PHYSICO-CHEMICAL, SENSORY, AND KEEPING QUALITY OF CASSAVA FLOUR PRODUCED BY SIMPLE DRYING TECHNIQUES.

Christine Akoth Onyango.

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DECLARATION.

This thesis is my original work and has not been presented for a degree in any other University.

Christine Akoth Onyango.

6/11/1990

Date

This Thesis has been submitted with our approval as University Supervisors.

Dr. J.K. Imungi
Department of Food Technology
and Nutrition,
University of Nairobi

6/11/90

Date

Dr.E.L. Keya.
Department of Food Technology
and Nutrition,
University of Nairobi

6/11/1990

Date

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DEDICATION

I would like to dedicate this work to my parents Mr. and Mrs. B. E. Onyango, who started it all, with patience and love. Most of all I dedicate this work to my son, Omondi. He will always be my inspiration.

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ABSTRACT.

A study was carried out to determine the effect of temperature of dehydration on the total cyanide content of cassava, evaluate the keeping quality of cassava flour so produced and to investigate the possibilities of incorporating the cassava flour into some common Kenyan foods.

It was found that sun-drying, solar-drying and air drying at 30°C all resulted in higher percent total cyanide reduction than air drying at temperatures of either 40 or 60°C.

The keeping quality of the cassava flour was evaluated by storing at ambient temperatures and at 37°C. The flour was packaged in kraft paper and polythene bags.Storage at 37°C resulted in large reductions in moisture, total cyanide and blue value index in both types of packages. There was, however, a definite increase in non-enzymatic browning, which was more prominent in the flour packaged in polythene bags than in that packaged in kraft paper bags. These changes were much less pronounced during storage at ambient temperatures, than during storage at 37°C.

It was found that cassava flour could be favourably incorporated into the Kenyan foods "ugali", "mandazi" and "uji". In "ugali" levels of only upto 20% gave acceptable products, while with "mandazi" and "uji", levels of upto 50% could be tolerated. However at these high levels of substitution,the sensory attributes texture general appearance and overall acceptability were significantly reduced.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of the most important root crops in the tropics. Because of its efficient production, year-round availability, tolerance to extreme stress conditions and suitability to the present farming systems in Africa, cassava could play a major role in alleviating the food crisis in the continent. The potential of cassava can be realised by improving on the yields of the available varieties, adapting it to simple processing and storage techniques and diversifying its utilization.

The production and utilization of cassava in Kenya is limited because several factors militate against its development as a food crop. Firstly cassava is considered as a "poor peoples food". For this reason it is consumed mainly in times of drought or famine, when staple foods such as cereals and legumes are in short supply. Secondly cassava roots are very perishable and can hardly be stored for more than three days at ambient temperatures after harvesting. Thirdly some cassava varieties contain toxic cyanogenic glucosides at levels which require reduction before the roots are considered safe for consumption.

However, reasonable amounts of cassava are produced mainly at the Coast and Western parts of the country. In Kenya today, emphasis is being placed on expansion of production of drought resistant crops which can be grown in the marginal rainfall areas. There is therefore potential for expansion of cassava cultivation.

Cassava is consumed in Kenya in various forms. Commonly practised is the sundrying of cassava chunks by traditional techniques which are not standardised. The dried cassava chunks which are then milled into flour for incorporation into various traditional dishes. Very little information is, however, available on the quality of the sundried products or the acceptability of the foods prepared by incorporating cassava flour.

This project was therefore designed with the following aims in mind:

1. To assess the effiency of the traditional sundrying in the reduction of cyanide levels in cassava.

2. To determine the keeping quality of the flour produced.

3. To determine the acceptability of some popular Kenyan foods; namely 'ugali', 'mandazi',and 'uji' prepared from cereal flours composited with different levels of cassava flour.

2. LITERATURE REVIEW

2.1 THE CASSAVA PLANT

Cassava (*Manihot esculenta* Crantz) is known by several names, some of the common ones being cassava, manioc and tapioca. Cassava is commonly used in English speaking countries while manioc is common in French speaking countries, and tapioca is favoured in Asian countries.

Cassava belongs to the family Euphorbiaceae which includes the rubber and castor bean plants. It is a perennial woody shrub which grows to a height of 3-5m, though the habit varies between cultivars (*Cock, 1985; Onueme, 1978*). The cassava plant is shown in Figure 1. It is mostly cultivated in hot lowland tropics between latitudes 30°S and 30°N of the equator. It thrives under various conditions of climate and soil types and is capable of withstanding a certain period of drought (*Nestel,1973; Grace,1977; Cock,1985*). Feeder roots from the stem and from the storage roots grow downwards and penetrate the soil to a depth of 50-100cm. This helps the cassava plant to obtain nourishment from some distance below the surface and explains its ability to grow in inferior soils even in times of drought (*Doku,1969*).Cassava is indigenous to tropical America from where it was introduced to the tropical areas of Africa, Asia, Far East and the Caribbean by early Portuguese slave dealers (*Cock, 1985*).

2.2 PRODUCTION AND IMPORTANCE OF CASSAVA.

Cassava is one of the most important staple food crops in Africa, where total production amounted to 47million tonnes in 1980 (FAO,1981). Cassava is potentially able to produce more food calories per unit area than any other lowland crop, owing to its high yielding ability, adaptability to diverse cultural and environmental conditions and ability to survive 4-6 months of the dry season (*Mahungu and Hahn, 1982*). Cassava has a comparatively high biological efficiency of food energy production due to its rapid and prolonged growth, and produces 2.2 times more calories per hectare than maize at a lower resource cost (*Hahn et al, 1986*). The value of cassava as a food item is therefore that it is a cheap and abundant source of food energy for many people in developing countries, where calories are the paramount nutritional shortage (*Cock, 1985*).

Cassava is generally grown as a subsistence crop. It is not season bound and can be planted or harvested at any period of the year. At the same time cassava can be left in the ground for long periods without harvesting. This makes it a useful security against famine (*Nestel, 1973; Rosling, 1986*). This is important in the face of the declining per capita of food in Africa and the food shortages brought about by heavy dependence on cereals such as wheat, rice and maize, which are sometimes imported (*Sanchez, 1976*).

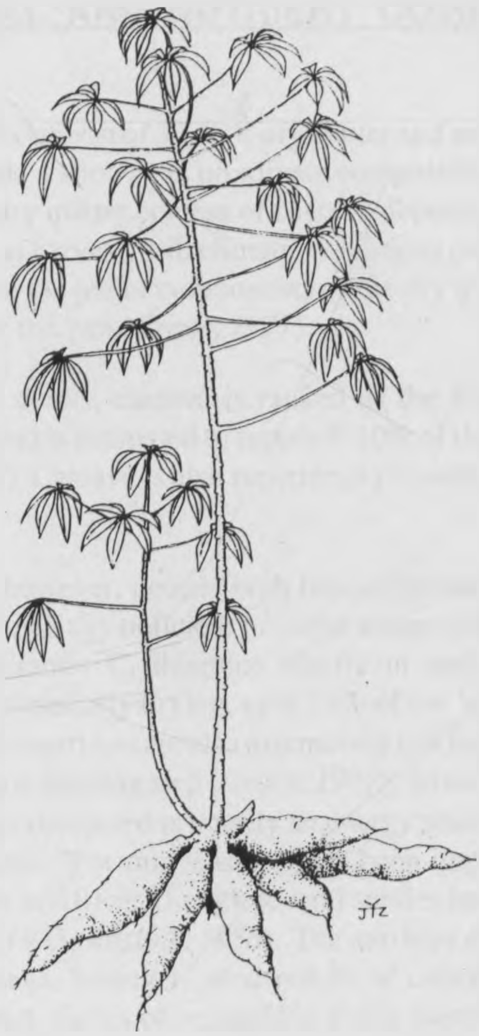

Figure 1: The cassava plant

Although cassava is one of the most important food crops in Africa and other tropical countries, its potential is little developed because it is considered a famine crop (*Cock, 1985*). At the same time cassava is disparaged as an inferior food containing little of nutritional value besides energy (*Nestel, 1973; Cock, 1985*). It is also mainly consumed in the rural areas. Growing food deficits, however, especially in developing countries have stimulated greater interest in cassava research and to-date both governments and organizations are placing more emphasis on its production and utilization in order to increase food sufficiency and security (*UNECA,1985*).

2.3 CHEMICAL AND NUTRIENT COMPOSITION OF CASSAVA.

Cassava roots consist of 30-40% dry matter and are an excellent source of food energy. Table 1 shows the proximate composition of freshly peeled cassava roots . The dry matter content of cassava depends on such factors as variety, age of roots at harvest, soil, climatic conditions and health of the plant. Starch and sugar are the major components of the dry matter, starch being the more important of the two (*Grace, 1977*).

As Table 2 shows, cassava is ranked as the fourth major calory provider worldwide and is estimated to supply 8-10% of the daily caloric needs of man (*Cock, 1973*). Cassava is also superior in providing energy as shown in Table 3.

Cassava is, however, poor in both fats and proteins (Table 1). Protein from cassava is especially deficient in sulfur amino acids. Cassava has significant levels of Vitamin C, thiamine riboflavin and niacin. However, during processing, especially drying, upto 75% of the Vitamin C can be lost. Other water soluble nutrients are also extensively leached out, if the process involves a soaking or a steeping step (*Grace, 1977*). In nutritional terms cassava must therefore be considered primarily an energy source, contributing little of any other nutrients. For this reason it has been implicated as a major cause of malnutrition in Africa: Though several studies have shown that this is not the case (*Cock, 1985; Rosling, 1986*). The nutritive deficiencies due to consumption of cassava, however, need not be of concern if cassava is eaten with supplementary dishes of vegetables and/or meat or fish, as is the practice in most communities (Lancaster et al, 1982). It should be noted that absence of cassava in the present day farming and food production systems of Africa would lead to catastrophic levels of starvation and death of millions of people. Cassava therefore deserves a special position as a crop that has saved many lives especially in Africa (*Hahn et al, 1986*).

2.4 CASSAVA TOXICITY

There have been various classifications of cassava. One of the most common is based on the hydrocyanic acid (HCN) content leading to two broad categories of "bitter" and "sweet" cultivars. Bitter cultivars are believed to have high HCN contents, while sweet cultivars have low HCN contents (*Doku, 1969; Bruijn, 1971; Coursey, 1973*). These are ,however, approximate terms as there is great overlap between the two categories. The presence of high levels of cyanide makes cassava toxic. Cyanide occurs naturally in cassava in a number different forms the three main ones being the following:

(1) Bound cyanide: This consists of two cyanogenic glucosides; Linamarin and Lotaustralin (Figure 2a). Lotaustralin always accompanies linamarin but in much smaller quantities.

(2) Free cyanide: Occurs as hydrocyanic acid (HCN) also called prussic acid.

(3) Acetone cyanohydrin: This is an unstable compound which rapidly dissociates to yield HCN (*Conn, 1969; Moduagwu and Adewale, 1980*)

The hydroxynitrile formed by the action of linamarase(Figure 2b & 2c) dissociates to acetone for linamarin or methyl ketone for Lotaustralin, and HCN. This process can also be catalysed by the enzyme hydroxynitrile lyase (*Conn, 1973*). The release of HCN from cyanogenic glucosides only occurs when the plant tissue cells are ruptured like in peeling, chopping and grating (*Conn, 1973; Bruijn, 1973; Nartey, 1973*).

Cyanogenic glucosides are distributed throughout the cassava plant although the concentration varies within the plant parts. In most cultivars, under most cultural conditions , the concentration of cynanogenic glucosides is substantially higher in the "peel" fraction of the root, than in the flesh. It has also been shown that leaf blades, leaf stalks and stems have high levels of the cyanogens (*Bruijn, 1973*).The concentration also varies greatly between cultivars and is dependent on climatic, edaphic and cultural conditions (*Coursey, 1973; Bruijn, 1971; Grace, 1977*). Levels of cyanogenic glucosides vary greatly between 15-400mg/kg (fwb) though values as low as 10mg/kg and as high as 2000mg/kg have been encountered (*Coursey, 1973*). The level of cyanide determines the degree of toxicity and bitterness of the roots. The following is a rough guide to toxicity of fresh peeled roots (*Bruijn, 1971*).

- Innocuous: Less than 50mg/kg.
- Moderately poisonous: 50-100mg/kg.
- Dangerously poisonous: over 100mg/kg.

Table 1: Proximate Composition of Freshly Peeled Cassava Roots at Harvest-time (*Grace, 1977*). .

Component	%
Moisture	70.25
Starch	21.45
Sugars	5.13
Proteins	1.12
Fats	0.41
Fibre	1.11
Ash	0.54

Table 2: Staple Crops as Sources of Calories in Human Diets in the Tropics and Worldwide (Billion kcal/day) (*FAO, 1980*).

Crop	Tropics	World
Rice	924	2043
Sugar	311	926
Maize	307	600
Cassava	172	178
Sorghum	147	208
Millet	128	204
Wheat	100[a]	1877
Potato	54	434
Banana	32	44
Plantain	30	30
Sweet Potato	30	208

[a]Excluding Brazil, Mexico and India, as the major wheat production zones of these countries are outside the tropics.

Table 3. Dry matter, Carbohydrate and Protein contents of root and tuber crops (Leslie, 1967).

Crop	Dry matter (%)	Carbohydrates (%)	Proteins (%)
Cassava	37.5	92.5	3.2
Sweet Potato	30.0	91.0	4.3
Yams	27.6	87.3	8.7
Taro	27.5	84.4	6.9

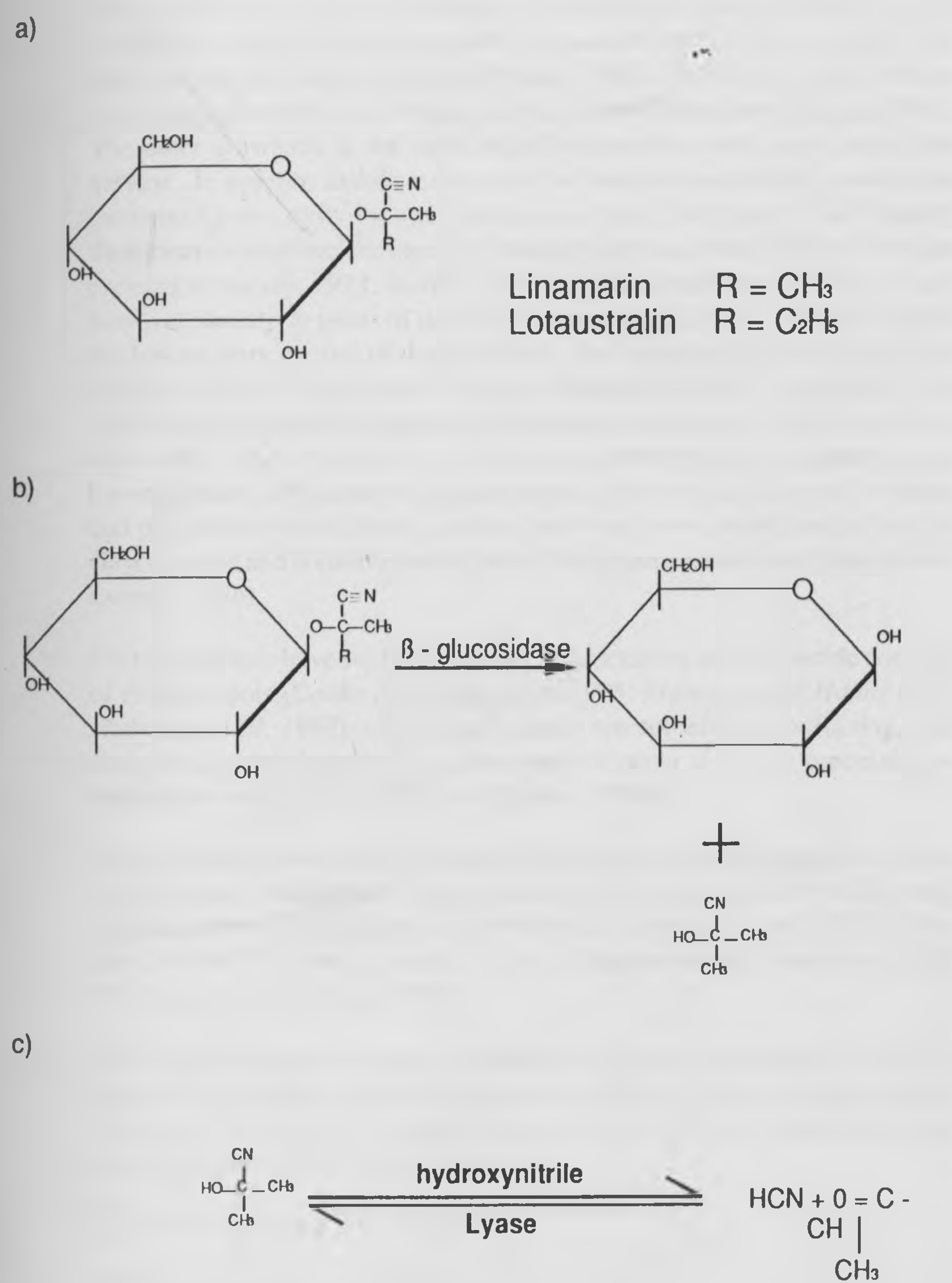

Fig 2: Cyanogenic glucosides of cassava (a) and the mechanism for their enzymatic decomposition (b +c)

2.5 CASSAVA PROCESSING AND DETOXIFCATION.

The presence of cyanide in cassava limits popularization of cassava and its products as foods. Consumption of cassava with high levels of cyanide can lead to acute or chronic toxicity (*Rosling, 1987*). In Kenya a few cases of poisoning by cassava have been reported, some of them fatal (*Imungi, 1986*). The other drawback is the rapid deterioration of cassava roots soon after harvest. In order to make cassava safe for human consumption, which also increases its versatility for use, cassava is normally processed. Traditionally, the processes used include steeping, roasting and sundrying, after grating and pressing (*Coursey, 1973; Rosling, 1987*). These traditional techniques are, however, limited in terms of their conditions of application, their low yields, the low sanitary quality of their products, the inadequate contributions they make towards reducing losses, and the small quantities they can handle. As a result they are generally unreliable (*Chinsman and Fiagan, 1986*). In addition, traditional African societies evolved simple technologies for reducing post harvest losses, but because of rapid population growth and shortened handling and preparation times, these ingenious methods have proved inadequate for current needs,and consumers now prefer foreign processed foods (*Numfor and Lyonga, 1986*).

