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1. AGRONOMIC EVALUATION OF SORGHUM FOR THE MALTING AND BREWING PROCESS

1.1 INTRODUCTION

Although the selection of sorghum as an industrial brewing raw material started only recently compared with centuries of studies on the selection and characterization of to-day's brewer's barley, some sorghum varieties with good malting and brewing tendencies have already been identified. It is however utmost necessary to ascertain the adaptability and sustainability of these varieties to the harsh local Ghanaian climate and environmental conditions, characterized by erratic rainfall pattern and low soil fertility obtained predominantly in the northern Ghana, where sorghum thrives best and therefore grown widely. The establishment of Raw Material Development Programme (RMDP) under the sorghum project has exactly this purpose, namely to develop good malting sorghum varieties –collected both locally and internationally in the framework of a good sorghum beer development programme.

1.2 SORGHUM VARIETAL TRIALS; 1990/91 DRY SEASON CROPPING

1.2.1 INTRODUCTION

Three foreign white sorghum varieties, Dorado, Sureno from Texas, USA and IITA LOT from Ibadan , Nigeria and four local varieties, the white NSV I, NVS II, Belko white and the red Framida were planted at Tono in the Upper East Region in the late 1990 on a 1.34hectare land acquired from the Irrigation Company of the Upper Region (ICOUR) LTD. The trials were to study the performance of these varieties under irrigation during the dry season.

1.2.2 GENERAL FIELD PRACTICES

The general trials were conducted using the Randomized Block (RCB) design with three replications, Standard culture practices including ploughing, harrowing, ridging, basal fertilizer application, top dressing with urea, regularly weeding and sparing of field regularly against pests were carried out.

Seed treatment with Apron-plus, an insecticide-fungicide, to forestall the occurrence of sorghum head smut disease was given before the first planting and refilling nine days after. After germination Furadan, a systemic insecticide was applied against stem-borers and spittle bugs, Field spraying with Acatellic against grasshoppers took place three weeks after planting followed by thinning and transplanting. Later, basal application of the fertilizer, NPK 25:15:5, a Nitrogen-Phosphorus-Potassium compound was followed by top dressing with Urea just before booting. Harvesting took place from March to early April 1991.

1.2.3 OBSERVATIONS, RESULTS AND DFISCUSSION

The relevant specific agronomic data are recorded in the following Table 1 for easy reference. Dorado and Sureno are both early maturing, attaining the 50% flowering stage in less than seventy-five days. Both varieties were prone to sorghum head smut disease. Grain yield was higher for Dorado than for Sureno. Both yields could however be said to be encouraging. Dorado is a relatively short variety. This makes the plant resistant to lodging. Sureno is a relatively tall plant and therefore more prone to lodging.

Table 1
SPECIFIC AGRONOMIC DATA ON THE VARIETIES

Variety	Grain colour	Days to 50% flowering	Days to 100% maturing	Plant height at maturity (cm)	Grain yield per hectare (Kg/Ha)	Remarks
Dorado	Cream	70	105	119	1574	Prone to Head smut. Early maturing
Sureno	Cream	72	102	176	1244	Prone to Head smut. Early maturing
IITA LOT	Cream white	80	120	200	1890	Prone To Head smut. Medium Maturing
Framida	Dark red	80	110	120	2490	Early maturing high yielding but extensive plant height.
NSV I	White	90	140	110	1950	Late maturing, high yielding and very extensive plant height.
NSV II	Grey	90	140	140	1950	Late maturing, high yielding and very extensive plant height
Belko white	White	85	135	135	1885	Late maturing and very extensive plant height.

IITA lots is a medium variety and was prone to head bug attack. It is a relatively tall plant and therefore prone to lodging. Grain yield was relatively high. Framida is early maturing, high yielding but quite a tall variety. The three other local varieties, mainly NSV I, NSV II and Belko white also fairly yielding but late maturing, all are extensively tall at maturing and therefore very prone to lodging. They can therefore thrive only at specific areas and indeed areas, which are less windy.

