

**TECHNICAL REPORT #2**

**METHODS TO BE USED TO IDENTIFY AND SPECIFY  
CHARACTERISTICS DESIRED BY INDUSTRIAL  
PROCESSORS THAT USE SORGHUM AS AN INPUT**

**FOR**

Regional Activity to Promote Integration through  
Dialogue and Policy Implementation (RAPID)



**RAPID**

**TASK ORDER No. 4.1**

**DEVELOPMENT OF SIMPLE, COMMON GRAIN QUALITY  
STANDARDS FOR SORGHUM, TO FACILITATE GRAIN  
TRADE IN SOUTHERN AFRICA**

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## SUMMARY

To determine and develop methods to identify and specify characteristics desired by industrial processors that use sorghum as an input, the current situation regarding sorghum grain quality standards in SADC (the Southern African Development Community) was surveyed.

South Africa and Zimbabwe are the only countries in SADC with sorghum grain quality standards, although Botswana has proposed standards. A clear need was identified to determine criteria considered important by the sorghum community with respect to sorghum utilisation.

Persons in the sorghum community in Botswana, South Africa, Tanzania and Zimbabwe categorised as: brewer, government/parastatal, maltster, miller, scientist, stockfeed manufacturer and trader were interviewed by the author and food scientist on the project (Prof J R N Taylor) and/or the market economist and team leader on the project (Dr F Niernberger). They were asked to complete a simple questionnaire, selecting sorghum grain quality criteria they considered important and to propose other criteria not listed. A total of 39 responses were obtained. It was found that the sorghum community in SADC considers the criteria: high-tannin/non-tannin, grain colour, hardness, germinability and grain purity all to be important with respect to sorghum end-use quality. Certain other criteria, in particular grain cultivar, are also considered 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.

A literature review of standard methods for measuring parameters based on these criteria was undertaken. It was found that none of the standard methods were directly suitable to be used in sorghum grain trading in southern Africa, since they generally require high-level technical skills, specialised instrumentation and analytical chemicals. Even the simplest method required some modification.

Five methods were developed. To determine tannin (high-tannin) sorghum, the Bleach test, which stains tannin (high-tannin) sorghums black, was modified so that it could be performed at room temperature using commercial chemicals. For sorghum colour a simple procedure which classifies sorghum into white and coloured grain was devised. To estimate grain hardness a visual determination method of grain endosperm texture was devised using a reference chart. For germinability, the Germinative Energy test was modified to perform it without the requirement for a temperature-controlled incubator or special filter papers. To determine grain purity, a procedure for the determination of total defects in a sample was devised based on measurement of "area" of defects when distributed on a grid, obviating the requirement for a weighing balance or sieves.

The methods developed were written up in the format for standard methods of the International Association for Cereal Science and Technology.

Based on the author's experience and local and international standards, trading standards for sorghum end-use quality in southern Africa, based on the application of these methods are recommended. In brief:

Batches containing  $\geq 95\%$  tannin (high-tannin) or non-tannin (low-tannin) sorghum be classified as Tannin or Non-tannin Sorghum, respectively

Batches containing  $\geq 95\%$  white or coloured sorghum be classified as White or Coloured) Sorghum, respectively

Batches containing  $\geq 90\%$  hard or medium or soft sorghum be classified as Hard or Medium or Soft Hardness Sorghum, respectively

Sorghum grain for malting should have a Germinative Energy at 72 hours of  $\geq 90\%$ .

The maximum permissible total defects in sorghum grain for human consumption should not exceed 8%

# 1 INTRODUCTION

The objectives of this United States Agency for International Development (USAID) sponsored project “Development of simple, common grain quality standards for sorghum, to facilitate grain trade in southern Africa” are set out in Appendix 1 of this report.

The major team members undertaking the project were:

A Market Economist and Team Leader (Dr F Niernberger of Chemonics, formerly an agricultural economist with the United States Department of Agriculture) and a Food Scientist (Prof J R N Taylor of the Department of Food Science, University of Pretoria, South Africa).

They found the partnering of a market economist with a food scientist to be highly effective, generating considerable synergy. For example, the food scientist could provide inputs on improving existing sorghum processing technology in a country and the market economist could estimate its economic feasibility, or the market economist could determine potential new market opportunities in a country and food scientist could propose technologies to exploit them.

This Technical Report #2 “Methods to be used to identify and specify characteristics desired by industrial processors that use sorghum as an input” describes:

- Current and proposed sorghum grades and standards in southern Africa
- A survey, with appropriate analysis, of sorghum grain quality criteria considered important by the sorghum community in selected southern African countries
- A review of methods available to measure these criteria describing their advantages and disadvantages
- A description, with appropriate statistical analysis, of the development of simple methods to determine the sorghum grain quality parameters considered important
- Methods for determining the various sorghum grain quality parameters, written in the format of the International Association for Cereal Science and Technology (ICC)
- Proposals for sorghum grain quality grades and standards for the various criteria

## **2 CURRENT AND PROPOSED SORGHUM GRADES AND STANDARDS IN SOUTHERN AFRICA**

In southern Africa, only South Africa and Zimbabwe currently have sorghum grades and standards. The South African standards (South African Department of Agriculture, 1999) (Appendix 2) classify sorghum varieties according to their potential to produce good quality malt, that is malt having high diastatic power (amylase activity) which is used for opaque beer brewing.

### **2.1 SOUTH AFRICAN STANDARDS**

The South African classification system grades sorghum into the three groups

- GM-malting class, no tannins, high diastatic power
- GL-feed class, no tannins, low diastatic power
- GH-malting class, tannins

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. The major omission in the South African grading system is that there are no specifications for sorghum for milling, which is other major use for sorghum in southern Africa. This omission is of importance since malting sorghum varieties are often soft, whereas for milling hard kernel sorghums are required. There is also a problem with respect to malting quality. Sorghum grain (ungerminated grain) has no diastatic power. To develop diastatic power the grain must be malted (germinated). Dead grain does not germinate. The standard does not specify germinability

### **2.2 ZIMBABWEAN REGULATIONS**

The Zimbabwean Grain Marketing Board regulations (Beta, 1998) (Appendix 3) divide sorghum into four grades: A, B, C, or D according to colour, endosperm type and whether grain is birdproof (high tannin) or not.

- Grade A-unmixed white and red varieties, excluding bird proof and horny endosperm types
- Grade B & C-unmixed white and red varieties possessing a horny endosperm, excluding birdproof varieties
- Grade D-any variety of sorghum, which is birdproof (high-tannin) or fails to comply with provisions applicable to A, B, or C.

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 (horny endosperm grain). However, methodology for the Regulations does not appear to have been standardised.

### **2.3 PROPOSED BOTSWANAN STANDARDS**

The Botswana Bureau of Standards is in the process of developing standards for sorghum for human consumption (Botswana Bureau of Standards, 2000) (Appendix 4). Four classes have been proposed:

- White sorghum-sorghum grains consisting of not less than 90% by weight white sorghum, irrespective of any purplish anthocyanic blotches in or on the pericarp, which does not have a dark nucellar layer (i.e. not high-tannin sorghum)
- Red sorghum-sorghum grains consisting of not less than 90% of weight sorghum of any colour ranging through yellow, pink, red and reddish brown, which does not have a dark nucellar layer (i.e. not high tannin sorghum)
- Mixed sorghum-sorghum grains of not less than 90% weight sorghum of any colour and which does not have a dark nucellar layer.
- Sample-grade sorghum-sorghum other than sorghum of any the above-mentioned classes.

Grades within the standards, specifying grain purity, are also proposed.

It can be seen that the proposed Botswana standards are descriptive with regard to the identity of the sorghum but are not directly related to end-use quality. It seems probable, however, that the regulations will be revised to make them more end-use orientated.

#### 2.4 CONCLUSIONS

Considering the present situation with regard to sorghum standards in southern Africa, there are clear needs:

To identify which particular criteria are considered important by the sorghum community with respect to sorghum utilisation

To develop simple analytical methods to measure well-defined parameters based on these criteria

To develop uniform quality standards for sorghum in southern Africa

### **3 SURVEY OF SORGHUM GRAIN QUALITY CRITERIA CONSIDERED IMPORTANT BY THE SORGHUM COMMUNITY IN SELECTED SOUTHERN AFRICAN COUNTRIES**

#### 3.1 EXPERIMENTAL

During the period February to April 2001 a survey of persons in the sorghum community in southern Africa was undertaken to determine which sorghum grain quality criteria they considered to be of importance with regard to end-use. Based on the author's experience and the advice of Dr D D Rohrbach (Agricultural Economist, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Bulawayo, Zimbabwe) five criteria were selected:

- High/Non-tannin grain. High-tannin grain is not desirable for porridge or rice type applications. High-tannin grain also is not appropriate for use in home brewing of traditional beverages, but can be used for industrial malting.
- Grain colour. Brown and red grain is required for brewing. Some communities like porridges from red grains. Typically, white sorghum grain is preferred for stiff porridge; i.e. when maize meal is the alternative.
- Degree of grain hardness. For milling, the grain must be hard, otherwise the meal yield is poor and often uneconomical. For malting, hardness is not so important.
- Live versus dead grain (Germinability). Obviously if the grain is dead it does not germinate. If it does not germinate it will not produce the diastatic power (amylase activity) required from malt for brewing traditional beverages.
- Grain purity. Consumers have a strong preference for sorghum products that are not full of foreign matter (sand, dirt, small rocks, rodent remains and droppings, chaff, etc.). Foreign matter reduces the units of output per unit of input for industries and may significantly increase the rate at which industrial equipment wears out.

A questionnaire was prepared whereby respondents were asked to rate these criteria on a 1 to 5 scale, where 1 = most important and 5 = least important.

The respondents were also asked to state which other quality criteria they considered as being important with the regard to end-use.

The respondents were given the choice of either: not specifying the end-use for which the criteria were important, or specifying the criteria which were important for milling and/or malting.

The survey was performed in four selected countries in SADC: Botswana, South Africa, Tanzania and Zimbabwe. The countries were selected for the following reasons:

Botswana – has the highest per capita consumption of sorghum

South Africa – has the most developed sorghum processing industry

Tanzania – has the highest sorghum production

Zimbabwe – has considerable potential to increase commercial production and sorghum processing

In so far as practical as wide a range as possible of respondents involved in sorghum utilisation was surveyed. The respondents were categorised as follows: brewer, government/parastatal, maltster, miller, scientist, stockfeed manufacturer and trader. They were interviewed in person by the author (Prof J R N Taylor and/or Dr F Niernberger. A total of 39 questionnaires were completed: 9 from Botswana, 16 from South Africa, 5 from Tanzania, 8 from Zimbabwe, plus 1 from a Mozambique sorghum scientist currently studying in South Africa.

### 3.2 RESULTS

**Table 1: Sorghum grain quality criteria considered as important by industrial processors and other persons in sorghum community in selected countries in southern Africa (Scale: 1 = most important, 5 = unimportant)**

Respondent description	Country	Quality Criteria					
		High tannin/ Non-tannin	Grain colour	Hardness	Germin- ability	Grain purity	Other
<b>End-use Milling</b>							
Miller	Botswana	1	2	1		2	Moisture
Miller	Botswana	1	1	1		1	Cultivar
Scientist	Botswana	1		3		2	
Brewer	Botswana		1				
Gov/Parastatal	Botswana	1		3		2	
Scientist	Mozambique		2	1		1	
Miller	South Africa	1		2			
Trader	South Africa		2	1			
Trader	South Africa	1		1			
Gov/Parastatal	South Africa	2	3	1			
Gov/Parastatal	South Africa		1			1	
Miller	South Africa	2	3	1			
Scientist	South Africa	1	2	1		1	Cultivar
Trader	Tanzania					1	Grain size
Miller	Tanzania		1			2	
Trader	Zimbabwe		3	2		1	
Miller	Zimbabwe		2			1	
Miller	Zimbabwe		3	1		2	
<b>End-use malting</b>							
Maltster	Botswana		1		1	2	Moisture
Scientist	Botswana	1			2	3	
Brewer	Botswana	2	3		1		
Brewer	South Africa	3	2		1		Noxious seeds, Mould, Diastatic power
Brewer	South Africa	1			2		
Maltster	South Africa				1		Weather staining
Trader	South Africa	1			1		
Trader	South Africa				1	2	
Gov/Parastatal	South Africa	2			1	3	
Gov/Parastatal	South Africa	1			1		
Maltster	South Africa	2			1	3	
Scientist	South Africa	1	1			1	Cultivar
Trader	Tanzania		2		1		Grain size
Trader	Zimbabwe		1		2		
Brewer	Zimbabwe			3	1	2	Diastatic power Cultivar
Brewer	Zimbabwe		2		1	3	Cultivar
<b>End-use not specified</b>							
Trader	Botswana	1		3		2	
Brewer	Tanzania	3	2			1	
Stockfeed	Tanzania					1	Nutritional value
Stockfeed	Zimbabwe		2			1	
Stockfeed	Zimbabwe			2		1	