Various workers have studied the effect of processing an the cyanide contents of cassava roots (*Cooke and Moduagwu, 1978; Mahungu and Hahn, 1982; Mahungu et al. 1987*), and though results are sometimes conflicting, it is generally agreed that acute toxicity does not occur if proper processing or preparation methods are followed (*Rosling, 1986*).

In general most processes reduce cyanide levels by bringing together enzymes and substrate through cell rupture followed by elimination of the liberated HCN by either volatilization or dissolution in water (*Coursey, 1973*). It has been shown that most cyanide is lost during the initial processing stages (*Moduagwu and Adewale, 1980*).

The main traditional cassava processing in Kenya is sundrying, which is carried out according to the scheme shown in Figure 3. This traditional method is especially common in Western Kenya. Cassava for traditional processing can be divided into two main groups:

(i) Those requiring a fermentation step.

(ii) Those requiring no fermentation.

Cassava in the first group includes the "bitter" cultivars. The end of the fermentation is determined by the growth of grey mold all over the roots. Those in the second group mainly include the sweet cultivars. These cassava processing methods are similar to those found in West Africa. These methods have not been improved at all. At the Coast, the cassava is commonly pounded into a pulp before cooking and consumption.

The processing of cassava is especially important when it is considered that preservation of fresh roots has limitations. Under favourable conditions, cassava in the dried form can be stored for years without appreciable loss in quality. Therefore with greater emphasis on processing and preservation, coupled with new products development, cassava could find great popularity amongst consumers.

2.6 CONSUMPTION AND UTILIZATION OF CASSAVA

Although cassava has been an important food crop in the lowland tropics for centuries, its cultivation and utilization are little understood outside that world. This is attributed to the subsistence nature of the crop, though it is believed to contribute significantly to the diets of over 800 million people (*Nestle, 1973; Hahn and Keyser, 1985*).

Cassava is primarily eaten either fresh, prepared or processed. Because of its bulk and perishability, it is usually consumed at or near the growing place (*Cock, 1985*). Cassava is also used as animal feed and for starch and alcohol production (Table 4). Most of the starch and feed are exported to Europe from the producing countries.

2.6.1 Consumption and Utilization of sweet cassava

In Kenya, sweet cassava is eaten in a number of ways. It can be eaten raw as a snack or cooked. A popular way of consuming cassava roots is as boiled chunks. The boiled chunks maybe eaten mashed or whole, alone or accompanied with a sauce. The sauce is usually prepared from vegetables and/or meat or fish and sometimes beans. This method of consumption is also very popular in West Africa (*Doku, 1969; Lancaster et al. 1982*). The roots may also be stewed in coconut milk together with vegetables and meat or beans. This is common at the coast of Kenya (*Imungi, 1986*).

Cassava roasting and frying is also popular especially in the main towns. For roasting, the cassava is peeled, washed and split lengthwise. The splits are then roasted over an open charcoal fire until the outer crust turns deep brown in colour. The inside becomes soft and crumbly. For eating, the roasted halves are split in the middle, sprinkled with chilli powder and fresh lemon juice. Roasting of cassava is extremely common in Nairobi and Mombasa.

Cassava can also be eaten deep fried. For frying the cassava is prepared in the same way as for roasting, then the halves deep fried in any available edible oil.

Cassava is also be sliced and fried into crisps. These are a good alternative to the more expensive potato crisps.

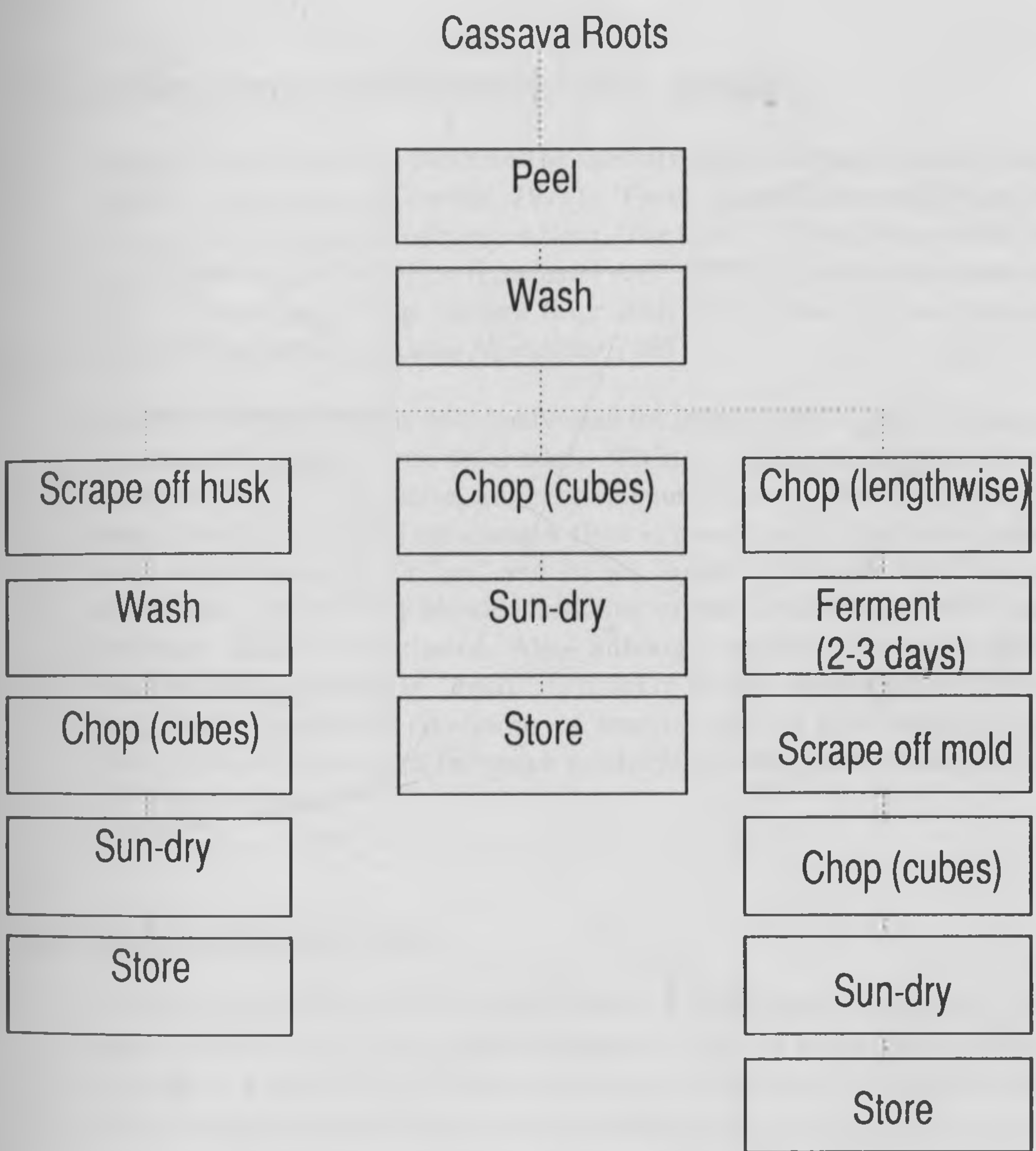

Figure 3. Traditional Processing of Cassava in Western Kenya

Frying and roasting in the rest of Africa and other tropical countries has been reviewed by Lancaster et al. (1982). In West Africa, a variety of pastes are prepared by peeling and pounding the cooked roots. The roots are normally cooked in steaming or boiling water to produce a sticky dough which is eaten with soups of okra, or stews of meat or fish (Lancaster et al. 1982). Fresh cassava roots are also used as an animal feed, especially when other foods are in plenty.

2.6.2 <u>Consumption and Utilization of "Bitter" Cassava</u>

Bitter cassavas have to be processed by special methods in order to make them safe for consumption (*Coursey, 1973*). These methods inevitably lead to production of some form of cassava flour. The flour is utilised in a number of ways depending on the region (*Lancaster et al. 1982*). A number of countries have started compositing cassava flour with wheat flour for commercial production of bread (*Cassava Newsletter 1985*)

In Kenya, cassava flour is commonly used for preparation of *<u>"uji"</u>* (porridge or gruel) and *<u>"Ugali"</u>* (semi-solid cake). When used thus, the cassava flour is normally blended with maize, millet or sorghum flours. Under conditions of normal food availability, the cassava flour is usually mixed with the cereal flour in the ratio of 1:2 for *"uji"* and 1:4 for *"ugali"*. Although *"Uji"* can be made from cassava flour blended with any of the cereal flours, millet and sorghum flours are preferred. Also, although cassava flour is normally blended with maizemeal in *"ugali"*, in times of famine, sorghum flour can be used, while in extreme conditions of scarcity cassava flour maybe used alone.Cassava is also used for starch production in Kenya by a company in Kilifi at the Coast.

2.6.3 <u>Storage of Dried Foods.</u>

The desire to maintain the nutrient quality of foods during processing and storage is an extension of our desire to preserve foods. Changes in the quality of foods as a function of nutrient destruction, development of off flavours, colour deterioration and changes in textural properties have become important in the determination of shelf life of foods. The chemical, nutritional and microbial quality of foods has been shown to be a function of storage temperature, light, oxygen, total moisture contents and the physico-chemical nature of water in the food system (*Kirk, 1981*).

The physico-chemical nature of water in a food is illustrated by sorption isotherms of the food. Sorption isotherms show the equilibrium relationships between moisture contents of foods and the water activities (a_w) at constant temperatures and pressures. Water activity determines the extent of microbial growth, enzymatic reactions, non-enzymatic browning, lipid oxidation and

Table 4: World utilization of cassava, 1975 - 1977 (as a percentage of total production) (FAO, 1980).

	Human Food		Animal	Industrial			Changes in
	Fresh	Processed	Feed	& Starch	Export (b)	waste	stock
World	30.8	33.8	11.5	5.5	7	10	1.4
Africa	37.9	50.8	1.4	c	c	9.5	c
America	18.5	23.9	33.4	9.6	c	14	c
Asia	33.6	21.7	2.9	8.6	23	6.3	3.9
Asia without Thailand	45.6	27.9	3.9	11.7	2.3	8.6	c

a - Excludes chips and pellets as Animal feeds

b - Includes exports for animal feed.

c - Less than 1%

changes in textural properties. Sorption isotherms are also important for engineering purposes related to concentration and dehydration of foods (*Iglesias and Jorge, 1982*).

Changes in temperature affect sorption isotherms. Temperature gradients are important because they lead to water vapour pressure gradients with resulting transfer of moisture and changes in the water activity levels. Food moisture sorption isotherms at several temperatures usually show a decrease in amount sorbed with increasing temperature. This indicates that with increasing temperature water sorption is not favoured and the food becomes less hygroscopic. This may not necessarily be always the case as other factors such as history and pre-treatment of the food may also exert an influence (*Troller and Christian, 1978*). In Kenya storage evaluation has not been carried out on the dried cassava, although it is known to be stable in storage for several years if proper processing is carried out.

3. MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Cassava Roots.

Fresh cassava roots from varieties MS-30395, TMS-30555-18, TMS-63397-9 and KME-1 were obtained from the National Dryland Research Station, Katumani, Machakos. These had been planted during the long rains of March-May 1986, and had been given little attention during growth apart from occasional weeding.

Some cassava roots of unknown varieties were also purchased from the local open air markets in and around Nairobi. The roots had been harvested from plants which were, according to the vendors, at least 18 months old. In both cases the roots were stored for not more than 24 hours at 4°C before processing or analysis.

3.1.2. Cereal flours

Maize flour (Jogoo Brand, Unga Limited, Nairobi) and wheat flour (Home baking flour, Unga Limited Nairobi) were purchased from Uchumi supermarkets in Nairobi. Sorghum and finger millet flours were purchased from local open air markets in Nairobi.

3.1.3. Packaging Materials

Kraft paper bags (1kg capacity) were provided by Unga Limited, Nairobi, free of charge Polythene bags (100 gauge) were purchased from supermarkets in Nairobi.

3.1.4. Fats and Oils

Cooking oil (Corn oil, Crispo brand, Aberdare Millers Limited,Nyeri) and Margarine (Blue Band brand, East Africa Industries, Nairobi) were purchased from Uchumi Supermarkets in Nairobi.

3.1.5. Milk

Pasteurized milk (Butter fat 2.3% from Kenya Cooperative Creameries, Nairobi) was purchased from Supermarkets in Nairobi.

3.1.6. Sugar

Ordinary table sugar was purchased from Uchumi Supermarkets, Nairobi.

3.1.7. Baking powder

Baking powder (Zesta Brand, Trufoods, Limited Nairobi) was purchased from Uchumi supermarkets, Nairobi.

3.1.8.Chemicals and Reagents

All chemical and reagents used in this study were of analytical grade and were purchased from Kobian (K) Limited, Nairobi.

3.2 METHODS

3.2.1. Preparation of cassava for Drying

The cassava roots were peeled and trimmed with kitchen knives The peeled roots were sliced to 1mm thickness in a kitchen machine (Combirex 1R.B., Jacob Lips, Urdof Switzerland).

3.2.2. Drying of Cassava Slices

The slices were dried using three methods as described in 3.2.2.1 to 3.2.2.3 according to the flow chart shown in Figure 4.

3.2.2.1 Traditional solar drying

The slices were loaded on trays constructed of a wooden frame and wire gauze base. The trays were placed on racks, inclined to the windward side at approximately 30°. The trays were then left outside in direct sun until the moisture content was about 10%

3.2.2.2 Improved solar drying

The slices were spread evenly on the trays and placed inside a solar drier with open sides and a black painted floor.

3.2.2.3 Hot air drying.

This was carried out using a Fessman cabinet dryer at three different temperature and humidity conditions as shown in Table 4 Stainless steel trays were used for the drying.

The drying took different times depending on the temperature. Drying at 60° took 2 hours to complete, while drying at 40° and 30°C took 4 hours and 8 hours respectively.

This hot air drying was used as a control.

3.2.3.Incorporation of cassava flour into some Kenyan foods.

In order to evaluate its functional properties, the cassava flour was incorporated into the traditional Kenyan foods, "mandazi", "ugali" and "uji". For all the products, the proportion of cassava flour was varied from 10-50% (w/w). Before product preparation, the composite was homogenized by mixing in a Henry Simon Orbitots Tumbler Mixer for 10 minutes.

3.2.3.1 Preparation of "Mandazi" (doughnuts).

In this product cassava flour was composited with wheat flour. The ingredients used were as in Table 6.

The ingredients were placed together in a plastic bowl and mixed by hand until a dough of acceptable consistency was obtained. This mixing took about 7 minutes. The dough was allowed to rest for 15-20 minutes, after which it was rolled out flat on a benchtop to a thickness of approximately 10mm then cut into portions of equal size with a biscuit cutter of 6.5 cm in diameter, or cut into equal size squares using a knife. The portions were fried in oil at 200°C for 15 minutes.

3.2.3.2.Preparation of "Ugali" (stiff porridge).

For this product, cassava flour was composited with maizemeal.. The product was prepared from flour and water in the ratio of 1:2 (v/v), as follows:

Water was first heated to boiling. The flour was then added with constant stirring to obtain a stiff paste which was continuously patted and turned for a further 20 minutes.

