Aspects of the manufacture and consumption of Kenyan traditional fermented beverages

Promotor: dr. E.H. Kampelmacher, buitengewoon hoogleraar in de voedingsmiddelenmicrobiologie en -hygiëne

M.J.R. Nout

Aspects of the manufacture and consumption of Kenyan traditional fermented beverages

Proefschrift
ter verkrijging van de graad van
doctor in de landbouwwetenschappen,
op gezag van de rector magnificus,
dr. C.C. Oosterlee,
hoogleraar in de veeteeltwetenschap,
in het openbaar te verdedigen
op woensdag 9 september 1981
des namiddags te vier uur in de aula
van de Landbouwhogeschool te Wageningen

ISN= 90-220-0774-03

The investigations described in this thesis have been carried out in the Department of Food Science and Technology, University of Nairobi, Kenya, the Laboratory of Food Science, Federal School of Technology, Zürich, Switzerland, the Laboratory of Microbiology, Delft University of Technology, the Netherlands, the Department of Clinical Biochemistry, CIVO-TNO, Zeist, the Netherlands, and the Company Laboratory of Kenya Breweries Ltd., Nairobi, Kenya.

Cover: Traditional Chekwè party

Errata

p.84, reference (13) should read :

(13) Pollock, J.R.A., Essery, R.E. & Kirsop, B.H., J. Inst. Brew., *61* (1955) 295-300.

p.94, line 12 :

"Reissenweker" should read : "Reissenweber".

Stellingen

1. Hoewel de voedingswaarde van Afrikaanse troebele bieren in bepaald opzicht hoger is dan die van helder gerstebier, mag dit geenszins worden opgevat als verontschuldiging voor onbeperkte consumptie van eerstgenoemde produkten.
Platt, B.S., Food Technol., *18*(1964)662-670.
Chevassus-Agnes, S., Favier, J.C. & Joseph, A., Cahiers de Nutrition et de Diététique, *11*(1976)89-104.
Dit proefschrift, hoofdstuk 6.

2. Akinrele's veronderstelling dat geen zetmeelafbraak optreedt gedurende het weken van maïskorrels in water tijdens de ogi-bereiding, is ongegrond.
Akinrele, I.A., J.Sci.Fd Agric., *21*(1970)619-625.
Dit proefschrift, hoofdstuk 8.

3. Overmatige fermentatieve verzuring van Busaa kan het meest effectief worden voorkomen door pasteurisatie van dit produkt. Indien pasteurisatie niet kan of mag worden toegepast, kan deze verzuring twee weken worden uitgesteld door bewaring bij 3-5°C.
Dit proefschrift, hoofdstuk 9.

4. Gezien de verdovende eigenschappen van foezelalcoholen mag worden verondersteld dat de - regelmatig met fatale gevolgen gepaard gaande - verslaving aan Chang'aa mede wordt veroorzaakt door het vaak hoge foezelgehalte van dit produkt.
Müller-Limmroth, W., Piendl, A. & Hoffmann, H., Brauwiss., *30*(1977)303-311.
Dit proefschrift, hoofdstuk 7.

5. In de methode, beschreven door Bathgate, ter bepaling van de activiteit in mout van "endo-β-glucanase", wordt dit enzym ten onrechte vermeld als β-(1,4)-glucaan 4-glucanohydrolase: EC 3.2.1.4. Bovendien is het aannemelijk dat, door de keuze van gezuiverd β-glucaan uit gerst als substraat, deze methode niet specifiek is voor het enzym endo-β-glucanase (endo-1,4:1,3-β-glucaan 4-glucanohydrolase), maar ook tegelijkertijd de activiteit van o.a. cellulase (β-(1,4)-glucaan 4-glucanohydrolase) weerspiegelt. Zonder verdere kennis omtrent de structuur van β-glucanen van andere graansoorten, en de intrinsieke enzymen die kunnen leiden tot hun afbraak, verdient het geen aanbeveling de eerder genoemde methode toe te passen ter voorspelling van de filtreerbaarheid van wort, bereid uit mout van andere graansoorten dan gerst.
Bathgate, G.N., J.Inst.Brew., *85*(1979)92-94.
Fincher, G.B., J.Inst.Brew., *86*(1980)163.
Dit proefschrift, hoofdstuk 10.

6. Gezien vanuit het oogpunt van volksgezondheid, aanvaardbaarheid, en verpakkingskosten, verdient de invoering van losse zure melkprodukten de voorkeur boven verpakte gesteriliseerde melk in het Keniaanse schoolmelkprogramma.

7. Het gebruik van een aantal hoogwaardige Afrikaanse traditionele gerechten getuigt van een op lange praktijk berustende wijsheid. Het verdient aanbeveling aandacht te besteden aan promotie - gesteund door produktontwikkeling en conservering - van zulke gerechten teneinde hun verdringing door minder aangepaste of geïmporteerde levensmiddelen te voorkomen.

8. Het zijn tegenwoordig niet zozeer problemen van technische aard, doch politieke factoren, die er in belangrijke mate toe bijdragen, dat - omvangrijk technologisch en op consumenten gericht onderzoek ten spijt - meel van tropische landbouwgewassen, in daartoe geschikte landen, nog slechts in geringe mate als bakkerijgrondstof wordt toegepast.

9. In plaats van het direct overnemen van stringente eisen voor hygiëne en microbiologische kwaliteit van levensmiddelen zoals aanbevolen door een aantal internationale organisaties (WHO, Codex Alimentarius, e.a.), zouden ontwikkelingslanden gebaat zijn bij een genuanceerd systeem waarin zulke normen geleidelijk aan worden verscherpt.

10. Het toenemende Salmonella-probleem in ontwikkelde landen is een van de voorbeelden, die aantonen dat de begrippen "ontwikkeld" en "verstandig" niet verward mogen worden.
Oosterom, J., Wit, J.C. de, Schothorst, M. van, Leusden, F.M. van & Kampelmacher, E.H., Zbl.Bakt.Hyg., I.Abt.Orig. A*248*(1980)190-201.

11. Beroepsmatige wisselwerking tussen buitenlandse en plaatselijke collega's wordt bevorderd door een zodanige mate van kennismaking, dat het woord "buitenlander" zijn bijklank "vreemdeling" verliest. De hokjesgeest, en relatief grote persoonlijke luxe, die zich regelmatig manifesteren bij buitenlanders werkzaam in ontwikkelingslanden, dragen tot zulke kennismaking niet bij.

12. Tijdens de voorbereiding en uitvoering van projecten voor technische samenwerking met ontwikkelingslanden wordt herhaaldelijk onvoldoende aandacht besteed aan het feit, dat de te verschaffen faciliteiten door de ontvangende instantie, na beëindiging van zulke projecten, vaak niet optimaal kunnen worden benut.

13. Recent onderzoek wijst uit dat het tot poeder vermalen hoornmateriaal van neushoorns een belangrijke rol speelt in de traditionele Chinese geneeskunde, met name ter behandeling van koortsen. Afgezien van het belang van natuurbehoud, zou deze rol reden genoeg moeten zijn voor de betrokken Chinese autoriteiten om koortsachtig mede te werken aan het voorkomen van de dreigende uitroeiing van deze diergroep.
Martin, E.B., The international trade in rhinoceros products. A report for the WWF and the IUCN, 1979.

M.J.R. Nout
Aspects of the manufacture and consumption of Kenyan traditional fermented beverages
Wageningen, 9 september 1981

Acknowledgements

I would like to express my gratitude to Professor E.H. Kampelmacher for his active interest in the subject studied, and his guidance during the preparation of this thesis.

I would like to express my sincere thanks to the Office of the President of the Republic of Kenya for the permission granted to carry out nation-wide field-work in Kenya.

I am much indebted to dipl. Ing. agr. W. Schulthess and my colleagues of the Department of Food Science and Technology, University of Nairobi, and to members of the Kenyan public for their encouragement, inspiring discussions, and untiring co-operation in the field. *Asante sana!*

I would like to recall the highly appreciated co-operation of Messrs. H.P. Neukom and K. Grob Jr., Kantonales Labor, Zürich, Switzerland, of Drs. L. Rodrigues de Miranda, Centraalbureau voor Schimmelcultures, Yeast Division, Delft, the Netherlands, of Ir. J. van der Toorn, Laboratory of Microbiology, Delft University of Technology, the Netherlands, of Mr. B.J. Davies, Kenya Breweries Ltd., Nairobi, Kenya, of Dr. W.H.P. Schreurs, Head of the Department of Clinical Biochemistry, CIVO-TNO, Zeist, the Netherlands, and of Dr. A. Williams and Mr. R.G. Barber of the Departments of Food Science and Technology, and Soil Science, respectively, University of Nairobi, Kenya.

The skillful technical assistance of Messrs. B.O.J. Odenyo, J. Ngige, and A. Murundo, Department of Food Science and Technology, University of Nairobi, and of Messrs. G.F. Ndubi and S.K. Shah, Kenya Breweries Ltd., Nairobi, Kenya, is gratefully acknowledged.

Finally I must acknowledge with gratitude the great assistance given me by my wife.

Contents

1 Introduction

Kenya straddles the equator in East Africa and occupies an area of 584,000 km^2 (approximately 17 x the size of the Netherlands). Figure 1 shows a sketch of the country, its 8 provinces, 41 districts, and the major towns (provincial headquarters). As a result of the wide variation in altitude (highest point: Mount Kenya 5200 m), a variety of climatological zones exists, ranging from desert to humid-tropical to alpine. Table 1 summarises the major areas and their climatological characteristics.

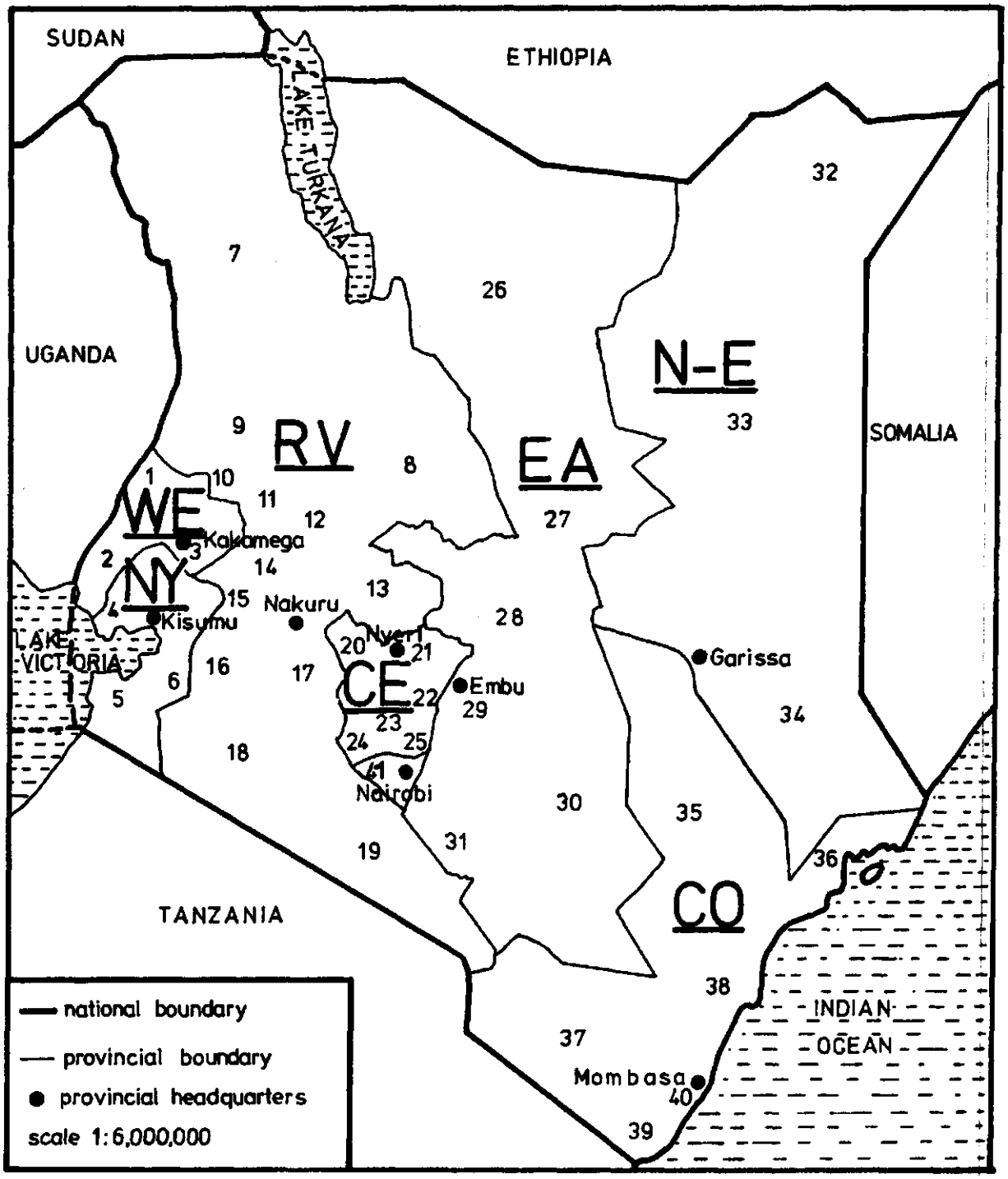
Table 1. Kenya: climatological zones acc. to Bhushan (10).

Area	Av.altitude (m)	Av.annual rainfall (mm)	Temperature min. (^oC)	max. (^oC)	Description
Western Kenya	1150	1000-1300	16	32	hot and rainy all year with typical rain forest vegetation, now extensively cultivated.
Rift Valley and Highlands	1650	750-1200	12	24	temperate climate with two rainy seasons from March to May and October to December; the Highlands are the most productive agricultural areas of Kenya.
Northern and Eastern Kenya	130	250- 500	22	34	semi-desert and desert areas with little vegetation, the home of pastoralists.
Coastal belt	17	1000-1250	22	30	warm and humid, thin coastal belt suitable for farming, giving away to thorn scrub and semi-desert inland.

The Kenyan population, estimated at 15.2 million by the 1979 census, comprises 98 % Africans, with the remaining 2 % consisting mainly of Asians. The African population comprises three major ethnic groups; the numerical strength, tribes, and their traditional residential areas are summarised in Table 2.

Although industrialisation and commerce are increasingly gaining momentum in Kenya, it is nevertheless an agricultural country, where the majority of the population is engaged in agriculture.

Figure 1. Kenya: provinces and districts*).



*) adapted from Van der Mark (49).

Legend to Figure 1.

WE Western Province	15 Nandi district	30 Kitui district
1 Bungoma district	16 Kericho district	31 Masaku district
2 Busia district	17 Nakuru district	
3 Kakamega district	18 Narok district	N-E North-Eastern Province
	19 Kajiado district	32 Mandera district
NY Nyanza Province		33 Wajir district
4 Siaya district	CE Central Province	34 Garissa district
5 Nyanza district	20 Nyandarua district	
6 Kisii district	21 Nyeri district	CO Coast Province
	22 Kirinyaga district	35 Tana River district
RV Rift Valley Province	23 Murang'a district	36 Lamu district
7 Turkana district	24 Kiambu district	37 Taita district
8 Samburu district	25 Thika district	38 Kilifi district
9 West Pokot district		39 Kwale district
10 Trans Nzoia district	EA Eastern Province	40 Mombasa district
11 Elgeyo Marakwet district	26 Marsabit district	
12 Baringo district	27 Isiolo district	
13 Laikipia district	28 Meru district	41 Nairobi area
14 Uasin Gishu district	29 Embu district	

However, only approximately 35 % of the gross national product is derived from this sector (10,49) due to widespread subsistence farming.

Table 2. The major ethnic groups of Kenya acc. to Bhushan (10).

Ethnic group	% of African population	Major tribes	Main area
Bantu	66.5	Central Bantu: *Kikuyu, Embu, Meru*	Rift Valley and Highlands
		Western Bantu: *Luhyia, Kisii, Kuria*	Western Kenya
		Eastern Bantu: *Kamba, Kenda, Swahili, Pokomo*	Eastern Kenya and Coast
Nilotes	30.4	Highland Nilotes: *Kipsigi, Nandi, Pokot, Suk, Tugen*	Rift Valley and Highlands
		River/Lake Nilotes: *Luo*	Western Kenya
		Plains Nilotes: *Maasai, Samburu, Turkana*	Rift Valley
Cushites (Hamites)	3.1	*Somali, Galla, Rendille*	Northern and Eastern Kenya

As a background to the following chapters, a few relevant aspects (mainly derived from Acland (1)) are presented of those agricultural crops grown in Kenya which, among others, provide ingredients for the manufacture of fermented beverages. These are mainly cereals (maize, sorghum, finger millet, bulrush millet, barley), sugarcane, and coconut palms.

Maize (*Zea mays*) is the most important staple crop in Kenya. It is grown throughout the country but in particular in the Western, Rift Valley, Central, and Eastern Provinces. Almost exclusively, white dent floury cultivars are grown which produce a creamy white meal when processed. All the maize produced is used for human consumption. The majority is processed either by hammer milling or (increasingly) by extraction milling into a coarse meal (either whole or sifted). A common dish prepared by cooking maize meal and water is Ugali, characteristically a stiff porridge.
Maize meal is also used in the preparation of fermented products. When maize meal is immersed in water and left overnight at ambient temperatures, a spontaneous souring takes place as a result of microbial activity in the presence of fermentable sugars derived from the maize meal. The resulting sour slurry is added in a certain proportion to boiling water, which causes the maize meal to gelatinise and produces a viscous gruel (Uji), which has a pleasant and refreshing sour taste.
The names Ugali and Uji are not specifically used to denote maize-derived dishes. Ugali (stiff porridge) and Uji (gruel) are also prepared from sorghum, millets, and cassava.
A third product in which maize meal is used as an ingredient is Busaa, a traditional beer. A description of this product and its manufacture will be given in Chapter 2.
Table 3 summarises the estimated maize production in 1978, its mode of processing, and a breakdown of the various uses of maize meal (Kariungi, F.T., personal communication).

Table 3. Kenya: estimated maize production, processing and utilisation (1978).

NET MAIZE PRODUCTION (*i.e.* after post-harvest losses): 1.7 $.10^6$ tonnes		
PROCESSING:		% of net production
Hammer milling		45
Extraction milling		16
Others (incl. fresh consumption and starch manufacture)		39
UTILISATION OF MAIZE MEAL (WHOLE & SIFTED) (TOTAL 8 $.10^5$ tonnes)		
Unfermented products:	Ugali (stiff porridge)	81-84 %
Fermented products:	Uji (gruel)	10-12 %
	Busaa (opaque beer)	6- 7 %

The net production includes the marketed maize (through the National Cereals and Produce Board) as well as the non-marketed maize (subsistence farming). It should be noted that although some statistics are available in Kenya, a number of activities mentioned in this study are not yet controlled or recorded. In such cases, estimates based on field-work and interviews have been used in conjunction with official statistics to give an overall impression of the situation.

Sorghum (*Sorghum bicolor*) is mainly grown as a subsistence crop, exclusively for human consumption. Because of its relative resistance to drought it can be grown in areas where poor soil conditions and insufficient rainfall preclude maize cultivation. At present, due to the introduction of maize cultivars of increased drought-resistance, sorghum and maize are often found together in

areas of varying climatological character, *e.g.* in the Western, Eastern, and Rift Valley Provinces. The estimated annual production of sorghum is approximately 200,000-500,000 tonnes.
On a home scale, sorghum grains are pounded or ground to produce meals, ranging in colour from creamy white to pink, which are used in the preparation of Ugali and Uji dishes.
In several African regions (West Africa, East Africa, South Africa) sorghum is a major raw material for the manufacture of sorghum malt and traditional beers. In Kenya however, field observations revealed that sorghum is used in negligible quantities for this purpose.

Finger millet (*Eleusine coracana*) is a millet grown mainly in the warm, humid areas of Zimbabwe, Uganda, Tanzania, and Kenya. It is found mainly in the Lake Victoria region of Kenya, in particular in the Kericho, Kisii, Bungoma, Busia, and Siaya districts.
Although finger millet is a cash crop of considerable importance, notably in the Western Province, official statistics concerning its production are not existent.
The importance of sorghum as a malting cereal in several African regions was mentioned above. In East Africa however, finger millet is the major ingredient used in the traditional manufacture of malt. Although sorghum would be available for malting purposes, local malt manufacturers maintain that finger millet is superior to sorghum in terms of activity and flavour. Because of its popularity as a traditional source of malt, and its limited availability, finger millet is approximately twice as expensive as sorghum or other millets (*e.g.* bulrush millet). This partly explains why only a minor quantity of finger millet is used for food preparation (Ugali, Uji), since it is traditionally considered a luxury item and reserved for special occasions.

Bulrush millet (*Pennisetum typhoides*) is more resistant to drought than sorghum and is therefore found mainly on poor (sandy), arid soils. It is widely distributed in the arid and semi-arid zones of Africa and other continents. In Kenya it is grown mainly in the lower altitude areas of Kirinyaga, Embu, Meru, and Machakos districts.
The yields of this crop are usually 450 kg/ha. Little is known about the area under cultivation or total production, since it is mainly used for subsistence purposes, rather than as a cash crop.
Most bulrush millet is processed into a meal (using mortar and pestle, grinding stones, or hammer mill), which is used in the preparation of Ugali and Uji, either as the sole ingredient, or mixed with sorghum or maize meal. Occasionally, and on a small scale, bulrush millet is used for the manufacture of traditional beer (*e.g.* Marwa in Meru district) (see Chapter 2).

Barley (*Hordeum vulgare*) is grown under contract for Kenya Breweries Ltd., which have their malt factory in Nairobi. The higher altitude areas (mainly in the Rift Valley Province) of over 2000 m are suitable for barley growing; at lower altitudes the rainfall is often too unreliable. The major varieties grown are Proctor, Tumaini, and Research. For the 1980/1981 season 27,500 ha of barley were grown with a total expected production of 54,500 tonnes.
After grading at the maltings plant, the screenings (grains

passing through a 2.2 mm sieve) are used for the manufacture of barley syrup, and approximately 30,000 tonnes of malt are produced per annum (1981).

Sugar-cane (*Saccharum officinarum*) is mainly grown in the Lake Victoria basin (approximately 30,000 ha), and at the coast near the Tanzanian border at Ramisi (approximately 5,000 ha). The main product derived from sugar-cane in terms of tonnage, is white sugar. This is manufactured by seven mills in the Lake Victoria basin, with an estimated annual production of 320,000 tonnes (17), and by one mill at Ramisi, with an annual production of approximately 30,000 tonnes.
The manufacture of another sugar-cane derived product, Jaggery, is more scattered in East Africa than the production of white sugar, which is restricted to the vicinity of sugar-mills. Jaggery factories are small and simple. The sugar-cane is crushed to extract the juice, which is then boiled until it is thick enough to set in moulds when cooled. If good quality cane is used, and if the juice is well clarified, good quality "superfine" Jaggery can be produced. This is a sweetening material used by the Asian community in cooking and in the preparation of sweetmeats. Its use however is declining. Poor quality cane is often used for Jaggery and clarification is given little attention. The result is a bitter product, sometimes called Black Jaggery, which is widely used in the manufacture of traditional spirits (Chang'aa).
Cane is also grown in small plots for direct consumption and brewing throughout the lower altitude, wetter areas of Kenya.

Coconut palms (*Cocos nucifera*) are only of importance along the coast. A rough estimate of the number of coconut palms in Kenya is approximately two million, grown on about 16,000 ha. Their main commercial products are mature nuts, immature nuts, and palm wine. Because of lack of incentive to produce good quality copra, the production and quality of copra is low. The fresh mature fruits, immature fruits, and palm wine are claimed (1) to provide better returns.
Palm wine is obtained by the spontaneous fermentation of palm-sap, collected from the immature inflorescences. After cutting off the tip of the inflorescence, a calabash is attached to collect the sap which trickles from the severed tip. At regular intervals the cutting of the tip must be repeated to provide fresh wound tissue from which the sap can flow.

2 Fermented beverages and their environment in Kenya

2.1 GENERAL

In this study, fermented beverages will be used to denote carbohydrate-based, low viscosity liquids containing a noticeable amount (>1 % by volume) of alcohol. This excludes other, non-alcoholic, fermented products of higher viscosity such as sour milk or Uji.
Furthermore, the fermented beverages consumed in Kenya will be distinguished according to their origin, *i.e.* into traditional and foreign beverages.
Traditional fermented beverages are those which are indigenous to the area and have been developed by the African people themselves. Although the majority of Kenyan traditional fermented beverages have a long history and form an integral part of the culture of the land, the word "traditional" does not necessarily mean "ancient". It rather indicates that the products are produced using age-old techniques from locally available (mostly home-grown) raw materials. Formulations for traditional beverages are flexible and depend partly on the availability and/or price of the ingredients. This can be illustrated by the following example. According to oral tradition, various Kenyan traditional fermented beverages were prepared from wild honey in the past. Nowadays however, the same traditional beverages are mostly manufactured from either sugar-cane juice, or crude or refined sugar since these are cheaper and more available than honey.

In legal terms, the Traditional Liquor Act (25) describes traditional liquor as:
"(a) Any intoxicating liquor manufactured by traditional African methods, other than distillation, which is offered, or intended to be offered, for sale in a state of continuing fermentation without further processing; or
(b) such other intoxicating liquor manufactured in Kenya, otherwise than by distillation, as the Minister may, by notice in the Gazette, declare to be traditional liquor for the purposes of this Act." (25).

Foreign fermented beverages have been introduced into Kenya, mainly during the 20th century. Missionaries, colonial administrators, and settler-farmers have been instrumental in introducing a variety of technologies and foreign products, including fermented beverages.
Although it is generally known that beer was produced by the Sumerians before 7000 B.C. and wine by the Assyrians in 3500 B.C., specific types of beer developed in Europe as a result of techno-

logical progress and regional taste preferences. These specific types of beer such as lager, ale, porter, bock, etc., could therefore be termed as "indigenous" or "traditional European beers".

One relevant difference between the two groups, namely Kenyan and European traditional fermented beverages should be indicated. During the past few centuries, European traditional fermented beverages (ales, lager beers, wines, and spirits) have been subject to a gradual process of sophistication as a result of rapid scientific and technological development. The European beers and wines of say, 200-300 years ago would therefore be rejected by most present-day consumers on the grounds of their turbidity, poor shelf-life, and fluctuating quality characteristics. Kenyan (and most African) traditional fermented beverages have not yet benefitted from the scientific and technological developments mentioned above. Their status could therefore be conveniently compared to that of the European fermented beverages of before the industrial and technological revolution. Consequently, a wide scientific/technological gap separates the Kenyan traditional fermented beverages from the foreign fermented beverages of today.

2.2 KENYAN TRADITIONAL FERMENTED BEVERAGES

As mentioned in Section 2.1, the traditional fermented beverages are prepared from locally available ingredients. The origin of some Kenyan traditional fermented beverages can therefore be traced to those regions where soil and climatological conditions permit the production of the essential ingredients. This is illustrated by *e.g.* the manufacture of palm wine which originated at, and is still limited to the coastal belt, since this is the sole region in Kenya where palms grow in abundance. Likewise, honey-based wines originate from forest and bush areas where wild honey was available in sufficient quantities.
Although documentary evidence is not available, it appears that occupational factors also played a role in the emergence of fermented beverages. Whereas most agricultural societies prepare traditional fermented beverages from ingredients containing carbohydrates as the major constituent, the pastoral tribes (*e.g.* the Maasai) do not appear to make fermented beverages, other than sour milk products.
At present, these rather well-defined regional and possibly occupational patterns have disappeared to some extent as a result of improved infrastructure and increased migration (urbanisation).

For the purpose of this study , beers are defined as those beverages formed by alcoholic fermentation of sugars in solution, which have been generated by a brewing (saccharification) process. Wines, on the other hand, are obtained from raw materials containing naturally occurring fermentable sugars. Based on these definitions, the Kenyan traditional fermented beverages can be distinguished into beers, wines, and spirits (distilled from beers or wines).

2.2.1 Beers

2.2.1.1 Introduction

Pombe is a general name to denote African opaque beers made from maize, sorghum, or millets. Several types of Pombe have been described (13, 30, 36) which differ in characteristics and chemical composition as a result of specific ingredients and traditional processes involved in their manufacture.
The Kenyan traditional beers can all be classified as Pombe. They are however significantly different from one each other with regard to ingredients used and methods of preparation.

2.2.1.2 Busaa

Busaa is an opaque maize beer and originates from the western part of Kenya, where it plays an important role in the traditional Bantu and Nilotic cultures, particularly in the Luhyia, Luo, Kisii, and Kuria tribes. At present, the habit of Busaa consumption has spread all over Kenya as a result of the increased migration of people from western Kenya throughout the country, and in particular to the urban areas.

The traditional process for the manufacture of Busaa has been described by Saint-Hilaire and Weibel(44). In principle, Busaa is obtained by a two-stage fermentation process. In the first stage, a stiff mixture of water and raw maize meal is allowed to ferment at ambient temperatures (22-30 ^{o}C) for two to three days, which results in its acidification. Subsequently, the soured mass is roasted (Plate 1). The roasting operation results in a partial gelatinisation of the maize starch and the formation of a desirable roasted flavour. In the second stage, the roasted fermented maize crumb is mixed with water, and finely ground malt made from finger millet is added. The mixture is allowed to ferment at ambient temperatures for two to three days. During this second phase, simultaneous generation of fermentable carbohydrates (from the maize and millet, by amylases from the finger millet malt) and fermentation take place.
The (spontaneous) fermentation results in the formation of, among others, alcohol and lactic acid. The final product contains varying amounts of alcohol (2-4 % v/v)(volume/volume) and lactic acid (0.5-1.0 % w/v)(weight/volume). At the time of consumption, good quality Busaa has an opaque, creamy brown appearance due to a stable dispersion of starch and other cereal residues. However, after prolonged storage, fermentative acidification continues and the stability of this dispersion breaks down, resulting in a separation of sediment and clear supernatant. Due to the visual deterioration and increased sourness, the product becomes unacceptable and is rejected (personal communications from several beer hall operators).
After fermentation, Busaa contains a considerable amount of coarse particles originating from the maize meal and finger millet malt. These are usually removed prior to consumption by straining. Traditionally, this is achieved using filters which have been attached to wooden drinking straws through which the beer is sucked from a pot. Using such straws, a group of people, sometimes as many as 60, share a pot of Busaa.

Plate 1.
Roasting of fermented maize as part of the Busaa manufacturing process.

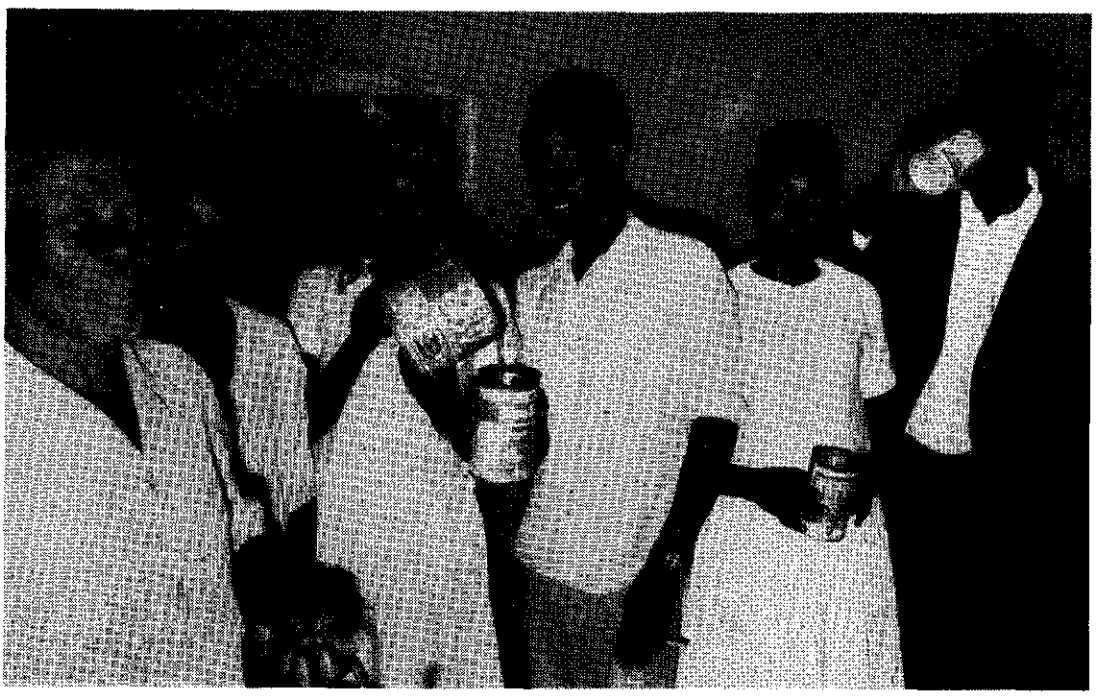


Plate 2. Busaa is nowadays mainly consumed from mugs or margarine tins.

Because of the present wide distribution of Busaa consumption throughout the country, and the increased commercialisation of the product, the traditional method of consumption (using drinking straws) is gradually disappearing. Nowadays, the crude beer is often strained through a coarse milk sieve, and is then drunk from plastic mugs or margarine tins (Plate 2).