**Table 2: Relative importance of the sorghum grain quality criteria with respect to end-use**

	Quality criteria				
	High/non-tannin	Grain colour	Hardness	Germinability	Grain purity
<b>All data</b>					
% respondents rating criterion important	51	56	41	38	64
Importance of criterion (scale 0-100)	67	53	58	83	63
<b>Milling</b>					
% respondents rating criterion important	50	72	72	0	67
Importance of criterion (scale 0-100)	83	50	67	0	67
<b>Malting</b>					
% respondents rating criterion important	63	59	0	83	42
Importance of criterion (scale 0-100)	56	44	0	94	50
<b>Not specified</b>					
% respondents rating criterion important	50	50	40	0	83
Importance of criterion (scale 0-100)	40	40	40	0	100

**Table 3: Relative importance of the sorghum grain quality criteria with respect to country**

	Quality criteria				
	High/non-tannin	Grain colour	Hardness	Germinability	Grain purity
<b>All countries (Botswana, South Africa, Tanzania, Zimbabwe) (38 Respondents)</b>					
% respondents rating criterion important	53	58	42	39	66
Importance of criterion (scale 0-100)	67	53	59	83	59
<b>Botswana (9 Respondents)</b>					
% respondents rating criterion important	78	56	56	33	67
Importance of criterion (scale 0-100)	91	63	45	77	43
<b>South Africa (16 Respondents)</b>					
% respondents rating criterion important	75	33	38	50	38
Importance of criterion (scale 0-100)	67	50	83	91	56
<b>Tanzania (5 Respondents)</b>					
% respondents rating criterion important	20	40	0	20	80
Importance of criterion (scale 0-100)	33	67	0	100	77
<b>Zimbabwe (8 Respondents)</b>					
% respondents rating criterion important	0	75	50	38	88
Importance of criterion (scale 0-100)	0	45	50	77	63

### 3.3 DISCUSSION

It can be seen from Table 1 that all five of the selected end-use quality criteria (High-tannin/non-tannin, Grain colour, Hardness, Germinability and Grain purity) were considered as being very important by the sorghum community. It can also be seen that end-use had a great influence on which particular criteria were considered as being important. There were also some differences between countries.

Some other quality criteria were also considered to be important: Cultivar, Diastatic power (amylase activity of malt made from grain), Grain size, Moisture content of grain, Nutritional value of the grain, Presence of noxious seeds, Weather staining of grains. Of these other criteria, cultivar was the one most frequently cited.

With respect to end-use (Table 2), considering all data, grain purity was rated as important by most respondents (64% of respondents) and germinability the by the least (38% of respondents). Interestingly, however, of the criteria, germinability had the highest importance rating (83). Considering milling as the end-use, most respondents rated grain colour and hardness as being important (72% of respondents), whereas no respondents rated germinability as being important for milling. However, of the criteria, high-tannin/non tannin received the high importance rating for milling (83). For malting, germinability was considered as being important by most respondents (83%) and it had the highest rating (94). In contrast, grain hardness was not considered important for malting. Where end-use was not specified, grain purity was considered as being important by the most respondents (83%) and of the criteria it had by far the highest rating (100). In contrast, germinability was not considered important.

Considering the data with respect to country, all quality criteria were rated as important by Botswanan and South Africa respondents, whereas Tanzanian respondents apparently did not consider grain hardness as important and Zimbabwean respondents apparently did not consider high/non-tannin as important. In contrast, most Botswanan and South African respondents rated high/non-tannin as an important criterion (78% and 75% of respondents, respectively). Most Tanzanian and Zimbabwean respondents rated grain purity as important (80% and 88% of respondents, respectively).

### 3.4 CONCLUSIONS

The sorghum community in southern Africa considers the five selected criteria: high-tannin/non-tannin, grain colour, hardness, germinability and grain purity all to be important with respect to sorghum end-use quality. Certain other criteria, in particular grain cultivar, are also considered 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.

## 4 REVIEW OF METHODS AVAILABLE TO MEASURE SORGHUM GRAIN QUALITY CRITERIA

To facilitate sorghum grain trade in southern Africa, it is essential that the methods developed to measure quality parameters fulfil certain requirements; some of which are particular to the Region, such as entrepreneur small milling and malting enterprises and a lack of scientific infrastructure:

- 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 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.

### 4.1 TANNIN ANALYSIS

In essence there are two ways to analyse high-tannin sorghum: The amount of tannin can be quantified, or the presence or absence of tannins can be assessed.

Quantification of tannins is difficult even for research laboratories to perform (Rooney et al, 1980). Different methods of extraction and different methods of analysis yield different results, (Rooney et al, 1980, Earp et al, 1981). Most tannin assays measure the level of phenols, which may or may not be condensed tannins. A number of methods have been used to determine phenolic compounds in sorghum grain, (reviewed by Serna-Saldivar and Rooney, 1995). The absolute amount of tannin present in a sorghum grain is virtually impossible to determine because a significant portion of the tannins cannot be extracted and assayed. Different assays also result in different values for tannins as they respond to different chemical parts of the tannin molecule.

Quantitative assays include:

The Vanillin-HCl method and its variations (Burns, 1971, Price et al, 1978) - This involves reaction with vanillin, which reacts primarily with flavanol compounds such as condensed tannins, but other flavonoid compounds do give colour development (Hahn et al, 1984). Tannin content is determined by comparison with a catechin standard. This method, since it is probably the most specific for tannins, is the one most commonly used

The Prussian Blue, Folin-Denis and Folin-Ciocalteu methods - These measure phenolic acids, flavonoids and tannins.

The ISO method (International Organisation for Standardisation, 1988) - This involves reaction with ferric ammonium citrate. Tannin content is determined by comparison with a tannic acid standard. Sorghum, however, does not contain tannic acid. The method determines total phenols and it is difficult to estimate what proportion of the phenols present are condensed tannins. Notwithstanding these drawbacks, this method is recommended for the determination of tannins in sorghum by Codex Alimentarius (Codex Alimentarius, 1995)

Protein precipitation and enzyme inhibition methods - These are most highly correlated to the nutritional value of the grain.

In view of the problems with quantitative tannin measurement, the expensive reagents and equipment, the skilled manpower required and the fact that for the purpose required, it is only necessary to know whether or not tannins are present, a test for the presence or absence of tannins would seem to be more appropriate. Concerning such tests, the colour of sorghum grain is not a guide to the presence or absence of tannins, (Boren and Waniska, 1992). Pericarp colour is due to other phenolic compounds namely a combination of anthocyanin and anthocyanidin pigments, as well as other flavonoid compounds (Hahn et al, 1984). Two or the more reliable non-quantitative tests for detecting tannins are the Scratch test and the Bleach test. The Scratch test consists of scratching away the outer pericarp with a sharp knife and determining the presence or absence of a pigmented testa (Waniska et al, 1992). The Bleach test uses reagents which dissolve the pericarp revealing the presence or absence of a pigmented testa layer (Waniska et al, 1992; Dewar et al, 1995).

The major problem with the Scratch test is that only a small area of the grain is scratched. Thus a false positive result may be obtained due to the presence of the purplish anthocyanic spots, caused by insect or fungal attack. A further problem is that it is very laborious to scratch sufficient grains to obtain a representative sample. There are also problems with the Bleach test. As carried out according to the modified method of the CSIR (South African Council for Scientific and Industrial Research (Dewar et al, 1995) an oven at 70°C and chemical grade sodium hydroxide are required. Also, experience in the author's laboratory has revealed that it is easy to obtain a false negative result due to excessive bleaching. Notwithstanding these problems, the Bleach test seems to have the best potential as a simple test for high-tannin sorghum.

## 4.2 GRAIN COLOUR

The colour of sorghum grain, like other materials, can be assessed visually or instrumentally. Concerning instrumental methods, ICRISAT in their book of methods of sorghum and millet analysis (Gomez et al, 1997) describe the use of the Agtron color meter. The problem with this particular instrument is that it does not actually measure colour, but merely lightness and darkness. Hence, false results could be obtained. True colour is generally measured using a Tristimulus colorimeter which measures red-green ('a' scale) and yellow-blue ('b' scale) in addition to light and dark ('L' scale). The drawback of such an instrument is its very high cost.

Visual assessment is the method of analysis recommended for colour determination in both the Codex (Codex Alimentarius, 1995), United States (United States Department of Agriculture, 1999) and South African standards (South African Department of Agriculture, 1999). The problem is that visual colour assessment can be rather subjective. What is brown to one person is red or purple to other people. Rooney and Murty (1982) have suggested the use of standard colour charts which could be compared until an appropriate colour match is obtained. The problem is to get an inexpensive set of colour standards which would all be the same for a given colour and that would not fade, discolour or get dirty. In the view of these problems, the best solution would appear to be a very simple and well-described visual classification.

### 4.3 GRAIN HARDNESS

Grain hardness is the resistance of the kernel to a crushing force, as occurs in milling. In the case of sorghum like other grains, the fundamental causes of grain hardness are not well understood (Chandrashekar and Mazhar, 1999)

Available methods for sorghum grain hardness can be divided into:

Direct methods of measuring sorghum grain hardness by pearling (decorticating/dehulling), crushing or milling the grain

Indirect methods such as assessing the proportions of vitreous (hard) and floury (soft) endosperm in the grain or the density of the grain.

Commonly used direct methods involve the use of the Tangential Abrasive Dehulling Device (TADD) (Oomah et al, 1981) or Brabender instrument (Pomeranz, 1986). The TADD instrument employs an abrasive circular disk to progressively rub off the outer layers of the sorghum kernel. The TADD can be used to determine the abrasive hardness index (AHI) as described by Taylor et al, (1997) or the percentage dehulling loss as described by Gomez et al, (1997). AHI is determined by progressively decorticating grain using the TADD and then calculating the time in seconds to abrade off 1% by weight of the grain. The percentage dehulling loss is a simpler method, which measures the percentage weight lost when a known mass of sorghum grain is dehulled given time using a TADD. Brabender hardness is the energy required to grind sorghum grain into meal and is measured as the area under a load curve obtained when a given amount of grain is milled using a specially adapted Farinograph instrument where the dough mixing equipment is replaced by a small burr mill. The problem with these direct milling methods is that expensive, specialised equipment is required.

Indirect methods include:

The visual assessment of the endosperm in individual grains, which have been cut longitudinally, (Rooney and Miller, 1982). A rating can then be applied, for example where 1 means there is little floury endosperm to 5, indicating all floury endosperm. Alternatively, digital image analysis can be used to quantify the proportions of floury and vitreous endosperm.

Determination of grain density by immersing the sorghum grain in an organic solvent or in a solution of sodium nitrate, as described by ICRISAT (Gomez et al, 1997). The author's experience with such a method is the solvents are difficult to handle and rapidly become contaminated with dirt and filth from the grain sample, leading to false results

Of the many potential methods for assessing sorghum grain hardness, the most promising method for adaptation appears to be the visual assessment of the endosperm of longitudinal half kernels of sorghum grain, as described by Rooney and Miller, (1982). The method is simple and uses no specialised equipment but amendment to the method is required to make it less subjective.

### 4.4 GERMINABILITY

The standard methods for assessing grain germinability for malting were developed for barley. The European Brewery Convention (1987) Analytica-EBC describes three different

methods: the Schonfeld method, the Aubry method and the BIRF (Brewing Industry Research Foundation) method. All are similar, and involve moistening a given number of grains and calculating the percentage germination after a given time under standard conditions. A seemingly unresolvable problem with all the methods is that the grain must be allowed to germinate for up to 72 hours to obtain a definitive result.

The BIRF method was adapted by the CSIR (Dewar et al, 1995) for the determination of sorghum Germinative Energy (the percentage of grains which can be expected to germinate if the sample is malted normally at the time of the test). This method is simple and has potential for adaptation to a grain trading situation. The method's major drawbacks, apart from its very long duration, are the requirements for an incubator with controlled temperature and relative humidity and filter papers of a specific type to hold the water required by the grains for germination. Thus it is necessary to modify the existing CSIR method to eliminate these drawbacks.

#### 4.5 GRAIN PURITY

The South African sorghum grain standards go into considerable detail on the determination of grain purity, (South African Department of Agriculture, 1999). They define what defective sorghum is in terms of broken kernels, foreign matter, and damaged kernels. The Standards state how to determine percentage foreign matter, percentage unthreshed sorghum, percentage defective sorghum and percentage small kernel sorghum using a combination of sieving and hand sorting and then weighing the resultant fractions. Codex Alimentarius (Codex Alimentarius, 1995) and the United States (United States Department of Agriculture, 1999) standards give maximum permissible levels of grain defects and some information on methodology. The ICC has a standard method with full details for the determination of Besatz (also known as dockage, defects or screenings) of wheat (International Association for Cereal Chemistry, 1972) which could be applied to any grain. All these methods are similar in principle in that they involve sieving and/or manual separation of the various fractions and then weighing to determine the mass of the fractions.

