The Food Uses Potentials of Mango *(Magnifera indica)* Seed Kernel.

By

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DECLARATION

I, Isaac Isah Achoba, hereby declare that this thesis is a record of my own research work and has not been submitted for the award of degree of any other University. Information and excerpts from published and unpublished works of others have been gratefully acknowledged in the text.



Isaac Isah Achoba

CERTIFICATION

This thesis, titled "The Food Uses Potentials of Mango (*Magnifera indica*) Seed Kernel" by Isaac Isah Achoba meets the regulations governing the award of the degree of Doctor of philosophy of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to the memory of all those who have died as a result of "ignorance of the abundance of food in our environment".

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ABSTRACT

Fresh ripe mango fruits were depulped, the seeds sundried and the seed kernels (MSK) processed into flour. The nutrient composition of the MSK was investigated. The tannin content, a major limitation to the utilization of the MSK nutrients, was eliminated by water treatment. Tannin-free MSK flour was substituted at between 0 and 33% levels into wheat for cookie making. The cookies were assayed for proximate nutrients and amino acid contents, fatty acid profile and selected mineral ions. Sensory evaluations were carried out by a trained taste panel of 12-membeis and a consumer panel of 56 untrained members. The effects of environmental relative humidity and temperature fluctuations on the storability of the cookies were Investigated.

MSK constitutes about 10% of total fruit weight and contained 6.0% crude protein, 12.8% crude fat, 2.)% crude fibre, 2.0% ash and 0.44% tannins on moisture-free basis. Fat contents were significantly ($P<0.05$) affected by both the variety and source of the MSK. The fat was yellow with iodine value (Wijs) of 40.3, saponification number of 190, melted at 40.3 ± 1.1°C. Stearic (46%) and oleic (40%) acids were the principal fatty acids, other fatty acids detected were palmitic (6.0%), linoleic (4.4%), arachidic (2.4%), behenic (0.6%) and linolenic (0.4%). Even though the protein level is low, most of the essential amino acids $(eaa)_r$ which together gave an eaa index of 72, occurred at higher levels in the MSK than those of the FAO Reference protein, indicating the good quality of the protein in the SK.

Potassium (360 mg/lOOg), phosphorus (130mg/100g) and magnesium (lOOmg/lOOg) were the major mineral ions detected in the MSK. The tannin contents of the MSK floir dropped significantly ($P<0.05$) from 0.44% to 0.03% on treatment with water at 70°C for 30 minutes, indicating 93% reduction of tannins.

There was no significant difference ($P>0.05$) between the 20% and 30% MSK cookies in terms of their proximate composition which ranged from 5.0-5.1% crude protein, 18.1-19.8% crude fat, 0.2-0.4% crude fibre, 0.8-0.9% ash and 5.3-5.4 kcal/g crude energy. Unlike the MSK fat, myr.stic and oleic acids were the predominant fatty acids (73% in the cookie oil with stearic (10.3%), linoleic (8.6%), palmitic (4.0%), lauric (2.1%), arachidic (1.6%) and linolenic (0.4%) constituting less than 30%. All the essential amino acids occurred generally in the MSK cookies at levels that were significantly ($P<0.05$) lower than those of the MSK flour or FAO Reference protein. The 20% MSK cookies with monolayer moisture content M_x of 18.4g H_2O/100g dry sample had higher storability prospects than the 30% MSK cookies wiose M_1 value was 13.3g H_2O/100g dry sample. The consumer rating of the 0,10,20 and 30% MSK cookies gave mean hedonic scores of 5.5, 5.4, 5.6 and 5.5 respectively. This shows that there is no significant difference ($P>0.05$) between these MSK cookies and the whole wheat (0% MSK) cookie.

The MSK flour therefore has nutritional and industrial potentials for cookie making.

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CHAPTER ONE

1.0 INTRODUCTION AND REVIEW OF LITERATURE

1.1 INTRODUCTION

Nutrition is the study of the food we eat and the use of this food in our bodies. It is a process by which organisms utilize food to maintain normal physiological functions. The benefits of nutrition translate primarily into the promotion of optimal health of individuals, hence the dependence of human life on food is obvious. Although good nutrition is the ultimate goal attainable only through optimal food intake, starvation is at one extreme of the spectrum of food intake, obesity is at the other.