2. ANALYTICAL EVALUATION OF SORGHUM FOR THE MALTING AND BREWING PROCESS

2.1 INTRODUCTION

To ascertain the technical viability of the sorghum grain as a raw material for the malting and brewing process specific analytical investigation have to be carried out initially on the grain itself, and on the malted sorghum. Further investigations on the following processes to the end-product, the finished beer, will depend on the results of the initial analytical work on the grain and its malt.

2.2 THE SORGHUM GRAIN

2.2.1 MOISTURE CONTENT

The determination of the moisture content is one of the most important operations for the assessment of the grain, since it is purchased on the basis of weight, it is only the dry matter which delivers the extract, which is worthy and therefore useful and interesting to the maltster. A lower moisture content is therefore preferable, since it presupposes less water in the grain and therefore more useful dry matter. Further, a grain with higher moisture content means extra investment due to supplementary artificial drying involved. Otherwise the grain deteriorates very quickly, becomes musty and mouldy and loses its viability and germinating power resulting in its inability to be malted. The estimation of the moisture content is also of economic importance and indispensable since it allows the calculation of analytical data, for example, the thousand corn weight, the nitrogen and extract content etc. to be done on a dry basis, which, in turn permits comparable results to be obtained with other samples.

2.2.1.2 APPARATUS REQUIRED

1. Universal Grinding Mill
2. Aluminum Weighing Dish with Lid
3. Analytical Balance
4. Drying Oven

5. Dessicator

2.2.1.3 METHOD AND CALCULATION

About 20g of the sample under investigation is ground using Universal Grinding Mill. The milling must be carried out rather slowly and fairly coarsely to avoid water loss through frictional heat.

The weighing dish with lid is first weighed empty. About 5g of the grounded grain is then placed in it and covered immediately, and quickly weighed accurately on an analytical balance. The weighing dish without lid is finally brought into a drying oven and then dried for exactly three hours at temperature of 105-107°C. After drying, the weighing dish is immediately covered with the lid and transferred into a dessicator. After cooling, the weighing dish with the lid is weighed again.

The percentage loss of weight is calculated (see below) and reported as moisture content of the grain.

The determinations are carried out in duplicates to enable results to be compared and a means struck.

Wt. of weighing dish with lid and grounded grain = a gm.

Wt. of empty weighing dish with lid = b gm.

Wt. of grounded grain = (a-b) gm.

Wt of weighing dish with lid and grounded grain after drying =c gm.

Water loss (d) = (a-c) gm.

$$\% \text{ Water loss (moisture content of the grain)} = \frac{(a-c)}{(a-b)} \times 100$$

2.2.2 THOUSAND- CORN WEIGHT

The thousand corn weight is, like the moisture content, an important factor by the assessment of the grain during purchase, since it also delivers the average dry weight of thousand corns minus the moisture content. Grain size is here the determination factor.

2.2.2.1 APARRATUS REQUIRED

- Sample Divider
- Analytical Balance

2.2.2.2 METHODS AND CALCULATION

Duplicate samples, each at least of 40gm weight, are taken using a sample divider. Due to the possibility that weight change can take place through moisture intake or discharge, it is strictly stipulated that the samples must be weighed first and counted afterwards. The counting can be made by hand or by any other convenient method. Half-corns and foreign matter are removed from the batch and their weight subtracted before calculating the thousand-corn weight. the actual analytical balance and correspondingly converted into a thousand-corn dry weight, taking into consideration the moisture content of the sample determined earlier.

Wt. of sample minus wt. of half- corns and foreign matter $=(40-r)$ gm.

Moisture content of sample $= d$ gm.

Dry weight of sample $= 40-(e+d)$ gm.

No. of Corns in the sample $= f$

Dry wt. of f no. of corns $= 40-(e+d)$ gm.

Dry wt. of 1000 corns $= \frac{1000 \text{ gm.}}{40-(e+d)}$

2.2.2 GERMINATIVE CAPACITY

Germination tests are fundamental to the whole success of the brewing process. Germinative capacity is given the percentage of all grain in a given quantum. For the maltster, the germinative capacity of the grain is of a particular importance. In the malt house the aim is to bring the grains to germinate. It is therefore very necessary that a high percentage of the grains have the capacity to germinate and that the germination is also even and regular. The germinating capacity is therefore an indicator of the extent of viability of the grain for malting (germination) and therefore an important factor by grain purchase.