2.2.1.3 Chekwè

Chekwè is a finger millet opaque beer, and is consumed in limited quantities in the Busia and Bungoma districts by the Luyia people. In contrast to Busaa, Chekwè is still very limited to its area of origin.
Because of the relative high price of finger millet, Chekwè is a more expensive beer and is therefore kept for special occasions (Amoth, M.C., personal communication). Still strongly associated with the local culture, Chekwè is consumed communally (by social clubs, at festivities, etc.) using the traditional drinking straws. Plate 3 shows a close-up of the woven filters which are permanently attached to the drinking straws. Once in a while, the filter is blocked by the particles from the beer and needs to be tapped gently in order to be freed. The front cover shows a Chekwè party, held by a cultural association (the Lumumba Society) in Busia district. Singing, playing music, story telling, and sipping beer provide for relaxation on Sundays, and play an important role in the life of many people in the rural areas.
The flow-sheet of operations for the manufacture of Chekwè is almost identical to that for Busaa, although instead of uncooked maize meal, freshly ground finger millet is used in the first fermentation stage. After roasting the fermented finger millet mass, the second fermentation phase is initiated by the addition of water, and malt from finger millet. The final product has a pleasant, refreshing sour taste (acidity approximately 0.5-0.8 % w/v as lactic acid) and usually contains 4-5 % v/v alcohol.

2.2.1.4 Marwa

Marwa is an opaque beer, made from bulrush millet only. As far as is known, it is manufactured only in Meru district on the eastern slopes of Mount Kenya where bulrush millet is grown in considerable quantities as a subsistence crop by the Meru tribe (Central Bantu). The Marwa manufacturing process is somewhat more complex than that for Busaa or Chekwè. Malt is made from bulrush millet, which is mashed with warm water. After the required mashing time, the mash is filtered and the liquid concentrated by a long boiling process. A mash concentrate is obtained, which can be stored well in sealed containers until it is required for the manufacture of Marwa. During the Marwa preparation, fresh meal from bulrush millet is cooked with water to form a thin paste, to which the required quantities of mash concentrate and fresh bulrush millet malt are added. A short spontaneous fermentation takes place overnight and results in the final beer. The product has only a short shelf-life since undesirable souring soon takes place (Imungi, J.K., personal communication).

2.2.1.5 Chibuku

In the strict sense of the definition given earlier (Section 2.1), Chibuku is not a traditional fermented beverage, since its manufacture involves foreign technologies (see further). In legal terms however, Chibuku fulfils the description of traditional liquor laid down in the Traditional Liquor Act (25). In 1975, Chibuku was officially gazetted as a traditional liquor for the purposes of this Act.
Chibuku, which could be termed an "industrial imitation traditional maize beer", is obtained by the following process. Whole maize kernels are gelatinised and sterilised by cooking under pressure in an autoclave. After cooling, saccharification is achieved by additions of purified α- and β-amylase enzymes. The opaque mash is then cooled further and inoculated with dehydrated baker's yeast (*Sacch. cerevisiae*) which is responsible for a 24 h alcoholic fermentation at 28-30 °C. The product is sold in a state of active fermentation, as required by the Traditional Liquor Act (25). Because of the continuous CO_2 generation in Chibuku during transport and temporary storage, the product must be kept in open containers. Bulk distribution is carried out by tanker lorries to bars where it is sold from open 50-100 litre vats. Smaller quantities are packed in waxed carton containers of a half or one litre size provided with vented seals, allowing the escape of excess CO_2 gas. At the time of consumption, 30-60 h after inoculation, the product has an alcohol content of approximately 4-5 % v/v.
Chibuku plays an insignificant role in the Kenyan market for traditional fermented beverages (Lancaster, P., personal communication). One major reason is the limited shelf-life of the product (one to two days) which restricts distribution to those areas close to Nairobi, where the only factory is located. An additional factor which affects its consumer appeal is that in contrast to genuine traditional maize and millet beers, fermentative souring does not occur during the manufacture of Chibuku. As a result, Chibuku lacks the attractive refreshing sour taste and aroma of its counterparts. It is therefore considered less acceptable by many regular consumers of traditional fermented beverages (personal communications from several beer hall operators).

2.2.2 Wines

2.2.2.1 Muratina

Mead is a collective name for fermented beverages made from honey which are indigenous to several African countries.
Muratina is the traditional mead of the Central and Eastern Bantu tribes (Kikuyu, Embu, Meru, Kamba). Traditionally, the source of fermentable carbohydrates was wild honey, but nowadays most Muratina is prepared from sugar-cane juice, which is cheaper and more easily available. As a result of widespread migration (Kikuyu in particular) within Kenya, Muratina is manufactured at a small scale in most urban centres in the country.
The wine derives its name from the fruits of the Sausage Tree (Cucumber Tree) (*Kigelia pinnata* syn. *K. africana*) (Kikuyu: Muratina), which have been reported to act as a flavouring agent (44). The fruits, resembling cucumbers, are cut in halves, boiled in

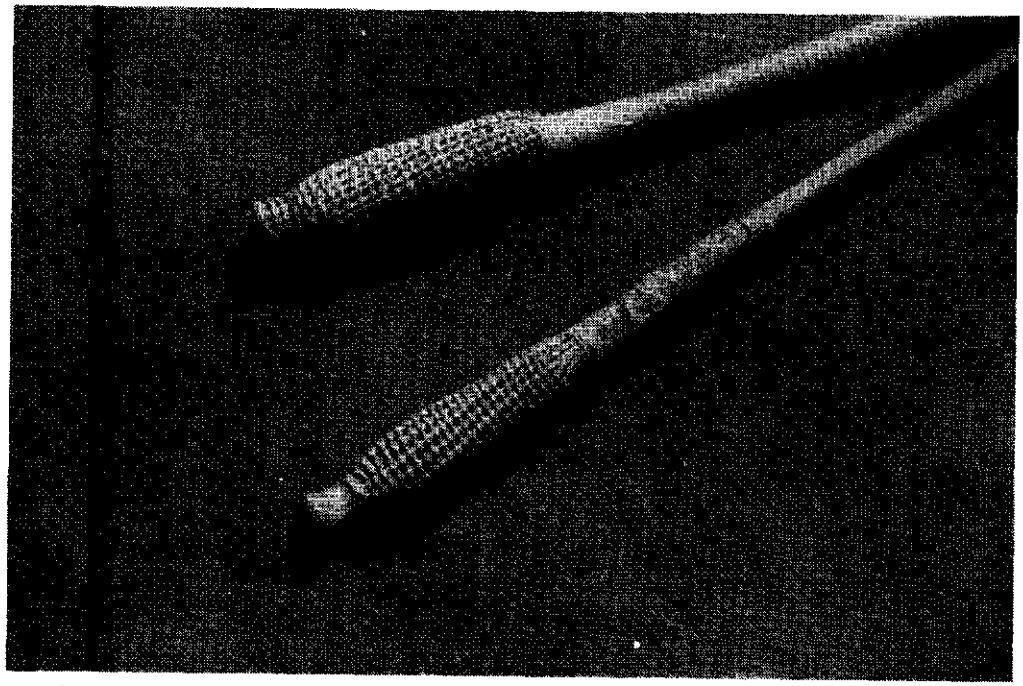


Plate 3. Traditional drinking straws with attached filters.

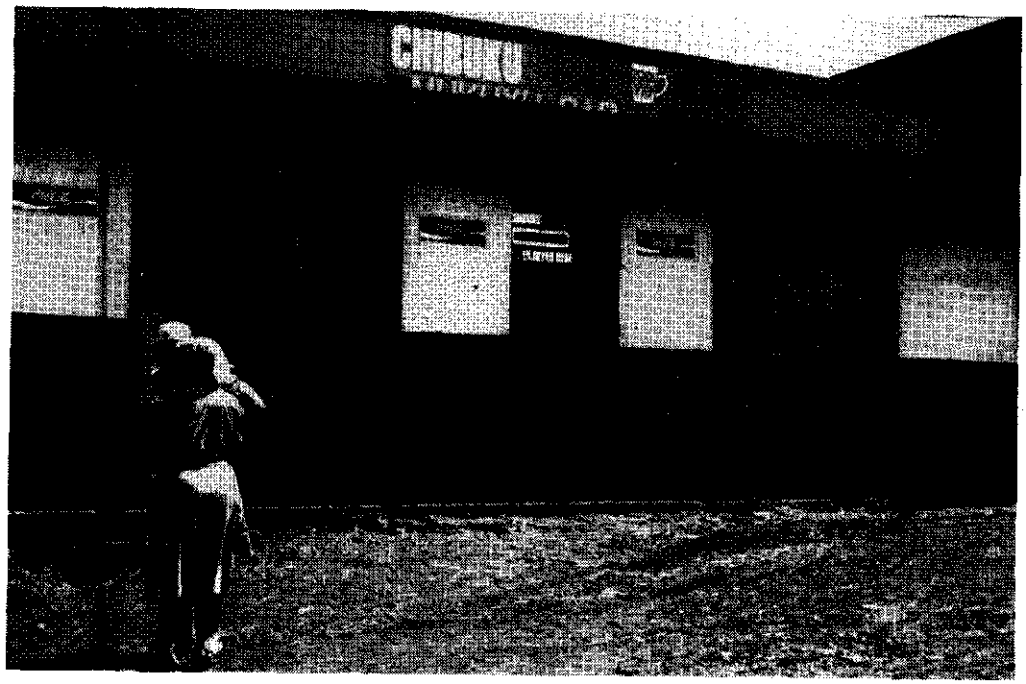


Plate 4. Traditional beer hall in a Nairobi suburb.

water or roasted, and soaked in order to extract undesirable bitter substances, and then sun-dried. Pieces of the dried fruit are added to honey or sugar-cane, which is diluted to the required strength. The fermentation is carried out in earthen pots or oil drums in a warm environment and takes two to four days to complete. Although some fermentative acidification takes place, the fermentation is mainly of an alcoholic character. The alcohol content of Muratina varies from 3-6 % v/v. After fermentation, the Muratina fruits are recovered, sun-dried and stored for use in future fermentations. Apart from producing a certain flavour, it is likely that the Muratina fruits, having once been used in fermentation, will serve as an inoculum for subsequent fermentations.

2.2.2.2 Mnazi

In contrast to West Africa, palm wine is of only minor importance in Kenya (see further Chapter 5). Palm wine, also referred to as Toddy, is extremely popular in West African countries, *e.g.* Nigeria, Cameroon, Benin, Togo, Ghana, and Ivory Coast, and has been investigated by several workers (19,20,34,36).
Palm wine can be obtained from different palms. In West Africa, the raphia palm (mainly *Raphia hookeri*) and the oil palm (*Elaeis guineensis*) are commonly tapped for palm-sap. In Kenya, the most common palms are the coconut palm (*Cocos nucifera*), the borassus palm (*Borassus aethiopum*), the doum palm (*Hyphaene coriacea*), and the wild date palm (*Phoenix reclinata*). Although palm wine could be obtained from all these four types of palms, only the coconut palm is tapped, in the Kenyan coastal region (Swahili, Giriama, Pokomo tribes).
Coconut palm-sap is collected twice daily from calebashes suspended from the immature male inflorescence which has been damaged deliberately by crushing or cutting it.
Wine from coconut palms has not been studied in detail, but studies on oil palm wine (34) indicated the presence of yeasts and a wide range of bacteria during the fermentation of the palm-sap. The bark of the male inflorescence of the (oil) palm was identified (34) as the source of micro-organisms which occurred during the fermentation and which were present in the final product.
The fermented coconut palm-sap is locally referred to as Mnazi. The alcohol content of Mnazi depends on several factors, including the chemical composition of the sap, the time allowed for fermentation, and the temperature during the fermentation, and usually varies between 0.5 and 7 % v/v.

2.2.3 Spirits

The origin of the craft of traditional distilling in Kenya cannot be reliably traced. It is believed by some, that this technique was copied from Nubian (Sudanese) soldiers enlisted in the Kings African Rifles (KAR) shortly before the First World War. This would explain the name "Nubian gin" which is used as synonym for the Kenyan traditional spirit Chang'aa. It is likely however, that spirit manufacture was already practised in western Kenya at an earlier date, but that Chang'aa was given its name "Nubian gin" later during the colonial period because of its popularity among the Sudanese soldiers.

In rural areas of western Kenya, Chang'aa is traditionally made at home on a small scale. Nowadays, it is also in heavy demand in the urban centres of the country (Appendix, No.9).

In principle, Chang'aa is manufactured by adding excess crude brown sugar (Black Jaggery), white refined sugar, or molasses to Busaa or its residues. The mixture is allowed to ferment until CO_2 production has stopped. It is then distilled. The spirit which may be clear or slightly turbid, and may vary in colour from colourless to yellowish brown, contains 25-60 % v/v alcohol, depending on manufacturing conditions (see further in Chapter 7). Chang'aa is an illicit spirit. Places of manufacture are therefore often well concealed in bushes or in urban slums, while the marketing of the product leads an underground life. Customers often use pseudonyms to denote the product, partly as a safety precaution, and partly out of fun. Some of these names have become popular and are at present common synonyms for Chang'aa (such as Enguli, Kali, Kangari, Kill-me-Quick, and Kisumu Wisky).

2.3 FOREIGN FERMENTED BEVERAGES

2.3.1 Beers

Lager beer has been manufactured in Kenya by Kenya Breweries Ltd. since 1922. All of the required barley is grown in Kenya (mainly in the Rift Valley Province). Hops or hop-extracts however have to be imported. The increasing popularity of lager beers among Kenyan consumers is reflected by the continual expansion of this enterprise which includes four breweries and a central malt factory in Nairobi, and one brewery in Mombasa (43). A new brewery is under construction in Kisumu, and will start production in 1982 (Davies, B.J., personal communication).
In comparison to the volume of locally produced barley lager beers, an insignificant volume of foreign canned beers is imported into Kenya by the Kenya Wine Agencies Ltd., which are mainly engaged in the import/export marketing of foreign wines and spirits (Pavitt, N.R., personal communication).

2.3.2 Wines and spirits

At present, foreign wines are not locally produced in Kenya. They are imported, either in bulk or bottled, by the Kenya Wine Agencies Ltd. (KWAL).
The KWAL are the only firm appointed by the Kenya Government to label and distribute these products. Recently, KWAL have started producing Woodpecker cider locally under licence from H.P. Bulmer Ltd. (Appendix, No.7).

Foreign spirits are also imported by KWAL, either as finished and bottled products (the expensive types), or as half-products (botanicals). The botanicals are mixed with potable ethanol, adjusted to the required strength, bottled, and labelled by KWAL. Depending on availability, potable ethanol may either be obtained locally or imported.
Two KWAL spirits may be considered as genuine locally manufactured

products. These are a spirit derived from sugar-cane juice (Kenya Cane, Askari brand) which, according to its manufacturing process, can be characterised as a vodka, and a coffee liqueur (Mount Kenya Coffee Liqueur), a coffee extract made to strength with potable ethanol (Pavitt, N.R., personal communication). However, they form an insignificant fraction of the total volume of spirits marketed by KWAL.

2.4 THE ENVIRONMENT OF FERMENTED BEVERAGES IN KENYA

The East Africa Protectorate, including the area later known as Kenya, was established in mid-1896. Settlement of European and South African farmers in the Kenya Highlands started at a small scale around the turn of the century.
During the colonial period, the Native Liquor Ordinance (1930) (24) stipulated the conditions under which traditional fermented beverages were manufactured and sold. According to this Ordinance, the manufacture and consumption of traditional liquor, other than spirituous liquor, was permitted only to persons of "African extraction or of Arabian extraction born in Kenya" (24). Although the African population was permitted to consume foreign fermented beverages except spirits, their relatively high price was a deterrent to such an extent, that in practice two separate groups of consumers evolved, that is to say, those buying traditional fermented beverages (Africans), and those buying foreign fermented beverages (non-Africans).
Under the Native Liquor Ordinance, provision was made for the local authorities (county councils) to establish municipal breweries, canteens, etc., which automatically obtained exclusive rights to the manufacture and sale of traditional fermented beverages in that area. The profits of such municipal activities were to be spent on projects aimed at promoting the welfare of the African population. The present-day traditional beer halls (Plate 4) have gradually evolved from such municipal beer halls.
The Native Liquor Ordinance was succeeded and replaced by the Traditional Liquor Act in 1971. A number of unacceptable relict-colonial sections were removed from the Ordinance, amongst which was the restriction of the manufacture, sale, and consumption of traditional fermented beverages to Africans only. However, certain legislation which originated during the colonial period persisted, and is still reflected in the current Act.

Although this is not stipulated by the Act, the marketing of foreign fermented beverages is usually not licensed if a retail licence for traditional fermented beverages has already been given for the same premises, and vice-versa.
Under the Traditional Liquor Act (25) the following types of licences may be granted: manufacturer's licence, small brewer's licence, and retail licence. Applications for such licences are made to the Traditional Liquor Licensing Board of the district concerned, which is chaired by its District Commissioner. A nominal licensing fee is payable for retail licences. This fee is not based on sales volume or floor space of the traditional beer hall, but should rather be considered as a registration fee.
Apart from the yearly or half-yearly licences which may be granted

for the manufacture or sale of traditional beverages, an additional opportunity existed within the Traditional Liquor Act to apply for a temporary licence (maximum three days validity) to manufacture fermented beverages during certain festivities (this clause was deleted in the 1980 edition). These occasions (family or village festivities, rituals, etc.) fall outside the commercial concept of the traditional beer halls, and beverage consumption covered by temporary licences is probably insignificant compared with the consumption in traditional beer halls.

Whereas the licensing system is similar for both traditional and foreign fermented beverages, this is not the case with regards to excise. The foreign fermented beverages are subject to payment of excise (at the factory) on basis of the marketed alcohol content, whereas the traditional fermented beverages are not subject to excise. Considering the centralised, large-scale production of foreign fermented beverages, in contrast to the scattered small-scale manufacture of traditional fermented beverages, it is obvious that the latter trade would require a massive administration to monitor and excise the traditional fermented beverages. As a result of the excise and customs duty, and overheads, foreign fermented beverages are considerably more expensive than the traditional ones.

The nature of traditional fermented beverages implies that everybody has access to the know-how and materials to produce them. It is therefore not surprising that in many families the regional beverage is manufactured in the household for home-consumption, according to tradition.
In the context of the Traditional Liquor Act, it is illegal practice to offer such home-brewed products for sale without a licence. However, the trade tends to be difficult to monitor or control because of its scattered and small-scale character.

3 Recent developments affecting the consumption of fermented beverages

Early travellers in Africa observed that traditional fermented beverages fulfilled important social functions among African communities. Platt (39) discussed this aspect and quoted experiences from various explorers' diaries. From this account it can be concluded that, although over-indulgence in alcoholic beverages in the early days was not uncommon, the customary provision of beer during agricultural work (planting, etc.) ensured a feeling of community spirit and an endurance which resulted in "a far greater acreage being covered in a day than can be achieved by the same number of men and women working separately in their own gardens" (39).

Migration of young workers, especially to urban areas, started during the colonial period and is still increasing, due to unattractive employment opportunities in the rural areas. Although the people working in towns usually visit their families in the rural areas from time to time, they gradually lose contact with their former rural environment. As a result, the tight social structure of the village life tends to break down and the traditional system in which the village society regulated, among others, the use of traditional fermented beverages, gradually loses its impact. This change of attitude is often regretted by the older generation, and probably contributes to the increasing abuse of fermented beverages (Sitati, J.N., personal communication).

Compared to the pre-Independence period when Africans consumed only traditional fermented beverages, a stratification of African consumers has developed since foreign fermented beverages became available to them, as a result of their increased spending-capacity. While the high and medium income earners generally become accustomed to consuming foreign fermented beverages, the consumption of traditional fermented beverages is increasingly associated with the poor, who cannot afford alternative beverages.
Although the reasons behind this trend have not been systematically investigated, the following aspects are presumably important:

(a) Although considerable effort has been made in terms of research, development, quality control, and advertisement of the foreign fermented beverages, traditional Kenyan beverages have not received such attention. Thus, a wide gap in terms of quality and status exists between the two types of products. So, it is not surprising that the prestige of the foreign beverages, derived from their storage characteristics, well-defined and consistent quality and character, attracts those consumers who can afford their relatively high prices.

(b) The relative cheapness of traditional fermented beverages also has a selective effect by providing a cheap alternative for the low income group of consumers who cannot afford the foreign fermented beverages.
(c) The traditional fermented beverages are low-cost products in all aspects: they are manufactured using only rudimentary equipment such as empty oil vats, earthen vessels, etc., and the handling and consumption often take place under conditions of poor hygiene. Unpredictable quality, fear of transmission of diseases, as well as the rather uninspiring environment provided by many traditional beer halls, are factors which probably result in the diminishing interest of the educated Kenyan in the consumption of traditional fermented beverages.

Leu and Lutz (26) estimated the cost to the Swiss nation of alcoholism and its effects relating to mortality, public health, accidents, criminality, productivity, and family life, to be in the order of Swiss Francs 850 million per annum. Although such detailed analyses have not been published for other countries, it is generally accepted that misuse of alcohol poses an increasing problem to most developed countries.

Although statistics are not yet available for the alcohol consumption in Kenya, the Government, after the installation of Daniel T. arap Moi as its second President, has expressed a growing concern about low productivity in the rural areas, increasing criminality, and the abuse of alcohol. This resulted in a public campaign by the Government aimed at reducing the number of traditional beer halls (Appendix, No.4).
The first of a series of nation-wide public meetings (Barazas) was held in October 1978, during which the people were urged to reduce alcohol consumption. After January 1979, the number of licences issued for the manufacture and sale of traditional fermented beverages was considerably reduced. County councils were advised to put former traditional beer halls to more useful purposes such as adult education centres, dispensaries, primary schools, etc.
More recently, a new law, the Chang'aa Prohibition Act, came into force, prohibiting the manufacture and sale of Chang'aa (Appendix, No.8). With regard to Chang'aa it should be noted that its manufacture or marketing hitherto fell beyond the scope of the Traditional Liquor Act (25), although it had been banned by the Native Liquor Ordinance (24). The Chang'aa Prohibition Act thus fulfils the function of supplementing the Traditional Liquor Act.

Although strict measures were taken to curb the consumption of all traditional beverages, this has not been the case for the foreign fermented beverages. Employment and excise earnings generated by the industrial manufacture of foreign fermented beverages are undoubtedly important reasons why the Kenyan Government tends to tolerate an increased production and consumption of the latter products.

It may be assumed that the reduction in the number of licensed traditional beer halls has led to some reduction in the national alcohol consumption. Nevertheless, the existing demand for traditional fermented beverages still needs to be satisfied (Appendix,

No.6, 11). Where traditional beer halls cease to exist, two alternatives are open to the consumer, namely either to switch over to the expensive foreign fermented beverages (in particular foreign beers), or to illegal consumption of traditional beverages. The increased consumption of traditional beverages, especially of illicit Chang'aa was reported soon after the closure of a number of beer halls (Appendix, No.10, 12). However, such reports were not supported by statistical evidence.

4 Aims

Due to various factors, including the increasing expenditure on oil imports, the Kenyan foreign exchange reserves are rapidly diminishing. The Kenyan Government has strengthened its policy of restricting the importation of luxury items, especially those which can be produced locally. In this context it would also be advisable to include a restriction on the imports of foreign fermented beverages, and to promote the manufacture of locally made alternatives.

As mentioned in Chapter 3, the manufacture of traditional fermented beverages has recently been strongly discouraged by the Kenyan Government. Considering (a) the cultural role played by traditional fermented beverages in *e.g.* various festivities and traditional land courts (Appendix, No.13), (b) the employment and cash income generated by their manufacture and sale (29), and finally (c) the limited purchasing-power of a large majority of the Kenyan public, it would appear highly desirable to prevent a complete banning of these products. In addition, it would be useful to follow a selective policy according to which products, deemed inappropriate, could be prohibited, and whereby the manufacture of alternative, low-cost products of a high quality is officially supported by the Government.

In the context of both the necessity to encourage the local manufacture of food products in general, and the desirability to provide cheap, high quality beverages in lieu of the present-day traditional fermented beverages, it would be beneficial to develop products which:

(a) have a retail price which is significantly lower than that of the cheapest foreign beverage,
(b) have a high consumer appeal, and adequate shelf-life when stored under ambient conditions,
(c) are acceptable to the Government from the public health point of view, and which preferably also provide nutritional benefits,
(d) are labour intensive to produce, whilst the manufacturing technology is simple enough for small-scale rural enterprises to fulfil the required quality standards.

In Nigeria, bottled and preserved palm wine was successfully introduced recently by the Federal Institute of Industrial Research, Lagos (Ngoddy, P.O., personal communication). Palm wine is a major traditional fermented beverage in the southern part of Nigeria where it is an integral part of the daily life. The cultural importance attached to palm wine by the Nigerian people is underlined by their efforts to upgrade its quality and shelf-life, thereby enabling it to compete with foreign fermented beverages.

Similarly, it should be just as urgent to upgrade the status of selected traditional Kenyan fermented beverages, before they disappear altogether. The availability of one or more officially accepted traditional fermented beverages of improved quality offers the Government the possibility to take strict measures to eliminate the trade in less appropriate products. Considering the public health, technological, economical, nutritional, as well as political aspects involved, the implementation of such an upgrading effort requires a multi-disciplinal approach, and cannot be successful without being fully supported by the Kenyan Government.

Statistical data concerning the comparative importance of traditional fermented beverages compared with the total consumption of alcohol in Kenya are not yet available. Fundamental aspects of the manufacturing processes, and the composition of the different traditional fermented beverages also need to be studied. It was therefore decided that an investigation of the aspects mentioned below might provide a useful contribution to a possible Government policy controlling the production and marketing of fermented beverages in Kenya:

(a) Estimates of the consumption of the major traditional fermented beverages would provide information on:
    (i) the relative importance (in terms of consumption) of traditional fermented beverages compared with that of foreign fermented beverages, as well as the importance of individual traditional fermented beverages.
    (ii) the total alcohol intake in Kenya; this would facilitate an assessment of the extent of alcoholism and its undesirable effects within the country.

(b) Nutritional aspects of selected fermented beverages. In particular the non-distilled beverages (traditional beers and wines) are crude, that is to say, the fermenting micro-organisms, and residues from the ingredients are not removed before consumption. There is some reason therefore, to expect a higher nutritive value for some traditional fermented beverages compared with that of the foreign fermented beverages. Analysis of selected fermented beverages and their ingredients will therefore enable an appraisal of their comparative attractiveness, from nutritional point of view.

(c) The quality of the major traditional spirit, Chang'aa. As outlined in Chapter 2, Chang'aa can be prepared from a variety of raw materials, including residues from Busaa, crude cane-sugar (Jaggery), refined sugar, or molasses. The distillation takes place under primitive conditions. The use of ambient temperatures (25-30 ^{o}C) during fermentation, and of extremely simple stills suggest that the final product might contain considerable levels of fusel oil. Observations made by members of the public, that addiction to Chang'aa is a frequent problem, also point to the likelihood that this product has a high fusel oil content. Addiction to Chang'aa, which is usually accompanied by malnutrition, sometimes results in acute and fatal alcohol intoxication. Not surprisingly, Chang'aa is dubbed as a "toxic", "lethal", etc., product (Appendix, No.1,2,3,5). Hence, an investigation of the composition of Chang'aa will mainly focus attention on the prevailing levels of fusel oil,

and the extent to which its occurrence is influenced by raw materials and distilling techniques used.

(d) The possibility of upgrading the quality of the major traditional beer, Busaa. This is aimed at providing fundamental data applicable to small-scale industries. The following aspects of the manufacture of Busaa will be considered:

(i) microbiological aspects of the traditional manufacture of Busaa. These should provide a basic insight into the mechanism of the fermentations involved in its manufacture, the microbial population responsible for these fermentations, the resulting compositional changes in the product, as well as the usual technology employed for its manufacture.

(ii) process development and preservation of Busaa, aimed at the development of a stable and acceptable product. Optimisation of process conditions, and the effect of various fermentation techniques and ingredients on consumer acceptability will be studied, bearing in mind that the resulting process should remain as simple as possible. Different preservation techniques will also be examined for their suitability.

(iii) the suitability of finger millet for malting purposes. Finger millet malt is extensively used in the traditional manufacture of Busaa. In several other African countries, sorghum is used instead as a malting cereal for the preparation of traditional beers (13). Considerable scientific investigations have been devoted to the malting properties of sorghum (3, 30, 31, 32, 33, 51). These have made a significant contribution to the development of large-scale industries manufacturing sorghum malt in *e.g.* South Africa. On the other hand, very little is known about the malting properties of finger millet (16). It would therefore be of much interest to provide basic data on the comparative malting performance of this cereal. Because of the role played by sorghum as a malting cereal in other countries, the malting characteristics of finger millet should be compared with those of sorghum, and barley. The latter is included as it is the standard malting cereal for foreign beers.

Many rural households, especially in the western part of Kenya, derive income from growing finger millet and from the home scale manufacture of malt, which is sold in the village markets.

If Busaa were to gradually lose its importance, this home industry would consequently suffer. It will therefore not only be of interest to assess the suitability of finger millet for Busaa manufacture, but also to evaluate its potential as a malting cereal for use in other brewery products.

5 The estimated market for fermented beverages in Kenya

5.1 FOREIGN FERMENTED BEVERAGES

5.1.1 Foreign beers

The consumption of lager and stout beers shows an increase of over 200 % during the period 1969-1978. Table 4 summarises the total consumption of foreign beers over this period. The respective alcohol contents of the various marketed products were taken into consideration in order to express the consumption in terms of litres absolute alcohol.

Table 4. Consumption of lager and stout beers in Kenya.*)

Year	10^6 litres beer	10^6 litres abs. alcohol
1969	67.6	2.74
1971	92.0	3.74
1973	126.7	5.13
1975	153.9	6.23
1976	163.5	6.62
1977	197.0	7.95
1978	206.5	8.35

*) based on data received from Kenya Breweries Ltd., Ruaraka.

5.1.2 Foreign wines and spirits

The consumption of wines and spirits is summarised in Table 5 and is expressed in terms of litres absolute alcohol. For this purpose the average alcohol content of spirits was taken to be 40 % v/v and that of wines 12 % v/v.

Table 5. Consumption of foreign wines and spirits in Kenya (10^5 litres absolute alcohol).*)

Year	Spirits	Wines	Total
1971	4.28	1.08	5.36
1973	4.09	1.10	5.19
1975	4.39	1.12	5.51
1976	4.45	1.18	5.63
1977	4.92	1.38	6.30
1978	5.00	1.38	6.38

*) based on data received from Kenya Wine Agencies Ltd., Nairobi.

5.2 TRADITIONAL FERMENTED BEVERAGES

5.2.1 Chibuku

The manufacture of Chibuku started in December 1974. In 1978 the product was sold in 116 traditional beer halls in Nairobi and Kiambu district, which borders on Nairobi. The alcohol content of Chibuku at the time of consumption is estimated at 4.5 % v/v. As has been mentioned earlier, the product is actively fermenting and consequently, the alcohol content will increase with storage. The consumption of Chibuku is summarised in Table 6.

Table 6. Chibuku consumption in Kenya. *)

Year	10^6 litres Chibuku	10^4 litres abs. alcohol
1975	1.0	4.5
1976	2.0	9.0
1977	3.9	17.5
1978	3.9	17.5

*) based on data received from Chibuku Ltd., Nairobi.

5.2.2 Other traditional fermented beverages

5.2.2.1 Introduction

No statistics exist for the consumption of traditional fermented beverages in Kenya. From what has been outlined in Chapter 2, this is understandable since (a) licences for traditional beer halls are not based on turnover rate, and (b) the extent of brewing and consumption at home is not known.
In order to obtain at least an impression of the consumption of traditional fermented beverages, other than Chibuku, an estimate was prepared based on the following considerations:

(a) The estimate was based on the year 1978, just before the Government campaign against traditional beer halls (mentioned in Chapter 3) was started. This choice was made because (i) there was adequate access to statistics revealing the number of traditional beer halls in the country under previous conditions, and (ii) it could be assumed that there was a more or less stable extent of illegal trade and home-brewing which had not yet been affected by the recent Government measures.

(b) Although, as has been mentioned in Chapter 3, the campaign against traditional beer halls may have resulted in a reduction in the total demand for traditional fermented beverages due to customers who switched over to foreign beverages, it is nevertheless assumed that the 1978 estimate still gives a valid impression of the present total demand for traditional fermented beverages.

As was mentioned under (a), statistics concerning the number of licensed traditional beer halls were obtained, both from official sources (Traditional Liquor Licensing Boards), as well as informal ones (the newspapers).
Visits were made to a random selection of traditional beer halls, and their operators were interviewed. This procedure yielded data concerning the type of beverage sold in the beer hall, the average

daily sales, and the rate of illegal trade and home-consumption estimated to take place in the vicinity of the beer hall.

Chang'aa has never been marketed through the system of traditional beer halls. Therefore, the estimated production of Chang'aa could only be based on the quantities of the specific raw materials used in its preparation. During field-work the Chang'aa process was studied (Chapter 7). It was observed that (i) practically all Chang'aa manufacturers utilise Black Jaggery as one of the ingredients during fermentation, (ii) that Black Jaggery is hardly used for other purposes, and (iii) that by analysis of the procedures used and the yields of Chang'aa obtained by 25 observed and interviewed Chang'aa manufacturers, an average yield of Chang'aa per kg Black Jaggery used could be calculated. This average yield amounts to 0.38 litre absolute alcohol per kg Black Jaggery used. The estimated Chang'aa consumption was based on this yield factor and on the production level of Black Jaggery, estimated by earlier workers (2, 4, 23).

5.2.2.2 Traditional fermented beverages marketed through traditional beer halls

Table 7 gives an estimated breakdown of traditional fermented beverages which found their way to consumers through traditional beer halls in 1978. Chekwè and Marwa consumption are included in the estimate for Busaa.
Data concerning the number of licensed traditional beer halls were received from the Provincial Commissioners of Nairobi, Coast, North-Eastern, and Eastern Provinces, and from the "Daily Nation" and "The Standard" newspapers.
In early 1979, visits to between two and twenty traditional beer halls which were still in operation in each province, provided an insight into the type of products marketed, their average daily sales, and the estimated extent of illegal trade and home-consumption in the region.