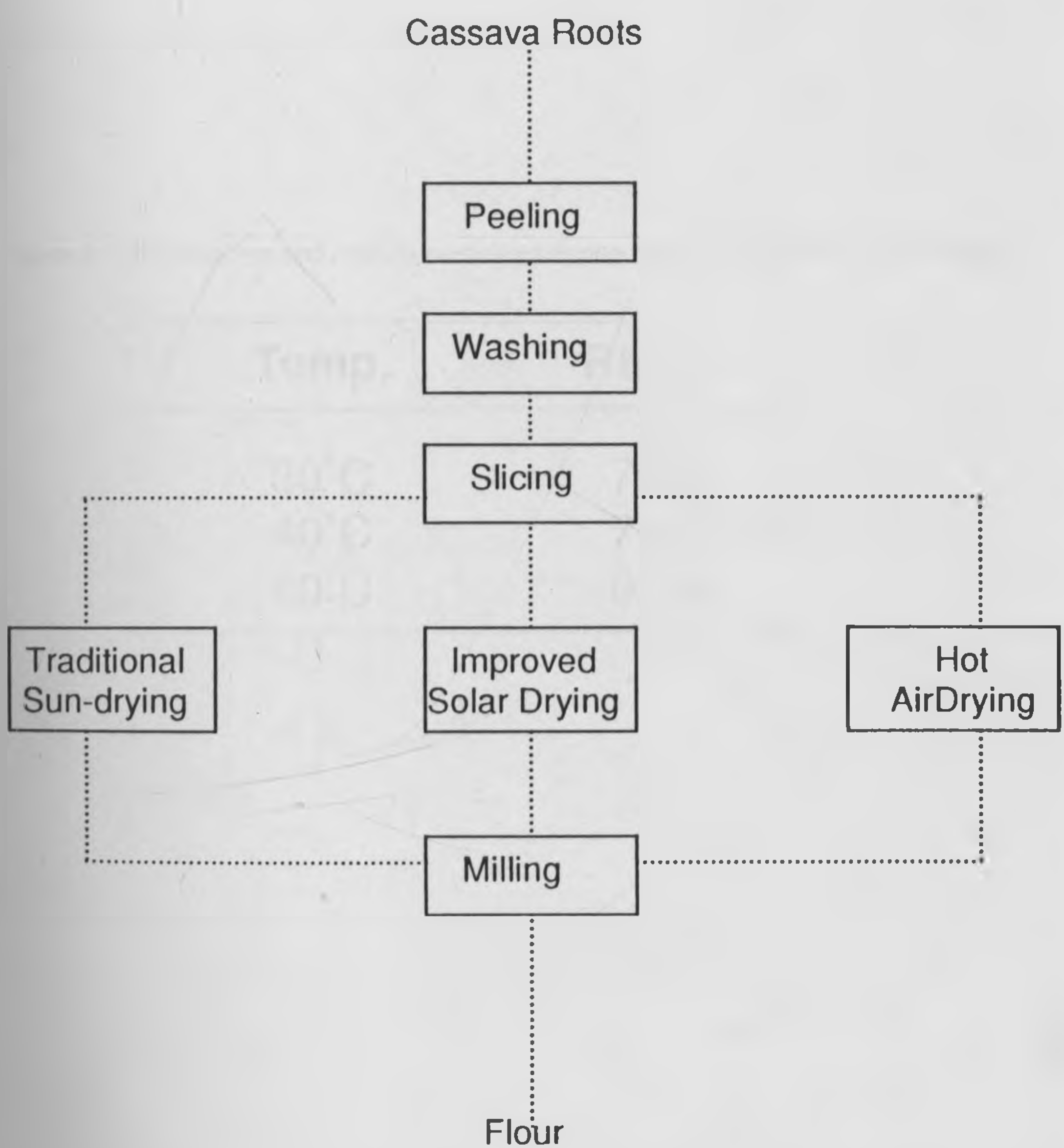

Fig 4: Basic flow sheet for dehydration of cassava slices to produce flour

Table 5: Temperatures and relative humidities during cabinet drying of cassava slices

Temp.	Rh %
30°C	75.8
40°C	71.2
60°C	62.8

Table 6: Ingredients for preparation of "mandazi"

Item	**Quantity**
Flour	125g
Sugar	20g
Baking powder	4g
margarine	15g
milk.	25ml
water (tepid)	80-100 ml

3.2.3.3. Preparation of "Uji" (porridge).

In this product cassava flour was composited with finger-millet ("*wimbi*") flour and sorghum ("*mtama*") flour. The ingredient composition is shown in Table 7. The product was prepared as follows:

300mls of the water were heated to boiling, then a slurry prepared from the remaining water and the flour was added with constant stirring. The mixture was heated to boiling, the heat lowered and allowed to simmer for 1-2 minutes. Sugar and milk were then stirred in and the "uji" allowed to simmer for a further 15 minutes.

3.2.4. Analytical Methods

3.2.4.1.Determination of moisture content.

Moisture contents of fresh cassava roots and cassava flours were determined by drying at 105°± ° 2°C in an air oven to constant weight.

3.2.4.2.Determination of crude protein.

Crude protein contents of fresh cassava roots were determined as total nitrogen by the Kjeldahl method (AOAC, 1984). The percent nitrogen was multiplied by 6.25 to convert to percent protein.

3.2.4.3.Determination of ether extract.

Ether extract was determined by extracting the sample for 16 hours with petroleum spirit (b.p. 40-60°C) in a soxhlet extractor.

3.2.4.4.Determination of crude fiber.

Crude fiber contents of the roots were determined by AOAC methods (AOAC, 1984).

3.2.4.5.Determination of total ash.

Total Ash contents were detemined by incinerating 2g samples in porcelain crucibles at 550°C, in a Muffle furnace to constant weight.

Table 7: Ingredients for preparation of "uji"

Item	Quantity
Flour	25 g
Water	300 mls
Milk	25 mls
Sugar	25 g

3.2.4.6.Determination of starch content.

The starch contents of fresh roots were determined by AOAC methods (AOAC, 1984). The standard curve used for this determination is shown in Figure 5.

3.2.4.7.Determination of total sugars.

The total sugar contents of the fresh roots were determined by the Luff Schoorl method, Method 4 of the International Federation of Fruit Juice Producers (*IFFJP, 1968*).

3.2.4.8.Determination of vitamin C (Ascorbic acid).

Vitamin C as reduced ascorbic acid was determined by the titration method of Barakat et al.(1955).

3.2.4.9.Determination of total cyanide

Total cyanide contents of fresh roots and cassava products were determined by titration with a standard Silver Nitrate (AgNO3) according to the method by Grace (1977). By this method, 1ml 0.01N $AgNO_3$ 1.08 mg HCN.

3.2.4.10 Determination of Blue Value index.

The blue value indices of the cassava flours were determined by the method of Mullins et al.(1955). This method is a based on the measurement of the absorbance of the blue color developed in a reaction between iodine and starch.

3.2.4.11 Determination of non-enzymatic browning.

The extent of browning was assessed by the method of Hendel et al.(1950). In this method the sample is extracted with ethyl alcohol (50% v/v) and the optical density of the extract determined at 390nm.

3.2.4.12 Determination of sorption properties.

The method of Rockland (1960) was used. Eight salts were each dissolved in distilled water to make saturated solutions. The salts were then each left to

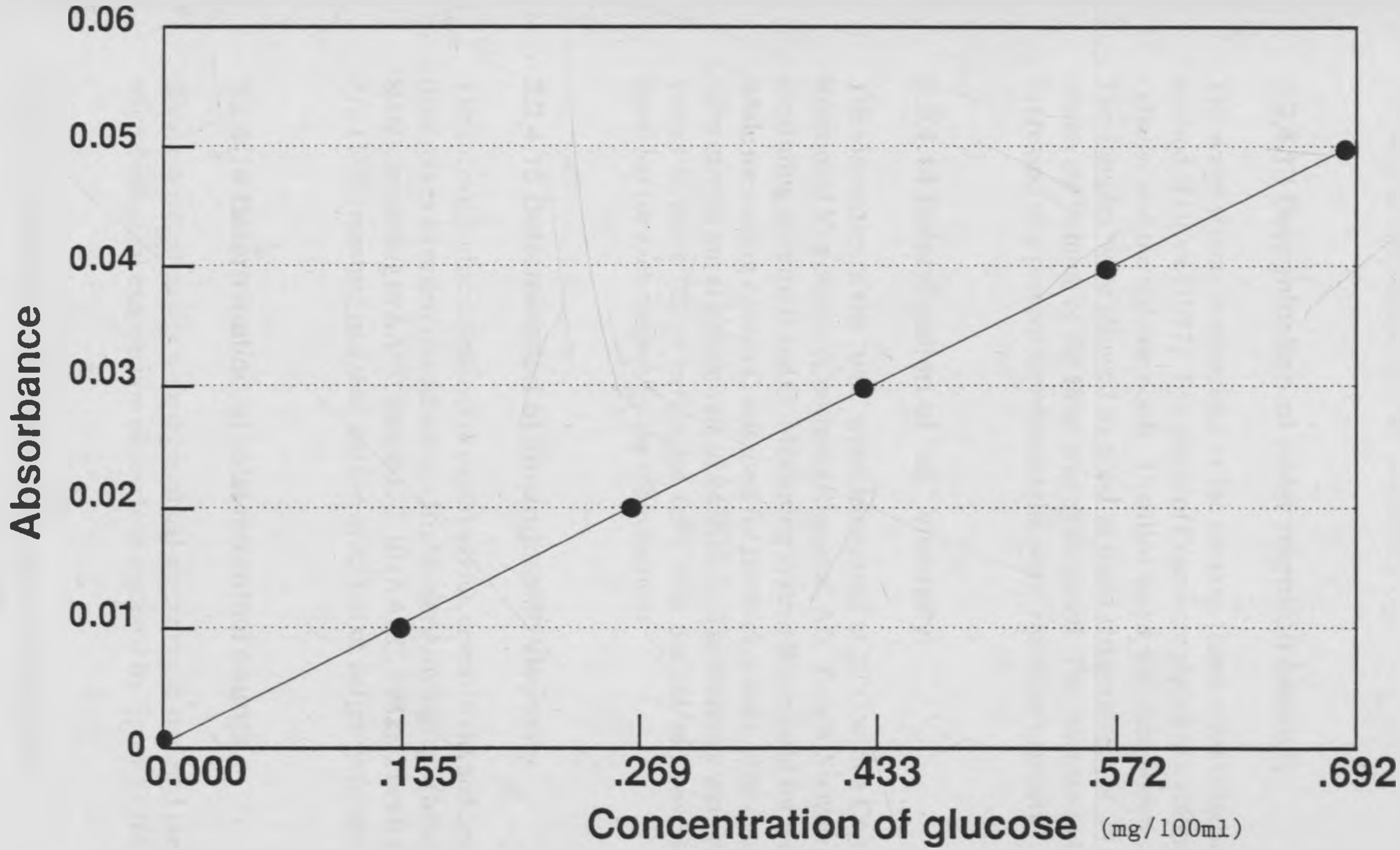

Figure 5: glucose standard curve for starch determination

achieve the equilibrium relative humidity (ERH) at the test temperature. The ERH's for the salts are shown in Table 8. Three grams samples of each product were then weighed into a receptacle within the atmosphere above each salt solution and the moisture content allowed to equilibriate at the test ERH. The moisture contents of the samples were then determined and the values used to plot the sorption isotherms. These measurements were carried out at three different temperatures: 20°, 30° and 37°C.

3.2.4.13 Determination of water retention capacity.

The water retention capacities of the cassava flours were determined by the method of Grace (1977). Ten grams of flour were placed in a 100ml measuring cylinder and the volume noted. Distilled water was then added to the mark. The samples were allowed to stand at room temperature for 24 hours after which the volume of the flour was again noted. The increase in the volume, expressed as a percent represented the water retention capacity.

3.2.4.14 Determination of "uji" viscosity.

The viscosities of the "ujis" were determined at 20°C with a Contraves STV Rotational Viscometer (Contraves Rheomat, AG. Zurich, Switzerland), using measuring systems B and C. Measuring system B was used for the thin "ujis" while measuring system C was used for the thicker ones. The determinations were carried out at a shear rate of 24.9DS-1. The readings were converted to values in poise (P) or centipoise (cP) with the aid of conversion factors provided for each system by the manufacturer.

3.2.4.15 Determination of amylographic viscosity.

The amylographic viscosities of cassava flour, cereal flours and cereal-cassava flour mixes were determined using a Brabender Amylograph (Model No 8001/8002), according to AACC method 22-10 (AACC, 1982). For all experiments 77g (14% moisture basis) of sample in 453ml of buffer were used.

3.2.4.16 Determination of total microbial counts.

Total microbial counts were determined according to standard procedures for microbiological examinaton of foods as outlined by Speck (1986).

3.2.4.17 Determination of particle size distribution.

Particle size distribution was determined by shaking 50g samples in a stack of sieves arranged in decreasing mesh size for 15 minutes. The weight of flour retained in each sieve was noted and expressed as a percent.

Table 8: Equilibrium Relative Humidities (ERH) for the salts used for determination of Sorptions Isotherms at 20°C,30°C and 37°C (*Rockland 1960*)

	Temperature (°C)		
Salt	**20°C**	**30°C**	**37°C**
Lithium Chloride	0.11	0.11	0.11
Potassium Acetate	0.23	0.23	0.23
Magnesium Chloride	0.32	0.32	0.32
Potassium Carbonate	0.44	0.42	0.41
Magnesium Nitrate	0.52	0.52	0.51
Cupric Oxide	0.68	0.67	0.67
Sodium Chloride	0.75	0.75	0.75
Potassium Chloride	0.86	0.84	0.84

3.2.4.18 Determination of flour water absorption.

The flour water absorption was determined on a 14% moisture basis, according to the centrifuge method of Sosulski (1962).

3.2.4.19 Determination of "ugali" tenderness.

"Ugali", containing cassava flour at the levels of 0-50% (w/w) was prepared as outlined in section 3.2.5.2. The "ugali" was compacted into a level measure in a 250ml plastic container. A penetrometer, (Model FT 011 (0-11lbs) was used to determine the tenderness after 0, 15, and 60 minutes.

3.2.5 Evaluation of shelf Stability of Cassava Flour.

Cassava flour obtained by the milling of dehydrated slices from the improved solar drying method, were filled into kraft paper bags and polythene bags in lots of 250g. The paper and polythene packages were divided into two batches. The first batch was stored at 37°c and an average relative humidity of 75%. The second batch was stored at the ambient conditions whose temperature and relatiive humidity are shown in Table 6. After every month of storage, one bag from each batch was withdrawn and the contents analyzed for changes in moisture content, blue value index, non-enzymatic browning, odour development and changes in microbial load. The storage study was carried out for a total period of six months.

3.2.6 Sensory Evaluation.

The acceptability of each of *"ugali"*, *"uji"* and *"mandazi"* was evaluated by a sensory panel consisting of 14 Kenyan students from the Department of Food Technology and Nutrition. A 7-point hedonic rating scale was used to assess color, appearance, taste, texture and overall acceptability of the products (Appendix I). The results were subjected to analysis of variance and the means compared by Duncan's Multiple Range Test (*Larmond, 1977*).

Table 9. Changes in the ambient temperature relative humidity and during storage of cassava flour between February and August 1988.

Number of months	Mean daily Temperature (°C)	Mean daily rH(%)
0 February	19.7±0.85	67.7±0.91
1 March	20.2±1.04	63.1±0.18
2 April	18.8±0.94	81.6±0.77
3 May	18.1±0.56	83.8±0.46
4 June	16.8±1.15	87.6±0.95
5 July	16.1±0.99	89.7±0.78
6 August	16.5±0.88	77.4±1.59

[a]Mean + SD (n=30 or 31 days)

4. RESULTS AND DISCUSSION

4.1 NUTRIENT AND TOTAL CYANIDE CONTENTS OF SOME KENYAN CASSAVA CULTIVARS.

The chemical composition of some Kenyan cassava cultivars are shown in Table 10. The chemical composition of the cassava roots differed considerably. The dry matter contents, which varied between 27.4 and 42.1 percent, were within the range of 24-52 percent reported by Grace (*1977*). The average dry matter content for cassava has been reported as 35 percent. (*Grace, 1977*). The dry matter of cassava consists mainly of starch and sugar which together comprise upto 90% (*Grace, 1977*). There were differences between the cultivars which could also be attributed to age and growing conditions. It has been shown that the dry matter content of cassava depends on variety, age of root at harvest, soil and climatic conditions during growth and the health of the plant (*Grace, 1977; Onwueme, 1978*).

The protein contents of the cassavas were generally low, ranging between 0.95 and 1.67 percent. There was however no significant difference ($P<0.05$) between the cultivars. These results compare well with published reports which also give low protein values ranging from 1-6 percent, with an average of 2 percent. Apart from protein, cassava is also poor in fats. The results show that the fat contents fell between 0.20 and 0.67 percent. This is in agreement with the findings in previous studies(*Doku, 1969; Grace, 1977*).

The fibre content varied between 0.68 and 1.40 percent. The roots obtained from Katumani generally had higher fibre contents than those from local markets. It was possible that the latter roots were older than the former at harvest. It has been shown that fibre contents of cassava roots vary with age of root at harvest; such that the older the root, the higher the fibre content (*Doku, 1969; Onwueme, 1978; Cock, 1985*).

The ash contents of all the cassavas were low and ranged between 0.53 and 0.91 percent. This was comparable to the range of 0.3 - 0.5 reported in the literature,and indicates that cassava is a poor source of minerals, though it has been reported to have reasonable amounts of calcium,phophorous and iron (*Doku, 1969; Onwueme, 1978; Grace, 1977; Cock, 1985*).

Table 11 shows the starch, sugar, Vitamin C and total cyanide contents of the cultivars studied. The starch content varied between 18.24 and 23.25 percent. There was significant difference at $P<0.05$. The low value of K1 was probably due to the fact that the roots were young and had not achieved the maximum starch content (*Grace, 1977; Cock, 1985*)

The sugar contents of the cassavas studied ranged from 5.13 to 7.52 percent. Varietal difference were noted between the cassavas. This variation is normal

Table 10: Nutrient contents of some fresh Kenyan cassavas (g/100g fresh roots) [a]

Variety	Moisture content	Dry matter	Crude protein	Crude fat	Crude fiber	Ash
TMS-30395-30[1]	64.9±1.06a	35.1±1.06a	1.19±0.04a	0.66±0.12a	0.66±0.12a	0.72±0.12a
TMS-30555-18[1]	64,8±0.99a	35.2±0.99a	1.20±0.03a	0.20±0.08a	0.96±0.63a	0.85±0.08b
TMS-63397-9[1]	72.6±1.59b	27.4±1.59b	1.01±0.16a	0.32±0.18b	1.40±0.08b	0.67±0.21c
KME 11	63.4±1.03a	36.6±1.03a	0.95±0.45a	0.40±0.25b	1.11±0.07a	0.73±0.04a
K1[2]	57.9±1.09a	42.1±1.09a	1.11±0.95a	0.60±0.28b	0.68±0.13c	0.73±0.29a
K2[2]	61.7±1.12a	38.3±1.12a	1.67±0.30a	0.67±0.30a	0.78±0.16c	0.53±0.14c
R[2]	58.4±1.17a	41.6±1.17a	1.67±0.05a	0.57±0.06b	1.25±0.17b	0.70±0.20a
W[2]	63.5±0.07a	36.5±0.07a	1.12±0.29a	0.48±0.08b	0.98±0.40a	0.91±0.12b

[a] means ± SD (n=3)

[1] Known varieties from Dryland Research Station, Katumani.

[2] Mixed varieties from local markets.

Means in columns followed by the same letter are not significantly different at $P \leq 0.05$.

Table 11: Total starch, total sugar, vitamin C (as reduced ascorbic acid) and total cyanide contents of some Kenyan cassavas (fresh roots)[a].