2.2.3.1 METHOD

The best and simplest method for the determination of the germinative capacity is the color reaction. Living cells reduce certain dyes, which turn solutions of these applied to them to red coloring hydrogenation products. Common dyes used for this purpose are 1% solution of 2, 3, 5-triphenyl tetrazolium chloride in water or 0.3% solution iodo-nitrotetrazolium chloride (exactly: 2-(p-iodophenyl) -3(p-nitro phenyl)-5-phenyl tetrazolium chloride: iodo-tetrazolium for short). The iodo-tetrazolium is reported to be less photo-sensitive and reacts more quickly with the living grain tissue than the ordinary 2, 3, 5-triphenyl tetrazolium. The method is carried out as follows: 200 grains are in duplicate determination, cut in half longitudinally with a shaving blade or any other suitable appliance. the half grains are placed in test tube and covered with about 10ml of 0.3% solution of iodo-tetrazolium and the air removed by evacuating and tapping for 3-4 minutes, when the solution is forced into the half grains. After 10 minutes of reaction the grains are spread on a filter paper and the colored ones counted. The living grains are stained bright starlets whilst the dead ones remain colorless.

The germinative capacity is then calculated as a percentage of the number of colored grains to the total grain number (200) of the sample.

2.2.4 GERMINATIVE ENERGY

The germinative energy is the percentage of grains in a given quantum which after days 3 and after 5 days under normal ambient temperature and very high relative humidity, germinate. It is an important factor at the point to malting and a test of the regularity of germination.

2.2.4.1 METHOD: AUBRY'S GERMINATION BOX METHOD

Three corresponding filter sheets are placed on a 20cm x 20cm glass plate and 500 grains are spread on the surface. The grains are covered with another filter sheet and the whole is flooded with water under the tap and then the plate is slantly held over the drain for the excess water to drain off. The plate is then slid into the Aubry Germination box, which is a closed box with slots to avoid excessive evaporation. Over and below the test plate is an additional glass, each covered with three filter sheets, which are equally flooded with water before being slid into the germination box in the same way as the test plate. The germination box is then closed and placed in a room of fairly even temperature of about 20°C.

The test filter sheets are on the first day and on the fourth day after removal and counting of the germinated grains (that is, germnative energy after three days) re-moistened. The test filter sheets are generally to be examined daily to ensure that they are at the right degree of dampness, and if they show any signs of drying out, they should be cautiously re-moistened by spraying.

On the 6^{th} day the grains, which are still not germinated by then, are counted and subtracting this figure from the total number of test grains (500) the germinative energy after 5 days is easily calculated.

The estimation is done in duplicates to enable result to be compared and the reliability of the method to be tested.

The Aubry-method gives from experience slightly higher figure from Schonfield's Funnel method.

It has also the advantage that it is less time consuming, involves less physical work and better use of time, because the experiment can continue to run also on work –free days.

2.2.5 THE PROTEIN CONTENT BY KJELDAHL METHOD

A very important criterion for the assessment of the grain is the protein content. Protein is an important structural component of the corn. A grain with too high level of protein delivers malt with unsatisfactory characteristics. It leads to a lower extract figure and affects adversely the stability of the beer. On the other hand a grain with too low level of protein is undesirable, for protein is an important source of nourishment for the yeast during fermentation. It is also responsible for the palate fullness of the beer and important for the formation of foam and body of same.

The total protein of the grain cannot be determined directly. The total nitrogen content is first determined by means of the Kjeldahl method, and this value is then multiplied by the factor 6.25 to give the protein content. This factor is based on the assumption that 16% of the grain protein forms the nitrogen content.

Figures for the total nitrogen or protein when they are given are always understood to have been based on the dry weight of the sample. It is therefore necessary to determine first the moisture content as has already been pointed out earlier with regard to the importance of this determination in analytical work of the brewer.