Thus, the problem with such methods for the desired application is that they require specialised sieves of a specific mesh size (and often specific hole shape) and a balance weighing at the gram level to at least one decimal place of accuracy. Thus some modification of methodology is required.

#### 4.6 CONCLUSIONS

None of the standard methods for determining the desired sorghum quality parameters are directly suitable for the desired application. Even the most suitable methods require some simplification. Modifications to the following methods are required:

- High/Non-tannin grain - the Bleach test described by Dewar et al (1995) requires modification 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) is required to be developed with more simple criteria

- Germinability – the Germinative Energy test described by Dewar et al (1995) requires modification so that it can be carried out without the use of a temperature and humidity controlled incubator and filter papers.
- Grain purity – A method needs to be developed based on the Codex Alimentarius (Codex Alimentarius, 1995) and South African (South African Department of Agriculture, 1999) sorghum purity methods to determine grain purity without the requirement for a balance and sieves.

## 5 DEVELOPMENT OF SIMPLE METHODS TO DETERMINE THE SORGHUM GRAIN QUALITY PARAMETERS CONSIDERED IMPORTANT

### 5.1 SORGHUM GRAIN SAMPLES

For method development, sorghum grain samples representing a wide range of origin and quality were obtained:

- Sorghum samples (17) supplied by the University of Pretoria.

**Table 4: University of Pretoria sorghum samples**

<b>Identity and description</b>	<b>Details of origin</b>
GH ex Nola 93 (tannin)	Ex CSIR,-March 2000
BR 9 (red, non-tannin)	Nola, May '97-Ex CSIR, March 2000
GH ex Nola 97 (tannin)	Nola, May '97-Ex CSIR, March 2000
PAN 8564 (1) (red, non-tannin)	EU project, October '96-Ex CSIR, March 2000
PAN 8564 (2) (red, non-tannin)	EU project, October '96-Ex CSIR, March 2000
GH ex Nola 91 (tannin)	Ex CSIR,-March 2000
Mapira (red, non-tannin)	WSV-387, Maputo, '95-Ex CSIR, March 2000
SNK 3640 (red, tannin)	Ex CSIR,-March 2000
NK 304 (red, non-tannin)	G87/25-Ex CSIR, March 2000
SNK3377 (red, non-tannin)	G87/17-Ex CSIR, March 2000
Mozambique (white, non-tannin)	EU project, Mozambique, 1997
SSK52 (tannin)	G87/18-Ex CSIR, March 2000
Barnard Red (red, non-tannin)	GM Nola-Ex CSIR, March 2000
GM ex Nola 97 (red, non-tannin)	Ex CSIR,-March 2000
Black (black, non-tannin)	Ex CSIR,-March 2000
DC 99 (tannin)	Ex CSIR,-March 2000
KAT 369 (white, non-tannin)	EU project, Kenya, September 1996
NK 283 (red, non-tannin)	Ex Nola, February, 1999

- Sorghum samples (14) kindly supplied by ICRISAT, Bulawayo, Zimbabwe: MRS 94, Kuyuma, SV3, Pirira 2, SV2, MRS 13, Sima, MRS 12, Macia, Farmers Local, Lars 46-85, Pato, Brown Tsweta, Pirira 1. Unfortunately, all these samples were infested with insects and insect damaged to a greater or lesser degree. The samples were used

for method development but could not be used in all cases for comparison between methods.

## 5.2 DETECTION OF HIGH-TANNIN SORGHUM GRAIN

### *EXPERIMENTAL*

#### **CSIR (Dewar et al, 1995) Bleach Test and Modifications**

##### ***Reagents***

Sodium hydroxide (AR) (Merck, Halfway House, South Africa)

Commercial caustic soda (drain cleaner), (Hi-lite Hardware, Hatfield, Pretoria)

Commercial bleach (3.5 % minimum sodium hypochlorite) 2 products, Jik and Pick'n Pay No Name Brand (Pick'n Pay Supermarket, Hatfield Pretoria)

##### ***Equipment***

Forced draft circulating fan oven (Labcon, Roodeport, South Africa)

Tea strainer

Aluminium foil

Paper towel

##### ***Methods***

The development of a simple method for detection of tannins in grain sorghum was based on the Bleach method of Waniska et al (1992), as modified by the CSIR (Dewar et al, 1995).

The CSIR method was as follows:

Bleaching reagent was prepared by making up a 5% (w/v) sodium hydroxide solution in commercial bleach containing a minimum of 3.5% sodium hypochlorite.

One hundred whole, sound sorghum kernels were placed in a 50 ml beaker and just covered with Bleaching reagent. The beaker was closed with aluminium foil and placed in an oven at 70°C for 20 min. Samples were mixed by swirling every 5 min. The beaker was then removed from the oven and the Bleaching reagent drained off using a tea strainer. The grains were rinsed off with tap water and then tipped onto paper towel and blotted dry. The number of kernels staining completely black was recorded (Fig. 1). One high-tannin and one non-tannin sorghum variety were used as positive and negative controls.

The method was modified as follows:

Commercial caustic soda (drain cleaner) was used in place of sodium hydroxide.

Incubation was carried out at room temperature (24°C) for 20 minutes

It was also confirmed that variables such as brand of bleach and variation in concentration of sodium hydroxide over the range 2.5-5.0% (w/v) did not affect the assay.

#### **Vanillin HCl Method**

##### ***Reagents***

*Vanillin HCl reagent*

A: 8% HCl in methanol

B: 1% vanillin in methanol.

Solutions A and B were mixed in equal proportions just before use.

*Catechin standard curve*

Catechin (2 mg/ml) stock standard was diluted to give a standard curve with a range of 0-2mg/ml with 0.2 mg/ml increments.

4% HCl in methanol

***Equipment***

Visible Spectrophotometer (Milton Roy, Spectronic, New York, USA)

1024 Shaking water bath (Tecator AB, Hogands, Sweden)

Coffee grinder (Moulinex, Bagnolet, France)

***Method***

Whole sorghum grain (30 g) was milled using a coffee grinder for 2 x 1 min. Sorghum (1.00 g) was weighed in duplicate into 125 ml Erlenmeyer flasks and 50 ml methanol added to each. The flasks were placed into a shaking water bath at 30°C for 20 min. After extraction, the samples were filtered through a Whatman No 4 filter paper and the extract collected.

Standards or extracts (1 ml) were mixed with 5 ml mixed vanillin HCl reagent and incubated at 30°C. After exactly 20 min the absorbance was read at 500 nm, zeroing the spectrophotometer with distilled water. The vanillin HCl reagent was used as a reagent blank. Extract blanks were prepared to compensate for highly coloured extracts not due to tannins. Extract (1 ml) was mixed with 5 ml 4% HCl in methanol and incubated at 30°C. After 20 min the absorbance was read at 500 nm.

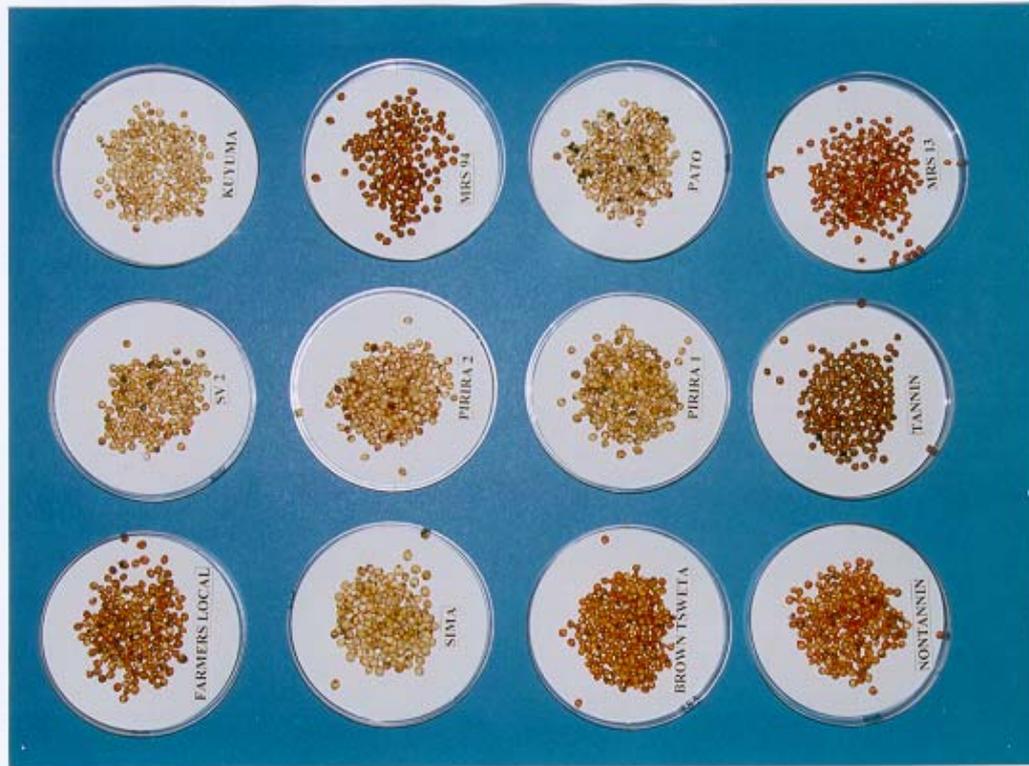
A standard curve was prepared and values of catechin equivalents determined for the samples and blanks. Results were then calculated as is or with blank correction.

## RESULTS

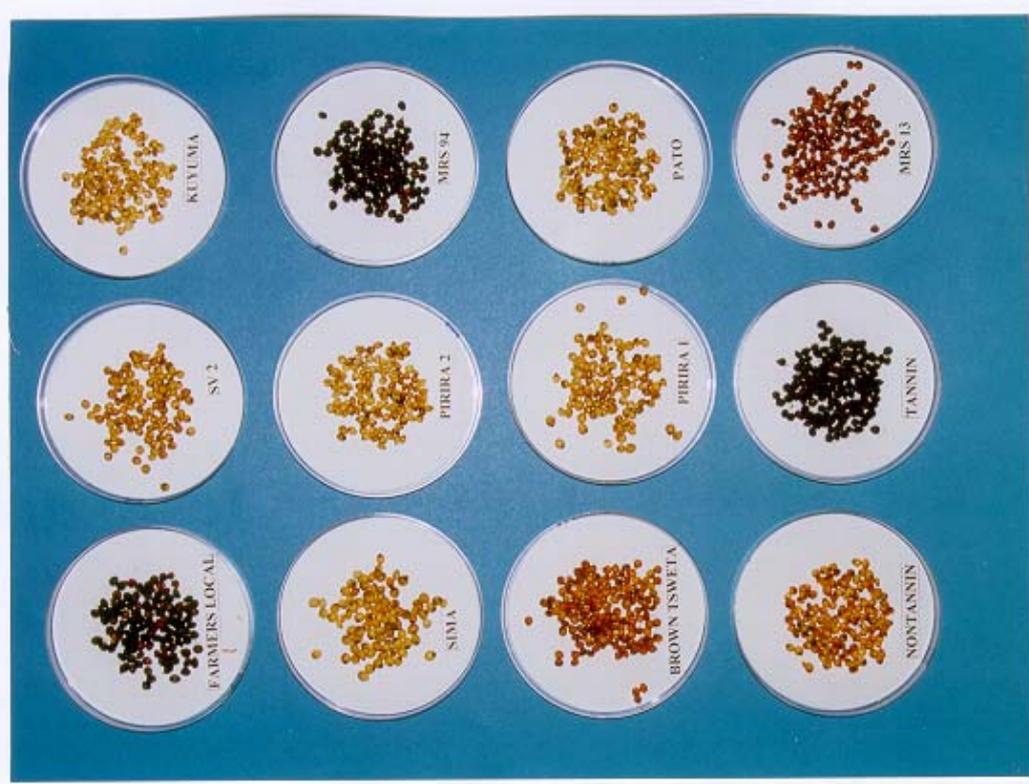
**Table 5: High-tannin sorghum determined by the modified bleach test, the CSIR bleach test and the vanillin HCl method**

<b>Sorghum Sample</b>	<b>Modified Bleach Test (% completely black grains)</b>	<b>CSIR Bleach Test (% completely black grains)</b>	<b>Tannin content (mg catechin equivalents/100 mg sorghum) with blank subtraction</b>
NK 283 (non-tannin standard)	0	1	0.07
DC 99 (high-tannin standard)	100	100	5.73
KAT 369	0	0	0.09
GM ex Nola 97	1	2	0.06
Barnard Red	4	5	0.22
SSK52	96	96	6.44
SNK3377	0	1	0.06
GH ex Nola 93	1	1	0.07
BR 9	1	2	0.10
GH ex Nola 97	91	94	7.75
PAN 8564 (1)	0	0	0.07
PAN 8564 (2)	0	0	0.02
SNK 3640	92	93	11.02
NK 304	0	0	0.07
GH ex Nola 91	91	94	14.09
Mozambique	0	0	0.19
Mapira	0	1	0.05

Results are the means of 4 replicates determinations



(a)



(b)

Figure 1: Application of Bleach test to sorghum samples. (a) controls, (b) samples subjected to Bleach test

It was not possible to draw a correlation of regression of the modified Bleach test against the Vanillin HCl method for tannin analysis, as the Bleach test is not quantitative for the amount of tannin, only for the percentage of high-tannin kernels. Also, it was not meaningful to draw a regression line of the modified Bleach method against the CSIR Bleach method, since the samples were either high-tannin or non-tannin sorghum.

