	12.4ef	81.8i
Kanye Std	82.7b	9.2a	58.4b	79.6c	10.0a	57.0b
LARSVYT	87.4g	11.2f	81.6h	85.8g	11.8d	81.4i
Lekgeberwa	87.7h	10.7e	80.0g	86.4h	11.8d	78.9h
Buster	86.7f	11.7g	75.0f	82.7f	12.5f	67.3e
Marupantsi	83.2c	9.7b	63.2c	78.5b	10.7b	59.2c
Mmabaitse	74.4a	10.1c	44.1a	71.4a	11.3c	44.3a
Phofu	86.4e	11.7g	81.0h	85.7g	12.4ef	81.2i
Sefofu	86.2e	11.4fg	75.6f	85.6g	12.1de	74.5g
Segaolane	84.6d	10.3cd	70.0e	82.4e	11.2c	68.5f
SNK	84.5d	10.6de	68.6d	81.5d	11.4c	64.9d
Town	84.6d	10.7e	68.3d	81.7d	11.4c	64.6d
Mean	84.6c	10.8b	70.5b	82.4a	11.6c	68.6a

L* - lightness, C*_{ab} - chroma, and h*_{ab} - hue

Ash and oil content

Ash content is an indicator of the level of bran contamination in milled products (Kent and Evers, 1994). ADHM produced meals with the lowest ash content, retaining 46-79% of the whole grain ash, while RM gave the highest ash content, with 70-84% of the whole grain ash retained in the meals (Table 4). Meal ash content correlated significantly and negatively with grain hardness with ADHM, indicating that the softer the grain, the more contaminated with bran the meal would be.

TABLE 4. Effects of Abrasive Decortication & Hammer Milling (ADHM) and Roller Milling (RM) on the Ash Content of Sorghum Meal

Sorghum type	Ash content of the meal (g /100 g)		
	Whole grain	ADHM	RM
BSH1	1.64g	1.38f [70.1]	1.49f [74.3]
Kanye Std	1.14a	1.00a [62.2]	1.04a [78.2]
LARSVYT	1.43d	1.31e [72.8]	1.42e [81.5]
Lekgeberwa	1.38cd	1.11b [64.4]	1.25b [77.5]
Buster	1.42cd	1.23d [64.3]	1.33cd[78.8]
Marupantsi	1.16a	1.01a [63.8]	1.04a [75.3]
Mmabaitse	1.58fg	1.10b [45.5]	1.33cd[69.9]
Phofu	1.36bc	1.21d [72.1]	1.27bc[75.1]
Sefofu	1.50e	1.24d [62.7]	1.38de[77.8]
Segaolane	1.32b	1.22d [78.7]	1.28bc[84.5]
SNK	1.43d	1.12b [52.9]	1.23b [71.7]
Town	1.55ef	1.16c [51.4]	1.41e [75.2]
Mean	1.41	1.18a [63.4]	1.29b [76.6]

Figures in square brackets are amounts (%) of whole grain ash retained in the meal

RM generally produced meals with significantly higher oil content than ADHM (Table 5). Overall, 55-69% of the oil originally present in the whole grain was retained in the meal with RM, while ADHM retained 39-70%, indicating that with ADHM high meal purity was achieved at the expense of extraction rate.

Table 5. Effects of Abrasive Decortication & Hammer Milling (ADHM) and Roller Milling (RM) on the Oil Content of Sorghum Meal

Sorghum type	Oil content of the meal (g /100 g)		
	Whole grain	ADHM	RM
BSH1	3.63e	2.53g [57.9]	2.56d [57.5]
Kanye Std	3.34c	2.14cd [45.4]	2.22b [56.9]
LARSVYT	3.31c	2.04bc [49.0]	2.31bc[57.4]
Lekgeberwa	4.67i	3.44i [58.9]	3.62h [66.3]
Buster	3.47d	2.36f [50.6]	2.68e [65.1]
Marupantsi	3.38c	2.28ef [49.4]	2.38c [59.1]
Mmabaitse	2.82a	1.67a [38.8]	2.06a [60.7]
Phofu	3.03b	1.99b [53.5]	2.37c [63.1]
Sefofu	4.20h	3.17h [57.4]	3.40g [68.6]
Segaolane	3.87g	3.19h [69.9]	3.03f [67.9]
SNK	3.65e	2.56g [47.4]	2.57d [58.6]
Town	3.79f	2.18de [39.4]	2.53d [55.1]
Mean	3.98	2.46a [51.5]	2.64b [61.4]

Figures in square brackets are amounts (%) of whole grain ash retained in the meal;

Particles size of the meals

RM produced finer meals, with all the particles passing through a 710 µm sieve size opening, whereas ADHM produced relatively coarser meals.

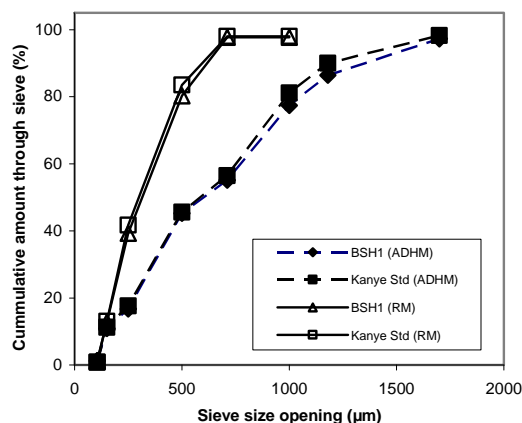


Figure 3. Particle size distributions of sorghum meals produced from corneous (BSH1) and intermediate (Kanye Std) endosperm grains with abrasive decortication & hammer milling (ADHM) and roller milling (RM).

CONCLUSIONS

RM produces meals with slightly darker colour and higher ash and oil contents than ADHM, but this slight loss in meal purity is offset by a substantial gain (11%) in extraction rate. Thus, RM holds great potential as a large-scale milling process for sorghum.

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WHY FORTIFY SORGHUM AND PEARL MILLET MEALS?

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INTRODUCTION

Malnutrition together with micronutrient deficiencies are of the common nutrition problems in Botswana, (NPAN, 2005). These nutrition problems are mainly caused by inadequate food intake, pre-disposing diseases, poverty and lifestyle diseases, among others. Statistics show that almost 5% of the children below the age of 5 are malnourished, (MoH BNNSS, 2007). The 2006 National Food Consumption Survey conducted by NFTRC on adults aged between 18-75 years indicated that 33% of the population is at risk of hunger. The same study also indicated that the prevalence of hunger in Botswana is 33%. The percentage of people living below the poverty datum line in Botswana is estimated to be 30%, (CSO, 2003).

The National Food Consumption Survey study investigated the consumption patterns of the population. It was evident from the study that most people consumed nutrient deficient diet. A further analysis showed that the mostly consumed foods were sorghum and pearl millet porridge. These foods were consumed as breakfast (soft porridge) and also during lunch and supper (stiff porridge). This confirms Ubomba-Jaswa *et al*, (1996), who stated that sorghum and maize porridge constituted 90-100% of the staple diet of 60-90% of the households in Botswana. Kebakile *et al*, (2003) also reported that sorghum was the most consumed food accounting for up to 74% of total cereal consumption in Botswana. Clearly, sorghum and pearl millet are the principal sources of energy, protein, vitamins and minerals for many of the vulnerable groups in Botswana. However, studies have shown that sorghum and millet, are low in essential nutrients such iron, protein and B vitamins, (FAO, 1995). Recent studies conducted by NFTRC aimed at assessing the nutritional quality of common household dishes showed that sorghum porridge contained approximately 90% moisture, 1% protein, 0.1 % ash, 0.09%, fibre and 8% carbohydrate. Millet porridge on the other hand contain 71% moisture, 4% protein, 23% carbohydrate and 0.4% fibre, (MRC, 2003). Both grains lack vitamin A and C. Sorghum is also low in two essential amino acids, namely, lysine and threonine. These deficiencies are the cause of chronic malnutrition among children. There is therefore need to improve the nutritional quality of sorghum and millet meal in order to address the nutritional inadequacies of the Botswana population.

It is apparent from these studies that nutrition intervention programmes are essential to address not only the micronutrient deficiencies but also malnutrition and hunger among the population. The government of Botswana, through the Department of Food and Nutrition at the Ministry of Health, currently has a number of intervention programmes that address the nutritional inadequacies in the country. However most of these programmes are targeted at different vulnerable groups and also addresses isolated nutritional problems. Such programmes include oral supplementation of Vitamin A, the provision of supplementary, (Tsabana weaning food and fortified maize meal) to children under the age of 5, and iron and folate supplementation to all pregnant women, (NPAN, 2005). There is also the salt iodization programme that addresses iodine deficiency. The latter programme has proved to be a success because almost 95% of the salt in Botswana is iodized, (NPAN, 2005).

JUSTIFICATION FOR THE NEED TO FORTIFY

Though the existing intervention programmes have long been introduced, it is clear that they are still inadequate to completely eradicate the micronutrient deficiencies. More efficient and effective strategies are needed to address this problem especially at national level. One possible strategy is the mandatory fortification of staple diets with micronutrients. Food fortification is one of the accepted methods for delivering both macronutrients and micronutrients to the population and is widely practiced in developed countries where it has proved successful. However food fortification can only be successful if the correct foods are fortified and with correct doses, (Steyn et al, 2008). Food fortification is also justified when wide spread coverage is desired (Motswagole and Kwape, 2006). Recent studies in South Africa showed that implementation of mandatory fortification of staple diets significantly improved the overall micronutrient density of children's diets and improved micronutrient intake, (Steyn et al, 2008). Generally sorghum and pearl millet have been successfully used in feeding programmes after fortification with legumes in different countries. For instance in Botswana, Tsabana weaning foods which is made from sorghum and soy has been used in Botswana to combat child malnutrition and survey results showed that facility-based malnutrition rates decreased; from 14.6% in 1993 to 4.6% in 2007.

In light of the progress made with the vulnerable feeding programmes and the results of fortification trials in South Africa, it seems prudent that Botswana should fortify staple diets with micronutrients and macronutrients to address deficiencies. Studies conducted by NFTRC showed that that most households purchased sorghum and pearl millet meal from the shops. These cereal crops are the most grown in Botswana accounting for 86% of the total cereal production, (FAO, 1995). Therefore these cereals appear to be the best vehicles for fortification..

NFTRC is currently proposing that fortification be adopted in Botswana as one measure that could considerably mitigate against prevalent macro and micronutrient deficiencies. This program can only be successful if government can facilitate planning, implementation, monitoring and evaluation of the fortification exercise. Most importantly legislation should ultimately be enacted and implemented to make fortification of any food item compulsory.

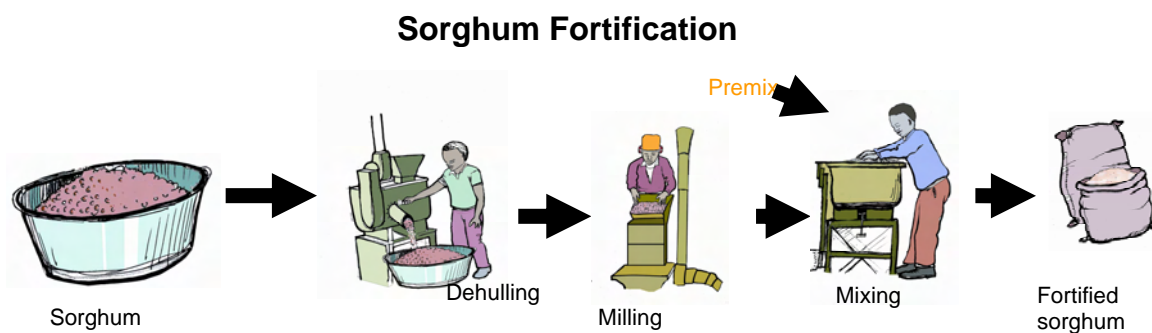


Figure 1. Flow chart for sorghum meal fortification at cottage mill level

NFTRC recently embarked on a study to determine the efficacy of Vitamin A fortified sorghum meal. The objective of this project was to contribute to the improvement of the micronutrient status of Botswana by increasing accessibility and availability of nutritious foods through fortification of sorghum meal with several micronutrients (Iron, Zinc, folic

acid, vitamin A and B-vitamins). It was evident from the study that fortification of sorghum meal is at cottage mill level could be possible. Studies have to be carried out to determine the viability of pearl millet meal with micronutrients like sorghum meal.

CONCLUSION

In conclusion, nutritional well being cannot be achieved in Botswana without improving the nutritional quality of sorghum and millet. These two grains are the staple foods in Botswana, and are therefore good candidates for fortification. The improvement of nutritional content of these staple foods is important to food security particularly for young children and the elderly and other vulnerable groups. If done successfully, fortifying sorghum and millet meal with micronutrients can provide sufficient amounts of essential nutrients to satisfy daily requirements and improve adequacy of diets across the nation. Fortification needs to be supported by adequate legislation, regulations and quality monitoring to ensure compliance and desired impact. (NFTRC) has gained extensive experience in fortification during the formulation of a supplementary feed (*Tsabana* weaning food) for vulnerable groups in Botswana. Therefore, NFTRC has a vital role to play in facilitating the adoption of fortification by the millers.

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SUPPLY CHAIN MANAGEMENT AND UTILIZATION OF SORGHUM AND MILLET

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INTRODUCTION

Many foods have been produced from sorghum and millets with increasing numbers of very successful, profitable products. I will summarize some of my experiences with sorghum and millet products and present some future research needs to improve their use.

Consumer Demands

Urban consumers want food products that deliver convenience, taste, texture, color and shelf-stability at an economical cost. Upscale sorghum and millet products that meet these requirements are usually not available in many urban areas. We have made excellent prototype products from sorghum and millet using grain with good processing quality. However, disaster struck when products were made with grains obtained from local markets. Poor-quality grain cannot be made into acceptable value-added products. It is impossible to compete with rice when 10% of the "white" sorghum kernels have a purple testa which gives a dark-colored product, and when 10-15% of the sample is sand/impurities, not to mention the damaged kernels and off aromas.