Variety	Starch (%)	Total Sugar (%)	Vitamin C (mg/100g)	Total cyanide (mg/kg)
TMS-30395-30[1]	21.05±0.24	6.22±0.11	20.18±0.82	55.3±1.08
TMS-30555-18[1]	23.25±1.32	5.94±0.19	18.72±0.75	45.0±0.03
TMS-63397-7[1]	21.25±0.31	5.13±0.66	17.28±0.49	37.8±0.09
KME 1[1]	20.98±0.29	5.56±0.36	27.40±1.16	11.4±0.42
K1[2]	18.24±1.01	7.52±1.03	23.76±0.35	45.4±0.95
K2[2]	22.57±0.83	6.15±0.06	19.01±1.73	38.8±1.32
R[2]	22.25±0.67	6.30±0.16	39.89±0.29	45.4±0.70
W[2]	21.45±1.21	5.72±0.25	19.30±0.61	46.4±0.29

1 Known varieties from Dryland Research Station, Katumani

2 Mixed varieties from local markets

a means ± SD (n=3)

and expected. It has been reported that bitter cultivars contain less sugar than sweet ones. The sugar imparts a pleasant sweet taste to the roots (*Grace, 1977*).

Results presented in Table 11 show that the cassavas studied could all generally be categorised as sweet varieties except TMS - 303395 - 30 from Katumani,which had total cyanide levels above 50mg/kg,and could therefore be categorised as moderately poisonous. The total cyanide contents varied between 11.4 and 55.3mg/kg with an average of 40.7mg/kg. There was significant difference between the cultivars at $P< 0.05$.

Cyanide toxicity of cassava roots was previously associated with species or varieties. However presently even within varieties, cyanide contents have been found to vary markedly with growing conditions, soil, moisture, temperature and age of the plant. Certain cultivars for instance which are innocuous become poisonous when grown under different environmental conditions (*Grace, 1977*). Actually cultivars TMS-30395-30, TMS-30555-18 and TMS-63397-9 were bitter cultivars under the growing conditions of the International Institute for Tropical Agriculture (IITA), Nigeria, but as Table 11 shows, when grown under the conditions prevailing at Katumani, Machakos, Kenya, their levels of cyanide were markedly reduced,so that they could only be categorised as innocuous or moderately poisonous.

Also as the results in Table 11 show, the cassavas had reasonable levels of Vitamin C. The values ranged from 17.28 to 39.89mg/100g and were significantly ($P<0.05$) different between the cultivars. Cassava is reported to have significant amounts of Vitamin C ranging from 20-30 mg/100g, though upto 90% of it could be lost when cassava is cooked or processed (*Grace, 1977; Onwueme, 1978; Cock, 1985*). In nutritional terms therefore, cassava can be considered primarily as an energy source contributing little else except Vitamin C, especially in the fresh form.

It should be noted that although cassava maybe consumed raw, its palatability and digestibility, just like other foods, are greatly improved by cooking and preparation. Moreover, cooking lowers the levels of the toxic cyanide (*Grace, 1977; Cock, 1985*). Levels of cyanide are also reduced during processing to produce various products and traditional food items (*Coursey, 1973; Lancaster et al., 1982*).

4.2. DEHYDRATION OF CASSAVA ROOTS.

4.2.1 Effect of Drying Techniques on The Cyanide Contents of Cassava Roots.

Cassava from the three known varities were separately dried under the conditions already described and the reduction in total cyanide determined.The results are presented in Table 12. The calculation of percent reduction in total cyanide contents of each of the varieties TMS-30395-30, TMS-30555-18 and

Table 12: Changes in total cyanide ofthree varieties of cassava during dehydration.

	Hot Air Drying (°C)			Improved solar drying	Traditional Sun-drying
Variety	60°	40°	30°		
TMS-30395-30					
mg/kg	43.2±1.6	23.7±0.05	16.3±1.1	18.3±0.7	16.3±1.1
%reduction	21.9	57.1	70.5	66.9	70.5
TMS-30555-18					
mg/kg	29.1±1.2	9.7±2.2	17.4±2.0	15.9±1.6	13.3±1.2
%reduction	35.3	56.2	61.3	64.7	70.4
TMS-63397-9					
mg/kg	30.4±1.6	25.5±2.4	18.8±1.7	19.1±0.4	13.1±1.5
%reduction	19.6	32.5	50.3	49.5	65.3

a means ± SD (n=3)

TMS-63397-9 were based on the levels in the fresh roots, which have already been shown in Table 11.

Air drying, was carried out at the three different temperatures: 30°, 40° and 60°C for comparison with traditional sun-drying and improved solar drying. Results show that roots dried at 30°C and those subjected to sundrying and improved solar drying showed greater reduction in total cyanide than those dried at 40°C and at 60°C. No significant differences were observed among the three treatments at $P<0.05$. The interactions between the treatments and varieties were also not significant. Drying at 60°C resulted in a significantly ($P<0.05$) lower reduction than at either 30° and 40°C. Air drying at 30°C, sundrying and improved solar drying reduced cyanide levels by the largest proportions and to almost equal extents. These results compare well with those reported by other workers. Charavanapavan (1944) showed that low temperature drying resulted in a greater reduction in cyanide contents than high temperature drying. This was supported by Razafimahery (1953) who showed that sun-drying, for three consecutive days , resulted on an average of 73% reduction in total cyanide. However, Cooke and Moduagwu (1978) found that drying at low and high temparatures both rapidly removed free cyanide but bound cyanide was only significantly affected when drying was carried out at lower temperatures for long periods. It has been postulated that drying for long periods at low temperatures allows for high moisture levels to be maintained in the product for long periods of time. This favours the action of the endogenous enzyme linamarase (*Cooke and Moduagwu, 1978; Mahungu et al., 1987*).

Traditional sun-drying is therefore more effective in eliminating cyanide than artificial drying at high temperatures. There are hygiene problems associated with traditional sundrying. However, these can be overcome by use of cheap, improved solar drying on raised trays which is equally effective in reducing levels of cyanide (*Kwatia, 1986*). From the range of their cyanide levels it can be concluded that the reduction of cyanide levels in the assorted varieties from the local markets would be in the same range as the known varieties tested.

4.2.2 Mass Balance for Cassava Flour Production

Cassava purchased from the local markets was dried on the improved solar dryer. On average 100kg fresh roots of 63.4% moisture yielded 17.7kg cassava flour of 10.3% moisture, representing an average yield of flour of 17.7%. These results are illustrated in Figure 6.

The major losses ocurred during peeling and drying, while only minor losses occured during the slicing and milling processes. Peeling losses tended to be greater with smaller roots, probably due to the tendency to remove a larger proportion of the flesh with the peel. Peeling losses were also greater in roots that were older and therefore more fibrous. These results correlate well with

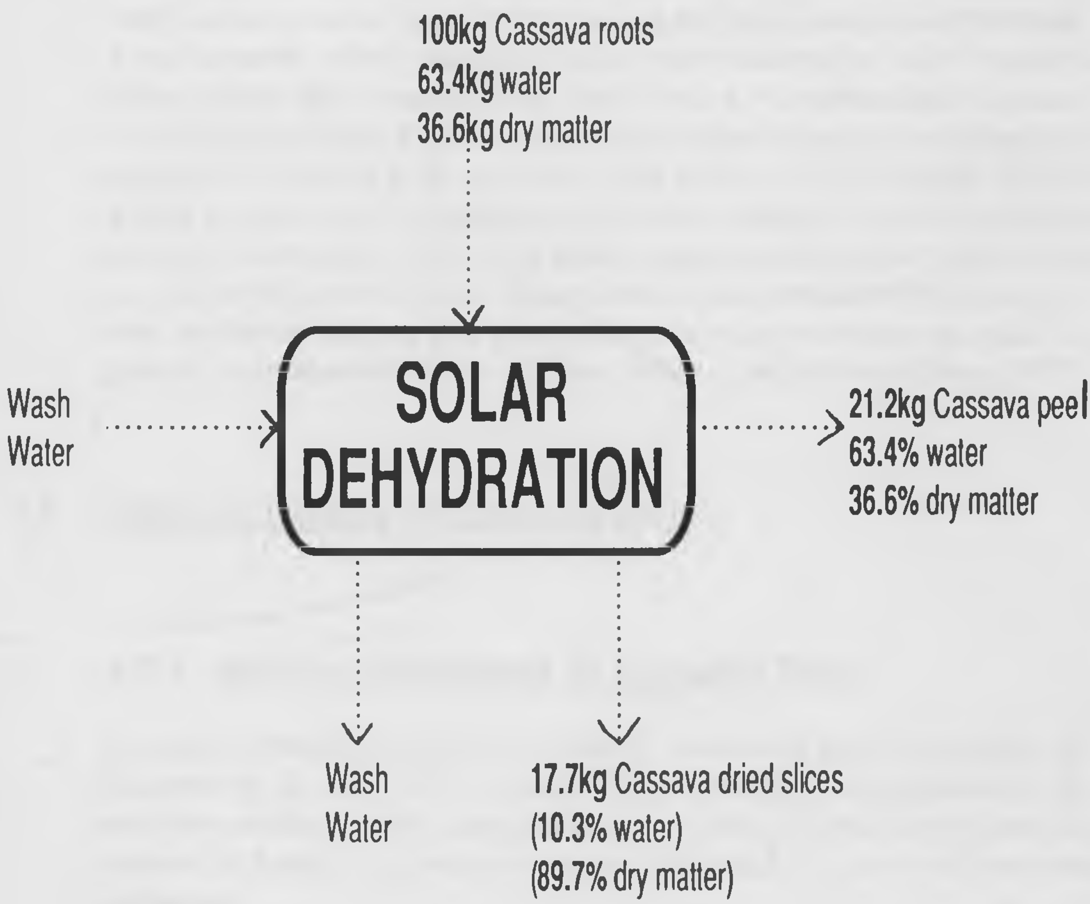

Figure 6: Estimated mass balance for cassava flour production

results obtained during processing of cassava roots for '*gari*,' a fermented and dried product. The major losses in '*gari* 'production were from removal of water and peel which were responsible for upto 80% of the losses. Less loss occurred from cultivars having high dry matter contents. It was also shown that peeling losses were reduced by having relatively large roots that were easily peeled (Hahn et al., 1984). The large contribution of water loss to the drying loss was expected since water constitutes the bulk of cassava roots.

4.3 WATER RETENTION CAPACITY OF CASSAVA FLOUR.

The results for the water retention capacity (percent) of cassava flour obtained from the various drying techniques are shown in Table 13. No significant differences were observed at $P<0.05$ among the water retentions of the flours. It was however, noted that there was a general increase in water retention capacity as the drying temperatures were lowered. Traditional and improved solar drying produced flour with higher water retention values compared with controlled air drying at 40° and 60°C. Air drying at 30°C resulted in flour having a water retention capacity similar to flour produced by sundrying and improved solar drying. The lower water retention at the higher temperatures may be attributed to the faster drying rates at these temperatures resulting in case hardening, leading to a flour with poor water retention capacity. In general, high water retention capacities in flours are prefered (Grace, 1977).

4.4 Keeping Quality of Cassava flour

4.4.1. Sorption Isotherms of Cassava flour.

Changes in the physio-chemical nature of foods have become important in determining the shelf life of foods. These changes are functions of the variables existing in the storage enviroment such as light, oxygen and the content of foods. The relationships are illustrated by means of sorption isotherms.

Sorption isotherms for cassava flour at 20°, 30° and 37°C are presented in Figure 7. The curves are typically sigmoid in shape. The curves show that there was a general decrease in water sorption with increase in temperature from 20° to 37°C. According to literature Region A in Figure7 is considered to be the most stable for storage under the prevailing conditions. For cassava, this would represent moisture contents of 9% at 20° and 30°C, and 9.5% at 37°C. These moisture contents represent water for all activity (a_w) values of 0.38. This is the monolayer region for the cassava flour. In this region, large changes in aw are necessary to cause appreciable condensation or evaporation of water which accounts for the increased stability of the product. In this region

Table 13: Water retention capacity of cassava flour (percent).

Variety	Hot Air Drying (°C)			Improved solar drying	Traditional Sun-drying
	60°	40°	30°		
TMS-30395-30					
% MC[1]	8.2	8.8	10.2	9.8	10.1
% WR[2]	57.5	56.1	58.4	60.1	62.9
TMS-30555-18					
% MC[1]	8.6	9.1	10.5	10	10.1
% WR[2]	54.3	56.5	60.4	64.3	68.1
TMS-63397-9					
% MC[1]	8.1	8.6	10	9.9	10.9
%WR[2]	50.7	56.4	54.8	58.4	62.1

[1] Moisture Content
[2] Water Retention

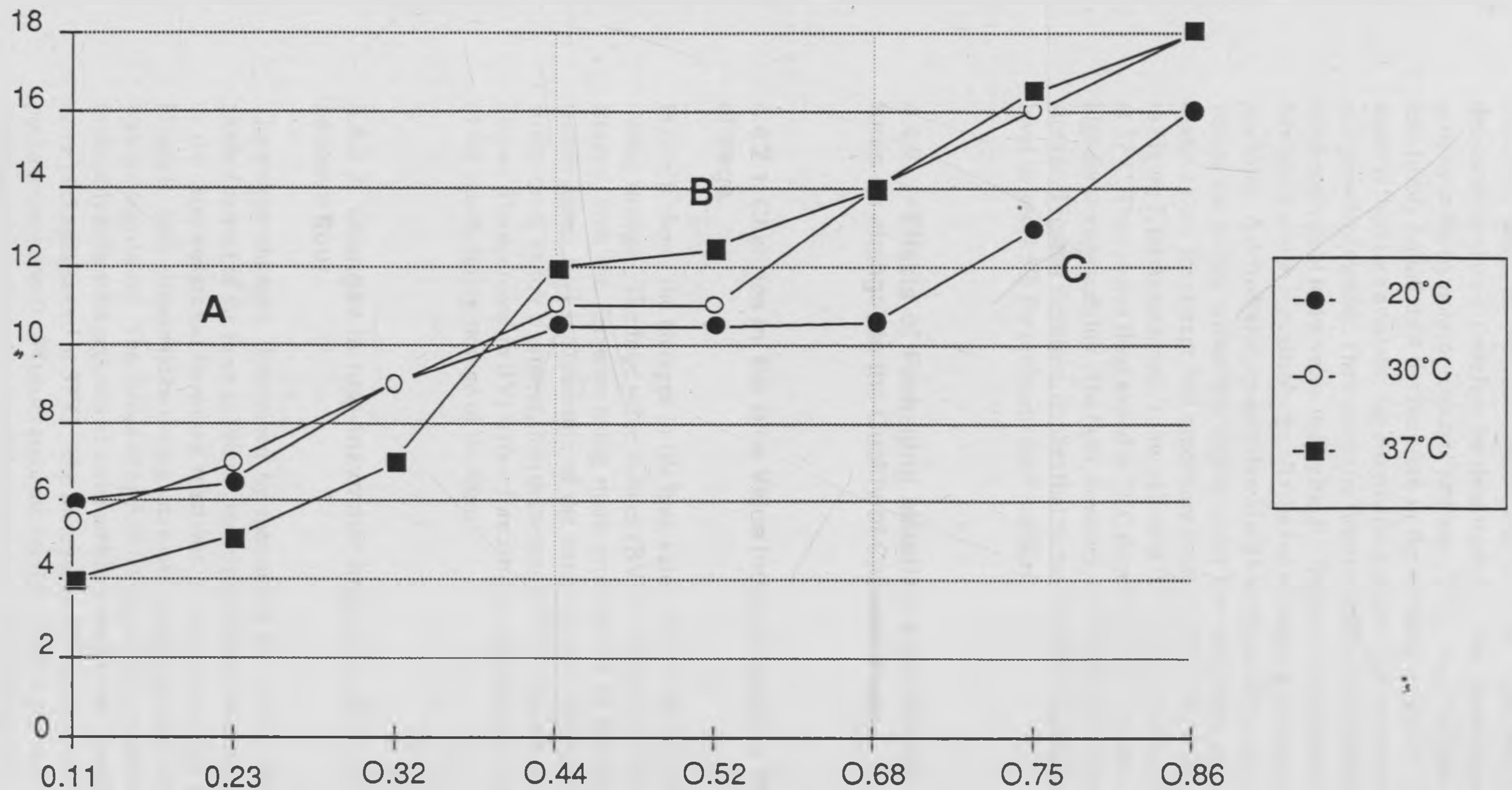

Fig 7: Sorption isotherms of cassava flour at 20°, 30° and 37°C

therefore, water in the food behaves as a solid. The endpoint of food dehydration should therefore be determined by the acquisition of a water activity in the monolayer region (*Fennema, 1985*). Region B has water that is less firmly bound than the moisture in the monolayer region. Some of this water is therefore available for enzymatic activity, non-enzymatic browning, and growth of moulds. The cassava for flour production was dried to a moisture level equivalent to aw value in Region B. Region C represents the region of free water which is available for all types of microbical and physicochemical reactions. A dehydrated product should not have a moisture content which develops aw falling within this region under the conditions of storage. The cassava flour for storage had a moisture content of 11.6 ± 2.21%. According to Figure 7, this corresponds to aw values of 0.44 at 20°, 0.60 at 30°C and 0.72 at 37°C. The cassava flour stored at 37°C therefore, had a moisture content too high for storage stability. The flour, however, lost some of this moisture during storage. Figure 7 therefore, implies that cassava needs to be dried to a moisture level below 9.5% for optimum shelf stability.

4.4.2 Effects of Packaging Materials and Storage Temperatures on changes in the Quality of Cassava Flour

4.4.2.1 Changes in the Blue Value Index of cassava flour during storage.

Figure 8 shows the changes in the blue value indices of the cassava flours during storage. The blue value indices (BVIS) decreased with time during storage, with the decrease being more pronounced at the higher storage temperature. BVI is a measure of the extent of the coiling of the helical structures of starch, a property that decreases with increasing starch retrogradation. The decrease in BVI is therefore attributed to possible retrogradation of the starch during storage of the flour.