Table 7. Estimated sales of traditional fermented beverages through traditional beer halls in Kenya in 1978.

Province	Number of licensed beer halls	Average daily sales per beer hall (litres)	10^6 litres				
			Busaa	Muratina	Mnazi	Chibuku	Total
Western	1328	82	39.8	0	0	0	39.8
Nyanza	1926	124	87.3	0	0	0	87.3
Rift Valley	2060	126	93.2	1.6	0	0	94.8
Central	2072	179	0	134.4	0	1.0	135.4
Eastern	2103	118	0	91.2	0	0	91.2
N.-Eastern	4	41	0	0.06	0	0	0.06
Coast	467	82	1.3	5.2	7.5	0	14.0
Nairobi	135	205	3.4	3.4	0	3.3	10.1
Total	10095		225.0	235.9	7.5	4.3	472.7

Taking into account the average alcohol contents of Busaa, Muratina, Mnazi, and Chibuku of 3, 4, 3, and 4.5 % v/v respectively, the consumption of these products, expressed in terms of litres

absolute alcohol, is summarised in Table 8.

Table 8. Estimated consumption of traditional fermented beverages through traditional beer halls in Kenya (1978).

Beverage	10^6 litres abs. alcohol
Busaa	6.8
Muratina	9.4
Mnazi	0.2
Chibuku	0.2
Total	16.6

5.2.2.3 Illegal trade and home-consumption of traditional fermented beverages, other than Chang'aa

Based on interviews mentioned in Section 5.2.2.1, the estimates for the consumption of home-brewed products were as summarised in Table 9. It was observed that the extent of home-brewing in some areas appeared to be related to the number of traditional beer halls available. The lower the number of traditional beer halls, the higher the incidence of home-brewing appeared to be. Generally speaking, a considerable volume of traditional fermented beverages was claimed to be produced in the homesteads (beer hall operators, personal communications).

Table 9. Indication of illegal trade and home-consumption of traditional fermented beverages, other than Chang'aa (1978).

Product	Illegal trade and home-consumption		
	% of legally marketed	10^6 litres product	10^6 litres abs. alcohol
Busaa	40	91.1	2.7
Muratina	50	121.2	4.8
Mnazi	80	6.1	0.2
Chibuku	0	0	0
Total			7.7

5.2.2.4 Illegal manufacture and consumption of Chang'aa

As mentioned in Section 5.2.2.1, an impression of the extent of Chang'aa manufacture was obtained through the use of one of its essential ingredients, namely Black Jaggery (crude cane-sugar). Since the distribution pattern of Black Jaggery through the country is not on record, it was not possible to obtain a breakdown according to provinces. Furthermore, such a regional breakdown would be meaningless, in view of the fact that Chang'aa is the only traditional fermented beverage which is transported, *e.g.* from the western part of Kenya to the urban centres.

The Jaggery industry is a small-scale industry; no official statistics on the number of Jaggery factories or their production

figures are available. However, several estimates have been made (2, 4, 23), based on searches for small factories, followed by interviews of their managers. These estimates are summarised in Table 10.

Table 10. Estimated Black Jaggery production in Kenya.

Year	Total production (kg)	Reference
1966	$11.0 \cdot 10^6$	4
1967	$15.0 \cdot 10^6$	23
1974	$50.6 \cdot 10^6$	2

This table shows a considerable discrepancy between the 1967 and 1974 figures, which could be due to expansion of the Jaggery industry, but might also have been caused by the use of different estimation techniques. If one assumes that both factors may have been involved, that is to say, that the 1974 estimate is on the high side, but that there is also a steady rise in Jaggery production, then the 1974 estimate might give a fair impression of the actual 1978 production.

In order to enable the conversion of utilised Black Jaggery into Chang'aa production, the procedures employed by 25 Chang'aa manufacturers were analysed.
From (i) the weight of Black Jaggery per brew, (ii) the yield of Chang'aa, and (iii) the alcohol content of the final product, it was calculated that on average 0.38 litres (standard deviation 0.19) absolute alcohol in the form of Chang'aa was obtained per kg of utilised Black Jaggery. Consequently, a rough estimate of the total Chang'aa manufacture in 1978 in Kenya would amount to $50.6 \cdot 10^6 \cdot 0.38\ l = 19.2 \cdot 10^6$ litres (expressed in terms of absolute alcohol).

5.3 TOTAL ESTIMATED CONSUMPTION OF FERMENTED BEVERAGES IN KENYA IN 1978

In Table 11 the data presented in Sections 5.1 and 5.2 have been summarised. Notwithstanding the inevitable degree of inaccuracy inherent in the estimation techniques employed, it is obvious that the traditional fermented beverages as a whole form a large fraction of the total market for fermented beverages in Kenya. In particular the products Chang'aa, Muratina and Busaa are the major traditional fermented beverages consumed.

Population censuses in Kenya were held in 1962, 1969, and 1979. By interpolation from the 1969 and 1979 values, the 1978 population was estimated at 14.8 million. The per capita consumption of alcohol would consequently amount to 3.55 litres absolute alcohol per year. Although this value compares favourably with many other countries (Table 12), it must be viewed with some caution since a significant part of the Kenyan population does not consume alcohol for religious reasons. When it is considered that the entire Muslim

Table 11. Estimated total consumption of fermented beverages in Kenya (1978)

Beverage	Consumption	
	10^6 litres abs.alcohol	% of total
Foreign beers	8.4	16.0
Foreign wines and spirits	0.6	1.3
Chibuku	0.2	0.3
Busaa	9.5	18.2
Muratina	14.2	27.0
Mnazi	0.4	0.8
Chang'aa	19.2	36.4
Total	52.5	100.0

Table 12. Per capita consumption of alcohol in selected countries (1972)*)

Country	Per capita consumption (litres absolute alcohol per annum per head)	Proportion of total consumption (%)		
		Beers	Wines	Spirits
France	16.9	13	74	13
Italy	13.8	11	75	14
Portugal	12.8	10	83	7
Fed.Republic of Germany	12.3	55	22	23
Switzerland	10.7	35	47	18
Belgium	9.9	65	18	17
Australia	8.7	75	13	12
Denmark	8.3	67	15	18
Canada	8.0	54	9	37
England	7.8	72	9	19
The Netherlands	7.5	51	15	34
Poland	6.9	28	11	61
U.S.A.	6.6	51	11	38
Bulgaria	6.2	30	37	33
Japan	5.3			
Kenya (own estimate)	3.6	35	28	37

*) source: Anon.,(5).

community, estimated at 30 % of the total population(10), does not consume alcohol, a corrected per capita consumption of 5.05 litres absolute alcohol is arrived at, which corresponds to a daily corrected per capita intake of 12 g absolute alcohol.
Another factor which needs to be taken into account when appraising the consumption of alcohol is the high percentage of children among the Kenyan population. The percentage of persons younger than 16 years in Kenya is 54 % of the total population (1979 census). Assuming that this group of the population does not consume alcohol or only very little, the alcohol consumption per adult head of the consuming population would be $\frac{100}{100-54}$. 5.05 l = 11 litres absolute alcohol per year, equivalent to 26 g per day.

Although it is claimed that a quantity of 60-80 g alcohol per day can be absorbed by the human body without adverse effects (37, 53), it it likely that a limited extent of alcoholism occurs amongst the adult, non-Muslim members of the Kenyan public. In view of their different life styles, nutritional status, and other (*e.g.* climatological) factors, no direct comparisons should be made between the Kenyan and European populations, and the effect of alcohol intake on the incidence of alcoholism. Nevertheless, it appears that there is a good reason for attempting to reduce, or at least stabilise, the consumption of alcoholic beverages in Kenya. This can be illustrated by the following examples which show that the yearly consumption of 11 litres of absolute alcohol (26 g daily) per adult head of the non-Muslim population is associated (in Europe) with a number of persons addicted to alcohol approximating to 2 % of the total population.

It was estimated (27) that in Switzerland the per capita consumption of alcohol was 26 g absolute alcohol per day in 1976. Since youths younger than 16 years represent approximately 22.5 % of the total Swiss population, a correction as applied for Kenya would result in $\frac{100}{100-22.5} \cdot 26$ g = 33.5 g absolute alcohol consumed per day per adult head. The known number of alcoholics among the Swiss population was 2 % of the total population (27), which represents an estimated cost (26) to the Swiss nation of approximately SFrs. 850 million per annum (see also Chapter 3).
Similarly, in the Federal Republic of Germany the number of alcoholics was estimated (6) at 2-3 % of the total population. This higher incidence of alcoholism compared with that in Switzerland is associated with a similarly higher alcohol consumption in that country of 30.8 g absolute alcohol per capita per day (27), or $\frac{100}{100-25.2} \cdot 30.8$ g = 41.2 g per adult head of the population.

From the above it can be concluded that the low per capita alcohol consumption in Kenya is rather deceptive, since the habit of alcohol consumption is certainly not evenly distributed over the population.Instead, there are indications that a limited extent of alcoholism occurs amongst part of the Kenyan public.

6 Nutritional aspects of the major fermented beverages of Kenya

6.1 INTRODUCTION

Several investigations have been made into the nutritional characteristics of traditional African opaque maize beers (9,13,18, 36,40), and of palm wine (19,34,40). Chevassus-Agnes (13) compared the nutrient content of Cameroonian traditional sorghum beers with that of a European Pilsner beer; elsewhere various analyses of European beers were published (28,37,38,40). The nutritive value of palm wine has been studied to a lesser extent and is limited mainly to its crude protein, and vitamins B_1, B_2, C, and niacin contents (19,34,40).

Nutrient data (mean values and ranges) reported by earlier investigators have been summarised in Table 13. Hulse *et al.* (22) recommended that a conversion factor of 5.70 instead of 6.25 is used for the calculation of crude protein content of foods derived from maize, sorghum, and millet. Accordingly, protein values reported as N x 6.25 were converted into N x 5.70. In addition, energy values expressed as kilo calories, were converted into kilo Joules; the conversion factor 1 kcal = 4.2 kJ was used (28).

Various workers (9,39) claim that particularly the traditional opaque beers are considered as a type of food, rather than just a beverage by African consumers. They indicate the important role played by these products in supplying vitamins of the B-group (18, 41), taking into account the deficiencies of vitamin B_2 and niacin which were reported *e.g.* in the South African diet (18).

Several workers have studied the health and nutritional status of Kenyans (11,12,35,47,50). Bohdal *et al.* (11) observed satisfactory intakes of energy, protein, iron, vitamin B_1, niacin, and vitamin C in Kikuyu, Luo, Akamba, and mixed urban populations.
Satisfactory intakes of energy and protein by Akamba infants and toddlers were also reported by Van Steenbergen *et al.* (50).
However, stunted growth was noticed with children older than six months. The incidence of cases of retarded growth, compared to the Harvard Standards for weight-for-age and height-for-age, was estimated at 35.5 % for Kenyan children from 6-60 months old (12).
Growth retardation was suggested to be caused by factors such as inadequate vitamin A intake (11), early decline in breast milk yields, watery weaning foods, and childhood/infectious diseases (50). In particular *Ascaris* (roundworm) infection was regarded by Stephenson *et al.* (47) as an important factor influencing the nutritional status of pre-school children.
On the whole, the occurrence of serious protein energy malnutri-

Table 13. Nutrient content per 100 g of African traditional opaque beers, palm wine, and European Pilsner beers. Mean values and ranges from multiple sources.

Source	Opaque beers (9,13,18,36,40,52)		Palm wine (19,34,40,52)		European Pilsner beers (13,28,37,38,40)	
	mean	(range)	mean	(range)	mean	(range)
energy (kJ)*)	155	(130-185)	143		164	(147-185)
dry matter (g)	7.9	(4.3-13.7)	6.0	(2.6-8.8)	4.0	
insol. dry matter (g)	3.9		n.p.**)		0	
protein (N x 5.7)(g)***)	0.59	(0.27-1.09)	0.27	(0.18-0.36)	0.34	(0.27-0.46)
fat (g)	0.06	(0-0.3)	0.1	(0-0.2)	n.p.	
carbohydrate (g)	4.8	(3.0-8.0)	3.1		3.2	(2.7-4.0)
ash (g)	0.25	(0.18-0.30)	0.2	(0.1-0.4)	n.p.	
alcohol (g)	2.9	(2.1-3.9)	5		4	(3-5)
pH	3.4		3.7	(3.4-4.0)	n.p.	
Ca (mg)	2.2	(1.0-4.0)	2		6.3	(3.0-8.0)
P (mg)	39	(7-63)	5	(3-8)	32	(11-53)
K (mg)	84	(74-94)	n.p.		47	(40-54)
Na (mg)	1.1	(0.9-2.3)	n.p.		3	
Fe (mg)	2.5	(0.6-4.5)	0.32	(0.1-1.0)	0.1	
vitamin B_1 (mg)	0.11	(0.03-0.39)	0.02	(0.009-0.04)	0.003	(0-0.0077)
vitamin B_2 (mg)	0.05	(0.04-0.06)	0.02	(0.009-0.024)	0.04	(0.02-0.06)
niacin (mg)	0.43	(0.32-0.60)	0.39	(0.35-0.40)	0.71	(0.53-1.0)
vitamin B_{12} (µg)	0.03		16		n.p.	
pantothenic acid (mg)	0.09		n.p.		0.18	(0.16-0.20)
vitamin C (mg)	0.04		9	(0-18.6)	n.p.	

*) the original data expressed as kilo calories, were converted into kilo Joules, as follows : 1 kcal = 4.2 kJ (28).
**) n.p. = not published by the sources mentioned.
***) original data expressed as (N x 6.25) were converted into (N x 5.7).

tion is considered to be limited (35,50), and serious clinical vitamin deficiencies are exceptional for both children and adults (Jansen, A.A.J., personal communication).

For adults as well as children, Bohdal *et al.*(11) found that the main deficiencies were calcium, vitamin A and vitamin B_2. The occurrence of inadequate intakes of calcium and vitamin B_2 was also confirmed by Van Steenbergen (50). Bohdal *et al.*(11) used American and British standards of recommended daily allowances to assess the adequacy of the daily vitamin intake by the sampled population. However, when the data from their survey are compared with FAO/WHO recommended intakes (15), the average intake of niacin is inadequate as well.
The food intake data reported by Bohdal *et al.*(11) were obtained by weighing and recording the ingredients used in the preparation of food dishes. The nutrient intake from the consumption of fermented beverages was not taken into account. The average intake of vitamin B_2 by the population was reported as 70 % of the recommended daily allowance of 1.2 mg per adult person. The deficit of

0.3 x 1.2 mg = 0.36 mg vitamin B_2 (riboflavin) would be supplied by a daily consumption of 750 g of opaque maize beer containing 0.05 mg of this vitamin per 100 g (using mean value from Table 13). This is not an excessive quantity for people who consume *e.g.* Busaa on a regular basis.
According to Table 13, this quantity of beer can be expected to contain 3.2 mg niacin as well, representing approximately 25 % of the recommended daily intake, based on an energy consumption of 8400 kJ per day (15).
It would appear therefore that the regular consumption of moderate quantities of maize-millet opaque beer by adults, would have the nutritional benefit of supplying additional vitamin B_2 and niacin, in cases where their recommended intakes are not adequately covered by the local diet.

To permit a comparative appraisal of the nutritive value of the major Kenyan fermented beverages, analyses were undertaken of the traditional products Busaa, Muratina, and Chang'aa. Selected foreign fermented beverages, *i.e.* Tusker lager beer and Guinness stout beer, were also analysed.

Several authors (9,13,36) have studied the fate of nutrients from raw materials, when processed into opaque maize and sorghum beers. They observed that the processes always resulted in a considerable increase of the vitamin B_2 content, whilst increased vitamin B_1 and niacin contents were reported in some cases (9,13). Périssé(36) on the other hand, reported an increased vitamin B_{12} content in Togolese sorghum beer, when compared with the vitamin content of its ingredients. Such favourable enrichments, resulting mainly from vitamin synthesis by the micro-organisms present during fermentations, have been described by Platt (41) as "biological ennoblement" of foods.
The preparation of Affouk, which was described by Chevassus-Agnes (13) as a Cameroonian sorghum wine, is rather similar to that of Kenyan Busaa. According to the definition of beer formulated in Chapter 2, this product should be classified as a beer, since (sorghum) malt is added to saccharify a previously fermented and roasted sorghum paste. During the process of Affouk manufacture, considerable gain (on a dry matter basis) of vitamin B_1 (+ 67 %), vitamin B_2 (+ 315 %), and niacin (+ 37 %) were reported (13). However, the losses of energy (- 19 %) and crude protein (- 28 %) were very low compared with those reported in the manufacture of another sorghum beer, Amgba (13), and those calculated for Kaffir beer production (9).
Because of the apparent similarity in the manufacturing processes of Cameroonian Affouk and Kenyan Busaa, analyses were carried out to study the fate of selected nutrients from maize and finger millet in the production of Busaa. To this effect, samples of ingredients, intermediate products, and final product were analysed.

6.2. METHODS

6.2.1 Samples

Samples of Busaa, its ingredients and intermediate products were

obtained, with the assistance of a commercial Busaa brewer, from a traditional style brewing cycle carried out in the Department of Food Science and Technology, University of Nairobi.
Samples of Muratina, Chang'aa, Tusker lager beer, and Guinness stout beer were composite samples taken from 5 purchased samples.

6.2.2 Dry matter

Samples were dried to constant weight in a hot air oven at 105°C.

6.2.3 Crude protein

The Kjeldahl method, A.O.A.C. 2.047 (21) was used, and a conversion factor of 5.7 applied to calculate the protein content,

6.2.4 Crude fat

Method A.O.A.C. 7.044 (21) was applied on dry matter.

6.2.5 Crude fibre

According to A.O.A.C. 7.54 (21).

6.2.6 Ash

The cereal samples were analysed according to A.O.A.C. 14.006 (21); the beer, wine, and spirit samples according to A.O.A.C. 10.035 (21).

6.2.7 Carbohydrate

Carbohydrate content was calculated by difference: dry matter minus crude fat minus crude protein minus crude fibre minus ash.

6.2.8 Alcohol

According to A.O.A.C. 11.003 (21) for wine and beer; A.O.A.C. 9.021 (21) was used for the spirit samples.

6.2.9 Energy

The energy content was calculated from the protein, fat, carbohydrate, and alcohol content using the following factors (28):
1 g protein = 17 kilo Joules (kJ); 1 g fat = 38 kJ; 1 g carbohydrate = 17 kJ; 1 g alcohol = 29 kJ.

6.2.10 Calcium

According to A.O.A.C. 2.096 (21).

6.2.11 Iron

According to A.O.A.C. 2.096 (21).

6.2.12 Phosphorus

A.O.A.C. method 7.102 (21) was used for cereals and beer; for wine

and spirit A.O.A.C. 11.030 (21) was used.

6.2.13 Vitamin B_1

Carried out by high pressure liquid chromatography (HPLC) with fluorometric detection after thiochrome reaction (48).

6.2.14 Vitamin B_2

Carried out by HPLC with fluorometric detection (48).

6.2.15 Niacin

Using microbiological method with *Lactobacillus plantarum* (ATCC 8014) (7).

6.2.16 Vitamin B_{12}

Determined by competitive protein binding assay (42).

6.2.17 Pantothenic acid

Using microbiological method with *Lactobacillus plantarum* (ATCC 8014) (8).

6.3 RESULTS AND DISCUSSION

The nutrient content of the five major Kenyan fermented beverages is presented in Table 14.
A comparison of the three traditional products, Busaa, Muratina, and Chang'aa, reveals that the nutritive value of Busaa is significantly higher than that of Muratina and Chang'aa. Whereas the energy supplied by Muratina and Chang'aa is mainly derived from alcohol (63 % and 100 %, respectively), this is not the case with Busaa. The considerable amounts of crude protein, fat, and carbohydrate in the latter product supply the majority (58 %) of its total energy. The mineral, as well as the vitamin contents of Busaa, are superior to those of Muratina and Chang'aa.
It appears that Busaa has a rather different composition than the average for the opaque beers listed in Table 13. These differences are mainly due to variations in formulation, ingredients used, and processing techniques. The higher energy content as well as the higher protein, fat, carbohydrate, and ash contents are in agreement with the higher dry matter content of Busaa, compared with that of the opaque beers (Table 13). It should be borne in mind that the preparation of Busaa, particularly with regard to the amounts of water used and fermentation time allowed, varies to some extent from brewer to brewer, and will directly influence the nutrient content of the product.
The Busaa sample contains much more calcium and iron than would be expected from Table 13. The origin of the high concentration of these minerals will be discussed below.
The vitamin B_1, B_2, and niacin contents of Busaa are within the range of values reported in Table 13 for opaque beers. However, higher values of vitamin B_{12} and pantothenic acid were obtained

Table 14. Comparative nutrient content per 100 g of some traditional and foreign fermented beverages marketed in Kenya.

	Traditional			Foreign	
	Busaa (filtered)	Muratina	Chang'aa	Tusker lager beer	Guinness stout beer
moisture (g)	89.80	93.32	99.85	97.49	96.87
energy (kJ)	292	303	901	161	214
protein(N x 5.70)(g)	1.55	0.05	0	0.24	0.56
fat (g)	0.65	0	0	0	0
carbohydrate (g)	6.96	6.50	0.10	2.06	2.22
alcohol (g)	4.22	6.61	31.01	4.21	5.75
fibre (g)	1.04	0.01	0	0	0
ash (g)	0.55	0.12	0.05	0.21	0.35
acidity (% w/v lactic acid)	0.99	0.47	0.04	0.25	0.33
Ca (mg)	18	5	0.2	3	0.5
Fe (mg)	12	3	0.2	0.1	0.2
P (mg)	82	0	2	9	34
vitamin B_1 (mg)	0.05	<0.01	<0.01	<0.01	<0.01
vitamin B_2 (mg)	0.03	<0.01	<0.01	0.02	0.05
niacin (mg)	0.46	<0.01	<0.01	0.66	1.70
vitamin B_{12} (µg)	0.09	<0.05	<0.05	<0.05	<0.05
pantothenic acid (mg)	0.44	0.02	<0.01	0.05	0.11

than reported in the literature. Though, it must be realised that the values of the latter vitamins reported in Table 13 come only from one source (36), which dealt with beer made from a different cereal, namely sorghum.

The nutrient content of fermented sugar-cane juice has not been reported earlier. It is therefore not possible to compare our analysis of Muratina to previous analyses of similar products. If however, the composition of Muratina is compared to that reported for palm wine (see Table 13), the following observations can be made. The protein content of Muratina is considerably lower than that of palm wine. In addition, vitamin B_1 and B_2 contents of Muratina are somewhat lower, and niacin and vitamin B_{12} contents much lower than the corresponding mean values for palm wine. The overall conclusion is therefore that the nutritive value of Muratina is inferior to that of palm wine as reported in Table 13.

The composition of Chang'aa is characteristic of products which have been obtained by distillation. Its nutrient and vitamin contents are too low to justify the use of the term "nutritive value".

Considering the two foreign beers, the composition of Tusker lager beer is generally within the range of values reported for a European Pilsner beer (Table 13). Guinness stout beer contains more protein, alcohol, vitamin B_2, niacin, and pantothenic acid than Tusker lager beer.

A ranking of the five analysed beverages, based on protein, carbo-

hydrate, calcium, iron, phosphorus, vitamin B_1, vitamin B_2, niacin, vitamin B_{12}, and pantothenic acid contents shows the following sequence (increasing overall nutritive value): Chang'aa < Muratina < Tusker lager beer < Guinness stout beer < Busaa.

Table 15. Comparative nutrient content of Busaa and of the corresponding quantities of ingredients required for its manufacture (based on a pilot plant scale process).

	INPUT			OUTPUT	
	maize meal (5.0 kg)	finger millet grain (1.15 kg)	total input	Busaa (17.1 kg)	gain/loss (% of total input)
protein (g)	399	64	463	265	- 43
energy (kJ)	75,100	15,525	90,625	49,932	- 45
P (mg)	17,150	2,473	19,623	14,022	- 29
Fe (mg)	350	932	1,282	2,244	+ 75
Ca (mg)	400	5,060	5,460	3,078	- 44
vitamin B_1 (mg)	37.5	1.61	39.11	8.55	- 78
vitamin B_2 (mg)	2.5	0.35	2.85	5.61	+ 97
niacin (mg)	95	7.13	102.13	78.66	- 23
vitamin B_{12} (µg)	<2.5	5.18	<7.68	16.83	>+119
pantothenic acid (mg)	32.5	5.06	37.56	82.28	+119

In Table 15, the nutrient content of a batch of Busaa is compared with that of the quantity of maize meal and finger millet grain required for its manufacture. From this table it can be seen that on the one hand, losses of protein, energy, phosphorus, calcium, vitamin B_1, and niacin occur. These losses, which are inherent in any brewing process, result from various factors, such as leaching, heating, decomposition by micro-organisms, and filtration. With regard to calcium, it is the exceptionally high calcium content of finger millet which, in spite of the losses due to filtration, is responsible for a high calcium content in the final product. On the other hand, a considerable rise of the iron, vitamin B_2, vitamin B_{12}, and pantothenic acid contents is achieved during the manufacture of Busaa.

A more detailed nutrient balance of the Busaa manufacturing process is presented in Table 16. With regard to iron, it shows that during the roasting operation a considerable amount of iron is added to the processed maize. This could be expected, since the roasting of the maize is usually carried out in a flat pan made of galvanised iron sheet. A steel shovel is used to stir and turn the maize, so rust particles will be scraped from the pan and introduced into the maize crumb.

During the first stage of manufacture, namely the fermentative souring of the maize slurry, a significant increase of vitamin B_2, vitamin B_{12}, and pantothenic acid contents which is probably of microbial origin, can be observed. Only a fraction of these vitamins is destroyed during the subsequent roasting process.

Whereas the malting of finger millet does not result in noticeable changes in its vitamin B_2 and vitamin B_{12} contents a significant

Table 16. The fate of iron, vitamin B_2, vitamin B_{12}, and pantothenic acid during the manufacture of Busaa (based on a pilot plant scale process).

Manufacturing stage	Quantity of product (kg)	Total content			
		Fe (mg)	vitamin B_2 (mg)	vitamin B_{12} (µg)	pantothenic acid (mg)
maize meal	5.0	350	2.50	<2.50	32.50
↓					
fermented maize slurry (fermented for 3 days)	9.8	294	4.90	5.88	43.12
↓					
roasted fermented maize	8.5	2125	3.40	5.10	41.65
finger millet grain	1.15	932	0.35	5.18	5.06
↓					
finger millet malt	0.85	519	0.34	5.27	24.82
beer mixture, fresh	22.4	2637	2.24	11.18	64.82
↓					
beer mixture (fermented for 3 days)	21.5	2623	8.60	17.20	86.00
↓					
Busaa, filtered	18.7	2244	5.61	16.83	82.28

increase in the level of pantothenic acid can be observed. Without further experimental evidence, it is not possible to ascribe the production of pantothenic acid to either microbial activity or to the germination process of the millet seeds.
During the final fermentation of the beer, a further increase in vitamin B_2, vitamin B_{12}, and pantothenic acid contents ensues, most likely as a result of microbial activity.
Inevitably, a certain quantity of the vitamins present in the beer mixture is removed during the final filtration. Vitamin B_2 appears to be affected most by this operation.

6.4 CONCLUSION

Busaa has a superior nutritive value, compared with Muratina and Chang'aa, as well as with Tusker lager and Guinness stout beer.
In view of the inadequate intakes of calcium, vitamin B_2 and niacin by the Kenyan population, which were previously discussed, the consumption of a moderate daily quantity of ¾ litre of Busaa would supply 28 % of the recommended calcium intake of 488 mg (11), 19 % of the recommended vitamin B_2 intake of 1.2 mg (11), and 27 % of the recommended niacin intake of 13.2 mg based on a daily energy consumption of 8400 kJ (15).
No data are available for the intakes of vitamin B_{12} and pantothenic acid by the Kenyan population. Nevertheless, it should be noted that the quantity of Busaa mentioned above also contains 68 % of the vitamin B_{12} requirement of 1 µg per day (14) and approximately 30 % of the daily requirement of pantothenic acid of 10-15 mg per day (14).

From a consideration of nutritive values, Busaa is the most attractive product among those investigated. Even when consumed in moderate quantities, it offers distinct nutritional benefits.

Lebensm.-Wiss. u. -Technol., 12, 212–216 (1979)

40

The Manufacture and Composition of Chang'aa (Nubian Gin)

M.J.R.Nout

Department of Food Science and Technology
University of Nairobi, P.O.Box 29053, Kabete (Kenya)
(Received December 19, 1978; Accepted March 24, 1979; lwt 580)

The manufacture of Chang'aa is described. The compositions of 33 commercial samples of known history are reported and related to the following: (a) the regions of origin; (b) the ingredients used for mash preparation; (c) the distillation technique employed; and (d) the odour of the final product. Distillation equipment used in the rural and urban areas is compared; the urban equipment is shown to yield a product of higher quality. The distillation behaviour of Chang'aa components is observed from a fractionated distillation. A set of quality requirements for Chang'aa, based on Swiss quality standards for spirits, is used for product evaluation. Nine samples are of satisfactory quality. Twenty-four samples are rejected because of their excessive content of fusel alcohols; among the rejected samples, two also show a high furfural content beyond the accepted level. It is concluded from the results that the quality of Kenyan Chang'aa could be improved considerably by, (a) the adoption of urban distillation equipment; and by (b) the use of raw materials which after fermentation will yield relatively low levels of fusel alcohols.

Introduction

Chang'aa is the common local name for Kenyan traditional spirits obtained by the distillation of fermented cane sugar or molasses to which components of busaa beer (made by a mixed lactic-alcoholic fermentation of maize and millet) may have been added. This product is also known as Nubian gin, resulting from the belief that the art of distilling was introduced into Kenya by immigrating Nubians during the first World War. The occurrence and principles behind the manufacture of Chang'aa have been reported earlier by SAINT-HILAIRE and WEIBEL (1). The manufacture of Chang'aa is concentrated mainly in the Western, Nyanza, and Rift Valley provinces, as well as in and around the urban centres of Nairobi and Mombasa. The rural manufacturing technique differs considerably from the urban procedure.

In the rural area visited (Busia district in the Western province), the majority of family compounds possessed a hut where relatively small quantities of Chang'aa could be produced (10–15 l of Chang'aa every 2–4 weeks). After busaa beer has been produced, the maize and millet solids (dregs) are removed by straining, and 20–25% (w/v) crude cane sugar (jaggery) is added to the remaining liquid. Fermentation continues at ambient temperature (25–30 °C) and is carried out by the microorganisms from the beer until gas production stops (1 week). The distillation apparatus is shown in **Fig. 1** and consists of a clay-pot heated from below and covered by a basin full of cold water, the latter acting as a condenser. The condensate drips into a collecting tray which is suspended over the boiling fermented liquid in the pot. When the water in the condenser-basin reaches a temperature of 50–60 °C it is syphoned off and replaced by fresh cooling water. In general, the distillation is stopped after 3–4 basins of water have been heated. The residue from the distillation process is, in most cases, used as an animal feed. In a few cases however, it is again diluted with water and supplemented with jaggery. The addition of bakers yeast or some fresh busaa beer will now start a second fermentation. Chang'aa obtained by this system of repetitive heating and fermenting of the distillation residue is said to possess a burning taste which is unacceptable to most consumers.

In urban areas, dwellings do not normally offer sufficient space to accommodate both brewing and distillation activities. This is a major reason why a number of inhabitants of shanty areas (e.g. Mathare Valley, Nairobi) earn a living by manufacturing Chang'aa on a larger scale (200–1000 l Chang'aa/week). Since the type of distillation equipment used in the

Fig. 1 Rural «basin» distillation equipment

rural areas is difficult to hide and has a relative low production capacity (4–5 l Chang'aa/h/vessel), the majority of manufacturers in urban areas tend to use the distillation apparatus illustrated in **Fig. 2.** A 200 l oil-drum is placed horizontally over a charcoal fire (smokeless and thus difficult to detect). A rubber pipe of 5–10 m length and approximately 2½ cm internal diameter is attached to the drum and, at the collecting end, to a tin vessel standing in running cooling water (river). The production capacity measured during on-site experiments was approximately 10–15 l Chang'aa/h/vessel. Since the production of 200 l Chang'aa, according to the rural style, would require at least 500 l of busaa beer as the ingredient for fermentation, some urban manufacturers tend to use busaa dregs instead, a low-cost by-product of the regular busaa trade. However, for convenience reasons, the majority of urban distillers often use only jaggery as their raw material for fermentation. To a 25% (w/v) jaggery solution in water, normally dehydrated bakers yeast is added as an inoculum. In a few cases where a natural fermentation was observed, the yeast was isolated on malt extract agar and later identified as *Saccharomyces cerevisiae.*

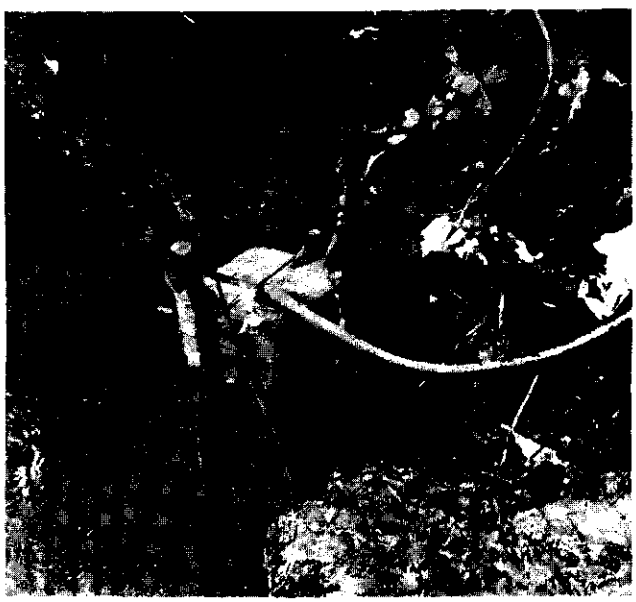


Fig. 2 Urban «drum and pipe» distillation equipment
2a. Collecting vessel immersed in cooling water
2b. Heating – drum and pipe leading to collecting vessel

Most urban distillers add approximately 2% (w/v) NH_4NO_3 to the fermenting liquid to activate yeast metabolism. Fermentation is carried out at ambient temperature (20–25°C). The fermentation period (until gas production stops) of 24–48 h is considerably shorter than that in the rural areas.