### *DISCUSSION*

Figure 1 shows that colour is not a good guide to whether a sorghum variety is a high-tannin variety or not. For example, the variety Brown Tsweta is coloured brown but subjecting it to the Bleach test reveals that it does not have a pigmented testa. In fact, as can be seen from Table 5 the Bleach test gives results in complete agreement with the quantitative vanillin HCl tannin assay. The four samples containing high levels of tannins (lowest 5.73% catechin equivalents, highest 14.09), comprised more than 90% grains with a pigmented testa, according to the Bleach test. In contrast, the samples containing low levels of tannins (lowest 0.02% catechin equivalents, highest 0.22), comprised between 0 and 5% grains with a pigmented testa.

The modified Bleach test, which uses commercial caustic soda and is carried out at room temperature, gave identical results to the CSIR method. Thus, the modified Bleach test should enable the simple determination of the percentage high-tannin sorghum in consignments of sorghum grain.

## 5.3 GRAIN COLOUR

### *EXPERIMENTAL*

#### ***Equipment***

Hunterlab Colorquest 45/0 tristimulus colorimeter equipped with Universal Software, Version 3.1 (Hunter Associates Inc., Reston, USA)

Agtron Color Quality Meter (Agtron Inc., Sparks, USA)

#### ***Methods***

Visual determination of sorghum grain colour: Grains were classified as 'white' or 'coloured':

- A 'white' grain is defined as being coloured white all over its surface regardless of signs of mould or purplish anthocyanic blotches caused by weathering.
  - A 'coloured' grain is coloured yellow, red, pink, brown, purple or combinations of these colours all over its surface.

Grains (100 kernels) were spread onto a sheet of white paper and viewed with the naked eye. Known white and coloured sorghum samples were included as standards. The number of 'white' or 'coloured' grains were counted and expressed as a percentage. The test was performed in duplicate.

Instrumental determination of sorghum grain colour:

Colour was measured using the Hunterlab Tristimulus colorimeter (L, a, b scale) and Agtron Color Quality Meter (red filter) according to the manufacturers' instructions.

## RESULTS

**Table 6: Sorghum grain colour determined by the developed visual method and the Tristimulus and Agtron instruments<sup>a</sup>**

Sorghum Sample	Visual colour (% white grains)	Tristimulus values <sup>b</sup>			Agtron values <sup>c</sup>
		L	A	B	
NK 283	1	36.4	10.3	12.4	30.3
KAT 369	100	46.6	4.5	14.9	40.6
DC 99	0	28.4	7.5	9.2	13.4
GM ex Nola 97	0	32.5	9.3	11.1	21.2
Barnard Red	0	37.1	11.2	13.4	27.3
SSK52	0	33.3	11.1	11.3	22.0
SNK3377	0	34.9	6.5	10.8	23.3
GH ex Nola 93	0	33.5	9.9	12.6	25.6
BR 9	1	34.8	9.2	11.4	25.6
GH ex Nola 97	0	28.1	11.2	10.8	17.8
PAN 8564 (1)	0	33.9	10.0	12.7	26.4
PAN 8564 (2)	0	34.8	9.4	12.5	26.0
SNK 3640	0	26.7	8.1	8.7	10.9
NK 304	1	35.5	8.7	11.3	24.5
GH ex Nola 91	0	37.1	8.6	12.3	26.7
Mozambique	100	51.1	2.5	11.9	35.9
Mapira	0	31.8	13.0	11.4	24.9

<sup>a</sup>Results are the mean of two replicate determinations

<sup>b</sup>Tristimulus colorimeter: L 0-dark, 100-light, a: -60 = green, + 60 = red, b: -60 = blue, +60 = yellow

<sup>c</sup>Agtron meter: 0-dark, 90-white

## DISCUSSION

It can be seen from Table 6 that the two samples visually identified as white could be clearly differentiated from the other samples (which were visually identified as coloured) by the two non-subjective instrumental methods. The minimum Tristimulus colorimeter L (lightness) value for the white samples was 46.6 and the maximum for coloured samples was 37.1. Similarly, with the Agtron meter the minimum reading for the white samples was 35.9 and the maximum for the coloured samples was 30.3.

Thus, it appears that a simple visual method can be used to quantify white sorghum in a consignment.

## 5.4 GRAIN HARDNESS

### EXPERIMENTAL

#### Rooney and Miller (1982) Endosperm Texture Method and Modifications

##### Equipment

Rubbery gum used to attach posters to wall (for example Prestik)

Sharp disposable scalpel or sharp, single-edged razor blade

Sheets of white (A4) paper

**Methods**

At least 20 sound, whole sorghum kernels of each sample were selected. Each grain was pressed into the side of a small (same size as the kernel) piece of “rubbery gum” placed on the paper cutting surface, germ side upwards and cut longitudinally using a scalpel into two equal halves, so that each half contained an equal portion of the germ. Half of each kernel was then mounted on a card with “rubbery gum” and examined visually (Fig. 2).



The cut kernels were compared with illustrations of sorghum kernels of different texture given by Rooney and Miller (1982) and their rating from 1-5 allocated, where 1 is corneous and 5 is floury, (Fig. 3). According to the Rooney and Miller (1982) method an overall rating was given for all the kernels in the sample (Table 7).

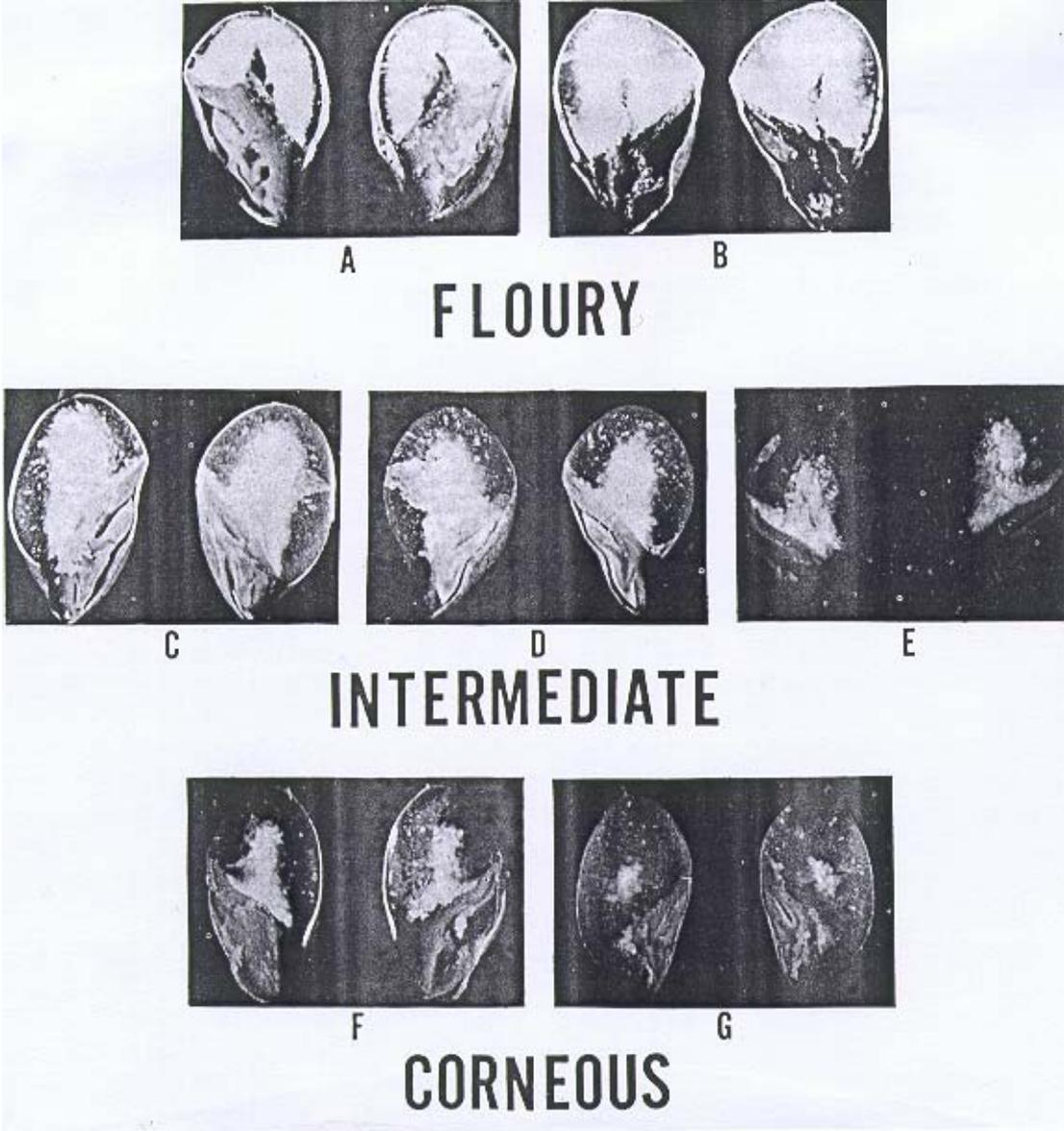


Figure 3: Rooney and Miller (1982) illustrations for visual estimation of grain hardness. The ratings for the kernels are: A and B 5, C 4, D 3. E and F 2, G 1.

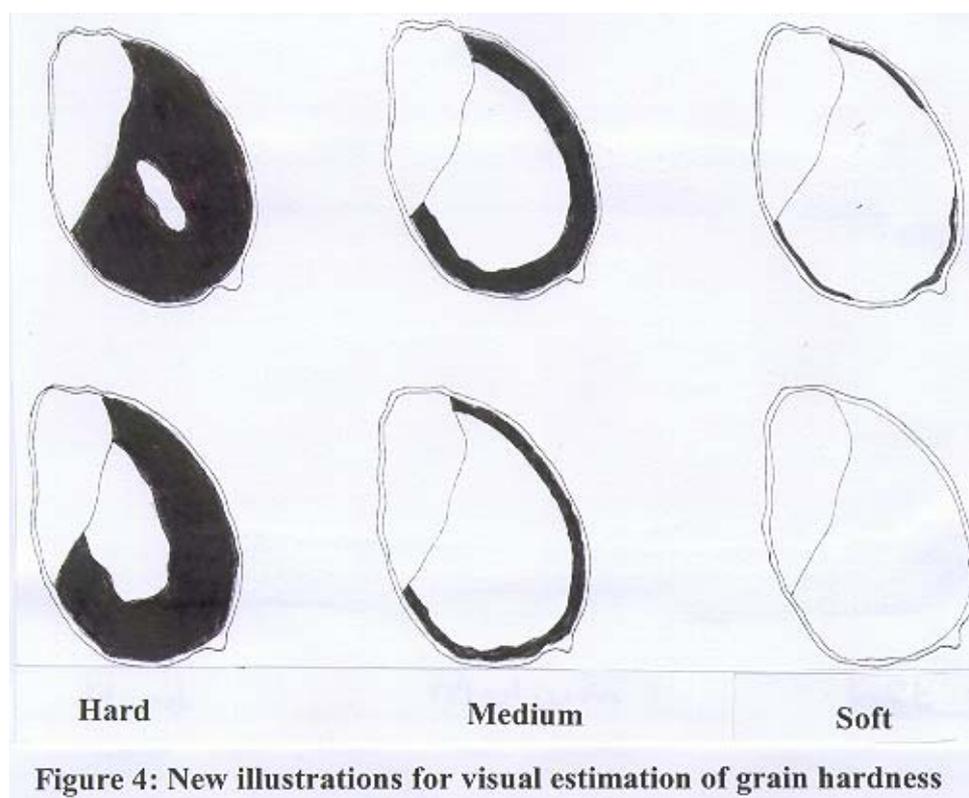
The individual kernels in the sample were then scored in terms of corneous (hard), intermediate (medium) and floury (soft). New illustrations, (Fig. 4) were drawn to make classification easier and definitions were written for the three classes as follows:

**Hard-** the endosperm is totally corneous (translucent) or most (>50%) of the endosperm is translucent.

**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).

**Soft-** the endosperm is totally floury or the outer, corneous endosperm is very narrow and incomplete.

In the simplified method, the percentage Hard, Medium and Soft kernels were recorded (Table 7).



