MALTING AND BREWING POTENTIAL

OF A LOCAL VARIETY

OF SORGHUM

(SORGHUM BICOLOR L MOENCH)

BY

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CERTIFICATION

This project thesis entitled Malting and Brewing Potential of a Local variety of Sorghum (Sorghum bicolor L. Moench) by HARUNA ADE meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION.

This work is dedicated to all lovers of

alcoholic beverages, including myself.

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DECLARATION

I declare that this work is wholly the author's and has not been part of any presentation for any other qualification.

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ABSTRAC

The malting and brewing potential of a Local sorghum variety (LFSV) has been studied.

The sorghum grain had germinative energy of 96%, germinative capacity of 98%, Hot water extract (H.W.E) of 41.27 Lit. deg. Kg^{-1} diastatic power (D.P.) of 9.5 °L and cyanide was 19.7 ppm. The percentage broken kernels and foreign matter were 0.14% respectively. Similarly, the 1000 kernel weight was 27.3g, while no evidence of mould was detected. Proximate analysis of ungerminated grains gave 9.0% moisture, 70.0% starch and fat content of 2.52%.

Sorghum grains steeped for 9hr in distilled water and malted for 5 days produced malt with the highest level of cold water extract (~~cold water extract~~) of 14.13%, D.P. of 15.0 °L and malting loss of 27.78%, while grains steeped for 21hr. gave highest level of Hot water extract (H.W.E.) of 111.03 Lit. deg. Kg^{-1} and wort filtration rate of 11.05 ml per 20 mins. Sorghum grains steeped in 0.2% calcium hydroxide for 18hrs and malted for 5 days gave the highest ($p<0.05$) H.W.E. of 177.10 Lit. deg. Kg^{-1}, D.P. of 16.60 °L and malting loss of 30.09%. Formaldehyde treated grains produced malt with the highest wort filtration rate (W.F.R.) of 8.20 ml/20 mins. While ammonia treated grains gave lowest values (P.0.05) of C.W.E., malting loss and W.F.R. as compared to those steeped in ammonia, formaldehyde and water (i.e control).

Grains germinated for 6 days (after 18 hours steeping in 0.2%, $ca(OH)_2$) gave the highest C.W.E. of 8.30%, H.W.E. of 177.74 Lit. deg. Kg^{-1} D.P. [illegible] loss of 22'82%; as compared to those germinated for 2,4, 8 days and ungerminated [illegible] control). Grains germinated for 8 days produced malt with the highest W.F.R of 15.4 ml/20 mins. These findings were further confirmed by profiles of (proteolytic and amylolytic) enzymes activities during germination.

Sensory evaluation of the sorghum lager beer produced from sorghum malt with the best characteristics gave acceptable (chi-square) values for colour (2.25), odour (0.86), bitterness (2.82), bodyfulness (0.60), brilliance (1.28) and sourness (0.85), but unacceptable values for foam. (3.98) and sparkling (3.36) as compared to star lager beer (control) which gave acceptable values for all the attributes (at 0.05 level of significance).

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Chapter 1

1. INTRODUCTION

In conventional brewing practice, barley malt occupy a unique position as the primary raw material by virtue of its superior brewing characteristics (Hulse, et al, 1980 Chukwura, 1988). However, following precipitated decline in the Nigerian economy which became acute in 1982, the Federal Government banned barley malt importation in 1988. The brewing industry as a result suffered a substantial decrease in production, which was further aggravated by the fact that the principal raw material barley does not thrive well under tropical climates like ours. This new trend provided much of the initial impetus, for research into identification of local cereal substitute for barley in brewing (Chukwura, 1988; Ikediobi; 1989). Statistical information (Nwasike and has Aba, 1986) has however shown that cereal grains such as sorghum, millet and maize abound in the country, of these sorghum (Sorghum bicolor, L Moench) or Guinea corn is the major cereal cultivated in Nigeria (Olugbemi, 1989). It contributes, well over 50% of the total cereal under production with an estimated annual yield of about 4.8 million metric tonnes (Nwasike and Aba, 1986, 1989; Akingbala, 1989).

Reports on the malting and brewing behaviour of sorghum for larger beer production in Western countries have been scanty (Michael, 1989). Canals and Sierra (1966) have shown that sorghum endosperm grits can be employed as unmelted adjuncts without adverse effect on the characteristics of lager beer produced.

Most recently, attention has been focused on the use of sorghum for lager beer production, Novellic (1982) Okafor and Aniche (1980) and Skinner (1976) have produced acceptable lager beer from malted sorghum Aisien and Muts (1987) also reported the problems associated with brewing using malted sorghum.

Some of the numerous problems associated with the use of sorghum as a reliable cereal for beer production are the low levels of malting enzymes that effect the grain modification. (Novellie, 1960 ab, 1962 abc; Dyer, and Novellie 1966; Botes, et al., 1967 ab; Daiber and Novellie, 1968).

Sorghum grain has closely packed starchy granules (Rooney, 1973). This phenomenon is believed to contribute significantly to the inherently low modification of sorghum malt as compared to barley malt.

Uneven germination is a common occurrence in sorghum malting. It has however been attributed to non-uniformity of grain size and lack of uniform humidity and temperature in the germinating bed itself (Ikediobi; 1989).

A unique property of sorghum as a cereal, is its unusually high contents of tannins and polyphenols. This creates a serious brewing problem of chill haze and imparts astringent taste detrimental to beer quality (Alsien and Muts, 1987; Ikediobi, 1989; Arri, 1989).

The sorghum grain is found to contain a toxic cyanogemic glycoside dhurrin at levels considered innocuous (Ikediobi, et al 1988), However, a tremendous increase in dhurrin synthesis during sprouting to acute levels in the roots and shoots occur (Ikediobi, et al 1988). Long time ingestion of incompletely detoxified sorghum products has been linked with chronic cyanide toxicity in rats (Ikediobi, et al., 1988).

Sorghum Varieties have been associated with high gelatinization temperatures upto 75°c (Palmer, 1969). This in part is largely responsible for inactivation of grain modifying enzymes during mashing long before gelatinization of starch' is attained (Aisleh and Muts, 1987; Arri, 1989). So far no report is made on Sorghum varieties with low gelatinization temperature (Rooney, 1973).

Briggs, et al. (1981) reported that the following parameters could be used to assess the quality of barley malt. These include; malting loss, cold water extract, hot water extract, dias tactic power, wort filtration rate and detrinizing unit. These determinations give estimates of the brewing quality of the malt in the sense of nutrient yielded by the malt.

Novellie (1962c), reported the effect of steeping duration, germinating temperature, variety of grain on malt quality (assessed using diastatic power and malting loss).

In Nigeria, it has been reported that majority of sorghum grain used for industrial malting and brewing is being purchased locally (Ikediobi, 1989).

Presently, little literature information on the effect of length of steeping, duration of germination and additives on malt quality of local sorghum varieties is available.

1.1 Research Objectives

The aim of this project therefore is to determine the effect of additives, duration of steeping, duration of germination on malt quality of a local sorghum variety (LFSV). Malt with the best quality will be used to carry out trial brewing as well as organoleptic assessment of the beer so produced.

Chapter II

2.1 Literature review.

The genus (Sorghum bicolor L. Moench) or guinea corn belongs to the family gramineae and of the tribe and ropogoneae. It is a grass plant whose botanical characteristics show tremendous variation within species, so indicating a large degree of interspecific and intraspecific hybridization.

2.2 Historical perspective

There appears to be no reliable historical records of the origin or pattern of dispersion of the sorghum plant. However, the first records of cultivated sorghum appeared in a 2700 year old carving found in a Assyrian Palace (Anderson and Martins, 1949). The ancestors of what we now know as sorghum may have been carried across North Africa to West Africa about 3000 B.C. (Hulse, et al., 1980). The sorghum race guinea was diversified in West Africa and in Ethiopia race dura appeared to have been carried to the near East and India. The race Kaffir is associated with the Bantu tribe people from Tanzania South wards.

Historical records (Hulse, et al; 1980) suggest that sorghum reached India from East Africa soon after 2000 B.C. It may have been carried from around the Persian Gulf and into the near East. The spread along the coast of South East Asia and around China may have taken place about the christian era. Grain sorghum appeared to have arrived America as guinea corn from West Africa with the slave trade (Hulse, et al., 1980).

2.3 Distribution and production

Sorghum is the fourth cereal crop in the world (Hulse, et al.; 1980; Dogget, 1970). Its production encircles the entire earth starting from China through India and extending to most parts of Africa, and stretches close to 15th parallel, north of the Southern United States and Latin American. In Europe, sorghum extends about the 44th parallel north (Hulse, et al., 1980). In developing countries, the averaged yield of sorghum is less than that of the developed world. The distribution of sorghum

depends on varietal choices attributed to local preferences and environment.

2.4 Plant characteristics

Sorghum is a plant of wide genetic diversity. It consists of head or panicle which ranges from 75 to 500 mm in length and 40 to 200mm in width. Each panicle consists of between 800 and 3000 kernels enclosed in floral tracts (Dogget, 1970). The kernel, lemma and palea are located inside the glumes which may be coloured. The seeds are usually red, white, yellow or brown (Rooney, 1973).

2.5 Varieties of sorghum in Nigeria

In Nigeria, sorghum has different varieties also and on the basis of the difference in time of maturity, area of distribution and description of plant are classified into seven races Martins and Leonards (1949). The races in Nigeria include:-

Guinea corn: It has tall stem and usually is found in the northern part of the country in states like Niger, Kano, Kaduna, Plateau and Sokoto States. It takes about 115 - 150 days to grow and mature.

Kaura races: Has large round yellowish grain with dry tall stems. Found in the same area with guinea race and takes about 100 - 115 days to grow and mature.

Fara race: These are the white varieties. They are found in Kano, Bauchi and Kaduna states and takes about 115 - 130 days for growth and maturity.

Chad race: Here the grains exceeds glumes in length but bent towards the glume at maturity. They have dry tall stems and are found around the Borno province and south west of lake chad. Takes about 80 - 110 days from growth to maturity.

Sokoto Race: Early maturity occurs here with the result that they have small round grains. They are usually found in Sokoto and Gongola States.

Umbellate Race: They have umbellate panicles and brick red elongated grains. They are found in Kaduna State.

Tunicate Race: They have long, paperly glumes which enclose grains at maturity. They bear resemblance to the guinea race and are found in Kaduna, Niger, Kwara and Plateau.

2.6 Malting

Malting is the process whereby cereal grains are germinated under controlled conditions (of moisture, aeration and temperature) in order to produce large compliment of enzymes capable of grain modification. (Briggs, et al., 1981). Malt is therefore a cereal grain which has been germinated and then dried under a defined set of conditions (Briggs, et al., 1981; Hulse, et al., 1980).

2.6.1 Unit operations in malting

The operations carried out in malting are: grain assessment, grain cleaning, steeping, germination, Kilning (drying), sprout removal and packaging (Palmer and Pathgate, 1976; Briggs, et al., 1981, Ikediobi, 1989).

2.6.2 Grain assessment

Quite a number of parameters are being assessed on raw grain at inception prior to malting. These include the determination of broken Kernels and foreign matter, one thousand kernel weight, germination energy, germination capacity, flotation and evidence of insect and mould infestation. Other determinations include biochemical tests such as; Starch determination, protein, lipids, tannins, polyphenols, moisture, cyanide etc. Extracts (cold and Hot water extracts), diastatic power and the level of malting enzymes (α and β amylase, proteolytic enzymes and β-glucanase) are often assessed (Briggs, et al., 1981; Aisien, 1989; Hulse, et al., 1980). Presence of broken kernels and foreign seeds in grains is often associated with poor post - harvest handling, remove insect and rodent attack on grains (Ikediobi, 1981) High percentage of broken kernels and foreign seeds is undesirable in a particular variety of grain for malting, since broken kernels fail to germinate while foreign seeds will not produce the same kind of malt (Briggs, et al; 1981). The one thousand corn weight is a measure of grain size. Arnon (1972) reported 1000 Kernel weight of between (20-40g) for different varieties of sorghum. Palmer, (1969) reported that the germination potential, 1000 Kernel weight and nitrogen content of the grain have significant effect on the level of brewer's extract obtained from the malted grain under normal malting conditions. Poor germination, high nitrogen content and low 1000 Kernel weight will give low extract potential. (Palmer, 1969; Okon, and Uwaifor, 1985).

The germination energy measures, the proportion of the seeds that will germinate under the test condition, whereas the germination capacity is a measure of viable seeds in the sample (Briggs, et al., 1981). The difference between the two tests is a measure of the dormancy of the grain sample. Palmer and Pathgate (1976) and Ikediobi (1989) reported germinative capacity of at least 96% for barley and 95% for sorghum respectively.

2.6.3 Structure, composition and biochemical changes in sorghum during malting

The sorghum Kernels are roughly spherical in shape and have a thousand corn weight (Kernel weight) of 26-30g (Rooney, 1973). Botanically the sorghum seed is a caryopsis which is a dry fruit with a single seed enclosed in a dry outer covering which is fused to the seed coat. The major portions of the Kernel are the outer covering (pericarp), the storage tissue (endosperm) and the germ or embryo (Hulse, et al., 1980; Rooney, 1973; Dogget, 1970). The endosperm, germ and pericarp is comprised of approximately 80.0 - 84.6%, 7.8 - 12.1% and 7.3 - 9.3% of the whole kernel dry weight respectively. The pericarp is composed of four different portions, the epicarp, the mesocarp, the cross cells and tube cells, with the last two being referred to as the epicarp. The endocarp contains wax and sometimes phenolic substances (Rooney, 1973). Unlike sorghum, barley has a large husk (outer covering) which is rich in lignified poly saccharide cellwall and silica. These properties gives barley its abrasive nature desirable in malting and lauter tun (self forming filter bed) filtration, an advantage over sorghum grain. Partial removal (by abrasion) of the pericaps has been reported to promote germination (Aisien and Muts, 1987).

The seed coat is found just immediately beneath the pericarp and above the aleurone layer. It is in this region that most of the polyphenolic compounds exists and impart varying shades of pigments to the grain (Rooney, 1973). The so called bird resistant sorghum have intense brown seed coat (or testa). The importance of phenolic components to grains is still obscure (Palmer, 1959). However, they have been associated with the regulation of micro-organisms. They also serve as endogenous growth regulators (Mayer and Poljakoff, 1963). Briggs, et al. (1981) and Hough, et al., (1971) reported that polyphenolic compounds add "astringency" to beer flavour. The most important

characteristic of malt phenolic materials are tannins (the most predominant being anthocyanogen polymers) and their precursors. (Rooney, 1973). Tannins are able to precipitate unsoluble nitrogen resulting in protein-tannin complex during either wort boiling (being referred to as "Hot break" or "trub") or in subsequent cooling of wort resulting in non-biological haze in beer. (Aisien and Muts, 1987; Arri, 1989). Rooney (1973) reported tannin content of sorghum grain in the range of 0.003 - 0.17% dry weight. Briggs, et al (1981) reported increase, in polyphenols levels during germination. Alkaline steeping with $Ca(OH)_2$,NaoH, etc have been employed to reduce polyphenolic compounds in grains as do husk removal. (Dyer and Novellie, 1966, Hahn, et al., 1984.).

The endosperm of sorghum grain is composed of the aleurone layer and the peripheral, corneous and the floury areas (Rodney, 1973). The aleurone layer is beneath, the seed coat and is believed to be three cells deep. These cells forms a continuous layer around the Kernel and are high in protein, fat, minerals and enzymatic activity (Palmer and Pathgate, 1976). The peripheral endosperm is beneath the aleurone layer and is made up of small block like cells filled with protein and interspersed with small starch granules (Dogget, 1970). The corneous endosperm consists of (hard, horny) layers of cells that are translucent to light. The floury (soft) endosperm is inside the corneous endosperm. Inside the cells, the endosperm structure resembles a honey comb in which starch granules are encased in a matrix of protein. (Rooney, 1973). The floury endosperm is more easily broken into small particles during processing than the corneous endosperm. The starchy endosperm provides bulk of the brewer's extract. (could and hot water extracts), (Hough, et al., 1971). During malting it is the accumulation of hydrolytic enzymes in the starchy endosperm and the partial breakdown of its structural components that constitutes "modification". (Hough, et al., 1971; Brigg, et al., 1981). The endosperm cellwall contains glucose, mannose, galactose, arabino - xylan and ß-glucans, (Rooney, 1973)., Starch make up 60.4 - 76.6% dry weight of sorghum grain in contrast to 63-65% in barley' (Hulse, et al., 1980) During malting only about 5-10% of starch is utilized (Holdt and Brand, 1960). Starch is the major component of the sorghum grain and so the major part of the brewer's extract. Starch is degraded during malting (to a limited extent) into soluble substances (constituting in part to the cold water extract) and it is converted by hydrolysis during the mashing process to fermentable sugars.

Large and small starch grains occur in sorghum grain and the latter is found to be more resistant to amylases. (Rooney, 1973). Most Sorghum Starches are made up of two fractions of amylose (20-30%) and amylopectin (70-80%) of high molecular weights, (Hulse, et al., 1980). 'Pure' amylose consists of unbranched chains of poly (1-4) α - glucopyranose, containing some "impurities" like a number of α - (1-6) links and some lipids. (Palmer, 1969). It gives an intense blue - black colour with iodine. Amylopectin differs from amylose in that these molecules have ramified structures of α - (1-4) linked and α - (1-6) linked glucose units and so are branched. Amylopectin gives a characteristic red tint with iodine. The mixture of enzymes that degrade starch (α and ß - amylase and limit dextrinase) is termed diastase.