Other major constraints (Table 1) are discussed. Government policies significantly affect the utilization of local cereals because subsidized wheat flour and other products are often lower priced than local grains. The high cost and poor quality of local grains make it difficult to market acceptable food products.

TABLE 1. Major constraints to sorghum and millet utilization

<ul style="list-style-type: none"> ○ Lack of consistent, uniform, quality grain supplies ○ Extension of existing processing technology unavailable ○ Governmental policy, 14% VAT on sorghum (Rep. South Africa) ○ Subsidized maize, rice or wheat-based food systems ○ Nutritional myths, tannins, poor digestibility 	<ul style="list-style-type: none"> ○ Few shelf-stable convenience foods ○ Logistics/markets ○ Subsidized imported cereals ○ Poor image of sorghum and millet ○ Grain molds
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Sorghum and millets have excellent quality for processing, but to obtain that inherent quality, a value-added marketing chain securing identity-preserved grain for processing profitable upscale urban products is necessary. Processing technology is not the major obstacle to successful production of products. Consistent supply of a quality grain is a major constraint. Several examples of failures and recent successes will be discussed.

Excellent progress is occurring in West Africa, especially in Senegal, Mali, Burkina, Niger and others where progress is continuing to develop effective supply chains. Professor Sanders, INTSORMIL PI, and his colleagues have promoted the use of supply chain

management in West Africa with increasing successes. Their work has shown benefits to all members of the supply chain to produce and market value-added products. In Senegal, yogurt containing 30% of cooked, decorticated pearl millet is very successful along with many other processed products which offer convenience at affordable cost. The key to these successes is the development of an effective supply chain to produce and supply the processors with good quality grains with profits for all involved, and provision of consistent quality products for consumers. It has taken a long time, but many new products based on traditional foods, i.e., cous cous, porridges and related products are produced profitably.

The development of adequate supply chains from producers to processors, and ultimately consumers, allows profitable production of new cultivars with improved quality. These cultivars stimulate greater use of new technologies in these agribusiness systems. For example, processors do not need to spend significant time and labor to clean the grain when farmers keep the grain free of sand. The concepts of supply chain management and sharing of profits with all participants is difficult to initiate, but that is an essential need in most areas of the world including the developed countries.

Several myths, i.e., tannins, affect the perceived nutritional and processing quality of sorghum. Most sorghums are tannin free, have similar levels of phytin and phytic acid as maize and other cereals, and have only slightly reduced digestibility compared to maize. Sorghum proteins are slightly less digestible than maize, but when consumed in processed forms, they are readily available. The nutritional value of even the high tannin grains is acceptable when fed to livestock since they consume more sorghum to produce about the same amount of weight gain. Thus, the feed efficiency is reduced, but contrary to popular belief, the animals do not get sick and do not die. These myths are largely extended by scientists who read review articles where older, inaccurate data is cited.

More local grain products are being sold, and demand is increasing for both export and domestic markets. This is especially true in Dakar, Senegal where a wide variety of high-quality pearl millet products are marketed profitably. These processors have learned to produce high-quality products that are in demand by local consumers with some exports to Europe.

In South Africa, in spite of a local 14% value-added tax on processed sorghum products, significant amounts of decorticated sorghum are sold to consumers. The product made from local sorghums with red or brown color is consumed even though it costs more than mealy meal. Thus, there is a demand for sorghum products perhaps more than we realize. The major problems usually relate to the lack of a good-quality supply of grain for processing. Some processors have resolved these problems by investing in cleaning facilities, and by selling only high-quality products. This improves the image of local grains. Such products are successful in competing with rice and wheat since they have the convenience and quality desired by modern consumers.

Progress has been made in recent years in the United States to provide identity-preserved white food sorghums for use in domestic ethnic and dietary foods, and for export to Japan for snacks and other products. Many new ethnic and special dietary recipes have been developed and published in cookbooks. The white food sorghums have excellent properties and are appreciated by consumers. The identity-preserved food sorghums have stimulated significant interest and demand for food products from sorghum. Reasonable chances for growth of these markets exist, provided progress to produce good-quality sorghum continues.

VALUE-ADDED SUPPLY CHAIN

Excellent food products can be and are made from sorghum and millets; however, the lack of a consistent supply of good-quality grain for processing usually precludes successful marketing of these products. The value-added supply chain includes:

- Seed supplier (seed production) - quality and purity
- Grain producer
- Harvesting
- Storage
- Handling and transportation
- Processing into products
- Marketing

Millets and sorghum grains in existing markets are extremely variable in kernel size, color, and cleanliness. The major limitation is the lack of high-quality grain in sufficient quantities for processing. More efficient methods of threshing and cleaning the grain to remove sand and other impurities are essential.

Methods to assess quality are required to facilitate supply chain management. A set of standards along with practical specifications for each important quality criteria is required. These specifications must be agreeable and practical both to producers and processors. The type, or cultivar, of grain can be determined by mutual agreement, but environment will modify grain quality and this must be measurable. Communications among seed producers, production specialists, farmers and processors are required. Contracts are also required along with credit systems to build grain storage facilities to hold grain throughout the year to assure a consistent supply of grain for the processor.

Profit for all is necessary to make the scheme work. Communications are critically important. It is inherently difficult for producers and processors to understand each other's needs and problems. A long-term relationship between producers and processors is required.

More efficient methods of threshing and cleaning the grain to remove sand and other impurities are essential. Millets and sorghum grains in existing markets are extremely variable in kernel size, color, and cleanliness.

Strategy For Value-Added Products

The best strategy for developing convenient, shelf-stable sorghum and millet foods is to use identity-preserved grains to produce high-value products that can be priced slightly lower than imported products (Table 2). The targets should be middle class and wealthy people where sufficient prices can be obtained to provide profits for all. There is no need to develop low-cost, inferior-quality foods that do not provide significant profits.

TABLE 2. Strategy for value-added products

<ul style="list-style-type: none">○ Identify upscale products○ Niche markets, supermarkets○ Develop sorghum and millet products○ Use low input, appropriate technologies○ Educate farmers and producers	<ul style="list-style-type: none">○ Use identity preserved grain○ Specify variety and hybrids○ Economics, share value-added processing profits with members of the supply chain
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The image of sorghum and millet as a poor man's food can be overcome by developing highly improved products that have attractive, more socially accepted names that appeal to wealthy consumers. The new name along with identity-preserved production schemes would lead to improved acceptability. The marketing of new grains calls for imagination along with new superior types.

Functionality Of Sorghum And Millets

Functional advantages for sorghum include a white, light color and bland flavor without GMOs that has excellent processing properties similar to rice for use in snacks, breakfast cereals and an array of flours, grits, meals and porridges. There are many different sorghums that are used in various ways. However, the bland flavor and light color of food type sorghums afford a real advantage in functionality to sorghum. It does not contain gluten and its slower hydrolysis makes it attractive to diabetics, celiacs and ethnic groups. In addition, it is an alternative to rice in extruded and processed foods because of its bland flavor, light color and good expansion. When white sorghum cannot be produced in humid environments, then other tannin sorghums may be used which could be promoted on the basis of health claims regarding high antioxidants and slow digestibility for diabetics.

Pearl millet has a stronger flavor and darker color which is desired in millet consuming areas. For example, in Senegal, many processed products are sold domestically and for export. A yogurt containing cooked pearl millet grits is profitable. In fact they cannot supply the demand for these products. Some white and yellow grain types would also have functional advantages for processed foods.

Rice is considered a convenience food in many areas because it is ready for cooking. Similar products, e.g., meals, cous cous, flours, grits, snacks made from sorghum and millet could be targeted. There are numerous examples of small entrepreneurs in Bamako, Mali profitably selling locally processed products because they produce a high quality meal that can be cooked conveniently. These ladies provide a convenience ready to eat product that consumers desire by maintaining good consistent quality. Precooked fonio cous cous is very popular.

Technology for processing sorghum and millet is available and is not the most limiting factor. In most cases, existing milling techniques applied to good quality grain make acceptable products. More efficient technology is always welcome, but we cannot wait until we have perfect processing procedures. The perfect new process will not work efficiently on poor-quality grain.

Sorghum Food Use In Central America

White tan food-quality sorghums have been developed and are grown extensively in Central America where local people utilize them in a wide variety of foods including tortillas and related products. A wide variety of baked products where sorghum flour is blended with varying levels of wheat flour. In 2008, many large bakeries and related food companies found that the white sorghum flours could be used to substitute for expensive wheat flour in a wide variety of baked products, rice-like substitutes and many other products due to the cost of wheat. Unfortunately, there was insufficient sorghum to meet the demands. Many small producers in El Salvador market their sorghums by milling the grain, baking different products and selling them in local village markets. They are essentially vertically integrated; the income is enough to support their families.

Unfortunately, the extensive interest in sorghum because of its low cost and good functionality

caused a shortage of the grain. However, the utilization of sorghum was demonstrated to both large and small processors which may lead to continued interest and use in a wide variety of products if the cost of wheat flour remains high.

Plant Breeding And Improvement Of Grain Quality

For plant breeders, yield should be considered in terms of useful quantities of food produced per unit of land (Table 3).

TABLE 3. Sorghum and millet breeding objectives

<ul style="list-style-type: none"> ○ Useful products per hectare ○ Value-added characteristics ○ Need economic grain yields and quality ○ Mold/head bugs /weathering resistance ○ Screening methods available
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Breeding for yield without regard for quality is a major mistake. Farmers in the Semi-Arid Tropics have not planted many improved sorghum varieties because of susceptibility to weathering and head bugs, and unacceptable processing and food properties. For example, we showed many years ago that women will not accept a thin-pericarp sorghum because the work required to dehull it by hand pounding is increased by 50% or greater. Therefore, it is important that sorghum breeders recognize that food quality is critically important and is an essential part of grain yield (Table 4). This has proven true in Honduras where Sureno, an improved sorghum, has been adopted by farmers because it has good tortilla-making qualities and a sweet juicy stalk that improves its forage quality.

TABLE 4. Properties of new varieties / hybrids

<ul style="list-style-type: none"> ○ Optimum grain yields and quality ○ Photosensitivity required in some areas ○ Avoids molds / weathering / head bugs ○ Tan plant, straw glumes 	<ul style="list-style-type: none"> ○ Bright white or red color, no pigmented testa ○ Milling yields, hardness, spherical shape, white ○ White/yellow millets, light color products for processing
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In the more humid areas of West Africa, a major priority should be to develop improved local varieties that have photosensitivity and good food quality (tan plant, straw color glumes). Such varieties could be utilized for identity-preserved sorghum production for value-added products. Until we obtain superior quality sorghums consistently, sorghum food use in urban areas is difficult because of inadequate quality in some years when molds are prevalent.

Sorghum Image

The allegedly "poor nutritional quality" of sorghum is detrimental to its use in foods and feed. Tannins and poor protein digestibility are major problems in the eyes of some. Often, key nutritionists and others believe that all sorghums contain tannins, and thereby potential users are scared away. For example, a poultry nutritionist from India indicated he "would only feed sorghum if it was priced at 60 to 70% the value of maize because of the tannins in sorghum", even though most, if not all, Indian sorghums do not contain condensed tannins.

Tannins in Sorghum

Many scientists believe that all sorghums contain tannins. The sorghums without a pigmented testa do not contain tannins; they should be referred to as “tannin free”. Often laboratories use general phenol assays to measure tannins, which result in erroneous information since all sorghums contain phenols, but most do not contain tannins. The tannin sorghums (brown sorghums) have a very definitive pigmented testa which is caused by combinations of dominant B₁-B₂-S-genes. Such sorghums have significant levels of condensed tannins with resistance to birds and grain molding.

The tannin sorghums decrease feed efficiency by about 10% when fed to livestock depending upon feeding systems, livestock species, and processing of the grain. The tannin sorghums have high antioxidant activities in addition to being more slowly digested and contain many highly desirable phytochemicals that are desirable for healthy foods. Sorghums with a pigmented testa and dominant spreader genes are potent sources of antioxidants that rival fruits or berries. Other sorghums contain very high levels of flavones, flavanones and 3-deoxyanthocyanins which in several *in-vitro* assays have desirable effects on cancer cell cultures.

Dry Milling Quality

The milling quality of sorghum and millet is determined mainly by kernel shape, density, hardness, structure, pericarp thickness, color and presence of a pigmented testa. Kernels with a high proportion of hard endosperm, white, thick pericarp without a pigmented testa have outstanding dehulling properties. Soft floury kernels disintegrate during dehulling and cannot be milled efficiently. For hand dehulling, a thick starchy mesocarp (zz) reduces labor 50% or more. Long, slender pearl millet kernels have very poor dehulling properties, while spherical kernels have the highest yields of decorticated grain. The white tan food sorghums have significantly improved yields of light-colored flour and decorticated kernels. The modified roller mills are efficient in producing sorghum flour.

Food Utilization

The proper sorghum and millet cultivars can be processed into a wide variety of very acceptable commercial food products. These grains can be extruded to produce a great array of snacks, ready-to-eat breakfast foods, instant porridges and other products. The flakes of a waxy sorghum obtained by dry-heat processing can be used to produce granola products with excellent texture and taste. Tortillas and tortilla chips have been produced from sorghum and pearl millet alone, or with maize blends. The sorghum products have a bland flavor while pearl millet products have a unique strong flavor and color. The critical limitation is cost efficient, reliable supplies of grain.

Neither sorghum or millet have gluten proteins, so to produce yeast-leavened breads, they are usually substituted for part of the wheat flour in the formula. The level of substitution varies depending upon the wheat flour quality, the sorghum quality, the millet flour, the baking procedure, and the type of product desired. In biscuits (cookies), up to 100% sorghum or millet flour can be used. The non-wheat flour gives a drier, sandier texture, so the formula must be modified. White sorghum has a definite advantage over maize and millet in composite flours because of its bland flavor and light color.

The colored sorghums have significant potential as natural pigments and colorants for various food products and applications where natural pigments are desired. The black sorghum varieties are significantly more stable than other natural sources like red cabbage.