## RESULTS

**Table 7: Sorghum grain hardness as estimated by the simplified endosperm texture method and the Rooney and Miller (1982) endosperm texture method**

Sorghum Sample	Hardness rating (Simplified method) <sup>a</sup>	Rooney and Miller score <sup>b</sup>
NK 283	S0, M100, H0	3
KAT 369	S5, M75, H20	2
DC 99	S95, M5, H0	5
GM ex Nola 97	S15, M80, H5	3.5
Barnard Red	S55, M45, H0	4
SSK52	S30, M70, H0	4
SNK3377	S5, M70, H25	2
GH ex Nola 93	S5, M95, H0	3
BR 9	S30, M70, H0	3.5
GH ex Nola 97	S65, M35, H0	5
PAN 8564 (1)	S0, M100, H0	2
PAN 8564 (2)	S5, M95, H0	2
SNK 3640	S90, M10, H0	5
NK 304	S10, M90, H0	3
GH ex Nola 91	S70, M30, H0	4
Mozambique	S0, M25, H75	2
Mapira	S55, M45, H0	4

<sup>a</sup>Simplified method: S-soft, M-medium, H-hard

<sup>b</sup>Rooney and Miller score: 1 and 2 corneous, 2-4 intermediate, 5 floury

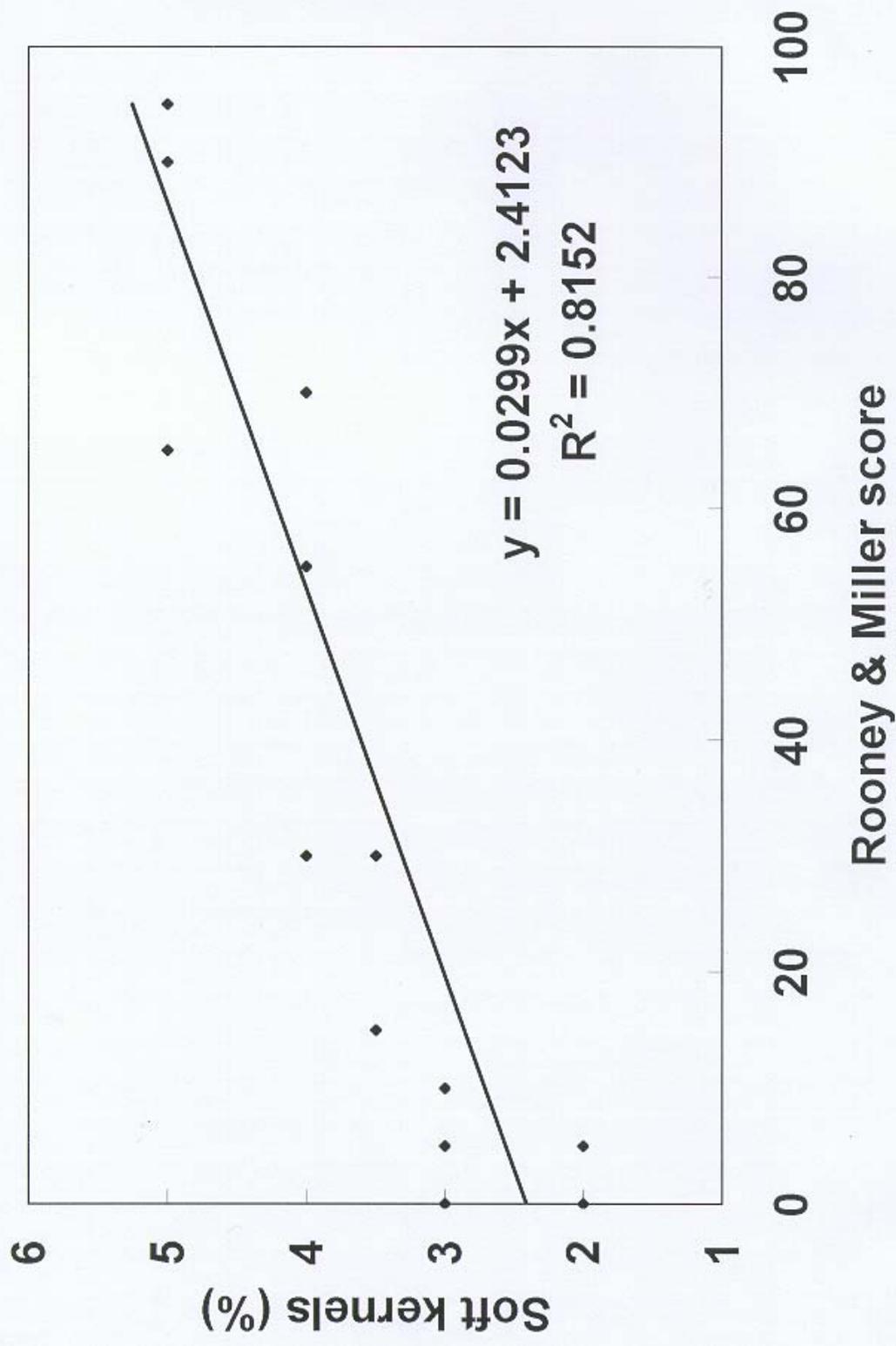


Figure 5: Correlation between sorghum hardness estimated by the simplified and Rooney & Miller (1982) endosperm texture methods

## *DISCUSSION*

It can be seen from Table 7 that sorghum endosperm characteristics varied greatly between the samples, from 95% soft endosperm types (DC 99) to 75% hard endosperm types (Mozambique), according to the chart that was created (Fig. 4). The hardness rating of soft, medium and hard endosperm kernel sorghums generally agreed with the Rooney & Miller (1982) overall scoring system. For example, sample DC 99 scored 5 (floury) and sample Mozambique 2 (corneous). In fact, the two methods were highly significantly ( $r < 0.001$ ) correlated (Fig. 5), with an  $R^2$  value of 0.82, in other words 82% of the variation was accounted for by the linear relationship. Thus, it appears that the percentage of floury (soft), intermediate (medium) and corneous (hard) grain in a sample can be quantified visually by comparison with a simple chart.

## 5.5 GERMINABILITY

### *EXPERIMENTAL*

#### **CSIR (Dewar et al, 1995) Method**

##### ***Equipment***

Low temperature incubator set at 25°C, (Labcon, Roodeport, South Africa). Relative humidity maintained by use of damp cotton cloths inside an insulated box placed in the incubator.

Whatman No 1 filter paper (9 cm diam.)

Plastic petri dishes

#### **Modified Method**

##### ***Equipment***

Plastic lids approximately 9 cm diam. x 2 cm high

Newspaper (black news print only) circles cut to size of lid

Aluminium foil

Polystyrene cooler box. Relative humidity maintained by damp cotton cloths placed inside the box.

##### ***Methods***

The CSIR method was as follows: Filter paper (2 sheets) was placed in a petri dish and 4 ml distilled water was added. Whole sorghum kernels (100) were spread evenly over the surface of the filter paper. The petri dish was closed and placed in an insulated box containing damp clothes to maintain the relative humidity near to 100%. The box was then placed in an incubator at 25°C. Each sample was prepared in triplicate. After 24 h the number of germinated kernels (Fig. 6) were counted and removed. Germination is defined as when the grain has chitted, i.e. the root tip has emerged. The petri dish was then returned to the incubator for a further 24 h. Again the germinated grains were counted and removed. This was repeated again at 72 h and the percentage of germinated grains after 72 h calculated.

The CSIR method was modified as follows: Plastic lids were substituted for petri dishes. These were covered with a slightly larger sized lid or foil to close. Filter paper was substituted with 4 sheets of newsprint cut to the size of the lid. No coloured newsprint was used. Tap water (5 ml, measured using a teaspoon) was used. Germination was carried out at room temperature in a cooler box lined with damp cotton clothes to maintain the relative humidity at near to 100%. The cooler box was kept out of direct sunlight for the period of the test.

Since ambient temperature is variable, the effect of temperature (20°C, 25°C, and 30°C) was examined using the modified method and comparing it with the CSIR method at 25° C. Germination at 24, 48 and 72 h was recorded. Correlations of linear regression were drawn between the CSIR method at 25° C and the modified method at 20, 25, and 30°C (Fig. 7).



Figure 6: Sorghum subjected to the Germinative Energy test on newspaper and filter paper. Arrows indicate chitted grains

## RESULTS

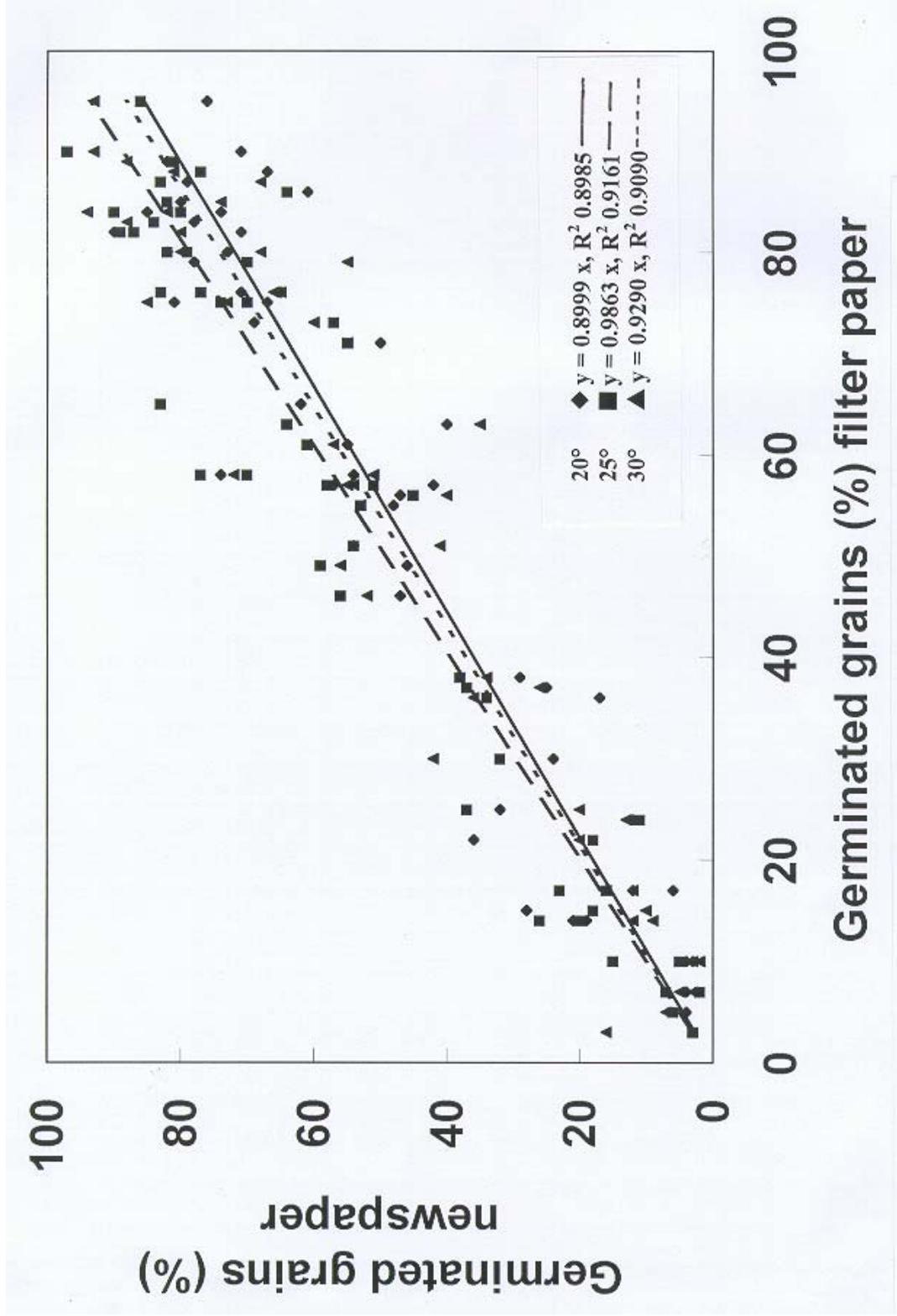


Figure 7: Correlations between Germinative Energy measured at 25°C on filter paper and at 20, 25 and 30°C on newspaper

## *DISCUSSION*

Figure 7 shows that the germination method using newspaper in place of filter paper was highly significantly correlated ( $r < 0.001$ ) over a wide range of ambient temperatures (20-30°C) with the CSIR method using particular filter papers at a specified temperature of 25°C. At all three temperature  $R^2$  was around 0.9, in other words 90% of the variation was accounted for by the linear relationship. Analysis of variance revealed that there was no significant effect ( $p > 0.05$ ) of treatment between incubating with filter paper at 25°C and with newspaper at 20°C, 25°C or 30°C.