The use of molasses as a source of fermentable sugars is limited; this is probably because of limited availability and difficulty in handling. During visits to 20 Chang'aa distillers in both rural and urban areas, it was observed that only 1 rural and 2 urban distillers used molasses supplemented by jaggery and/or busaa beer for their fermentations.

* Although it is now possible to obtain an official permit to produce Chang'aa, the distillers prefer, for economic reasons, to carry out their craft illegally at hide-outs. The use of primitive low-cost distilling equipment is commonly believed to yield a product of poor quality. The aim of this study is to test this common belief on the basis of chemical analysis of Chang'aa samples of known history and to observe the effect on product quality of the different raw materials and distillation techniques employed.

* Chang'aa has now been prohibited (see **Materials and Methods** Chapter 3).

Materials

Chang'aa. 33 commercial samples of Chang'aa were collected, of which 10 were produced in rural areas (Busia district), 15 in an urban shanty area (Mathare Valley, Nairobi), and 8 in suburbs of Nairobi. The history of the samples (raw materials, distillation techniques) were recorded by interview and observation. Prices paid were recorded and later expressed per volume Chang'aa and per volume of absolute alcohol.

In addition, 17 experimental samples were obtained from on-site distillation experiments.

Methods

Colour, Clearness: all samples were assessed visually.

Absorbance at 600 nm: measured against a blank of distilled water as an indication of colour and clearness.

Filtratable solids: determined as a measure of physical cleanness by filtering the samples through Whatman No. 1 filterpaper and weighing the oven-dried residues, and expressed as mg solids/100 ml sample.

Odour: evaluated by a trained panel of 3 persons and recorded as follows: "alcohol" 8 points, "alcohol and weak esters" 7 pts, "esters and alcohol" 6 pts, "esters and weak alcohol" 5 pts, "esters" 4 pts, "strong esters" 3 pts, "very strong esters" 2 pts, "foul" 1 point.

Alcohol vol.%: determined by hydrometer and by distillation using method 32.04 of the "Schweizerisches Lebensmittelbuch" (2).

Extract: determined using method 32.05 (2) and expressed as mg/100 ml sample.

Total titratable acids: determined using method 32.07 (2) and expressed as mg acetic acid/100 ml abs. alcohol.

Esters: determined using method 32.09 (2) and expressed as mg ethylacetate/100 ml abs. alcohol.

Acrolein and Furfural: determined using methods 32.21 and 32.12 (2), respectively.

Analysis by Gas Chromatography: carried out using the technique developed by Grob Jr et al (3). A glass capillary column of 40 m length and internal Ø 0.32 mm was used, liquid phase PG 400, carrier gas H_2 at 0.8 kg/cm^2, stream splitting 1:25. Temperature isothermal at 25°C during the first 4 minutes after injection, followed by increase of 4°C/

minute until 160°C. Dioxane (500 ppm v/v) was used as an
42 internal standard.

Results

1. Analysis of commercial samples

Tab. 1 presents the mean and standard deviation of all analytical results. It can be seen from the standard deviations that a considerable variation in the composition of the samples occurred. This necessitates having to group the samples in clusters of higher degrees of homogeneity, as follows.

Regions: When the samples were arranged according to their region of origin, significant differences in price, alcohol content and fusel alcohol content (sum of C_{3-5} alcohols) were observed as is shown in **Tab. 2.**

Raw materials: The result of grouping the samples according to the raw materials used for mash preparation, as illustrated in **Tab. 3,** leads to the following observations:

In Chang'aa produced from jaggery only, lower isobutanol, lower 2-methyl-1-butanol and lower fusel alcohol contents were observed, when compared with the Chang'aa made from jaggery and busaa or molasses. The levels of acetaldehyde, methylacetate, and n-propanol are however higher than those in the products from jaggery and busaa.

Chang'aa produced from jaggery and busaa contains less acetaldehyde, methylacetate, n-propanol, n-butanol, but more 2-pentanol, 2-methyl-1-butanol, and 3-methyl-1-butanol than the products obtained from only jaggery or jaggery and molasses. Furthermore, the total fusel alcohol content is significantly higher than in the products from jaggery only.

Samples obtained from jaggery and molasses show a higher isobutanol content compared with Chang'aa from only jaggery. Compared with Chang'aa from jaggery and busaa, the product from jaggery and molasses shows higher contents of acetaldehyde, methylacetate, n-propanol, n-butanol, and lower values for 2-pentanol and 3-methyl-1-butanol.

Distillation technique: **Tab. 4** shows that the total fusel alcohol content is significantly lower in the products obtained by the urban "drum and pipe" system, compared with the rural technique.

Odour: **Tab. 5** presents the significant correlation coefficients between assessed odour and acidity, isobutanol, 2-methyl-1-butanol, 3-methyl-1-butanol, and total fusel alcohol content. It may be observed that although during the panel assessment of odour, "poor odour" was associated with "esters", it rather seems that fusel alcohols play an important role in the development of poor odour in Chang'aa.

2. Distillation experiments

A comparison between the rural "basin" system and the urban "drum and pipe" technique: A batch of fermented broth for which only jaggery was used as a source of fermentable sugars, was processed by a distiller employing the rural "basin" technique and a distiller using the urban "drum and pipe" system. In each case 2 strengths were prepared: strength 1 (45 vol.% alcohol) and strength 2 (25 vol.% alcohol). **Tab. 6** presents the results of this experiment, and shows that although equal yields of product are obtained using both techniques, the rural "basin" technique leads to products of lower quality (higher fusel alcohol content) compared with the urban technique.

Fractionated distillation using the "drum and pipe" equipment: In order to assess the effect of prolonged distillation on the composition of Chang'aa, a fractionated distillation was carried out and samples, taken every 5 minutes, were analysed. The results are summarised in **Fig. 3.** The observed

Tab. 1 Composition of Chang'aa (average of 33 commercial samples)

	mean	S.D.
price/1 Chang'aa (KShs)[1]	18.5	9.6
price/1 abs. alcohol (KShs)	68.6	44.0
colour	colourless, sometimes light yellow	
clearness	clear or slightly turbid	
filtratable solids (mg/100ml sample)	4.1	3,0
absorbance (600 nm)	0.021	0.036
odour	"esters and alcohol"	
alcohol vol.%	31.4	12.0
extract (mg/100 ml sample)	5.2	4.6
acidity(mg HAc/100 ml alcohol)	19.0	11.7
esters(mg EtOAc/100 ml alcohol)	4.8	2.6
acrolein(mg/100 ml alcohol)	0	0.1
acetaldehyde[2]	314	155
methylacetate[2]	1202	584
ethylacetate[2]	235	359
methanol[2]	20	45
sec.butanol[2]	41	201
n-propanol[2]	712	469
isobutanol[2]	490	195
2-pentanol[2]	4	8
n-butanol[2]	36	23
2-methyl-1-butanol[2]	322	220
3-methyl-1-butanol[2]	1386	906
n-pentanol[2]	2	8
ethyl octanoate[2]	38	67
ethyl lactate[2]	552	350
3-methyl-1-pentanol[2]	6	11
n-hexanol[2]	2	10
furfural[2]	45	119
benzaldehyde[2]	8	22
1-heptanol[2]	15	38
total C_{3-5} alcohols[2]	3016	2089

[1] 1 Kenyan Shilling = approx. 0.23 Swiss Francs
[2] ppm on the basis of abs. alcohol

Tab. 2 Regional differences in composition of Chang'aa

	A Rural Busia		B Urban (Nairobi) Suburbs		C Mathare Valley		unrelated t test	
number of samples	10		8		15			
	mean	S.D.	mean	S.D.	mean	S.D.		$p \leq$
price/1 Chang'aa (KShs)	12.0	3.3	32.6	4.8	15.4	5.9	B>(A=C)	0.001
price/1 abs. alcohol (KShs)	27.1	10.8	129.4	32.1	63.8	21.5	B>C>A	0.01
alcohol vol.%	46.4	9.7	26.3	5.3	24.2	4.6	A>(B=C)	0.001
total C_{3-5} alcohols (ppm/abs.alcohol)	3807	1133	3354	1266	2183	597	(A=B)>C	0.01

Tab. 3 Effect of raw materials used during fermentation stage on composition of Chang'aa (ppm on the basis of abs. alcohol)

	A jaggery		B jaggery busaa		C jaggery molasses busaa		unrelated t test	
number of samples	12		10		6			
	mean	S.D.	mean	S.D.	mean	S.D.		p≤
acetaldehyde	358	151	195	90	393	181	(A=C)>B	0.05
methylacetate	1413	386	687	337	1556	887	(A=C)>B	0.05
n-propanol	902	379	357	126	1020	731	(A=C)>B	0.01
isobutanol	366	147	554	117	555	152	(B=C)>A	0.05
2-pentanol	–	–	11	13	3	7	B>(A=C)	0.05
n-butanol	46	23	18	11	53	18	(A=C)>B	0.01
2-methyl-1-butanol	159	73	547	216	289	161	B>A	0.01
3-methyl-1-butanol	693	223	2355	729	1300	737	B>C; B>A	0.05; 0.01
total C_{3-5} alcohols	2166	662	3709	1089	3432	1311	(B=C)>A	0.01

Tab. 4 Effect of distillation technique on fusel alcohol content of Chang'aa

	A rural ("basin")		B urban ("drum and pipe")		unrelated t test	
number of samples	11		12			
	mean	S.D.	mean	S.D.		p≤
total C_{3-5} alcohols (ppm/abs.alcohol)	3790	1076	2093	518	A>B	0.01

Tab. 5 Influence of composition of Chang'aa on observed odour[1)]
(Pearson's correlationcoefficient *r*)

	r	p≤
acidity (mg HAc/100 ml alcohol)	− 0.352	0.025
isobutanol[2]	− 0.355	0.025
2-methyl-1-butanol[2]	− 0.286	0.05
3-methyl-1-butanol[2]	− 0.356	0.025
3-methyl-1-pentanol[2]	− 0.539	0.001
total C_{3-5} alcohols[2]	− 0.272	0.05

[1] odour – grades: 8 = "alcohol"; 7 = "alcohol and weak esters"; 6 = "esters and alcohol"; 5 = "esters and weak alcohol"; 4 = "esters"; 3 = "strong esters"; 2 = "very strong esters"; 1 = "foul".
[2] ppm on the basis of abs. alcohol.

Tab. 6 Composition of two strengths of Chang'aa produced with rural and urban equipment

grade	1		2	
equipment	rural "basin"	urban "drum & pipe"	rural "basin"	urban "drum & pipe"
alcohol vol.%	45.2	45.1	24.9	25.4
yield %[1]	17	18	35	34
acetaldehyde[2]	320	300	365	325
methylacetate[2]	1514	1054	1942	1723
ethylacetate[2]	191	173	248	225
methanol[2]	7	8	8	9
n-propanol[2]	802	735	1104	989
isobutanol[2]	321	265	457	337
n-butanol[2]	87	77	136	102
2-methyl-1-butanol[2]	125	92	218	163
3-methyl-1-butanol[2]	672	519	999	782
n-pentanol[2]	–	–	3	2
ethyl octanoate[2]	21	23	28	29
ethyl lactate[2]	820	735	972	814
furfural[2]	18	15	47	33
benzaldehyde[2]	–	–	–	1
1-heptanol[2]	–	–	4	2
total C_{3-5} alcohols[2]	2007	1688	2917	2375

[1] yield = $\frac{\text{vol. final product}}{\text{vol. fermented liquid}}$ 100%
[2] ppm on the basis of abs. alcohol.

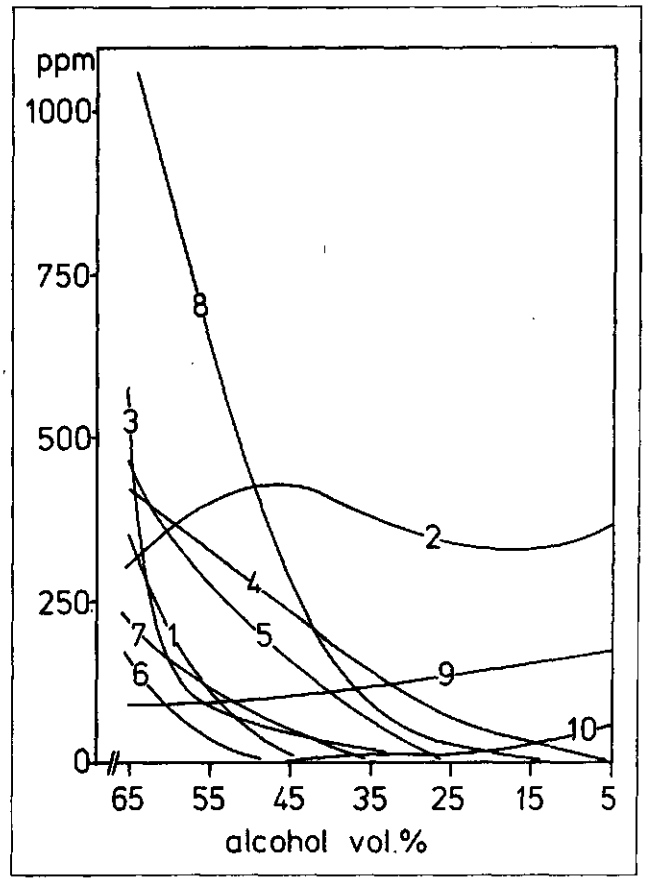


Fig. 3 Distillation of components of Chang'aa using the «drum and pipe» apparatus
1 = acetaldehyde, 2 = methylacetate, 3 = ethylacetate, 4 = n-propanol, 5 = isobutanol, 6 = n-butanol, 7 = 2-methyl-1-butanol, 8 = 3-methyl-1-butanol, 9 = ethyl lactate, 10 = furfural.

distillation pattern matches very well with the performance of the French pot-still for brandy manufacture (4), where the aldehydes and higher alcohols are mainly distilled as heads and the esters, which are also found in the heads, continue to pass over in the tails. Furfural also starts to pass over in the tails.

Discussion

In order to evaluate the overall quality of the Chang'aa samples, the Swiss standards for spirits (2) are used as a basis for comparison. Since the requirements for the product Chang'aa are not specified, the existing standards will be interpreted in a lenient manner: for all quality attributes taken from the Swiss standards, the highest tolerable level will be used in this assessment. **Tab. 7** summarises the set of adapted standards used for the assessment of the Chang'aa samples. According to these criteria, 9 samples (27% of total) were of a satisfactory quality, whereas 24 samples (73% of total) were rejected. All rejected samples had a fusel alcohol content which was too high; 2 of the rejected samples (6% of total) also had a content of furfural which was too high.
Poor quality brandies often contain up to 3500 ppm total C_{3-5} alcohols (on the basis of absolute alcohol). Compared with this high level of fusel alcohol content, 9 samples (27% of total) had even higher C_{3-5} alcohol contents, the highest

Tab. 7 Standards used for assessment of quality of Chang'aa
(adapted from Swiss standards for spirits)

	max. tolerable level (ppm/abs. alcohol)
furfural	110
aldehydes (as acetaldehyde)	1600
total titratable acidity (as acetic acid)	1500
esters (as ethylacetate)	7000
fusel alcohols (sum of C_{3-5} alcohols)	2000
methanol	20000
acrolein	4

observed level being 5479 ppm (on the basis of absolute alcohol). These 9 samples all originated from rural "basin" equipment, the raw material for fermentation was jaggery and busaa (7 samples) and jaggery and molasses (2 samples). Seven of the nine samples which were considered to be of acceptable quality on the basis of the adapted Swiss standards **(Tab. 7)** were made from jaggery only, using the urban "drum and pipe" system; the history of the remaining two samples was not known.
Although the comparison of distillation techniques **(Tab. 6)** shows that the "drum and pipe" method is superior compared to that of the rural "basin" system, it may also be expected that the choice of raw materials for fermentation has a considerable influence on the character of the final product. In particular, the combination of only jaggery as a source of fermentable sugars and the use of "drum and pipe" equipment appears to yield a product of a more acceptable chemical composition: of the 10 Chang'aa samples prepared in that way, 7 were considered to be of satisfactory quality according to the requirements laid down in **Tab. 7.**

Conclusion

It is concluded that the majority of the analysed Chang'aa samples were of low quality due to a high content of fusel alcohols. However, the product quality could be considerably improved by using locally available jaggery as the only source of fermentable sugars, combined with the use of the "drum and pipe" distillation apparatus.

Acknowledgement

The author is indebted to **Messrs. H.P. Neukom** and **K. Grob Jr.** who supplied the capillary glass column used in the Gas Chromatography.

References

1 SAINT-HILAIRE, P. and WEIBEL, E.K. Schweizer Brauerei-Rundschau, *88*, 261, (1977)
2 Schweizerisches Lebensmittelbuch. Methoden für die Untersuchung und Beurteilung von Lebensmitteln und Gebrauchsgegenständen. Fünfte Auflage. Eidg. Drucksachen- und Materialzentrale, Bern, 1967, Kapitel 32: Spirituosen.
3 GROB, JR., K., NEUKOM, H.P. and KADERLI, H. *Journal of* High Resolution Chromatography and Chromatography Communications *1*, 98, (1978)
4 LAFON, R. in: M.A.AMERINE, H.W.BERG, and W.V.CRUESS, "The Technology of Winemaking", AVI Publ. Co., Westport, Connecticut, 1972, p.620.

Chem. Mikrobiol. Technol. Lebensm. *6*, 137-142 (1980)

Microbiological Aspects of the Traditional Manufacture of Busaa, a Kenyan Opaque Maize Beer

M.J.R. Nout

Department of Food Science and Technology, University of Nairobi, Kenya

Eingegangen am 30.1.1980

Summary: The microbial population responsible for spontaneous lactic acid and alcoholic fermentations in Busaa, a Kenyan traditional opaque maize beer, is investigated. During the initial stages of manufacture, a spontaneous souring of uncooked maize grits takes place in water, the microbial population of which is dominated by the following: (a) yeasts (*Candida krusei* and *Saccharomyces cerevisiae*), (b) *Lactobacillus spp.* (*L. helveticus, L. salivarius, L. brevis, L. viridescens, L. plantarum*), and (c) *Pediococcus spp.* (*P. damnosus, P. parvulus*). Laboratory experiments presented show that fermentable sugars needed for this souring are provided by auto-amylolysis of the maize caused by maize amylases. The fingermillet malt (*Eleusine coracana*) used for brewing contains a high microbial load (10^7 - 10^8 g^{-1}), which is rather divers. The following microorganisms could be identified: *Corynebacterium sp., Bacillus sp., Listeria sp., Enterobacter cloacae, Klebsiella pneumoniae, Propionibacterium sp., Eubacterium sp., Lactobacillus casei* var., *Pediococcus damnosus, Rhizopus sp., Mucor sp.*, and *Candida krusei*. The final product is obtained by simultaneous spontaneous alcoholic and lactic acid fermentations. The alcoholic fermentation was dominated by *Saccharomyces cerevisiae*. The lactic acid fermentation was initiated by hetero- and homofermentative lactobacilli (those identified were *L. brevis, L. salivarius* var. *salicinius, L. plantarum, L. viridescens, L. casei* var. *rhamnosus*, and *L. buchneri*) and showed a gradual domination by *L. plantarum*.

Mikrobiologie der traditionellen Herstellung von Busaa, einem opaken Mais-Bier in Kenia

Zusammenfassung: Die Mikroflora, welche die spontane Milchsäure- und alkoholische Gärung in Busaa, einem traditionellen Mais-Bier in Kenia bewirkt, wird untersucht. In der Anfangsphase der Herstellung geht eine Säuerung der ungekochten Maisgrieß-Maische vor sich. Die dafür in erster Linie verantwortlichen Mikroorganismen sind: (a) Hefen (*Candida krusei* und *Saccharomyces cerevisiae*), (b) *Lactobacillus spp.* (*L. helveticus, L. salivarius, L. brevis, L. viridescens, L. plantarum*), und (c) *Pediococcus spp.* (*P. damnosus, P. parvulus*). Die beschriebenen Laborexperimente zeigen, daß die hierfür notwendigen vergärbaren Zucker durch Hydrolyse von Maisstärke mittels Maisamylasen verfügbar werden. Malz, hergestellt aus Fingerhirse (*Eleusine coracana*), welches in der weiteren Busaa-Bereitung Verwendung findet, ist mit Keimzahlen von 10^7 - 10^8 g^{-1} sehr stark infiziert. Die Analyse zeigt eine heterogene Mikroflora. Insbesondere wurden folgende Mikroorganismen identifiziert: *Corynebacterium sp., Bacillus sp., Listeria sp., Enterobacter cloacae, Klebsiella pneumoniae, Propionibacterium sp., Eubacterium sp., Lactobacillus casei* var., *Pediococcus damnosus, Rhizopus sp., Mucor sp.*, und *Candida krusei*. Das Endprodukt entsteht durch gleichzeitige, spontane alkoholische und Milchsäure-Gärungsprozesse. Bei der alkoholischen Gärung dominiert *Saccharomyces cerevisiae*. Für die Milchsäuregärung sind hetero- und homofermentative Lactobacteriaceen verantwortlich, wovon folgende identifiziert wurden: *L. brevis, L. salivarius* var. *salicinius, L. plantarum, L. viridescens, L. casei* var. *rhamnosus* und *L. buchneri*. Im Laufe der Milchsäuregärung wurde ein allmähliches Überhandnehmen von *L. plantarum* beobachtet.

1. Introduction

Busaa, a Kenyan opaque maize beer, is commonly prepared from maize endosperm grits and fingermillet malt (*Eleusine coracana*). The product contains a considerable amount of solid matter (maize endosperm and fingermillet particles) which is kept in stable colloidal dispersion throughout the liquid. Busaa has undergone several stages of spontaneous lactic acid and alcoholic fermentations when it reaches the consumer. The beer is consumed when actively fermenting, after removal of coarse particles by simple straining. Many Busaa-drinkers prefer the beer lukewarm, in order to bring out the full flavour. On average, Busaa when ready for consumption, contains 0.5 - 1 % lactic acid and 2 - 4 vol. % ethanol.

The traditional Busaa brewer employs only rudimentary equipment and the fermentation, being of spontaneous and uncontrolled nature, results in a product of variable quality. During storage, a further souring of the beer takes place producing an increase in the acidity to approximately 2 % (as lactic acid), which causes both unacceptable taste and a destabilisation of the colloidal beer stability. In practice therefore, the shelflife cannot be extended beyond 24 hours at ambient temperatures. Consequently, only small amounts of Busaa are brewed at one time so that

they can be sold and consumed the same day.

Although large quantities of Busaa are still consumed in Kenya, its status appeal as a symbol of bygone traditions is declining. Presently, the product is associated with the low-income groups (the price is approx. 75 % lower than that of the industrial but locally produced lager beer) and it appears to lose popularity among higher income groups due to a poor shelflife and suspected unhygienic manufacturing techniques.

Opaque maize beers prepared from maize, sorghum or millets are common in several African countries. A number of beers were reportedly obtained by mixed lactic and alcoholic fermentations [1,2,3,4,5], whereas others were reported to undergo only alcoholic fermentations [6]. The nutritional value of opaque maize beer is considered superior to that of clear lager beers thanks to higher contents in crude protein, thiamine and riboflavin [6,7]. Also the presence of lactic acid in alcoholic beverages was reported to be of nutritional importance [8].

Considering the nutritional potential of lacto-alcoholic opaque maize beers, the image of these products should be improved by developing adequate, hygienic manufacturing techniques in order to ensure hygienic products of a standard quality and acceptable shelflife.

At present, the only lacto-alcoholic opaque maize beer produced on an industrial scale is Kaffirbeer [9]. In order to provide background data for the development of an improved Busaa brewing technology, the microbial population responsible for the fermentations involved in the traditional process was investigated.

2. Material and Methods

2.1. *Sampling*

Samples were taken at varous stages of fermentation. In total, 8 complete brewing cycles, which were carried out by a local Busaa brewer, were examined.

2.2. Enumeration

0.1 ml of appropriate decimal dilutions were streaked on plate count agar, malt agar, and potato dextrose agar, and incubated under aerobic conditions for 2 days at 30°C, 3 days at 28°C, and 3 - 4 days at 25°C for the determination of total aerobic count, yeast count, and mould count, respectively. In the same way, Rogosa agar and yeast extract - 1 % glucose - 1 % $CaCO_3$ - agar (YGC) plates were inoculated and incubated under anaerobic conditions (Gas-Pak system) for 2 - 3 days at 30°C to determine lactic acid bacteria count and total anaerobic count, respectively.

2.3. Sampling technique for isolation

Where the composition of populations was studied, $\sqrt{N}$ colonies on counting plates containing N colonies were sampled at random for the purpose of purification and identification. The composition of such samples was assumed to be representative of the populations, for which the counting medium had been employed.

2.4. Purification and maintenance of cultures

Yeasts and moulds were purified by repetitive streaking on malt agar and maintained on the same medium. Lactic acid bacteria were purified by repetitive streaking on tomato juice agar and maintained on the same. Cultivation and maintenance of lactic acid bacteria was carried out under anaerobic conditions. Other aerobic and anaerobic bacteria were purified and maintained either on nutrient agar, plate count agar, or YGC agar, depending on growth requirements. All media except YGC agar were obtained from Difco.

2.5. Identification of isolates

Preliminary grouping of bacteria was carried out according to Cowan and Steel [10]. *Lactobacillus spp.* were identified according to Rogosa and Sharpe [11] employing the API 50 L system (API system S.A., Montalieu Vercieu, France). *Pediococcus spp.* were identified according to Back [12]. *Enterobacteriaceae* were identified using the API 20 E system. Other bacteria were classified according to Cowan and Steel [10] and Bergey's Manual [13]. Mould isolates were classified on the basis of their morphological properties. Yeast isolates were identified according to Lodder [14].

2.6. Acidity

Because samples were often dark coloured, the acidity was determined by potentiometric titration of 20 ml samples with 0.1 N NaOH and expressed as % lactic acid.

2.7. Ethanol

The ethanol content was determined by chemical oxidation (A.O.A.C. method 11.006) [15], and was expressed as % by volume.

2.8. Reducing sugars

After clarification of the sample by centrifugation at 3500 rpm for 10 minutes followed by filtration of the supernatant, the reducing sugar content was determined according to Somogyi's colorimetric method [16].

2.9. Fumigation of maize

When required, maize endosperm grits were sterilised by fumigation with 500 ppm of a mixture of 90 % ethylene oxide and 10 % formic acid ethyl ester for 24 h at 25°C.

3. Results

3.1. *Traditional Busaa manufacturing process*

The major operations involved in the preparation of Busaa beer are shown in Fig. 1. The results reflect the average of 8 complete commercial brewing cycles as carried out by a Busaa brewer in Nairobi.

3.2. Maize souring

The degree of acidification and the major microorganisms present during the souring of raw maize mixed with water are summarised in Table 1. Whereas yeasts, lactobacilli, and *Pediococcus* were found in abundance, the number of moulds was negligible. Although lactobacilli can grow as pure cultures in this environment, the acitve multiplication of *Lactobacillus* in the souring maize is probably stimulated by the presence of yeasts which ensure an adequate supply of B-vitamins. It has been suggested [17] that microbial amylases play an essential role in the production of fermentable sugars from maize immersed in water. Our laboratory experiments with uncooked maize grits sterilised by fumigation and subsequently im-

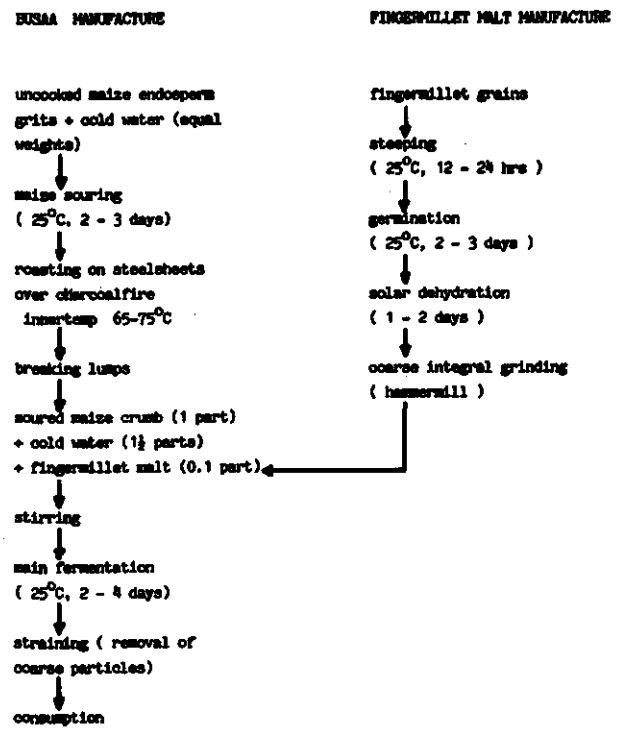


Fig. 1 A flowsheet for traditional Busaa manufacture.

mersed in sterile water showed a considerable auto-amylolysis (Table 2). This finding, added to the fact that no starch-hydrolysing microorganisms could be isolated from souring maize, leads to the conclusion however, that the maize amylases are the driving force behind this fermentation. Additional evidence can be found in Table 3 which demonstrates that pure cultures of *Lactobacillus* show a sharp decrease in acid production when the maize/water mixture is autoclaved prior to inoculation, thus inactivating the maize amylases and rendering saccharification impossible. Table 3 summarises the acid production of several pure cultures isolated from spontaneously souring maize. Whereas the yeasts did not actively contribute to the acidification, there appears to be a range of lactobacilli and pediococci which would be able, as pure cultures, to produce amounts of acid comparable to those determined in spontaneously soured maize.

Table 2 Auto-amylolysis of uncooked maize grits in water (100 g maize sterilised by fumigation, suspended in 100 ml sterile water and incubated at 25° C).

Incubation time [h]	Reducing sugars [%w/v]
0	0.09
6	0.36
24	1.37
48	1.70
72	2.25

Table 3 The effect of heating maize on subsequent acid production (% as lactic acid) by some isolated lactic acid bacteria and yeasts (25 g maize grits in 75 ml water, incubation period of 2 days at 30 °C).

Inoculum	Not Heated (fumigated maize + sterile water)	Heated (maize + water autoclaved at 110°C for 15 min)
Saccharomyces cerevisiae	0.05	0.01
Candida krusei	0.09	0.02
Lactobacillus plantarum	0.47	0.11
L helveticus	0.40	0.06
L. salivarius var. *salicinius*	0.47	0.05
L. salivarius var. *salivarius*	0.29	0.02
L. viridescens	0.48	0.07
Pediococcus damnosus	0.43	0.08
P. parvulus	0.37	0.05

3.3. Roasting

The effect of the subsequent roasting operation on the majority organisms in the soured maize is illustrated in Table 4. Although this treatment leads to a sharp overall reduction in microbial numbers, the lactic acid bacteria show a higher survival rate than the yeasts.

Table 1 Spontaneous Busaa maize souring.

Fermentation time [days]	pH	Acidity [%][a]	*Lactobacillus*[b] [g^{-1}]	*Pediococcus* [c] [g^{-1}]	Yeasts[d] [g^{-1}]
0	5.85	0.05	$3.4 \cdot 10^2$	$1.9 \cdot 10^2$	$7.6 \cdot 10^3$
1	5.10	0.35			
2	3.90	1.36	$1.5 \cdot 10^5$	$1.6 \cdot 10^5$	$1.2 \cdot 10^6$
3	3.80	2.10			
4	3.70	2.30	$2.7 \cdot 10^7$	$1.3 \cdot 10^7$	$3.2 \cdot 10^8$

a) as lactic acid.
b) Out of 20 isolated *Lactobacillus* cultures, 8 were identified as *L. helveticus*, 6 as *L. salivarius* var. *salicinius*, 2 as *L. brevis*, 2 as *L. viridescens*, and 2 as *L. plantarum*.
c) Out of 8 isolated *Pediococcus* cultures, 5 were identified as *P. damnosus*, and 3 as *P. parvulus*.
d) Out of 19 isolated yeast cultures, 12 were identified as *Candida krusei*, and 7 as *Saccharomyces cerevisiae*.

Table 4 The influence of roasting on the microbial population in soured maize.