Feed Utilization of Sorghum and Millet

Sorghum is a very good feed grain as long as it is properly supplemented for the particular species fed. Sorghums without a pigmented testa have 95% or greater the feeding value of yellow dent maize for all species of livestock. Pearl millet has outstanding feed value for poultry and swine because of higher fat content and increased essential amino acid content. Feed and food use of sorghum and millet go together since not all grains will have desirable food processing properties; hence, the poor quality grain will go into feeds.

Methods to eliminate the tannins have been devised. Effects of tannins are overcome by addition of formaldehyde in trace levels, malting, alkaline processing, and adding extra protein to the ration. Animals fed rations containing high-tannin sorghums usually consume more of the ration to produce similar weight gains which reduces the feed efficiency significantly. The concern that animals will not consume tannin sorghums is erroneous.

Improving Sorghum Digestibility

It is difficult to improve digestibility without enhancing the susceptibility of the grain to deterioration since sorghum kernels are exposed to ambient conditions during maturation, and are prone to attack by molds and insects. Soft, digestible sorghums are destroyed by molds in the field prior to harvest except when they mature in very dry areas, i.e., Sudan, Ethiopia. Thus, efforts to enhance digestibility of sorghum must be done with care.

Some yellow endosperm hybrids that are more digestible have reduced seed vigor and poor emergence. Thus, the most efficient way to increase sorghum digestibility is to properly process it. Therefore, the emphasis should be to breed grains that resist molds and post harvest weathering. It is not feasible to grow soft, floury sorghums in most areas of production. The Sudan and some other areas of the world where extremely dry conditions occur after anthesis are exceptions to this statement.

Increasing the levels of lysine and tryptophan in sorghum is extremely valuable in terms of human and animal nutrition. Developing high yielding sorghums with improved levels of lysine and tryptophan would greatly enhance its value for both humans and animals. However, these new cultivars must be productive in terms of grain yields.

Effect of Molds, Insects and Weathering on Grain Quality

Grain molds, weathering and head bugs are major problems in many sorghum-producing areas. Molds discolor the grain, break down the endosperm and significantly deteriorate processing qualities. Mold damaged or weathered grain cannot be decorticated; the flour or grits are badly discolored and cannot be used for food. This problem can be overcome most quickly by the production of white, tan plant, straw-colored glume photosensitive sorghums. This is critically important in West Africa where most new, improved types have been devastated by head bugs and mold. For example, N'Tenimissa recently released in Mali as the first tan plant local photosensitive sorghum, has improved characteristics for processing into a wide variety of food products ranging from biscuits to decorticated rice-like convenience foods. The principle has been demonstrated; more extensive production is being encouraged. However, it turns out that the grain yields are too low to compete, but it does eliminate weathering and mold damage.

Mycotoxins

Sorghum does not develop aflatoxins prior to harvest like maize does. Sorghum contains *A. flavus* and other species, but, apparently the exposure of the grain to the atmosphere prevents significant levels of aflatoxin formation in the field. Sorghum containing aflatoxin occurs during improper storage of high moisture grains. In addition, sorghum does not produce significant amounts of fumonisin. The relative resistance to field contamination of sorghum by these major mycotoxins is a major advantage for sorghum over maize. As maize is grown under more marginal conditions, the risk of increased levels of mycotoxins should be considered. Sorghum has less problems with mycotoxins. There is less information on pearl millet, but it evidently does not produce significant levels of aflatoxins and fumonisins in the field either.

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SORGHUM MALTING

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INTRODUCTION

Today's food consumer is more value-conscious and knowledgeable. Increasingly qualities such as naturalness and healthiness (low sugar, low fat, minimal additive and cholesterol contents) are being demanded in food meant for human consumption. In addition consumer sophistication demands that modern food also provide value (e.g. nutraceutical benefit) to the consumer. Most of the most significant initial scientific research for the industrial utilization of sorghum in Africa started in South Africa in the early to mid 20th century mostly due to the then social policies of the then apartheid regimes to develop the so-called "Bantu beer" for the black population. The second wave of significant scientific research for the industrialization of sorghum in Africa started in the late 1970s and was driven entirely by economic realities – most importantly, the banning by the Nigerian Government of the importation of barley malt, wheat and other cereals such as maize as a means of conserving the nation's scarce foreign exchange, and as a deliberate policy to instigate the use of local materials in local production of cakes, biscuits, beer and non-alcoholic beverages (Palmer, 1992).

By definition, malt is the dried product resulting from the controlled germination of cereal grains. Traditionally malt has been produced from barley although recently, increasingly more malt is being made in Africa from local cereals, especially sorghum. Malt derivatives include malt extracts or syrups, dried or viscous concentrates of dried malt alone or in conjunction with non-malted cereals. As a natural product, malt is considered to have a generally recognized as safe (GRAS) status all over the world and as a result has been widely used in human food preparation for various purposes.

INDUSTRIAL MALTING

The basic malting process is made up of three steps: steeping, germination; and drying each of which can be very critical to the ultimate quality of the product. Irrespective of the malting method, the product of malting is usually a dry grain. This can be ground and used in the brewing industry for lager beer production or it can be coarsely ground, water-extracted and concentrated to give a liquid malt extract. Many variations of malt extracts exist. Usually these will differ in flavor, color, solids content, enzymatic activity, etc. Variations of malt extract may also be obtained through "mashing in" with unmalted grains, like corn grits, sorghum grits etc. during the extraction stage (Hickenbottom, 1983). Whereas the products of sorghum malting can be used in for various food industry purposes, in Africa, the overwhelming use of malted sorghum has been in the brewing industry where it has been employed in the manufacture of alcoholic as well as and non-alcoholic beverages.

A significant part of the research and development work for the use of sorghum for industrial malting in Africa started in the mid-to-late 1980s (Dufour *et al.*, 1992; Owuama, 1999; Taylor *et al.*, 2006). Sorghum malt is rich in α -amylase. Although not as rich in β -amylase as barley malt, the sorghum amylases, through their combined actions split sorghum starches to sugars and dextrins. The proteolytic enzymes of sorghum are also able to generate protein breakdown products such as amino acids and peptides which, besides their nutrient quality, are also impact greatly on the final flavor of sorghum malt and its products.

Steeping

Steeping has been described as the most important step in barley malting (Brookes *et al.*, 1976). This holds true also for sorghum. Like barley malting, the most important steeping variables influencing sorghum malt quality include: steeping temperature; duration of steeping; level of steep aeration; steep liquor chemical composition as well as level and nature of microbial activity during steeping. A judicious and well informed manipulation of those variables can lead to enhanced malt product quality. Whereas an out-of steep moisture content of 31-35% (w/w) is critical to the germination initiation in sorghum malting, good malt quality demands that grain hydration be up to at least $\geq 40\%$ (w/w) at steep-out, the rationale being that the higher level of hydration facilitates better enzyme mobility/mobilization in the germinating grain with the attendant benefits of enhanced and more uniform endosperm modification (Dewar *et al.*, 1997a, 1997b). The time required to achieve this level of aeration in sorghum grain during steeping is itself highly dependent on factors such as the steep water temperature, level of aeration (the oxygen and carbondioxide tensions), the presence/absence of air rest cycles (and their timing) in the steeping regime, the chemical composition of the steep liquor etc. Variety-dependent differences in sorghum grains such as grain size, physical properties (hardness, softness etc) and composition (e.g. β -glucanase and protein content) also significantly influence rates of hydration. Steeping in alkaline liquor or with a combination of air-rests and final warm water steeping has been shown to enhance water hydration rates (Ezeogu and Okolo, 1994; 1995; Okungbowa *et al.*, 2002) as well as malt quality (β -amylase, lower malting losses) in sorghum, while a combination of air-rests and final warm water steeping, depending on sorghum variety could lead to significant reductions in malting loss with concomitant increases in key malt enzyme activities (Ezeogu and Okolo, 1994; 1995).

Germination

For germination, steeped sorghum grains are transferred to germination floors or rooms, depending on the particular malt house capabilities. For products of optimal quality, at least 40-43% w/w moisture must be attained in the grain before germination. Similarly, a germination temperature range of 25-28°C (with optimum of about 24°C) has been established (Morrall *et al.*, 1986; Palmer, 1989; Palmer *et al.*, 1989; Taylor *et al.*, 2006) as optimal for optimum malt quality (especially β -amylase) development in sorghum. Because sorghum is huskless and loses tremendous amounts of moisture during germination, it is required, for optimum malting process, to spray the germinating grains at intervals during the growth phase. Alternatively, grains may be germinated in an atmosphere of near-water saturation to reduce moisture loss from grains. Like barley, the total germination time for sorghum malting ranges from about 4-7 days depending on the grain variety as well as the process and the end-user requirements of the malt. During that period, all aspects of the germination process (moisture content, temperature, aeration etc.) must be controlled to obtain the best product. Initially excessive growth of the sorghum acrospires and rootlets, as well as germination losses, resulted in high malting losses, requiring the addition of compounds such as KBrO_3 to the steep liquor or to the watering liquor during germination. Recent findings have shown that this could be significantly reduced with the application of final warm steeping used with the right combination of air-rests, without negatively impacting malt proteolytic activity as occurs with KBrO_3 (Ezeogu and Okolo, 1994; 1995).

Technically important physiological processes occurring during the germination phase of malting include: the synthesis of hydrolytic enzymes; and the degradation of grain structure components by the released enzymes. Together, these processes impact greatly on the end-user properties of the resultant sorghum malt.

Drying

Drying or kilning is the last phase of malting. Drying is designed to stop grain germination at the peak of enzyme development and grain structure modification. The heat applied during the drying process also catalyses additional reactions, some of which result in the development of favorable malt flavor and color properties. Because of enzyme lability, sorghum drying is conducted at about 50°C, although higher drying temperatures may be employed when required to develop specialty products. Depending on the intended use of the malt, the drying techniques employed may be selected to optimize quality.

SORGHUM MALT TYPES AND THEIR APPLICATION

Like barley, various types of malt can be made from sorghum. These products may be distinguished by their end-user qualities, flavor, physical state etc. Potential malt products to be made from sorghum include: malt extracts, malt syrups, liquid or dry, enzymatic or non-enzymatic, dark or light colored malt. The optimum malt quality is dependent on the flavor, color, enzyme content and texture desired for the finished product. In practice the choice of malt products for any given industrial processes is determined by factors such as malt pH, color, enzymatic activity, sugar content, protein, ash and microbiological profile. The use of malt in food is based on their relatively high physiological and nutritional values based on their content of very readily digested carbohydrates, low sucrose content, enzymatically hydrolyzed proteins, vitamins, minerals, enzymes and highly distinctive flavor and aroma components.

Dry diastatic sorghum malt

The dried diastatic sorghum malt is the most common, being currently used in food and beverage preparation, especially lager beer brewing, across Africa. Sorghum malt for brewing has been associated with shortcomings like low β -amylase activity, inadequate β -glucanase and proteolytic activities deficiencies (Palmer, 1992), as well as problems of inadequate extract recovery during mashing and the relatively high glucose content and reduced fermentability of its worts. Inadequate β -amylase activity results in insufficient maltogenesis and lower levels of fermentable extracts in brewing. Efforts have been made to improve sorghum β -amylase through the selection and breeding of cultivars with increased β -amylase activity and through the optimization of the malting conditions as well as by the adoption of so-called decantation mashing procedure whereby the enzymic mash is first separated from the starch then re-united with it after the latter has been gelatinized (Palmer, 1992). Some significant success has been attained with studies to improve sorghum malt β -amylase activity, although most has been concerned with the effects of malting conditions and involved only very few lines, mostly grown in Nigeria, India and South Africa (Ezeogu and

Okolo 1994; Dewar *et al.*, 1997a, b; Okungbowa *et al.*, 2002). In a recent study from Botswana, Letsididi *et al.* (2008) observed that β -amylase constituted up to 80% of DP in at least four of the varieties studied. This challenges long-held views that α -amylase is the main source of DP in all sorghum (Dufour *et al.*, 1992; Taylor and Robbins, 1993; Okungbowa *et al.*, 2002) and highlights the need to investigate the sorghum germplasm more. Dry diastatic sorghum malt is employed in the brewing of the following; clear European-type lager beers; opaque African beers (e.g. chibuku, pito and burukutu); nonalcoholic unfermented products (like the non-alcoholic malt drinks widely consumed in West Africa); non-alcoholic lactic fermented products (like the Mageu of southern Africa and kunu of West Africa). The key requirement of sorghum malt used for the above processes is their diastatic property.

Dry sorghum malt products may also be used in the baking industry where they may be used either in the form of the diastatic or non-diastatic sorghum malt. As for a similar barley malt product, non-diastatic sorghum malt can be used to improve bread crust and flavor in crackers and cookies (Hickenbottom, 1983). In baking, diastatic malt, can be employed as supplement for wheat flour amylase and to help in the production of sugars for fermentation. When added this can improve pan flow as well as crumb flavor and break and shred in bread type products. Sorghum malt, like barley malt may potentially be used in baking to improve fermentation, as well as sheeting and the laminating properties of dough during the dough conditioning phase of crackers' manufacture. Sorghum malt has potential applications also in the manufacture of buns and rolls, pizza, pretzels, English muffins, Kaiser rolls, and bread sticks. Dark variety malt may be employed for the manufacture of the darker variety products.

Sorghum malt proteases play important roles in seed structure modification during germination and the generation of free-amino acids during lager beer brewing. Sorghum malt proteinase and carboxypeptidase are markedly dependent on both grain variety and condition of malting (Evans and Taylor, 1990; Okolo and Ezeogu 1995b). Macedo *et al.* (1999a; 1999b) purified a metalloprotease as well as two pepstatin A-sensitive (aspartyl-) proteinases while Garg and Virupaksha (1970) purified a cysteine protease from sorghum. Beyond these, no attempt has been made to study the functions of sorghum proteases during malting or germination. On-going work in our lab in Botswana (Mokhawa *et al.*, unpublished) indicates that sorghum may contain from five to eleven or more endoprotease forms (including cysteine, aspartyl, metallo- and serine endoproteinases). These proteases differ in their activities on kafirin, gelatin and casein and their profiles vary by assay pH and grain variety. The work also looks at the effect of steeping condition and germination time on the appearance of the various protease isoforms as a means of further elucidating their individual contributions to sorghum endosperm modification during malting. A critical elucidation of the roles played by the enzymes in this cocktail of proteinases as well as that played by other enzymes in various other sorghum malt hydrolase groups (e.g. amylases, β -glucanases, hemicellulases etc.), followed by a clarification of how these functions are influenced by environmental conditions of malting is vital to the accelerated development of optimal sorghum malting processes.