Malnutrition appears in many forms in different parts of the world, but no country is without its problems. The obvious malnutrition of very young children (0.5 - 5 years of age) starving to death in overpopulated developing countries is perhaps the most compelling problem requiring solution (Stare and Williams, 1984). The vulnerability of Nigerian children to malnutrition was recognised by the Nutrition Society of Nigeria (NSN) who at a symposium in 1989 strived to address the issue of "school lunch" for school children (NSN, 1989). This recognition also led to the setting up of a programme of cooperation between the Federal Government of Nigeria (FGN) and the United Nations Children's Fund (UNICEF) for the attainment of, among other things, household food security and nutrition for Nigerian households (FGN/UNICEF, 1991). The household food security and nutrition program though pragmatic in its approach to the food and nutrition problems, is endangered by economic hardships. Economic

depression and the effects of the Structural Adjustment Programme (SAP) has further exacerbated the problems of protein energy malnutrition (PEM) in Nigeria. Research efforts are currently geared towards identifying the less known but possibly abundant potential sources of nutrients.

The Mango tree grows everywhere in Nigeria. The mango seed kernel (MSK) which is approximately 14% (by weight) of the fruit is under-utilized since much of the fruit produced is consumed fresh and in season due to a lack of processing industries or storage facilities. The waste associated with this current practice is enormous though there is no sufficient published information on the quantity of mango produced annually in Nigeria. However, similar oilseeds (for instance African mango, cashewnut) are known to be good/fair sources of high quality proteins (Umoh and Oke 1974; Spindler and Akosionu, 1985).

Although in the Indian culture the MSK is used to some extent as food for human consumption in the forms of boiled kernels, kernel pickled in oil, baked mango kernel and kernel flour (Mittal and Singh, 1979 and 1982), the full nutritive potential of the MSK is not fully understood and consequently such potentials remain untapped. Other workers in Asia (Ali *et al.* 1985; Lakshminarayana *et al.* 1983) have reported the effect of variety on the nutrient composition of MSK. Currently in Nigeria, the MSK is usually discarded as waste (Mittal and Singh, 1979) and no information exists on the nutrient composition of Nigerian MSK. This study was therefore designed to:

a) ascertain the nutrient composition of some available mango seed kernel (MSK) varieties in Nigeria;

b) determine the naturally occurring toxic components of the MSK that may limit its use as human and/or animal food;

c) device techniques for removing such toxic components; and

d) formulate and test edible snack foods from the Nigerian MSK.

1.2 REVIEW OF LITERATURE

1.2.1 THE PROBLEM.

Food, population, economy and political stability are, not only intricately related to each other in any society but also are determinants of development. These determinants of development are harmoniously blended in developed countries. In developing countries, the seemingly uncontrollable population explosion, delicate political stability, economic depression coupled with food shortage and crises due to natural disasters lead to several societal ills associated with underdevelopment especially poor health and nutrition status. Of all these indicators of development, food plays an important role because population explosion, economic depression and political instability usually translate to food insecurity.

The implications of the structural adjustment programme and incessant political instability on household food security in Indochina and Africa as well as the effects of the present harsh economic situation on the Nigerian food problem have been discussed (Kachondham and Dhanamitta, 1992; Sahn, 1992 and Idachaba, 1991). Hence, the most compelling problem of developing nations is food and nutrition.

1.2.2. Food and Nutrition Problem

The problem of food and nutrition was been highlighted at the Fifth World Food Survey (FAO, 1985) and is seriously addressed in several developing nations by both Federal and Local Governments as well as international agencies such as UNICEF (UNICEF, 1985)

and the Food and Agricultural Organization (FAO) of the United Nations (FAO, 1985).

Whereas the FAO (1985) and UNICEF (1992) recognised that the interrelationships of malnutrition with other indices of development are complex, they however agreed that malnutrition does not have equal impact on all population groups and in general, the poorest people suffer most because of their lack of resources. Within the vulnerable groups, young children, pregnant and lactating women are the most vulnerable because of their extra nutrient requirements. Again UNICEF (UNICEF, 1985 and 1992) in its publications on "The State of the World's Children" showed data from 129 countries representing about 4,600 million individuals that were assessed for human development based on a wide range of inputs: the nutritional status and the health knowledge of mothers; the level of immunization and oral rehydration therapy (ORT) use; the availability of maternal and child health services; income and food availability in the family; the availability of clean water and safe sanitation and the overall safety of the child's environment. These data represent basic statistical information on the area of nutrition, health, education, economics and population growth. It is of interest to note that almost all correlation coefficients obtained in this study were significant ($P<0.001$) as determinants of nutritional status (Pellet, 1987). Major findings from these data (UNICEF, 1985 and 1992) showed that the third world or developing countries have the lowest gross national product (GNP) per capita, life expectancy, birthweight and, the highest under five's as well as maternal mortality rates