	Before roasting [g^{-1}]	After roasting [g^{-1}]
Lactobacillus spp.	$2.7 \cdot 10^7$	$2.3 \cdot 10^2$
Pediococcus spp.	$1.3 \cdot 10^7$	$3.5 \cdot 10^2$
Yeasts	$3.2 \cdot 10^8$	65

3.4. Fingermillet malt

One of the last operations in the traditional manufacture of fingermillet malt is solar dehydration which is carried out in order to stop further germination. Whereas it has been shown under modern barley malting conditions that the kilning operation results in a considerable reduction in microbial load [18], it may be expected that during "kilning" by solar dehydration, the microbial load will tend to increase, due to the initially favourable temperatures and times involved. The average analysis (5 samples) of ground fingermillet malt is presented in Table 5. A wide range of aerobic and anaerobic microorganisms was detected, originating from the grain and various external sources of contamination, the germination operation being carried out in jute bags and the solar dehydration on mats spread on the soil. It may be expected that apart from supplying amylases necessary for saccharification, the traditional fingermillet malt plays a role as an inoculum for the main fermentation of Busaa. Part of the fluctuation in final product quality could well be attributed to variations in the microbial population of the malt.

3.5. Main fermentation of Busaa

During the main fermentation of Busaa, acidity and ethanol content increase as illustrated by Table 6. This table also shows that in the course of the fermentation the yeasts, after an initial increase, begin to decrease in number. However, the total number of lactic acid bacteria increases steadily, probably aided by the release of B-vitamins from the autolysing yeast cells. The number of moulds showed a gradual decrease with increase in fermentation time, and, after prolonged fermentation no viable moulds could be detected at all. It was observed that at pH 3.5 a destabilisation of the colloidal beer structure occurred which produced a sedimentation of the solid beer components. At this stage the beer was considered spoilt.

Fig. 2 illustrates the changes in the microbial population that were observed in two of the fermentations investigated. Although data are limited, the shifts in the lactic acid bacteria population appear to follow a similar trend to that observed in the manufacture of sauerkraut [19], where heterofermentative lactic acid bacteria are actively contributing to the fermentation during the initial stages, but are gradually replaced by homofermentative lactic acid bacteria. This work shows that a prolonged Busaa fermentation results in a nearly pure culture of *L. plantarum* (as far as lactic acid bacteria are concerned) and confirms once more the importance of this species in fermentations of plant material.

Table 5 Microbial population of fingermillet malt (average of 5 samples).

	Viable count [g^{-1}]
Aerobic bacteria a)	$2.2 \cdot 10^7$
Anaerobic bacteria b)	$2.4 \cdot 10^7$
Lactic acid bacteria c)	$1.3 \cdot 10^7$
Moulds d)	$8.0 \cdot 10^5$
Yeasts e)	$2.5 \cdot 10^3$

a) Out of 24 isolated aerobic bacteria cultures, 10 were identified as *Corynebacterium sp.*, 7 as *Bacillus sp.*, 5 as *Listeria sp.*, and 2 as *Enterobacter cloacae.*
b) Out of 14 isolated anaerobic bacteria cultures, 5 were identified as *Klebsiella pneumoniae*, 4 as *Propionibacterium sp.*, 3 as *Eubacterium sp.*, and 2 as *Enterobacter cloacae.*
c) Out of 8 cultures of isolated lactic acid bacteria, 5 were identified as *Lactobacillus casei* var. *rhamnosus*, and 3 as *Pediococcus damnosus.*
d) Out of 16 isolated mould cultures, 8 were identified as *Rhizopus sp.*, whereas 8 cultures were identified as *Mucor spp.* (6 different mycelial variations were observed).
e) All 15 isolated yeast cultures were identified as *Candida krusei.*

4. Discussion

Although there are points of similarity between Kaffirbeer [1] and Busaa, the manufacturing techniques are fundamentally different. In Kaffirbeer the wort resulting from saccharification of fermented maize by

Table 6 Spontaneous main fermentation of Busaa.

Fermentation time [days]	pH	Acidity a) [%]	Ethanol [vol. %]	Yeasts [g^{-1}]	Moulds [g^{-1}]	Lactid acid bacteria [g^{-1}]
0	4.90	0.28	0.05	$3.5 \cdot 10^3$	$4.0 \cdot 10^4$	$1.7 \cdot 10^5$
1	4.00	0.35	1.10	$7.0 \cdot 10^4$	$2.0 \cdot 10^4$	$9.2 \cdot 10^5$
2	3.81	0.54	2.30	$1.0 \cdot 10^7$	$1.0 \cdot 10^4$	$3.5 \cdot 10^6$
3 (marketing stage)	3.55	0.82	3.20	$1.1 \cdot 10^6$	$2.9 \cdot 10^3$	$4.3 \cdot 10^6$
6 (spoilt)	3.25	1.22	4.10	$9.5 \cdot 10^4$	—	$9.7 \cdot 10^7$

a) as lactic acid

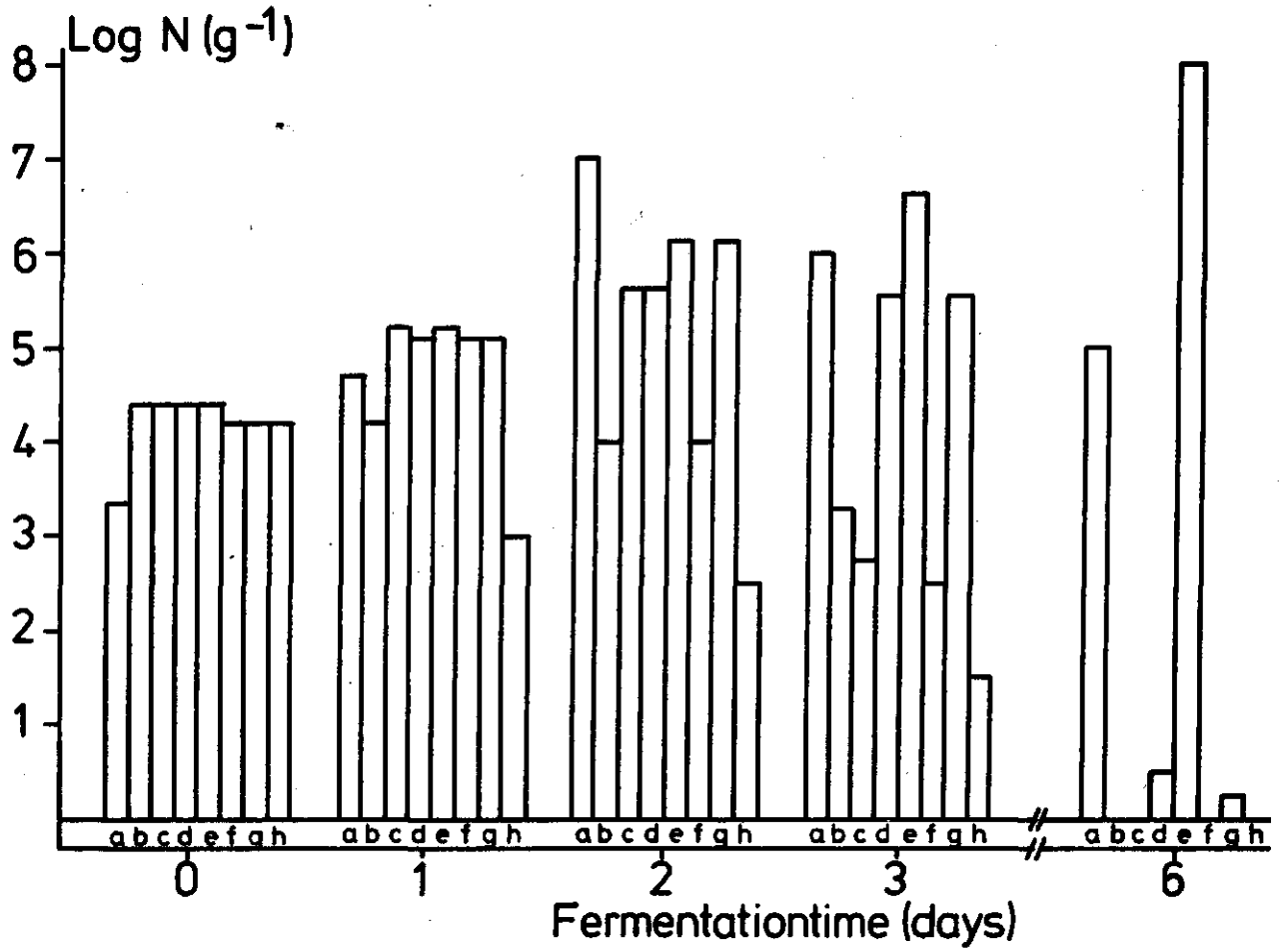


Fig. 2 Changes in microbial population during spontaneous main fermentation of Busaa.
a = Saccharomyces cerevisiae; b = Mucor sp; c = Lactobacillus brevis; d = L. salivarius var. salicinus; e = L. plantarum; f = L. viridescens; g = L. casei var. rhamnosus; h = L. buchneri.

sorghum malt is boiled for 2 hours prior to inoculation with a quantity of previously manufactured beer. The importance of acidification of the mash by fermentation was reported [1] to create optimum pH conditions for the sorghum amylases. In Busaa production however, such wort heating is not applied. The acidity provided by the soured maize at the onset of the main fermentation might well play an important role in providing the selective environmental conditions necessary for the rapid development of yeasts and lactic acid bacteria. Only one (*L. casei* var. *rhamnosus*) of the major organisms responsible for the main fermentation of Busaa (Figure 2) has been detected in fingermillet malt. Although traditionally manufactured fingermillet malt has been shown to contain considerable numbers of other lactic acid bacteria and yeasts, the role of fingermillet malt as a starter for the main fermentation of Busaa appears, therefore, to have only a limited value.

Brettanomyces yeasts have been reported [20] to play an essential role in the spontaneous fermentation of lambic and gueuze beers in Belgium. We have found no indication of the presence of this genus in Busaa. Similarly, it could not be detected in Kaffir-beer [21]. Acetic acid bacteria have been reported [5] to be present in considerable numbers during the manufacture of Merissa beer. Although it can be expected that acetic acid bacteria will develop at the surface of Busaa after prolonged open storage, they have not been detected in appreciable numbers during our investigations. At present the major toxicogenic moulds are considered to belong to *Aspergillus, Penicillium* and *Fusarium* genera [22]. Zearalenone, produced by *Fusarium graminearum* has been detected in Zambian opaque maize beers [23]. This mycotoxin was found to originate from the maize grains used as raw material for the beers. During our investigations only *Mucor* and *Rhizopus spp.* were detected. Although mycotoxin determinations were not carried out by us, it appears therefore unlikely that mycotoxins are produced during the fermentation stages of Busaa manufacture.

5. Acknowledgement
The author wishes to thank L. Rodrigues de Miranda (Centraalbureau voor Schimmelcultures, Yeast Division, Delft, the Netherlands) and J. van der Toorn (Laboratory for Microbiology, Technical University, Delft, the Netherlands) for working facilities and guidance during identification of yeasts and bacteria, respectively, and B.O.J. Odenyo and J. Ngige (Department of Food Science & Technology, University of

50 Nairobi) for their skilled technical assistance.

6. References

[1] Novellie, L., Wallerstein Labs. Commun. *104*, 17 (1968).
[2] Ekundayo, J.A., J. Food Technol. *4*, 217 (1969).
[3] Faparusi, S.I., J. Sci. Food Agric. *21*, 79 (1970).
[4] Ogundiwin, J.O., Brew. and Distill. Int. *7*, 40 (1977).
[5] Dirar, H.A., J. Food Sci *43*, 1683 (1978).
[6] Chevassus-Agnes, S., Favier, J.C. and Joseph, A., Cahiers de Nutrition et de Diététique *11*, 89 (1976).
[7] Aucamp, M.C., Grieff, J.T., Novellie, L., Papendick, B., Schwartz, H.M. and Steer, A.G., J. Sci Food Agric. *12*, 449 (1961).
[8] Strobl, A., Brauwelt *118*, 1171 (1978).
[9] Schwartz, H.M., J. Sci. Food Agric. *7*, 101 (1956).
[10] Cowan, S.T. and Steel, K.J. Manual for the identification of medical bacteria, Cambridge University Press, 1974.
[11] Rogosa, M. and Sharpe, M.E., J. Appl. Bacteriol. *22*, 329 (1959).
[12] Back, W., Brauwissenschaft *31*, 237, 312, 336 (1978).
[13] Buchanan, R.E. and Gibbons, N.E. (Ed.), Bergey's Manual of determinative bacteriology, 8th Ed. The Williams & Wilkins Co., Baltimore, 1975.
[14] Lodder, J. (Ed.), The Yeasts, North-Holland Publ. Co., Amsterdam, London, 1971.
[15] Horwitz, W. (Ed.), Official methods of analysis of the A.O.A.C., Washington, 1975.
[16] Somogyi, M., J. Biol. Chem. *160*, 61 (1945).
[17] Akinrele, I.A., J. Sci Food Agric. *21*, 619 (1970).
[18] Haikara, A., Mäkinen, V. and Hakulinen, R., Proc. Eur. Brew. Conv., p. 35, Amsterdam, 1977.
[19] Pederson, C.S., Microbiology of food fermentations, p. 117, AVI Publ. Co., Westport, Connecticut, 1971.
[20] Van Oevelen, D., Agricultura (Heverlee) *26*, 353 (1978).
[21] Van der Walt, J.P., J. Sci. Food Agric. *7*, 105 (1956).
[22] Northolt, M.D., The effect of water activity and temperature on the production of some mycotoxins. Dissertation, Agricultural University, Wageningen, The Netherlands, 1979.
[23] Lovelace, C.E.A. and Nyathi, C.B., J. Sci Food Agric. *28*, 288 (1977).

Mailing address author:
M.J.R. Nout
Department of Food Science & Technology
University of Nairobi
P.O. Box 29053
Kabete
Kenya

9 Process development and preservation of Busaa, a Kenyan traditional opaque maize beer*

9.1 SUMMARY

Traditional Busaa is obtained by spontaneous mixed lactic acid and alcoholic fermentations of roasted soured maize saccharified by finger millet malt. It has a short shelf-life of one to two days, mainly due to excessive acidification by homofermentative *Lactobacillus spp.* causing unacceptable sourness and destabilisation.
This investigation, aimed at development of a process for the manufacture of Busaa with extended shelf-life, included (a) optimisation of mashing conditions, (b) assessment of the stability of opaque maize wort, (c) selection of single and mixed pure starter cultures, (d) evaluation of preservation methods, and (e) influence of major process parameters on consumer acceptability.
Mashing for one hour at 50°C produced the highest degree of saccharification. The stability of opaque maize wort was not affected by added ethanol, or by heating at 93°C for four minutes. However, it destabilised at pH≤3.5, or by autoclaving at 110°C and 121°C. A mixed inoculum of *Saccharomyces cerevisiae* and *Lactobacillus brevis* yielded an acceptable and stable product containing 3.25 % v/v alcohol and 0.80 % w/v lactic acid. Preservation by (a) final fermentation and (b) pasteurisation, both in sealed bottles, yielded acceptable products. The latter technique was preferred from the point of view of processing and consumer acceptability.
A simple process is described for the manufacture of Busaa; an extended shelf-life was achieved as a result of pasteurisation.

9.2 INTRODUCTION

Microbiological and processing aspects of the traditional manufacture of Busaa, an opaque maize beer made from maize and finger millet, were reported earlier (1).
Traditional Busaa is obtained after spontaneous lactic acid and alcoholic fermentations of soured and subsequently roasted maize, to which water and malt from finger millet have been added. During the course of this mixed fermentation, the product attains a desirable composition, containing two to three % v/v alcohol and ½-1% w/v lactic acid, at which stage it is consumed. At ambient storage however, acidification continues, due to the increasing dominance of homofermentative *Lactobacillus spp.*, notably *L. plantarum* (1), causing unacceptable sourness as well

* (Chem.Mikrobiol.Technol.Lebensm., accepted for publication).

Table 1. Deterioration of traditional Busaa during ambient and refrigerated storage.

Days of fermentation	pH		Acidity[1]		Stability[2]		Flavour score[3]		Acceptability[4]	
	25°C	4°C	25°C	4°C	25°C	4°C	25°C	4°C	25°C	4°C
2	3.81	-	0.52	-	+		4		+	
3	3.55	3.55	0.78	0.78	+	+	5	5	++	++
4	3.25	3.55	1.03	0.78	-	+	4	5	-	++
7	3.08	3.50	1.35	0.80	--	+	2	4	-	+
14		3.50		0.81		+		4		+

1) as % w/v lactic acid.
2) + stable; - slight separation; -- fully sedimented.
3) 5 = like very much; 4 = like; 3 = neither like nor dislike; 2 = dislike; 1 = dislike very much.
4) ++ highly acceptable; + satisfactory; - rejected.

as destabilisation of the colloidal beer structure, leading to sedimentation of the suspended solid matter.
In practice therefore, the product, having a shelf-life of approximately one to two days at ambient temperatures, should be consumed in a stage of active fermentation.
Although preliminary experiments showed that the shelf-life of Busaa could be extended to 7-14 days using refrigerated storage (Table 1), this method would not constitute a feasible proposition for preservation on a commercial scale in rural areas of Kenya, since it would require widespread refrigerated storage facilities.
The present investigation is aimed at producing bottled Busaa, having an extended shelf-life at ambient temperatures and a good consumer acceptability.

9.3 MATERIALS AND METHODS

9.3.1 Maize

Locally available grade 1 sifted maize meal (endosperm grits from white maize) was used.

9.3.2 Finger millet malt

One batch of traditionally prepared malt from finger millet *(Eleusine coracana)* was used. The diastatic power of the malt, determined according to Rinke (2), was 84 g maltose/100 g dry matter.

9.3.3 Maintenance of cultures and preparation of inocula

Yeasts and *Lactobacillus spp.* were maintained on slopes of malt agar and tomato juice agar, respectively.
Yeast inocula were prepared by cultivation in 100 ml of malt extract broth contained in shaking flasks (150 rpm) at 29°C for 48 hours. This was followed by centrifugation at 3000 rpm for 10 minutes, after which the cells were washed with physiological saline and then suspended in 100 ml of the same. Using the same technique but omitting shaking, *Lactobacillus* inocula were prepared from cultures grown in Lactobacilli-MRS-broth. All media were purchased from Difco. For all fermentations, an inoculum size of 2% v/v was used.

9.3.4. Acidity

Acidity was determined by potentiometric titration of 20 ml samples with 0.1 N NaOH and expressed in terms of % w/v lactic acid.

9.3.5 Alcohol

The alcohol content was determined by chemical oxidation (A.O.A.C. method 11.006) (3) and was expressed in terms of % v/v.

9.3.6 Specific gravity

The specific gravity of the fermented opaque maize wort was determined using a hydrometer at 25°C; the suspended solid matter having been removed earlier by 15 minutes centrifugation at 3500 rpm.

9.3.7 Preparation of maize paste

Unless otherwise stated, maize paste was prepared by slowly adding 14% w/v wetted maize (based on dry matter) into boiling water (95°C)under stirring to avoid lumps. After all the maize had been added, the paste was cooked for a further 5-10 minutes at 93°C.

9.3.8 Mashing

Unless otherwise stated, mashing was carried out with 5% w/v finger millet malt (based on dry matter) for one hour at 50°C using slow stirring (50 rpm).

9.3.9 Bottling

450 ml product was dispensed into 500 ml beer bottles which had previously been sterilised. Prior to crown capping the head space was flushed for 10 seconds with carbondioxide.

9.4 RESULTS AND DISCUSSION

As described earlier (1), during traditional Busaa manufacture mashing and fermentation take place simultaneously, the micro-organisms responsible for the fermentation originating from the soured maize and the finger millet malt.
In this investigation, a pasteurised opaque maize wort was prepared prior to inoculation, enabling a study of the effects of fermentation by selected pure cultures on final product characteristics.
In order to assess the flavour developed by the tested pure cultures,the opaque maize wort was prepared from fresh maize grits instead of the usual soured and roasted maize which contributes a pronounced roasted flavour to the final product.

9.4.1 Optimisation of the brewing process

9.4.1.1 Mashing

Based on the traditional recipe used for the manufacture of Busaa, a lump-free maize paste was prepared as described under Methods (9.3.7), and adjusted to the required mashing temperature in a stirred vessel connected to a reflux condenser, after which 5% w/v finger millet malt (based on dry matter) was added. Table 2 shows that the highest initial rate of saccharification was obtained at 65°C although this temperature led to early inactivation of the malt amylases, resulting in the lowest final extent of saccharification. The highest final degree of saccharification was obtained by mashing at 50°C. As can be seen from Table 2, a mashing time of one hour at this temperature can be considered adequate.
It should be noted that after this mashing operation the opaque

wort still contains undamaged starch originating from the maize grits. The presence of residual starch is considered essential since it probably contributes to the desirable opacity of the final product.

Table 2. Mashing of 14 % w/v maize paste with 5 % w/v finger millet malt (extent of saccharification as °Brix).

Mashing time (min.)	Mashing temperature (°C)					
	40	45	50	55	60	65
0	2.4	2.4	2.4	2.4	2.4	2.4
15	6.2	6.7	7.0	7.7	8.5	9.2
30	8.9	9.5	10.0	11.0	10.6	10.8
45	10.4	11.0	11.6	11.6	11.3	10.8
60	11.0	11.7	12.3	11.7	11.4	10.9
90	11.5	12.2	12.4	11.7	11.4	10.9
120	12.2	12.5	12.6	11.8	11.4	10.9

9.4.1.2 Stability of opaque maize wort

Opaque maize wort was prepared as described under Methods (9.3.7; 9.3.8). Separate aliquots were treated as follows: (a) lactic acid was added to adjust the pH value to: 2, 2½, 3, 3½, 4, 4½, 5, and 5½, (b) absolute ethanol was added to obtain ethanol concentrations of 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 % v/v, and (c) the following heat treatments were applied: (i) under reflux for 30 minutes at 65°C, 45 minutes at 65°C, 15 minutes at 75°C, 10 minutes at 80°C, 4 minutes at 93°C; (ii) by autoclaving in a pressure-cooker for 15 minutes at 110°C, and for 10 minutes at 121°C.
The treated wort samples were left in covered beakers at 25°C, and at regular time intervals (12, 24, 36 h) the extent of separation and sedimentation of the wort solids was assessed visually. Table 3 summarises the effect of pH on wort stability and shows that destabilisation occurred at pH < 3.5 within 24 hours. On the other hand, added ethanol up to 10 % v/v did not affect the stability of opaque maize wort. Heat treatment of the wort at 65°, 75°, 80°, and 93°C resulted in a slight increase of the wort viscosity while the wort samples fully retained their stability. However, when more thorough heat treatment under pressure (110° and 121°C) was applied, an immediate collapse of the colloidal wort structure occurred resulting in complete sedimentation of all suspended solid matter.

It can thus be concluded that, whereas the ethanol concentration in the final product does not appear to affect its opacity, the product gradually destabilises at pH levels below 3.5. This explains the destabilisation of Busaa under commercial conditions where homofermentative lactobacilli were found to acidify the product well below pH 3.5. Although the opaque maize wort could not withstand a sterilisation treatment by autoclaving, it has been shown to endure a thorough pasteurisation (4 min at 93°C) without destabilising.

Table 3. Effect of pH on stability of opaque maize wort.

	Storage (hours) at 25°C			
pH	0	12	24	36
2.0	+[1)]	-	-	--
2.5	+	+	-	--
3.0	+	+	-	--
3.5	+	+	+	+
4.0	+	+	+	+
4.5	+	+	+	+

1) + stable; - slight separation; -- fully sedimented.

9.4.1.3 Fermentation of opaque maize wort by single pure cultures

Opaque wort was prepared as described under Methods (9.3.7; 9.3.8), dispensed in 100 ml portions in pre-sterilised 250 ml conical flasks, and pasteurised at 93°C for 4 minutes. Duplicate wort samples were inoculated with 2 ml suspensions of (a) yeasts : *Saccharomyces cerevisiae* (strains "A" and "B"), (b) heterofermentative *Lactobacillus spp.* : *L.viridescens, L.buchneri, L.brevis,* and (c) homofermentative *Lactobacillus spp.* : *L.casei* var. *rhamnosus, L.casei* var. *alactosus, L.salivarius* var. *salicinius,* and *L.plantarum,* which had all been isolated from commercial Busaa fermentations, and were suspended in physiological saline. Incubation was carried out at 29°C for 3 and 6 days after which the products were analysed for the following : pH, acidity, alcohol content, and wort stability; a subjective assessment of the flavour was given by a small expert taste panel.
The results, shown in Table 4, indicate that (a) the maximum level of acidity produced by the heterofermentative *Lactobacillus spp.* is such that the stability of the wort is maintained, whereas most of the homofermentative species produce more acid than can be tolerated by the wort, (b) *Sacch. cerevisiae* "A" produces more alcohol than strain "B", and (c) the flavour produced by the heterofermentative species obtained a better overall assessment than that produced by homofermentative cultures.

9.4.1.4 Fermentation of opaque maize wort by mixed pure cultures

On the basis of their favourable flavour characteristics, *L.viridescens, L.brevis* and *L.plantarum* were selected and their behaviour as mixed starter cultures with *Sacch. cerevisiae* "A" was studied as follows.
Pure cultures were grown as described under Methods (9.3.3) in flasks containing 100 ml of the appropriate broth. After 48 h incubation at 29°C, cells were harvested and washed. A mixed inoculum was obtained by suspending the washed cells of two pure cultures -

Table 4. Fermentation of opaque maize wort by single pure cultures.

	pH		Acidity % w/v lactic acid		Alcohol % v/v		Stability[1]		Flavour score[2]	
Fermentation time	3 days	6 days	3 days	6 days	3 days	6 days	3 days	6 days	3 days	6 days
Control (not inoculated)	5.85	5.85	0.07	0.07	0.0	0.1	+	+		
Yeasts :										
Sacch.cerevisiae "A"	4.43	3.79	0.32	0.53	3.28	3.70	+	+	3	3
Sacch.cerevisiae "B"	4.76	4.24	0.23	0.34	2.75	2.84	+	+	3	3
Heterofermentative *Lactobacillus spp.* :										
L.viridescens	4.06	3.47	0.47	0.78	0.3	0.3	+	+	4	4
L.buchneri	4.04	3.39	0.48	0.86	0.3	0.4	+	-	4	3
L.brevis	3.96	3.40	0.53	0.83	0.2	0.2	+	+	5	5
Homofermentative *Lactobacillus spp.* :										
L.casei var. *rhamnosus*	3.37	3.04	1.05	1.36	0.0	0.1	-	—	3	3
L.casei var. *alactosus*	3.96	3.40	0.51	0.84	0.0	0.1	+	+	3	2
L.salivarius var. *salicinius*	3.44	3.09	0.96	1.21	0.1	0.1	+	—	3	3
L.plantarum	3.27	2.99	1.17	1.46	0.0	0.1	-	--	4	4

1), 2) For symbols see Table 1 , footnotes 2 and 3, respectively.

- each grown in 100 ml of medium -, together in 100 ml of sterile physiological saline. Pasteurised opaque maize wort was inoculated with 2 % v/v of this mixed inoculum and incubated at 29°C for 12 days. The cultures were analysed at regular intervals for pH, acidity, alcohol content, and stability, whereas flavour was assessed subjectively.
Table 5 summarises the results of this experiment and indicates the following: (a) maximum levels of acidity were reached considerably earlier than maximum levels of alcohol content, (b) in

Table 5. Fermentation of opaque maize wort by mixed pure cultures.

Fermentation time (days)	Mixed inoculum[1)]	pH	Acidity % w/v lactic acid	Alcohol % v/v	Stability[2)]	Flavour score[3)]
0		5.85	0.07	0.05	+	4
3	1	3.55	0.75	2.75	+	5
	2	3.60	0.70	2.78	+	4
	3	3.20	1.10	2.95	--	3
6	1	3.60	0.71	3.30	+	5
	2	3.58	0.72	3.34	+	3
	3	3.10	1.28	3.40	—	2
9	1	3.55	0.75	3.30	+	4
	2	3.55	0.74	3.29	+	2
	3	3.10	1.30	3.30	—	2
12	1	3.50	0.80	3.25	+	4
	2	3.52	0.75	3.30	+	2
	3	3.05	1.37	3.40	—	1

1) 1 = *Sacch.cerevisiae*"A" + *L. brevis*; 2 = *Sacch.cerevisiae*"A" + *L. viridescens*; 3 = *Sacch.cerevisiae*"A" + *L. plantarum*.
2), 3) For symbols see Table 1, footnotes 2 and 3, respectively.

mixed cultures, the yeast produced slightly less alcohol, probably due to the lower pH compared with pure yeast cultures, (c) mixed starter No. 3 containing *L. plantarum* produced excessive acidity resulting in early destabilisation and poor flavour which was described as harsh, (d) mixed starter No. 2 containing *L. viridescens* maintained stability of the wort but developed a rather unacceptable mousy flavour and (e) mixed starter No. 1 containing *L. brevis* produced a stable fermented product with attractive flavour.

9.4.2 Evaluation of preservation methods

Preservation studies were carried out on Busaa obtained from pasteurised opaque maize wort fermented by a 1:1 mixed inoculum of *Sacch. cerevisiae*"A" and *L. brevis*. The fermentations were carried out in a Chemap 14 litre laboratory fermenter. The changes in pH, acidity, alcohol content, and specific gravity which took place during these fermentations are presented in Table 6 (refer to analysis after storage period 0 days only).
Successfully preserved Busaa should not destabilise on prolonged storage at ambient temperatures as a result of continued acidifi-

Table 6. Preservation of Busaa by final fermentation in sealed bottles.

Time of bottling (h after inoculation)	Storage period (days, 25°C)	pH	Acidity (% w/v lactic acid)	Alcohol (% v/v)	Stability[1)]	Pressure in the bottle[2)]	Specific gravity
0	0	5.85	0.04	0.10	+	0	1.053
19	0	3.70	0.53	1.27	+	0	1.040
	14	3.35	0.94	2.70	-	+++	1.025
	30	3.30	0.98	2.80	--	+++	1.022
43	0	3.50	0.74	2.60	+	0	1.032
	14	3.40	0.85	3.10	+	++	1.022
	30	3.35	0.86	3.20	-	++	1.020
49	0	3.50	0.76	2.80	+	0	1.031
	14	3.45	0.80	3.40	+	++	1.024
	30	3.40	0.82	3.50	-	++	1.020
58	0	3.50	0.78	2.95	+	0	1.029
	14	3.45	0.81	3.45	+	++	1.023
	30	3.45	0.80	3.50	+	++	1.020
62	0	3.50	0.80	3.15	+	0	1.029
	14	3.50	0.81	3.50	+	++	1.023
	30	3.45	0.80	3.50	+	++	1.020
65	0	3.50	0.80	3.20	+	0	1.029
	14	3.50	0.80	3.50	+	+	1.023
	30	3.48	0.79	3.52	+	+	1.020
70	0	3.50	0.81	3.30	+	0	1.028
	14	3.50	0.81	3.40	+	+	1.022
	30	3.50	0.80	3.45	+	+	1.020
73	0	3.50	0.81	3.35	+	0	1.027
	14	3.50	0.80	3.45	+	0	1.022
	30	3.45	0.79	3.55	+	0	1.020

1) For symbols see Table 1, footnote 2.
2) +++ explosive; ++ gushing; + "pfft" (desirable); 0 dead (no pressure).

cation and should sparkle slightly, thereby suggesting that the product is actively fermenting. The two preservation methods which were assessed for their suitability are described below.

9.4.2.1 Final fermentation in sealed bottles

This method is similar to the traditional method for the preservation of *e.g.* Berliner Weissbier (4) and refermented Gueuze (5) and implies that the product is bottled when fermentation is almost complete. No pasteurisation is applied so that the remaining fermentable carbohydrates will slowly be finally fermented by the inoculum. Since the acid production by *L. brevis* is limited to approximately 0.8 % w/v lactic acid, as determined by its acid tolerance, then beyond this stage, fermentation of the remaining fermentable matter in opaque maize wort can be expected to be of an alcoholic nature. The moment of bottling will determine the extent of final fermentation taking place in the sealed bottle

and thus the pressure that will develop as a result of the generation of carbondioxide.
Experiments to define the appropriate moment of bottling are summarised in Table 6.
The results indicate that a stable product with acceptable CO_2 pressure was obtained by bottling 65-70 hours after inoculation. However, in practice it was found rather difficult to determine the correct moment for bottling, which lead to several unexpected occurrences of gushing which was brought on by bottling too early, resulting in an excessive build-up of carbondioxide pressure.

9.4.2.2 Short fermentation in sealed bottles, followed by pasteurisation

After 58, 62, and 65 hours of fermentation, samples of fermenting wort were bottled and crown capped. Fermentation was allowed to continue for 6 hours at 25°C, to generate approximately one atmosphere of carbondioxide over-pressure, after which the product was pasteurised (holding at 93°C for 30 minutes).
Table 7 summarises the results obtained using this method, and shows that stable products with acceptable CO_2 pressure were obtained. It should be noted that as a result of this heat treatment, the colour, taste, and viscosity of the product change slightly.

Table 7. Preservation of Busaa by bottling and pasteurisation.

Time of bottling (h after inoculation)	Storage period (days, 25°C)	pH	Acidity (% w/v lactic acid)	Alcohol (% v/v)	Stability[1)]	Pressure in the bottle[2)]
58	0	3.55	0.70	2.85	+	0
	14	3.50	0.75	2.80	+	+
	30	3.50	0.72	2.85	+	+
62	0	3.50	0.80	3.10	+	0
	14	3.60	0.75	3.05	+	+
	30	3.60	0.78	3.10	+	+
65	0	3.50	0.80	3.20	+	0
	14	3.55	0.76	3.20	+	+
	30	3.50	0.78	3.25	+	+

1) For symbols see Table 1, footnote 2.
2) For symbols see Table 6, footnote 2.

Although both preservation techniques were shown to yield stable products, the method involving pasteurisation proved to be more reliable and convenient in practice.