Sorghum Malt Extracts

Extracts are products of sorghum malting containing only the liquid extract of the malt, which may be available in diastatic activity from 0 to 200° Lintner. The levels of malt extract brownness may also differ. Dry malt extracts are also available in various shades of brown. Malt extracts may be used in the brewing industry as both sources of extract and enzyme. In certain African countries such as Nigeria, extracts from sorghum malt have been employed, in place of imported malted barley extracts, since the early 1980s in the production of beverage food products like Milo and Bournvita and other nutrient-rich food products for infants.

Sorghum malt syrups

Although not very common, sorghum malt syrups are products made of sorghum malt and an adjunct material (a starch-rich carbohydrate source like unmalted cereals, or tubers like cassava). The finished product which is generally sweeter than 100% malt extracts also has superior flavor qualities, and is less expensive. Syrups may be used in the baking industry and may be used like malt extracts in baked foods and infant foods and pharmaceutical preparations. Other potential applications include use in soybean milk products, various confections, pet foods etc. In fermented bakery products, all barley malt syrup types have been added to optimize effects of other ingredients, reduce processing requirements, balance product flavor and to obtain a richer, more sealable, finished product. Sorghum malt syrups can be used for similar purposes in baking.

Sorghum malt sprouts

Sprouts from malted sorghum are rich sources of organic nitrogen and minerals for microbial fermentation (Ezeogu *et al.*, 2001; Ezeogu and Ogbonna, 2005). Employing various acid and tryptic digests of sorghum malt sprouts Ezeogu *et al.* (2001, 2005b) showed enhanced ethanol fermentation by yeast in very high gravity ethanol fermentation. Sorghum steep liquor as well as a water extract of sorghum malt sprout is currently being studied for a similar process in Botswana. Because it is rich in organic nitrogenous (free amino nitrogen and peptides) and minerals malt sprouts and extracts from sorghum malt sprouts may find use as nutrient supplements in various food and feed applications. A koji-like sorghum malt product has been developed as source of enzyme to hydrolyse cassava starch in ethanol fermentation (Ugwuanyi and Ezeogu, unpublished). Sorghum malt contains β -linked carbohydrates like β -glucan and arabinoxylan (hemicelluloses) (Verbruggen *et al.*, 1998) and should be a good candidate for the production of prebiotics.

BREEDING (RESEARCH) FOR INDUSTRIAL UTILIZATION

Sorghum improvement has relied heavily on conventional breeding processes with only limited improvement (Galili and Larkins, 1999). Transgenic sorghum presents an opportunity for the accelerated development of sorghum grains with superlative industrial quality (O'Kennedy *et al.*, 2006). Sorghum, transformed for enhanced β -amylase activity and thermostability, better β -glucanase and hemicellulases activities, enhanced protease levels and mold resistance, and higher protein and starch digestibility could become industrially successful in the brewing, fermentation and other industry. Recombinant DNA technology can also help develop fast molecular screening methods for the selection from the sorghum germplasm of cultivars with desirable industrial qualities, as has been done for barley (Erkkilä

and Ahokas, 2001). Basic tools have been developed for sorghum improvement. These include the development of reliable and efficient *in vitro* protocols for plant regeneration, molecular markers, and gene transfer (O'Kennedy *et al.*, 2006).

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FROM PROTOTYPE TO REALITY – SORGHUM PRODUCT DEVELOPMENT AND ENTREPRENEURSHIP

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INTRODUCTION

Dr. Jackson will discuss a unique program designed to promote small entrepreneurial food businesses in the first half of his presentation, followed by a brief segment outlining the elements a successful food product must have, and techniques for helping entrepreneurs develop new ideas.

In the early 1980's the University of Nebraska's Department of Food Science & Technology developed a fee-for-service Extension unit (The Food Processing Center) to provide both technical and business development services. The concept behind the Center was to help Nebraska develop its highly agricultural base into a more diverse economy, and thereby help add value to its commodity production.

The concept has been highly successful for both the mid-sized businesses it was intended to help develop, but also as a way to assist large multinational and entrepreneurial businesses as well.

In the late 1980's the Center established a formal Entrepreneurial Assistance Program. This program is designed for individuals or small groups that are thinking about producing food products. The program begins with a one-day workshop that provides an overview of starting a food business. Topics include: understanding markets, product development, laws, food safety, costs/pricing, and distribution. In more than 75% of the cases, participants in this workshop DO NOT decide to move forward with a business. Those that do decide to move forward, receive additional one-to-one assistance by Food Scientists and Business/Marketing professionals. Since 1989, 58% of the businesses that were started remain in operation.

The INTSORMIL program has funded a similar program in Tanzania. This program contains many of the elements of the Food Processing Center program, but has been "localized." Sokoine University of Agriculture (SUA) delivers the program, and it emphasizes general entrepreneurship, development of sorghum and millet foods, and farmer grain quality education. The program has helped approximately 100 business groups and individuals, with approximately 40 ongoing clients. New efforts are starting this year with 22 additional workshop participants and more active assistance to 5 processor groups. Grain quality and farmer – entrepreneur partnerships are also being emphasized.

During the 2nd part of his presentation, Dr. Jackson will discuss the basic elements of successful product development.

Success depends on a product having the following elements:

- Unique idea
- Meets a consumer need and offers meaningful benefits
- Appeals to large enough market
- Fulfills a promise with no drawbacks
- Good value for the money
- Superior to competition
- Not slow to the market
- If others are selling a product for you, that the retailers accept it
- Advertising persuasively explains concept, overcomes natural resistance to change
- Marketing funds and/or time for marketing (where to find the product)
- Easy for consumers to adopt
- Product makes both rational and emotional connection
- Incremental (no big changes if they use your product)

While some of these factors are related to technical aspects of product development, it is worth noting that many are business related. To conclude the session, the participants will work with some creative techniques to develop new product concepts

STRATEGIES TO ENSURE GRAIN SUPPLY TO PROCESSORS IN BOTSWANA

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INTRODUCTION

- Botswana Agricultural Marketing Board (BAMB) is public enterprise under the Ministry of Agriculture established by an act of Parliament, BAMB No. 2 of 1974 to provide a market for locally grown arable crops, to ensure that adequate supplies exist for sale to customers at affordable prices. The Act allows BAMB to undertake the following activities:
 - To buy, package, process, distribute and sell farmers produce (scheduled produce):
 - Cereals: - sorghum, processed sorghum products (mosutlhane – sorghum rice, ntlatlwane – dehulled sorghum), maize and millet.
 - Pulses: - tswana cowpeas, purple cowpeas, blackeye beans, white harricots, jugo Beans, tepary beans and china peas.
 - Oilseeds: - groundnuts and sunflower
 - To trade on farming inputs (Fertilisers, seeds, agrochemicals and packaging materials) and animal feeds.
 - To import import when demand cannot be met from local sources.
- BAMB currently operates eleven (11) branches countrywide with storage capacity in excess of 100 000 metric tons in the form of grain silos and warehouses. These branches have been set up to buy, store and sell to its customers.
- Government of Botswana has contracted BAMB to manage the National Strategic Grain Reserve (SGR) for national food security purposes. The composition of the Strategic Grain Reserve has recently been increased from 10,000 Mt of sorghum to 70,000 Mt comprising 30,000 Mt of Sorghum, 30,000 Mt of Maize and 10,000 Mt of beans.

BAMB BUSINESS PHILOSOPHY

- **Vision**

To be preferred market for quality agricultural products and services

- **Mission**

To provide marketing and storage services for growing the agricultural industry through knowledge, information and dedicated staff

BAMB GRAIN BUSINESS

Grain Purchases

On average BAMB handles about 30-40,000 Mt of grain of which sorghum constitute about 70%, while the rest include maize, pulses and cowpeas and sunflower. In 2007 the Board purchased only 10,335 Mt of scheduled produce which included 9,070 Mt of sorghum from Pandamatenga farms, 1204 pulses and groundnuts, 35 Mt of sunflower and 26 Mt of white maize. The following commodity were imported: 1309 Mt of white maize from Zambia and South Africa, 1069 Mt of yellow maize from South Africa and 2,250 Mt of sugar beans from South Africa (BAMB, 2008).

Grain Sales

On the total sales of agricultural produce realised this year, sorghum contributed 64%, pulses (beans, cowpeas) at 25%, maize at 7% and sunflower 4% (BAMB, 2008). Of late there has been an increase in demand for pulses as compared to previous year and this presents an opportunity for farmers to increase their earnings by producing these high value crops. Agricultural Produce which covers cereal and pulses contributed 83% of total sales while agricultural inputs (seeds, fertiliser and agrochemicals) contributed 17% (BAMB, 2008)

STRATEGIES EMPLOYED BY BAMB TO ENSURE CONTINUOUS SUPPLY OF GRAIN TO AGRO-PROCESSORS

The demand for cereals in Botswana is estimated at 300,000 metric tons (Mt), while average annual production over the past ten (10) years is about 46,000 Mt, which makes Botswana a net importer of grain i.e. sorghum, maize and pulses of various types. In the last few years there has been evidence of an increase in commercialisation of agriculture. The introduction of the Integrated Support for Arable Agriculture Development (ISPAAD) is expected to provide further impetus to commercialisation of farming. BAMB plays a complementary role in ensuring that there is increased production by constantly providing the following services to the farming community:

- **Provision of Market information:** informing farmers about market conditions ahead of planting to guide them to plan their production as well as access financial support from financial institutions such as CEDA, NDB and others. Information imparted to farmers typically includes, among other things market demands and price projections.
- **Provision of Market and Contract Farming:** providing a ready market for farmers' produce including contracting farmers to produce specified crops at agreed prices and quantities. The contract farming tool facilitate forward buying and selling commitments and not necessarily the physical commodity.
- **Offering Competitive / Market Related Price:** In well developed markets, commodity (grain) prices are influenced by supply and demand conditions, that is, during times when there are shortages prices tend to rise, conversely they drop when there is excess in the market. As a result market prices constantly fluctuate i.e. prices can vary within a season and from one year to another. In Botswana Millers who are the main customers of BAMB are free to import, if they feel local produce is too expensive. This forces BAMB to set

producer prices at par with imports using the South African Futures Exchange (SAFEX) as a benchmark.

- Producer price = SAFEX price + transportation – (2% for foreign matter and moisture loss + 15% Mark up provision).
- Farmers always complain about low prices offered by BAMB vs high production costs. How do you untie this Gordian knot? Quantify both, costs and potential returns!!
 - For example if a farmer spend P 3,000/ha and sell maize at P90/50 kg bag, s/he needs 34 bags to breakeven.
 - He or she will have to produce more than 34 bags per hectare to stay in business.
- These prices are reasonable provided farmers reduce cost and improve productivity through the use of recommended crop husbandry practices and Technology Adoption i.e. fertilizer applications, use high yielding seeds, weeding.
- At times farmers perceive BAMB to be cheating them indicating that BAMB buys from them (farmers) at lower price and sells to millers at higher prices. BAMB has to add a Mark up to cover marketing costs as follows i.e.
 - Transportation
 - Handling - electricity, labour etc
 - Management – staff costs, pest control etc.
 - Insurance premiums
 - Unavoidable losses/shrinkage
 - Interest on bank overdraft

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1. BAMB Annual Report, 2008

SIMPLE SORGHUM GRAIN QUALITY EVALUATION PROCEDURES

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INTRODUCTION

Sorghum is well-known as a subsistence crop. It plays a crucial role in rural food security in the semi-arid tropics. Consequently, sorghum is not usually traded internationally. Rising grain prices are forcing commercial industry to look for alternative sources of raw material for manufacture of their products. One example is the interest in brewing lager beer from sorghum. In order for this to become commercially viable, large amounts of sorghum will be needed of consistent quality. Since the cost of transport of raw materials is expensive it makes sound economic sense to use locally produced grain. This is a potential opportunity for upliftment of subsistence and small-scale farmers, providing them with an opportunity to become commercial farmers. However, to ensure both the farmer and the processor are satisfied with their trade, grain quality criteria are needed. Indeed, to encourage trade in sorghum, in southern Africa, a set of simple methods for determination of sorghum grain quality would be extremely useful.

SORGHUM GRADES AND STANDARDS

Currently in southern Africa, only South Africa, Zimbabwe and Botswana have sorghum grades and standards. The South African standards (South African Department of Agriculture, 1999) classify sorghum varieties into three classes according to their potential to produce good quality malt, having high diastatic power (amylase activity) which is used for opaque beer brewing. The malt quality of the grain is not considered, so the standard does not specify germinability. Sorghum grain which does not germinate has no diastatic power.

The three classes are then divided into various grades, according grade purity, with specifications for: foreign matter, unthreshed sorghum, defective sorghum, small kernel sorghum, sorghum of another group, white sorghum, weather-stained sorghum.

There are no specifications for sorghum for milling, a major use for sorghum in southern Africa. This is important since malting sorghum varieties are often soft, whereas for milling hard kernel sorghums are required.

The Zimbabwean Grain Marketing Board regulations (Beta, 1998) divide sorghum into four grades: A, B, C, or D according to colour, endosperm type and whether grain is birdproof (high tannin) or not. Within the grades there are specifications for: maximum moisture content, test density (weight), defects, and germination. In summary, the Regulations deal with the issues of malting quality (germination) and milling quality (corneous endosperm grain). However, methodology for the Regulations does not appear to have been standardised. The Botswana standards define four classes which are descriptive with regard to the identity of the sorghum, defining colour and presence of tannin but are not directly related to end-use quality (Botswana Bureau of Standards, 2000).