Thus, notwithstanding the problem that the Germinative Energy test takes up to 72 hours to obtain a definitive result, it is clear that accurate results can be obtained without the use of temperature-controlled incubator or special filter papers. Thus, the modified test could be performed in situations where this specialised equipment is not available.

## 5.6 GRAIN PURITY

### *EXPERIMENTAL*

#### ***Equipment***

Mettler Bas Bal balance (Mettler Instruments, Greifensee, Switzerland) accurate to 0.1 g  
20 x 20 cm square grid with 10 x 10 cm square highlighted (Fig. 8)  
35 mm film container or similar container with 30-35 ml capacity.

#### ***Method***

The method used for grain purity determination was based on the South African Sorghum Grain Standard (South African Department of Agriculture, 1999) using the Codex Alimentarius descriptions of defects (Codex Alimentarius, 1995).

Purity was determined by manual sorting of 25 g samples of sorghum grain. A grid system, (Fig. 8) was devised for estimating the proportions by area of sound, whole grain, and defects (broken grain, chaff, insect remains, insect damaged grain, noxious seeds, stones and sand). The grid was 20 x 20 cm, divided into 1 cm squares with a 10 x 10 cm square marked. A sample of sorghum (25 g either weighed or if a balance is not available measured using a 35 mm film container or similar filled to the brim) was spread out as a monolayer on the 10 x 10 cm square. The monolayer of sample should approximately cover the 100 square centimetres. The square acts as a check that the right amount has been measured if a balance is not available.

The sorghum was then sorted with the aid of a 15 cm ruler or similar into whole grain and defects. The defects were then spread as a monolayer with no spaces between them onto the 1 cm squares (Fig. 9). The number of squares covered by the impurities was counted. The grain fractions were retained on sorting and weighed to 0.1 g. The percentage of each fraction was recorded and a correlation of linear regression drawn between purity values obtained by weight and those estimated by area (Fig. 10).

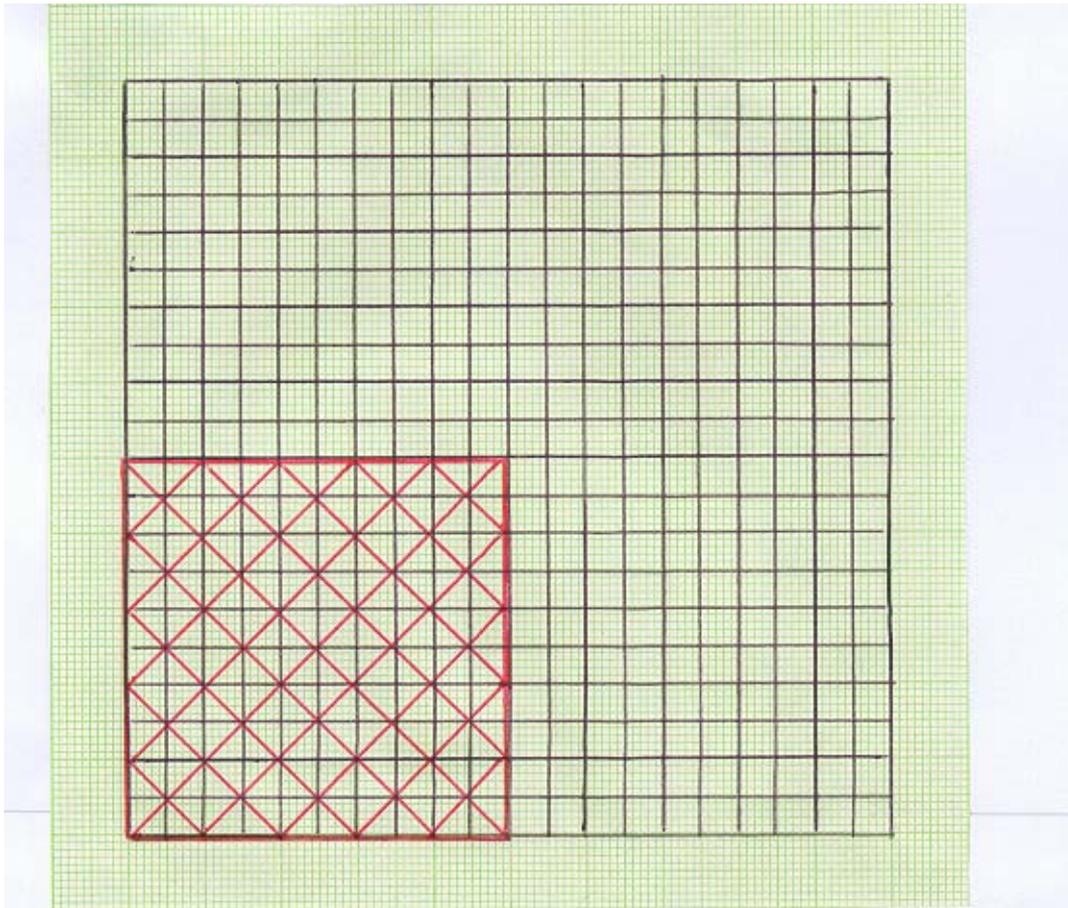


Figure 8: 20 x 20 cm square grid for sorting total defects from sound whole sorghum grains, with 10 x 10 cm insert for checking sample size



Figure 9: Sorghum sample after sorting defects and sound whole grain

**RESULT**

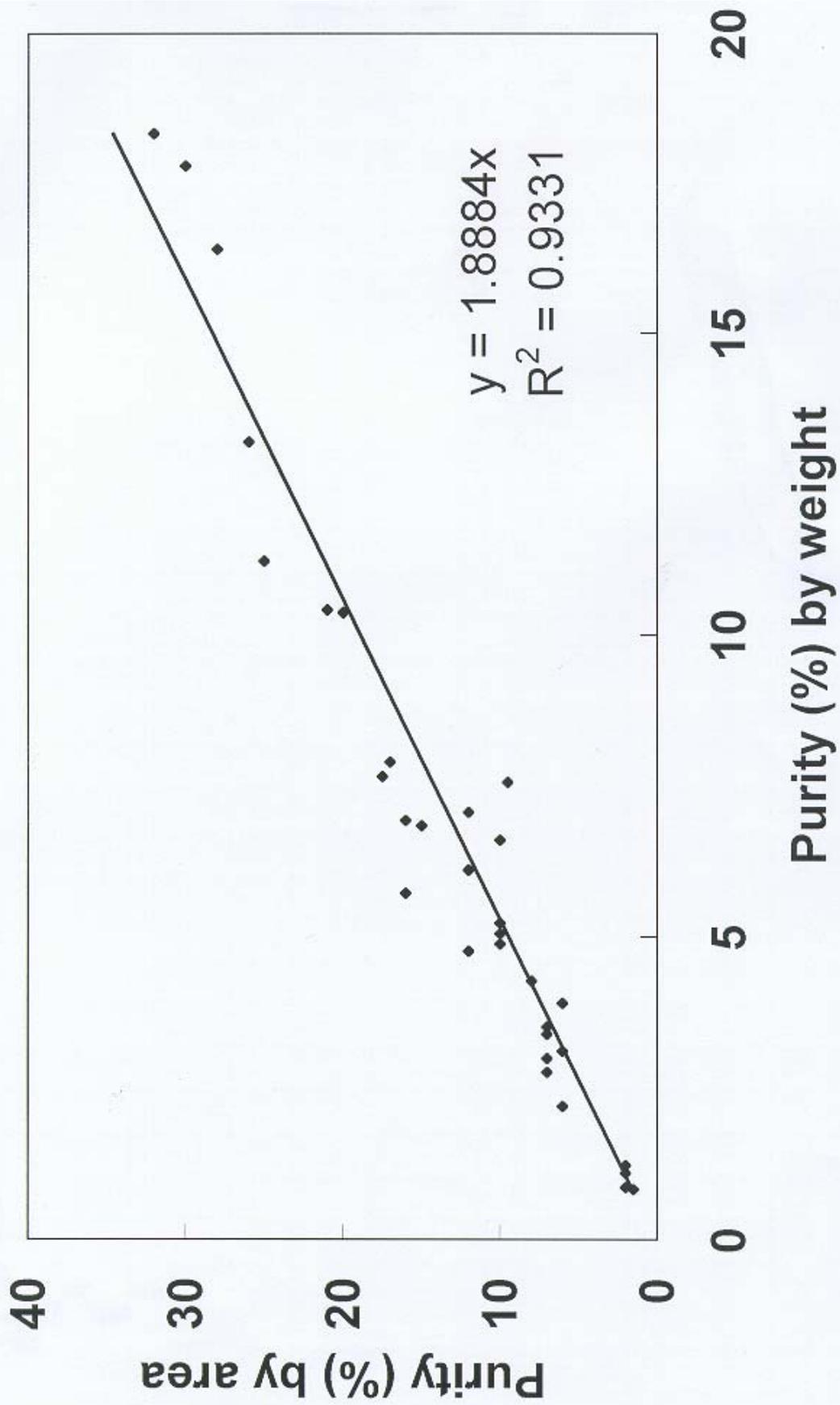


Figure 10: Correlation between percentage total defects in batches of sorghum measured by area and by weight

## DISCUSSION

It can be seen from Fig. 10 that when spread out in a monolayer the area occupied by the defects in samples of sorghum was highly significantly correlated ( $r < 0.001$ ) with the weight of the defects. In fact, 94% of the variation was accounted for by the linear regression. The equation of the relationship, grams defects =  $0.52 \text{ cm}^2$  defects, reveals that the area of defects was almost exactly twice the weight. Therefore, to relate area to weight, it is simply a matter of dividing by 2.

By the use of a simple grid, the defects in a sample of sorghum can be estimated in terms of percentage by weight. Thus, defects in a consignment of sorghum in trade can be quantified without the requirement for sieves and a weighing balance.

## **6 METHODS FOR DETERMINING THE VARIOUS SORGHUM GRAIN QUALITY PARAMETERS, WRITTEN IN THE FORMAT OF THE INTERNATIONAL ASSOCIATION FOR CEREAL SCIENCE AND TECHNOLOGY (ICC)**

### **6.1 Title**

#### **1. Detection of Tannin Sorghum Grain by the Bleach Test**

#### **2. Scope**

Applicable to whole grain sorghum.

#### **3. Definitions**

Certain varieties of sorghum contain proanthocyanidins (commonly referred to as tannins or more strictly-speaking condensed tannins) in the seed coat layer beneath the pericarp (commonly referred to as the testa layer) of the grain. These varieties are variously referred to as: tannin, high-tannin, brown, bird-proof, bird-resistant, or bitter sorghums.

Varieties of sorghum not containing tannins are variously referred to as: non-tannin, low-tannin, condensed tannin-free, or sweet sorghums.

In this Standard the term “tannin sorghum” shall be used for those sorghums containing tannins and the term “non-tannin sorghum” used for those sorghums not containing tannins.

#### **4. Principle**

Sorghum grain is immersed in a sodium hypochlorite solution (bleach) containing alkali. The solution dissolves away the outer pericarp layer of sorghum grain, revealing the presence of a black pigmented testa layer in the case of tannin sorghums, or its absence in the case of non-tannin sorghums.

#### **5. Reagent**

##### **5.1 Bleaching reagent**

Five g<sup>1</sup> sodium hydroxide<sup>2</sup> is dissolved in 100 ml<sup>3</sup> of 3.5% sodium hypochlorite solution (commercial bleach). Reagent can be stored at room temperature in light-proof bottle for up to one month.

##### **5.2 Sorghum standards**

An appropriate tannin and non-tannin standard.

#### **6. Apparatus**

Glass beakers (50 ml)<sup>4</sup>.

Tea strainer

Aluminium foil

Paper towel

## 7. Reference

Waniska, R.D., Hugo, L.F. & Rooney, L.W. 1992. Practical methods to determine the presence of tannins in sorghum. *Journal of Applied Poultry Research* 1:122-128.

## 8. Procedure

8.1

Test must be performed in duplicate

8.2

Known tannin sorghum and non-tannin sorghum standards must be included each time the test is performed.

8.3

One hundred whole, sound sorghum grains are placed in a beaker.