2.2.5.1 METHOD

The principle of the kjeldahl method of determining total nitrogen is as follows:

1-2g of sample fine grist is heated with 20ml of concentrated sulphuric acid containing 6g Wieniger's selenium- copper mixture as catalyst to accelerate the reaction. In the coarse of the combustion nitrogen from the organic substance of the grain is converted into ammonia, which is, in turn, absorbed by the sulphuric acid to form ammonium sulphate. At the end of this digestion, when the combustion is complete, and the whole organic substance of the sample is destroyed, a clear light green liquid is obtained and the total protein nitrogen is converted over ammonia into ammonium sulphate.

After cooling, about 150ml distilled water and 5g of zinc chips (to prevent retardation of boiling or ebullition) are added to the light green liquid obtained after digestion and contained in a Kjeldahl flask. Then 70ml of 33% caustic soda is added so carefully that it collects as layer on the floor of the flask. The flask is then joined to the Kjeldahl distillation system, carefully shaken to mix together its content and then brought to boiling by heating.

During the distillation ammonia is expelled from the ammonium sulphate, condenses and is received in an Erlenmeyer flask containing a solution of boric acid, in which it is bound as ammonium borate. Through direct titration with n/14 sulphuric acid and mixed indicator, whereby the ammonia borate decomposes again into ammonium sulphate and boric acid, the nitrogen and then the protein content of the sample can be easily calculated. The determination is made in duplicate and a blind probe is also carried out.

Equation of the reaction follows the following sequence:

1. $2NH_3 + H_2SO_4$.....$(NH_4)\ SO_4$
2. $(NH_4)_2SO_4 + 2NaOH$.....$Na_2SO_4 + 2H_2O + 2NH_3$
3. $3NH_3 + H_3BO_3$.....$(NH_4)_3\ BO_3$
4. $(NH_4)_3\ BO_3 + 3H_2\ SO_4$.....$3(NH_4)_2SO_4 + 2H_3\ BO_3$

It needs to be pointed out that using boric acid to receive the expelled ammonia during distillation differs in a way from the other method, where the ammonia is received in sulphuric acid to form again ammonium sulphuric acid. In this case exactly 50ml n/20 sulphuric acid is used. The excess sulphuric acid is then back titrated with n/30 caustic soda solution using few drops of mixed indicator in the operation. This is to enable the exact amount of n/20 sulphuric acid required to convert the ammonia to ammonium sulphate to be determined (by different calculations) and therefore the nitrogen content of the sample.

The advantage of the boric acid method is that the boric acid can be presented in excess and does not need to be exactly measured as in the case of the sulphuric acid (50ml exactly). The constant control of the titrating caustic soda solution (carbonate factor in the case of the sulphuric acid method does not occur here. Moreover, the titration of the ammonia occurs direct and not through difference calculation as in the case of the sulphuric acid method.

2.3 THE SORGHUM MALT

Moisture Content

The determination of the moisture content of the malt is carried out exactly the same way as for the grain except that here fine ground grist is used.

Total Nitrogen

The determination of the total nitrogen follows also the same technique as that for the grain and carried out in each case with fine ground sample.

Determination of Extract

All the components of the malt corn, which are useful to the brewer, are contained in the extract. After the special mashing process designed for sorghum malt and described in the technical report on "project", the exact level is determined using the specific gravity of wort, which is, in turn is determined using standard specific gravity bottles, the pycnometers. During the mashing the saccharification time is also estimated. The saccharification time is the time in which the starch of the sample under certain specified

conditions is converted into sugar (the iodine test) by the saccharifying enzyme, the amylases present. The saccharification time should not be too high or too low, is each way a reflection of failure somewhere.

Soluble Nitrogen

After the determination of the total nitrogen of malt, the soluble nitrogen is also determined on a cold water extract. This is then filtered and 10ml of filtrate is used to determine soluble nitrogen in the usual way.

Kolbalch Number (Index)

Kolbalch Number is the percentage soluble nitrogen from the total malt nitrogen based on dry weight. The Kolbalch Number gives an indication of the degree of dissolution of the protein in the sample.