Watson and Novellie (1976) discussed the development of the amylases during germination and malting on both "normal" and "bird resistant" (high tannin) sorghum cultivars. They referred to earlier publications by Novellie (1959, 1960a and 1962a) and stated that combined α and ß amylase activity increased rapidly and at roughly the same rate during the first 2-4 days of malting, with ß - amylase constituting 25-30% of total amylase activity. Unlike barley which possesses ß-amylase activity before germination, sorghum grain has been reported to be devoid of this enzyme (Novellie, 1962a). Beta amylase cannot attack starch granules on its own, but it attacks dextrins and soluble starch at the non reducing chain ends (Benfeld, 1955). Limke in barley, sorghum ß-amylase occur in soluble and insoluble forms (Dyer and Novellie, 1966). For their complete extraction, the use of peptone, salts or proteinase (papain) was suggested by Novellie (1966). For their complete extraction the use of peptone salts or proteinase (papain) was suggested by Novellie (1959). All the ß - amylase of sorghum and barley is located in the endosperm (Dyer and Novellie 1966). Alpha amylase attacks α - (1-4) linkages and degrade starch at random to a complex mixture of sugars including glucose, maltose and a wide range of dextrins (Benfeld, 1955. Ikediobi and Ukoha, 1987). This degradation is slow and is speeded up in presence of ß-amylase , so the kilning process must be done very carefully. (Hough, et al., 1971). Compared to barley sorghum is reported to have low levels of malting enzymes that effect grain modification (Novellie, 1959, 1960 abc; Dyer and Novellie, 1966; Botes, et al., 1969 ab; Daiber and Novellie, 1968). Rooney (1973) and Novellie (1960c, 1962a) reported low diastatic power (30 - 40 °L). In sorghum malt as compared to that of barley malt (100 - 250 °L) even under proper malting conditions. Cereal gums (ß-glucans) and hemicelluloses •

(pentosan) exists in sorghum particularly in the endosperm cell wall (Rooney, 1973). Beta glucans are linear polymers of ß - 1,4 - and ß-1,3 linked glucose units while pentosan are polymers of arabino - xylans concentrated in the aleurone layer (Palmer, 1969). Rooney (1973) and Aisien and Muts (1987) reported poor development of ß-glucanases and pentoganase enzymes responsible for the degradation of these gums in sorghum. Incomplete breakdown of ß-glucans in malted sorghum results in filtration problems during the process of wort separation and filtration of finished beer, due to the high viscosity they impart (Palmer, 1969; Briggs, et al.,1981). A short germination time gives a malt with high viscosity caused by the undegraded ß-glucans (Palmer and Pathgate, 1976). Ikediobi (1989) further reported that ß - glucans influence foam and palate fullness of beer, though the mechanism by which these are accomplished is still obscure. Gelatinous precipitate associated with chill haze in beer has been associated to the presence of ß - glucans (De clerk, 1957).

The proteins of sorghum averages 11.0% dry weight as compared to 13% in barley. (Rooney, 1973). By convention the "Crude protein" is the nitrogen content multiplicate with the factor 6.25 The proteins consists primarily of alcohol soluble kaffirins and of alkali soluble proteins (glutelins) with the latter serving as cementing materials between protein materials. The level of protein in the sorghum kernel is influenced by environmental as well as genetic factors (Rooney, 1973). Lysine and threonine are the first and second limiting amino acids of sorghum grain (Rooney, 1973; Hulse et al., 1980). Other protein fractions are the albuminous (water soluble) and globulins (soluble in dilute salt solufrons) which serve as the storage proteins and are broken down into free amino acids and resynthesized into various enzymes in the embryo and aleurone layer during germination (Mayer and Poljakoff, 1963; Hough, et al., 1981 Hough, et al., 1971). The quality of beer (flavour palatefulness and tendency to foam) is influenced by the nitrogen content of malt. (Palmer, 1969; De derk, 1957). During mashing nitrogen - substances are solubilized and constitutes the total soluble nitrogen (TSN). After wort boiling the nitrogen - compounds remaining is referred to as the permanent soluble nitrogen (PSN). (Hough, et al. 1971). The ratio of soluble nitrogen obtained from malt to the total nitrogen content of the malt is used to follow the progress of

malting (Palmer, 1969; Briggs, et al, 1981). The sorghum grain contains several proteases and endo-peptidase which have been found to increase during malting (Mayer and Poljakoff (1963); Briggs, et al, (1981). Germinating sorghum grains contains carboxyl peptidase which are able to attack Kaffirin thereby increasing the solubility of β - glucans with consequent liberation of bound α - amylase (Hough, et al ., 1971). The stimulating effect of gibberellic acid has been found to influence the solubilization of proteins during the malting process (Briggs, et al., 1981). Hough, et al, (1971) reported that proteases and carboxyl peptidase accumulate in the starchy endosperm during germination. During kilning free amino acids reacts with sugars forming coloured complexes (melanoidines) which give malt its characteristic colour and flavour (Palmer, 1969; Hough, et al., 1971; Briggs, et al.,

The total lipid content of sorghum and maize ranges between 2.66 - 3.77% dry weight as compared to that in barley (3.5%). Lipids found in sorghum are further characterized as free lipids consisting of hydrocarbons, Mono, di-and triglycerides, free fatty acids etc. On the other hand bound lipids fraction contains lecithin, lysolecithin and other components (Hulse, et al., 1981; Dogget, 1970). Most malt lipids are retained in the spent grains during lautering (Mash filtration). Small quantities that disperse into wort may collapse beer foam while some lipids may stabilize it (Hough, 1971; Joseph, 1977). Yeast requires sterols and unsaturated fatty acids for growth and maintenance of membrane during fermentation. (Joseph, 1977; De clerk, 1958). Hough, et al. (1971) reported that lipids sometimes have bad effect on the beer flavour.

The inorganic material of sorghum grains is termed as ash, which is obtained after combustion. Minerals are concentrated in the embryo and the aleurone layer free or bound to enzymes and cellwall materials (Rooney, 1973). During malting some minerals are leached out into the steeping liquor thereby adding to malting loss (Palmer, 1969). Malt contains all minerals needed to support yeast growth (Briggs, et al ., 1981). Phosphates and phosphate esters occur in the grains combined in a wide range of substances such as phospho lipids, nucleic acids and phytic acid. Phosphatases hydrolyse phytic acid releasing inorganic phosphate from the aleurone layer which accumulates in embryo (Palmer and pathgate, 1976).

Sorghum malt is rich in substances that are growth factors (Vitamins) for yeast. These are thiamin (B1); riboflavin '(B2), nicotine acid, pantothenic acid, pyridoxine (B6), Vitamin E, biotin, folate, choline and myo-inositol which occur in varying proportions (Briggs, et al. 1981). Usually these materials are concentrated in the living tissues, the embryo and aleurone layer (Rooney, 1973). Some of the vitamins partly move into the rootlets during malting and are lost in the malt or destroyed by kilning.

The sorghum grain ordinarily is found to contain a toxic cyanogenic glycoside dhurrin which when hydrolysed by the enzyme dhurrinase yields parahydroxy - benzalaldehyde, glucose and HCN (prussic acid). Ikediobi, et al (1988). Half a gram of HCN can Kill a cow while 0.0066% is fatal to man. (Martins and Leonard, 1949). Sheep are less susceptible than cows while horses and pigs are not injured by HCN acid. A tremendous increase (4,000-7,000 times) in dhurrin synthesis during sprouting (germination) to acute levels in the roots and shoots occur in sorghum seedlings (Ikediobi, et al., 1988). Drought and high nitrogen in soil (fertilizer usage) are reported to lead to high cyanide levels in the sorghum plant. Longtime ingestion of incompletely detoxified sorghum products has been linked with chronic cyanide toxicity in rats (Ikediobi, et al., 1988). Following the ingestion of food containing cyanide, it is absorbed completely in the gastro intestinal tract and is transported to the liver where it is converted to less toxic thiocyanate by the rhodanase enzyme (Ikediobi, et al., 1988).

2.6.4 Temperature and moisture effects on germinating sorghum

Sorghum germinates ideally at temperatures between 25-30°c in contrast to that of barley (18-20°c) for warm germinating and (12-13°c) for cold germinating varieties (Von Holdt and Brand, 1960). An increase in germinating temperature makes rootlets grow faster (higher malting loss) and hastens development of enzymes (Michael, 1989; Von Holdt and Brand, 1960). However, some enzymes such as α - amylase and protease rapidly fall off. (Briggs, et al., 1981; Okoli and Ogunsua, 1987). At lower temperature the production of enzymes proceed slowly but the malt containing more enzymes than at higher temperatures (Novellie, 1962b). The moisture content prior to germination must be exact for the germination and the biochemical reactions. The moisture content of steeped grain depends on the variety of grain. (Novellie, 1962b). For instance, barley with low nitrogen content must start with 42-43%

moisture while that with high nitrogen content requires 46-48% moisture content if good modification must be attained. (Briggs, et al., De clerk, 1957). In sorghum moisture content of 35-40% is found to be optimal prior to germination (Gholahan, 1989). The moisture content is lost during malting by respiration and hydrolysis and so the germinating grains must be re-wetted to avoid drying of the embryo.

2.6.5 Assessment of malt quality

The brewing quality of malt is estimated in terms of the nutrient yielded by the malt (Briggs, et al., 1981). Determinations such as diastatic power, malting loss, cold/hot water extracts, wort filtration rate, kolbach index and dextrinizing power are being used to assess maltquality (Briggs, et al., 1981). These determinations also serve as guide for commercial transaction. Diastatic power is the degree of amylolytic activity of the malt (Bishop, 1930). Novellie (1962a) reported that, the diastatic power is a better index of malt quality than extract yield and that malt with high diastatic power is best adopted for malting. The diastatic power of malt is influenced by several factors. These include temperature, moisture level of grain, germination time, variety and age of grain. Novellie (1962a) malted sorghum in the temperature range of 15-35°c and obtained low diastatic power between 15 to 20°c while the highest diastatic power of 39.5% °L was obtained at 25°c. He also demonstrated that low moisture levels resulted in a reduction in diastatic power with an increase in diastatic power of 20-25 units for higher moisture levels. A negligible reduction in diastatic power was shown to occur when germinating sorghum was dried between 40 - 60°cc whereas a marked loss resulted when drying temperature was raised to 70°c, (Novellie, 1962a).

Malting loss represents the combined losses during steeping (leaching of preformed matters into the steep liquor and minerals), respiratory loss (as carbon dioxide and water) and weight of shoot/roots. A high malting loss is undesirable and is attributed to excessive growth during germination. The relatively higher malting loss of sorghum (20-30%) compared to barley (9-12%) has been attributed to differences in the solubility patterns of their amylases (Malomo, 1989), as well as to the higher temperature employed in sorghum malting. Of the 9% malting loss in barley, steeping loss contributes

1.5%, respiratory loss 3.5% and root weight loss 4%

The cold water extract (C.W.E) represents the preformed sugars or (matters soluble) which leached out into solution from ground malt under conditions which excludes the intervention of enzymes (Hough, et al., 1971) while the hot water extract (HWE) is a measure of the quantity of dissolved materials in a wort prepared by infusion or decoction mashing on a laboratory scale (Briggs, et al., 1981). Extract yield remains a very important index of malt quality in India, since the extract yield is an important measure of brewhouse performance of the malt, (Novellie, 1962b). Several factors which affect extract yield are: the type of raw material, the milling operation (fine or coarse), mash tun behaviour and filtration (Briggs, et al., 1981). It has been reported that extract yield increases with fine grinding at the expense of wort filtration rate (Palmer and Pathgate, 1976).

Mash filtration rate decides the number of brews obtainable. Factors influencing the filtration rate includes mash viscosity, particle size, milling operation and type of raw material (Palmer, 1969). The filtration problems of cereal malts mash such as barley, sorghum, millet etc. depends on the grain variety, the β - glucan content and the husk, (Palmer and Pathgate, 1976). Replacement of the lauter tun with a mash filter improves the brew house performance of sorghum malt (Arri, 1989; Joseph, 1977).

The ratio of total soluble nitrogen (TSN) in wort after mash filtration to total nitrogen (TN) of malt is referred to as the Kolbach index of modification. This gives an indication of malt and nitrogen modification (Palmer and Pathgate, 1976, Briggs, et al., 1981; De clerk, 1958). Barley malts with values below 35 are poorly modified; those with values above 42 are regarded as over - modified, a well modified malt having values of 38-40 (Palmer, 1969; Hough, et al., 1971; Briggs, et al., 1981).

During steeping, various additives such as alkalis, formal-dehyde, hot water, hypochlorites, ammonia are reportedly used to reduce polyphenol levels, and/or improve germination and to control mould growth (Gbolahan, 1989; Brigg, et al., 1981; Mayer and Poljakoff, 1963).

2.6.6 Steeping

The initial stage of malting (proper) involves the soaking (steeping) of cleaned grains to an appropriate moisture level which will allow it to germinate, produce enzymes and an optimal level of brewers extract (Palmer, 1969). Water passage into the grain during steeping is effected via the Ventral crease (Mayer and Poljakoff, 1963). The amount of water imbibed into the grain depends on the mechanical restriction by the seed coat (imbibition pressure), temperature of the steeping liquor, the presence of additives, nature of the endosperm, duration of steeping and is found to be independent of grain viability (Mayer and Pojakoff, 1963; Brigg et al., 1981). A wide range of steeping schedules have been employed ranging from short steeps with or without aeration to intermittent steeps with air resting cycles (Palmer, 1969). Steeping plants vary in different malting. These extend from small old flat bottomed concretes steeps without aeration or emptying facilities to large conical steeps with aerating and gravity discharge systems and to very large flat bottomed steeps with automatic discharge facilities (Palmer, 1976: Schwartz, 1956). Like barley, the optimal water that enhance maximal germination is one of the important criteria for assessing the steeping efficiency (Novellie, 1962 b). However, prolonged steeping without sufficient air resting periods has been found to degenerate grains due to unset of anaerobiosis (Novellie, 1962 b; Briggs, et al., 1981). The main by-products of sorghum steeps are floats which are immature grains and are used as animal feeds (Ikediobi, 1989).

2.6.7 Germination

Germination is the second stage of malting. Conditions leading to the conversion of the endosperm of sorghum by hydrolytic enzymes into friable malt have been discussed. However, in traditional floor malting there is little control of germinating conditions (Such as temperature, relative humidity, etc.) in contrast to modern malting where larger samples are handled and automated control of germination is made (Schwartz, 1956). The former influence often result in non-uniformity of brews and many quality deviations (schwartz, 1956).

2.6.8 The kilning process:

Kilning is the last stage in the malting process whereby germinated grains are dried at controlled

temperatures. The main objective of kilning is to arrest enzyme activity, develop colour and flavour components and to produce a storehouse of enzymes and their substrates in readiness for mashing (Brigg, et al., 1981., Palmer, 1976). The temperature of kilning depends on the intended use of the malt. Pale malts are lightly Kilned and are essentially employed in la.ger beer production where the preservation of enzyme is of paramount importance (Briggs, et al., 1981). On the other hand, high temperature kilns are used in the production of poor enzyme malts for dark aromatic beers (De clerk, 1958). The initial stage of kilning involves rapid moisture evaporation, which is followed at the final stage by colour development due to the formation of melanoidins (Sugar, amino acid complex) and other compounds which give colour to the wort and beer (Briggs, et al, 1981). Lightly kilned malts produces among others the potential flavour component dime thyl sulphide (DMS) characteristic of beers. (Palmer, 1976). Kilns vary from the traditional open sun drying to pneumatic processes that employ dryers with controlled temperatures and force air circulation (Schwartz, 1956).

2.6.9 Current trends on sorghum malting in Nigeria.

In whatever form sorghum is used for beer production it has been found necessary to add exogenous enzymes (Alsien, 1989; Arri,1989). Following the ban on barley malt importation, alternative measures to circumvent this ranges from initiation of local barley production or the use or local cereal substitutes with or without enzymes addition (Srugis and Hope, 1987). However, Laboratory activities accounts for 90 - 98% of the reports on sorghum malting (Ikediobi et al., 1989), while pilot malting of sorghum is responsible for less than 1% of reports (Ikediobi, 1989; Aisien, and Muts, 1987). On the other hand industrial scale malting is completely novel practice in Nigeria accounting for less than 0.1% of reports (Ikediobi, 1989). Associated with laboratory scale malting are such organizations as Universities, Polytechnic and research institutes. In the areas of pilot plant malting, the Federal Institute of Industrial Research Oshodi (FIIRO), the Project Development Institute (PRODA) Enugu and North Brewery, Kano have made significant contributions (Malomo, 1989; Ikediobi, 1989; B.S. G., 1986).

Despite the lack of facilities for sorghum malt production in the country at least two rather unsophisticated small soala sorghum malting plants exists (Srugis and Hope 1987). In view of the

aforementioned neophyte, companies, it is apparent that only tiny fraction of the 30 breweries in the country could meet their sorghum malt requirements. Unlike other major cereal grains produced in the country, sorghum has prove superior in beer making than any other (Ikediobi, 1989). Claims have been made in which an acceptable 100% sorghum lager beer have been made without addition of exogenous enzymes (Haase, 1985; Ogundiwin; 1989) on a pilot scale. Despite this new development, the economic viability of such a process still stands as a limiting factor in implementing such technology (Srugis and Hope, 1987). Although the sorghum variety SK 5912 and a few other hybrid varieties have proved distinctive characteristics for malt production, malters tend to overlook other varieties. As a result, full and reliable information about the malting characteristics of most Nigerian sorghum varieties is still wanting. (Ikediobi, 1989).

2.7 Brewing

2.7.1 Milling

The initial stage of beer processing is the reduction of malt or unmalted grain to a particle size suitable for subsequent rapid enzyme digestion and extraction with hot water during mashing (Palmer, 1969; De cherk 1958). particle size must not be too small, as wort run off will be impaired nor must it be too large, or extract yield will be reduced (Briggs, et al., 1981).