Internationally, Codex Alimentarius has standards for sorghum grain (Codex Standard 172, 1989, Rev-1995). Quality factors covered by Codex for sorghum grain include purity, tannin

content, contaminants (heavy metals, pesticide residues, mycotoxins), colour and proximate composition. The two main processing quality parameters namely, hardness and germinability are not covered by the Codex standard.

IDENTIFICATION OF GRAIN QUALITY CRITERIA

In order to identify sorghum grain quality criteria applicable to the sorghum processing industry, a survey was carried out in four SADC countries under the auspices of the USAID (REF). The countries chosen were; South Africa, (the most developed sorghum processing industry), Tanzania (highest sorghum production), Zimbabwe (at the time had potential to increase commercial production and processing of sorghum) and Botswana (highest per capita sorghum consumption). The respondents interviewed had an interest in a wide range activities involving sorghum utilisation. The survey identified five quality criteria; high-tannin/non-tannin, grain colour, hardness, germinability and grain purity all to be important with respect to sorghum end-use quality. Grain cultivar was also thought to be important. Of the five criteria, grain colour, hardness and high/non-tannin are considered most important for milling. Germinability is considered to be of critical importance for malting. Grain purity is generally considered to be of importance. It can be seen that existing grades and standards do not satisfy all the sorghum grain quality criteria which may be considered important by the producers and processes of sorghum.

METHODOLOGY FOR DETERMINATION OF GRAIN QUALITY

Having identified sorghum grain quality criteria, methods for determining these criteria were investigated bearing in mind specific needs of the industry in the region such as a lack of scientific infrastructure. These requirements were as follows:

- The methods must be simple to perform, i.e. they should not require a skilled laboratory technician to perform them.
- The methods must not require the use of specialised equipment or instruments
- Any chemicals required to perform the analyses must be readily available
- The methods should ideally be robust and rapid
- The methods should be such that they can be performed by those in the sorghum trade, i.e. there must be no necessity to send samples to a specialist organisation to perform the analyses.

None of the existing standard methods for determining the chosen sorghum quality criteria were directly applicable. The quantification of tannins for example is difficult even for research laboratories to perform (Rooney et al, 1980). There are different methods of extraction and many different methods of analysis which yield different results, (Rooney et al, 1980, Earp et al, 1981). Also for the purpose required, a quantitative measurement of tannins is not needed, it is only necessary to know whether tannins are present or not. Regardless of the parameter measured, the methods are generally long, complex, use expensive equipment and chemicals and need considerable training and skills before they can be carried out accurately and efficiently. Even the most suitable methods require some simplification. From the available literature the most promising existing method for each quality parameter was taken as a starting point and modified accordingly as described below:

- High/Non-tannin grain - the Bleach test described by Dewar et al (1995). Modification needed so that it can be carried out at room temperature with chemicals that are readily available
- Grain colour – a visual assessment procedure is required with simple criteria

- Grain hardness – the visual grain endosperm assessment method of Rooney and Miller (1982). The assessment criteria needs to be simplified
- Germinability – the Germinative Energy test described by Dewar et al (1995). Modification required so that it can be carried out without the use of a temperature and humidity controlled incubator and without the use of specific filter papers
- Grain purity – based on the Codex Alimentarius (Codex Alimentarius, 1995) and South African (South African Department of Agriculture, 1999) sorghum purity methods to determine grain purity modified for use without the requirement for a balance and sieves

FIVE SIMPLE METHODS FOR SORGHUM GRAIN QUALITY ASSESSMENT

The above methods were simplified as described briefly below. Further changes are available for use when balances, volumetric measuring equipment, chemicals and other consumables are unavailable.

TANNIN/NON-TANNIN GRAIN

Known tannin sorghum and non-tannin sorghum standards must be included each time the test is performed. One hundred whole, sound sorghum grains are placed in a beaker. Bleaching reagent, consisting of 5 g sodium hydroxide dissolved in 100 ml of 3.5% sodium hypochlorite solution (commercial bleach) is added to just cover the sorghum grains and close beaker with aluminium foil. Incubate beaker at room temperature (20-30°C) for 20 minutes, swirling contents of beaker every 5 minutes. Empty contents of beaker into tea strainer, discarding bleaching reagent. Rinse sorghum grains in tea strainer with tap water. Empty contents of tea strainer onto sheet of paper towel. Spread grains out into a single layer and gently blot them dry with another piece of paper towel. Count tannin sorghum grains. Tannin sorghum grains are those grains that are black over the entire surface of the grain, with the exception of the where the germ is which is somewhat lighter in colour (Figure 1 right). Non-tannin sorghum grains are those which are either completely white, or are brown over part of the surface of the grain (Figure 1 left). Calculate tannin sorghum grains as percentage of total sorghum grains.



Figure 1: Tannin and non-tannin standards after the simple tannin bleach test

GRAIN COLOUR

Known white and coloured sorghum standards must be included each time the test is performed.

Count out 100 intact sorghum grains and spread evenly over the surface of the sheet of white paper so that none of the grains are touching each other. Examine the grains and count the number of “white” or “coloured” grains, whichever is the least. A “white” grain is coloured white all over its surface, irrespective of whether the grain is: “weathered” i.e. shows signs of mould on its surface, and/or has purplish anthocyanic blotches on its surface. A “coloured” grain is coloured yellow, pink, red, brown, or purple (or combinations of these colours) all

over its surface. Calculate white (or coloured) sorghum grains as percentage of total sorghum grains (Figure 2). This method still requires further refinement.

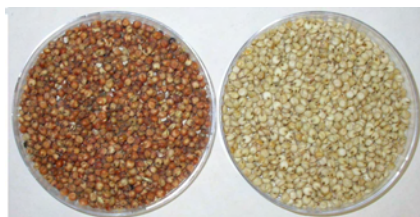


Figure 2 Coloured (left) and white (right) grain standards

ENDOSPERM TEXTURE (GRAIN HARDNESS)

Press a small piece of 'prestik' (approximately the same size as a sorghum kernel) onto the cutting surface (approximately 5 sheets of white paper). Push a sound sorghum grain germ side up into the side of the piece of 'prestik' to hold it in place. The germ side has a circular indentation at the end of grain. Cut the grain in two lengthwise, to produce two even size halves, so that each half contains an equal portion of the germ. Repeat until 20 grains have been cut. Compare one half of each grain against the illustration (Figure 3) and classify it as:

Corneous (hard) – the endosperm is totally corneous (translucent) or most (>50%) of the endosperm is translucent

Intermediate (medium) – the outer, corneous endosperm is continuous, but comprises less than 50% of the total endosperm; the inner part of the endosperm being floury (having a chalky appearance)

Floury (soft) – the endosperm is totally floury or the outer, corneous endosperm is very narrow and incomplete.

Calculate the number of corneous (hard), intermediate (medium) and floury (soft) and grains as a percentage of total sorghum grains.

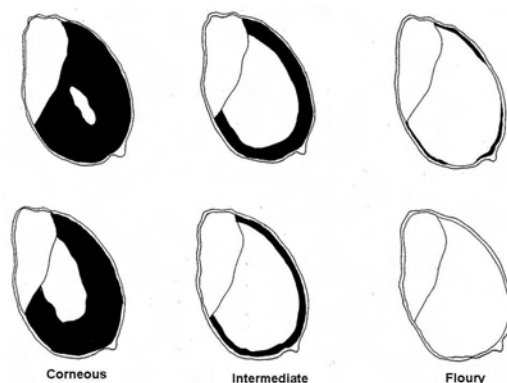


Figure 3 Illustrations for visual hardness of grains

GERMINABILITY (GERMINATIVE ENERGY)

Place two filter paper circles into the bottom of the petri dish. Moisten the filter paper with 4 ml of distilled water. Count out 100 intact sorghum grains and spread evenly over the surface of the moistened filter paper so that none of the grains are touching each other. Close the

petri dish. Place the filled petri dishes in the incubator. After 24, 48 and 72 hours, the grains are examined (Figure 4). At each time interval, the germinated grains are counted and removed from the petri dish. Germinated grains are grains where the root has penetrated the pericarp, i.e. the grain has chitted. At each time interval calculate the percentage germinated grains.

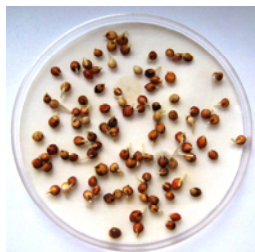


Figure 4 Illustration of germinability test

GRAIN PURITY (TOTAL DEFECTS)

The method is based on the principal that the area covered by the grain x 0.5 is equivalent to the weight of grain. Weigh out an average (final) sample of 25.0 g and empty sample onto A4 sheet. Spread sample into a monolayer on the 10 x 10 cm square. The sample should approximately fill the square. With the aid of the ruler move all defects described out of the 10 x 10 cm square. When all the entire sample has been carefully and completely sorted through and all defects have been moved out of the 10 cm square block, with the aid of the ruler systematically fill the 1 cm square blocks with a monolayer of defects (Figure 5). There must be no space between the defects. Count the number of 1cm squares of defects. If there is a square that contains less than 1 square cm of defects it should be counted as a full square. Express total defects as percentage of the sample. The following formula should be used to convert the number of squares of total defects into percentage total defects.

$$\% \text{ Total defects} = \text{number squares of defects} \times 0.5$$

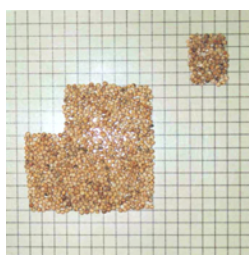


Figure 5 Illustration of grid used for estimating total defects

VERIFICATION OF THE METHODS

The simplified methods were verified against a scientifically accepted method for each parameter. This was necessary to ensure that the developed method did determine the quality parameter correctly whilst still fulfilling the special needs of a trading situation. Appropriate methods do not necessarily have to be quantitative but they must be robust and still give correct results even if abused. A sorghum processor for example does not need to know the absolute amount of tannin in a consignment, only whether the grain contains tannin or not or whether the consignment has been adulterated and contains a mixture of tannin and non-tannin grain. This determines whether the grain offered is suitable for its intended end use. A quantitative tannin test will give an absolute value to the processor but will not detect

adulteration. The simple tannin test tells the processor whether there is tannin is present or not and whether the consignment has been adulterated.

Already these methods have proved valuable to the sorghum malting and brewing industry throughout sub-Saharan Africa and also in Burkino Faso.

The methods, with adaptations for use without laboratory facilities are available on the INTSORMIL web site (www.INTSORMIL.org). The methods for detection of tannin, endosperm texture (grain hardness), germinability (geminative energy) and grain purity (total defects) have been accepted as draft ICC (International Association for Cereal Science and Technology) standard methods.

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MYCOTOXINS ASSOCIATED WITH CEREAL CROPS IN SOUTHERN AFRICA

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INTRODUCTION.

The world population is expanding rapidly and therefore food safety and security has become one of the main challenges over the last decade. This has resulted in harmful substances such as mycotoxins to become more relevant in high risk commodities such as grains. Mycotoxins have been characterized by the World Health Organization (WHO) as significant sources of food-borne illness (WHO, 2002). Therefore, countries worldwide are laying down regulations to protect humans and animals against the exposure of these toxins. This is evident in a document prepared by the FAO indicating regulations of mycotoxins in countries worldwide (FAO, 2004).

Mycotoxins are mainly secondary metabolites produced by filamentous fungi that are toxic to humans and animals. Fungi that produce mycotoxins are normally pathogens that invade plants when cultivated in the field, while others cause post harvest spoilage or storage problems. It is estimated that about 25% of all food commodities produced on earth are contaminated with mycotoxins to some extent. As fungi colonize and develop in these food commodities, they produce mycotoxins that can range from almost non-toxic to highly toxic, depending on the specific fungal species present. Besides the formation of mycotoxins, these fungi can also cause physical damage, loss in nutritional value, off odours and lowering the overall quality of food products.

Losses are not only experienced by the producer, but also by the end user. The trend is that commodities not fit for human consumption are fed to animals. The losses here are not only due to acute toxicity but also due to chronic effects such as lower egg and milk production, infertility, immunological problems and short life spans. Many of the mycotoxins cause permanent damage to man and animal and tend to target the organs such as the liver and kidneys that can develop into cancer, depending on the dose and type of mycotoxin.

By looking on an international scale according to an FAO report in 2003, at least 99 countries have regulations for mycotoxins for food and/or feed. It is estimated that about 87% of the world's population are represented by these countries. Markets worldwide are becoming more aware of mycotoxins due to international recommended levels of mycotoxins. This makes it necessary for especially food and feed industries to make sure that they conform to the regulations of countries where their products are sold.

MYCOTOXINS IN SOUTHERN AFRICA.

Reports over the last 100 years have indicated that at least 19 mycotoxins occur naturally in South Africa (Rabie & Marais 2000). These include aflatoxin B₁, aflatoxin M₁, alternariol monomethyl ether, beauvericin, cyclopiazonic acid, deoxynivalenol, diacetoxyscirpenol, fumonisin B₁, fusaproliferin, fusarin C, moniliformin, nivalenol, ochratoxin A, patulin, penicillic acid, sterigmatocystin, tenuazonic acid, T-2 toxin and zearalenone. A total of 190 fungal species have shown to be toxic to laboratory animals and are capable of producing at

least 33 mycotoxins under laboratory conditions. However, there are also a number of fungi that are toxic although the mycotoxins are unknown. Table 1 indicate the most common mycotoxins associated with food and feed commodities in southern Africa.