and, moderate to severe underweight, wasting and stunting amongst children. These coupled with heavy debt burden, inflation and absolute poverty make the situation of the developing countries even worse. The food and nutrition programmes of these world bodies take root from the understanding of "the multi-dimensional nature of malnutrition".

Food problems, being poorly understood as they may be, in concrete terms translate into undernutrition (Idachaba, 1991) for the ordinary citizens of developing nations. The problem of malnutrition in Nigeria is probably a good example of the consequence of lack of concrete food policy and economic instability which translate into national food insecurity.

The definition of the national food insecurity problem within the context of national self-reliance and self sufficiency (Idachaba, 1992) differs fundamentally from the World Bank formulation which sees no national food insecurity problem so long as domestic food supply shortfalls and shortages can be filled with food imports or food aid (World Bank, 1986). A host of strategies, action plans and programmes are put together to solve the food insecurity problem in Nigeria. One obvious fact is that a lasting solution to the national food insecurity problem can only emerge from a multi-dimensional and multi-disciplinary approach that is pragmatic and geared towards national self-reliance and self-sufficiency. Some of the suggested strategies include:-

a) a specification of the full consequences of national self-reliance and local sourcing of raw materials on the domestic

food economy both in terms of the competition for food output between human consumption and industrial utilization (Aribisala, 1989; Idachaba, 1991);

b) reduction in the massive food losses during storage/marketing (Etim, 1985; Adeyemo and Adeyemi, 1984)

c) an improvement in the adaptation of well known food processing methods to the production of indigenous foods (Banigo, 1984; Akobundu, 1985).

d) a comprehensive study and determination of the shelf-life of local foods (Gomwalk, 1985; Achoba *et al.* 1991),

e) the development and evaluation of composite flours tailored towards snack foods (Ogazi, 1985; Addo, 1988) and,

f) evaluation of less known but abundant plant foods and animal feed (Ukhun and Ifebigh, 1989; Igene *et al.* 1991; Achoba *et al.* 1993).

In furtherance of the strategy involving scientific evaluation of foods, Bressani (1989) suggested the application of food science and technology in solving malnutrition problems in developing countries (Table 1). Consequently, non-conventional plant foods stand out as solution to malnutrition.

Table 1: Malnutrition problems and the application of food science and technology in developing countries.

Malnutrition Problem	Food Science and Technology research	Output
Protein/Calorie	Vegetable proteins	high
Malnutrition	Fish protein concentrate, single cell protein.	nutritive value of foods
Poor nutritional status of people and low nutrient intake	Food analysis	Food Composition tables
Iodine deficiency	Potassium iodate addition	Iodized salt
Vitamin A deficiency	Vitamin A stability in sugar	Fortified sugar.
Iron deficiency	Heme iron from animal blood	Fortified bakery products
Low food intake in Children	Increasing Caloric density.	Partially hydrolyzed food products

Source: Bressani (1989).

1.2.3 Non-Conventional Plant Foods

In Nigeria, the Federal Government food and industrial programmes favour the local sourcing of industrial raw materials and replacement of imported foods with locally available substitutes. Some of these programmes are:-

a) the ban on the importation of wheat (RMRDC, 1989)

b) local wheat production programme (RMRDC, 1987) and

c) the establishment of the Raw Materials Research and Development Council, RMRDC (RMRDC, 1987)

According to Igene *et al.* (1991), virtually all major food industries (in Nigeria) are constrained by a lack of local sources of raw materials, water, energy, technical know - how, industrial equipment, machinery and spare parts. This situation has placed heavy burden on agricultural produce that serve concurrently as industrial raw material and human food. The sliding value of the Nigerian currency (Naira) and the consequent foreign exchange problems make the local sourcing of raw materials a viable option for industrialists/manufacturers to obtain their much needed industrial raw materials. Laudable as it appears to be, the local sourcing of industrial raw materials places a heavy burden on the food crop production and therefore creates a gap on the domestic food economy especially where such raw materials concommitantly serve as human food. For instance, the breweries, in finding substitute for barley, had to compete for sorghum, a popular cereal grain produced in the Northern parts of Nigeria, with the local human consummers. Non-conventional plant foods should fill

the gap created by the industrial raw material on human food requirments in developing countries.