The trend towards the use of less modified malts has led brewers to change from 2 to 6 roller mills (Briggs, et al., 1981; De Clerk, 1958; Palmer, 1969). Wet milling have been employed especially where increase in extract potential and wort drainage properties is desired (De clerk, 1958). In which case malt may be soaked in water and milled with special patterned roller at high speed (Palmer, 1969). Wet milling tend to preserve more husk which serve as lauter tun filter and offers maximal enzymatic attack during mashing than do dry milling (Palmer, 1969). Arri, 1989 however reported that, unlike barley, sorghum husk is fused to the endosperm as a result does not favour the formation of lauter bed during wort filtration.

2.7.2 Mashing and wort lautering

Mashing is the second of the major enzymatic system involved in brewing. The process of mashing is the mixing together of proper proportions of malt and adjunct (cereal grit or sugar) in hot water, followed by a number of heating and resting cycles (Joseph, 1977). The substances which are thus solubilized in water are collectively called the extract. The solution of extract and water is called "Sweet wort".

During mashing β - and α - amylases liquefy starch into non-fermentable dextrins and fermentable sugars such as (glucose, maltose and trisaccharides such as maltotriose). (Briggs, et al., 1981). This dextrinizing activity results in consequent reduction in starch viscosity and in addition to β - amylase activity is expressed as the diastatic power of malt (Benfeld, 1955). Proteases solubilize and modify proteins into lower molecular weight fractions that impart flavour, tactile impression (mouth feel), foam potential in beer and serve as yeast nutrients in wort (Palmer and Pathgate, 1976), phosphatases liberates phosphates which buffers the mash pH between (5.2 - 5.5). The control of pH of mash is of great importance in view of the optimum enzyme activities. Unmalted cereal adjunts (or sugar) could be ground and sent to a cereal cooker where it is gelatinized and mixed with malt mash in a variety of ways (Palmer and Pathgate, 1976).

Principally, mashing may be carried out in one of the two different ways: infusion mashing or decoction mashing. Infusion mashing employs a single temperature of 65°C. It is simple efficient and suitable for conversion of well modified malts (Palmer, 1969). On the other hand, Decoction mashing is a multi temperature mashing system. Part of the main mash is usually withdrawn, boiled and returned to the main mash to raise the temperature in stages to 65°C (Palmer, 1969). Decoction mashing is essentially used in Europe where malts are traditionally less modified than traditional U.K. made malts (Joseph, 1977).

Lautering is the process of separation of insoluble malt substances from wort by filtration. The mash (grain residue - liquid mixture) produced by mashing operation is passed through a straining

device called lauter tun, where the insoluble spent brewers grains are removed. These residual grains are rich in proteins and can be used as feed supplements. (De clerk, 1957). Wort filtration is greatly impaired where sorghum is used due to low levels of β - glucanase activity in the malt, hence the use of mash filter in place of the lauter tun used in the case of barley. (Briggs et al., 1981)

2.7.3 Water

More than 90% composition of average beer is water (Palmer and Pathgate, 1976). Brewing water contains mineral salts which influences enzymatic actions during mashing, fermentation, extraction of hop in the kettle and on yeast growth (Pickett, et al., 1976). These effects are directly attributable to ions such as Ca^{2+}, Mg^{2+}, HCO^{-}_{3}, OH^{-}, SO_4^{2-} and Cl^{-} present in water. Water to be used for brewing should be clean, palatable, free from iron and preferably of a moderate degree of permanent or sulphate hardness (Palmer and Pathgate 1976).

2.7.4 Wort production

After lautering is completed, the sweet wort is boiled in a wort kettle and hop pallet (or extract) is added. Pressure boiling or atmospheric boiling is carried out for about an hour (Palmer, 1969). During this process beer colour develops due to reactions between amino acids and sugars which forms melanoidins and partially due to the caramelization of sugars (Palmer, 1976). Alongside with this, most high molecular weight proteins that evaded mashing enzyme hydrolysis are heat coagulated, wort becomes sterile, concentrated, bitter and produces a precipitate called 'hot break' A free amino nitrogen level of 130 - 250 mg/ml is considered adequate for yeast nutrition, while the wort pH is expected to lie between 5 - 6.0 before yeast pitching (Palmer, and Pathgate, 1976). Hot and cold water extract of about 290 °L/Kg and 17%, a wort colour of about 2.5 EBC, a total soluble nitrogen and yeast fermentability of 1.6% and 0.75% have been reported for high quality barley wort respectively. (Hough, et al., 1971, Joseph, 1977). The original and specific gravities and bitterness of barley malt wort varies from (10.7 - 18%), (1.040 - 1.080) and (20 - 40 B.U) respectively (Joseph, 1977; Briggs, et al., 1981. After wort boiling the hopped or bitter wort is pumped to the next stage leaving the semi-solid cone behind. Freshly boiled wort is sent to hop strainer which removes spent hop, coagulated proteins (hot trub) by use of

flat or basket shaped screens (Canals and Sierra, 1976). Wort is aerated, and rapidly cooled to 10°C by use of double pipe coolers or plate type heat exchangers with wort flowing counter current. This process further precipitate proteins and polyphenols referred to as "cold trub", (Palmer and Pathgate, 1976).

2.7.5 Hop

The hop (Humulus lupulus) belongs to the family Canna binaceae. The hop of commerce is the dried hop cone derived from the collection of female flowers, with or without pollination and fertilization. The flavouring substances are contained in the lupulin gland and can be divided into non-volatile portions containing the alpha and beta acids (resins) which produces the more bitter iso-derivatives during wort boiling and a team of volatile components which contains all the aroma substances (chapman, 1988).

There are two principal resins in hops, the α - acids of humulone and the less bitter β - acids or lupulone. The α- acids are a family of compounds, differing with respect to a side chain thus humulone ($C_{20}H_{30}0_5$)has an isovaleryl side chain Cohumulone ($C_{20}H_{28}0_5$)nd adhumulone (which are other member of the series) have isobutyryl 2 - methylbutyryl side chains respectively. The β - acids are a similar series of analogues; for instance, lupulone ($C_{26}H_{38}0_4$)and colupulone ($C_{25}H_{38}0_4$)have isovaleryl and isobutyryl side chains respectively. (Palmer, 1969). The chief chemical changes that can befall α - acids are: oxidation and polymerization during storage and isomerization products (formed during wort boiling) of α - acids (isohumulone etc) are particularly bitter. The derivatives of α - acids are the most important hop constituents in brewing (Palmer, 1969). Beta acids also oxidise readily but do not isomerise during boiling hence they are less, bitter. Hop extract (1.5-3.0g/litre) is often added during wort boiling.

There are two main groups of essential oils in hop, the hydrocarbon fraction and the oxygenated fraction (Palmer, 1969). They are volatile and are partially lost from the hop during wort boiling. The hydrocarbon fraction comprises mainly monoterpenes and sesquiterpenes. (De, clerk, 1958). Monoterpenes are made up of two isoprene units joined together and have the formula $C_{10}H_{16}$ (eg.

myrcene). Sesquiterpenes are made up of three isoprene units and their formula is $C_{15}H_{24}$ (e.g humulene and caryophyllene). The oxygenated fractions is complex and includes aldehydes, acids and esters of the terpenes mentioned above. (Palmer, 1969). Essential oils influence beer flavour and aroma if the hops are added in the copper boil (De clerk, 1958; Palmer, 1969). In addition to these role, hop acts as a bacteriostatic agent while hop tannins precipitate proteins and clarify beer (Hough, et al., 1971). Brewers spent hop is processed and used as fodder and/or manure.

2.7.6 Yeast pitching and primary fermentation

Yeast is added to cooled aerated wort in a fermenting vessel between 8 - 10°C for 7 days (chapman, 1988). Yeast grows, ferment sugars to alcohol, carbon dioxide and energy (160K, Cal/Kg of extract). Active yeast budding takes place with the first 48 hours and ceases. However, active fermentation goes on and at this stage several wort components are taken up by yeast; fermentable sugars, vitamins, minerals salts, amino acids for yeast growth with consequent reduction of wort gravity (Palmer and Pathgate, 1976). Wort pH falls while temperature rises and is generally kept high after the initial fermentation inorder to reduce the vicinal diketone (V.D.K.) flavour components which tends to mask the unpleasant diacetyl flavour formed at the initial stage of fermentation of lager beer (Joseph, 1977). Yeast produces metabolic bye-products such as: sulphur compounds, fatty acid (e.g. capric acid), organic acids, aldehydes, esters and alcohols of high molecular weight all of which may contribute favourably or adversely to beer quality (Palmer and Pathgate, 1976). Glucose is first fermented via the Emden - Mayerholf - Parnas pathway which requires 12 different stages employing 12 different enzyme systems) by permeating the yeast cell membrane. When glucose concentration becomes low, yeast cellmembrance will allow maltose to permeate. Trisaccharides such as maltotriose is taken as maltose becomes depleted (chapman, 1988; Kirk 1978).

The course of fermentation is measured in terms of wort attenuation. This is the decline in wort specific gravity over the fermentation period. The degree of fermention (fermentability) is the difference between the extract in the original wort and real extract in sample (obtained after dealcoholization of the of the fermented wort) divided by the original extract multiplied by 100. (Michael, 1989).

Factors which bring about abnormal fermentation include abnormal wort composition, wort infection, abnormal wort aeration, poor temperature control, weak yeast, wrong pitching technique and so on, (Joseph, 1977). Abnormal fermentation is characterized by late start of fermentation, development of strange odour, foaming etc. (Hough et al., 1971). Most lager beers have an alcohol content of between 3-8% and a PH between 3.9 - 4.4 (Joseph, 1977). Brewer's yeast is then recovered after primary fermentation is completed and pumped to yeast handling area. It is washed, reconditioned and prepared for re-use. Spent yeast (recovered after fermentation) may be dried and sold as feed supplement (Palmer, 1969). After primary fermentation is over, the young beer or "Ruh beer" is bubbled with carbon dioxide (carbon dioxide washing) to rid off undesirable off flavour and off odour gaseous compounds in readiness for lagering (Pickett et al., 1976).

2.7.7 Yeast

Yeast is an important raw material for the production of beer. Yeast is a unicellular micro-organism with diameter 0.004 - 0.010 mm and reproduces by budding (Chapman, 1988). Two types of yeast are used in brewing, top fermenting and bottom fermenting yeast (Chapman, 1988). Top fermenting yeast is essentially employed in Britain and parts of U.S. for brewing ales (Palmer, 1976). Yeast to be used for fermentation should be able to ferment malt wort vigorously and should be capable of flocculating (deposit itself from the beer at the end of fermentation). Top Fermentation is carried out using a strain of saccharomyces cerevisiae. It is pitched at higher temperatures (23°C) after an initial lag period and multiplication of yeast crop of 3 - 5 times the weight of the original pitching being obtained (Hahn, 1966). Temperature of the tank rises and is controlled to a maximum of 25°C by circulating chilled water through coils of pipes (attemparators). Fermentation takes 3 - 5 days (Chapman, 1988). Yeast cells are skimmed and beer is cooled before "racking" into casks or storage for conditioning (Palmer and Pathgate, 1976). Pale ales, and mild ales are sold a few days after racking while bottled beers are stored for a week or more.

Saccharomyces carlbergensis is the yeast strain employed for bottom fermentation (Palmer, 1969). Majority of the world's beer is produced by bottom fermentation yeast (Palmer and pathgate,

1976). Yeast pitching is carried out at lower temperatures of 14°C. Fermentation is usually carried out in open vessels and takes 10 - 14 days to complete (Larry, 1978). The beer is then chilled to between 12 - 13°C and dropped into close tanks in cold cellars for lagering (De clerk, 1957).

2.7.8 Lagering.

The "Ruh beer" obtained from primary fermentation has an inferior taste and aroma. Thus, it is stored in cold cellars which ranges from two weeks up to as long as 6 months to mature (Canals and Sierra, 1976). At this stage secondary fermentation takes place and yeast is actively removing undesirable odours and flavours. A temperature range of (0 - 10°C) is maintained in the storage cellars (Palmer and Pathgate, 1976). Beer is chilled proofed and charged with carbon dioxide. After maturation beer is filtered through kieselguhr (diatomaceous earth) to produce a highly clarified beer. Filtered beer is then filled into bottles, carbonated and pasteurized (to enhance micro-biological safety). After capping and labelling it is ready for sale and consumption.

2.8 Sensory evaluation

Food quality is evaluated by sensory, chemical and physical methods. Sensory methods in contrast to chemical and physical methods are used to determine whether food differ in such qualities as taste, odour, texture and the extent and direction of difference (Jean, 1977). Quality will be considered as the relative excellence of a food based on sensory estimates of colour, flavour, odour etc. Organoleptic means making an impression on an organ of special sense; sight, hearing, feeling, smell and taste (Jean, 1977). The physical and chemical characteristics of beer are stimuli for the sense organs whose receptors initiate impulses that travels to the brain where perception occurs (Jean, 1977). Perception or the correlation of sensory impressions determines whether a food will be accepted or rejected (Amerine, et al., 1965).

Sensory evaluation is a valuable tool in solving problems involving beer acceptability. It is used in product improvement, quality maintenance, new product development and market research (Elizabeth, 1977). The major attributes used in sensory evaluation of beer are: colour, taste, sparkling, foam, smell, bitterness and brilliance (Amerine, et al., 1965; Elizabeth, 1977). Several methods exists for sensory evaluation of food (Elizabeth, 1977; Caul, 1957; Amerine, et al., 1965; Ihekoronye and Ngoddy, 1987). These are: single stimulus method, paired comparison and triangle test. Other methods include; multiple comparison in which many samples are compared with the standard at the same time; ranking method in which large number of samples must be evaluated or when differences in quality are readily detected. Finally, scoring-coded samples which are evaluated for some specified characteristics by the panellists who record evaluation on a descriptive scale. Scoring is considered the best method and gives indication of the size and the direction of the differences among samples (Elizabeth, 1977). Because of the quantity of data obtained from sensory evaluation results must be summarized and analyzed statistically (Elizabeth, 1977). Amerine, et al., (1965), Caul (1957) Harper, 1981; Romatzi, (1976), Ihekoronye and Ngoddy (1987) have described several statistical techniques of data analysis such as the use of t-test, f-test or analysis of variance with or without statistical tables.

Statistical analysis is further classified into parametric and non-parametric test such as the Mann Whitley - U test and chi-square test which are employed where no assumptions are made about the underlying distribution (Wright, 1976). In other, words it utilizes purely discrete distribution and is particularly applicable where doubt about parametric assumptions necessary for t-test or f-test exists (Ronalgi, 1976). Unlike the chi-square test the Mann-Whitley-U test is an extremely powerful efficient (0.95) test and is reported to be easy in theory and practice except where over 25% ties in values occur Wright (1976).

3. MATERIALS AND METHODS

3.1 Source of Sorghum Grains

Sorghum bicolor (L.) ,Moench variety (LFSV) grains were purchased from a farm at Kawo, Kaduna, Nigeria.

3.1.1 Chemicals

The soluble starch, boric acid, trichloroacetic acid and petroleum ether were from BDH. Sodium hydroxide and hydrochloric acid were purchased from Hopkins and Williams. Ammomia, ninhydrin and vanillin were obtained from sigma. All other chemicals and solvents used were of analytical grade.

3.2 Methods

3.2.1 Sample pretreatment

The bulk of sorghum grain (as purchased from the farm) was washed several times with distilled water to separate the stalks, sand and other extraneous particles. It was then sun dried for 3 days. The untreated portion was reserved for the determination of foreign kernels, percentage floats and moisture.

3.2.2 Milling and particle size analysis

A portion of the sample was thoroughly mixed by shaking vigorously and crushed using hammer mill. Various sieves (2mm, 1mm, 710 µm, 500 µm, and 355 µm) were tried and the grain was finally milled to suitable particle size (355 - 1000 µm) as determined by the screen analysis described below. The sieve which gave this particle size range was employed for all the subsequent milling operations in this project.

The empty sieves of the screen analyzer were separately weighed. Sorghum flour was thoroughly mixed and 100g weighed out and placed on the topmost sieve and covered. All the sieves were fastened together, and the shaker switched on for 15 minutes. At the end of this operation sieves and the retained flour were weighed. The weight of flour retained in each sieve was calculated by difference and expressed as a fraction of the total weight. Calculation showed that 93.21% of the flour had particle sizes in the range (355 - 1000 μm).

3.3 Physical properties of sorghum grain

3.3.1 Determination of broken kernels and foreign seeds

Thirty grams lot of sorghum grain were spread out on a clean flat surface. All non-sorghum particles and broken grains were hand picked and classified as foreign seeds and kernels. The percentage of broken Kernels and foreign seeds were calculated using the formula below.

$$P = \frac{W_1 - W_2}{W_1} \times 100$$

Where P = broken Kernels and foreign matter percentage

W_1 = original weight of sorghum sample.

W_2 = weight of foreign matter and broken seeds.

3.3.2 Determination of percentage floats

One hundred sorghum Kernels were randomly selected and mixed with water in a test - tube. The floating kernels were scooped off, counted and expressed as percentage. The procedure was carried out in triplicates.

3.3.3 One thousand kernel weight determination

The official method of analysis of the Association of Official Analytical chemist (AOAC, 1980) was adopted. Five hundred grammes of sorghum grain from which broken kernels and foreign matter have been separated were weighed out using analytical balance. This was quartered into smaller portions until not more than 20g remained in opposite quarters. The number of sorghum grains in each quarter was counted. The weight of one thousand kernel of dry sorghum in grams was calculated using the formula.

$$G = \frac{W \times 1000}{N \times 100} \times DM$$

G = one thousand kernel weight of sorghum grain (dry weight basis)

W = total weight of sorghum taken

N = total number of grains counted

DM = per cent dry weight of sorghum grain.