4.4.2.2 Changes in non-enzymatic browning during storage of cassava flour.

The colour changes, determined by measuring the optical density of the alcohol extract of the flour at 390nm, mainly indicated the extent of Maillard or the non-enzymatic browning reactions. These results are presented in Figure 9. Non-enzymatic browning increased during storage but the increase was not significant. The values of optical density (OD) increased upto 0.228 in the polythene packages stored under ambient conditions ; upto 0.860 for the same packages stored at 37°C. The increase in OD for the products in kraft packages was upto 0.134 under ambient conditions and to 0.336 at 37°C. These increases are attributed to possible interaction between the little protein and

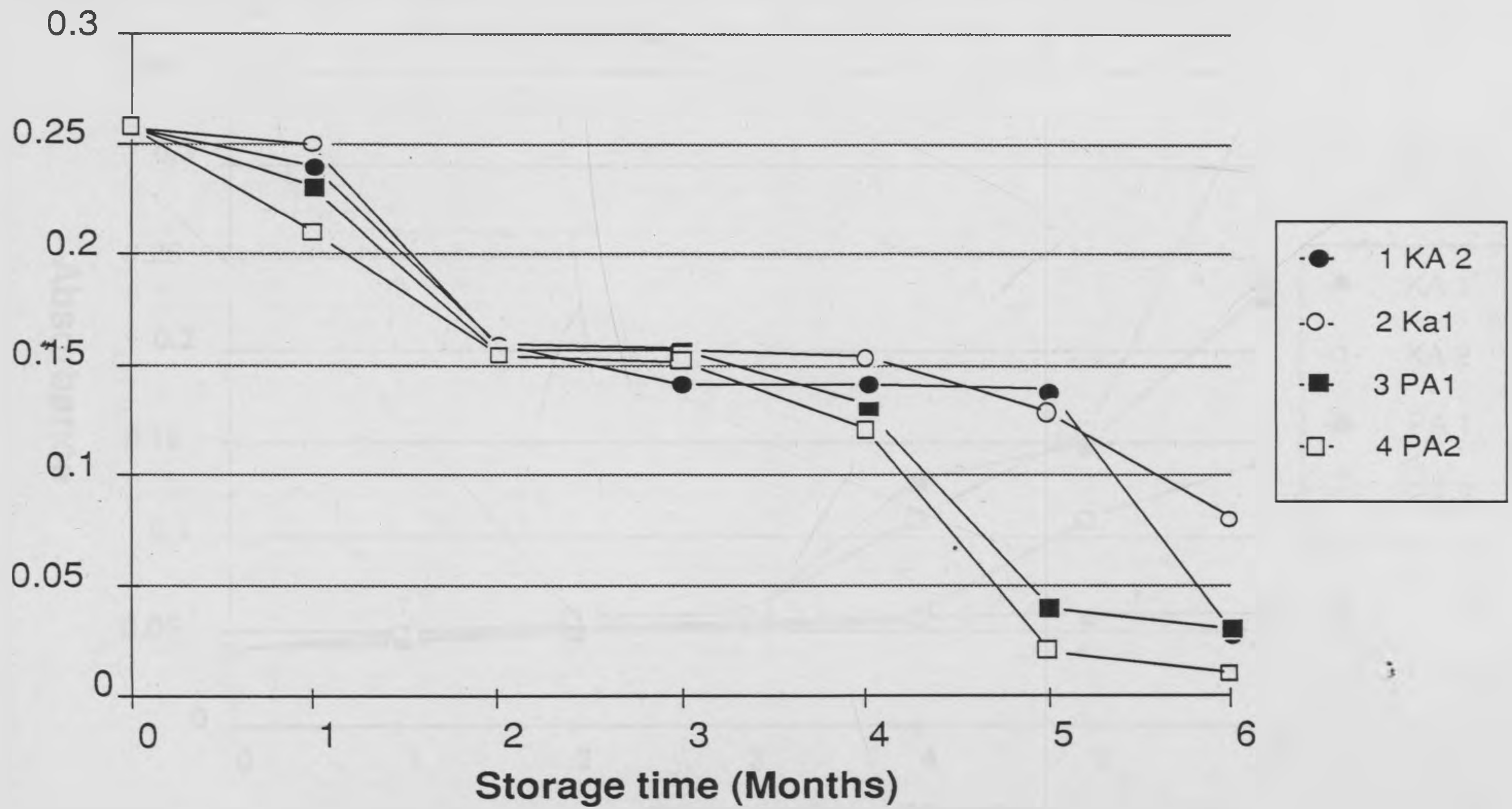

Fig 8: Changes in blue value index (BVI) of cassava flour during storage

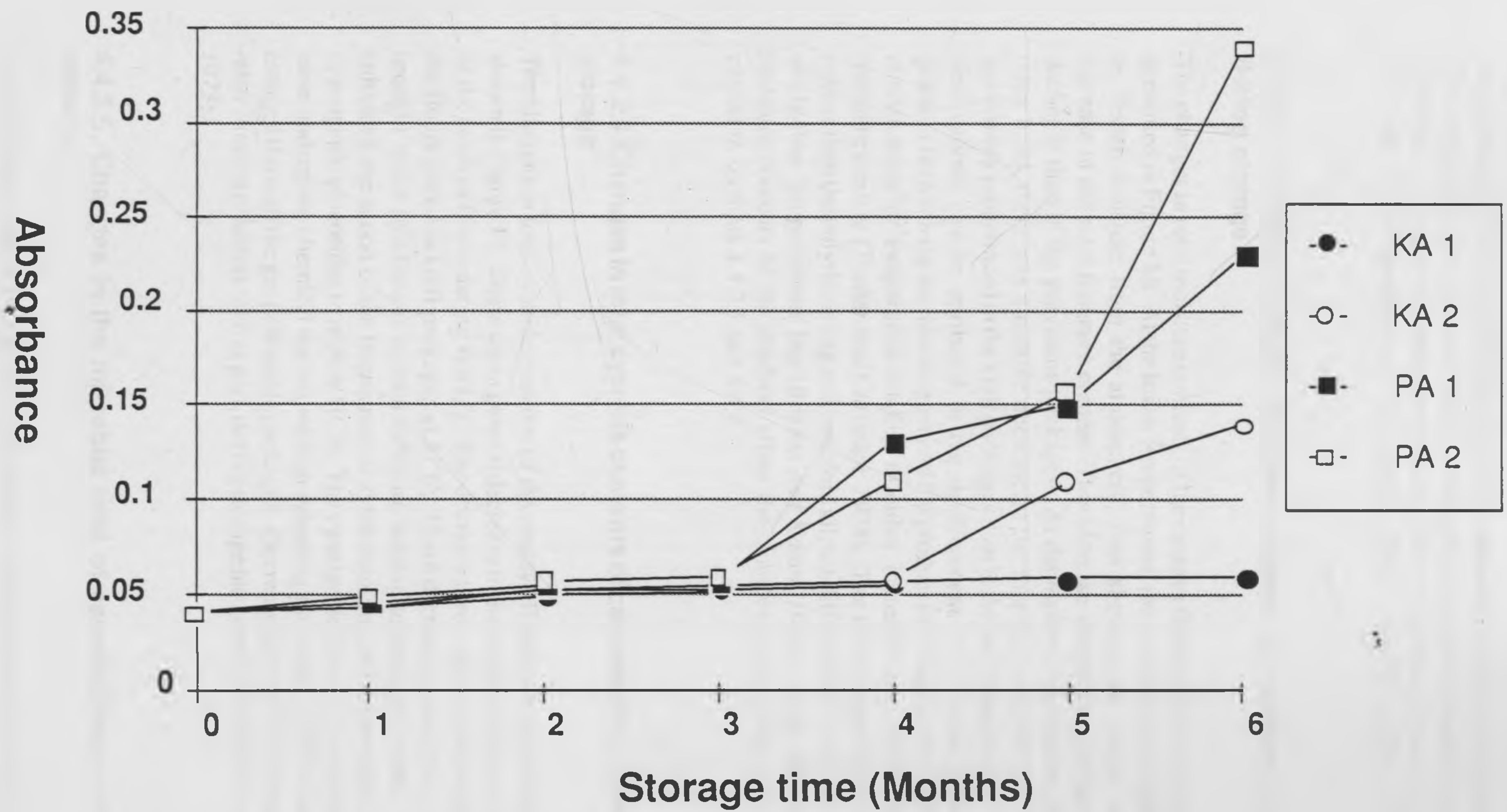

Fig 9: Changes in non-enzymatic browning of cassava flour during storage

sugar present in the flour. These reactions are favoured by high water activity. The aw levels of the cassava flours during storage were favourable for the reactions. At higher temperatures however, non-enzymatic browning reactions may be attributed to a scorching effect (*Troller and Christian, 1978*).

4.4.2.3 Changes in total moisture contents of cassava flours during storage.

The changes in total moisture contents of the cassava flours during storage are presented in Figure 10. At the lower temperatures, the cassava flour appeared to absorb moisture from the atmosphere, thus showing an overall slight increase in the total moisture content. This increase was greater in the kraft packages than in the polythene packages. At the higher temperature, on the other hand, there was a notable decrease in the moisture content. This was again more pronounced in the kraft packages than in the polythene bags. These observations can be attributed to the development of a vapour pressure gradient between the surrounding air and the product environment resulting in condensation or evaporation leading to either increase or decrease in the moisture content (*Troller and Christian, 1978*). The kraft paper bag is more porous than the polythene bag and therefore allows diffusion of moisture more easily than the polythene bag (*Briston and Katan, 1974*). These changes in moisture contents of the products affect the changes which have been discussed in sections 4.4.2.1 and 4.4.2.2.

4.4.2.4 Changes in total cyanide contents of cassava flours during storage.

The changes in total cyanide contents of the cassava flours during storage are shown in Figure 11. There was a general decrease in the total cyanide contents of the cassava flours during storage. The decreases were most pronounced in the flours stored in kraft packages at 37°C. These decreases could have been brought about by changes in total moisture leading to changes in aw. This enhanced the action of the linamarase enzyme resulting in decomposition of cyanogenic glucosides to release HCN. The cyanigenic glucosides could also have undergone chemical decomposition releasing the volatile HCN, which escaped through the gas permaeble packages. Decrease in cyanide contents of other cassava products such as gari, during storage has been reported (*Coursey, 1973*).

4.4.2.5 Changes in the microbial load of cassava flour during storage.

Standard plate counts for cassava flour during storage were determined. The results are presented in Table 15. Total plate counts did not change signifi-

Table 14: Standard Plate Counts of Cassava Flour during storage (per gram)[a]

	Room Conditions		37°C	
Time (months)	KA1	PA1	KA2	PA2
0	900	900	900	900
1	2000	3900	1500	1000
2	2600	4900	1000	1000
3	3500	5000	1800	1200
4	3500	6500	1500	1100
5	3000	6300	1800	1000
6	3500	6000	1800	1200

KA- Kraft package
PA- Polythene package
[a] means of duplicate plates

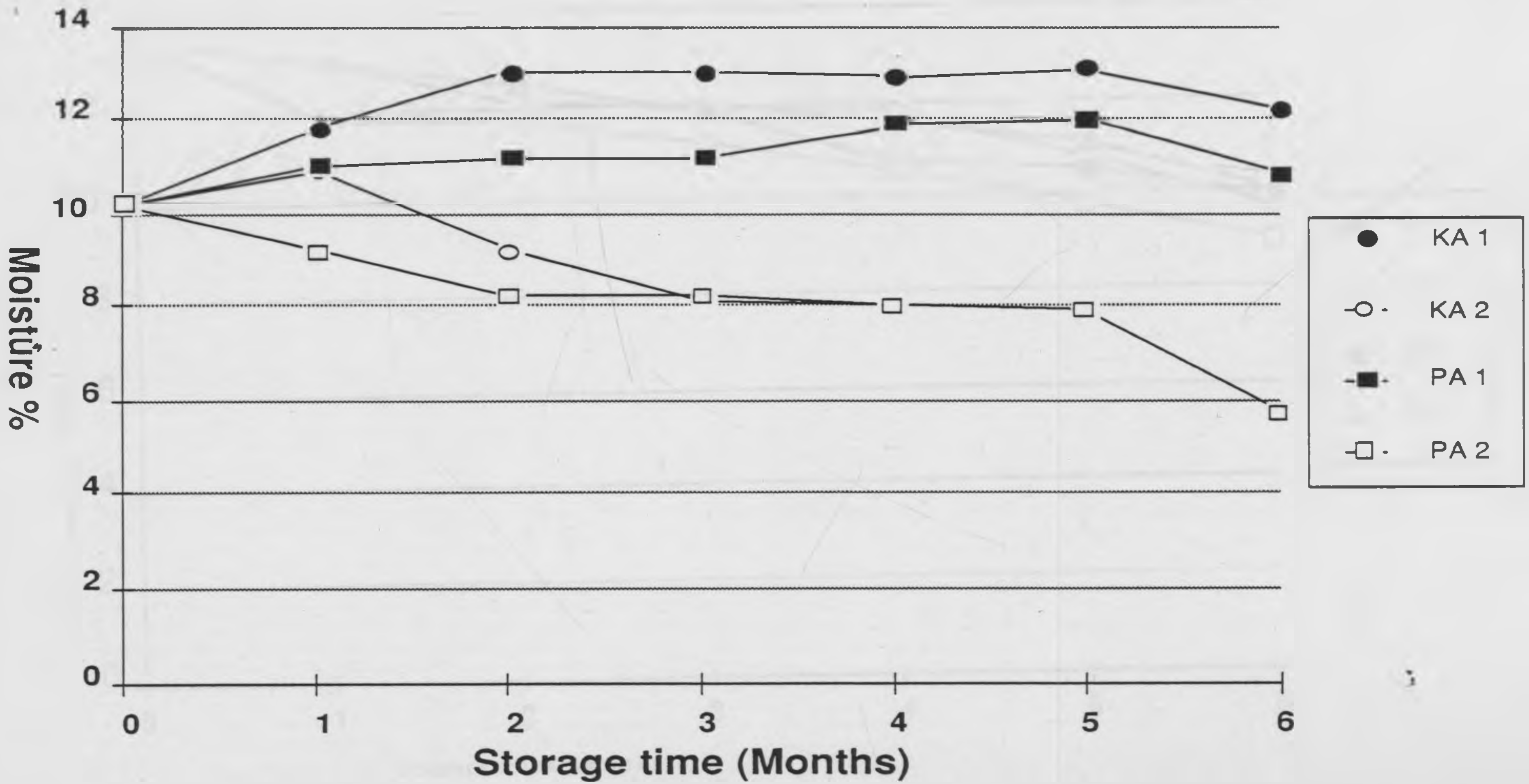

Fig 10: Changes in total moisture content of cassava flour during storage

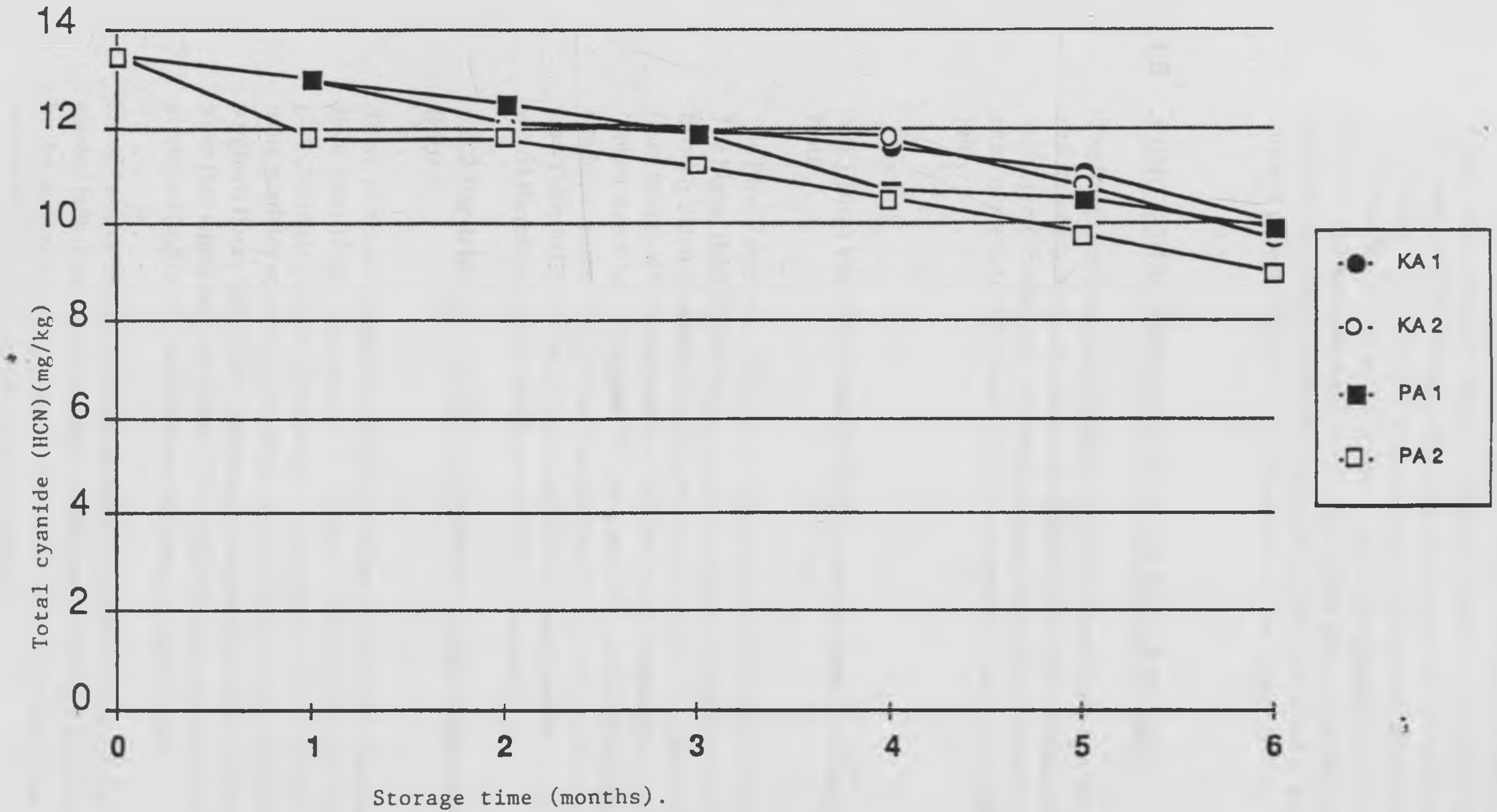

Fig 11: Changes in the total cyanide content of cassava flour during storage

cantly ($P<0.05$) during storage. This was expected since the moisture contents of the flours were below that which allows for growth of micro-organisms. There were however, slight variations between the storage temperatures. There was a slight increase in the total counts of the flours stored under ambient conditions. This increase was especially notable in the products stored in polythene bags. This could be due to the lower permeability of the polythene bags to moisture compared to the kraft paper bags. Polythene retains more moisture as a result, probably leading to isolated values of a_w high enough to support growth of mcro-organisms (*Briston and Katan, 1974*).