Permanent Soluble Nitrogen

Permanent soluble nitrogen is the percentage of the nitrogen which, after calculation of the protein by boiling, still remains in solution.

Coagulation Nitrogen

Coagulable Nitrogen is calculated out of the difference between the soluble and the permanent soluble nitrogen.

RESULTS OF ANALYTICAL EVALUATION OF SORGHUM GRAIN AND MALT

SORGHUM GRAIN

Variety:	Dorado
Moisture Content (%):	10.3
Thousand Corn Weight (g):	21.5
Germinative Capacity (%):	86.0
Germinative Energy after 3 days (%)	81.0
Germinative energy after 5 days (%):	81.0
Total N Content (%):	1.77
Total Protein Content (%):	11.06
Contamination (good/bad/average):	Average

SORGHUM MALT

Variety:	Dorado
Moisture Content:	5.85
Total N Content (%):	1.73
Total Protein Content (%):	10.80
Mash-in-pH:	5.54
Saccharification time (min):	10-15
Filtration speed (min);	90
Wort Appearance:	clear
Wort Colour:	dark yellow
Wort Viscosity (cp):	1.54
Extract yield (%):	84.6
Soluble Nitrogen (Index):	0.520
Kolbach Number (Index):	30.05
Free Amino Nitrogen (ppm):	

RESULTS OF ANALYTICAL EVALUATION OF SORGHUM GRAIN AND MALT

SORGHUM GRAIN

Variety:	Sureno
Moisture Content (%):	10.5
Thousand Corn Weight (g):	20.1
Germinative Capacity (%):	85.0
Germinative Energy after 3 days (%):	81.0
Germinative Energy after 5 days (%):	81.0
Total N Content (%):	1.75
Total Protein Content (%):	10.9
Contamination (good/bad/average):	Average

SORGHUM MALT

Variety:	Sureno
Moisture Content:	5.26
Total N Content (%):	1.70
Total protein Content (%):	10.6
Mash-in-pH:	5.43
Saccharification time (min):	10.0
Filtration speed (min);	60.0
Wort Appearance:	clear
Wort Colour:	dark yellow
Wort Viscosity (cp):	1.44
Extract yield (%):	85.6
Soluble Nitrogen (Index):	0.530
Kolbach Number (Index):	31.2
Free Amino Nitrogen (ppm):	

RESULTS OF ANALYTICAL EVALUATION OF SORGHUM GRAIN AND MALT

SORGHUM GRAIN

Variety:	IITA LOT
Moisture Content (%):	10.4
Thousand Corn Weight (g):	22.5
Germinative Capacity (%):	71.0
Germinative Energy after 3 days (%)	64.0
Germinative Energy after 5 days (%):	64.0
Total N Content (%):	1.78
Total Protein Content (%):	11.12
Contamination (good/bad/average):	Average

SORGHUM MALT

Variety:	IITA LOT
Moisture Content:	5.8
Total N Content (%):	1.74
Total protein Content (%):	10.88
Mash-in-pH:	5.44
Saccharification time (min):	15
Filtration speed (min);	92
Wort Appearance:	clear
Wort Colour:	yellow
Wort Viscosity (cp):	1.53
Extract yield (%):	84.4
Soluble Nitrogen (Index):	0.50
Kolbach Number (Index):	30.40
Free Amino Nitrogen (ppm):	

RESULTS OF ANALYTICAL EVALUATION OF SORGHUM GRAIN AND MALT

SORGHUM GRAIN

Variety:	NSV I
Moisture Content (%):	10.7
Thousand Corn Weight (g):	20.4
Germinative Capacity (%):	52.0
Germinative Energy after 3 days (%)	48.0
Germinative Energy after 5 days (%):	48.0
Total N Content (%):	1.78
Total Protein Content (%):	11.12
Contamination (good/bad/average):	Average