Several reports have indicated the nutritional potentials of a host of less known plant foods. Ukhun and Ifebigh (1989) reported their findings on the chemical composition of *Centrosema pubescence* legume seeds. Extensive biochemical assessments of the better known legumes such as cowpea, bambaranuts, soyabean and lima bean, among many others (Platt, 1980) have been carried out. Achoba *et al.* (1993) reported the nutrient composition of the Black (African) velvet tamarind (*Dialium guineense* Wild) seed and pulp from Nigeria. Temple *et al.* (1990 and 1991) reported their findings on the chemical composition of Tiger nut (*Cuperus esculentis*) and Livingstone potato tubers (*Plectranthus esculentis*) respectively. The nutritional aspects of the testaless seeds of white star apple (*Chrysophyllum albidium*) was reported by Obasi (1991) while Ajewole and Adeyeye (1991) studied the physicochemical characteristics and fatty acid composition of the seed oil of this plant food. Full fat fluted pumpkin seed flour was produced and evaluated for proximate and mineral composition as well as the functional properties of the flour protein by Fagbemi and Oshodi (1991). ACha (*Digitaria exilis*), a popular cereal grain in some part of Nigeria had its proximate chemical composition assessed by Temple and Bassa (1991). A major landmark in the documentation of the nutrient composition of Nigerian foods was the National Workshop on Food Composition during which several findings on Nigerian foods were documented (Elegbede *et al.* 1986; Oguntona, 1986). These and other reports have not just provided

the relevant nutritional value of these neglected foods but have enhanced their potentials for utilization as human food or animal feed and as industrial raw materials.

1.2.4 The Mango Seed Kernel

Despite the non-availability of the annual production figure for mango fruit in Nigeria, it is a fact that mango trees grow or are cultivated all over the country. Presently in Nigeria the mango fruit is under-utilized since much of the fruit produced has to be consumed fresh and in season due to the absence of processing industries. Lesser known oil-seeds such as African or wild mango, *Irvingia gabonensis* appear to be better utilized since the pulp surrounding the fibrous - coated hard shell is eaten fresh, while the kernel is dried and used as condiment in soup (Umoh and Oke, 1974).

The oilseeds, the group to which mango belongs, are known to contain proteins of high quality in the plant kingdom (Spindler and Akosionu, 1985). The mango seed kernel (MSK) is approximately 14% by weight of the fruit (Mittal and Singh, 1979, 1982).

The current practice in Nigeria whereby the MSK is discarded puts to waste, a potential source of industrial raw material, animal feed and possibly human food. A reversal of this current practice, to generate awareness on non-conventional plant foods such as mango, should begin with a comprehensive evaluation of such neglected, but cheap and abundant plant foods. This author is not aware of any published work on the Nigerian MSK apart from the report of Mittal and Singh (1979). These workers reported on the

proximate composition and possible uses of the MSK. Their report was based on work done at the Agricultural Engineering Department, Pantnagner University in India where a mango stone (seed) decorticator was desgined, fabricated and tested. Virtually all the reports available on MSK were either based on research findings in India or were the direct efforts of Indian scientists (Rukmini and Vijayaraghavan, 1984; Negi, 1985; Geetha and Devi, 1986 and Anisur-Rahman, 1981). This development is probably as a direct consequence of the socio-economic problems of India. Hence, their scientists had to intensify research into agricultural wastes and profer solutions to the mumerous food and nutrition as well as industrial raw materials problems characteristic of developing economies. The efforts of these scientists have led to the present limited knowledge on the nutritive value and uses of mango wastes.

1.2.5 Nutritive Value of Mango seed Kernel

Dhingra and Kapoor (1985a) and Augustin and Ling (1987) reported on the nutritive value of Indian MSK. Their findings showed variations in the proximate composition of MSK from different mango varieties. Values reported ranged from 6.9 - 8.8% (fat), 5.3 - 6.8% (protein), 1.3 - 2.4% (fibre), 2.2 - 2.8% (ash). Lakshminarayana *et al.*(1983) reported their findings on 43 varieties of MSK in India in which wide variations were found in the compositions of major nutrients as well as fatty acid.