Table 1: Most common mycotoxins associated with foods and feedstuffs in southern Africa

MYCOTOXIN	BACKGROUND INFORMATION
Aflatoxins	Fungus: <i>Aspergillus flavus</i> , <i>A. parasiticus</i> Disease: Liver damage and cancer Commodity: sorghum malt, ground nuts, oats, cotton seed, imported soy beans and maize Found where: Worldwide
Alternaria toxins (alternariol etc.)	Fungus: <i>Alternaria alternata</i> Disease: Inhibits protein synthesis, inhibits growth in animals Commodity: vegetables, animal feed, wheat, barley, oats, rye, rice, grapes Found where: worldwide
Cytochalasin E	Fungus: <i>Phoma exigua</i> , <i>Aspergillus clavatus</i> , <i>Drechslera</i> spp. Disease: Inhibits cell division Commodity: sorghum malt, grain, potatoes Found where: South Africa...
Deoxynivalenol (vomitoxin)	Fungus: <i>Fusarium graminearum</i> Symptoms: vomiting, nausea, abdominal pain and diarrhea in humans, emesis in pigs Commodity: maize, barley, wheat, mixed feeds Found where: South Africa, USA, Canada, Austria, France, Japan
Diacetoxyscirpenol	Fungus: <i>Fusarium sporotrichioides</i> , <i>F. poae</i> Disease: Alimentary toxic aleukia Symptoms: nausea, vomiting, necrotic oral lesions, dermatitis, bloody diarrhoea Species affected: Humans, cattle, pigs, poultry Commodity: Cereals such as barley, maize, millet and wheat Found where: South Africa, USSR, USA, Canada, Northern Europe
Fumonisin	Fungus: <i>Fusarium verticillioides</i> Disease: Leucoencephalomalacia (LEM) Symptoms: focal liquefactive necrosis of the brain in horses, oesophageal cancer in humans Commodity: maize, sorghum and other cereals Found where: South Africa, USA, Egypt, Argentina, Brazil, China
Luteoscyrin	Fungus: <i>Penicillium islandicum</i> Disease: liver necrosis Commodity: rice, maize and others Found where: Worldwide, especially in the East
Moniliformin	Fungus: <i>Fusarium subglutinans</i> , <i>F. nygamai</i> , <i>F. chlamydosporum</i> , <i>F. oxysporum</i>

	<p>Disease: Crooked leg syndrome in poultry, acute toxic</p> <p>Commodity: maize, sorghum, millet</p> <p>Found where: worldwide, Ovambo land in Namibia</p>
Ochratoxin A	<p>Fungus: <i>Aspergillus ochraceus</i>, <i>A. niger</i>, <i>A. carbonarius</i>, <i>Penicillium viridicatum</i></p> <p>Disease: kidney damage and cancer, liver damage</p> <p>Commodity: wheat, maize, barley and others</p> <p>Found where: Worldwide, especially in the North-east Europe</p>
Patulin	<p>Fungus: <i>Penicillium expansum</i>, <i>Aspergillus clavatus</i></p> <p>Disease: Cancer</p> <p>Symptoms: Liver and kidney damage</p> <p>Commodity: Apple juice and fruit products</p> <p>Found where: Worldwide</p>
Sterigmatocystin	<p>Fungus: Most <i>Eurotium</i> species, <i>Aspergillus versicolor</i>, <i>A. flavus</i>, <i>A. parasiticus</i>, <i>Bipolaris sorokiniana</i>, <i>Chaetomium thielavioides</i></p> <p>Symptoms: Liver damage and cancer</p> <p>Commodity: sorghum malt, ground nuts, oats, cotton seed, imported soy beans and maize</p> <p>Found where: Worldwide</p>
T-2 toxin	<p>Fungus: <i>Fusarium sporotrichioides</i>, <i>F. poae</i>, <i>F. acuminatum</i></p> <p>Disease: Alimentary toxic aleukia</p> <p>Symptoms: nausea, vomiting, necrotic oral lesions, dermatitis, bloody diarrhoea</p> <p>Species affected: Humans, cattle, pigs, poultry</p> <p>Commodity: Cereals such as barley, maize, millet and wheat</p> <p>Found where: South Africa, USSR, USA, Canada, Northern Europe</p>
Tenuazonic acid	<p>Fungus: <i>Phoma sorghina</i>, <i>Alternaria alternata</i>, <i>A. tenuissima</i></p> <p>Disease: Onyala</p> <p>Symptoms: Bloody vesicles in the mouth, hematuria and melena</p> <p>Commodity: Wheat, barley, sorghum, sunflower, rye, wild millet and mixed foods and feeds</p> <p>Found where: Worldwide</p>
Zearalenone	<p>Fungus: <i>Fusarium graminearum</i></p> <p>Disease: Estrogenic syndrome</p> <p>Symptoms: In pigs, the vulva becomes swollen, vaginal and rectal prolapse. Young males undergo a feminizing effect with enlargement of the mammary glands, atrophy of the testes, and swelling of the prepuce.</p> <p>Commodity: maize, other cereals such as wheat and barley</p> <p>Found where: USA, Canada, USSR, Japan, Australia, Denmark, Finland, France, Ireland, Italy, Hungary, Yugoslavia, Romania, South Africa</p>
Unknown mycotoxin	<p>Fungus: <i>Phoma sorghina</i></p> <p>Disease: Onyala</p> <p>Symptoms: Bloody vesicles in the mouth, hematuria and</p>

	melena Commodity: Wheat, barley, sorghum, sunflower, rye, wild millet and mixed foods and feeds Found where: Worldwide but disease symptoms only observed in southern Africa
Unknown mycotoxin	Fungus: <i>Stenocarpella maydis</i> Disease: Diplodiosis Symptoms: Collapse of the nervous system, coordination problems, paralysis, abortions, slow growth, death. Commodity: maize Found where: Southern Africa, South America and Australia

Some of the most important mycotoxins in southern Africa include an unknown mycotoxin that cause diplodiosis, as well as fumonisin B₁, aflatoxins, and patulin. Diplodiosis is a disease in cattle that is found in South America, Australia and southern Africa. The fungus is called *Stenocarpella maydis* and is mainly associated with maize. The symptoms include, nervous system defects, coordination problems, paralysis, abortions, inhibits growth and eventually death in especially cattle and sheep. To date the disease could not be linked to similar symptoms in humans.

Hole in the Head Syndrome, also known as leucoencefalomalacia, is caused by fumonisin B₁, a disease in horses, donkeys and mules that causes a necrosis of the brain. The disease is found in South Africa, USA and Egypt. Fumonisin is produced by *Fusarium verticillioides* and is most likely the cause of high incidences of esophageal cancer in humans in the Eastern Cape area of South Africa. It is also known that this mycotoxin cause liver cancer in rats and lung disorders in swine. The fungus is normally associated with maize but can also be found in other commodities.

Aflatoxins are the best known mycotoxins and it is sometimes wrongly interpreted that the lack of aflatoxins means that the commodity is safe for human and animal consumption. Aflatoxin B₁ is the most carcinogenic substance known to man. It must be kept in mind that a wide range of other mycotoxins can also have detrimental effects on human and animal health. The fungus, *Aspergillus flavus* that produce aflatoxin B₁, is normally associated with sorghum malt, ground nuts, oats and cotton seed oil cake in South Africa. This is, however, also associated with maize that are stored and processed under high moisture contents. Imported soy beans and maize are often infested with this fungus and are used for animal and poultry feed. It is known that aflatoxin B₁ can be converted to aflatoxin M₁ in the body of a cow and can end up in the milk. It means that dairy products can contain aflatoxins. Processed foods that contain peanuts must be regularly monitored to ensure that contaminated products are kept from the human food chain because of the tendency of these products to contain aflatoxins above the legal limits in breakfast cereals. Other animal products such as eggs and meat can also contain aflatoxins if contaminated feed is fed to these animals.

Patulin is a mycotoxin that is produced by a variety of fungi including *Penicillium expansum* and *Aspergillus clavatus*. These fungi are not only found on the outside of fruit but also on the inside. The toxin, which is carcinogenic, is normally associated with apple juices and fruit puree and cause damage to the liver and kidneys. This is why it is important to monitor especially processed fruits such as baby food and fruit juices for the presence of patulin. The levels of patulin must not be more than 50 µg/kg according to South African law.

Other toxins that are also sporadically found in South Africa include deoxynivalenol, diacetoxyscirpenol, zearalenone, T-2 toxin, tenuazonic acid, ochratoxin A and sterigmatocystin. Some fungi and their mycotoxins are only found in certain areas and specific crops in South Africa. The fungal contamination of these crops are closely linked to the rainfall and handling of the harvested crop. It is, therefore, extremely important to store commodities under the correct conditions. Moisture contents above 13% in most grains such as wheat, barley, oats, sorghum and maize can cause serious fungal problems if these grains are stored for long periods. It is recommended that oil seeds such as sunflower seed, nuts and cotton seed are stored under 10% moisture.

There is also a group of fungi of which the mycotoxins are not known. These include the *Eurotium* species such as *E. amstelodami*, *E. chevalieri*, *E. repens* and *E. rubrum* that are commonly associated with South African stored grains at moisture contents of 14 to 17%. It is known that a high infestation of these fungi can cause nausea, vomiting, ill thrift and feed refusal in humans and animals. In some cases these fungi can produce sterigmatocystin, a precursor of aflatoxins. Another example is *Stenocarpella maydis* that cause diplodiosis and is a major problem for the maize industry as a whole.

THE IMPORTANCE OF FUNGI IN THE PRESENCE OF MYCOTOXINS.

Based on a report to the Department of Health in 2000, there are about 190 toxigenic fungal species associated with food and feed commodities in South Africa (Rabie & Marais, 2000). These include both field- and storage fungi. By determining the fungal populations in food commodities certain interpretations can be made of the history of these commodities. It is that certain fungi need specific moisture contents and environmental conditions to develop. Under these conditions different fungi will develop in different commodities and even in the same commodity but under different conditions. This information is specifically important when mycotoxin contamination is expected. By understanding the conditions under which fungal development and mycotoxin formation occurs, one is in a position to alter handling and processing of commodities that can limit the presence of these organisms and their toxic substances.

It must be kept in mind that not all isolates of a specific fungal species have the ability to produce mycotoxins. The presence of a specific fungus is thus not necessarily proof that the mycotoxin is present. It is necessary in all cases to test chemically for the presence of the mycotoxin. The analyses for mycotoxins could be expensive and sometimes it is necessary to first determine the fungal population to indicate the likeliness of certain mycotoxins to be present.

It is only now that the impact of fungi and their mycotoxins is recognized on the agriculture, economy and medical burden in developing countries. People living in developing countries are regularly exposed to contaminated food commodities due to the shortage of food in general. These countries also normally have no regulations or monitoring programmes to protect the people from contaminated food.

When contaminated food is processed to mixtures or fruit juices it is very difficult to observe any problems. The public is thus dependent on the food processors and government institutions to monitor mycotoxin levels before processing. Mycotoxins can end up in the food chain if this monitoring is not done.

South African food and feed commodities such as grains become spoiled especially during wet seasons just before or during the harvesting process. In addition, levels of fungi increase dramatically during the milling process due to the conditions of milling. Wheat bran for example is, in many cases, highly infested with mycotoxin producing fungi and is regarded as a high risk commodity for mycotoxin contamination. If bran is purchased for human or animal consumption, one needs to make sure beforehand that the bran is loose and not caked together as this is an indication of fungal development and high moisture contents.

MYCOTOXIN REGULATIONS.

No international regulations exist for mycotoxin levels in food and feed commodities that are accepted by all countries. Each country has its own regulations. It is difficult to determine international standards due to the fact that people have different eating habits in different parts of the world. Maize serves as a staple food for most of South Africa's population and it is estimated that six times more grains are eaten per day per capita than people living in Europe and America. The chance for the intake of mycotoxins via contaminated food in South Africa is thus six times higher than in other countries.

No food for human consumption may contain more than 10 µg/kg aflatoxins of which only 5 µg/kg may be aflatoxin B1 based on the Food, Cosmetics and Disinfectants Act of South Africa. Food may also not contain more than 50 µg/kg patulin or any other mycotoxins produced by fungi. There may also not be more than 0.2 mg/kg ergot sclerotia in rye or wheat destined for milling. Ergot sclerotia are black hardened kernels infested with the fungus, *Claviceps purpurea*. This fungus produces ergot alkaloids that cause hallucinations, gangrene and eventually death. This is also known as Saint Anthony's Fire that caused epidemics in the dark ages in Western Europe. Animals can obtain these symptoms by eating contaminated grass in the field.

The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act allows 50 µg/kg aflatoxin in animal feed. The limit is 20 µg/kg for lactating cows, calves, swine, lambs, poultry, cats, dogs, horses and ostriches. Feed destined for young swine, chickens under laying age and lambs under four months may not contain more than 10 µg/kg aflatoxins.

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IMPLICATIONS OF BOS ISO 22000 AND SORGHUM STANDARDS ON THE CEREAL INDUSTRY

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INTRODUCTION

BOS¹ 26: 2008 Cereals – Sorghum grain for human consumption – Specification and BOS 63: 2008 Cereals–Classification and grading of sorghum grains intended for sale in Botswana–Specification, were developed by the Cereals and Pulses technical committee. This is the national technical committee developing cereals and pulses Botswana Standards and Botswana Bureau of Standards (BOBS) is the Secretariat. BOBS started operating as a parastatal organization in 1997 and is the only body in Botswana mandated by Standards Act to develop Botswana Standards. BOBS, amongst others, is mandated ‘to promote standardization and quality assurance in industry and commerce, with the aim of improving product quality, industrial efficiency and productivity and the promotion of trade, so as to achieve optimum benefits for the public generally, particularly in the interest of health, safety and welfare, and protection of the consumer’ (Standards Act, 1995). The technical committee (TC) has adopted other internationally recognized standards from the International Organization for Standardization (ISO) as Botswana Standards, for instance, BOS ISO 9648 Sorghum – Determination of tannin content.

What prompted the development of Botswana Standards?