9.4.3 Effect of process parameters on consumer acceptability

Traditional Busaa is obtained by spontaneous fermentation of previously soured and roasted maize, followed by filtration prior to consumption to remove coarse particles.
During the investigation, several alternative operations were identified at the following stages: raw material treatment, mode

of fermentation, filtration, and preservation. The effects of (a) use of fresh *vs.* roasted maize, (b) fermentation by mixed pure cultures *vs.* spontaneous fermentation, (c) filtration, and (d) pasteurisation, on consumer acceptability were studied in a series of 50 litre-sized batches.

Where roasted soured maize was used, a 1:1 mixture of water and maize endosperm grits was allowed to ferment for 3 days at 29°C after which it was roasted in a traditional flat iron pan over a charcoal fire until cooked and slightly brown. Where applicable, spontaneous Busaa fermentation was achieved by following the traditional method (1) using roasted soured maize as a raw material. Filtration was carried out over a 400 micron vibratory sieve, whereas pasteurisation was carried out as described in Section 9.4.2.2 (holding at 93°C for 30 minutes). In all cases where mixed pure inoculum was used, opaque maize wort was prepared as described under Methods (9.3.7; 9.3.8) and was pasteurised at 93°C for 15 minutes prior to inoculation at 30°C. All fermentations were continued until 3.0-3.2 % v/v alcohol and 0.75-0.80 % w/v acidity (as lactic acid) were obtained.

Organoleptic assessment of samples, warmed-up to 35°C, was carried out by an expert taste panel of 25 persons selected from staff and students of the University of Nairobi. Triangular tests were used to detect any differences among the samples, and separate paired preference tests were used to observe preferences where previously differences had been detected at significance level $\geq$ 95 %. In the triangular tests, any colour difference between samples was eliminated by appropriate illumination. Table 8 summarises the mode of preparation of the tested samples, whereas Table 9 indicates the results of their organoleptic assessment.

Table 8. Summary of process variables evaluated by organoleptic techniques.

Sample	Maize[1)]	Fermentation[2)]	Filtration[3)]	Pasteurisation[4)]
A	fr	mi	uf	pa
B	fr	mi	fi	pa
C	rs	mi	uf	pa
D	rs	mi	fi	pa
E	rs	sp	fi	pa
F	rs	sp	fi	np

1) fr = fresh; rs = roasted soured. 2) mi = mixed inoculum; sp = spontaneous.
3) uf = unfiltered; fi = filtered. 4) np = not pasteurised; pa = pasteurised.

It appears that the Busaa prepared from roasted soured maize was preferred with significance when compared with the product made from fresh maize. Comments by the panellists suggest that the flavour of roasted cereal as well as the light-brown colour, partly obtained from the roasted maize, are essential ingredients for acceptable Busaa.

The taste panel was not able to distinguish with significance between the product obtained by spontaneous fermentation and that fer-

Table 9. Organoleptic evaluation of Busaa process variables.

Effect	Samples		Triangular test			Paired preference test		
	1	2	correct	false	level of confidence(%)	1	2	level of confidence(%)
Maize	B*	D	19	4	99.9	B 7	D 20	95
Fermentation	D	E	10	15	-			
Filtration	A	B	15	9	99	A 16	B 8	90
Filtration	C	D	14	10	95	C 13	D 11	-
Pasteurisation	E	F	15	10	99	E 15	F 6	95

*) For symbols see Table 8.

mented by the mixed cultures of *Sacch. cerevisiae* "A" and *L. brevis*.

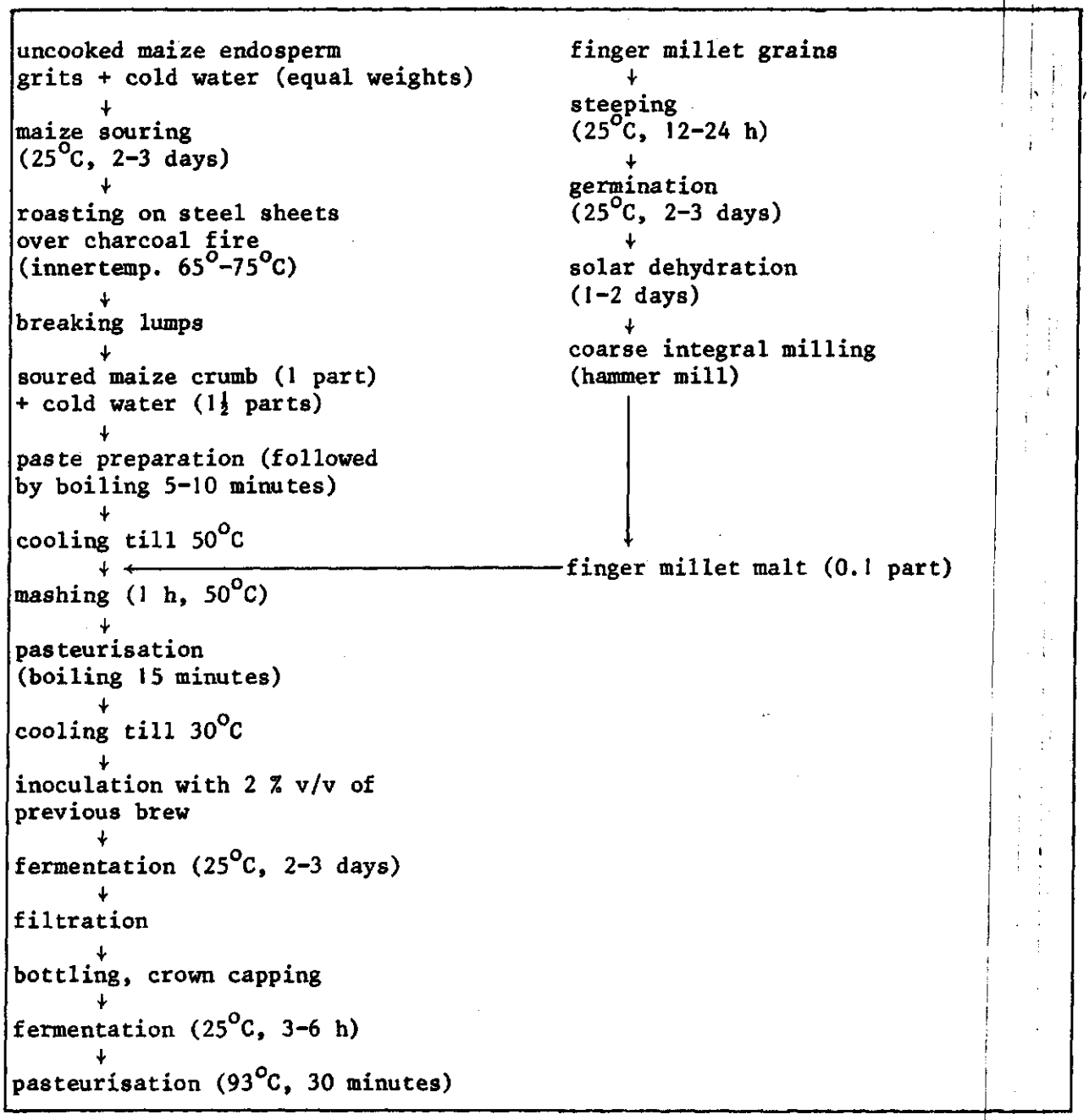
The difference between filtered and unfiltered samples of Busaa could be established at a significant level, mainly thanks to differences in texture, which were described as smooth and rough, respectively. Preference for either filtered or unfiltered product depended on whether fresh or roasted soured maize had been used as raw material. According to the panellists, unfiltered Busaa from fresh maize was preferred with significance compared with its filtered equivalent because the millet particles contributed additional colour and flavour to the beer, suggesting that roasted soured maize had been used in its preparation. In addition, some panellists also noted that the texture was of a minor importance when compared with flavour and colour. Although the panel could distinguish at a significant level between filtered and unfiltered Busaa, both made from roasted soured maize, neither of the two samples was preferred with significance. Panellists remarked that both samples possessed an attractive flavour as well as colour.
As indicated above (9.4.2.2), the pasteurisation leads to a slight darkening and an increase in viscosity, and changes the flavour of the product as well. As shown in Table 9, the pasteurised samples were preferred with significance, because, according to the panel, the slightly increased viscosity gave more body to the product; it was also noted that the flavour had improved.

9.5 CONCLUSION

The aim of this investigation was to develop a simple process which could be adopted by small-scale breweries. It was shown that the use of roasted soured, rather than fresh maize is an essential factor in flavour and colour development.
Although the product obtained with a mixed pure inoculum of *Sacch. cerevisiae* "A" and *L. brevis* was of equal acceptability when compared with Busaa obtained by spontaneous fermentation, the latter mode of fermentation is easier to carry out at a small-scale industrial level, particularly when considering the skill and equipment that would be required to maintain the purity of the starter cultures.
For reasons of safety and convenience, pasteurisation rather than final fermentation in sealed bottles, is the preferred method of preservation.
It would appear that bottling and pasteurisation of traditionally manufactured Busaa could solve the majority of problems linked with poor product quality and shelf-life. However, this is not the case, since gelatinisation of the residual starch from the traditional Busaa occurs during pasteurisation, and transforms the product into a gel which comes out of the bottle in lumps.
An adapted process which eliminates this problem was developed as shown in Figure 1. The inclusion of two heat treatments, one in particular during pasting and the other to a lesser extent during mash-pasteurisation, eliminates the undesirable gelatinisation that would normally take place during pasteurisation of the final bottled product.
Equipment that would be required in addition to that already available in the small-scale, traditional breweries should consist of at least one cooking vessel for mashing and pasteurisation, a

thermometer, bottles, and a manual crown capper.

Figure 1. Flow-sheet for the manufacture of preserved Busaa.



9.6 REFERENCES

(1) Nout, M.J.R., Chem.Mikrobiol.Technol.Lebensm., *6* (1980) 137-142.
(2) Rinke, W., Das Bier, p.124. Paul Parey, Berlin & Hamburg 1967.
(3) Horwitz, W. (Ed.), Official methods of analysis of the A.O.A.C. The Association, Washington DC 1975.
(4) Strobl, A., Brauwelt, *118* (1978) 1171.
(5) Van Oevelen, D., Agricultura (Heverlee), *26* (1978) 353-505.

10 Malting characteristics of finger millet, sorghum, and barley*

10.1 SUMMARY

Finger millet (FI), white (SI) and red (SA) sorghum were not water-sensitive and could be equally well steeped and germinated in either a continuous water-spray, or continuous immersion steep followed by dry germination. Barley "Research" (BR) (water-sensitivity 26 %) performed better under the latter conditions. Liquefying power yield (LPY), reflecting malt α-amylase activity, and malting losses depended more on germination temperature (range 15-30°C) in BR and SA, than in FI and SI. Diastatic power in BR represented predominantly β-amylase, whereas less β-amylase was developed in FI, SA, or SI. Peptone extraction of malt increased the diastatic power, mainly as a result of improved extraction of α-amylases. Proteolytic activity was highest in BR, followed by SI, FI, and SA. Endo-β-glucanase activity was highest in BR, followed by SI, SA, and FI. Application of bromate reduced malting losses in BR, had slight effect on FI and SI, and none on SA. Application of gibberellic acid accelerated the development of α-amylase and proteolytic activity in BR and FI, but had no significant effect on SI and SA. In all grains, β-amylase was inactivated faster than α-amylase by increased kilning temperatures. Proteolytic activity in FI had the highest thermal resistance. Wort filtrability of FI malt was extremely good, inspite of its low endo-β-glucanase activity. FI, SA, and SI malts were found unsuitable as barley malt extenders for conventional lager beer production, but FI and SI malts could be used for the manufacture of tropical lager beers.

10.2 INTRODUCTION

Traditional African opaque beers based on sorghum or sorghum-maize mixtures, *e.g.* Cameroonian Amgba (7), Nigerian Otika (28) and South African Kaffir beer (27), fulfil an important demand for low-alcoholic beverages, in particular for the low-income group of consumers. It has been estimated (3) that 30 % of the total sorghum harvest in Africa is used for malting and brewing purposes. In Kenya, the major traditional opaque beer Busaa is based on maize (*Zea mays*) and finger millet (*Eleusine coracana*), whereas bulrush millet (*Pennisetum typhoides*) is used in negligible quantities for the manufacture of a similar beer, Marwa.

* co-author: B.J. Davies, Kenya Breweries Ltd., Nairobi.
(J. Inst. Brew., accepted for publication).

Microbiological and technological aspects of the manufacture of Busaa have been reported earlier (21,22). The malt required for Busaa manufacture is exclusively obtained from finger millet and a large proportion of the finger millet harvest is used for this purpose. The traditional malting technique for finger millet is similar to that described elsewhere (7) for sorghum, and includes 24 h steeping by continuous immersion, two to three days germination in 5-10 cm thick layers covered by wet gunny bags, followed by solar dehydration for one or two days, all at ambient temperatures.

Much research has been carried out on the germination and malting properties of sorghum. Hulse *et al.* (12) have recently reviewed the work carried out in this field. Sorghum malting has been studied, not only in relation to its use in traditional beer making (23,25,26), but also as a possible replacement of barley malt in the manufacture of lager beers (1,29,34).

Apart from early work by Chandrasekhara and co-worker (6), little is known about the properties of finger millet as a malting cereal. The aim of this paper is to compare the malting properties of Kenyan finger millet with those of Kenya-grown sorghum and barley, in relation to the manufacture of traditional Busaa, as well as lager beers.

The scope of the investigations include (a) the effect of varying physical conditions on germination, (b) the influence of gibberellic acid treatment and kilning temperatures on the activity of important brewing enzymes, and (c) a comparison of the brewing potential of the worts obtained. The optimisation of germination conditions was based on 150 g sized laboratory trials, whereas 1 kg sized micro-malting experiments were used for investigating enzyme development in the grain, and for the preparation of malt for the mashing experiments.

10.3 EXPERIMENTAL METHODS

10.3.1 Samples

Samples of the following grains (1978 harvest) were collected and used throughout : (a) Finger millet (*Eleusine coracana* Gaertn) local variety Imele, a popular variety used in Kenya for traditional malting, (b) Sorghum (*Sorghum bicolor* (L) Moench) varieties locally known as Andivo (red coat) and Ingumba (white coat), all obtained from Maragoli market, Kakamega district, and (c) Barley variety Research, obtained from Kenya Breweries Ltd., Nairobi.

10.3.2 Germination conditions

10.3.2.1 Laboratory small scale

Batches of 150 g grain were either (i) steeped and germinated under continuous water-spraying in a buchner funnel fed by a circulating pump from a constant temperature water-bath, where the water was replaced with fresh water every 24 h, or (ii) steeped until 45-46 % moisture content, after which they were transferred for germination into large glass cylinders closed with vented stoppers, as suggested by Whitmore (37). The glass cylinders were incubated in a constant temperature water-bath.

In order to preserve enzyme activities as much as possible, kilning was carried out at 50°C under vacuum (20 mm Hg) for 12 h. The kilned malt samples were stored at 3°C in sealed polythene bags.

10.3.2.2 Micro-malting scale

Micro-malting trials were carried out in a Seeger, type 115/1978 micro-malting apparatus (8 x 1 kg dry grain capacity), as follows:
(i) steeping by continuous immersion for 48 h (water changes after 6 and 24 h) at 20°C for barley, Ingumba sorghum, and finger millet, and for 24 h (water changes after 2 and 6 h) at 25°C for Andivo sorghum.
(ii) germination was carried out at the temperatures mentioned under (i). The grains were turned twice daily. To compensate for dehydration, 30-60 ml water per kg dry grain wt was mixed daily into the grains during turning.
(iii) where applicable, addition of gibberellic acid (GA_3, supplied by Biocon Ltd., 164-166 Edgware Rd, London) or $NaBrO_3$, was carried out after a chit-count of over 90 % had been attained (Ingumba sorghum : after 6 h germination, others : after 12 h germination). The required wt of additives (GA_3 : 0.2 ppm, 0.02 ppm; $NaBrO_3$: 15 ppm, 150 ppm, all based on dry grain wt) was dissolved in 12.5 ml dist. water. This solution was fully absorbed by 1 kg (dry wt) germinating grains after thorough mixing.
(iv) all samples were kilned at 50°C air-on for 16-20 h, except for the trials on the effect of kilning temperature, where temperatures of 60°, 70°, 80°, 90° or 100°C were applied for 16 h.

10.3.3 Analyses

10.3.3.1 Germinative capacity

The sulphuric acid technique (13) was used.

10.3.3.2 Germinative energy, water-sensitivity

Institute of Brewing recommended methods of analysis (15) were used.

10.3.3.3 Water absorption during steeping

Excessive water was removed from samples by centrifuging at 1200 rpm for 5 min, after which their moisture content was determined by oven drying at 105°C for 24 h.

10.3.3.4 Root %

Radicles and cotyledons were hand-dissected from kilned samples and their wt expressed as % of the total sample wt.

10.3.3.5 Malting loss %

The method described by Novellie (26) was used, after removal of the radicles and cotyledons from kilned samples. Malting losses were based on dry wt.

10.3.3.6 Liquefying power yield

The α-amylase activity of small samples of kilned grains was estimated by their liquefying effect on a 8 % w/v paste of commercial maize starch (CPC, Kenya) in water, as inspired by Ranum *et al.* (32). In a Brabender Amylograph bowl, 450 ml dist. water was mixed with 39.0 g (dry wt) maize starch into a lump-free suspension. Between 0.5 and 1.0 g of the finely ground sample (qty depended on activity) was added and the Amylograph test carried out as usual. The reduction in peak viscosity, compared with that of a control containing only maize starch and water, was expressed in B.U. (Brabender Units). The liquefying power yield (L.P.Y.) was expressed as B.U./g original grain dry wt, and was calculated as follows :

$$L.P.Y. = \frac{(PV_c - PV_s) \cdot (100-ML) \cdot 10^4}{W_s \cdot (100-mc_s) \cdot (100-R) \cdot (100-mc_o)} \quad \text{B.U./g original grain dry wt.}$$

where : PV_c = peak viscosity of control (B.U.)
PV_s = peak viscosity of sample (B.U.)
ML = malting loss (%)
W_s = sample wt (g)
mc_s = moisture content of sample (%, as-is)
R = root %
mc_o = moisture content of original grain (%, as-is)

10.3.3.7 Modification

The modification was followed by determining the malt specific gravity, according to the method of Hartong & Kretschmer (11).

10.3.3.8 Diastatic power

Two methods were used : (a) the European Brewery Convention method (2), and (b) the Institute of Brewing recommended method (14). Diastatic power was expressed as ^{o}Windisch-Kolbach (^{o}WK) and ^{o}IoB (comparable to ^{o}L), respectively, per 100 g original grain dry wt. Note : ^{o}IoB = ^{o}Institute of Brewing ; ^{o}L = ^{o}Lintner.

10.3.3.9 Peptone extraction

Water-insoluble amylases were extracted according to Novellie (23), using a 2 % Bacto-peptone solution as the extraction solvent. After extraction, the E.B.C. method was used for determination of diastatic power.

10.3.3.10 α-/β-Amylases

The contribution of α- and β-amylases to the diastatic power was estimated by inactivating the β-amylase by heating at 70^{o}C in the presence of Ca^{++}-ions, according to Preece (31). The α-amylase was measured by subsequent determination of diastatic power and a correction was made for the α-amylase inactivation during the previous heating process. The β-amylase activity was calculated by difference.

10.3.3.11 Proteolytic activity

AACC method 22-61 (33) was used; proteolytic activity of malt samples was expressed as mg N/100 g original grain dry wt.

10.3.3.12 Endo-β-glucanase activity

The method described by Bathgate (5) was used; activities were expressed as I.R.V. units/100 g original grain dry wt.

10.3.3.13 Mashing and wort analysis

Mashing of a fine grind and determination of the extract (% Plato), conversion time (min), clarity, colour, pH, total soluble N (mg/ /100 ml wort), and filtration time of the resulting worts was carried out according to Analytica-E.B.C. (2). The buffering capacity of 100 ml wort was expressed as ml 0.1 N NaOH or HCl needed to raise the pH from 4.27 to 7.07.

10.4 RESULTS

Major characteristics of the grains used in the experiments are listed in Table 1. Table 2 summarises the steeping rate, *i.e.*

Table 1. Characteristics of grains used.

	Finger millet Imele	Sorghum Andivo	Sorghum Ingumba	Barley Research
Colour seed coat	light brown	light red	white	yellowish
Mealiness (%)	100	100	100	17
Average dorsal length (mm)	1.44	5.48	4.99	9.09
Moisture (%, as-is)	11.3	12.4	12.6	12.8
Thousand kernel weight (g)	1.95	25.5	18.8	39.6
Total Nitrogen (%, dry wt)	1.33	1.35	1.46	1.78
Germinative capacity (%)	95	97	99	100
Germinative energy (%)	95	94	96	99
Water-sensitivity (%)	4	0	0	26

the time required to reach a moisture content of 45 % in the kernel, as a function of water temperature.
The influence of method and temperature of steeping/germination, on the visual extent of germination is shown in Table 3. As could be expected from its relative water-sensitivity (Table 1), barley performed better using the W/D steeping/germination programme, whereas the other grains gave better germination by continuous spraying. Continuous spraying at temperatures higher than 25°C resulted in dead steeps in the case of barley. The other grains could not be successfully germinated beyond 72 h at 35°C, for the same reason.
The malting losses incurred during the small scale trials were high after prolonged germination. A summary of the results is pre-

Table 2. Effect of steeping temperature on rate of water absorption under conditions of continuous immmersion.

	Time (h) required to reach 45 % moisture content				
Temperature	15°C	20°C	25°C	30°C	35°C
Finger millet Imele	n.d.*	65	40	30	27
Sorghum Andivo	57	48	40	35	33
Sorghum Ingumba	65	38	27	20	18
Barley Research	60	48	37	30	28

* : n.d. = not determined.

Table 4. Malting losses incurred as a function of germination temperature and time (small scale experiments).

		malting losses (%)					
Temperature		20°C		25°C		30°C	
Time[1] (days)	Mode[2]	3	6	3	6	3	6
Finger millet Imele	C	5	36	11	55	11	57
Sorghum Andivo	C	4	27	8	31	9	35
Sorghum Ingumba	C	8	28	7	28	9	32
Barley Research	W/D	13	27	9	22	3	9

1) time of steeping + germination. 2) see footnote 1, Table 3.

sented in Table 4. The comparatively low loss for barley at 30°C is explained by the poor germination at that temperature. Malting losses in finger millet tended to be very high, partly due to the considerable length of the radicles compared to the dimensions of the grain.

Figure 1 shows the development of liquefying power yield (L.P.Y.), which mainly represents α-amylase activity, as a function of germination temperature and time during the small scale trials. In general, the L.P.Y. will be low at the start of germination because of low α-amylase activity in the malt. With increasing germination time, the L.P.Y. will increase to a maximum, beyond which it will decrease again due to excessive malting losses incurred. Figure 1 also shows that the time required to reach a maximum L.P.Y. is shorter at higher germination temperatures. The maximum L.P.Y.'s obtained with finger millet and Ingumba sorghum were hardly influenced by the germination temperatures used, whereas for barley and Andivo sorghum the maximum L.P.Y.'s were strongly affected by the temperature of germination. On the basis of these results, the temperatures for the micro-malting trials were chosen, as specified under experimental methods (Section 10.3.2.2).

Table 5 summarises the relevant periods in the germination of the

Table 3. Effect of Mode and Temperature of Steeping/Germination on extent of germination after 72 h (small scale experiments).

Temperature	15°C		20°C		25°C		30°C		35°C	
Mode[1)]	C	W/D	C	W/D	C	W/D	C	W/D	C	W/D
Finger millet Imele	+[2)]	-	++	+	+++	+	+++	+	++	+
Sorghum Andivo	+	-	++	+	+++	++	++	++	++	++
Sorghum Ingumba	+	-	++	+	+++	++	++	++	+	++
Barley Research	+	++	+	+++	+	++	-	+	-	+

1) C = steeping and germination under continuous water-spray; W/D = steeping by continuous immersion, followed by germination in glass cylinders with vented stoppers.
2) - = no germination; + = poor germination; ++ = satisfactory germination; +++ = good germination.

Figure 1. Liquefying power yield as a function of germination temperature and time.

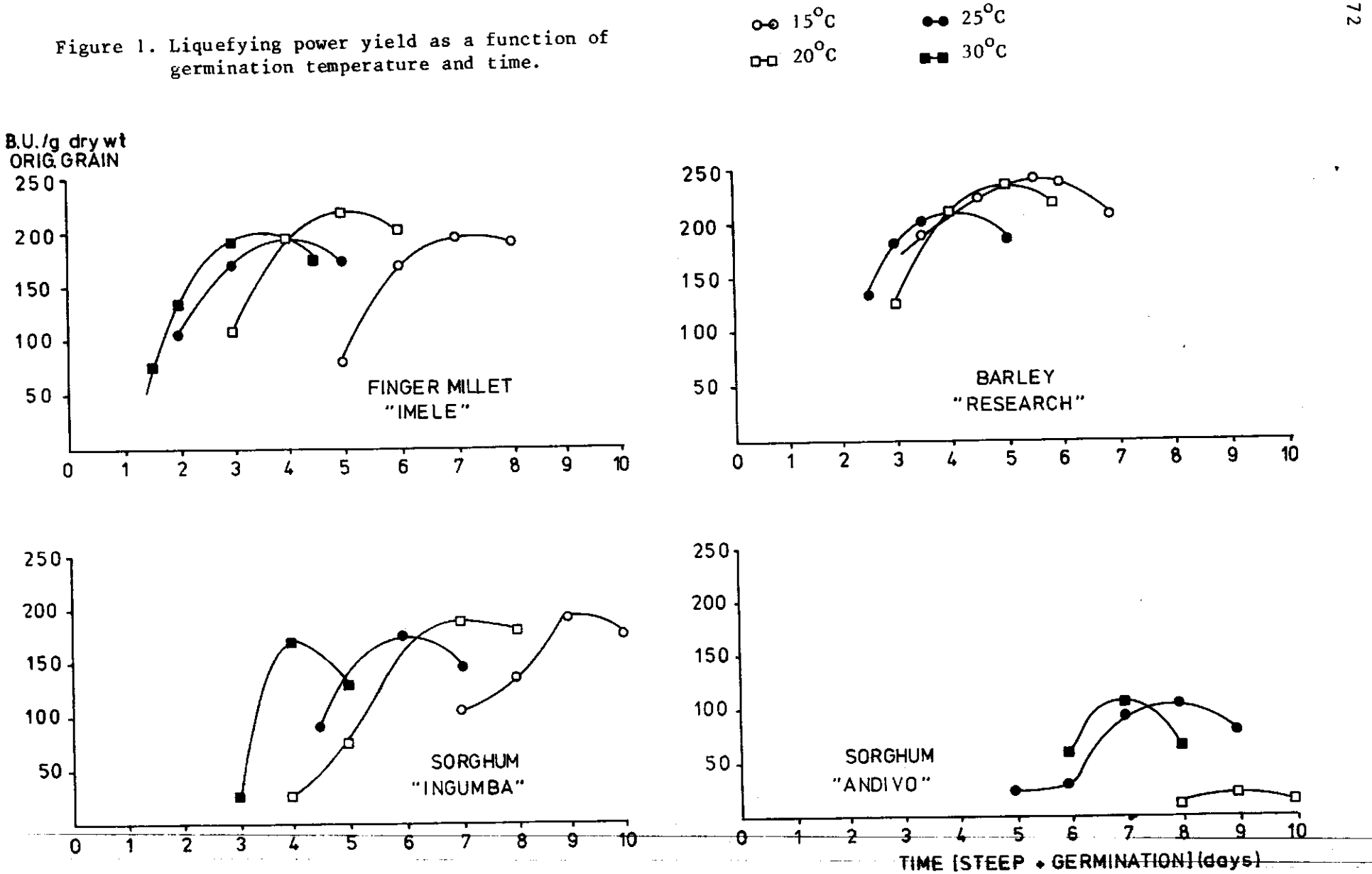


Table 5. Development of roots, malting losses, liquefying power yield, and modification as a function of germination time (micro-malting scale experiments).

Time [1] (days)	Root (%)	Malting loss (%)	Liquefying power yield (B.U./g orig. grain dry wt.)	Modification (Specific Gravity 20°C)
FINGER MILLET IMELE				
3	0.2	0.2	47	1.30
4	2.2	2.7	297	1.26
5	5.1	6.4	384	1.19
6	9.5	11.9	470	1.11
7	10.1	12.6	428	1.10
SORGHUM ANDIVO				
6	5.8	8.6	38	1.07
7	6.7	11.0	62	1.07
8	7.7	15.4	180	1.06
9	9.0	19.5	220	1.04
10	10.2	19.7	190	1.02
SORGHUM INGUMBA				
5	3.6	9.7	141	1.06
6	4.8	11.0	254	1.04
7	5.9	12.4	302	1.03
8	7.4	13.8	289	1.03
9	8.0	15.3	148	1.03
BARLEY RESEARCH				
3	1.5	5.0	309	1.21
4	3.0	8.5	306	1.20
5	5.0	11.0	441	1.16
6	6.0	13.0	391	1.16
7	6.5	15.0	365	1.14

1) see footnote 1, Table 4.

grains tested under micro-malting conditions. Development of radicles and cotyledons during the micro-malting trials was generally less pronounced than in the small scale experiments where malting losses were considerably higher. The times at which maximum L.P.Y. values were obtained correspond well with what had been established during the small scale tests (Fig.1). It was generally after attainment of these maxima, that a reasonably good modification was obtained.

In Table 6 the development of diastatic power, α-amylase, β-amylase, proteolytic activity, and endo-β-glucanase is presented. Regardless of which method was used for its determination, the development of diastatic power followed the same pattern as that of the L.P.Y. The considerable difference in diastatic power between barley on the one hand, and finger millet and the sorghums on the other, is due to the large β-amylase fraction in the diastatic power of barley. The α-amylase activities developed to a similar extent in all samples.

Novellie (23) advocated the use of a 2 % peptone solution during the determination of diastatic power in sorghum malt, since this would extract water-insoluble, but active amylases from the malt. He reported that the ratio of water-soluble / water-insoluble amylases in sorghum malt depends, among other factors, on the variety of sorghum. From Table 6 it can be seen that the use of peptone solution as an extraction solvent results in higher D.P. values, primarily due to a disproportionally improved extraction of α-amylases. Compared with water extraction, 2 % peptone solution improved the α-amylase extraction by a factor of approximately 13, 5, 13, and 2 for barley, finger millet, Andivo sorghum, and Ingumba sorghum respectively, whereas the β-amylase extraction was improved by factors of only 1.0, 1.3, 3.4, and 1.3.

Since bromate is commonly applied during barley malting to reduce malting losses and to control total soluble wort nitrogen, bromate treatments were included in the investigation. The influence of two bromate levels (15 and 150 ppm) is summarised in Table 7. Whereas considerable reduction of malting losses were obtained in barley, the response in the other grains was much less pronounced. Andivo sorghum was not affected at all; finger millet and Ingumba sorghum showed a slight reduction of malting losses at the low (15 ppm) bromate treatment but finger millet and the sorghums showed a rise in malting loss at the high (150 ppm) treatment.

The effect of gibberellic acid (GA_3) treatment on the development of amylases and proteolytic enzymes is summarised in Table 8. At the two GA_3 levels tested (0.02 and 0.2 ppm), barley showed a considerable response to the 0.2 ppm treatment only, which was characterised by an accelerated development of α-amylase activity, resulting in increased D.P.-values. Finger millet responded to the 0.02 ppm treatment with a significant acceleration in α-amylase activity. At 0.2 ppm GA_3 the development of both α-amylase and β-amylase was increased and put forward. In both sorghums, the GA_3 levels used did not affect the D.P. significantly, although the ratio α-amylase/β-amylase appeared to increase in Ingumba sorghum, particularly at the 0.02 ppm level.

Proteolytic activity in barley was increased considerably at both GA_3 levels, whereas the development of proteolytic enzymes in the other grains was either not affected, or even apparently inhibited (Andivo sorghum).

Table 9 summarises the influence of increasing kilning temperatures

Table 6. Development of amylases, proteolytic activity, and endo-β-glucanase as a function of germination time (micro-malting scale; all activities expressed per 100 g original grain dry wt).

Time[1] (days)	°I.o.B.	°W K						Proteol. Activity	Endo-β-glucanase
		Water extraction			Peptone extraction				
		D.P.[2]	α-A[3]	β-A[4]	D.P.[2]	α-A[3]	β-A[4]	(mg N)	(I.R.V. units)
FINGER MILLET IMELE									
0	2	4	4	0	46	46	0	82	
3	5	4	4	0	38	38	0	74	
4	13	32	28	4	54	54	0	101	25
5	16	37	32	5	72	65	7	151	80
6	21	61	54	7	87	78	9	102	162
7	17	42	36	6	83	77	6	104	158
SORGHUM ANDIVO									
0	5	17	11	8	31	31	0	24	
6	6	4	0	4	101	62	39	37	
7	20	52	13	39	104	64	40	66	75
8	24	70	38	32	135	86	49	55	115
9	25	72	44	28	152	118	34	39	180
10	16	36	36	0	67	67	0	32	237
SORGHUM INGUMBA									
0	11	28	20	8	58	48	10	8	
5	17	46	36	10	96	78	18	69	
6	21	55	43	12	103	83	20	120	50
7	33	101	59	42	113	93	20	189	110
8	26	74	58	15	118	96	21	133	190
9	22	59	42	17	101	83	18	119	238
BARLEY RESEARCH									
0	74	232	3	229	272	30	242	35	
3	103	334	33	301	373	68	305	129	
4	107	343	43	300	443	77	366	220	240
5	129	416	62	354	447	78	369	152	347
6	124	407	41	367	439	77	362	141	340
7	121	393	34	359	370	75	295	115	336

1) see footnote 1, Table 4.
2) D.P. = Diastatic Power.
3) α-A = α-Amylase.
4) β-A = β-Amylase.