3.3.4 Mould detection

The presence or absence of mould was determined by visual inspection of three aliquots of 50g sorghum grains spread out thinly on a clean bench and reported as, "none", "traces" etc.

3.3.5 Determination of germination energy

One hundred kernels of sorghum were placed in a 15 cm test tube and covered with distilled water at 28°C, filling the tube to within 20 mm of the tip. From time to time, floating kernels were forced below the surface of the water. After 48 hours of steeping, the water was drained off the kernels, and rinsed with water and drained again. A sheet of whatman No.1 filter paper was moistened by dipping in distilled water for 5 seconds and then allowed to drain for a few seconds. The wet filter paper was placed on a glass - sheet and steeped sorghum grain were distributed in a compact single layer of kernels in the centre of one - half of the filter paper. The other half of the filter paper was pressed down firmly on the layer of sorghum kernels and this was placed in a desiccator containing water in the bottom to maintain the relative humidity near saturation. The desiccator was kept on a bench at a temperature of 28°C. After 72 hours, the germinating sorghum grains were examined and those kernels which had roots or sprouts were removed. The percentage of sprouted kernels was reported as germination energy percent.

3.3.6 Determination of germination capacity

Kernels that showed no evidence of germination were replaced between damp filter papers and returned to the desiccator for an additional 48 hours. At the end of this time, kernels were examined closely for signs of germination. Kernels showing evidence of germination were counted, and their number added to the number of kernels that were germinated for 72 hours after steeping as in 3.3.5. The total sum was reported as germination capacity percent.

3.3.7 Determination of malting loss

The official method of analysis of (AOAC, 1980) was employed to determine the malting loss.

One hundred grammes lots of sorghum grains were malted as described in the malting procedure (4.1, 4.4 - 4.6). The kilned (dried) grains was weighed after the removal of rootlets and

shoots. The difference between the weight of the resulting malt and the unmalted grains was found as a percentage of the weight of grains malted.

3.4 Biochemical analysis of sorghum grain

3.4.1 Determination of moisture content

One hundred grams sample of sorghum was ground as described in the milling procedure (3.2.2). The ground sample was mixed thoroughly and 3 grams was weighed out and immediately placed in a moisture dish. The dish was closed and weighed immediately to 0.001g. The cover was removed and the dish was placed in a preheated oven for exactly 3 hours at 106°C. The lid was replaced and the dish was allowed to cool in a desiccator for at least 20 min. to room temperature. The dish was reweighed to 0.001g. The percentage of moisture in the sorghum sample was determined using the following formula.

$$M = \frac{W_1 - W_2}{W_1} \times 100$$

Where M = Moisture content (%)

W_1 = Weight of sample before drying

W_2 = Weight of sample after drying.

3.4.2 Determination of starch

Ten grams of ground sorghum was mixed with 25 ml. of petroleum ether and further ground into fine consistency in a mortar. The coarse material was allowed to settle, the ether and the suspended particles were decanted into 11cm filter paper (of sufficiently fine texture to retain the crude starch). The process was repeated until no more coarse particles remained.

After the ether had evaporated, the fatfree residue on the filter paper was transferred to a mortar by means of a jet of cold water and rubbed to a smooth paste. This was again filtered using the same type of filter paper. The process was repeated to remove any trace of reducing sugars. The insoluble residue was then heated under reflux for 2½ hrs. with 200 ml. of distilled water and 20 ml of conc. HGL acid in a round bottomed flask. The mixture was then cooled, neutralized with NaoH solution and transferred into a 250 ml. flask. It was then made up to the mark with distilled water. The resulting solution was filtered, and the weight of dextrose in the filtrate was determined using the Lane and Eynon's method as described in the official methods of analysis of the (A.O.A.C, 1976).

A 2% glucose solution was titrated against 10 ml. mixed Fehlings solutions under constant state of ebullition in a narrow necked flask until the blue colour was discharged. Three drops of 1% methylene

blue indicator was added to the mixture and the titration was continued until the blue colour of the indicator was completely discharged.

A second set of titration was carried out using the same procedure except that the 2% glucose solution was replaced with the hydrolysate (from sorghum). The weight of dextrose was calculated from the formula:

$$\frac{FX100}{C} = \text{mg of dextrose/100 ml solution}$$

Where C = the no of millilitres used in the titration

F = the Lane and Eynon factor

The weight of starch is then calculated by multiplying the dextrose equivalent by 0.925

3.4.3 Fat Estimation

The method of Shirlaw (1967) was used.

Sorghum grains were ground as described in the milling procedure (3.2.2) and mixed. 10g was accurately weighed and stirred with petroleum ether in a weighing dish. This was transferred an washed quantitatively with petroleum ether into an extraction tube banging just inside the lower part the Soxhlet apparatus. The ground material was held down by placing cotton wool on top of the material. The extraction tube was lowered into position and heating was started. Heating was done such as to give a continuous rather, rapid stream of condensate which fell into the previously weighed dried extraction flask. The 10g material was extracted for 2½ hours. After extraction the solvent was distilled off to dryness and the dry flask plus its content was placed in an oven at (106°c to constant weight.

The fat (%) was obtained using the following formula:

$$\text{Fatty substance (\%) (as is)} = \frac{B - A}{C} \times 100$$

and

$$\text{Fatty substance (\%) (dry weight)} = \frac{Y \times 100}{100 - M}$$

where A = Weight of dry empty flask

B = Weight of empty flask + Fatty material

C = Weightof sample taken (i.e. 10g)

Y = Fatty substances "as is" (before drying sorghum flour)

M = Moisture percentage

3.4.4 Cyanide analysis

The Cooke's modification of Epstein's method was adapted for cyanide determination as described by Ikediobi, et al., 1988.

EXTRACTION OF CYANOGENIC GLUCOSIDE

Approximately (0.1g) of powdered sample of sorghum was extracted with 5ml. aliquots of 0.1M sodium phosphate buffer, pH 6.8. The extract was stored in a tightly stoppered vessel until analyzed for cyanide.

Preparation of a standard curve for cyanide

A stock solution was prepared by dissolving 4mg. dry KCN in 100ml of doubly distilled water to give a solution of concentration 16g µg CN^-/ml. Eleven 15ml. tightly stoppered test tubes containing aliquots of the stock KCN solution to give a concentration of 0.32 - 3.2 µg CN^- were carefully set up. Each tube was made up to 7ml. with 50mM sodium phosphate buffer pH 6.0, and then 1ml. of 0.1M NaOH solution was added and the tube and contents left for 30 min. at room temperature (28 °C). To each tube 0.4ml of 0.5% W/V chloramine - T was added and mixed thoroughly. The tubes were again allowed to stand for 5 min. at 0° C, after which 1.6ml of the bispyrazolone reagent (0.1% bispyrazolone and 0.5% 3 - Methyl-1-phenyl-5-pyrazolone in pyridine was added, mixed and the tubes allowed to stand for 1 hour at room temperature in a fume cardboard. The absorbance of the resulting blue dye stuff was determined at 620 nm in an Sp 200-Bne Unicam Spectrophotometer. The cyanide level in the sample was obtained by extrapolation from a standard curve (Appendix 2).

Exactly 0.1ml of sorghum extract prepared was pipetted in quadruplicate into 15ml. stoppered test tubes. This was followed by the addition of 1ml. of 0.1M NaOH and subsequent incubation for 30 min. at room temperature to achieve total hydrolysis of the extracted cyanogenic glucoside, dhurrin.

The HCN liberated as (CN^-) was determined as described.

3.4.5 *Protein determination*

The method described by Pearson (1976) was adopted. Two hundred milligrams of sorghum flour was digested in digestion flask for two hours using mixed catalyst (2.4g) and concentrated sulphuric acid (6.5ml). The mixed catalyst was prepared using anhydrous sodium sulphate (96g), copper sulphate (3.5g), and selenium oxide (0.5g). A mixture of concentrated sulphuric acid (6.5ml), and catalyst (2.4g) constituting a blank was heated along with the samples. The digest was diluted to 100ml with distilled water. Ten millimetres of this solution was transferred to the steamed out Kjeldahl's apparatus and made alkaline with at least 15ml of 40% W/V sodium hydroxide. The ammonia liberated by steam heating the mixture was steam-distilled into 10ml. of 2% (W/V) boric acid containing a few drops of screened methyl red indicator (a mixture of 0.016% Methyl red and 0.083% bromocresol green in alcohol). The distillate was titrated with 0.01N hydrochloric acid. The blank was similarly titrated with the acid. The difference between the sample and the blank was the corrected titre. The percentage protein in the sample was calculated using the formula.

$$\% \text{ Nitrogen} = \frac{\text{Corrected titre} \times 0.02 \times 0.00014 \times 10 \times 100}{\text{Weight of Sample (grammes)}}$$

$$\% \text{ Protein} = 6.25 \times \% N_2$$

Where 0.0014 = Nitrogen equivalent

10 = dilution factor

0.02 = Normality of hydrochloric acid.

3.4.6 Estimation of tannin content

Aliquots of 0.2 grams of the sorghum flour was weighed and thoroughly mixed with 10ml of 1% concentrated hydrochloric acid in methanol for about one hour at room temperature using a mechanical shaker (300 rpm). The mixture was then centrifuged at 500 rpm for 10 mins. to get a clear supernatant and 1ml. supernatant was then transferred to two test tubes for each sample. The tubes were then put into the water bath at 30°C for exactly 20 minutes, Just before the incubation, 5.0 ml of Vanillin - HCL

reagent (preparation described below) was added (1 ml.) at 1 min, interval. The absorbance was measured at 500nm using sp6 - 200 PYE UNICAM Spectrophotometer. The amount of tannin in the sample was determined from a standard curve (Appendix 3).

Four grams of vanillin was dissolved in 100 ml methanol to give an effective concentration of 100 ml of the solution. The percentage concentration of hydrochloric acid in methanol in this is 8%. Equal Volumes of both solutions were mixed to give a freshly prepared vanillin - HCL reagent.

3.5 Malting of sorghum grains

Two hundred grams lots of sorghum grains (from which foreign substances and broken Kernels have been separated) were steeped in distilled water (1 part of grain to 3 parts of water) for various durations 6, 12, 18, 24, 27, 33, 39 and 45 hours respectively. After steeping, the grains were drained off water and put into a wooden box so as not to loose heat easily to the environment. This was necessary to allow the grains to build up enough heat energy which triggered off metabolic processes leading to subsequent germination of the grains. The casting period was 24 hours.

After casting, the grains were transferred to a dark partially opened wooden box measuring 3" x 1½" x 6". The grains were spread out at a constant thickness of 2cm. The temperature of malting was at room temperature (28°C). During germination process, the grains were Sprinkled with 20 ml of water at 6 hourly intervals and turned constantly (manually) to avoid matting of the roots and ensure even distribution. Malting was terminated after 5 days by kilning (including the one day casting period). The germinating sorghum grains were kilned (controlled drying) at 50°C for 24 hours after which the temperature was further increased to 55°C for another 24 hours using a forced air oven. After kilning, the rootlets were removed by using friction (abrasion).

3.6 Analysis of sorghum malt

3.6.1 Determination of specific gravity

The official method of analysis of the American Society for brewing chemicals (A.S.B.C, 1958) was employed.

A 25 cm^3 specific gravity bottle was filled with water at 20° C. The lid of the bottle was replaced and weight of the bottle and water was determined. The water was poured out, the bottle was rinsed with some sorghum extract and filled with the filtrate. The weight of the specific gravity bottle and filtrate was determined by weighing in the balance at 20° C (a temperature of 20° C was maintained during weighing by air-conditioning the weighing at 22° C). The specific gravity of the filtrate was calculated by subtracting the weight of the empty specific gravity bottle from its weight filled with filtrate and dividing the difference by the water capacity of the specific gravity bottle. The water capacity of the specific gravity bottle is the difference between the weight of the empty specific gravity bottle and its weight filled with water. The division was carried out to five places of decimal.

3.6.2 Determination of hot water extract

Sorghum grist (50 ± 10g) was placed in a 600 ml beaker and kept in a water bath at 65 °c for 15 mins. Distilled water (at 65 °c) was then added (initial mash mix temparature was 65 ± 0.2 °c. Mash was stirred at 10 min. intervals with beaker partly covered. After 1 hour mash was quickly cooled to about 20° C. Exactly 25 min. after removing from bath, mash was transferred through funnel with wide stem to a 515 ml flask, washing out beaker with distilled water and flask content was made up with distilled water to 515 ml at 20 ± o.2° C. The flask was vigorously shaken for 5 min, and the volume was adjusted to 515 ml. at 20° C. Thirty minutes after completion of mashing the entire mash was poured into 32 cm. diameter (Whatman No.1) filter paper in a 15 cm diameter funnel. The first 50 ml filtrate was returned to filter and filtrate collected for 30 min. Filtrate was used for specific gravity determination as in described (3.6.1). Throughout filtration and collection mash and wort was protected from evaporation and strong light. The specific gravity of filtrate was determined within one hour of collection. Hot water extract was determined using the formula: *Kashim*

$$E = G \times 10.13$$

where E = Hot water extract 'as is' (i.e. without moisture subtraction) expressed in Litre degree per Kilogramme (Lit. deg. Kg^{-1})

G = the excess degree of gravity of the filtrate, taking water at 20°C. as 1000 is given by the formula

$$G = 1000 (S.G-1) + C.F$$

CF = Correction factor (0.236 x every 1°C above or below) 15.5°C

$$\text{Extract (dry basis)} = \frac{E \times 100}{100 - M}$$

where M = Moisture (%).

3.6.3 Determination of cold water extract

The method of Hough, Briggs and stevens, 1971 was employed.

Ten grams of ground malt was digested with 200 ml of distilled water containing 12 ml of 0.1N ammonia for 3 hours at 28°C, being mixed every half hour The mixture was then filtered and the specific gravity determined as in (3.6.1). The cold water extract was calculated using the relationship below,

$$\text{Cold water extract}(\%) = \frac{(\text{Sp. Gr.} - 1)1000 \times 20}{3.86}$$

Where Sp. Gr. = *Specific gravity of the filtrate*

3.6.4 Determination of moisture

Moisture content of malted sorghum was determined as described in method (3.4.1).

3.6.5 Diastatic Power Determination

The method recommended by the A.S.B.C. (1958) as modified by (Novellie, 1959) was adopted.

Twenty five grams of malt sample of sorghum was extracted with 500 ml of distilled water at 30°C for 2½ hour. The mixture was stirred at ½ hourly interval with a stirring rod. After, the mixture was filtered for ½ hour. with Whatman No.1 filter paper after which 10 ml of filtrate was pipetted into 200 ml of 2% soluble starch at 30°C to digest the starch. After 30 minutes, the reaction was stopped by the addition of 20ml of 0.5N sodium hydroxide and the volume was made up to 250ml with distilled water. The sugar content or diastatic power of the malt solution was determined as follows:-

Five millilitres aliquots of mixed Fehling's solution were pipetted into a 150ml narrow-necked boiling flasks. The digested starch solution was added to cold Fehling's solution from a burette. The flask contents were mixed and were boiled moderately for 2 minutes. The boiling and addition of starch solution was continued for another 2 min. until the blue colour of Fehling's solution was discharged. Three drops of methylene blue indicator were added and the titration was completed. The end point was indicated by the decolorization of methylene blue and the reaction liquid just becoming red. The diastatic power (D.P.) expressed in degrees Linter is calculated from the following formula:

$$D.P. = \frac{2000}{XY} - \frac{200}{XS}$$

where X = number of ml of malt extract starch used to digest starch.

Y = number of ml of converted starch used to reduce 5ml Fehling's solution.

D.P = diastatic power of malt in degree lintner (°L).

S = titre for starch blank determined as follows:-

BLANK TITRATION FOR STARCH

The undiluted 2% starch solution was used to titrate a mixture of 1ml of mixed Feling's solution and 2ml of Fehling's solution B as was the case in the determination of Diastatic power. The correction from the apparent diastatic power of the malt is $\frac{200}{XS}$.

where X = ml of the malt extract for the conversion.

3.6.6 Determination of wort filtration rate

Mash prepared for hot water extract determination (as described in method 3.6.2) was stirred vigorously and immediately poured into 32 cm Whatman No.1 filter paper in a glass funnel (diameter 15cm). Thirty minutes after starting initial filtration, the filtrate was allowed to collect into a 20 ml measuring cylinder and the volume of filtrate collected after 20 min. was measured. This was taken as the wort filtration rate.

3.7 Steeping studies

3.7.1 Effect of duration of steeping on moisture percentage

Sorghum grains were steeped as described in method (3.5) at varying durations (3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 42, 45 and 48 hours) respectively. The moisture percentage was determined after initial mopping of grains between filter papers as described in method (3.4.1)

3.7.2 Effect of steeping duration on germination energy

The germinative energy of sorghum grain was determined at varying steeping duration (3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 39, 42, 45 and 48 hours) respectively following the A.S.B.C method 1958 as described in 3.3.5. The steeping water was changed after 24 hours for steeping durations exceeding 24 hours.

3.7.3 Effect of duration of steeping on malt quality

Five sorghum malt samples were produced following the procedure described in 3.5. However, duration of steeping used were (9, 21, 33, and 45 hours) with unmalted grains serving as control.. The procedure was carried out in triplicates. The following determinations: Hot water extract, cold water extract, Moisture, Diastatic power, wort filtration rate were carried out as described in (3.6) in order to assess the malt quality.

3.7.4 Effect of additives on malt quality

Four sorghum malt samples were produced following the procedure described in 3.5. However, 18 hours steeping duration was used and the steeping liquor consisted of 0.2% aqueous solution each of ammonia, calcium hydroxide, formaldehyde and distilled water as control. The following determinations; hot water extract, cold water extract, diastatic power, wort filtration rate were carried out as described in 3.6 in order to assess the malt quality.