4.5 FUNCTIONAL PROPERTIES OF CASSAVA FLOUR.

The functional properties of cassava flour were evaluated by compositing with maize, wheat, sorghum and finger-millet flours in various traditional foods. It was therefore necessary to determine some of the physico-chemical characteristics of the individual flours and the composites in order to evaluate compatibility.

4.5.1 Blue Value Indices (BVIs) of some cereal flours and cassava flour.

The Blue Value Index (BVI) is an indication of broken starch within the flour. The higher the BVI, the higher the proportion of of broken starch in that flour. Broken starch consists of a high amount of amylose. A product made from flour having a high proportion of broken starch tends to be dry and firm, as broken starch has a tendency to retrograde more and form a rigid gel which exudes moisture. The BVIs of some of the flours used are shown in Table 16. The Table indicates that cassava and wheat flours have the highest BVI and would therefore exhibit the characteristcs enumerated.

4.5.2 Particle size distribution of some cereal flours and cassava flour.

Table 17 shows the particle size distribution of the cereal flours and cassava flour used in the composites. In general, all the flours had most of their particles retained by the 250mm and 125mm sieves. However maizemeal had more particles retained by the 600mm and 500mm sieves. Finger-millet and sorghum flours had higher percentages of particles retained by the 500mm sieve than wheat or cassava flour. These differences, however, did not prevent proper mixing of the flours durimg the compositing process.

Dried cassava chunks or slices were easily ground to form a flour which had a lower bulk density than other flours within a comparable particle size range. In the preparation of products therefore, less composite flour was used compared to the pure cereal flour (w/w basis).

Table 15: Blue value indices of some cereal flours and cassva flour [a]

Flour	Blue Value Index (measured as OD at 610nm)
Wheat	0.393 ± 0.15
Maizemeal	0.290 ± 0.02
Sorghum	0.268 ± 0.10
Finger-millet	0.281 ± 0.04
Cassava	0.360 ± 0.22

[a]mean ± SD (n=3)

Table 16: Particle size distribution of some cereal flours and cassava flour[a]

Sieve size(mm)	% (w/w) of flour retained Cassava	Wheat	Maize meal	Finger-millet	sorghum
1000	0.3	0	0	0	0
600	1.1	0	15.8	14.3	1.7
500	3.6	0	32.7	5.3	13.6
250	31.4	49.5	28.8	34.7	70.8
125	51.4	37.5	16.3	33.7	14
63	11.8	13	0.1	11.1	0
32	0.3	0.4	0	0.9	0
20	0	0	0	0	0

[a]Arithmetic means of at least two determinations

4.5.3 Water Absorption of the Cereal Flour/Cassava Flour Composites.

The results of the flour water absorption are shown in Figure 12. These results show some clear trends. There was a general increase in water absorption upto 10% of cassava flour in the composite. This was followed by a slight decrease but the values still remained higher than those of the corresponding pure cereal flours. The peak value indicates the maximum amount of cassava flour which should be in the composite in order to realise the greatest benefit of water absorption for that composite. For our purposes this maximum benefit is realised when there is 10% (w/w) cassava flour in the composite

4.5.4 Amylographic pasting behaviour of the cereal flour/cassava flour composites.

The amylographic pasting behaviour of each composite was measured as pasting temperature and peak viscosity. The pasting temperatures of pure and composite flours are presented in Table 17. Onset temperatures represent the start of gelatinization or starch swelling, while the peak temperatures represent the maximum swelling attained or breakdown of starch granules and beginning of set-back. The level of cassava flour in the composite did not result in any significant difference at $P<0.05$ between the onset or peak temperatures. An average value was therefore determined over the 10-50% range for each cereal flour.

The peak viscosities during pasting are shown in Figure 13, while Appendix I has not been mentioned yet. Appendices II-VI show typical amylographic curves for the various flour composites. Figure 13 shows that the peak viscosity decreased with increase in proportion of cassava flour upto 10%, but increased for levels of cassava flour above this . This was especially so for wheat/ cassava flour composites.

Several factors can explain this behaviour. Firstly there is competition for the available water between the cereal flour components and the cassava flour components.This leads to reduced hydration of the components resulting in a decrease in the starch swelling capacity which results ina reduction in the viscosity. Secondly, as the proportion of cassava flour is increased, the cassava flour components absorb more water faster than the cereal flour components. This leads to more swelling causing the slight increases in viscosity for the levels of compositing between 10-50%. However, because of competition, neither the cassava flour nor the cereal flour components attain their maximum swelling capacity. It should also be noted that the higher the peak viscosity, the greater is the swelling power. Flour with a high swelling power strongly absorbs the available water leading to a firm and dry product. Such flours also have low amylolytic activity.

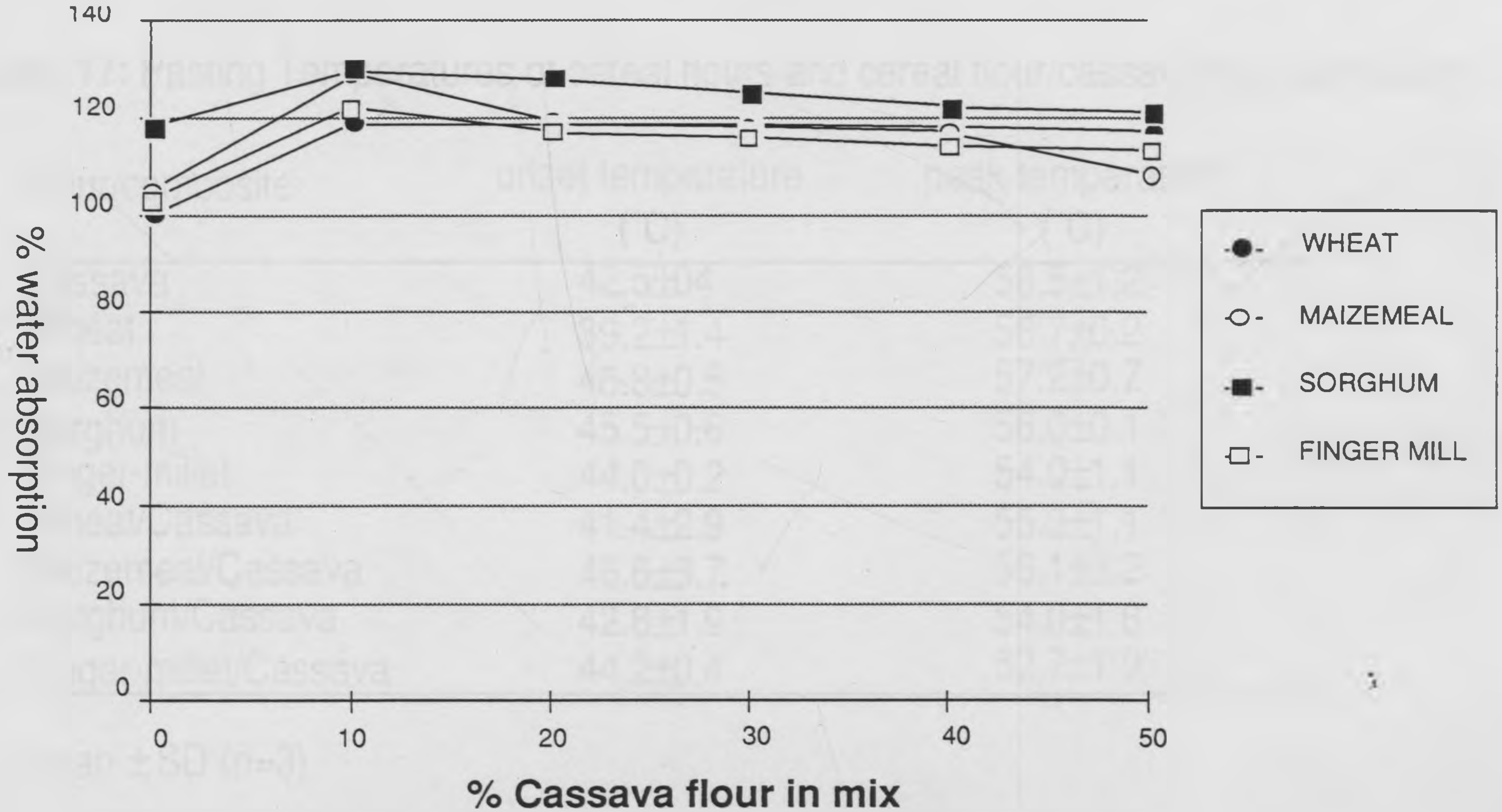

Fig 12: Flour Water Absorption of cereal flour/cassava flour composites

Table 17: Pasting Temperatures of cereal flours and cereal flour/cassava flour composites[a]

Flour/composite	onset temparature (˚C)	peak temparature (˚C)
Cassava	42.5±04	56.5±1.2
Wheat	39.2±1.4	56.7±0.2
Maizemeal	46.8±0.5	57.2±0.7
Sorghum	45.5±0.6	56.0±0.1
Finger-millet	44.0±0.2	54.0±1.1
Wheat/Cassava	41.4±2.9	55.3±1.1
Maizemeal/Cassava	46.6±3.7	56.1±3.2
Sorghum/Cassava	42.8±1.9	54.0±1.6
Finger-millet/Cassava	44.2±0.4	53.7±1.9

[a] mean ± SD (n=3)

Pure cassava flour had the highest peak viscosity. This was followed by flours from sorghum, finger-millet, maizemeal and wheat, in that decreasing order. The addition of cassava flour resulted in a composite which had a higher swelling power than any of the pure cereal flours. Composite flours were therefore able to hold more water than pure cereal flours. This agrees with the results of the flour water absorption shown in Figure 13. In general therefore, the higher the level of cassava flour in the composite, the less the amount of composite flour required to make the same product for a given volume of water.

It was also observed that the rate of reduction in viscosity after the peak value varied (Appendices II-IV). In these figures, the steeper the downward slope, the higher the retrogradation and set-back expected. Also the steeper the slope, the firmer the product should be on setting. However, it was noted that the products from the composites were springy and resilient and not as firm and dry as the products from the pure cereal flours. This observation was attributed to the fact that the starch granules of the cassava swell more than those of the cereal flour but do not achieve their maximum capacity due to competition for water. They therefore resist breakage during stirring resulting in softer products with reduced retrogradation.

4.5.5 Viscosity of "uji".

The viscosities of the "ujis" prepared from the recipe in section 3.2.5.3. are shown in Table 18. There was little variation between the viscosities of the "ujis". As has already been noted, less flour was used to prepare the "uji" for a given volume of water, as the proportion of cassava flour in the composite increased. This indicates that during " uji" preparation, the composite flour components do not swell to their maximum capacity. The "uji" becomes more jelly-like in appearance as the proportion of cassava flour in the composite increases. This can be attributed to the fact that because the flour components are not swelling fully, they retain a firm, resilient and springy texture. Therefore when the cereal/cassava flour composites are used to prepare "uji", less flour is needed to achieve the same viscosity for a fixed volume of water than when pure cereal flour is used. The required amount of flour further decreases with increase in the proportion of cassava flour in the composite.

4.5.6 Tenderness of "ugali".

The resistance to penetration (in kg/cm2,) into a uniform mass of "ugali" of equal volume, by a penetrating probe is presented in Figure 14. The Figure shows that the resistance decreased with increasing proportion of cassava flour in the composite.

The starches compete for the available water. Maximum swelling is therefore

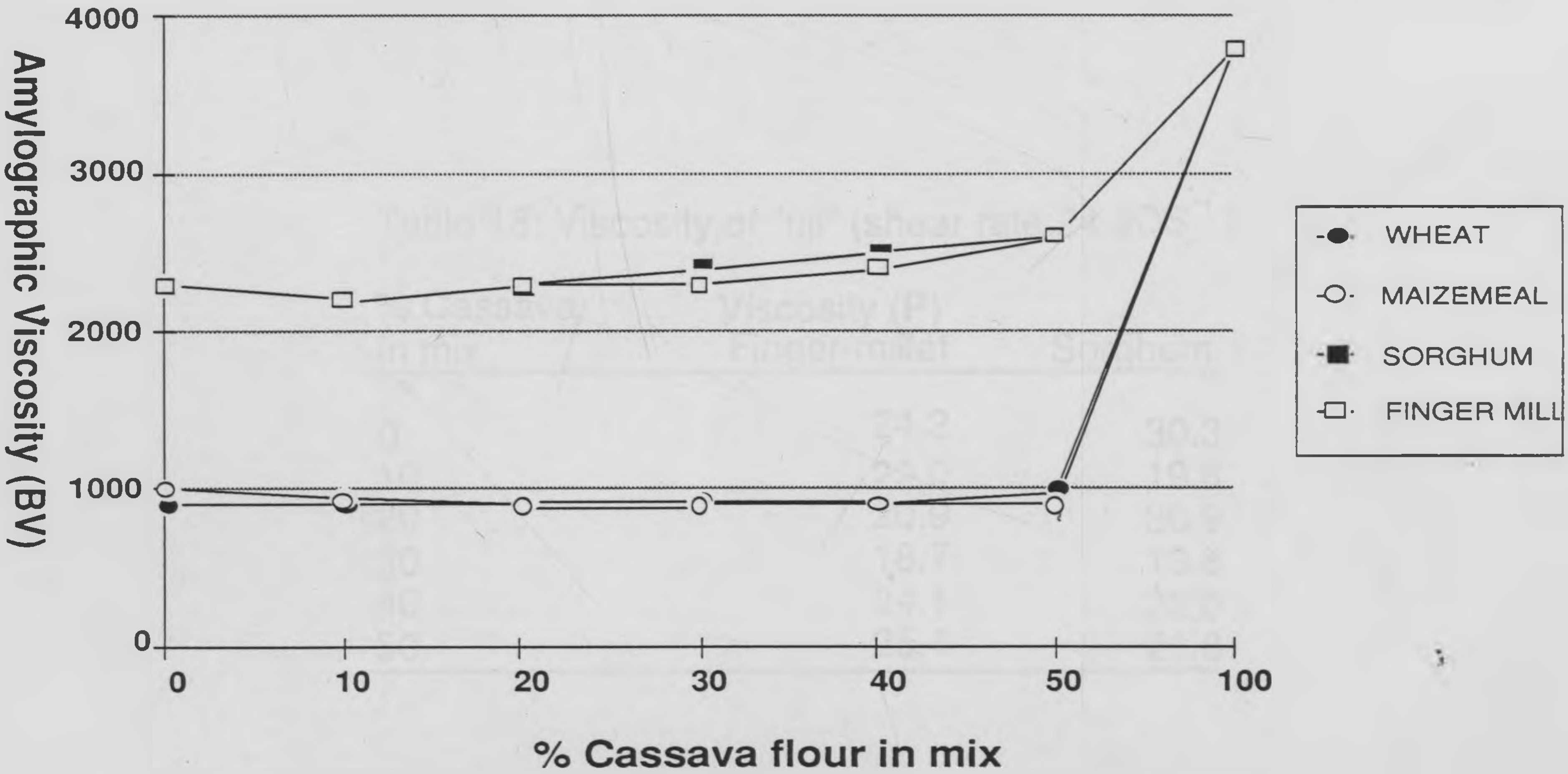

Fig 13: Changes in peak amylographic viscosity with increase in the percent of cassava flour in composites

Table 18: Viscosity of "uji" (shear rate 24.9DS^{-1})

% Cassava in mix	Viscosity (P) Finger-millet	Sorghum
0	24.2	30.3
10	22.0	19.8
20	20.9	20.9
30	18.7	19.8
40	24.1	22.0
50	25.4	21.8