Table 7. Effect of bromate treatment on malting losses (% of dry wt).

Time [1] (days)	Bromate addition (ppm)		
	0	15	150
FINGER MILLET IMELE			
3	0.2	0.3	0.1
4	2.7	2.4	4.5
5	6.4	5.8	8.0
6	11.9	10.5	14.9
7	12.6	11.5	16.1
SORGHUM ANDIVO			
6	8.6	8.4	9.0
7	11.0	10.1	11.7
8	15.4	14.1	16.2
9	19.5	18.8	19.7
10	19.7	19.8	20.1
SORGHUM INGUMBA			
5	9.7	6.2	7.9
6	11.0	7.8	9.1
7	12.4	11.4	9.8
8	13.8	13.1	11.5
9	15.3	13.7	16.1
BARLEY RESEARCH			
3	5.0	5.0	5.0
4	8.5	8.0	7.0
5	11.0	10.5	9.0
6	13.0	12.5	10.0
7	15.0	14.2	10.5

1) see footnote 1, Table 4.

on the extent of enzyme inactivation in the finished malts. In order to measure the effect of temperature only, the duration of the kilning was kept at 16 h for all temperatures. This period was adequate to achieve moisture contents below 5 % at 50°C, but was of exaggerated length at the higher temperatures. The thermal destruction of α-amylase and β-amylase showed similar patterns in all malted grain samples. The β-amylase displayed the highest sensitivity to increased kilning temperatures and had disappeared after kilning at 60°C in finger millet and Andivo sorghum malt, and at 70°C in Ingumba sorghum malt. In all cases, α-amylase was inactivated at a slower rate and only beyond 70°C. The sensitivity of the proteolytic activity differed among the grain samples; activity was considerably reduced beyond 50°C, 60°C, and 90°C in Ingumba sorghum, Andivo sorghum, and barley, respectively. In finger millet, proteolytic activity was not reduced by kilning at 100°C for 16 h. Finally, the major characteristics of worts obtained are given in Table 10.

10.5 DISCUSSION

Finger millet enjoys a certain popularity among Kenyan farmers since the extremely small kernel size seems to make it less susceptible to insect attack. In malting practice however, the grain size causes a few inconveniences which would necessitate alterations in conventional malting equipment, if the crop was to be malted on an industrial scale. First, bottom perforations in *e.g.* malting boxes would need to be reduced in size to prevent the grain from falling through. Second, the wetted grain behaves like wet sand, *i.e.* it shows poor drainage and consequently, would require heavier fans for aeration and CO_2 extraction. Third, the development of long radicles and cotyledons causes much stronger "matting" as compared with barley and sorghum, and therefore requires more frequent turning.

The rates of water absorption by an unspecified sorghum variety during steeping at various temperatures, reported by Novellie (25), are in agreement with the results of our steeping trials summarised in Table 2.

Novellie (25) found that high temperatures of 25°-30°C were required to develop sufficient diastatic power in sorghum. Although our results (Table 3 and Fig.1) confirm this finding, Ingumba sorghum developed similar diastatic power (measured as L.P.Y.) at temperatures ranging from 15°-30°C. Aisien and co-worker (1) reported an optimum temperature of 22°C for germination of *Sorghum bicolor* L 181. However, our results (Table 3) and those of Novellie (25) indicate higher optimum temperatures for germination, ranging from 25°-30°C.

From data published by Von Holdt and co-worker (36) we calculated that their K2 Red sorghum produced, after 7 days germination at 30°C, a root weight of 19 % of total green malt (dry wt basis). In this process, a calculated malting loss of 39 % was incurred. These values, obtained by germination with frequent watering, correspond well with our data obtained under small scale, continuous spraying conditions. In a subsequent publication, Novellie (26) showed that the malting losses in sorghum are much less determined by germination temperature than by the moisture content of the germinating grains. At different temperatures and moisture contents, he obser-

Table 8. Effect of gibberellic acid treatment on diastatic power, α- and β-amylase (water and peptone extraction methods) and proteolytic activity (all activities expressed per 100 g original grain dry wt).

Time[1] (days)	AMYLASES (°WK) Water Extraction									AMYLASES (°WK) Peptone Extraction									Proteolytic activity (mg N)		
	D.P.[2]			α-Amylase			β-Amylase			D.P.			α-Amylase			β-Amylase					
GA_3 (ppm)	0	0.02	0.2	0	0.02	0.2	0	0.02	0.2	0	0.02	0.2	0	0.02	0.2	0	0.02	0.2	0	0.02	0.2
FINGER MILLET IMELE																					
0	4	4	4	4	3	4	0	1	0	46	46	45	46	46	45	0	0	0	82	43	62
3	4	40	80	4	36	55	0	4	25	38	45	110	38	40	70	0	5	40	74	57	100
4	32	27	55	28	21	35	4	6	20	54	47	50	54	40	30	0	7	20	101	76	125
5	37	25	37	32	18	24	5	7	13	72	52	26	65	44	18	7	8	8	151	117	120
6	61	35	40	54	27	31	7	8	9	87	65	52	77	56	41	10	9	11	102	32	100
7	42	38	45	36	31	36	6	7	9	83	70	55	77	63	45	6	7	10	104	25	76
SORGHUM ANDIVO																					
0	17	18	16	11	10	11	6	8	5	31	32	31	31	30	31	0	2	0	24	20	24
6	4	6	7	0	3	3	4	3	4	101	65	52	62	60	52	39	5	0	37	21	24
7	52	50	55	13	15	10	39	35	45	104	60	53	64	60	53	40	0	0	66	20	27
8	70	68	70	38	35	40	32	33	30	135	57	55	86	57	55	49	0	0	55	16	24
9	72	72	70	44	40	46	28	32	24	152	55	42	118	53	42	34	2	0	39	23	18
10	36	30	35	36	25	34	0	5	1	67	52	38	67	51	36	0	1	2	32	26	20
SORGHUM INGUMBA																					
0	28	27	24	20	22	17	8	5	7	58	42	44	48	42	42	9	0	2	8	11	17
5	46	48	43	36	43	39	10	5	4	96	72	64	78	69	64	18	3	0	69	72	75
6	55	53	56	43	47	48	12	6	8	103	81	80	83	79	80	20	2	0	120	128	135
7	101	97	96	59	85	75	42	12	21	113	64	88	93	64	72	20	0	16	189	162	187
8	74	75	70	58	62	53	15	13	17	118	70	83	96	67	73	21	3	10	133	118	125
9	59	55	51	42	45	42	17	10	9	101	68	65	83	60	58	18	8	7	119	101	107
BARLEY RESEARCH																					
0	232	232	231	3	4	1	229	228	230	272	270	271	30	27	31	242	243	240	35	36	35
3	334	345	460	33	43	155	301	302	305	373	382	501	68	82	193	305	300	308	129	222	230
4	343	355	412	43	55	87	301	300	325	443	447	465	77	89	95	366	358	370	220	272	290
5	416	417	382	62	63	40	354	354	342	447	445	445	78	77	70	369	368	357	152	85	101
6	407	408	375	41	43	22	367	365	353	439	435	430	77	73	65	362	362	365	141	72	85
7	393	392	365	34	32	13	359	360	352	370	372	360	75	82	72	295	290	288	115	70	70

1) see footnote 1, Table 4. 2) see footnote 2, Table 6.

ved malting losses ranging from 10.9 - 35.0 %.
Our malting losses show a similar extent of variation (compare Tables 4 and 5); nevertheless, L.P.Y.'s which were obtained in our micro-malting trials (low malting losses) were higher than those obtained in our small scale continuous spraying experiments. This does not correspond with Novellie's (26) results where maximum diastatic power (on yield basis) could only be obtained with frequent watering, *i.e.* accompanied by high malting losses. Khan *et al.*(17) suggested the use of 0.3 % ammonia solution during steeping to reduce malting losses in sorghum (CSH 1 var.); unfortunately, malting losses were not quantified. Our trials with bromate (Table 7) show that bromate levels which considerably reduce malting losses in barley, have only a slight effect, if any, on the finger millet and sorghums tested.
Daiber *et al.*(8, 9) compared several methods to estimate malt modification, and concluded that the method described by Hartong and co-worker (11), in which the specific gravity or the porosity of the malt is measured, gave a good reflection of the modification. According to the guide-lines proposed by Hartong and co-worker (11), our finger millet, barley, sorghums Andivo and Ingumba malts (Table 5) were of good to very good, satisfactory, very good, and very good modification, respectively. Using the same guide-lines, the specific gravity data reported by Daiber *et al.*(8) for sorghum malt also indicate very good modification and are in agreement with our results.
In order to account for variations in malting losses due to *e.g.* different malting techniques, all our data on enzyme activities are based on original grain dry wt. As a result, they generally appear to be low compared with values reported elsewhere, which have mostly been based on malt dry wt. The D.P. values ($^{\circ}$L) reported for malts from American barley varieties (4) ranged from 94 - 163 $^{\circ}$L; malting losses were not taken into account. Thus, our optimum barley D.P. yield of 129 $^{\circ}$IoB ($\simeq$ $^{\circ}$L) (Table 6) falls well within this range. In many of the earlier investigations on sorghum malting, its diastatic power was expressed as K.D.U. (Kaffircorn Diastatic Units) which were equated as 2 K.D.U./g = 1 $^{\circ}$L/ 100 g by Novellie (23). The diastatic power of malts from different sorghum varieties, reported by Novellie (23), ranged from 12.3 - 53.8 K.D.U./g malt dry wt. Van Noort (35) reported that commercial batches of sorghum malt had diastatic powers ranging from 41.3 - 55.7 K.D.U./g malt dry wt. Taking into account the $^{\circ}$L conversion factor, and malting losses averaging 25 % (a conservative estimate), the D.P. of these commercial malts would be 15.5 - 20.9 $^{\circ}$L/ 100 g original grain dry wt. Compared to these values, our sorghum varieties, in particular Ingumba, gave very good results. Using an unspecified sorghum variety, Okafor and co-worker (29) obtained a D.P. of 31 $^{\circ}$L and a (rather low) malting loss of 8.5 %, which combined, convert to 28 $^{\circ}$L/ 100 g original grain dry wt, which is slightly lower than that obtained with our variety Ingumba.
Novellie (23) also reported the D.P. of one sample of finger millet malt (Rapoko) as 44.3 K.D.U./g malt dry wt. Taking into consideration the correction factors discussed above, this value could be converted into approximately 16 - 17 $^{\circ}$L/ 100 g original grain dry wt, which is slightly lower than our result (Table 6).
As mentioned above (Results), the increase in measured D.P., obtained when 2 % peptone solution was used as the extractant

Table 9. Effect of kilning temperature on residual activity of amylolytic and proteolytic enzymes (kilning time 16 h; all activities expressed per 100 g original grain dry wt).

Kilning temperature (°C)	AMYLASES (°WK) peptone extraction D.P.[1]	α-Amylase	β-Amylase	Proteolytic activity (mg N)
FINGER MILLET IMELE				
50	72	65	7	151
60	54	54	0	217
70	52	52	0	204
80	51	51	0	254
90	43	43	0	192
100	35	35	0	222
SORGHUM ANDIVO				
50	135	86	49	55
60	59	59	0	57
70	81	81	0	10
80	57	57	0	32
90	45	45	0	24
100	36	36	0	10
SORGHUM INGUMBA				
50	113	93	20	189
60	71	52	18	67
70	86	86	0	34
80	60	60	0	67
90	54	54	0	2
100	22	22	0	13
BARLEY RESEARCH				
50	447	78	369	152
60	332	68	254	117
70	225	54	171	211
80	141	43	98	322
90	117	50	67	269
100	64	23	41	96

1) see footnote 2, Table 6.

instead of dist.water, was mainly due to an improved extraction of the α-amylase fraction (see also Table 6).
It is therefore essential, when reporting on the ratio of β-amylase/α-amylase, to specify the extraction conditions employed. Novellie (24), using the peptone extraction technique, found β-/α-amylase ratios ranging from 0.22 - 0.52 in samples of commercial sorghum malt. Although our average β-/α-amylase ratios for Andivo and Ingumba sorghum, obtained using the same extraction technique, fall within this range, it must be noted that the α- and β-amylases did not develop in constant proportions during our germination trials, and that the same β-/α-amylase ratios would have been considerably higher if dist.water had been used as the extractant. Although β-amylase could be detected in finger millet malt, the β-/α-amylase ratio was on average only about 50 % of that measured in the sorghum malts (irrespective of extraction method). Chandrasekhara and co-worker (6) investigating finger millet varieties R.009 and H.22, stated that although finger millet malt contained more α- than β-amylase, the β-amylase activity was higher than in sorghum malts. Since these findings were only partly quantified, further interpretation or comparison with our results is not possible.
The stimulating effect of gibberellic acid on the development of α-amylase, protease, and endo-β-glucanase activities in barley has been discussed by MacLeod (18). Similar effects have been reported by Palmer (30) for α-amylase in wheat and rye, but the stimulus was much less pronounced in oats. Daiber and co-worker (10) compared the effect of GA_3 on the diastatic power developed in barley and sorghum. From their data, two conclusions may be drawn: (i) the development of diastatic power in sorghum was not accelerated as it was in barley, and (ii) that beyond a certain level, GA_3 does not stimulate, but will instead have an inhibitory effect on the development of diastatic power. Various workers (16, 30) have used only one concentration of GA_3. This level may be optimal for a particular grain, but could at the same time, be sub-optimal or even inhibitive for other grains that are being compared. As a result, differences in behaviour would be observed that might have been postulated to originate from genetic differences only. Our findings suggest that whereas no noticeable effect of GA_3 was exerted on sorghum amylases and proteases (in sorghum Andivo an inhibitory effect on protease activity was observed), the effect on finger millet and barley could be described as an accelerated mobilisation of predominantly α-amylase and proteases. The activities of these enzymes generally decrease after a few days of germination, to values below the corresponding activities of untreated samples.
Our kilning trials (Table 9) showed a consistently higher thermal resistance of α-amylase compared with β-amylase in all tested grains , but the extent of inactivation of proteolytic enzymes as a function of kilning temperature varied widely between grains. Narziss *et al.* (19,20) reported that endopeptidases, aminopeptidases, dipeptidases and carboxypeptidases in barley malt show considerable differences in thermal stability. It is suggested that the sorghum varieties in our investigation contained a higher proportion of thermolabile proteolytic enzymes, whereas a high proportion of thermostable proteolytic enzymes contributed to the relative thermostability of the proteolytic activity in finger millet.

Table 10. Wort characteristics of untreated and gibberellic acid-treated malts.

Time[1] (days)	GA_3 (ppm)	Extract fine grind (% Plato)	Conversion time (min)	Filtration[2]	Colour (E.B.C.)	Clarity	pH	Buffering capacity (ml 0.1 N)	Total soluble N (mg/100 ml wort)
FINGER MILLET IMELE									
0	-	15.8	>60	slow	n.d.[3]	turbid	6.45	9.25	15.7
7	-	47.5	35	fast	4.5	clear	5.90	12.65	50.4
7	0.02	52.4	35	fast	4.5	clear	5.93	13.00	55.4
7	0.2	51.9	35	fast	5.0	clear	5.86	14.00	58.2
SORGHUM ANDIVO									
0	-	6.7	>60	slow	n.d.[3]	turbid	7.30	6.75	6.0
10	-	30.9	60	slow	n.d.	turbid	6.50	n.d.	53.2
10	0.02	21.7	60	slow	n.d.	turbid	6.27	14.25	52.6
10	0.2	35.7	60	slow	n.d.	turbid	6.36	14.00	51.5
SORGHUM INGUMBA									
0	-	6.0	>60	slow	n.d.[4]	clear	7.27	7.50	6.2
9	-	54.3	60	slow	n.d.	clear	6.15	13.25	63.3
9	0.02	50.5	60	slow	n.d.	clear	6.27	14.25	63.8
9	0.2	55.4	60	slow	n.d.	clear	6.36	14.00	63.8
BARLEY RESEARCH									
0	-	23.1	>60	slow	n.d.[3]	turbid	6.09	8.25	25.2
7	-	73.2	15	normal	2.0	clear	6.05	9.50	56.6
7	0.02	75.5	15	normal	2.0	clear	6.08	9.50	61.6
7	0.2	76.5	15	normal	2.0	clear	6.08	10.50	68.9

1) see footnote 1, Table 4. 2) slow $\geq$ 1 h; normal < 1 h; fast < $\frac{1}{2}$ h.
3) colour not determined since wort was turbid. 4) colour did not match E.B.C. comparator disc.

During the laboratory preparation of congress worts (Table 10), a striking discrepancy was observed in finger millet, between the high filtration speed and the relative low endo-β-glucanase activity. In contrast, slow filtration occurred in the case of sorghum malts inspite of their reasonable endo-β-glucanase activity. Woolard *et al.* (38) isolated and purified a β-D-glucan from the endosperm of sorghum, but it is not known whether similar substances occur in finger millet. Further research needs to be carried out on sorghum and millets to investigate the occurrence of water-soluble gums, their structural properties and the substrate specificity of the endogenous enzymes degrading them. At present, the common method for the determination of endo-β-glucanase activity (5), using purified barley β-glucan, does not appear to be an adequate tool to predict the filtrability of either sorghum or finger millet worts.

Before assessing the applicability of the tested grain types as raw material for brewers' malts, a distinction should be made between the different types of beer likely to be manufactured from such malts. In the brewing of traditional opaque African beers, the major asset of a good malt is a high diastatic power, since the brewing mash consists mainly of adjunct, either maize or sorghum, which has to be converted. When finger millet or sorghum malts are to be considered as potential extenders of barley malt for the production of conventional Pilsner type lager beers, other factors, *i.e.* extract, colour, clarity, filtrability, and total soluble nitrogen are of more importance. A third type of beer, referred to as tropical lager beer by Skinner (34) is likely to become important in some barley importing countries. Skinner (34) has described the small-scale manufacture of a sorghum lager beer, which might not have the colour and flavour characteristics required for a conventional barley lager beer, but which could nevertheless be a satisfying beverage. For the brewing of such tropical lager beers, more flexibility can be allowed with regard to colour, flavour, and possibly, total soluble nitrogen.

Considering the manufacture of traditional African opaque maize beers, both sorghum and finger millet have proved their suitability for malting since time immemorial. Although the tested sorghums had a somewhat higher β-amylase content than the finger millet malt, the difference was small. Both types of cereals produce malts which are adequate in α-amylase, but which lack β-amylase. Given the small difference observed between sorghum and finger millet malts, it will be mainly the flavour, and possibly cultural conditions, which will determine the choice of either material in brewing.

As extenders for barley malt in the brewing of conventional Pilsner lager beers, the tested finger millet and sorghum varieties do not appear adequate, mainly because of their low extract content, their poor filtrability (the sorghums), and their dark colour (finger millet).

It would seem more appropriate to use these malts, in particular from finger millet Imele, for the brewing of tropical lager beers, which would have a somewhat darker colour and flavour than conventional Pilsner type lager beer. In order to improve on the extract content, a small addition of barley malt could be considered, which would at the same time increase the β-amylase activity in the mash. The same would apply to Ingumba sorghum, in which case a coarse grind of grist might improve on the filtrability.

10.6 REFERENCES

(1) Aisien, A.O. & Ghosh, B.P., J.Sci.Fd Agric.,*29* (1978) 850-852.
(2) Analysis Committee of the E.B.C., Analytica-E.B.C. (3rd Edition). Schweizer Brauerei-Rundschau, Zürich 1975.
(3) Arnould, J-P. & Miche, J-C., Agronomie Tropicale,*26* (1971) 865-887.
(4) Baker, C.W., Chan, H.Y., Pyler, R.E. & Banasik, O., The Brewers' Digest, *50* (1975) 46-52,60.
(5) Bathgate, G.N., J.Inst.Brew., *85* (1979) 92-94.
(6) Chandrasekhara, M.R. & Swaminathan, M., J.Sci.& Ind.Res., *12B* (1953) 51-56.
(7) Chevassus-Agnes, S., Favier, J.C. & Joseph, A., Cahiers de Nutrition et de Dietetique, *11* (1976) 89-104.
(8) Daiber, K.H., Malherbe, L. & Novellie, L., Brauwiss., *26* (1973) 220-225.
(9) Daiber, K.H., Malherbe, L. & Novellie, L., Brauwiss., *26* (1973) 248-251.
(10) Daiber, K.H. & Novellie, L., J.Sci.Fd Agric., *19* (1968) 87-90.
(11) Hartong, B.D. & Kretschmer, K.F., Brauwelt, *108* (1968) 517-524.
(12) Hulse, J.H., Laing, E.M. & Pearson, O.E., Sorghum and the Millets : their composition and nutritive value. Academic Press, London 1980.
(13) Institute of Brewing, I.o.B. Analysis Committee Recommended Methods. The Institute, London 1967.
(14) Institute of Brewing, J.Inst.Brew., *77* (1971) 193-195.
(15) Institute of Brewing, I.o.B. Recommended Methods of Analysis. The Institute, London 1977.
(16) Jain, A.K. & Date, W.B., J.Fd Sci. & Technol., *12* (1975) 131-132.
(17) Khan, A., Kolte, A.V. & Shiralkar, N.D., J.Fd Sci. & Technol., *14* (1977) 275-277.
(18) MacLeod, A.M., Proc.Eur.Brew.Conv.,Amsterdam 1977, pp. 63-76.
(19) Narziss, L. & Lintz, B., Brauwiss., *28* (1975) 200-205.
(20) Narziss, L. & Rusitzka, P., Brauwiss., *30* (1977) 105-111.
(21) Nout, M.J.R., Chem.Mikrobiol.Technol.Lebensm., *6* (1980) 137-142.
(22) Nout, M.J.R., Chem.Mikrobiol.Technol.Lebensm., *in press*.
(23) Novellie, L., J.Sci.Fd Agric., *10* (1959) 441-449.
(24) Novellie, L., J.Sci.Fd Agric., *11* (1960) 457-463.
(25) Novellie, L., J.Sci.Fd Agric., *13* (1962) 115-120.
(26) Novellie, L., J.Sci.Fd Agric., *13* (1962) 121-123.
(27) Novellie, L., Wallerstein Labs Comms, *104* (1968) 17-32.
(28) Ogundiwin, J.O., Brew. & Dist.Int., *7* (1977) 40-41.
(29) Okafor, N. & Aniche, G.N., Brew. & Dist.Int., *10* (1980) 32,33,35.
(30) Palmer, G.H., J.Inst.Brew., *76* (1970) 378-380.
(31) Preece, I.A., J.Inst.Brew., *53* (1947) 154-162.
(32) Ranum, P.M., Kulp, K. & Agasie, F.R., Cereal Chem., *55* (1978) 321-331.
(33) Schaefer, W.C., Approved Methods of the American Association of Cereal Chemists. The Association, St.Paul, Minnesota 1969.
(34) Skinner, R., Brew. & Dist.Int., *6* (1976) 26-27.
(35) Van Noort, G., Food Industries of South Africa, *24* (1971) 7,9.
(36) Von Holdt, M.M. & Brand, J.C., J.Sci.Fd Agric., *11* (1960) 467-471.
(37) Whitmore, E.T. & Sparrow, D.H.B., J.Inst.Brew., *63* (1957) 397-398.
(38) Woolard, G.R., Rathbone, E.B. & Novellie, L., Carbohydrate Res., *51* (1976) 249-252.

11 General discussion and conclusions

From the data presented in Chapter 5, it has been shown that traditional fermented beverages occupy a major proportion (82 %) of the total consumption of fermented beverages in Kenya. Ranked according to their consumption (expressed in terms of litres absolute alcohol), Chang'aa is the most important product, followed by Muratina, Busaa, and then the foreign beers. The per capita alcohol consumption in 1978 was estimated at 3.6 litres of absolute alcohol per year. This is a very low value compared with corresponding consumption figures for other countries. However, the per capita figure is considered rather misleading since considerable groups within the Kenyan population (Muslims, children) can be expected not to take part in the national consumption figure for alcohol. Thus, the yearly alcohol consumption per adult head of the non-Muslim population was estimated to be 11 litres of absolute alcohol. It was mentioned that because of their different life styles, nutritional status, and other factors, the known extent of the negative effects of increased alcohol consumption on European consumers cannot be directly related to the Kenyan population. Nevertheless, the above mentioned consumption figure of 11 litres of absolute alcohol per year per head of the adult, non-Muslim population indicates a consumption level which, in Switzerland for example, is associated with a number of alcoholics (persons addicted to alcohol) which approximates to 2 % of the population of that country. With regard to these figures, the Kenyan Government's concern to reduce alcohol consumption in the country is fully justified.

The nutritional aspects of the five most important Kenyan fermented beverages were discussed in Chapter 6. Analysis of the nutrient content of the various products showed that Busaa has the highest nutritive value compared with the other products.
It was argued that due to its high protein, calcium, vitamin B_2, niacin, vitamin B_{12}, and pantothenic acid contents, this product offers a distinct supplement to the adult diet, which was reported elsewhere (11,50) to be deficient in several of these factors.

In view of the publicly alleged toxicity of Chang'aa, an analysis of this traditional, illicit spirit was carried out, and described in Chapter 7. This investigation revealed that the majority of tested samples had a fusel oil content which was unacceptably high, judged by European (Swiss) standards.
The level of fusel oil in Chang'aa was found to be influenced by the traditional distilling techniques used, as well as by the choice of ingredients.
Methanol was either absent or only present in trace amounts, pro-

bably because of the low pectin content of the ingredients used. It was observed that the consumer safety of Chang'aa could be considerably improved by a better selection of traditional distilling methods and of the ingredients for fermentation.

In Chapter 8, a study was made of the traditional process for the manufacture of Busaa. The first stage of the process consists of a spontaneous fermentative souring of a mixture of water and maize meal, followed by roasting of the soured mass. It was observed that this roasted and fermented, crumbly mass gave flavour to the final beer, and that the micro-organisms in this crumb, which survived the roasting process, may play an important role in the later stages of the beer fermentation.
The rapid deterioration of the final product is due to fermentative acidification. In samples of spoilt Busaa, the microbial population was found to be dominated by *Lactobacillus plantarum*.

Chapter 9 describes several experiments aimed at the low-cost production and preservation of Busaa of acceptable quality. Variations in formulation and their influence on taste panel acceptability were studied. The major problem with regards to improving the public image of Busaa is its short shelf-life. It was found that open refrigerated storage (2-4 ^{o}C) of Busaa achieves an extension of its shelf-life by one to two weeks. However, this method was considered of limited value, particularly because refrigeration equipment is extremely expensive to purchase. For this reason, refrigerators and deep-freeze cabinets are few in numbers in the rural areas of Kenya (where 90 % of the population live). In addition, electricity is not yet widely available in the rural areas.

The main reason for the short shelf-life of Busaa was characterised in Chapter 8 as excessive acidification by homofermentative lactobacilli. Aimed at preventing over-acidification, Busaa was made on a laboratory scale using sterilised ingredients and pure starter cultures, as an alternative to the uncontrolled fermentation taking place in the traditional process. In particular, heterofermentative lactobacilli of limited acid tolerance, *e.g. L. brevis* were found to be unable to cause excessive acidification. Using this technique, acceptable Busaa was obtained which could be stored in airtight containers without pasteurisation for a period of over three months. Although this method of preparing a biologically stable product may seem attractive, it requires rather specialised skills to ensure aseptic handling of the product, as well as preventing the contamination of pure cultures, etc. Consequently, this method cannot be applied under the conditions of a rural small-scale industrial enterprise.
Finally, a modified Busaa process was developed which now makes it possible to pasteurise this starchy product in sealed bottles whilst at the same time preventing unwanted gelatinisation. The product had a long shelf-life and was well accepted by an expert taste panel. It needs to be stressed that this simple process can be applied on a small industrial scale and requires only limited capital investment.

A study of the properties of finger millet as a malting cereal was presented in Chapter 10 and revealed that, although its liquefying

capacity (due to α-amylase) is comparable to that of a good malting barley, the β-amylase content of finger millet malt is very low, and slightly less than that of germinating sorghum. Malting temperatures and germinating periods encountered during the traditional malting of finger millet offer very little scope for improvement. On the other hand, the losses of dry matter incurred during the traditional malting methods are substantial, and can be reduced considerably by controlling the levels of moisture content in the germinating finger millet. Inspite of its attractive technological properties (good liquefying capacity of the malt and excellent filtrability of the E.B.C. wort), finger millet malt cannot be used for the manufacture of bright Pilsner beers, because of the dark colour of its wort. On the other hand, it could be easily used as either (a) the sole cereal ingredient or (b) in conjunction with barley, for the manufacture of other foreign beers of a darker colour, such as Guinness stout; it could also be utilised to produce entirely new beverages which have been termed elsewhere (45) as tropical lager beers.

In conclusion, it would seem that particularly the low-income sector of the Kenyan public regularly consumes traditional fermented beverages. A prohibition of the manufacture and consumption of all traditional fermented beverages, aimed at reducing the national consumption of alcohol, will therefore mainly affect this group of the population; this sector can hardly afford the more expensive foreign fermented beverages which have been accepted by the Government, and would thus practically be deprived of a basic outlet for their relaxation and pleasure. In addition, the strong cultural role played by these traditional fermented beverages would make their indiscriminate banning undesirable. Instead, it would appear to be more beneficial to all concerned if the Government would control, rather than ban, the consumption of these products. Such a policy of control could be based upon the following guide-lines:

(a) restricting the manufacture and retailing of traditional fermented beverages to licensed establishments only. This could be combined with a gradual elimination of home-brewing.
(b) restricting the opening hours of retail outlets.
(c) the establishment of quality criteria and a subsequent system of quality control for the marketed traditional fermented beverages, aimed at improving their safety and public image.
(d) providing incentives for the development of high quality traditional fermented beverages of nutritional superiority.

In addition to the guide-lines proposed above, and in view of the nutritional and public health aspects described in Chapters 6 and 7, it is recommended that the consumer attention is distracted from Chang'aa and Muratina. Since the illegal trade tends to favour Chang'aa in particular, the consumption of traditional fermented beverages of superior nutritive value such as Busaa, should be allowed officially to continue, and the improvement of their quality should be encouraged.

The definition of traditional liquor given in the Traditional Liquor Act (see Chapter 2) accomodates the possibility of declaring other products, which have been preserved by processing, to be traditional liquors for the purpose of the Act. This opportunity should be embraced to enable the qualitative upgrading of appropriate traditional fermented beverages.

Summary

This study was aimed at providing fundamental information concerning the manufacture, composition, and consumption of the major Kenyan traditional fermented beverages.
In Chapter 1, the reader is introduced to Kenya, its population and climate, and several aspects of its agriculture underlying this study.
Chapter 2 offers an overview of the major fermented beverages consumed in Kenya. A distinction is made between traditional and foreign fermented beverages. Both groups of products include beers and wines, as well as spirits. The traditional fermented beverages play an important role, particularly in the rural daily life, they are cheap and are usually prepared from locally available ingredients such as honey, maize, millets or palm-sap. Their age-old manufacturing techniques are known through oral tradition and are often quite primitive. The final products are obtained by way of uncontrolled fermentations, and are mostly consumed in a stage of active fermentation.
Except for the spirits, the traditional fermented beverages have only a short shelf-life since excessive souring soon renders them unacceptable.
Most foreign fermented beverages have been introduced into Kenya during the period of colonial administration; nowadays, a number are manufactured locally, on a large industrial scale.
In Chapter 3, mention is made of recent measures taken by the Kenyan Government to curb alcoholism through prohibition and closure of beer halls, and to increase productivity. These measures tend to favour the illegal trade in traditional fermented beverages and, in particular, the consumption of illicit traditional spirit of dubious quality.
The aims of the ensuing study are formulated in Chapter 4, and include providing insight in the consumption of the major Kenyan traditional fermented beverages, their nutritive value, and their possible harmfulness to health. Furthermore, a study will be made of ways of improving upon the quality and shelf-life of a selected traditional beer of superior nutritive value.
In Chapter 5, an estimate is made of the total consumption of alcoholic beverages in Kenya. It is shown that the traditional fermented beverages represent a major proportion of the total consumption of alcohol. This is not surprising since the traditional products are relatively cheap and can be afforded by the majority of the Kenyan public.
In the same chapter, it is observed that the consumption of alcohol in Kenya is moderate, compared with other countries.
The nutrient content of selected traditional and foreign beverages is compared in Chapter 6. It is concluded that the traditional

beer Busaa has the highest nutritive value, particularly when considering its protein, vitamin B_2, and niacin contents. The nutritive value of the traditional spirit Chang'aa is the least.
The consumption of Chang'aa occupies a major proportion of the total quantity of alcohol consumed in Kenya. The chemical composition of this spirit is studied in some further detail in Chapter 7. In particular, the fusel oil content of Chang'aa is studied, as well as the effect of ingredients and distilling techniques on its occurrence in this spirit.
In Chapters 8, 9, and 10 several aspects of the manufacture of the traditional beer Busaa are dealt with. In Chapter 8, some microbiological aspects of the traditional manufacture of this beer are discussed. In particular, attention is given to the dominant yeasts and bacteria, involved in the stages of fermentation and subsequent spoilage. In Chapter 9, experimental work is described, aimed at the development of a process for the manufacture of bottled and preserved Busaa. The malt used as ingredient for Busaa is usually obtained from finger millet. In most other African countries however, sorghum is used for such purpose. Although sorghum is easily available in Kenya as well, the Busaa brewers nevertheless prefer the use of finger millet malt for the brewing of Busaa. In Chapter 10 therefore, the germination characteristics and the brewing potential of finger millet and sorghum are compared. Barley is also included in this comparative study, since it is grown in Kenya as ingredient for the manufacture of foreign lager beers.
In Chapter 11, the major findings from the study are discussed, and conclusions and recommendations are formulated with regard to a possible control of the consumption of traditional fermented beverages. On the one hand, these are aimed at a reduction and subsequent gradual abolishment of home-brewing of traditional fermented beverages. On the other hand, the consumption of cheap traditional fermented beverages of high nutritive value such as Busaa, is advocated to be allowed to continue off-licence on a restricted scale. Such products should offer a cheap, high-grade substitute for other, less appropriate, products which would eventually be phased out. It is finally observed that an upgrading of the quality and shelf-life of the former beverages would facilitate an adjustment of the present consumption pattern.