The amino acid profile of mango seed kernel protein showed that its content of some of the essential amino acids is higher

than the FAO Reference Protein (Augustin and Ling, 1987). This was again confirmed by Dhingra and Kapoor (1985a) who also noted that methionine plus cystine and isoleucine were the limiting amino acids. The essential amino acid index values for the Chausa and Dusheri cultivars of MSK they studied were 67 and 77 respectively.

The report by Narasimha-Char and Azeemoddin (1989) reviewed recent developmental work that have gone into making the MSK fat a technological and commercial reality. The findings of these workers revealed the MSK fat as an excellent edible fat with main component fatty acids being palmitic (6.9 - 7.3%), stearic (44.3 - 44.4%), oleic (38.9 - 42.1%) and linoleic (4.5 - 7.4%) acids. The high stearic acid contents placed MSK fat as a possible substitute for butterfat in the confectionery industry. Other authors have studied the fatty acid composition of MSK fat (Gaydou and Bouchet, 1984; Hemavathy *et al.* 1988; Abd El-Aal *et al.* 1987; Ali, *et al.* 1985, Rukmini, 1985; Shah *et al.* 1983; Mukhopadhyay and Bhattacharya, 1981 and Lakshminarayana *et al.* 1983). In all these findings on fatty acid composition of MSK fat, different mango varieties showed variations in fatty acid composition although oleic and stearic acids predominated with palmitic and linoleic acids occurring in that order. Linolenic and arachidic acids were not quantified in these studies except Hussain *et al.* (1983) who presumed that other fatty acids accounting for 3.6 - 4.0% of the fatty acid composition were linolenic and arachidic. The studies by Ali *et al.* (1985) and Hemavathy *et al.* (1987) gave the most detailed findings on MSK fat, fatty acid composition and classification.

Apart from the possibility of using the MSK fat in the confectionery and cosmetics industries because of the considerable quantities of unsaturated fatty acid (Bajpai and Mukherjee, 1967; Narasimha-Char and Azeemoddin, 1989), the high carbohydrate content (56 - 58%) of MSK makes it outstanding as a possible source of calorie in animal feeds (Das *et al.* 1988) while the high essential amino acid and protein quality indices are indicative of the good quality of the protein in MSK (Dhingra and Kapoor, 1985a).

These published materials on the MSK reveal therefore enormous nutritional potentials for this agricultural waste. However, a full realization of the resources of the MSK should take cognisance of the bioavailability of these nutrients.

1.2.6 Limitations to the use of Mango Seed Kernel

The most important antinutritional factor that could possibly limit the utilization of MSK for human and animal food is tannin. The tannin content of MSK ranges between 0.19 and 0.44% on dry matter basis (Dhingra and Kapoor, 1985b). Tannins are thermostable and cannot be inactivated by heat-treatments. The nutritional problem posed by tannin in feeds is well researched in sorghum and barley cultivars, peas, field beans and oak (Johnson and Lay, 1974; Eggum and Christensen, 1975; Makkar and Singh, 1991). In high-tannin sorghum, an increased lysine content does not improve the extremely low biological value (Axtell, 1976).

Adverse effects caused by tannins in the nutrition of man and animal species have been reviewed by Silano (1977).

The effects of tannins on protein digestibility is due to the formation of soluble and insoluble complexes which are poorly digestible and therefore partially or totally unavailable (Van Buren and Robinson, 1969; Feeney, 1969; Eggum and Christensen, 1975). Furthermore, tannins inactivate a number of enzymes including trypsin, alpha-amylase, and lipase (Tamir and Alumont, 1969; Milic *et al.* 1972). It must be noted too that free tannins have carcinogenic activity (Singleton and Kratzer, 1973). In terms of carcinogenicity of tannins, the protein-tannin complexes in some cereal and legume seeds may actually represent partially removed tannins but such complexes confer low digestibility on the seeds/meal.

Das *et al.* (1988) fed day-old male white leghorn chicks with 0, 5, 10 and 20% mango seed kernel or 10 and 20% washed mango seed kernel (WMSK) for 8 weeks as a replacement for maize in the diets. The report of these workers indicated that chicks given 5% MSK and 10% WMSK had normal organ histology while those given 10% MSK and 20% WMSK had hepatic changes. According to the report, increasing dietary content of MSK decreased growth rate, blood glucose and plasma protein concentrations, caused hypercholesterolaemia and pathological changes in the tissues of chicks (Das *et al.* 1988). This situation was ascribed to the tannin contents of MSK. Similar findings have been reported on the feeding of MSK or MSK meals to rats (Geetha and Devi, 1986; Okai and Aboagye, 1990), milch cows

(Patel *et al.* 1970), calves (Patel *et al.* 1971), ruminants (Punj, 1988) and pigs (Gupta, 1988).