8.4

Bleaching reagent is added to **just** cover the sorghum grains and close beaker with aluminium foil. Too much bleaching reagent will cause over bleaching and give false negative results. If in doubt repeat using less reagent.

8.5

Incubate beaker at room temperature (20-30°C) for 20 minutes, swirling contents of beaker every 5 minutes.

8.6

Empty contents of beaker into tea strainer, discarding bleaching reagent. Rinse sorghum grains in tea strainer with tap water.

8.7

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.

8.8

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.

Non-tannin sorghum grains are those which are either completely white, **or** are brown over **part** of the surface of the grain.

## 9. Presentation of results

9.1

Calculate tannin sorghum grains as percentage of total sorghum grains. Duplicate determinations should not differ by more than +/- 5 grains, for example first determination 90%, second determination 85%, or 95%.

**The mean of the duplicate determinations should be calculated.**

9.2

Expression of results

Results should be expressed as:

Percentage tannin sorghum, e.g. 90% tannin sorghum

## 10. Recommended standards

It is recommended that:

Batches containing  $\geq 95\%$  tannin or non-tannin sorghum be classified as Tannin or Non-tannin Sorghum, respectively

Where batches contain  $< 95\%$  tannin (or non-tannin) sorghum and  $> 5\%$  non-tannin (or tannin) sorghum, the batch be classified as Mixed Tannin and Non-tannin Sorghum and that the percentage tannin sorghum be given.

### NOTES

<sup>1</sup>A 5 ml medicine measuring spoonful may be used to measure out approx. 5 g of sodium hydroxide if a weighing balance is not available

<sup>2</sup>Commercial caustic soda, sometimes marketed as drain cleaner, may be used

<sup>3</sup>Measure using for example a 200 ml 'Buddy' soft drink bottle (after use wash out with water and then crush bottle before disposal) and use 2 x 5 ml medicine measuring spoonfuls of caustic soda.

<sup>4</sup>Any clear glass or plastic beaker or container with a diameter of around 3 cm.

## **6. 2 Title**

### **1. Classification of Sorghum Grain according to Colour**

#### **2. Scope**

Applicable to whole grain sorghum.

#### **3. Definitions**

Sorghum grain colour is the overall visual perception of the colour of the grain as viewed with the naked eye, where the colour results from a combination of intrinsic factors, principally: pericarp colour, the presence or absence of a pigmented testa, endosperm colour.

Sorghum grain colour is important with regard to end-use, in particular for milling to produce meal for porridge making and for malting for use in opaque beer brewing.

#### **4. Principle**

Sorghum grains are viewed with the naked eye.

Sorghum grains are classified as being either “white” or “coloured”.

#### **5. Apparatus**

Sheets of white (A4) paper

#### **6. Reference**

Rooney, L.W. & Miller, F.R. 1982. Variation in the structure and kernel characteristics of sorghum. in: Mertin, J.V. (ed.). Proceedings of the International Symposium on Sorghum Grain Quality. ICRISAT, Patancheru, India, pp. 143-162.

#### **7. Procedure**

7.1

Test must be performed in duplicate.

7.2

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

7.3

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.

7.4

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.

## **8. Presentation of results**

### 8.1

#### Calculation

Calculate white (or coloured) sorghum grains as percentage of total sorghum grains. Duplicate determinations should not differ by more than +/- 5 grains, for example first determination 90%, second determination 85%, or 95%.

The mean of the duplicate determinations should be calculated as a whole number.

### 8.2

#### Expression of results

Results should be expressed as:

Percentage white (or coloured) sorghum, e.g. 90% White Sorghum

## **9. Recommended standards**

It is recommended that:

Batches containing  $\geq 95\%$  white (or coloured) sorghum be classified as White (or Coloured) Sorghum.

Where batches contain  $< 95\%$  white (or coloured) sorghum and  $> 5\%$  coloured (or white) sorghum, the batch be classified as Mixed White and Coloured Sorghum and that the percentage coloured sorghum be given.

## **6.3 Title**

### **1. Estimation of Sorghum Grain Hardness**

#### **2. Scope**

Applicable to whole grain sorghum.

#### **3. Definitions**

Sorghum grain hardness is the resistance of the grain to breakage during decortication (dehulling) and milling.

Sorghum grain hardness is of importance as hard grains yield proportionally more clean (uncontaminated with bran) endosperm of large particle size during milling operations than soft grains.

Sorghum grain hardness is related to the proportion of corneous (horny/glassy/vitreous) endosperm in the grain. Hard grains have a higher proportion of corneous endosperm than soft grains.

#### **4. Principle**

Sorghum grains are cut into halves longitudinally.

One half is viewed with the naked eye and the proportion of corneous endosperm is determined by reference to a standard.

On the basis of the proportion of corneous endosperm, grains are classified into: hard, intermediate and soft.

#### **5. Apparatus**

5.1

Sharp disposable scalpel or sharp single-edged razor blade<sup>1</sup>

5.2

Sheets of white (A4) paper

5.3

Rubbery gum used to attach posters to walls (for example Prestik)

#### **6. Reference**

Rooney, L.W. & Miller, F.R. 1982. Variation in the structure and kernel characteristics of sorghum. in: Mertin J.V. (ed.). Proceedings of the International Symposium on Sorghum Grain Quality. ICRISAT, Patancheru, India, pp. 143-162,

#### **7. Procedure**

7.1

Test must be performed in duplicate.

7.2

Press a small piece of “rubbery gum” (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 “rubbery gum” to hold it in place. The germ side has a circular indentation at the end of grain.

7.3

Cut the grain in two lengthwise, to produce two even size halves, so that each half contains an equal portion of the germ.

7.4

Repeat until 20 grains have been cut.

7.5

Compare one half of each grain against the illustration (Figure ) and classify it as:

**Hard** – the endosperm is totally corneous (translucent) or most (>50%) of the endosperm is translucent

**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)

**Soft** – the endosperm is totally floury or the outer, corneous endosperm is very narrow and incomplete.

## 8. Presentation of results

### 8.1 Calculation

Calculate the number of hard, medium and soft and grains as a percentage of total sorghum grains. Duplicate determinations should not differ by more than +/- 1 grain in each class.

The mean of the duplicate determinations should be calculated as a whole number.

### 8.2 Expression of results

Results should be expressed as:

Percentage of hard, medium and soft sorghum grains, e.g.

Grain hardness (%)	Hard	Medium	Soft
Sample X	85	10	5

## 10. Recommended standards

It is recommended that:

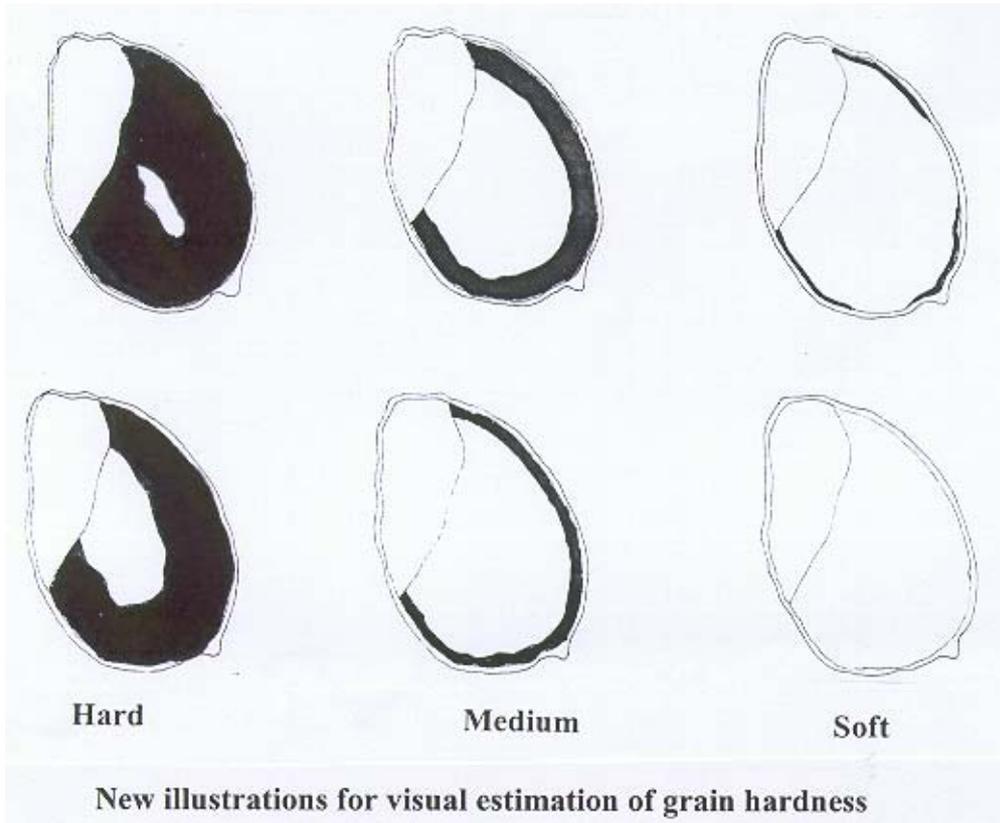
Batches containing  $\geq 90\%$  hard (or medium or soft) sorghum grains be classified as Hard (or Medium or Soft) Hardness Sorghum

Batches containing 100% of only hard and medium sorghum should be classified as Medium Hardness Sorghum

Batches containing  $>10\%$  and  $< 90\%$  soft, medium or hard should be classified as Mixed Hardness Sorghum and the percentages of Hard, Medium and Soft Sorghum must be given

### NOTES

<sup>1</sup>A very sharp, narrow bladed knife may be used



## **6.4 Title**

### **1. Determination of Germinative Energy of Sorghum Grain**

#### **2. Scope**

Applicable to whole grain sorghum.

#### **3. Definitions**

To produce sorghum malt, it is necessary that a high proportion of sorghum grains in a batch germinate.

Germinative Energy is the percentage of grains which can be expected to germinate if the batch is malted normally at the time of the test.

#### **4. Principle**

Sorghum grains are placed on damp filter paper in closed petri dishes and allowed to germinate at a set temperature for set periods of time.

The percentage of grains that have germinated at the end of each period is calculated.

#### **5. Apparatus**

5.1

Incubator set at 25°C and 100% relative humidity<sup>1</sup>

5.2

Petri dishes (glass or plastic) 10 cm diameter with lids<sup>2</sup>

5.3

Filter paper (Whatman No. 1) 9 cm diameter<sup>3</sup>

5.4

Graduated pipette with 4 ml measure<sup>4</sup>

5.5

Distilled water<sup>5</sup>

#### **6. Reference**

European Brewery Convention. 1987. Method 2.6. Germinative Energy. in: Analytica-EBC, 4th Ed. Brauerei- und Getränke-Rundschau, Zurich, E 19-20.

#### **7. Procedure**

6.1

Test must be performed in duplicate.

6.2

Place two filter paper circles<sup>6</sup> into the bottom of the petri dish.

6.3

Moisten the filter paper with 4 ml<sup>4</sup> of distilled water<sup>5</sup>

6.4

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.

6.5

Place the filled petri dishes in the incubator.

## 6.6

After 24, 48 and 72 hours, the grains are examined. 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.

## 7. Presentation of results

### 7.1 Calculation

At each time interval calculate the percentage germinated grains. Duplicate determinations should not differ by more than +/- 5 grains, for example first determination 95%, second determination 90%, or 100%

Germinative Energy is the mean of the duplicate determinations, expressed as a whole number.

### 7.2 Expression of results

Results should be expressed as:

Germinative Energy (%) 24 hours, 48 hours, 72 hours, e.g.

Germinative Energy (%)	24 hours	48 hours	72 hours
Sample X	84	92	95

## 8. Recommended standard

It is recommended that sorghum grain for malting should have a Germinative Energy at 72 hours of  $\geq 90\%$ .

### NOTES

<sup>1</sup>A polystyrene box with close-fitting lid may be used. Incubation may be carried out at ambient temperature (20-30°C). High relative humidity is maintained in the box by placing two layers of thin cotton dishcloth saturated with water at the bottom of the box covering the entire surface area; and placing two layers of thin cotton dish cloth saturated with water covering the petri dishes. The cloths must be re-saturated with water each day of the test.

<sup>2</sup>Any type of dish of similar diameter, such as a plastic lid, may be used. The dish may be covered with aluminium foil to close it.

<sup>3</sup>Circles of newspaper (black printing on only) of diameter the same size as the internal diameter of the smaller of the dishes may be used.

<sup>4</sup>When using newspaper circles, 5 ml of water should be used, which may be measured out using a 5 ml medicine measure, see also note 6.

<sup>5</sup>Tap water may be used, but there may be greater variability between results of different operators.