3.8 Germination studies

3.8.1 Effect of duration of germination on malt quality

Four sorghum malt samples were produced as described in 3.5, except that sorghum grains were steeped in 0.2% aqueous solution of calcium hydroxide for 24 hours and at varying duration of germination (2, 4, 6 and 8 days) respectively. The same set of analysis as in 3, 7, 3 above were carried out on the malt samples using unmalted grain as control.

3.8.2 Preparation of crude alpha and beta amylases extract

The method of Botes, et al., (1967a b) was employed.

Crude alpha amylase was prepared by extracting sorghum malt (produced as described in 3.51) overnight at 2°C using 40g malt flour to 100ml distilled water. The suspension was first centrifuged in a basket type centrifuge to remove the coarse particles and further clarified by filtering, using filter aid (celite, analytical filter acid). The clear extract was 40% saturated (by the use of nomogram) with solid ammonium sulphate which precipitated the alpha amylase. The precipitate was allowed to settle overnight, collected by centrifugation, dialysed against 0.05M acetate buffer (pH 4.6) for 8 hours to remove the salts and freeze dried. The supernatant contained beta amylase.

The supernatant, obtained after precipitation of alpha amylase at 40% saturation with ammonium sulphate was 70% saturated (as in the case of alpha amylase) with ammonium sulphate which precipitated the beta amylase. The precipitate was allowed to settle overnight, collected by centrifugation, dialysed against 0.05 acetate buffer pH 5.0 for 8 hours at 4°C to remove the salts, and freeze dried.

3.8.3 Determination of alpha and beta amylase activities

Soluble starch was used as substrate for both alpha and beta amylase determination. Apparent saccharification power was estimated from the amount of reducing sugars calculated as maltose, (Appendix 1.) produced from 2 ml of 2% Starch solution in 0.05 M acetate buffer pH 4.6, when treated with 0.1ml of enzyme solution for 10 min. at 30°C. The enzyme reaction was stopped by adding 2ml of the 3,5 - dinitrosalicylic acid reagent. The saccharifying unit was arbitrarily defined as that amount of enzyme which would liberate 1µ mole reducing group (calculated as maltose) per minute.

3.8.4 Protedytic activity of sorghum malt determination

Sorghum malt was produced as described in method 3.8.1. The official method of analysis of the American Association of Cereal chemists (A.A.C.C., 1962) was adopted.

Twenty five grammes of sorghum malt was ground (as described under milling procedure 3.2.2). Two 10g portions were weighed into 100 ml. glass centrifuge tubes and 50ml of 0.1M acetate buffer pH 7.4 was added to each tube, with rapid stirring. The tubes were placed in water bath at 45°C and stirred at 5 minutes intervals. After 1 hour, 10 ml trichloroacetic acid (TCA) solution (prepared by dissolving 30g TCA and made up to 100 ml with distilled water) was added to one portion, stirred and centrifuged. This was filtered and nitrogen determined (i.e non-protein nitrogen) in 20 ml filtrate. Twenty millilitres of filtrate was taken and 3 ml of conc. H_2SO_4 acid added. The mixture was evaporated to dryness. Foaming was prevented by initial gentle heating. Digestion and steam distillation was carried out as described under method for protein determination in (3.4.5). The distillate obtained was titrated against 0.02 N HCL using two drops of screened methyl indicator.

Percentage nitrogen was calculated using the formula:

$$\% \text{ Nitrogen} = \frac{\text{Corrected titre} \times 0.14 \times 10}{\text{Weight(mg)}} \times 100$$

where 10 = dilution factor.

3.9 Production of lager beer from sorghum malt

The procedure employed was a modified method of Aisien and Muts (1987) and Michael (1989).

Sorghum malt (2 Kg) was produced following the procedure earlier described in 3.5. The duration of steeping was 18 hours and the steeping liquor contained 0.2% W/V $Ca(OH)_2$. Sorghum malt was milled according to method (3.2.2) already described.

"Mashing in" was carried out using liquor/sorghum grist ratio (4 litres: 1 Kg) respectively at 45°C. The pH of mash was adjusted to (6.5) using HC1 acid and NaCl and Ca^{2+} ions (added as $Ca Cl_2.2H_20$) to give 100 mg/litre concentration. This was followed by the addition of (130 protein Units (P.U)/mg malt grist) commercial protease and 0.025% W/v β - glucanase and mash held for 30 min with constant stirring (peptonizing rest).

Mash was allowed to settle. About 1.5 litres of the enzyme supernatant was then carefully removed and kept aside. The main mash remaining was heated to 80°C and maintained at this temperature for 30 minutes to complete starch gelatinization. The mash was then cooled to 50°C and the clear "enzyme" supernatant added back to it. The pH of the mash was adjusted to 5.4 using NaCl/HCL buffer solution. Fungal α - amylase (0.3Kg/ton of malt grist) and β - amylase (0.2g/500g malt grist) were added and the temperature of mash raised at 1°C per minute to 65°C and then rested at 65°C for 1 hour. The temperature was finally raised to 75°C at 1°C per minute and after 10 minutes rest at 75°C (mashing off), the mash was rapidly cooled with ice block to room temperature. At the end of mashing, a few drops of the mash was mixed with 2 drops of iodine solution on a white tile. No evidence of starch (bluish - black colour) was observed.

The cooled mash was first strained in a clean jute bag and sparged with minimal amount of distilled water. The crude wort was made up to the initial mash - mix volume and filtered with Whatman No.1 filter paper using celite filter aid.

The clear wort obtained was boiled in an aluminium pot for 90 minutes. Thirty minutes to the end of boiling 2.5g/litre hop extract was added and the boiling completed. The boiled wort pH was adjusted to 5.0 with NaCl/HCL buffer solution after making up the wort volume to 3 litres with distilled water.

Brewers yeast (saccharomyces carlbergensis Uvarum) was pitched at 2.5g/litre of wort, after vigorous agitation of wort for 3 hours (to aerate wort). Fermentation was carried out in a 10 litre sterile glass jar for one week maintaining the temperature between 9-10°C. The "Ruh beer" so produced was filtered off to remove most of the bottom flocculated yeast, cold trub etc. The young beer was further stored to lager (mature) at 0°C for 2 weeks in the refrigerator. The sorghum beer produced was finally filtered through kieselguhr (diatomaceous earth). Ascorbic acid (4 mg per litre) was added, beer was bottled, carbonated and capped. Sorghum beer so produced was pasteurized by immersing in a water bath at 70°C for 1 hr. At each stage of beer production, cleanliness was maintained in order to avoid microbial contamination.

SENSORY EVALUATION OF LAGER BEER

To select panellists, three coded samples were presented to each of twenty test panellists (Comprising of students and staff of Ahmadu Bello University, Samaru, Zaria). These are sample 315 (star beer; to serve as a known control), sample 253 (Sorghum lager beer) and 345 (unknown control). Each panellist was requested to score the beer attributes, foam, colour, odour, bitterness, sourness, bodyfulness, sparkling and brilliance following the instructions in the questionnaire and the scoring sheet as shown in appendices (4) and (5) respectively. The test panel was carried out in a well air-conditioned room at 10.00 am in the morning. At the end of the first test, 10 people who were able to identify the two controls were selected for the test panel.

The selected panels (10) were presented with two samples coded 354 (control) and 218 (sorghum lager beer) under the same conditions (as described above) and requested to score the same beer attributes as earlier described. The test carried out consisted of the preference and hedonic scale scoring using a scale from 5 to 1 with 5 being "Excellent" and 1 "Poor".

Statistical analysis was carried out using chi - Square test. The chi - Square test is given by the formula:

$$X^2 = \sum \frac{(Oi-e)^2}{e}$$

where Oi = observed mean score

e = expected mean

Hypothesis Test:

The probability that the product is not acceptable is 0.05 and probability that it is acceptable ≤ 0.95.

Chapter IV

4. RESULTS AND DISCUSSION

Fig.1 shows the effect of duration of steeping on moisture percentage of sorghum. An initial sharp rise in moisture percentage occurred upto about the first 9 hours of steeping and thereafter rose gradually upto a peak of 35%. This pattern is consistent with the findings of Akingbala (1989). This determination is necessary as it is a peculiar characteristic for a particular variety of grain (Briggs, et al., 1981).

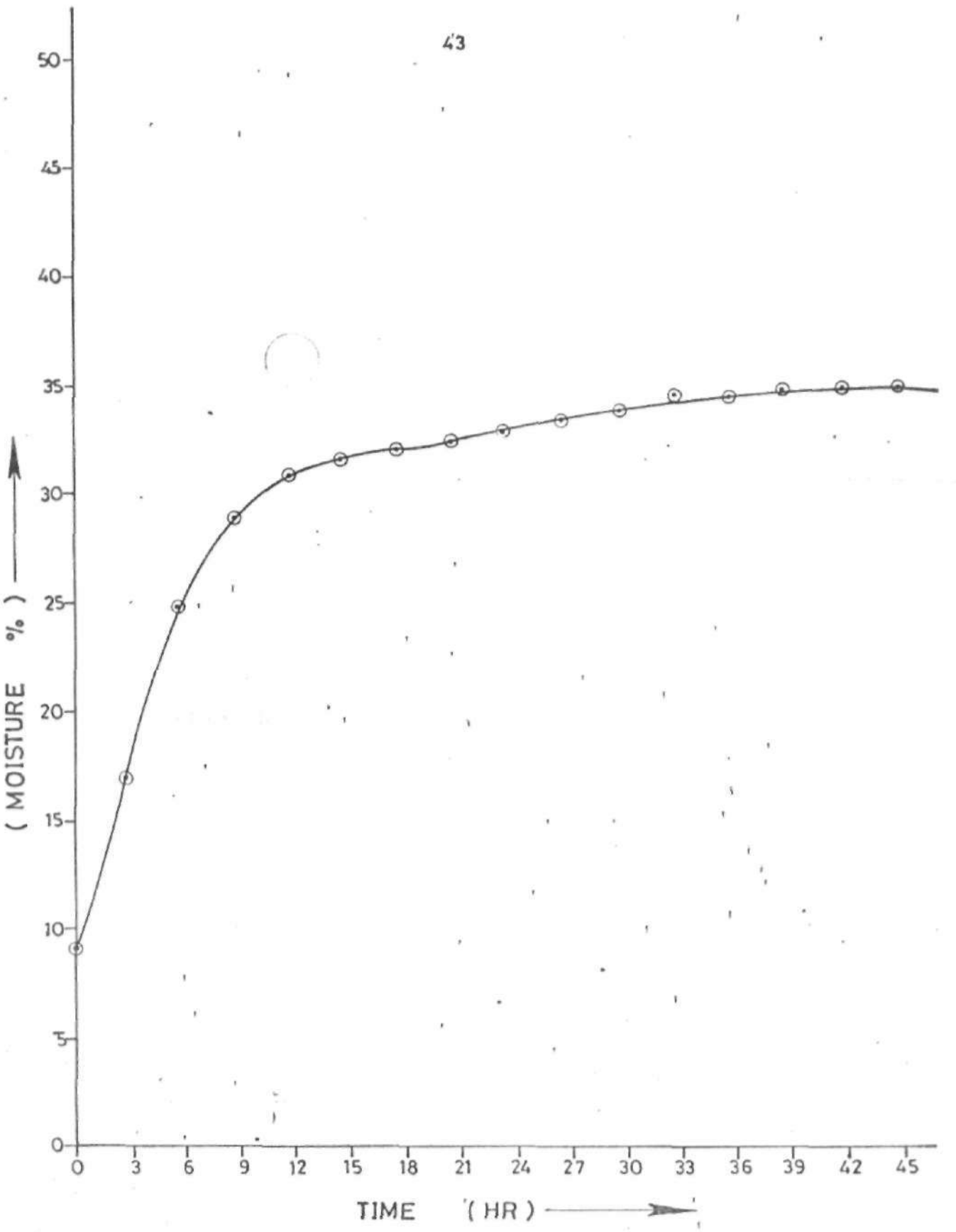

50
45
40
35
30
25
20
15
10
5
0
(MOISTURE %)
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
TIME (HR)

Fig 1

Further investigation showed that sorghum grains steeped upto 36 hours duration gave over 95% germinative energy (Fig.2), Values recommended for any given grain employed for malting (Palmer, 1969).

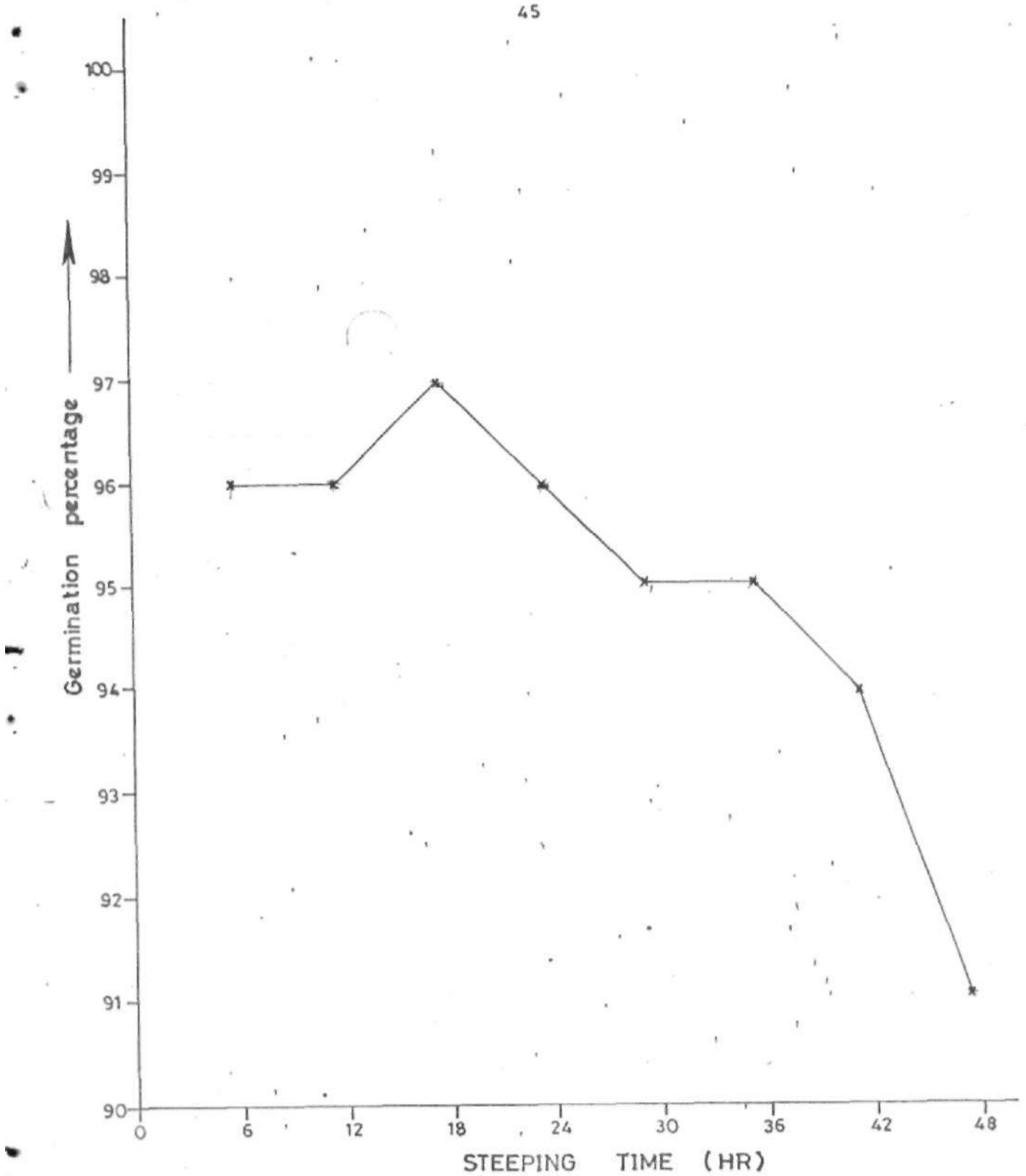

Germination percentage
100
99
98
97
96
95
94
93
92
91
90
0
6
12
18
24
30
36
42
48
STEEPING TIME (HR)

Fig 2

Table 1 shows the analytical results of the physical and biochemical properties of sorghum grain. The germinative energy and capacity obtained during the analysis were 96% and 98% respectively. These values were comparable to those of barley (95% and 96%) which suggests a good readiness of the grain for malting (Briggs, et al., 1981). The low could water extract (2.43%) of sorghum grain is indicative of low enzyme activity. Since the cold water extract measures the level of preformed soluble matter in the grain. However, the hot water extract (41.27 Lit deg. Kg^{-1}) suggests a significcant increase in enzyme activity under the test condition.

The diastatic power of the ungerminated sorghum was 9.5%. This value is higher than that reported by schwartz 1956 (0-7.8°L) for ungerminated Kaffir corn. The variability may be attributed to grain variety (Novellie, 1962a).

The 1000 Kernel weight obtained was 27.3g. As the 1000 Kernel weight is related to extract yield, it follows that the extract yield of sorghum might be predicted by working out a relationship as is the case with barely (Palmer, 1969). However, the 1000 Kernel weight obtained for sorghum grain fall below that of barley.

Low levels of floats (1.4%). was obtained for this variety of sorghum compared to the U.S. standard of 4-15% broken Kernels required for grade 1-5 sorghum. The lack of mould growth is indicative of good maturity of grain and proper post harvest handling.