We are living in a global village and countries, regardless of their location, are trading with one another. We have just recently learned about milk and milk products that are contaminated with melamine from China (Ministry of Health, 2008; BBC NEWS, 2008). For those people who travel a lot, how do you know that you might have come across the tainted food products and drank the contaminated milk! Clearly, it shows that food safety was compromised somewhere in the milk and milk products production chain. This is not a concern for China alone. A concern was received from the Department of Industrial Affairs about non nutritious and poorly labelled ‘juice powder and cold drink powder supplied to primary schools under the Government School Supplementary Feeding Programme (Ministry Health, 2004). Standards are developed to ensure that whatever, we consume meets basic minimum requirements specified in a standard or specification. In 2007, the Ministry of Agriculture recalled livestock feeds because they did not meet the basic requirements as stipulated by standards and thus farmers were urged to return all the concerned feeds to their suppliers (Ministry of Agriculture, 2007). The feeds compromised the safety of the animals and the ultimate consumers. In 2003, some people in Kanye, Moshupa etc., consumed sorghum porridge that was contaminated with noxious seeds from *Datura* spp (Mokhure) and a lot of them were hospitalized! This is an indication that the basic standard for sorghum grains for human consumption was not met, hence the usage of the contaminated sorghum grains. It is therefore imperative that BOBS, through her various technical committees,

¹ BOS stands for Botswana Standard

develops standards to safeguard incidents of food poisoning that are always encountered due to lack of standards if not ignorance.

Though standards may be developed for any food products, it is not always easy to implement them. This may be due to lack of institutional capacity to enforce such standards where they are declared compulsory/technical standards. This is confirmed by Seleka et al. (2008) as they stressed that ‘...it appears that BOBS may not currently have the human, physical and technical capacity to mount a QA & QC system for a food fortification programme’ as this would apply to other products.

An overview of BOS 26 and BOS 63

BOS 26 applies to whole and dehulled sorghum grains obtained from *Sorghum bicolor* (L.) Moench as spelt out in the scope. The normative references are listed documents referred to directly in the standard such as BOS 9, Pre-packaged goods for the ultimate consumer – Labelling, presentation and advertising – General requirements. According to BOS 9 (2000), the standard is applicable to all pre-packaged goods to be delivered as such to the ultimate consumer and addresses some aspects relating to presentation and advertising. Similarly, Chapter 65:05 (2003) requires labelling of pre-packaged foods sold in Botswana.

One aspect of the standard deals with definitions of certain terms to ensure easy usage and understanding by the reader as well as to avoid ambiguity. A good example is the definition of ‘defective grain’ which is defined as (BOS 26, 2000) ‘pieces of grains or grains of sorghum which:

- a) is broken, rotten, mouldy, smutty, or otherwise diseased;
- b) the embryo skin is cracked;
- c) has a green colour or shows other signs of immaturity;
- d) has been damaged by insects, heat, or any other means, but does not include weather stained sorghum; and,
- e) passes through a 1.8 mm slotted sieve’.

The standard has clauses that deals with requirements namely general and specific quality factors which specify the minimum that sorghum grains shall contain for them to be considered fit for human consumption. The standard states the requirements for moisture content, protein content, tannin content, mycotoxins, heavy metals and pesticide residues.

Hygiene is also covered in the standard but reference is made to CAC/RCP 1 which shall be dealt with under hygiene.

The other sorghum standard is BOS 63 which specifies classes and grades of sorghum grains intended for sale in Botswana. The four classes are outlined as food class sorghum, feed class sorghum, malting class sorghum and other class sorghum (BOS 63, 2008). However, these classes of sorghum differ from region to region. In the case of Botswana, these classes

attempted to cater for those specified in the Botswana Agricultural Marketing Board and the South African regulations for sorghum. South African regulations were considered as South Africa is the main country trading with Botswana and the region as a whole. According to the USDA (1999) sorghum is divided into four classes based on colour namely: Sorghum, Tannin sorghum, White sorghum and Mixed sorghum.

It is under the same standard, BOS 63, that it specifies screening test methods for detection of tannin sorghum using bleach test (See Figure 1), classification of sorghum grain according to colour (See Figure 2), estimation of sorghum grain hardness, determination of germinative energy/germinability of sorghum grain and determination of total defects in sorghum grains.

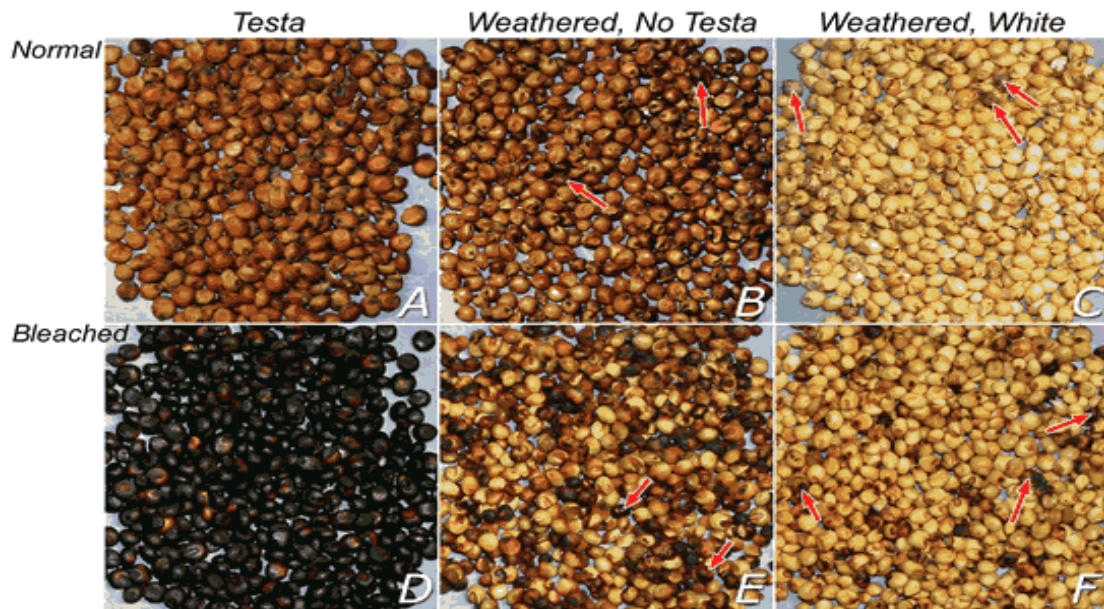


Figure 1: Photograph of sorghum (A, B, C) and bleached sorghum (D, E, F). Adopted from Bannyaditse 2004



Figure 2: Different pericarp shades of six grain sorghum varieties from Botswana. Source Bannyaditse 2004

Food safety

When considering food safety, three aspects should be taken into consideration and these are:

- a) Pre-requisite Programmes (PRPs) ;
- b) Quality Management System (QMS); and,
- c) Hazards Analysis and Critical Control Point –HACCP.

Hygiene and prerequisite programmes

In order to achieve hygiene for any product handled, it is imperative that we consider the applicability of 'Recommended International Code of Practice - General Principles of Food Hygiene' developed by the Codex Alimentarius Commission. The Code states that 'People have the right to expect the food they eat to be safe and suitable for consumption. Foodborne illness and foodborne injury are at best unpleasant; at worst, they can be fatal. But there are also other consequences. Outbreaks of foodborne illness can damage trade and tourism, and lead to loss of earnings, unemployment and litigation. Food spoilage is wasteful, costly and can adversely affect trade and consumer confidence (CAC/RCP 1, 2003).

Points to consider for proper prerequisite programmes (PRPs)

PRP in food safety is defined as basic conditions and activities that are necessary to maintain a hygienic environment throughout the food chain suitable for the production, handling and provision of safe end product and safe for human production (ISO 22000, 2005). Examples of terms that are usually used to refer to PRPs are Good Agricultural Practice; Good Manufacturing Practice; Good Hygiene Practice and Good Production Practice. PRPs as stated above lay a foundation for food safety by ensuring personnel hygiene, control of pest and sanitation, training of staff, etc., to ensure that possible food contamination in a food establishment is minimized hence less chance of exposing consumers to biological, physical and chemical hazards in the food chain. For example, the good manufacturing practice, where a farmer who has fumigated his sorghum grains should inform the next processor about the type of fumigant(s) used in order to avoid exposing the ultimate consumer to the residues of the fumigant(s). PRPs include:

- a) Cleaning , maintenance and personnel hygiene
- b) Location
- c) Pest control
- d) Handling, storage and transport
- e) Packaging
- f) Water supply
- g) Training
- h) Documentation and records
- i) Recall procedures.

All food establishment should ensure that PRPs are in place to reduce the chances of exposing food product to hazards that can be controlled using the measures stated above. Any establishment dealing with food products should have a trained workforce to enable it to perform its duties diligently. In addition to other requirements such as documentation and record keeping, it is imperative to ensure that food products produced by a food establishment can be easily traced and recalled in case of an emergency. That is why the sorghum standard specifies the following (BOS 26, 2008):

In addition to the requirements of Food Control - Labelling of pre-packaged foods regulations and BOS 9, the following requirements shall be met:

- a) The specific name of the product to be declared on the label shall be either 'Whole sorghum grains' or 'Dehulled sorghum grains';
- b) Sorghum grains shall be packaged in containers which will safeguard the hygienic, nutritional, technological, and organoleptic qualities of the product;
- c) The containers, including packaging material, shall be made of substances, which are safe and suitable for their intended use. They should not impart any toxic substance or undesirable odour or flavour to the product; and,
- d) When the product is packaged in bags, these must be clean, sturdy and strongly sewn or sealed.

BOS 9 and Food Control Regulations require that some of the following shall be included: the name of product, name of manufacturer, expiry date, and batch number of the food item, in order to be able to recall the product in case of emergency. Therefore as per the requirements of ISO 22000, even BOS 26- Cereals – Sorghum grains for human consumption – Specification requires documentation and records for sorghum to be maintained.

Quality management system

Examples of these are those outlined in the International Organization for Standardization's ISO 9001 (2000) quality system standard aimed at primarily ensuring customer requirements are met consistently. Points to be taken into consideration when looking at QMS are the requirements and six mandatory procedures mentioned in ISO 9001: 2000 standard namely:

- a) Control of documents;
- b) Control of records;
- c) Internal audit;
- d) Control of non conforming product;
- e) Corrective action; and,
- f) Preventive action.

It should be noted that the standard talks about **management responsibility** – management commitment, customer focus, quality policy; **resource management**; **purchasing, identification and traceability**, etc. All these should be met in order for any establishment or organization to be considered for certification against ISO 9001: 2000. For any organization or company engaged in cereal production and cereal processing, it is imperative that all the mandatory requirements of the standards as well as those that are applicable are met as a way of giving assurance to the ultimate consumer that the cereal product purchased was produced under a recognized quality management system.

As an example, why a company should have control of documents:

- a) All personnel who require copies of the documents are provided with copies. This is necessary to ensure that process owners do have access to their documents and also gives them ownership of the activity. It is further important to have access to documents for ease of reference and retrieval during auditing;
- b) No change is made without proper authorization – to ensure that everybody in the organization is using the right version of any document hence there is control to changes in the documents.

- c) Authorized changes are incorporated into all copies of the document in use. They must be authorized to be able to know who in the organization carried out the changes in case there is a need for clarification; that person would be in a better position to give explanation. Changes must be incorporated to all documents to ensure uniformity of documents used in the company;
- d) Obsolete documents are removed. This is necessary to make sure that the right document is used at the right time. For example, any change to a procedure must be applied to the entire company to avoid the use of multiple versions of the same procedure;
- e) The unofficial copying of documents is discouraged. This is vital to prevent issuance of controlled documents to the wrong hands. In most cases unofficial copies will not be coloured or not have coloured company logo thus clearly indicating that their originality is questionable.

Hazard Analysis and Critical Control Point - HACCP

Fourteen stages of the HACCP implementation process are to be implemented in food establishments. According to CAC/RCP 1 (2003) and ISO 22000 (2005) the stages are as follows:

Stage 1 – Assemble HACCP team

The HACCP team is required to carry out the HACCP study and the study would involve the collection, collation and evaluation of technical data and should be carried out by a multi disciplinary team including amongst other microbiologist, chemist, engineer, etc.. The team leader who reports directly to management must head the team.

Stage 2 -Terms of reference or scope of the HACCP plan

The team shall have terms of reference to enable the team to know exactly what product or process and hazards they are trying to control. The team should also know where the product is considered safe as well as the other systems inter related to the HACCP system.

Stage 3 – Description of the product

The description stage involves giving all the necessary requirements of the products such as composition, chemical and physical structure like water activity, processing method as, packaging needs, storage and distribution considerations, shelf life and any instructions for product use. This will also include identification of chemical, biological and physical hazards.

Stage 4 – Identification of intended use of the product

It is vital to ensure that the intended use of the product is clearly known; whether it is intended for the general public or for a specific group of people, for instance, Tsabana². The following group must be taken into consideration because of its susceptibility to hazards: the young, the old/elderly, pregnant, immuno-compromised, and the sick.

² Tsabana is a fortified cereal based supplementary food given to young children.

Stage 5 – Construction of a flow diagram

A detailed flow diagram encompassing all production lines, steps in sequence is required. The flow diagram should include floor plan and layout of equipment, microbiological, chemical and physical data requirements, packaging and any other relevant information such as time and temperature requirements.

Stage 6 – onsite confirmation of the flow diagram

This is the stage where all the information in the flow diagram must be cross-checked or verified to ensure conformity with what is on the ground. Each step must be cross checked to ensure its correctness.

Stage 7 – Hazard analysis

This is the stage where hazards are identified from raw materials, in-process and final product. It should be noted that the changes in the raw materials, product formulations, preparation procedures, packaging, distribution and/or use of product would all need a review of the hazard analysis. Hazards identified for each step should be assessed for their significance to check if they need to be controlled by PRPs or otherwise. For each hazard identified, there is a need to have a control measure for it in order to prevent, eliminate or reduce its occurrence to an acceptable level.

Stage 8 – Determination of critical control points (CCPs)

A CCP is a point, step or procedure at which control can be taken or applied and a food safety hazard prevented, eliminated or reduced to acceptable level.

CCPs shall be determined through the use of a decision tree. All CCPs must be numbered for ease of reference. Cooking and metal detection in line are some of the steps needed to control a hazard.

Stage 9 – Establishing critical limits

The level that separates acceptability from unacceptability must be set. Target levels and tolerances for each CCP must be defined. In cereal products, the heavy metal and/or pesticide residue levels must be specified as the critical limits and any deviation above the critical limit renders the product unacceptable for its intended use.