SORGHUM MALT

Variety:	NSVI
Moisture Content:	5.7
Total N Content (%):	1.77
Total protein Content (%):	11.06
Mash-in-pH:	5.0
Saccharification time (min):	10
Filtration speed (min);	80
Wort Appearance:	clear
Wort Colour:	dark yellow
Wort Viscosity (cp):	1.38
Extract yield (%):	77.8
Soluble Nitrogen (Index):	0.55
Kolbach Number (Index):	31.00
Free Amino Nitrogen (ppm):	

RESULTS OF ANALYTICAL EVALUATION OF SORGHUM GRAIN AND MALT

SORGHUM GRAIN

Variety:	NSV II
Moisture Content (%):	10.4
Thousand Corn Weight (g):	20.8
Germinative Capacity (%):	66.0
Germinative Energy after 3 days (%)	53.0
Germinative Energy after 5 days (%)	53.0
Total N Content (%):	1.82
Total Protein Content (%):	11.38
Contamination (good/bad/average):	Average

SORGHUM MALT

Variety:	NSV II
Moisture Content:	5.88
Total N Content (%):	1.80
Total protein Content (%):	11.25
Mash-in-pH:	5.55
Saccharification time (min):	11.0
Filtration speed (min);	88.0
Wort Appearance:	clear
Wort Colour:	dark yellow
Wort Viscosity (cp):	1.40
Extract yield (%):	80.0
Soluble Nitrogen (Index):	0.51
Kolbach Number (Index):	30.55
Free Amino Nitrogen (ppm):	

RESULTS OF ANALYTICAL EVALUATION OF SORGHUM GRAIN AND MALT

SORGHUM GRAIN

Variety:	Belko White
Moisture Content (%):	10.8
Thousand Corn Weight (g):	20.2
Germinative Capacity (%):	72.0
Germinative Energy after 3 days (%)	68.0
Total N Content (%):	1.70
Total Protein Content (%):	10.63
Contamination (good/bad/average):	Average

SORGHUM MALT

Variety:	Belko White
Moisture Content:	5.60
Total N Content (%):	1.78
Total protein Content (%):	11.13
Mash-in-pH:	5.60
Saccharification time (min):	13
Filtration speed (min);	90
Wort Appearance:	clear
Wort Colour:	dark yellow
Wort Viscosity (cp):	1.50
Extract yield (%):	89.0
Soluble Nitrogen (Index):	0.52
Kolbach Number (Index):	32.00
Free Amino Nitrogen (ppm):	

DISCUSSION OF RESULTS OF THE ANAL YTICAL EVALUATION

A good germination capacity (> 90%) of the grain is the first pre-requisite for the need to process the grain further and the need to attempt malting at all. On this score one notes marked deficiency with all the local varieties, namely NSV I, NSV II, Belko White, and the Nigeria variety, IITA LOT. Framida is a red sorghum variety and the concentration in this work is, in the first instance, on the white varieties. Framida is therefore not to be analyzed yet. Dorado and Sureno, the two American varieties, showed much better viability and they were also visually fairly healthy and buoyant. They were therefore further processed and malted.

Poor germination test results are normally associated with grains which have lost their viability due to contamination and poor sanitary conditions at harvesting and during storage in particular. Harvesting must therefore be carefully controlled and post-harvest storage conditions must be greatly improved to substantially reduce or completely eliminate occurrence of grain with very deficient viability. The two malted samples, Dorado and Soreno, saccharified fairly well, the extract yield was good (>81.5%), protein figure was normal (>10%) and filtration rate was much better with Dorado. They can therefore be accepted as part of the starting material for the brewing trails which are yet to be initiated, when enough suitable varieties have been identified, selected and characterized.

3.0 FINAL CONCLUDING COMMENTS

From the results of both the agronomic and the analytical evaluation of the test sample, Dorado and Sureno have emerged as varieties with good potentials for the malting and brewing process. They will therefore by incorporated together with other new samples in the program of the next cropping season, which begins in June-July. This will enable further agronomic assessment of these grains and other test varieties at on-field trials at different locations in the Northern Ghana under natural rain fed conditions. Parallel to these trails analytical evaluation of the same varieties will also be carried out to ascertain the technical viability of these varieties for malting and brewing.

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