Cyanide level of 19.7 ppm was determined in sorghum grain. This result was Similar to findings of Ikediobi, et al., 1988. During malting dhurrin synthesis increases resulting in high cyande levels in sorghum seedlings (Ikediobi, et al., 1988). Hence the need for complete detoxification during processing if the incidence of chronic cyanide toxicity is to be avoided.

Table 1 Physical and biochemical properties of sorghum grain

Hot water extract (Lit. deg. Kg^{-1})	41.27 ± 0.03
Cold water extract (%)	2.43 ± 0.12
Diastatic power (°L)	9.5 ± 0.10
Cyanide (ppm)	19.7 ± 0.30
Tannin (%)	0.23 ± 0.00
Germinative energy (%)	96 ± 0.25
Germinative Capacity (%)	98 ± 0.22
Broken Kernels (%)	0.14 ± 0.01
Foreign Matter (%)	1.4 ± 0.02
1000 corn weight (g)	27.3 ± 0.31
Mould infestation	"None"

Tannin content of ungerminated sorghum grain was 0.23%, a value consistent with those reported by Rooney (1973). Thus, this low tannin variety of sorghum appear desirable where protein - tannin problem of chill haze in beer is to be minimized (Briggs, et al., 1981)

Table 2 shows the result of the proximate composition of sorghum grain. The starch level in sorghum was (70.0%) which was higher than that in barley (58-60%). The malting significance of starch lies not only in the absolute level, but also in starch gelatinization temperature, the amylopectin/amylose ratio and starch solubility (Novellie, 1960a). Since starch exists bound to protein bodies, the efficacy of starch degradation also depends on the proteolytic activity of the grain and malt. The high level of starch of this variety of sorghum is indicative of high level of fermentable extract.

The protein level in sorghum (9.80%) compares favourably with that of barley (8 - 13%) and other sorghum varieties (9.5-12.5%). (Aisien, 1989; Rooney, 1973). Thus the suitability of wort from this sorghum malt for yeast nutrition is assured, since this depends on the total soluble intron (TSN) and free amino nitrogen (FAN) levels.

Raw grain gave moisture percentage of (10%). The low moisture content in grain suggests good storageability prior to processing (Ikediobi, 1989).

Fat content was found to be (2.52%) in sorghum grain as compared to (2.3%) barley. The low fat level obtained seems desirable in brewing in order to enhance yeast nutrition (unsaturated fatty acids and cholesterol), foam stability (calcium soap formation) and avoidance of beer gushing problem (Palmer, 1969). A high fat level in beer leads to the formation of polyphenol - fatty acid complex (haze) which is a negative quality index (Briggs, et al., 1981).

From the analytical results, ash content was found to be 2.49%. High ash content of sorghum grain is desirable in malting, as mineral leaching occur during steeping resulting in significant reduction of Valuable inorganic matter required in mashing and yeast growth.

Table II Proximate composition of sorghum grain

Moisture (%)	9.0 ± 0.02
% Nitrogen	1.48 ± 0.01
Crude protein (6.25 x N) (%)	9.8 ± 0.00
Ash (%)	2.49 ± 0.001
Starch (%)	70.0 ± 0.30
Fat (%)	2.52 ± 0.02

Table 3 Summarises the results obtained for the analysis of sorghum malt produced under various duration of steeping (9, 21, 33 and 45 hrs). Unsteeped grains served as the control. The results obtained were analysed using the analysis of variance (Ihekoronye and Ngoddy, 1987). From the data obtained higher malting losses (27.78%) were incurred using short steeping duration of 9 hours, prolonged steeping up to 45 hr gave the list malting loss (20.50%). Thus, result thisconfirmed the findings of Novellie (1962) and Mayer and Poljakoff (1963) that prolonged steeping impair germination.

The cold water extract (C.W.E.) decreased in the range (14.13 to 4.20%) with prolonged steeping as compared to the control which had (2.15%). Significant differences ($p < 0.05$) existed on the level of cold water extracts with duration of steeping.

Hot water extract (H.W.E) showed an initial increase of (104.95 to 111.65 Lit. edg. Kg^{-1}) from 9 hr. to 21 hr. and thenceforth declined to 74.0 Lit. deg. Kg^{-1} at 45 hr with the control having 41.25 Lit. deg. Kg^{-1}. At the 95% confidence limit ($f > 3.98$), significant differences ($p < 0.05$) were found to exist on the level of (HWE) with duration of steeping. As reported by Briggs, et al. (1981), the initial rise in (H.W.E.) was due to increase in enzymatic activity during germination which trailed off as steeping proceeded. This reached a peak between 9-21 hr. of steeping.

The diastatic power showed a progressive decrease from (15.0 °L) to 11.3 °L) with prolonged steeping as compared to the control which gave (9.4°L). The diastatic power (D.P.) obtained for the various duration of steeping as compared to the control showed significant differences ($p > 0.05$). As discussed earlier, prolonged steeping degenerate grains hence, may be responsible for the decrease in D.P. depicted in the results obtained.

Wort filtration rate (W.F.R.) was found to increase from (6.0 - 11.05 ml/20 mins) from 9 hr. to 21 hr. of steeping respectively. There was decline in W.F.R. from 8.0 to 6.0 ml/20 min when steeping was prolonged for 33 hr. and 45 hr. respectively. The presence of low level of β - glucanase activity in sorghum has been held responsible for incomplete hydrolysis of β - glucans resulting in poor wort

filtration rate (Arri, 1989 and Palmer, 1969). Since prolonged steeping has been reported to deteriorate grains, this may be responsible for the decline in W.F.R with prolonged steeping for 33 hr and 35 hr durations.

Table 3 Effect of duration of steeping on malt quality of sorghum

DURATION OF STEEPING (HR.)	UNSTEPPED GRAIN (CONTROL)	9	21	33	45
Malting loss (%)	0 ± 0.00	27.78±0.05	25.90±0.05	23.37±0.15	20.50±0.00
Cold water extract (%)	2.15±0.029	14.13±0.15	8.26±0.07	6.30±0.06	4.20±0.58
Hot water extract Lit.deg.kg^{-1})	41.25±0.05	104.95±044	111.65±008	86.48±0025	74.26±0.02
Diastatic power (°L)	9.35±0.03	15.00±0012	14.40±0.01	13.03±0067	11.27±0.02
Moisture (%)	9.0±0.00	3.84±0.17	4.30±0.14	3.6±0.21	4.0±0.19
Wort filtration rate (ml/20 min.)	5.0±0.30	6.0±0.31	11.05±0.19	8.0±0.15	6.0±0.13

Table 4 and figure 5a, b, c, d and e summarises the analytical results obtained when sorghum grains were steeped using (0.2%) of different additives (ammonia, calcium hydroxide, and formaldehyde). The control was steeped with distilled water. The result obtained was statistically analysed using the analysis of variance (Ihekoronye and Ngoddy, 1987).

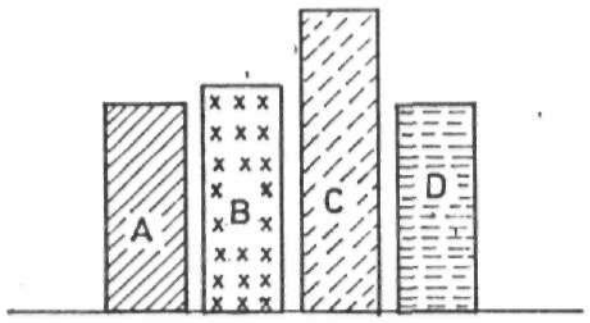


Fig 5a

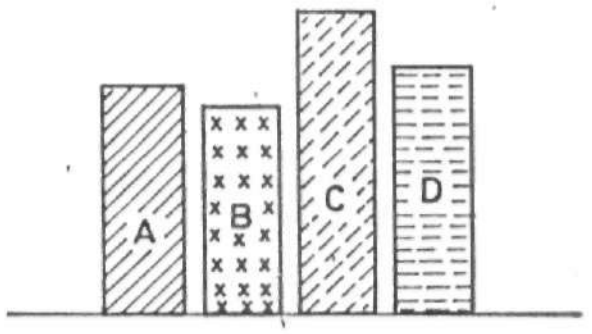


Fig 5b

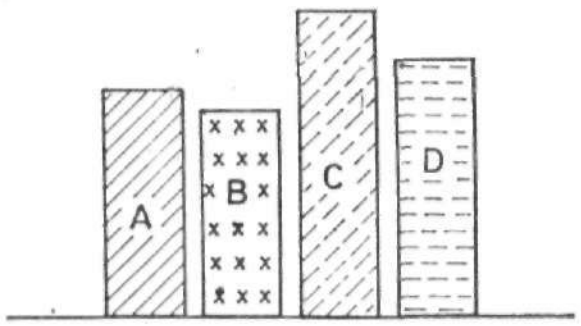


Fig 5c

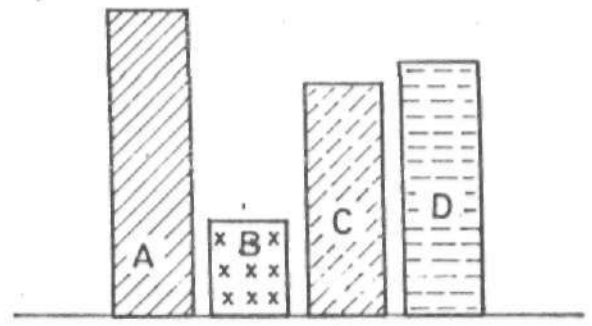


Fig 5d

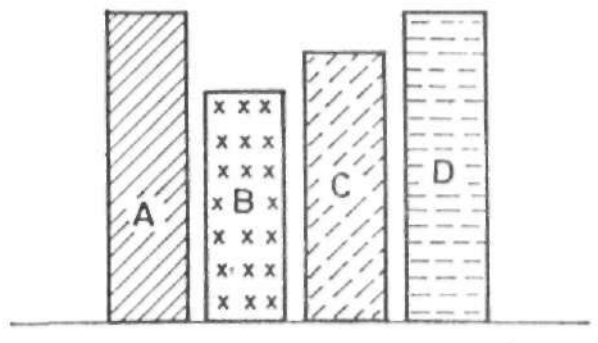


Fig 5e

The values obtained for malting loss show that significant differences existed ($p < 0.05$) with the additives used. Based on the results obtained grains steeped with calcium hydroxide gave the highest malting loss (30.09%) with ammonia treatment having the least (23.73%). Ammonia and formaldehyde have been reported to interact with some enzyme systems and this may be responsible in part for the reduction in respiratory activity. (Gbolahan, 1989; Hahn, et al., 1954; Siddappa, 1954). Alkaline steeping is found to reduce polyphenolic compounds which results in promoting germination and high malting loss (30.09%) as was the case with $Ca(OH)_2$ application during steeping.

Table 4 Effect of additives on malt quality (during steeping)

ADDITIVE	CONTROL (NO ADDITIVE ADDED)	AMMONIA (0.2%)	HYDRATED LIME (0.2%)	FORMAL DEHYDE (0.2%)
Moisture (%)	6.33 ± 0.00	5.11 ± 0.29	4.38 ± 0.05	4.78 ± 0.09
Cold water extract (%)	8.72 ± 0.096	2.40 ± 0.063	6.44 ± 0.09	6.58 ± 0.58
Hot water extract (Lit. deg^{-1})	140.83 ± 0.13	128.12 ± 0.08	177.10 ± 0.03	144.58 ± 0.12
Diastatic power (°L)	12.30 ± 0.01	12.90 ± 0.06	16.60 ± 0.01	12.30 ± 0.03
Malting loss (%)	24.73 ± 0.02	23.48 ± 0.02	30.09 ± 0.02	26.43 ± 0.08
Wort filtration rate (ml/20 min)	7.70 ± 0.06	5.86 ± 0.023	7.04 ± 0.03	8.20 ± 0.078

The cold water extracts were generally lower (2.40%, 6.58% for ammonia, and formaldehyde treated grains respectively) as compared to that of the control (8.72%). No significant differences were found ($p < 0.05$) between $Ca(OH)_2$ and formaldehyde treatments. These findings were indicative of low enzymatic activity of the malts under investigation. Since the C.W.E. is a measure of enzymatic activity during malting the use of additives must have suppressed the formation of soluble malt substances (such as sugars, β - glucans, etc.) resulting in lowering C.W.E. yields.

Calcium hydroxide (0.2%) treated grains gave the highest value of hot water extract (177.10 Lit. deg. Kg^{-1}) as compared to that of the control (140-83 Lit. deg. Kg^{-1}) with ammonia treatment having the least (128.12 Lit. deg. Kg^{-1}). This further confirmed that ammonia treated grains at 0.2% level suppressed enzymatic activity with subsequent lowering ($p > 0.05$) the extract yield.

Highest diastatic power was recorded for calcium hydroxide treated grains (16.6°L) while formaldehyde treated grains gave the least (12.3°L), a value similar to that of the control. It is apparent, therefore, that additives generally improved the diastatic power of this sorghum variety except formaldehyde which had no significant ($p < 0.05$) effect. This might be expected considering that the primary function of the formaldehyde is to check mould growth.

Wort filtration rate (W.F.R) was highest (8.20 ml/20 min) with formaldehyde treatment. On the other hand grains treated with ammonia gave the least ($p > 0.05$) (W.F.R) of 5.86 ml/20 min. as compared to the control (7.70 ml/20 min.). No significant ($p < 0.05$) improvement on the (W.F.R) was found to exist between formaldehyde, calcium hydroxide treated grains and that of that control. This indicates that $Ca(OH)_2$ and formaldehyde treatment did not improve breakdown of β - glucans in sorghum. Ammonia treated grains was found to lower wort filtration rate significantly ($p < 0.05$). Thus this further showed possible suppression of β - glucanase activity with (0.2%) ammonia treatment.

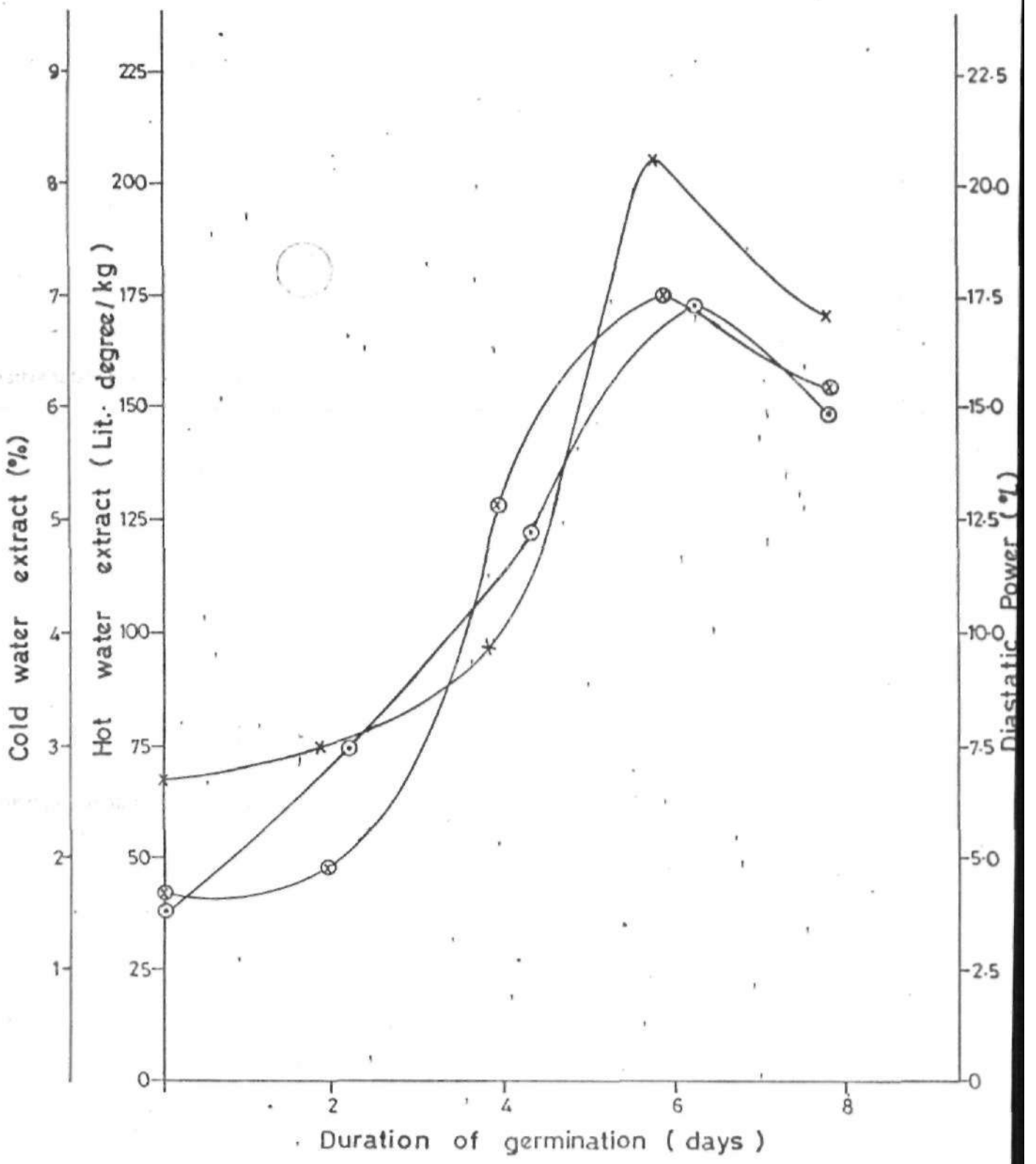
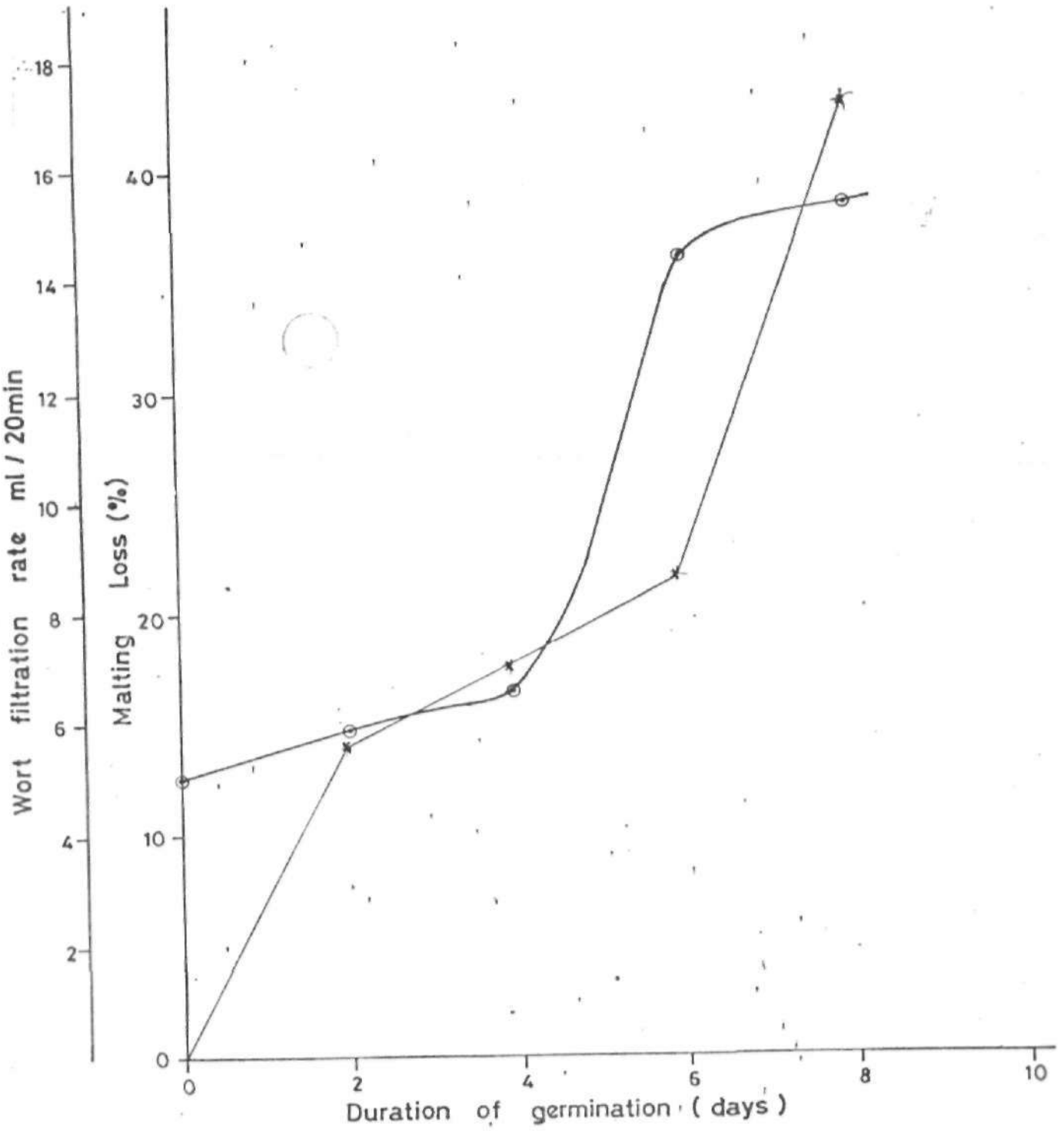