<sup>6</sup>Where newspaper and 5 ml of water are used, the number of circles of newspaper to be put in the dish has to be established prior to the test, since the thickness of newspaper is variable. The newspaper circles must be saturated with water, but there must be no free water on the surface, i.e. if for example it is found that after adding the 5 ml of water to two circles of newspaper there is still free water on the surface, additional circles must be added one at a time until such a number has been added that there is no free water.

## **6.5 Title**

### **1. Determination of Total Defects in Sorghum Grain**

#### **2. Scope**

This method is applicable to determination of total defects in consignments of whole grain sorghum intended for human consumption.

#### **3. Definitions**

The term total defects applies to all components of a sorghum sample which differ from the normal basic variety, including extraneous matter, filth, blemished grains, diseased grains, broken kernels and other grains.

##### ***3.1 Extraneous matter***

All organic and inorganic material other than sorghum, broken kernels, other grains and filth. Extraneous matter includes loose sorghum seedcoats.

##### ***3.2 Filth***

Impurities of animal origin including dead insects.

##### ***3.3 Blemished grains***

3.3.1 Grains which are insect or vermin damaged, of abnormal colour, sprouted, diseased, or otherwise materially damaged.

3.3.2 Diseased grains – grains made unsafe for human consumption due to decay, moulding, or bacterial decomposition, or other causes that may be noticed without having to cut the grains open to examine them.

3.3.3 Insect or vermin damaged grains – Kernels with obvious weevil-bored holes or which have evidence of boring or tunnelling, indicating the presence of insects, insect webbing or insect refuse, or degermed grains, chewed in more than one part of the kernel which exhibit evident traces of an attack by vermin.

3.3.4 Grains having an abnormal colour – Grains whose natural colour has been modified by bad weather conditions, contact with the grain, heat, and excessive respiration. These grains may be dull, shrivelled, swollen, puffed, or bloated in appearance.

3.3.5 Sprouted grains – Grains exhibiting obvious signs of sprouting.

3.3.6 Frost damaged grains – Grains which are damaged by frost and may appear bleached or blistered and the seed coat may be peeling. Germs may appear dead or discoloured.

##### ***3.4 Broken kernels***

Sorghum and pieces of sorghum which pass through a 1.8 mm round-hole sieve.

##### ***3.5 Other grains***

Edible grains, whole or identifiable broken, other than sorghum (i.e. legumes, pulses and other edible cereals).

#### **4. Principle**

The principle of the method is to separate all defects, defined under 3, from the normal basic grains by manual selection.

#### **5. Reagents**

No reagents are required for this determination.

#### **6. Apparatus**

6.1

Balance (precision 0.1 g)<sup>1</sup>

6.2

Sheet of cardboard approximately A4 size on which is drawn a 20 x 20 cm square divided into 400 x 1 cm square blocks with a 10 x 10 cm square marked in the corner of the larger square (Figure). If determination is to be carried out routinely, it is recommended that the square should be drawn on A4 sized piece of wood, metal or plastic, or on paper and then laminated.

6.3

Thin object with straight flat edge (for example 15 cm ruler)

#### **7. References**

Codex Alimentarius. 1995. Codex standard for sorghum grain. Codex Stan 172-1989 (Rev. 1-1995). in: Codex Alimentarius, Volume 7, Cereals, Pulses, Legumes and Derived Products and Vegetable Proteins. FAO/WHO, Rome, pp 37-42.

International Association for Cereal Chemistry 1972. Determination of besatz of wheat. ICC Standard No. 102/1. In: ICC Standard Methods. International Association for Cereal Science and Technology, Schwachet, Austria.

#### **8. Sampling**

According to ICC Standard 101/1<sup>2</sup>

#### **9. Procedure**

9.1

Test must be performed in duplicate.

9.2

Weigh out an average (final) sample of 25.0 g<sup>1</sup> and empty sample onto A4 sheet.

9.3

Spread sample into a monolayer on the 10 x 10 cm square. The sample should approximately fill the square.

9.4

With the aid of the ruler move all defects described out of the 10 x 10 cm square.

9.5

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. There must be no space between the defects.

9.6

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.

## **10. Presentation of results**

### 10.1 Calculation

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.

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

Duplicate determinations should not differ by more than +/- 2 squares, for example first determination 10 squares (5%), second determination 8 squares (4%), or 12 squares (6%).

The mean of the duplicate determinations should be calculated.

### 10.2 Expression of results

Results should be expressed as:

Percentage total defects of sorghum grain, e.g. 5%

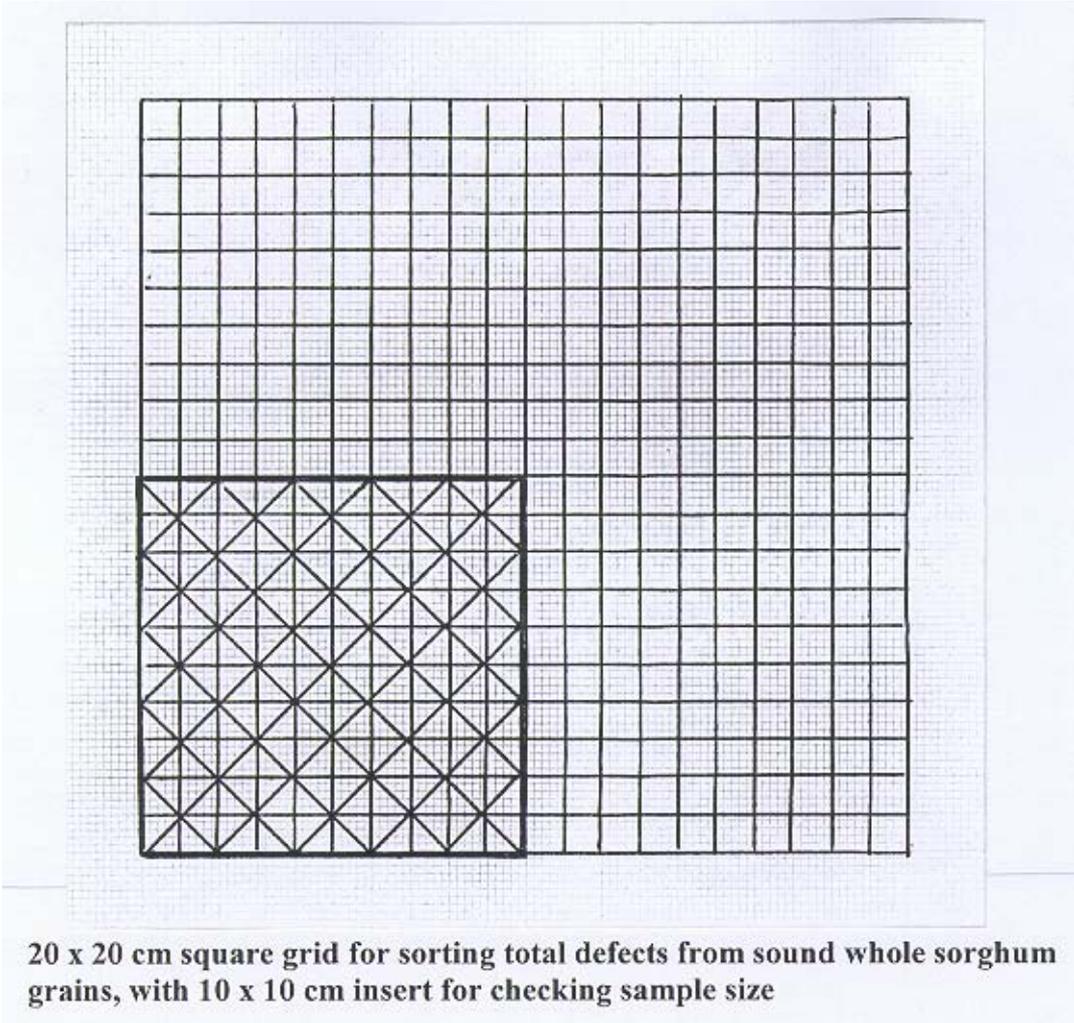
## **11. Recommended standard**

It is recommended that the maximum permissible total defects in sorghum grain for human consumption should not exceed 8%, as specified by Codex Alimentarius.

### **NOTES**

<sup>1</sup>A container holding between 30-35 ml (when filled to the brim), for example a 35 mm film container, may be used to measure the required quantity of grain (25.0 g)

<sup>2</sup>Representative laboratory samples may be obtained by emptying the bulk sample (normally 50-100 kg) onto a large plastic sheet (approx 3 x 3 m) and spreading it out and then heaping it. This procedure is repeated two further times before taking the laboratory sample.



## **7 CONCLUSIONS AND PROPOSALS FOR SORGHUM GRAIN QUALITY STANDARDS**

### **7.1 CONCLUSIONS**

South Africa and Zimbabwe are the only countries in SADC with sorghum grain quality standards, although Botswana has proposed standards. Needs were identified:

To determine criteria considered important by the sorghum community with respect to sorghum utilisation

To develop simple methods to measure well-defined parameters based on these criteria

To develop uniform quality standards for sorghum in southern Africa.

It was found that the sorghum community in southern Africa considers the five selected criteria: high-tannin/non-tannin, grain colour, hardness, germinability and grain purity all to be important with respect to sorghum end-use quality. Certain other criteria, in particular grain cultivar, are also considered 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.

None of the standard methods for determining the desired sorghum quality parameters were found to be directly suitable for the desired application. Even the most suitable methods required some simplification:

- To determine tannin (high-tannin) sorghum the Bleach test was modified to perform it at room temperature using commercial caustic soda.
- To determine sorghum colour a simple visual procedure which classifies sorghum into white and coloured grain was devised.
- To estimate grain hardness a visual determination method of grain endosperm texture was devised using a reference chart.
- To determine grain germinability the Germinative Energy test was modified to perform it without the requirement for a temperature-controlled incubator or special filter papers.
- To determine grain purity, a procedure for the determination of total defects in a sample was devised based on measurement of “area” of defects when distributed on a grid, obviating the requirement for a weighing balance or sieves.

The methods developed were written up in the format for standard methods of the International Association for Cereal Science and Technology.

Quality standards based on the application of these methods are proposed – see below.

## 7.2 PROPOSED SORGHUM GRAIN QUALITY STANDARDS

The following sorghum grain standards are recommended, in conjunction with the methods developed:

### **Tannin (High-tannin) Sorghum Grain**

It is recommended that:

Batches containing  $\geq 95\%$  tannin or non-tannin sorghum be classified as Tannin or Non-tannin Sorghum, respectively

Where batches contain  $< 95\%$  tannin (or non-tannin) sorghum and  $> 5\%$  non-tannin (or tannin) sorghum, the batch be classified as Mixed Tannin and Non-tannin Sorghum and that the percentage tannin sorghum be given.

### **Sorghum Grain Colour**

It is recommended that:

Batches containing  $\geq 95\%$  white or coloured sorghum be classified as White or Coloured Sorghum, respectively

Where batches contain  $< 95\%$  white (or coloured) sorghum and  $> 5\%$  coloured (or white) sorghum, the batch be classified as Mixed White and Coloured Sorghum and that the percentage coloured sorghum be given.

### **Sorghum Grain Hardness**

It is recommended that:

Batches containing  $\geq 90\%$  hard or medium or soft sorghum be classified as Hard or Medium or Soft Hardness Sorghum, respectively

Batches containing 100% of only hard and medium sorghum should be classified as Medium Hardness Sorghum

Batches containing  $>10\%$  and  $< 90\%$  soft, medium or hard be classified as Mixed Hardness Sorghum and the percentages of Hard, Medium and Soft Sorghum must be given

### **Germinative Energy of Sorghum Grain (Germination)**

It is recommended that:

Sorghum grain for malting should have a Germinative Energy at 72 hours of  $\geq 90\%$ .

### **Total Defects in Sorghum Grain (Grain Purity)**

It is recommended that:

The maximum permissible total defects in sorghum grain for human consumption should not exceed 8%, as specified by Codex Alimentarius.

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## **APPENDIX 1: OBJECTIVES OF PROJECT**

The purpose of the activity described in this task order is to facilitate grain trade, particularly sorghum, in Southern Africa. This will be accomplished by developing simple, grain quality grades and standards for sorghum. Common grain quality grades and standards are a prerequisite to increase the trade and marketing of this crop, particularly trade between countries within SADC. Under this task order, a simple set of standards for sorghum grain quality will be validated by the region's grain traders and the region's food and feed sorghum grain processing industry. An economic and institutional analysis will be carried out to estimate if the price premium that could be paid for sorghum of a particular quality for flour and beverages is sufficiently profitable to offset the costs of implementation to industry and governments. The analysis will also evaluate if these quality grades and standards establish price signals sufficiently strong to increase production. Regional grades and standards implemented by industry in SADC may also be endorsed by the International Association for Cereal Science and Technology (ICC), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and SADC.