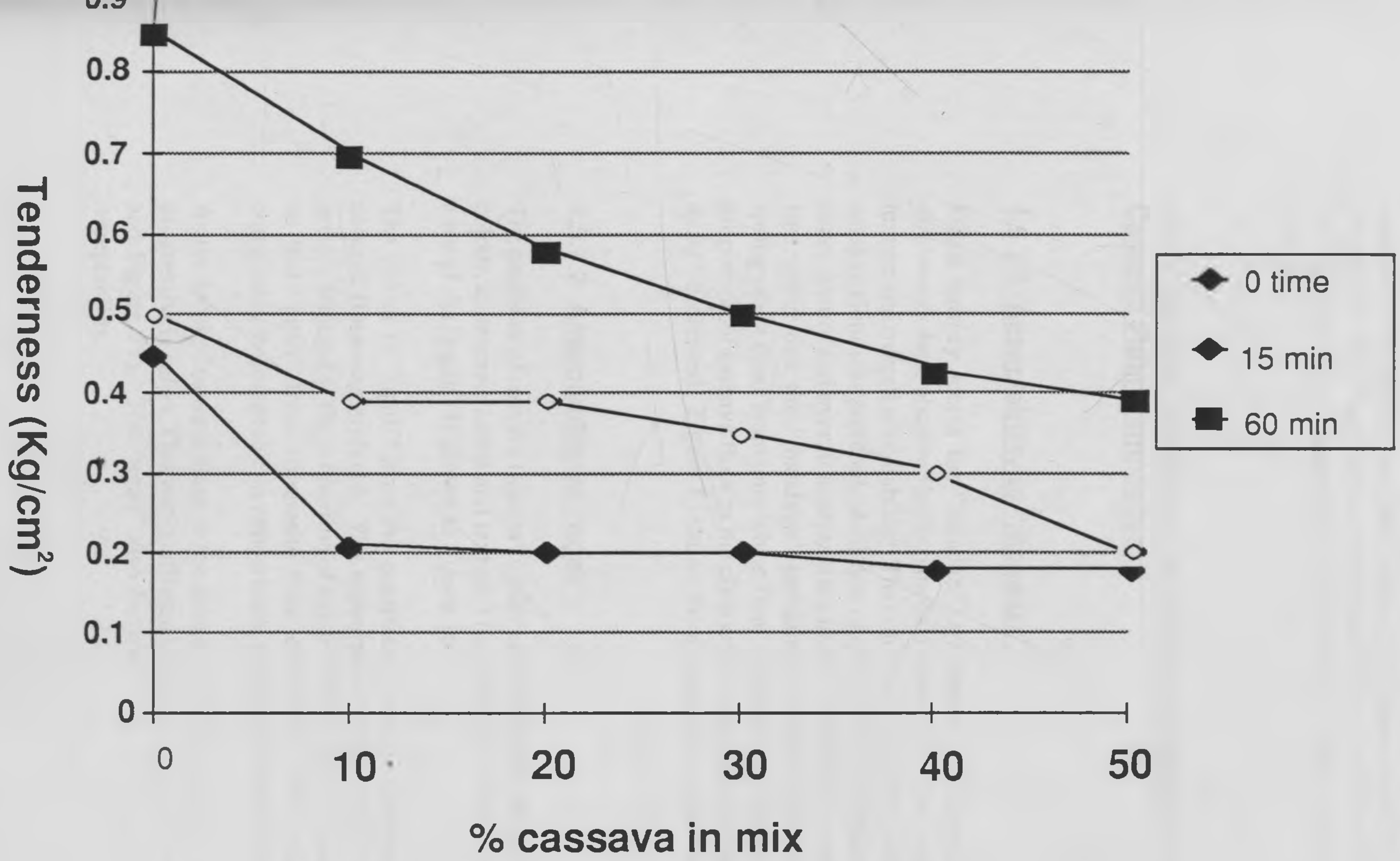

Fig 14: Changes in the tenderness of "ugali" with increase in the percent cassava flour and time

not attained. As a result, the starch granules especially those of cassava, become resilient and springy thereby reducing tendency to breakdown during "ugali" preparation. Consequently, "ugali" containing cassava flour becomes increasingly softer and resists set-back more than "ugali" prepared from pure maizemeal. Because fewer starch granules are broken down, there is less retrogradation and the product remains softer. These results are in contrast to results obtained from the amylographic pasting behaviour, which indicate that cassava starch forms very stiff gels as the downward slope of the curve (Appendix VI) is very steep (see section 4.5.4). Results also show that on cooling, the "ugali" containing cassava flour is still more tender than that without.

4.5.7 Sensory Properties of the Foods Prepared from Cereal/ Cassava Flour Composites.

4.5.7.1 Acceptability of "mandazi".

Mean sensory scores for "mandazi" are shown in Table 19. Significant differences were observed in the panelists scores for colour, appearance, taste, texture and overall acceptability. The colour of "mandazi" with less than 20% cassava flour was prefered. Addition of cassava flour seemed to improve the taste, texture and overall acceptability of the "mandazis" over the control. It was stated that the "mandazis" containing cassava flour were much less springy than those from pure wheat flour. However, it was noticed that as the proportion of cassava flour in the composite increased, the volume of *"mandazis"* decreased. Figure 15 shows the appearance of the *"mandazis"*.

4.5.7.2 Acceptability of "ugali".

The presence of cassava flour in "ugali" had significant ($P<0.05$) effects on its colour, appearance, taste and texture.This is shown in Table 20. The appearance of the "ugali" is shown in Figure 16.

The colour of "ugali" from the composite flour containing less than 30% cassava flour was prefered. The appearance of the "ugalis" was, however, greatly affected as the proportion of cassava flour was increased beyond 20%, so that "ugali" from composite flour containing 50% cassava flour was completely unacceptable in appearance, and also on taste and texture.

As the level of cassava flour in the composite increased, the "ugali" became progressively softer. This was confirmed by penetration tests (see section 4.5.6 and Figure 17). The "ugali" also became more sticky, which reduced its acceptability.

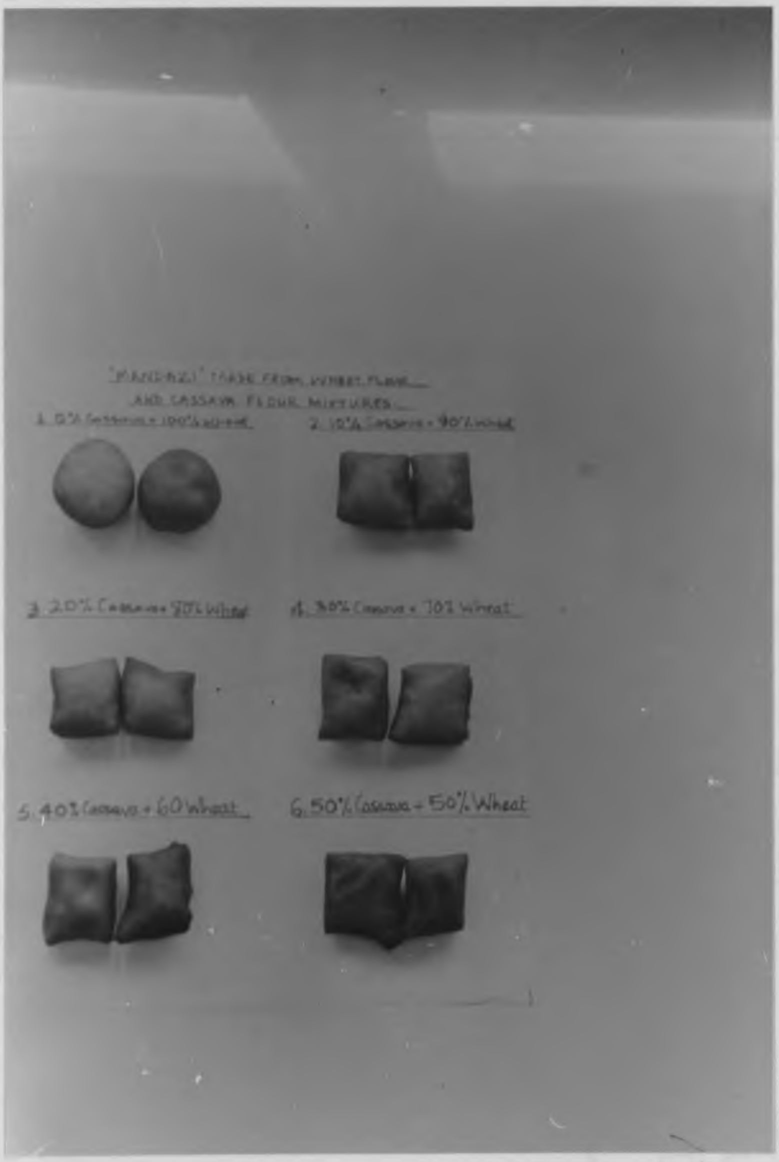

Figure 15: "Mandazi" made from wheat flour with different levels of cassava flour

Table 19: Mean sensory scores for "mandazis" from wheat flour/cassava flour composites.

% Cassava flour in mix	Colour	Appearance	Taste	Texture	Overall Acceptability
0	5.6a	5.5a	4.5b	4.0b	3.9b
10	5.1b	4.9b	5.5a	4.7a,b	5.0a
20	5.6a	5.4a	5.0a,b	5.0a	5.4a
30	4.8c	4.8b	5.4a,b	5.2a	5.2a
40	5.0b	4.9b	5.5a	5.1a	5.0a
50	5.2b	5.0b	4.5b	5.1a	5.1a

Means of 4.0 and above indicate accetability. Each score is a mean of 14 judgements.
Means within columns followed by the same letter are not significantly different at $P \leq 0.05$ by Duncan's Multiple Range Test.

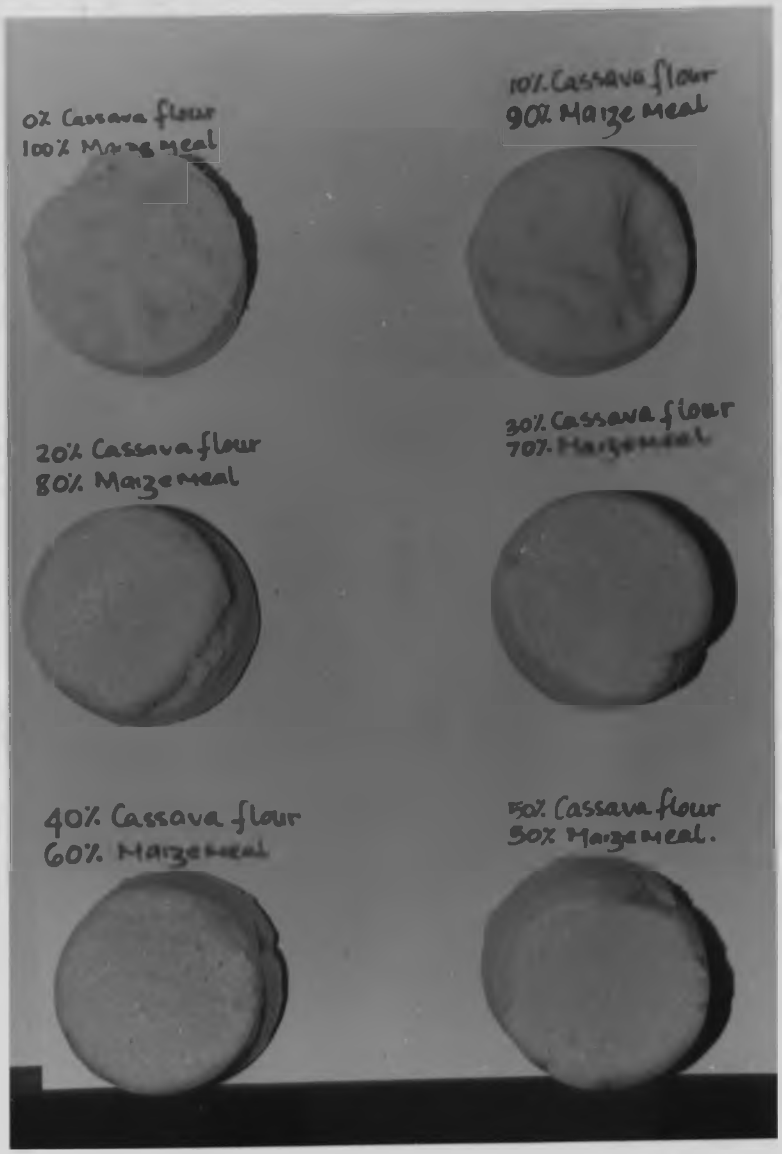

Figure 16: "Ugali" made from maizemeal flour with different levels of cassava flour

Table 20: Mean sensory scores for "ugali" from composites of cassava flour and maizemeal.

% Cassava flour In mix	Colour	Appearance	Taste	Texture	Overall Acceptability
0	6.4a	6.3a	6.4a	6.2a	6.4a
10	6.3a	6.1a	4.6b,c	7b,c	4.8b
20	5.8a,b	6.1a	5.7a,b	5.9 a,b	5.8a
30	5.1b,c	4.8b	2.9c,d	2.2c	2.9b
40	4.4c	4.1b	3.7d	4.1d	3.9c
50	4.2c	3.7c	2.6d	2.6d	2.7c

Means of 4.0 and above are acceptable. Each score is a mean of 14 judgements.
Means within columns followed by the same letter are not significantly different at $P<0.05$ by Duncan's Multiple Range Test.

4.5.7.3 Acceptability of uji.

The mean sensory scores for uji are presented in Tables 18 and 19. Table 18 shows that there were no significant differences between the quality attributes of the *ujis* based on finger-millet flour at $P<0.05$. Therefore, any amount of cassava flour, upto 50%, in the composite can be tolerated. The sorghum based uji on the other hand, showed significant differences in all attributes at $P<0.05$, but more variation was shown in the taste and texture. Figures 17 show the actual colour and appearance of the *ujis*. In both cases, the ujis were described as becoming more "jelly-like" as the proportion of cassava flour increased.

Figure 17: "Uji" made from sorghum or finger millet flour with different levels of cassava flour.

Table 21: Mean sensory scores for "uji" from composites of finger-millet and cassava flours.

% Cassava flour in mix	Colour	Taste	Texture	Overall Acceptability
0	5	4.8	5.4	5
10	5.2	4.8	5.4	5
20	5	5	4.8	5
30	5.6	5	5.8	5.4
40	5.2	5.8	5.4	5.4
50	5	4.6	5	4.6

The means were not significantly different at P<0.05 by Duncan's Multiple Range Test.

Table 22: Mean sensory scores for "uji" from composites of sorghum and cassava flours.

% Cassava flour in mix	Colour	Taste	Texture	Overall Acceptability
0	5.8a	6.0a	5.8a	6.2a,b
10	5.4a	6.0a	5.4a	5.4b
20	5.8a	6.2a	6.2a	6.4a
30	4.6b	6.0a	5.6a	5.6a,b
40	6.0a	5.2a,b	5.8a	5.4b
50	5.8a	4.2b	5.0b	4.6c

Means of 4.0 and above indicate acceptability. Each score is a mean of 14 observations. Means within columns followed by the same letter are not significantly different at $P \leq 0.05$ by Duncan's Multiple Range Test.

5. CONCLUSIONS AND RECOMMENDATIONS.

It was found that the cyanide contents of cassava is effectively reduced through traditional sundrying due to the low temparatures and long drying periods involved, and that the extent of reduction was not dependent on the variety. It is, however, recommended that in order to improve efficiency and hygiene, drying should be carried out in improved solar driers instead of drying in open sun-shine.

The study also showed that products containing cassava flour are acceptable to Kenyans. The proportion of cassava flour acceptable in each product however, depended on the product and the type of cereal flour used. For "mandazi" upto 50% of cassava in the composite was acceptable. Both fingermillet and sorghum "ujis" containing upto 50% cassava flour were acceptable. For "ugali", only upto 20% of cassava flour in the composite could be tolerated. Higher levels caused excessive softness and stickiness which were objectionable. It was also found that cassava flour could be stored for upto six months in both plastic and kraft paper bags with no appreciable loss in quality. It is, however, recommended that cassava be packaged in paper rather than plastic and stored under cool and dry conditions.

Future research should aim at ways and means of preparing ready to use composite flours of cereal flours and cassava flours of the recommended levels of cassava flour for "uji", "ugali" and "mandazi", then evaluating the shelf stability of the composites in paper bags under ambient conditions. More work should also be carried out to establish the level of cassava flour acceptable in composites with other cereals and the shelf stability of these composites.

Some work finally needs to be done on the effect on cyanide levels of the traditional fermentation/drying methods on the cassavas with very high cyanide levels.

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Name... Date...........................

You are given six different products and are asked to evaluate your degree of likeness of each product on the basis of the scale described below:

7 - Like very much
6 - Like moderately
5 - Like slightly
4 - Neither like nor dislike
3 - Dislike slightly
2 - Dislike moderately
1 - Dislike very much

A. First without tasting, place the number matching your degree of liking for colour and appearance in the corresponding box for each product.