Cold water extract (%)
Hot water extract (Lit.· degree/ kg)
Diastatic Power (°L)
Duration of germination (days)
0
1
2
3
4
5
6
7
8
9
25
50
75
100
125
150
175
200
225
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5

Fig 6a



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Zaria - Nigeria

Fig 6b

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The analytical results of the effect of duration of germination (2, 4, 6 and 8 days) with ungerminated grain serving as control, were summarised in Table 5 and Figs 6, a and b.

From the results obtained, high malting loss (42.92%) was incurred as compared to lower malting loss (13.41%) obtained with shorter duration of germination time of 2 days. These findings were in agreement with those of Novellie (1962).

Table 5 Effect of duration of germination on malt quality

GERMINATION TIME (DAYS))	0	2	4	6	8
Moisture	9.0 ± 0.0	4.0 ± 0.0	4.7 ± 0.0	1.30 ± 0.02	1.0 ± 0.01
Cold water extract (%)	2.55 ± 0.015	3.09 ± 0.03	3.75 ± 0.029	8.30 ± 0.15	6.89 ± 0.02
Hot water extract (Lit deg Kg^{-1})	41.28 ± 0.15	49.51 ± 0.16	130.17 ± 0.20	177.74 ± 0.00	157.03 ± 0.06
Diastatic power (°L)	3.70 ± 0.15	8.90 ± 0.01	12.30 ± 0.03	16.9 ± 0.02	14.70 ± 0.04
Malting loss (%)	0 ± 0.00	13.41 ± 0.03	17.49 ± 0.01	22.82 ± 0.02	42.92 ± 0.03
Wort filtration rate (ml/20 min)	5.0 ± 0.29	5.90 ± 0.01	6.30 ± 0.20	14.30 ± 0.01	15.4 ± 0.00

The cold water extract progressively increased (3.09, 3.75 and 8.30(%) for 2, 4 and 6 days of germination respectively) and declined to (6.89%) at the eighth day, as compared to that of the control (2.55%). These findings suggests that increase in duration of germination led to increased enzymatic activity of malt which fell off after the sixth day.

However, Hot water extract was found to increase (49.51, 130.17 and 177.74 Lit. deg. Kg^{-1} for 2, 4 and 6 days respectively) and decreased to 157.03 Lit. deg. Kg^{-1} at the eight day of germination as compared to the control (41.28 Lit deg. Kg^{-1}). The results indicates that for this variety of sorghum, high yield in H.W.E. can be attained by germinating grain between 4 and 6 days duration.

The diastatic power of malt was found to increase from (8.9 to 16.9°L) between 2 - 6 days of germination. These findings were parallel to those reported by Gbolahan (1989) and Siddappa (1954). However, Alslen and Muts (1987) reported a higher value (28°L) when sorghum grain were malted for 5 days using micro-malting plant. Various factors such as temperature of germination, variety of grain, aeration (Novellie, 1962c) may have resulted in low diastatic power of this particular grain.

The wort filtration rate showed continual increase (5.0 - 15.4 ml/20 min.) from 2 - 8 days germination period. Thus, indicating increase in grain modification (break - down of β - glucans) with increase in duration of germination.

Fig.3 shows the effect of duration of germination on the activities of amylolytic enzymes (α and β - amylases) over 8 days of germination. From the curve, the level of α - amylase was found to be low in raw grain but increased sharply upto about 2 days of germination. It then rose gradually and almost plateaus between 4 and 6 days after which it dropped gradually. These findings were in agreement with that of (Novellie, 1959) and may explain the high H.W.E. C.W.E., D.P. and WFR obtained within these periods of germination.

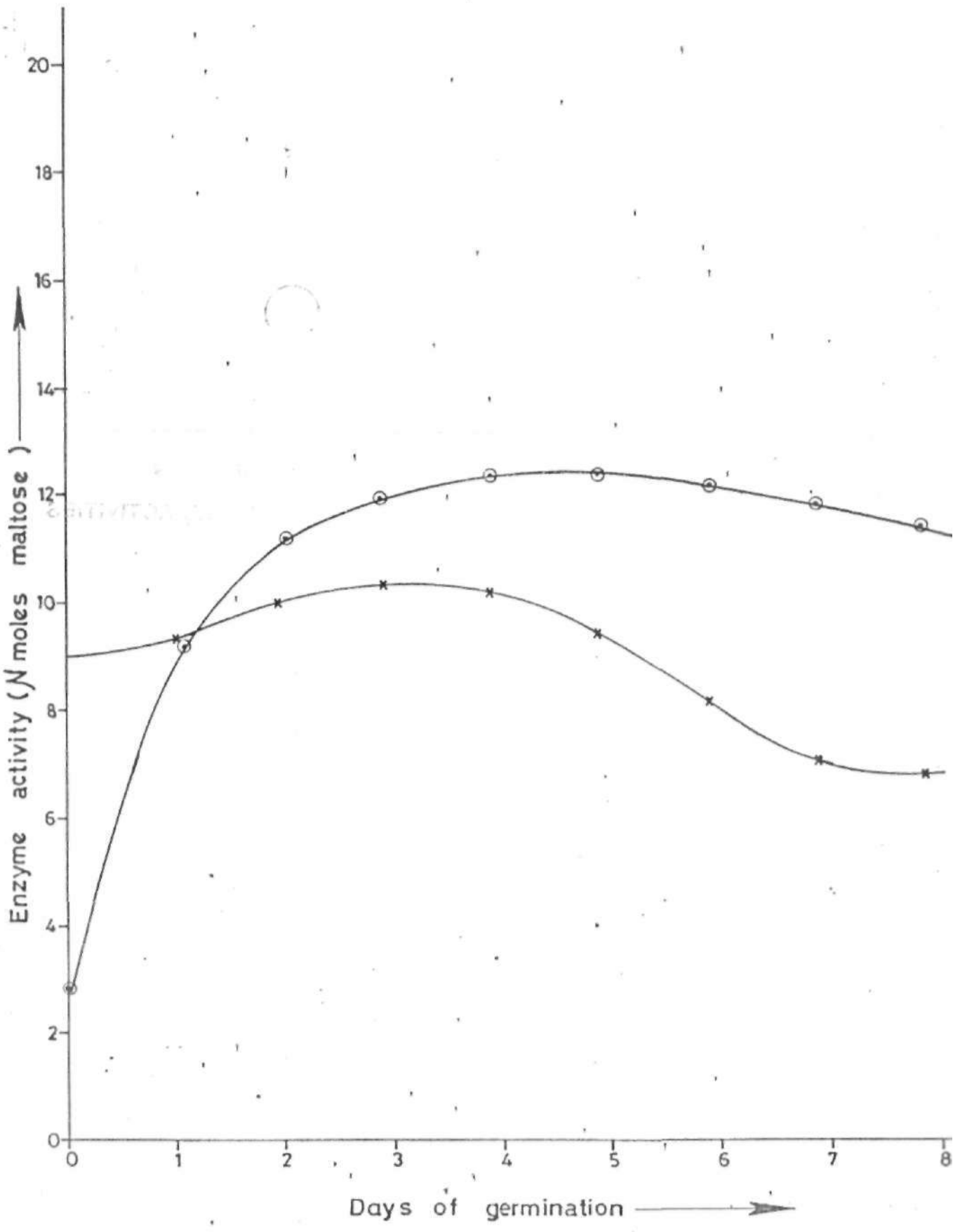

Enzyme activity (N moles maltose)
20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
Days of germination

Fig 3

On the other hand β - amylase activity was detected in the raw grain contrary to commonly accepted views (Novellie, 1960c) and its activity was found to rise only slightly to a peak after 3 days and dropped gradually with continual germination. This result confirmed the findings of (Novellie, 1960b) that the enzyme may be present in sorghum grain as a zymogen and is only activated during germination.

Proteolytic activity of sorghum (Fig.4) gradually increased and soon reached a peak at about the fourth day of germination and decline thence forth. High proteolytic activity is desirable during malting as it was in this study in order to maximise soluble nitrogen needed for yeast nutrition during fermentation.

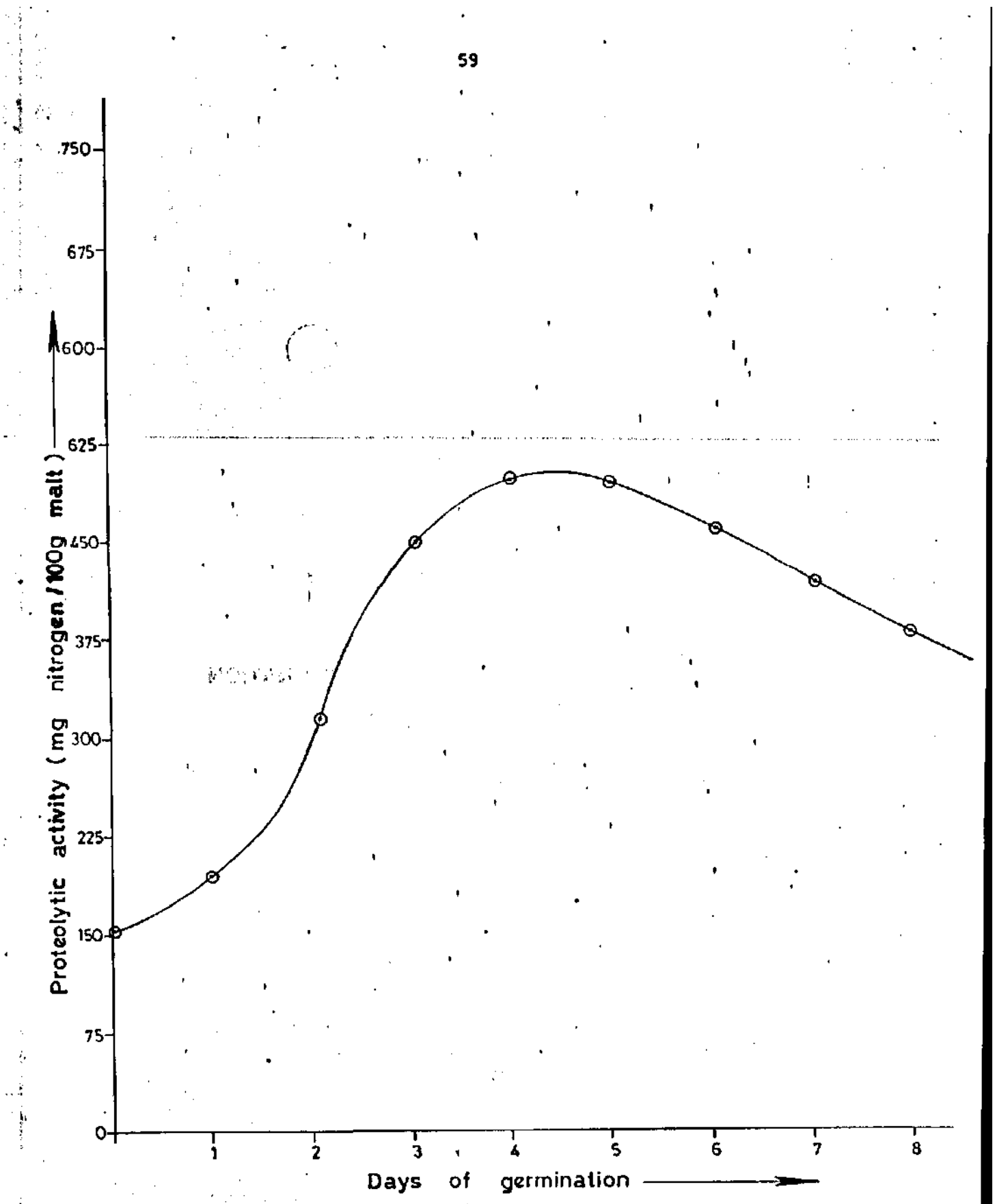

Proteolytic activity (mg nitrogen / 100g malt)
750
675
600
625
450
375
300
225
150
75
0
1
2
3
4
5
6
7
8
Days of germination

Fig 4

The sensory data show that panellists were able to detect differences in foam potential (chi-square = 3.98 and 1.63 for sorghum and star lager beers respectively). The chi-square value obtained for sorghum fall within the rejection region of the expected chi-square value (3.325), used throughout the analysis at 95% confidence limit. The poor foam stability of sorghum beer could be attributed to many causes. The carbonation process was carried out manually (due to small scale production). This made it technically impossible to carbonate beer upto the required pressure due to lack of filter counter pressure as is normally the case. A deviation as small as half a pound in pressure (representing 0.05 volume of carbondioxide) is significant (Hough, et al 1971), loss of isohumulones during beer filtration, low levels of some high molecular weight proteins and high lipid content contribute significantly to loss in beer foam (Joseph, 1976).

Table 6 shows the results of the chi - square analysis of sorghum and star lager beer.

Table 6 Results of chi - square analysis

PANELLIST	FOAM	COLOUR	ODOUR	BITTERNESS	BODY-FULNESS	BRIL-LIANCE	SPARKLING	SOURNESS	TOTAL
CHI-SQUARE FOR STAR BEER	1.63	1.66	0.56	2.73	0.51	1.05	1.76	0.87	
CHI-SQUARE FOR SORGHUM BEER	3.98	2.25	0.86	2.82	0.60	1.28	3.36	0.85	

Expected chi-square (from chi-square table) = 3.325 at 0.95 level of significance with degree of freedom (n - 1) = (10 - 1) = 9.

The sensory data shows that beer colour was acceptable for both sorghum and star lager beer (chi square - 2.25 and 1.66; 0.05 level of significance for sorghum and star beer respectively). The low tannin levels of this variety of sorghum, the moderate wort boiling time coupled with low pH during mashing must have attributed to acceptable beer colour.

From the result of the organoleptic assessment chi-square values of 2.70 and 0.90 were obtained for sorghum and star beer respectively. These values fall within the acceptance region. This suggests that the fermentation process was effectively controlled, so off-flavour components such as diacetyls, vicinal diketones, hydrogen sulphide etc, were virtually absent (Briggs, et al., 197; De clerk, 1957; Joseph, 1977).