Samenvatting

Het doel van deze studie was inzicht te krijgen in de aard van de belangrijkste Keniaanse inheemse gefermenteerde dranken, en de plaats die zij innemen in de Keniaanse samenleving.
In hoofdstuk 1 worden inleidende gegevens vermeld met betrekking tot Kenia, het land, de bevolking, en de teelt van de voor het onderzoek relevante landbouwgewassen.
In hoofstuk 2 wordt een overzicht gegeven van de belangrijkste in Kenia voorkomende gefermenteerde dranken. Er kan hier een duidelijk onderscheid worden gemaakt tussen inheemse en buitenlandse gefermenteerde dranken. Beide groepen omvatten bier, wijn, en gedestilleerd. De inheemse dranken nemen een belangrijke plaats in in het traditionele plattelandsleven, zijn goedkoop, en worden gemaakt van plaatselijk verkrijgbare grondstoffen zoals honing, maïs, gierst of palmsap. In alle gevallen worden vanouds overgeleverde, betrekkelijk primitieve bereidingsmethoden toegepast. De eindprodukten ontstaan als gevolg van vaak ongecontroleerde fermentatie, en worden meestal gedronken in gistende toestand. Afgezien van het inheems gedestilleerd, is de houdbaarheid van de bier- en wijnsoorten zeer kort aangezien snel overmatige verzuring optreedt. De meeste buitenlandse gefermenteerde dranken zijn tijdens de koloniale tijd ingeburgerd geraakt; een aantal worden tegenwoordig in Kenia op industriële schaal vervaardigd.
In hoofdstuk 3 wordt een korte beschouwing gewijd aan recente maatregelen, genomen door de Keniaanse regering, gericht op een verbod van alle inheemse gefermenteerde dranken, met als voornaamste redenen de bestrijding van het alcoholisme en de verhoging van de arbeidsproduktiviteit. Als gevolg van deze maatregelen, die geen goedkope keuze openlaten voor het gebruik van andere gefermenteerde dranken, doet zich het probleem voor van een toenemende illegale produktie en consumptie van overwegend inheems gedestilleerd van twijfelachtige kwaliteit.
Het doel van het hieropvolgend onderzoek, nader geformuleerd in hoofdstuk 4, omvat het verschaffen van inzicht in het gebruik van de belangrijkste Keniaanse inheemse gefermenteerde dranken, hun voedingswaarde, en hun eventuele schadelijkheid voor de gezondheid. Verder zal worden ingegaan op de mogelijke verbetering van de kwaliteit en de houdbaarheid van een uitgekozen inheemse biersoort van hoge voedingswaarde.
Een schatting van de totale alcoholconsumptie in Kenia wordt gemaakt in hoofdstuk 5. Hieruit blijkt dat het gebruik van alcohol in de vorm van inheemse gefermenteerde dranken aanzienlijk groter is dan de consumptie van buitenlandse dranken. Dit is niet verwonderlijk gezien het prijsverschil tussen de twee soorten produkten. Tevens wordt aan de hand van de schattingen vastgesteld dat het totaal alcoholgebruik in Kenia, gemeten naar Europese maatstaven,

als matig mag worden omschreven.
In hoofdstuk 6 wordt de samenstelling van enkele inheemse en buitenlandse gefermenteerde dranken vergeleken. Het blijkt dat het inheemse bier Busaa de hoogste voedingswaarde heeft, voornamelijk vanwege het betrekkelijk hoge gehalte aan eiwit, vitamine B_2 en niacine. De voedingswaarde van het inheemse gedestilleerd Chang'aa is het geringst.
Chang'aa draagt in zeer belangrijke mate bij tot de totale alcoholconsumptie in Kenia. De samenstelling van dit gedestilleerd wordt verder besproken in hoofdstuk 7. In het bijzonder wordt aandacht geschonken aan het gehalte aan hogere alifatische alcoholen (foezel), en de invloed hierop van gebruikte grondstoffen en destillatiemethoden.
Een aantal facetten van de bereiding van het inheemse bier Busaa worden belicht in hoofdstukken 8, 9, en 10. De microbiologische aspecten van de traditionele Busaa bereiding worden beschreven in hoofdstuk 8. In het bijzonder wordt aandacht besteed aan de belangrijkste gisten en bacteriën die verantwoordelijk zijn voor de fermentatie, en het daaropvolgend bederf van dit bier. Hoofdstuk 9 geeft de resultaten van een aantal experimenten, gericht op de ontwikkeling van een bereidingsproces voor geconserveerd Busaa in flessen. Als mout voor de bereiding van Busaa wordt overwegend gebruik gemaakt van een bepaald soort millet-gierst. In de meeste andere Afrikaanse landen wordt sorghum-gierst voor dit doel gebruikt. Hoewel sorghum-gierst in Kenia in voldoende mate aanwezig is, prefereren de Keniaanse brouwers millet-gierst. In hoofdstuk 10 worden de kiemingseigenschappen en de brouwkwaliteit van millet- en sorghum-gierst vergeleken. In deze vergelijking wordt ook de in Kenia verbouwde gerst betrokken, die op grote schaal als grondstof wordt gebruikt voor de bereiding van buitenlandse biersoorten.
In hoofdstuk 11 worden de belangrijkste punten uit het beschreven onderzoek besproken, en worden conclusies en aanbevelingen geformuleerd met betrekking tot de regulering van het gebruik van inheemse gefermenteerde dranken. Deze aanbevelingen zijn enerzijds gericht op een beperking en geleidelijke afschaffing van de thuisbereiding van deze dranken. Anderzijds wordt de mogelijkheid opengelaten tot consumptie, in bars, van inheemse biersoorten van relatief hoge voedingswaarde zoals Busaa, teneinde een verantwoord alternatief te bieden aan de minder draagkrachtige consument. Verbetering van kwaliteit en houdbaarheid van dergelijke produkten zal zeker bijdragen tot de aanbevolen verschuiving van het huidige consumptiepatroon.

References

The references listed below belong to Chapters 1, 2, 3, 4, 5, 6, and 11 only. Chapters 7-10 have their individual lists of references at the end of each Chapter.

(1) Acland, J., East African crops; an introduction to the production of field and plantation crops in Kenya, Tanzania and Uganda. Longman, London 1971.
(2) Agro-Invest industrial consultants and management agents, Small scale sugar production in Kenya, vol. 2, p. 8. Ministry of Agriculture, Nairobi 1976.
(3) Aisien, A.O. & Ghosh, B.P., Preliminary studies of the germination behaviour of guinea corn (*Sorghum vulgare*). J. Sci. Fd Agric., *29* (1978) 850-852.
(4) Anon., The Jaggery industry. Internal report, Ministry of Agriculture, Nairobi 1966.
(5) Anon., La consommation de boissons alcoolisées dans le monde. Revue Technique et Economique de l'Industrie Alimentaire, *23* (1975) 13-14, 17-18.
(6) Anon., Der Mensch ist was er isst: Alkohol, p. 40-45. Deutsche Gesellschaft für Ernährung, 1. Auflage, 1977.
(7) Anon., Difco Labs. Technical Bulletin No. 0247 (1977) 29-30.
(8) Anon., Difco Labs. Technical Bulletin No. 0247 (1977) 32-33.
(9) Aucamp, M.C., Grieff, J.T., Novellie, L., Papendick, B., Schwartz, H.M. & Steer, A.G., Kaffircorn malting and brewing studies. 8. Nutritive value of some kaffircorn products. J. Sci. Fd Agric., *12* (1961) 449-456.
(10) Bhushan, K., Kenya 79. Newspread International, Nairobi 1979.
(11) Bohdal, M., Gibbs, N.E. & Simmons, W.K., Report to the Ministry of Health of Kenya on the WHO/FAO/UNICEF assisted project: Nutrition survey and campaign against malnutrition in Kenya, 1964-1968.
(12) Central Bureau of Statistics, Report of the child nutrition survey 1978/79. Ministry of Economic Planning and Development, Nairobi 1979.
(13) Chevassus-Agnes, S., Favier, J.C. & Joseph, A., Technologie traditionelle et valeur nutritive des bières de sorgho du Cameroun. Cahiers de Nutrition et de Diététique, *11* (1976) 89-104.
(14) Den Hartog, C., Nieuwe voedingsleer. Aula-boeken, Utrecht 1964.
(15) FAO/WHO Expert group: vitamin A, thiamine, riboflavin, and niacin requirements. FAO Nutrition Meetings Report Series No. 41. Rome 1967.
(16) Garrison Wilkes, H., Tibetan beer and other beverages of the eastern Himalayas. Wallerstein Labs. Comms., *32* (1969) 93-100.
(17) Gibbons, E.T. & Widdershoven, T.M., The marketing and related aspects of the Kenya sugar industry. Paper presented to the Kenya Institute of Food Science and Technology, Nairobi, January 1981.
(18) Golberg, L. & Thorp, J.M., A survey of vitamins in African foodstuffs. 6. Thiamine, riboflavin and nicotinic acid in sprouted and fermented cereal foods. S. Afr. J. Med. Sci., *11* (1946) 177-185.
(19) Heard, C.R.C., Palm wine in human nutrition. Proc. Nutr. Soc., *14* (1955) xi.
(20) Herington, G.N., Palm wine tapping in Nigeria. The Nigerian Field, *44* (1979) 29-35.
(21) Horwitz, W. (Ed.), Official methods of analysis of the Association of

Official Analytical Chemists. Twelfth Edition. The Association, Washington DC 1975.
(22) Hulse, J.H., Laing, E.M. & Pearson, O.E., Sorghum and the millets: their composition and nutritive value. Academic Press, London 1980.
(23) Kerr, H.W., Report on Kenya sugar industry. Ministry of Agriculture, Nairobi 1967.
(24) Laws of Kenya, Chapter 106, Native Liquor Ordinance (3-9-1930), revised edition. Government Printer, Nairobi 1948.
(25) Laws of Kenya, Chapter 122, The Traditional Liquor Act (1971), revised edition. Government Printer, Nairobi 1980.
(26) Leu, R. & Lutz, P., Economic aspects of the alcohol consumption in Switzerland. Basler sozialökonomische Studien, Band 7. Schulthess Polygraphischer Verlag, Zürich 1977.
(27) Meier, H.U., Wein und Schnaps: La France bouge. Tages-Anzeiger Magazin, No. 46, p. 15-21. Tages-Anzeiger für Stadt und Kanton Zürich AG, Zürich 1978.
(28) Nederlandse Voedingsraad, Nederlandse voedingstabel, 31e druk. Voeding, *39* (1978) 366-380.
(29) Nelson, N., Busaa brewing in Mathare Valley. Internal report, Department of Sociology, University of Nairobi, undated.
(30) Novellie, L., Kaffircorn malting and brewing studies. 3. Determination of amylases in kaffircorn malts. J. Sci. Fd Agric., *10* (1959) 441-449.
(31) Novellie, L., Kaffircorn malting and brewing studies. 11. Effect of malting conditions on the diastatic power of kaffircorn malt. J. Sci. Fd Agric., *13* (1962) 115-120.
(32) Novellie, L., Kaffircorn malting and brewing studies. 12. Effect of malting conditions on malting losses and total amylase activity. J. Sci. Fd Agric., *13* (1962) 121-123.
(33) Novellie, L., Kaffircorn malting and brewing studies. 13. Variation of diastatic power with variety, season, maturity and age of grain. J. Sci. Fd Agric., *13* (1962) 124-126.
(34) Okafor, N., Microbiology and biochemistry of oil-palm wine. Adv. Appl. Microbiol., *24* (1978) 237-256.
(35) Oomen, H.A.P.C., Jansen, A.A.J. & 't Mannetje, W., Machakos project studies. 14. Growth pattern of rural Akamba pre-school children. Trop. geogr. Med., *31* (1979) 421-439.
(36) Périssé, J., Adrian, J., Rérat, A. & Le Berre, S., Bilan nutritif de la transformation du sorgho en bière. Préparation, composition, consommation d'une bière du Togo. Annls. Nutr. Aliment., *13* (1959) 1-15.
(37) Piendl, A., La birra come bevanda alcoolica e come alimento. Birra e Malto, *22* (1977) 3-32.
(38) Piendl, A., Deutsches Pilsener Lagerbier, ein Lebens- und Genussmittel. Brauwelt, *120* (1980) 518-532.
(39) Platt, B.S., Some traditional alcoholic beverages and their importance in indigenous African communities. Proc. Nutr. Soc., *14* (1955) 115-124.
(40) Platt, B.S., Tables of representative values of foods commonly used in tropical countries. Medical research council special report series No. 302. Her Majesty's Stationery Office, London 1962.
(41) Platt, B.S., Biological ennoblement: improvement of the nutritive value of foods & dietary regimens by biological agencies. Food Technol., *18* (1964) 662-670.
(42) Richardson, P.J. Favell, D.J., Gidley, G.C., Jones, G.H., Application of a commercial radio-assay test kit to the determination of vitamin B12 in food. Analyst, *103* (1978) 865-868.
(43) Rodwell, E., Fifty years of Kenya Breweries. Kenya Breweries Ltd., Nairobi 1973.

(44) Saint-Hilaire, P. & Weibel, E.K., Zwei traditionelle Biere in Kenya: Muratina und Busaa. Schweiz. Brauerei-Rundsch., *88* (1977) 261-263.

(45) Skinner, R., Tropical lager brewing with sorghum malt. Brew. & Dist. Int., *6* (1976) 26-27.

(46) Sodah Ayernor, G.K. & Matthews, J.S., The sap of the palm *Elaeis guineensis* Jacq. as raw material for alcoholic fermentation in Ghana. Trop. Sci., *13* (1971) 71-83.

(47) Stephenson, L.S., Crompton, D.W.T., Latham, M.C., Schulpen, T.W.J., Nesheim, M.C. & Jansen, A.A.J., Relationships between Ascaris infection and growth of malnourished pre-school children in Kenya. Am. J. Clin. Nutr., *33* (1980) 1165-1172.

(48) Van de Weerdhof, T., Wiersum, M.L., Reissenweker, H., Application of liquid chromatography in food analysis. J. Chromatography *83* (1973) 455-460.

(49) Van der Mark, D.F.W. (Ed.), Kenya; Landendocumentatie. Koninklijk Instituut voor de Tropen, Amsterdam 1978.

(50) Van Steenbergen, W.M., Kusin, J.A., Voorhoeve, A.M. & Jansen, A.A.J., Machakos project studies. 9. Food intake, feeding habits and nutritional state of the Akamba infant and toddler. Trop. geogr. Med., *30* (1978) 502-522.

(51) Von Holdt, M.M. & Brand, J.C., Kaffircorn malting and brewing studies. 7. Changes in the carbohydrates of kaffircorn during malting. J. Sci. Fd Agric., *11* (1960) 467-471.

(52) Woot-Tsuen Wu Leung, Food composition table for use in Africa. U.S. Department of Health, Education and Welfare; Food Consumption and Planning Branch, Nutrition Division, F.A.O., Rome 1968.

(53) Woschek, H-G., Weinkonsum und Alkoholismus. Weinwirtschaft, *111* (1975) 50-52.

Appendix

Dangers of Chang'aa

No.1. (Daily Nation, 16th January 1973)

SEVEN THOUSAND gallons of the illicit brew called *Chang'aa* were at the weekend seized by a police posse when, acting on information, it raided Nairobi's Mathare Valley.

It is seldom that the hard-working members of the Police Force earn from the general public the credit they deserve; but this is a fitting occasion for they did a really good job in the notorious "valley" on Sunday morning.

Costing about 8/- a bottle — or fifty cents a "tot" — the deadly brew has attracted many customers in recent years. It is also known that some of the addicts quench their thirst, at the same dens, with industrial alcohol.

It was conservatively estimated that the *Chang'aa* seized by the police at the weekend would have fetched the manufacturers of the brew approximately £1,000. It is indeed a lucrative, if illicit, business.

Chang'aa and industrial alcohol have claimed quite a few lives among the people who consume them. In November, 1970, for instance, 14 people died after drinking methylated spirit in Nairobi's Gikomba area. The incident made several others sick, forcing them to receive treatment in hospitals.

Despite incessant police action against the vendors who have been enriching themselves at the (health and mental) expense of their unfortunate customers, this iniquitous trade has been going on not only in Nairobi but also in several other parts of the country. Scores of *Chang'aa* drinkers have, over the years, been successfully prosecuted in the courts — but nothing appears to deter them.

Chang'aa and the other illegal drinks do not necessarily kill consumers. Dr. A. L. Ribeiro, the Government pathologist, told a NATION investigator after the Gikomba incident in 1970 that *Chang'aa* causes inflammation of the lungs, brain or heart.

It was further revealed that a *Chang'aa* addict's liver tends to shrink. Any intelligent layman can easily pity the fragile, unhealthy structure of many an addict. They seldom eat properly for their first penalty is a loss of appetite.

The brewers have nothing to lose — except their liberty if arrested and prosecuted. The real sufferers are those unfortunate customers who sit on benches in the various dens around the city where the brew is sold.

If one of the factors contributing to the lavish sale and consumption of illicit beverages is basically environmental, the authorities should go right ahead and demolish the unhygienic shanty dwellings in Mathare Valley and elsewhere, resettling their occupants in the process. Wananchi will always welcome regular visits by police officers to the places they suspect of *Chang'aa* brewing or storage.

Addicts claim it is uneconomical to drink bottled beer or properly brewed traditional beverages. Sentences for the type of offences they commit should be sufficiently stiff to become a salutory deterrent.

Beer prices and drinking hours in Kenya are far too liberal. In both neighbouring Tanzania and Uganda drinking sessions have been considerably reduced in the recent past.

One particularly disturbing aspect of the *Chang'aa* dens is that there is no age limit! Youths, too, some of them schoolboys and girls, are known to rub shoulders with elderly addicts, sipping the illicit brews to their fill.

What more can one say, really?

Drinking chang'aa is harmful

No.2. (The Standard, 25th May 1978)

WHILE I AGREE with Mr. Shikono's letter in your columns in respect of cessation of harassment of *chang'aa* drinkers especially as I don't think the law has ever stated that the specific act of consuming *chang'aa* or any other drink except deliberately to commit suicide is illegal, I see no justification for his view that laws against its production and sale to the public are unnecessary. Indeed if those laws had been merely colonial and discriminatory, I am sure that our independent Government would have removed them long long ago. Furthermore, laws which cover the production for sale of consumables as indeed laws which demand that alcoholic drinks carry excise/sales taxes, etc., are pretty well universal throughout the world today.

Leaving aside the failure to pay relevant taxes applicable to spirituous beverages to our country's treasury as laid down by law, there are very sound reasons for protecting the consumer from health risk in goods sold for human consumption.

Indeed this is particularly the case with *chang'aa* because in addition to the normal risks of unhygienic preparation and use of unfiltered river, etc., water in *chang'aa* production, there is a special risk where alcohol is distilled. This is because without proper rectification plant, there is a very real danger that methyl alcohol may be produced which latter is a dangerous poison and is usually the cause of fatalities or chronic health troubles which *chang'aa* drinkers encounter from time to time.

No government can permit it knowingly to be produced and sold for should a serious number of deaths or epidemic occur as a result, they would be in big trouble from the public as a whole.

It is not the danger of over-participating that is the main risk but the dangers involved in the unhygienic and dangerous production methods which create a very real health hazard.

I would point out to Mr. Shikono when he says that people sometimes also die from drinking too much whisky, etc., that it is possible to die from over-eating on rare occasions but is not to say that there is no reason for Government not to make laws to control and inspect the butchering of meat and to try and prevent the incidents about which we read in the Press from time to time of a number of persons dying a horrible death from anthrax poisoning.

B. H. HOBSON.
Nairobi.

No.3. (The Standard, 25th May 1978)

CHANG'AA KILLS 13 PEOPLE

Report by K.N.A.

CHANG'AA has killed 13 people in Kisii District since last month when the Attorney-General, Mr. Charles Njonjo, announced in Parliament that the drinking of the liquor was legal.

Urging the people to stop drinking chang'aa, the District Commissioner Mr. M. N. Kabugi warned yesterday that although the drinking of chang'aa was not illegal, those brewing it would be dealt with severely when found.

Mr. Kabugi also urged his people to use the money they earned from the farms by putting up good houses instead of spending it on beer and the easy life.

Addressing a *baraza* at Bondoyo Market in Bassi Borabu location of Ogembo Division, he said the district got alot of money from tea, coffee and pyrethrum, but little growth could be witnessed in the area.

Some people had even run away from their homes to the towns, he said.

Mr. Kabugi said the Government appreciated people's hard work, and that was why four tea factories were set up in the district, and the fifth was being built at a cost of Shs. 10.6-million at Nyamache.

No.4. (Daily Nation, 12th October 1978)

Cut number of beer hall licences, says Moi

PRESIDENT Moi yesterday ordered all county councils to reduce considerably the number of beer hall licences in rural areas.

The President said there was excessive drinking in the countryside and it was detrimental to rural development.

Efforts to develop rural areas were being frustrated by heavy drinking, he said.

The President, who was receiving a delegation of Baladia Muslims at State House, Nairobi, said that due to heavy drinking, many parents failed to fulfil their family obligations, such as paying school fees and providing essential commodities to their families, as they squandered all their money in bars.

The President ordered that in future people applying for beer hall licences in rural areas would be required to seek a mandate from residents.

"If residents reject such establishments their decision will be final," he said.

The President said he would not like anybody, even if he was "my friend," to be given a beer hall licence to enrich himself at the expense of the people.

No.5. (Daily Nation, 12th October 1978)

Dry times ahead for brewers

A BIG police crackdown on chang'aa brewers in Embu has drastically reduced production of the illicit liquor.

Brewing dens that were churning out 20 bottles of the lethal drink every day are now selling only a couple of bottles a day.

And law-abiding people in the area have thanked the Press for exposing the problems created by chang'aa, and police for acting on the reports.

Even some former chang'aa drinkers have expressed their thanks, saying that when lots of the drink was available they used to get drunk and incapable, and were sitting targets for thugs.

They also noted some newcomers were guzzling their way to an early grave, not realising how potent chang'aa could be. One old timer said: "These young fellows were drinking up to three bottles at a time. That's as good as trying to commit suicide."

Meanwhile, police have said they won't be satisfied until chang'aa production is completely eradicated. "Two bottles a day is two bottles too many."

—KNA

No.6. (Daily Nation, 22nd May 1980)

Chang'aa and busaa should now be legalised

Nation 22-5-80

LEADERS of this country engage in exhorting wananchi to stop the habit of chang'aa and busaa drinking.

Busaa was one of the most popular drinks in traditional African societies. It was served during weddings and in gatherings resolving social conflicts.

In the modern society, busaa and chang'aa are mostly consumed by the lowest class of people. These are the people who cannot afford, without doing irreparable harm to their families, to take beer.

It is true that the consumption of chang'aa and busaa sometimes kills, and sometimes causes other physical impairments.

However, one accepts this in the clear understanding that other beers or whiskies also cause harm to the drinkers. What matters then is the magnitude of the harm done.

Therefore, assuming that of all the intoxicating drinks in the market, chang'aa and busaa are the most injurious and are consumed by the lowest class in society, one wonders what measures the Ministry of Health is taking to avert this national hazard.

It is about the authorities concerned inspected chang'aa and busaa breweries scattered all over the country to legalise the brewing and the drinking. The brewers would have to have a clearance from the health officer either free of charge or for a small fee which would swell the Government's revenue. This is helpful in that the drinkers and the Government are assured of the fitness of the drinks.

To most of us, the police serve as invaders. They invade our havens and every time we drink like thirsty dogs in fear of the police. This is injurious to our health and morals! We can hardly ever think of helping the police even in their detection of crime.

Hence, in order to make us committed nation builders such drinks must, of necessity, be legalised. Alternatively, the Government should lower the price of ordinary beer so that ordinary wananchi can afford it.

Raising the cost of beer and denying us the permission to drink what we can afford is inffinging on our constitutional rights! By allowing others to be taking beer and whisky because they can afford them we are reduced to a status of slaves.

We state our case on the assumption that our leaders will safeguard our rights so long as those rights are compatible and in conformity with reason, justice and equality.

After all, if homosexual involvements are legalised in Britain, why not legalise busaa drinking which is part of our tradition just like traditional dances? Charging us in courts of law with possession of chang'aa and fining us heavily denies our children the right to good clothing, food and shelter.

Every coin we have is not a luxury, but an utmost necessity. We feel that we are the majority in society in that we consist of the unemployed, the poor students, the retired, and the victims of wage labour.

Lee Mwaniki Nyama,
Nairobi.

No.7. (Nairobi Times, 17th August 1980)

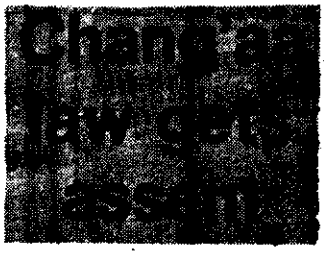
Cider to be brewed in Kenya

VISITING Kenya this week to attend the launching of locally produced and bottled Woodpecker Cider is Mr. Peter J. Prior, CBE, chairman of H.P. Bulmer Ltd, the world's largest cider making concern. Arrangements have now been made for Kenya Wine Agencies to produce and bottle Bulmer's popular Woodpecker Cider locally. As an expression of confidence in Kenya's stable economy and expansion of the cider market locally, Bulmer's has supplied all the bottling equipment free of charge to KWAL.

Prior, who is a council member of the British Institute of Management, will address a Marketing Society of Kenya luncheon on Tuesday (August 19) at the Hilton Hotel. That evening he will host a cocktail party at the Norfolk Hotel to launch the locally bottled cider.

H.P. Bulmer

No.8. (The Standard, 21st August 1980)



Standard Correspondent

THE Chang'aa Prohitition Act came into force on August 15 after receiving Presidential assent on August 12, 1980.

According to the Kenya Gazette Supplement No. 49 dated August 15 *chang'aa* means any spirit which is distilled otherwise than in accordance with a licence issued under part IX of the Customs and Excise Act of 1978.

By whatever name called, the name *chang'aa* includes spirits commonly known as *Enguli, Kali, Kangari, Kill-me Quick, Kisumu Whisky, Kivia, Maai-Matheru, Machozi-Ya-Simba, Machwara, Njeti and Waragi.*

"Spirits means any intoxicating liquor in the nature of an essence of abstract from any substance obtained by distillation and also includes any liquor mixed with spirits."

The notice sets out six conditions which deem the manufacture of *chang'aa* illegal.

No person shall manufacture, sell, supply, consume or be in possession of the brew.

"No person shall, without lawful excuse, be in possession of any implement, appraratus or utensils designed or adapted for the distillation of *chang'aa.*

"Any person who contravenes any of the provisions of Section 3 shall be guilty of an offence and liable to a fine not exceeding Shs. 10,000 or to imprisonment for a term not exceeding two years or both.

"On conviction of any person for an offence under this Act the court shall order the forfeiture and destruction of all the brew and any implement, apparatus or utensils used in connection with the commission of the offence.

"A person arrested under the Chang'aa prohibition Act shall, without unnecessary delay, and subject to the provisions of the criminal procedure code as to bail, be taken before a magistrate or an officer in charge of a police station."

No.9. (Daily Nation, 9th February 1981)

IT'S BOOM TIME FOR CHANG'AA DEALERS

From NATION Correspondent in NAKURU

CHANG'AA brewers in Nakuru had a field day over the weekend following an acute shortage of beer. When beer disappeared, the demand for illicit drinks grew and one chang'aa brewer who requested anonymity, said the price of chang'aa rose by 50 per cent. The price for a Tree-Top size bottle of the brew sold from 10/- to 15/-, he said. He added that the brew had been graded into two "super" and "lighter". He said the rush by drinkers started at 4 p.m and sale went on up to 9 p.m. He claimed that the most potential areas for sale were Government and Railway quarters, Flamingo and Kimathi estates and Mithonge areas. Most bars in Nakuru have closed down following the acute shortage of beer. Bar owners interviewed by the NATION alleged distribution of beer by agents was done on favouritism.

No.10. (Daily Nation, 11th February 1981)

Chang'aa drinkers fined

FOURTEEN people netted in a police raid at Iten market and Kariobangi were fined a total of 2,360/- for drinking chang'aa.

The prosecution told Iten district magistrate Gideon M'Rimbere that despite the Government ban on brewing and drinking chang'aa, it appeared that residents of Iten had disregarded the ban and were still drinking the illicit brew.

The magistrate warned the 14 and said they were encouraging the brewers and sellers. He added that if they were to stop buying the drink, business would dry up.

● Three women appeared before Busia magistrate J. Aburli and admitted supplying and consuming chang'aa.

Maria Wema, Namulu Lusiro and Rosa Auku were fined a total of 1,700/-.

Prosecuting, Corp. John Odinga said Wema was arrested with 15 litres of chang'aa which she was distributing at Angorom Sub-location. She was fined 800/-.

Lusiro admitted drinking 1½ litres of chang'aa at Nangoni market where she was arrested, while Auku said she was relaxing with a litre of chang'aa after a day's work. Lusiro and Auku were fined 600/- and 300/-, respectively.

No.11. (Daily Nation, 18th February 1981)

Lift ban on busaa

LET me comment on the ban which has been imposed on "busaa" drinking in Bungoma.

While we appreciate the efforts made by our leaders in eradicating crime which too emanates from drunkards, I would also sympathise with the common man who will miss his social hours with his friends after toiling hard in his shamba due to the ban on "busaa" drinking.

This means the law favours the rich who can afford to go to bars after working to refresh themselves. But a poor man cannot afford even a bottle of White Cap.

I would suggest that the authorities in Bungoma allow the poor common man to take his brew unmoleated during a specified time, possibly from 4.30 p.m. to 9 p.m., so that he too, can feel free as those who empty several cases of beer in bars due to their riches.

Miss Villy Wanyonyi,
Bungoma.

No.12. (Daily Nation, 2nd March 1981)

Sales of local beer shoot up

By NATION Reporter

THE illegal brewing and drinking of traditional liquor has increased tremendously in most parts of Kirinyaga District.

Most shopping centres in the district including Kagumo, Kaitheri, Kiamwami and Kiangege sell the illegal brew known as "makaha".

A survey carried out by the NATION in the shopping centres discovered that most of the brewers were women.

The NATION discovered that a middle size cup of the brew sold at 1/50 depending on the availability of customers and varying prices of the brew's ingredients.

In one of the shopping centres, the NATION found elderly women and men taking the beer, some with babies on their backs.

One brewer interviewed by the NATION said it was through the sale of the beer that she managed to educate her children and to buy them food.

In some of the centres the NATION also discovered that chang'aa was being sold.

No.13. (Daily Nation, 10th March 1981)

Brew leads to wisdom

IT is good to note that land disputes will be now the direct responsibility of elders, thanks to President Moi.

Although this is a commendable effort to recognise our traditional land values, I have always wondered how this operation would be effectively "felt" in an atmosphere devoid of what Wazee normally cherish — traditional pombe.

Historically, Wazee settled disputes over a bottle. The Government has banned traditional beer in rural areas and towns. How then will the courts sit and come to a compromise in an atmosphere of mere mechanical talk?

Let Wazee entertain themselves when tackling land cases with traditional beer like it used to be. These court sessions should be cordial, merry making, friendly and mumbo-jumboless.

George M. Syengo,
Mombasa.

Curriculum vitae

De auteur werd op 30 mei 1946 geboren te Den Haag. Na het behalen van het H.B.S.-B diploma in 1963 aan de Zuiderpark H.B.S., begon hij in hetzelfde jaar zijn studie aan de Landbouwhogeschool te Wageningen. In september 1970 werd het ingenieursdiploma met lof behaald, studierichting Levensmiddelentechnologie, chemisch-biologische differentiatie. De ingenieursstudie omvatte de vakken kennis van levensmiddelen (verzwaard), technische microbiologie en organische scheikunde. Tot 1973 was hij als gastmedewerker verbonden aan het Laboratorium voor Microbiologie van de Technische Hogeschool te Delft. In dienst van Unesco was hij vervolgens van 1973 tot 1974 werkzaam als associate expert aan het Institut Polytechnique Rural te Katibougou, Mali, in het kader van de multilaterale technische hulpverlening. Van 1974 tot 1977 was hij in het kader van de Nederlandse bilaterale technische samenwerking verbonden als lecturer aan het Department of Food Science and Technology, Universiteit van Ife, Ile-Ife, Nigeria. Sinds 1977 is hij werkzaam als lecturer in het Department of Food Science and Technology van de Universiteit van Nairobi, Kenia, in het kader van de Zwitserse bilaterale technische hulp. Het promotie onderzoek werd uitgevoerd onder leiding van Prof.Dr.E.H. Kampelmacher in de periode 1977-1981. Het adres van de auteur is Department of Food Science and Technology, University of Nairobi, P.O.Box 29053, Kabete, Kenya.