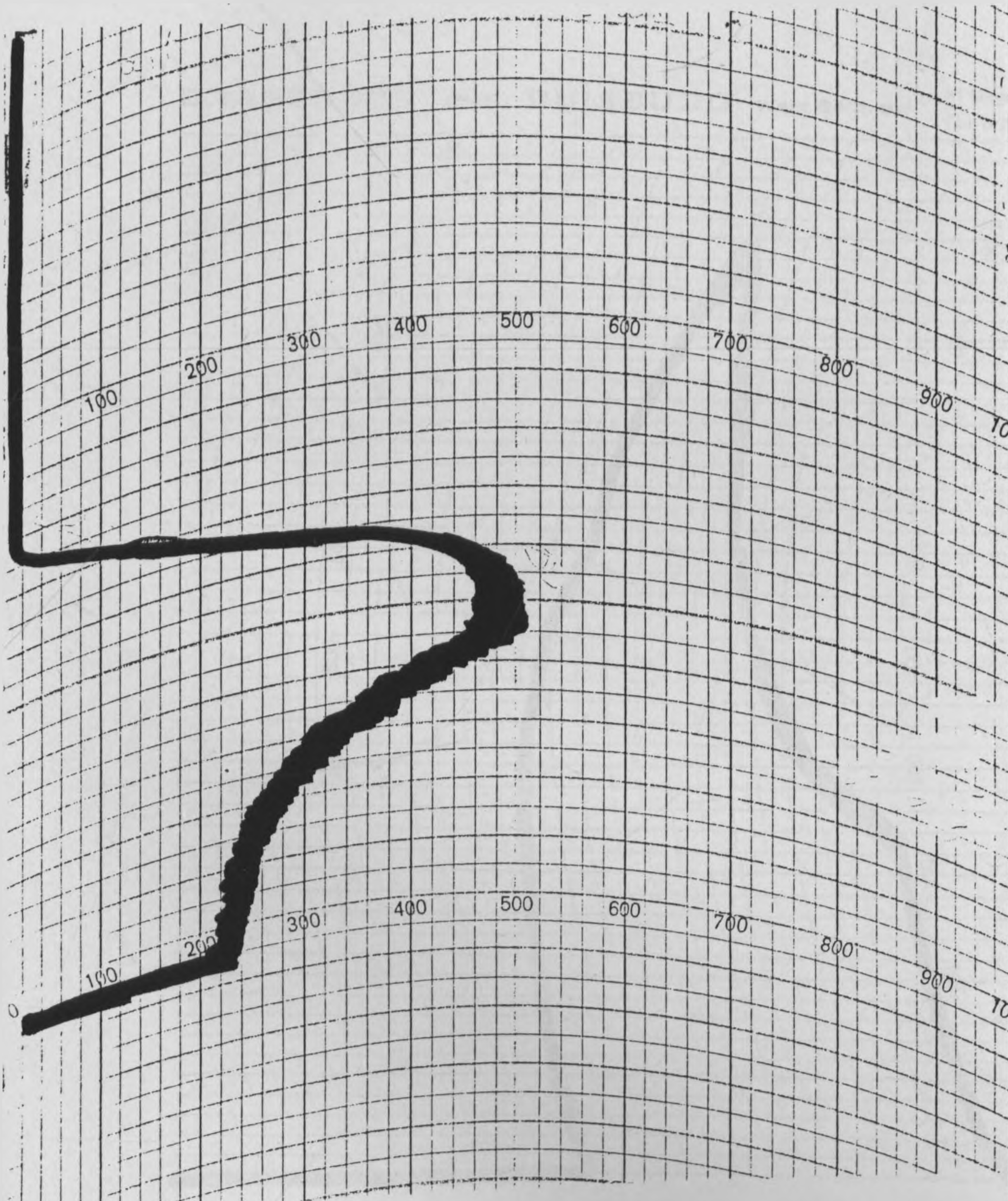
Sample code								
Colour								
Appearnce								

B. Now taste each sample one at a time and in any order, then indicate your degree of liking of the taste and texture (mouth-feel), and overall acceptance of each product.,

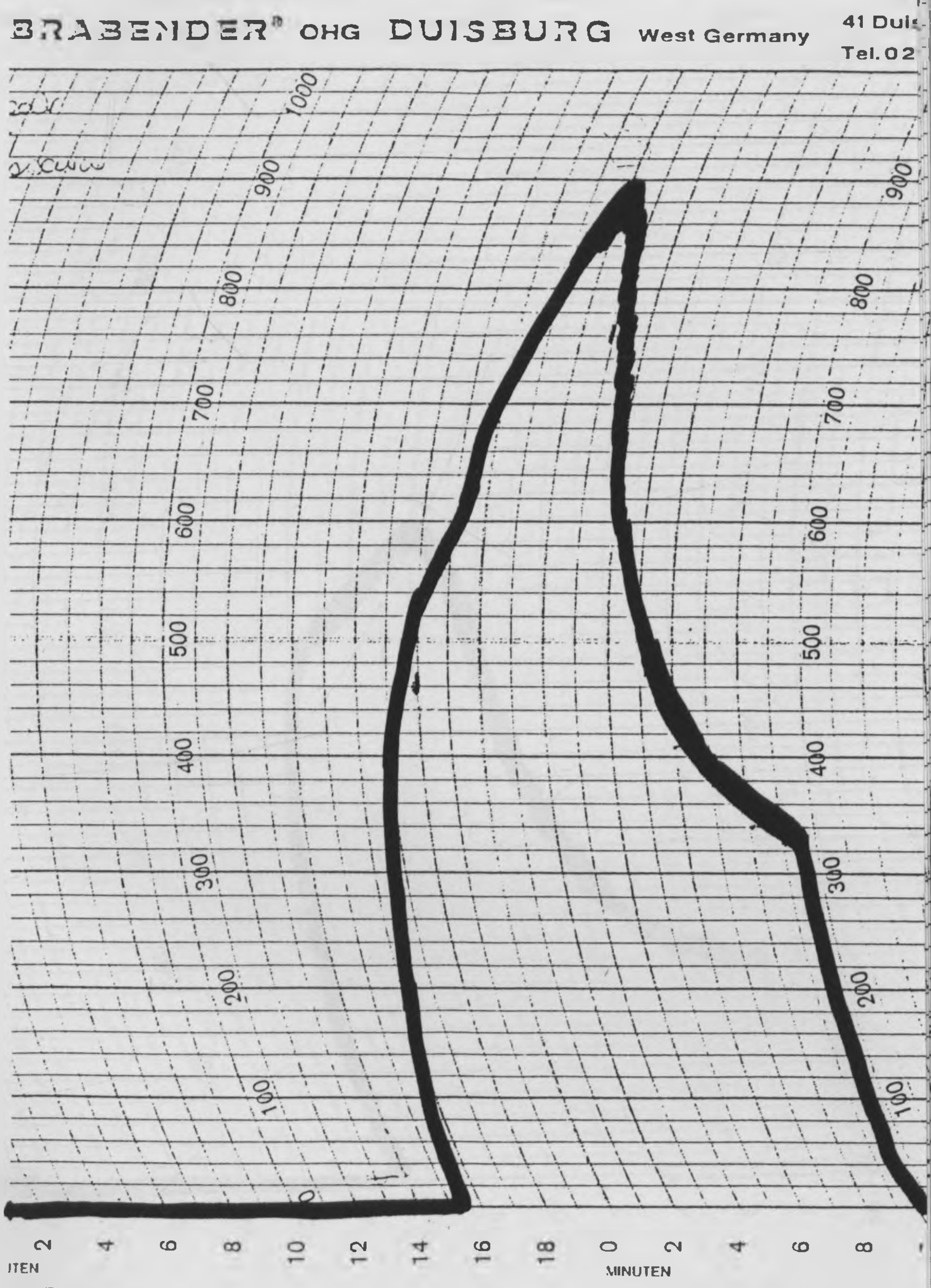
Sample code								
Taste								
Texture								
Overall Acceptance								

An other comments

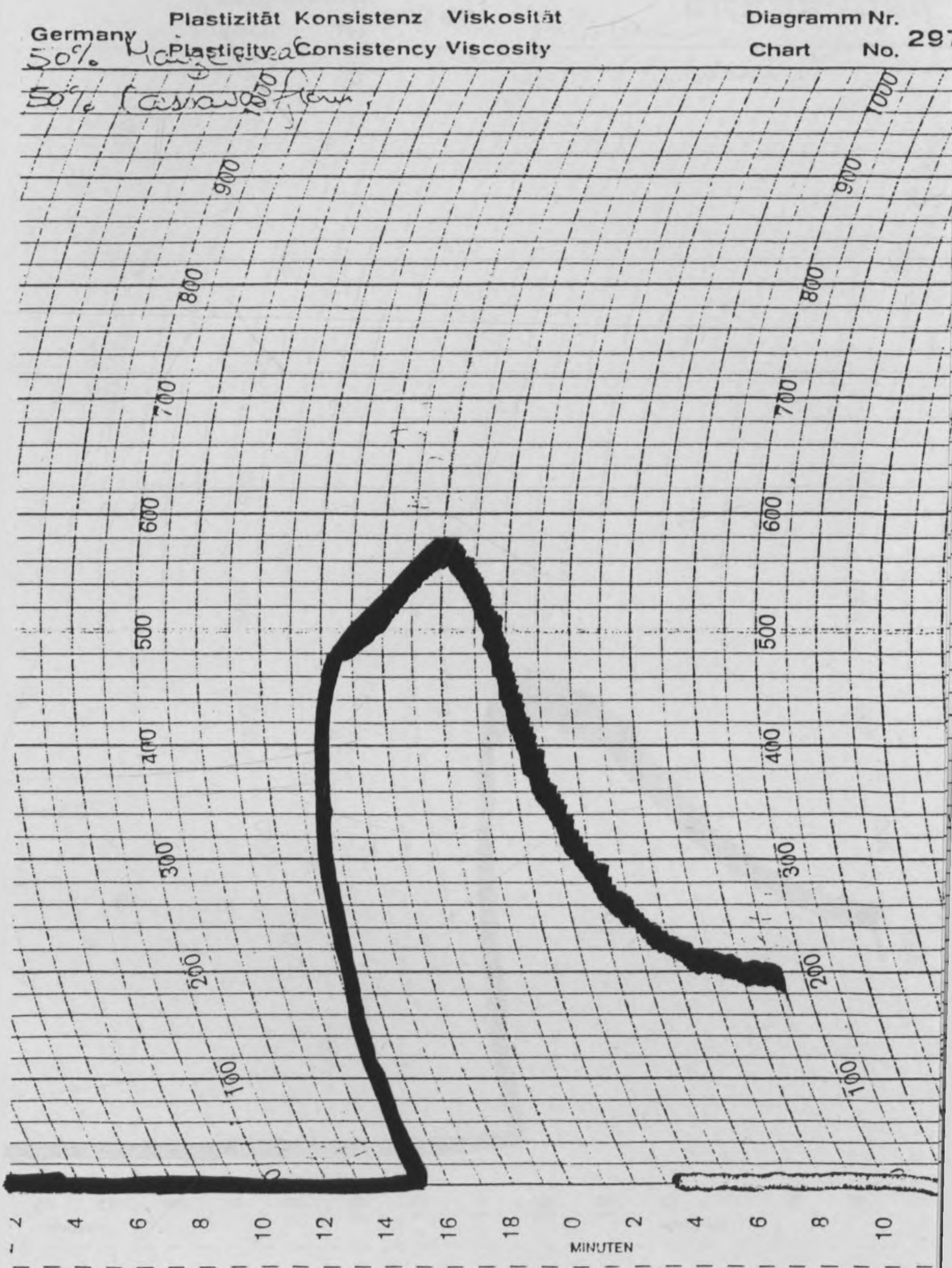
Appendix 1: Score sheet used in sensory evaluation



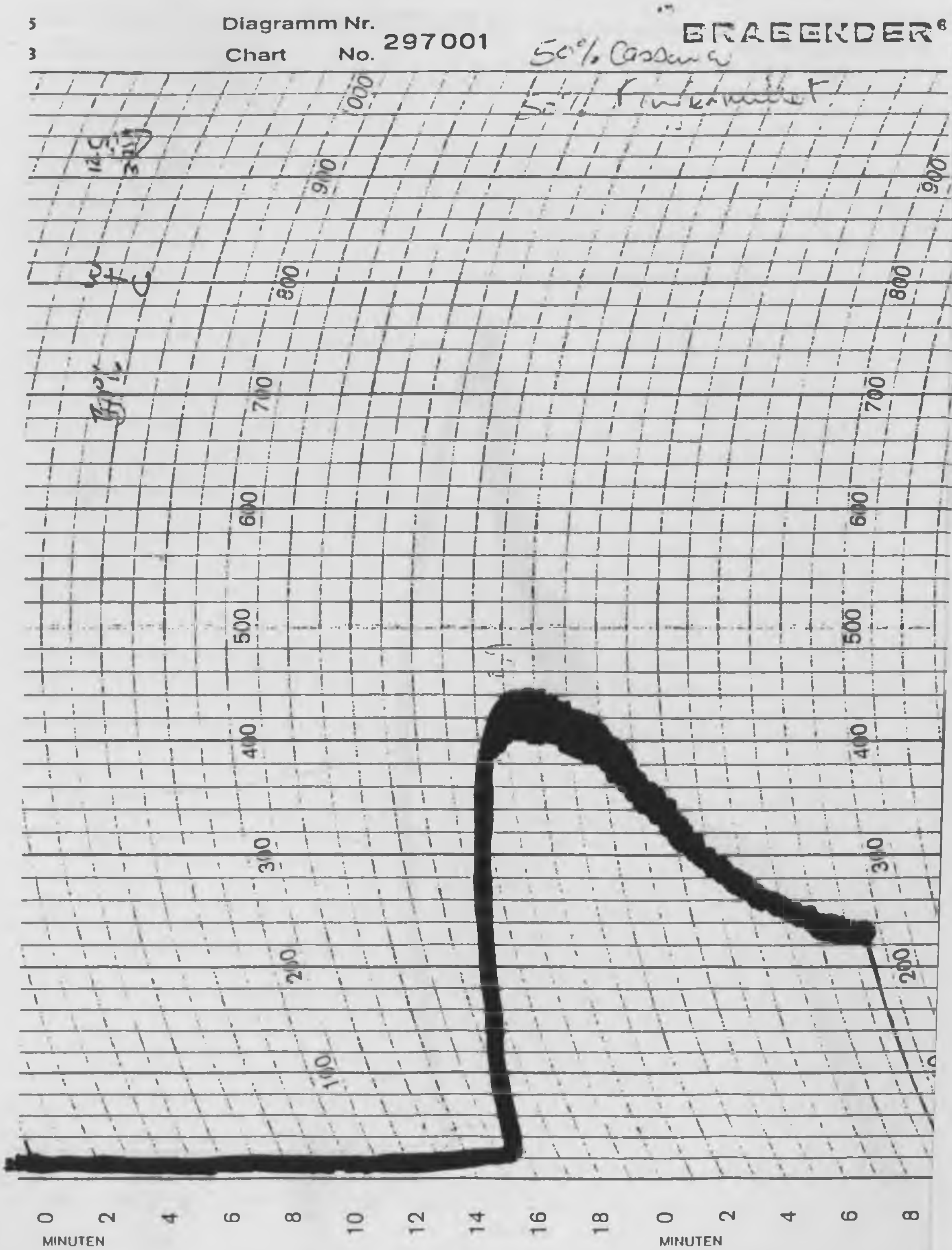
Appendix IV: Typical amylographic curve for fingermillet flour and cassava flour composites.



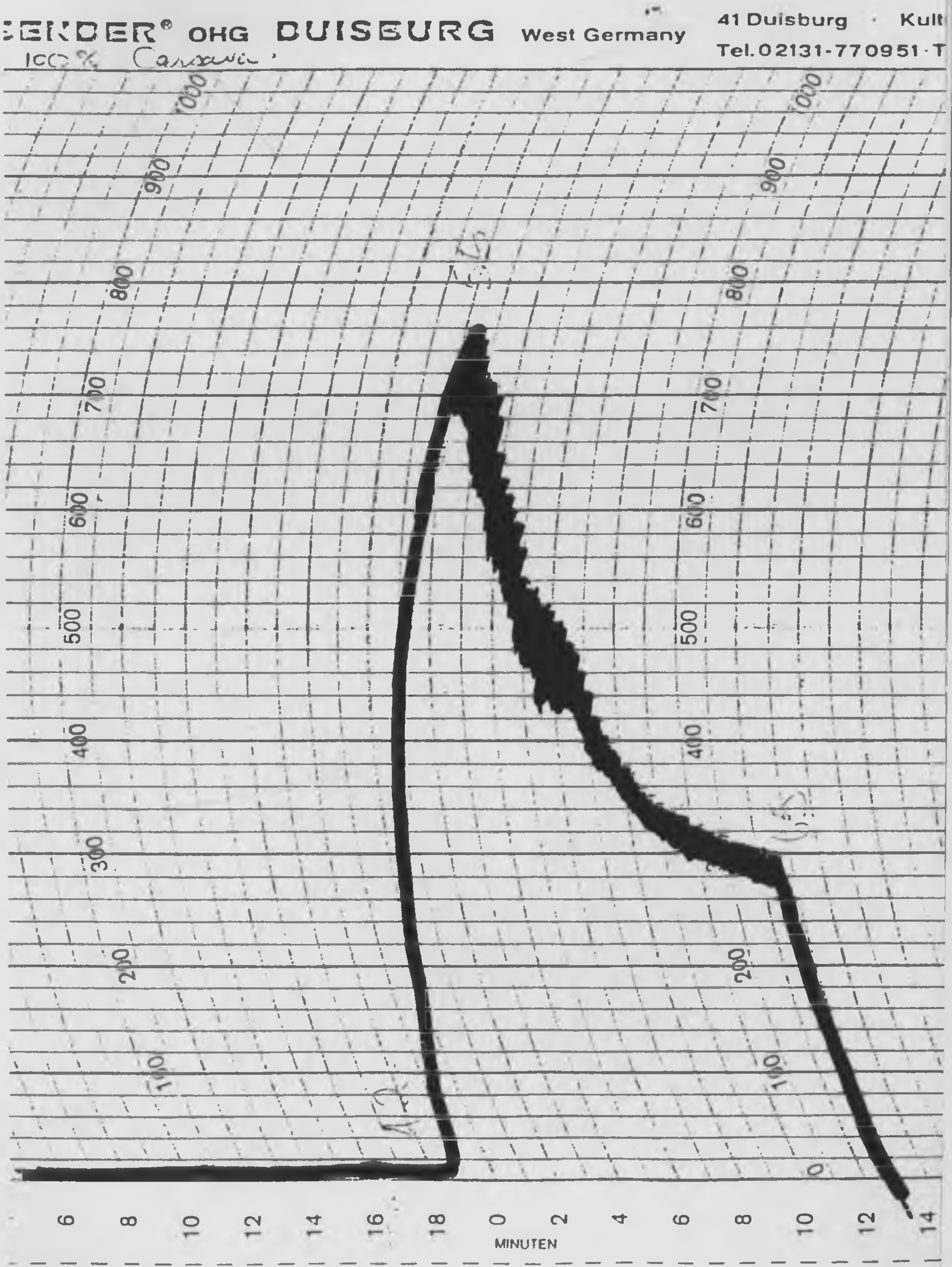
Appendix II: Typical amylographic curve for wheat flour and cassava flour composites.



Appendix III: Typical amylographic curve for maizemeal and cassava flour composites.



Appendix V: Typical amylographic curve for sorghum flour and cassava flour composites.



Appendix VI: Typical amylographic curve for cassava flour.