Bitterness in beer is attributed to hop resins, however, the presence of tannins in sorghum have been reported to impart astringency to beer, thereby deepening the bitter taste (Arri, 1989; Ikediobi, 1989; Aisien and Muts, 1987). Results of the sensory evaluation show that bitterness was acceptable for both sorghum and star lager beer (chi-square 2.82 and 2.73 for sorghum and star beer respectively) at the 0.05 level of significance. Both values fall within the acceptable region (3.325). This might be due to the low tannin level in this sorghum variety and probably explains the absence of astringent flavour in the beer. (Aisien and Muts, 1987).

Low levels of ß - glucanase and ß - amylase activities in sorghum malts have been held responsible for incomplete degradation of ß - glucans and limit dextrins resulting in high viscosity (bodylulness) in beer (Palmer, 1969; Briggs, et al., 1981; De clerk, 1957). The sensory data shows that body fullness was acceptable for both sorghum and star lager beer (chi-square = 0.60 and 0.51 respectively at the 0.05 level of significance).

From the sensory data, chi-square values obtained for brilliance were 1.05 and 2.28 for star and sorghum lager beer respectively. These values fall within the acceptable region of the expected chi-square (3.325). This is probable due the use of Kieş selghur (filter aid) which must have enhanced the removal of cloudy trub formed during the course of processing thereby giving an acceptable brilliant beer.

From the analytical results obtained panellists were found to reject the sparkling for sorghum beer in comparison to the control (chi-square = 3.36 and 1.76 respectively). The low counter pressure employed during carbonation contrary to what is obtainable in practice as well as the pre-chilling process prior to serving may have been responsible for this result.

Finally, sourness gave chi - square values of 0.85 and 0.87 for sorghum and star beer respectively, both of which fall within the acceptance region (3.325). As discussed earlier adequate control measures during fermentation must have moderated the production off flavour (organic acids) compounds to acceptable levels in beer during fermentation.

CONCLUSION

1. The analytical results obtained on the effect of duration of steeping on malt quality, showed, that shorter steeping duration enhance better malt quality than do prolonged steeping of the variety studied.

2. The result obtained indicated on the average that the use of alkaline steeping using 0.2% calcium hydroxide enhanced better malt quality.

3. Studies carried out on the effect of duration of germination on malt quality showed that (2-6 days) germination gave better malt characteristics.

4. From the results of the physical and chemical analysis of the sorghum variety studied, it has characteristics that are as acceptable as any other sorghum variety so far used to supplement barley malt in brewing.

5. Sensory evaluation of sorghum larger beer produced on a laboratory scale, was as acceptable as star lager beer except for foam, and, sparkling.

RECOMMENDATION FOR FURTHER WORK

1. There is need for screening of local varieties of sorghum for their malting characteristics

2. Crop breeders should intensify research in order to develop sorghum hybrids with high diastatic activity.

3. Research findings should be intensified on screening and induction of amylolytic, proteolytic and ß - gluncanases enzymes from microorganisms in order to supplement their low activities in malted sorghum and to forestall the high cost of their importation.

4. There is need to include cyanide estimation in the assessment of sorghum malt to forestall the incidence of cyanide toxicity in sorghum malt products.

5. There is need to screen more varieties of sorghum for low tannin content in other to reduce the off colour and astringency associated with this cereal.

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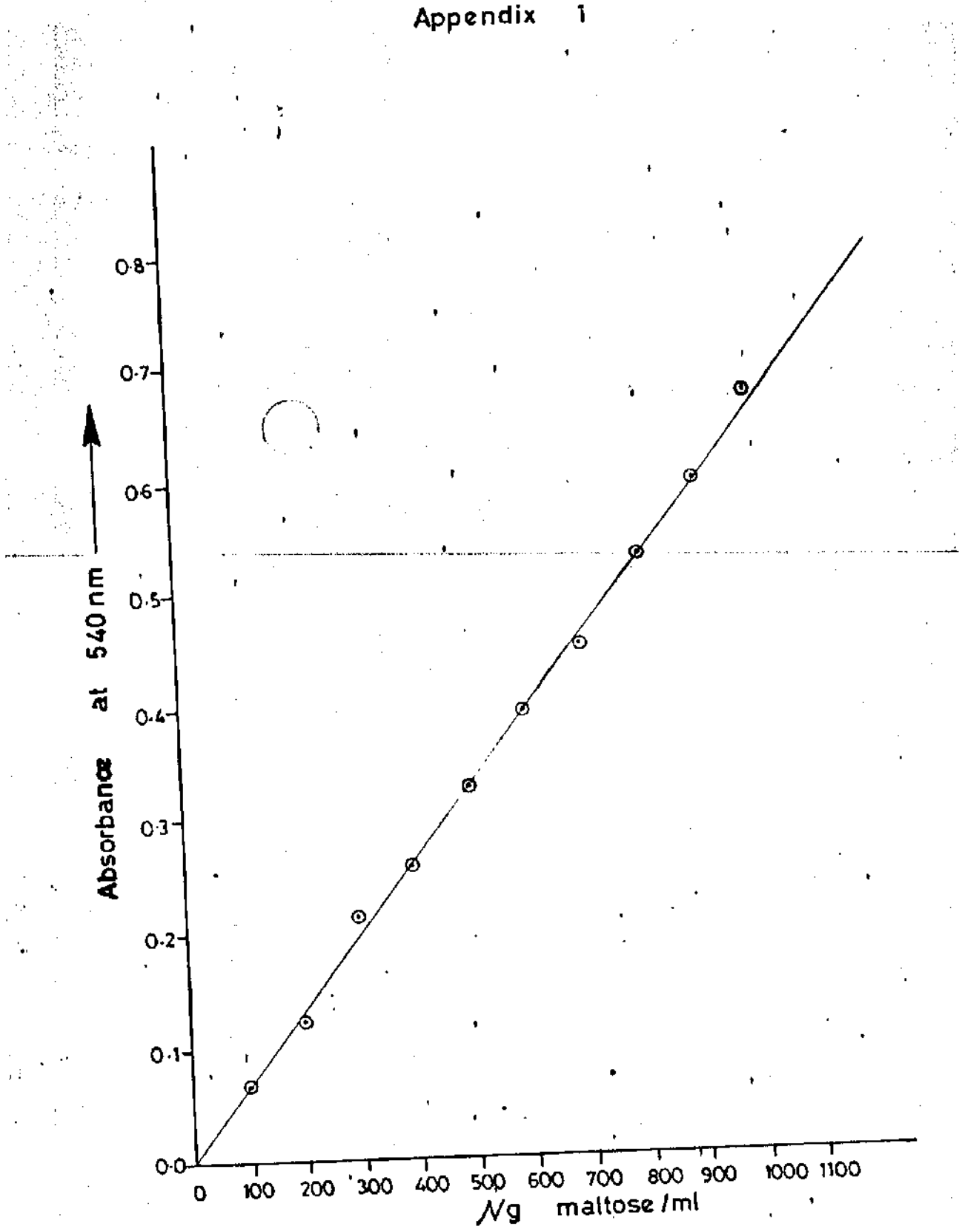
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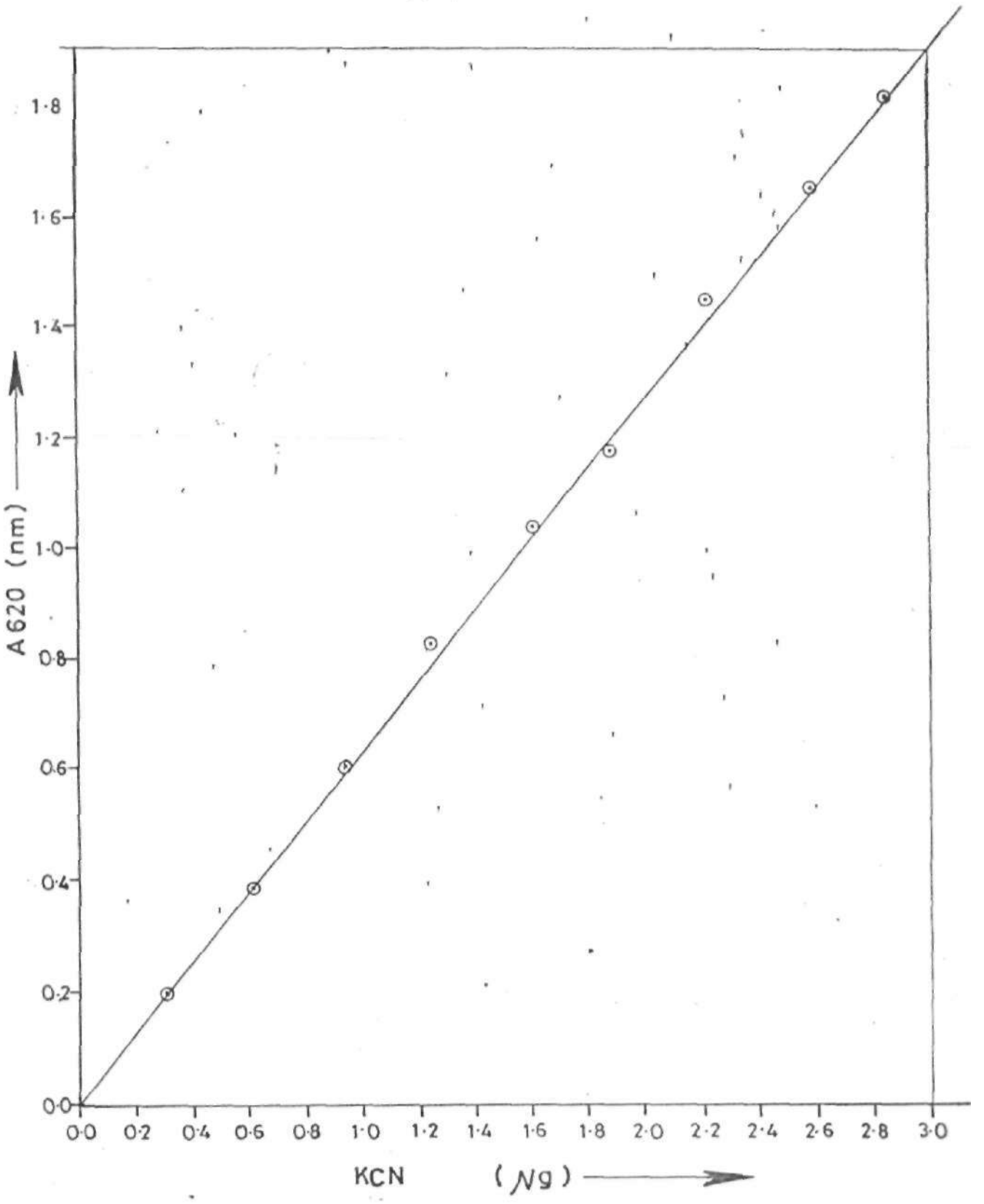
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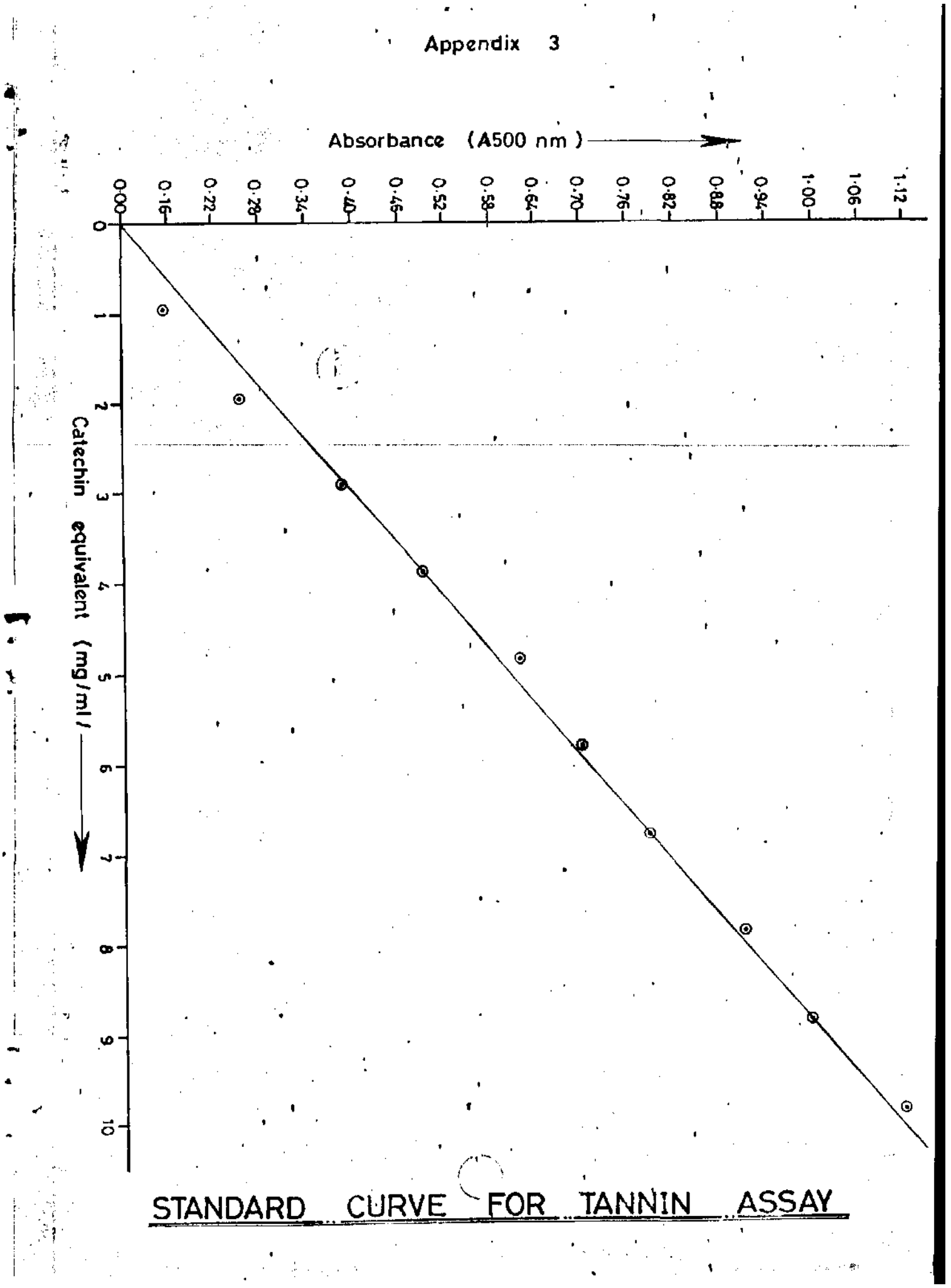
STANDARD MALTOSE CURVE

Appendix 2



STANDARD CURVE FOR CYANIDE ASSAY

Appendix 3



STANDARD CURVE FOR TANNIN ASSAY

APPENDIX 4.

QUESTIONNAIRE FOR ORGANOLPEPTIC ASSESSMENT OF LAGER BEER

Instruction: Assess the following samples glasses (1 - 3) for (foam, stability, colour, odour, bitterness, bodyfulness, brilliance, sparkling and sourness), and enter the appropriate score for each parameter on the questionnaire provided according to the table shown below:-

Parameter

Parameter	Grade	Score	Parameter	Grade	Score
Foam	Very good	5	Bodyfulness	Not watery	5
	Good	4		Moderately watery	4
	Fairly good	3		Watery	3
	Fair	2		Very watery	2
	Poor	1		Extremely watery	1
Colour	Golden yellow	5	Sparkling	Excellent	5
	Gold	4		Good	4
	Amber	3		Fairly good	3
	Brown	2		Fair	2
	Colourless	1		Poor	1
Odour	Very pleasant	5	Brilliance	Extremely brilliant	5
	Moderately pleasant	4		Very brilliant	4
	Pleasant	3		Slightly brilliant	3
	Slightly pleasant	2		Brilliant	2
	Unpleasant	1		Not brilliant	1
Bitterness	Slightly bitter	5	Sourness	Slightly sour	5
	Bitter	4		Moderately sour	4
	Very bitter	3		Sour	3
	Extremely bitter	2		Very sour	2
	Not bitter	1		Extremely sour	1

Appendix (5)

Score sheet for organoleptic assessment of lager beer.

	Glass 1	Glass 2	Glass 3	Glass 4
Foam	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Colour				
Odour				
Bitterness				
Bodyfulness				
Brilliance				
Sparkling				
Sweetness				
Sourness				
TOTAL				

Appendix 6

Sensory analysis data for sorghum lager beer

PANELLIST	FOAM	COLOUR	ODOUR	BITTERNESS	BODY-FULNESS	BRIL-LIANCE	SPARKLING	SOURNESS	TOTAL
1	1	1	4	3	3	2	1	2	17
2	1	5	3	1	4	2	1	5	22
3	1	4	2	2	3	3	1	5	21
4	3	4	4	5	5	5	5	4	35
5	1	5	2	4	3	3	2	3	23
6	1	5	2	4	4	3	1	5	25
7	1	1	2	3	2	3	3	3	18
8	5	4	4	4	4	4	1	5	31
9	2	3	2	3	4	4	2	4	24
10	3	3	3	1	3	3	3	5	24
TOTAL	19	35	28	30	32	20	20	41	240

Appendix 7

Sensory data for star lager beer

PANELLIST	FOAM	COLOUR	ODOUR	BITTERNESS	BODY-FULNESS	BRIL-LIANCE	SPARKLING	SOURNESS	TOTAL
1	5	5	5	4	5	5	5	2	36
2	5	5	4	4	4	2	4	5	33
3	5	5	3	4	5	4	4	4	34
4	4	4	4	5	5	5	5	4	36
5	5	4	4	4	4	4	5	4	34
6	5	5	4	4	4	4	5	5	36
7	4	3	4	3	3	3	4	4	28
8	5	3	5	2	5	2	5	5	32
9	5	5	5	4	3	5	3	4	34
10	3	5	3	5	4	5	5	5	35
TOTAL	46	44	41	39	42	39	45	42	338