Stage 10 – Establishing a monitoring system

A monitoring procedure is needed. Monitoring measures performance level, checks deviations and indicates compliance with the HACCP plan. A monitoring system is required for each CCP and formal records must be kept.

Stage 11 – Establishing corrective action plan

Corrective actions must be put in place for all CCPs identified. We need to identify the product, isolate it and evaluate the extent of the problem. A qualified person must carry out the evaluation.

Stage 12 – Validation and verification

It is important to validate or check if the HACCP plan is working prior to starting using it. This must be done prior to the full operation of the system. It is a trial for the system. When

the system is fully operational, then that verification or confirmation of conformance with the HACCP plan could be done through various means such as product testing and auditing the system. A verification procedure is therefore required and the results of verification shall be recorded.

Stage 13 – Review of the HACCP system

The management shall review the HACCP system and data from the review shall be recorded. Factors that, among others, will trigger a review are a change in raw materials, statutory changes and change in cleaning and disinfection programme.

Stage 14 – Establishing documentation and record keeping

A document control procedure shall be established and maintained to ensure that correct use of recent/updated versions and authorized documents/approved documents by an authorized manager. A HACCP manual containing flow diagrams, hazard analysis and decision trees shall be documented and their records kept. A master list of the latest versions of all documents shall be kept and each document issued be identified using an issue number, and date of issue, and must be signed by an authorized person. Documentation of all HACCP procedures for all the steps in the process shall be compiled as earlier illustrated.

CONCLUSION

As BOBS develops standards as mandated by the Standards Act of 1995, there is a need to clarify roles played by BOBS and the Ministry of Health (MoH). All food safety related issues should be the responsibility of the Ministry of Health and the role of BOBS should only come when standards are developed and implemented, especially at the certification stage. For instance, where fortification of sorghum meal is advocated for, the MoH should come up with a regulation that ensures that processors comply with the requirements of the set standard; in addition, that sorghum meal produced must be fortified.

This is a noble proposal as outlined by Seleka et al. (2008) who indicated that for sorghum more work needs to be done, beginning with advocacy and promotion through the development of legal instruments.

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WHAT IS CEREAL SCIENCE AND TECHNOLOGY-SA (CST-SA)?

- CST-SA is an association of organisations and individuals (from both the private and public sectors) who are actively involved in the science and technology of cereals.
- CST-SA is South and Southern Africa's official link to the ICC (International Association for Cereal Science and Technology), AACC International and the international cereal science and technology community at large.

WHAT DOES CST-SA DO?

- Promotes active collaboration between cereal scientists and technologists and advance the knowledge of the science and technology of cereals and other grains. **HOW: By organising lectures, meetings, conferences, symposia and workshops with local and international experts in the field.**
- Encourages research in the science and technology of cereals and other grains. **HOW: CST-SA awards a student travel award and an excellence in research and development prize annually.**
- Advises on world trends in the science and technology of cereals and other grains, and scientific and technological developments within ICC (the International Association for Cereal Science and Technology) and AACC International. **HOW: By circulating ICC and AACC International newsletters.**

HOW MUCH DOES IT COST?

Tertiary institution membership: R 620 per year

Company membership: R 1250 per year

WHAT DO I GET FOR MY MONEY?

Lecture evenings: Usually bi-monthly talks given by local and international experts on all aspects of cereal and grain science.

Workshops: Each year CST-SA organises a workshop or conference on a specific aspect of cereal and grain science with reduced registration fees for members. We are already planning for 2010 when there will be a 1½ day symposium organised by CST-SA directly after the IUFoST Congress in Cape Town, South Africa.

CST-SA Student travel award of R30 000 is awarded annually to the best postgraduate student attending a Southern African University and studying some aspect of cereal science.

CST-SA Excellence in Research and Development prize of R 30 000 is awarded annually to an individual who has shown excellence in cereal science and technology research and development in South Africa over the previous 5 years.

ICC Newsletter and AACC International E-News Capsule: CST-SA members receive the ICC Newsletter and the AACC International E-News Capsule, giving all the latest news, activities and events taking place under the auspices of each of the organisations.

Interaction with experts: CST-SA members through their interaction with ICC at the local and international level can get in touch with relevant experts in Cereal Science and Technology in all parts of the world.

Methods of analysis and Working and study groups: CST-SA members have access to the official Standard Methods in Cereal Science and Technology published by the ICC. CST-SA members can become members of the approximately 40 ICC working and study groups, which cover virtually all specialised areas of Cereal Science and Technology.

Access to Cereal Chemistry and Cereal Foods World: As a corporate member of AACC International, CST-SA has access to the latest research and developments in cereal science and technology published in the journals Cereal Chemistry and Cereal Foods World. Members of CST-SA are able to access these journals.

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INTSORMIL UPDATE

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INTRODUCTION

The Sorghum, Millet and Other Grains Collaborative Research Support Program, otherwise known as INTSORMIL, is composed of 15 projects and 17 scientists from 6 universities and the USDA-Agricultural Research Service (ARS). The University of Nebraska-Lincoln serves as the Management Entity for the program. The INTSORMIL vision is “To improve food security, enhance farm income and improve economic activity in the major sorghum and pearl millet producing countries in Africa and Central America”. There are 7 individual objectives directed to support international collaborative research to improve nutrition and increase income in developing countries and the United States. The current INTSORMIL program is a successor to the long-running program of the same name. In contrast to the previous program, the current INTSORMIL is becoming more involved in marketing and end-use programs in host countries while continuing as many research activities as possible.

WHAT IS INTSORMIL?

The official name for the current INTSORMIL is the Sorghum, Millet and Other Grains Collaborative Research Support Program (CRSP). The program is the successor to the International Sorghum and Millet CRSP. When the current CRSP was initiated (30 September 2006) the Management Entity decided to continue using the INTSORMIL name because of the name recognition. However, this CRSP is a new program with different objectives and more clearly defined and strict benchmarks and milestones.

There are nine CRSPs funded through the United States Agency for International Development (USAID) as part of the foreign assistance of the United States Government and thus the American people. They are designed to utilize the research and educational training capability of (primarily) land-grant universities to solve problems of mutual interest and benefit to collaborating host-countries and the United States. Historically, INTSORMIL has been involved primarily in education (long-term for graduate degrees or short-term technical) and research. Problems beyond the farm regarding marketing and end-use were secondary in the former crsp but are important in the new crsp. Much of the evaluation criteria for the new crsp will involve technology developed and its impact.

Currently INTSORMIL includes scientists at Kansas State, Nebraska, Ohio State, Purdue, Texas A&M, West Texas A&M, and the USDA-ARS. Involved are animal nutritionists, biotechnologists, breeders, cereal chemists, economists, entomologists, food scientists, plant pathologists and weed scientists. INTSORMIL currently works in at least 15 countries in Africa and three countries in Central America.

The original INTSORMIL CRSP was established in 1979. Several years ago USAID evaluated the CRSP activities and developed a list of recommended CRSPs for the 2006-2016 time period. In 2006, the U.S. Agency for International Development (USAID) issued a Request for Proposals (RFP) for the Management Entity of a new CRSP called the Sorghum, Millet and Other Grains CRSP. The University of Nebraska submitted the winning proposal

for the new program. The five-year grant began on 30 September 2006 and will run through 29 September 2011 contingent on availability of funds. During year 4 (30 September 2009 – 29 September 2010) USAID will review progress of the program and decide whether to renew the program. An extension would be for 5-years, 30 September 2011 – 29 September 2016.

TECHNICAL PLAN

The Technical Plan for the Management Entity proposal detailed the background and rationale for the program, the vision and proposed activities, and proposed benchmarks, specific indicators and impact.

INTSORMIL has 7 objectives:

1. Facilitate the growth of the rapidly expanding markets for sorghum and pearl millet (Primary Research Area: Supply Chain/Market Development)
2. Improve the food and nutritional quality of sorghum and pearl millet to enhance marketability and consumer health (Primary Research Area: Nutrition, Health, and Grain Quality)
3. Increase the stability and yield level of sorghum and pearl millet through crop, soil, and water management while maintaining or improving the natural resources of soil (land) and water (Primary Research Area: Integrated Crop, Soil and Water Management [ICSM])
4. Develop and disseminate information on the management of biotic stresses in an integrated system to increase grain yield and quality in field and in storage (Primary Research Area: Biotic Stress Management [IPM])
5. Enhance the stability and yield of sorghum and pearl millet through the use of genetic technologies (Primary Research Area: Genetic Enhancement)
6. Enhance global sorghum and pearl millet genetic resources and the conservation of biodiversity (Primary Research Area: Genetic Resources and Biodiversity)
7. Develop effective partnerships with national and international agencies engaged in the improvement of sorghum and pearl millet production and the betterment of people dependent on these crops for their livelihoods

For U.S. based projects the Management Entity advertised Request for Proposals (RFP) for 15 projects in March, 2007. Project proposals were due in mid-April, 2007 and evaluated by anonymous panel of experts. Based on recommendations by the panel projects were awarded effective 1 July 2007. The following projects are currently funded:

- Genetics (Breeding/Biotechnology) – 5
- Food Science – 4
- Economics & Marketing – 2
- Agronomy – 2
- Entomology – 1
- Plant Pathology – 1

Primary emphasis is Africa with 13 projects having primary activity in and in addition to the regional programs. In Central America, 2 projects have some primary activity.

Host country activity is conducted through four regional programs, one in Central America and three in Africa. To develop and implement regional programs planning meetings were held to develop a regional plan. Participants were selected by regional coordinators based upon prior performance and potential to contribute to the goals of INTSORMIL. Activity in

Central America is based in El Salvador and Nicaragua. The Horn of Africa (East Africa) primarily involves four countries – Ethiopia, Kenya, Tanzania and Uganda. Activity in West Africa primarily involves six countries – Burkina Faso, Niger, Nigeria, Ghana, Mali and Senegal. The Southern Africa regional program primarily involves four countries – Botswana, Mozambique, South Africa and Zambia.

The CRSP is also charged with conducting research on other grains – finger millet (East and Southern Africa), tef (Ethiopia), and fonio (West Africa). Other grains research is not supported not be from core funds but will be dependent upon USAID Mission funding. Currently there is no on the other grains.

INTSORMIL RESEARCH OPERATIONS

INTSORMIL is primarily a technology development and transfer organization. Prior to initiating projects stakeholder inputs were obtained to identify the activities that were the highest priority for sorghum and pearl millet producers and end-users. The research background of the scientists involved contributes to the generation of new knowledge and technology through applied and basic research. Transfer of the new technology to clientele is important and is receiving greater emphasis than in the old CRSP. Thus technology is tested for economic viability and ability to generate additional sustainable income. Ideally research is conducted by teams of scientist working across disciplinary, institutional, and national boundaries. Each scientist has the capability of use proven and new techniques to develop new technology. Technology developed should be mutually beneficial to the collaborating host country and the U.S.

Key elements of the program include training of host-country and U.S. scientists. INTSORMIL has been strong in training with the old CRSP in 28 years supporting more than 873 foreign graduate students and 211 post-doctoral fellows and visiting scientists. Training activities at this time are less than previously due to increasing costs and decreasing budgets. To enable training funds to support more students there is increasing interest in the use of ‘sandwich’ programs. A graduate student from a collaborating host country project will spend a semester or year with a U.S. principal investigator and then return to their home institution to complete their degree program.

INTSORMIL is looking for mutually beneficial partnerships between the U.S. government, land-grant universities, non-governmental organizations and the private sector. Within each project there should be activities that are mutually beneficial between host countries and the U.S. With the increased interest in technology transfer and adoption the anticipation is that partnerships between small entrepreneurs and businesses, and INTSORMIL, will be developed for value-added endeavors. However, INTSORMIL is not a grant organization with funds to support pilot or incubator activities. As mentioned previously, we generate and transfer new knowledge and technologies to clientele for the economic benefit of the host-country and the U.S.

OBJECTIVES, NOTATIONAL BENCHMARKS and INDICATORS, and NOTATIONAL EXPECTED DEVELOPMENT

In evaluating success of individual projects and INTSORMIL data on the number of new cultivars or technologies, number of clientele (including women) that have adopted the technology, number of hectares planted to the new cultivars, and economic impact will be very important.

Objectives	Notational Benchmarks and Indicators	Notational Expected Development Results
1. Supply chain/market development	Increased yield and incomes Quantity of clean pearl millet Purchases of sorghum for food and feed use	Increased farmer incomes Increased consumer welfare
2. Nutrition, health, and grain quality	Improved grain quality Adoption of new cultivars Availability of new food and feed products	Improved nutritional status New products and enterprises
3. ICSM	Increased and more stable yields Improved crop, soil and water management	Increased yields Increased income More sustainable production systems
4. IPM	Increased high-quality grain Improved pest management Decreased use of pesticides	Increased yields of better quality grain Improved nutrition and economic return More sustainable pest management
5. Genetic enhancement	More stable-yield genotypes More efficient water and nutrient use genotypes	Increased yield of high-quality grain Increased adaptation to environmental stress
6. Genetic resources and biodiversity	Higher-yielding genotypes Conservation of genetic biodiversity	Increased yields Increased economic return Conservation of genetic biodiversity for future needs
7. Partnerships and networking	Increased joint programs with partners	Improved delivery of information and technology to farmers

CURRENT STATUS

The Sorghum, Millet and Other Grains CRSP officially began operation on 30 September 2006. The grant is for 5-years ending on 29 September 2011. Proposals for U.S. based projects were solicited and evaluated during Year 1 with U.S. projects initiating activity on 1 July 2007. Concurrently, regional planning meetings were held to develop plans for activities in host countries. Regional program activities began on 30 September 2007. Scientists in the program are currently working towards the benchmarks and progress indicators for their individual activities, the regional program, and INTSORMIL.

Current indications are that USAID/Washington will conduct a review of INTSORMIL during year 4 (30 September 2009 – 29 September 2010). The review will be part of the process in determining whether INTSORMIL is achieving the benchmarks and indicators and expected development results and will be renewed for an additional 5 years. The additional 5 years would support INTSORMIL from 30 September 2011 to 29 September 2016.