The work of Dhingra and Kapoor (1985b) represents one of the few studies involving the incorporation of MSK flour in conventional but traditional Indian "Snack" food items such as "Pakora", "Mattar" and "Parantha", after removing tannins by soaking the MSK in water. Das *et al.* (1988) reported the removal of 51% tannin from MSK on washing with cold water. Up to 30% of chickpea flour in "pakora" and white wheat flour in "mattar" and about 20% of wheat flour in "parantha" was replaced by MSK (Chausa cultivar) without adverse effect on the acceptability of the product (Dhingra and Kapoor, 1985b). Hence, in traditional Indian food items such as "pakora' and 'parantha' 20-30% of MSK flour could be used without adversely affecting the acceptability of these foods although higher levels of substitution were not acceptable (Dhingra and Kapoor, 1985b).

Anisur-Rahman (1981) and Mittal and Singh (1979) presented an outline of the possible uses of mango seed kernel. Mango seed kernel contains about 11% fat, 5.5% protein, 2.1% ash and 56% carbohydrate, and can be used for breadmaking after mixing with wheat or rice flour (Anisur-Rahman, 1981). Kernel fat can be used as subsitute for cocoa butter in chocolate (Moharram and Moustafa, 1982). Kernel starch can be used as a sizing agent in the textile and paper industries (Anisur-Rahman, 1981).

In fact, reports available on the nutritive value of the MSK reveal that this abundant and cheap agricultural waste holds a great deal of potential as animal feed or human food. Apart from

the limitation imposed by the tannin levels in MSK, the other important constraint is that of culture. However, a well thought out scientific approach would not only obliterate the problem posed by tannins in MSK but also remove the cultural impediment to the use of MSK as animal feed or for human food.

The report presented in this thesis is therefore a contemplative scientific effort at:

a) unfolding the nutritive value of the Nigerian mango seed kernel.

b) assessing the levels of tannin in, and exploring ways and means of reducing or removing such tannins from the MSK.

c) incorporating of MSK into a suitable and acceptable snack food and

d) evaluating such MSK substituted snacks for sensory attributes and storability.

Accordingly, it is expected that the findings reported in this thesis would generate awareness on and possibly remove nutritional and cultural limitations to the use of Mango seed Kernel for animal feed and for human food.

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1. CHEMICALS

All Chemicals used except otherwise stated were of analytical reagent grade purchased from either British Drug House (BDH Chemicals Ltd., Poole, England) or Hopkins and Williams (Essex, England).

2.2 SAMPLES

Riped mango fruits and Mango seed kernel samples were obtained from various locations in Nigeria as stated in the experimental design.

2.3 EXPERIMENTAL DESIGN

Riped mango fruits were purchased from Zaria, Kaduna, (Kaduna State) Makurdi (Benue State) and Idah, (Kogi State), depulped and the seeds sundried (30-35°C). The dry seeds were split open to recover the kernels which were further sundried for about 2 days and then stored refrigerated in screw cap plastic containers until required.

The mango seed kernels were analyzed for proximate composition, amino acids, fatty acids and tannins. Mango kernel flour was produced from the dried mango kernel. A method for the reduction of tannin content was adopted and applied to the kernel flour. The tannin-free kernel flour was used in the formulation of

cookies. Cookies were assayed for proximate content, amino acids, fatty acids and assessed for acceptability and storability. A summary of the methodology is shown in figure 1.

2.4 SAMPLE PREPARATION

2.4.1 Depulping mango fruit.

Fresh ripe mango fruits (Plate 1) were depulped either by eating the fleshy pulp or by skinning off the pulp neatly, leaving the stony hard seed. The proportions of the different parts of the mango fruit were calculated. The hard seed (Plate 2) was sundried for 2-3 days. The dry seed was carefully split open and the kernel recovered. The kernel was further sundried for another 2 days. The dried mango kernels (Plate 3) were ground into flour size 0.15mm (Plate 4).

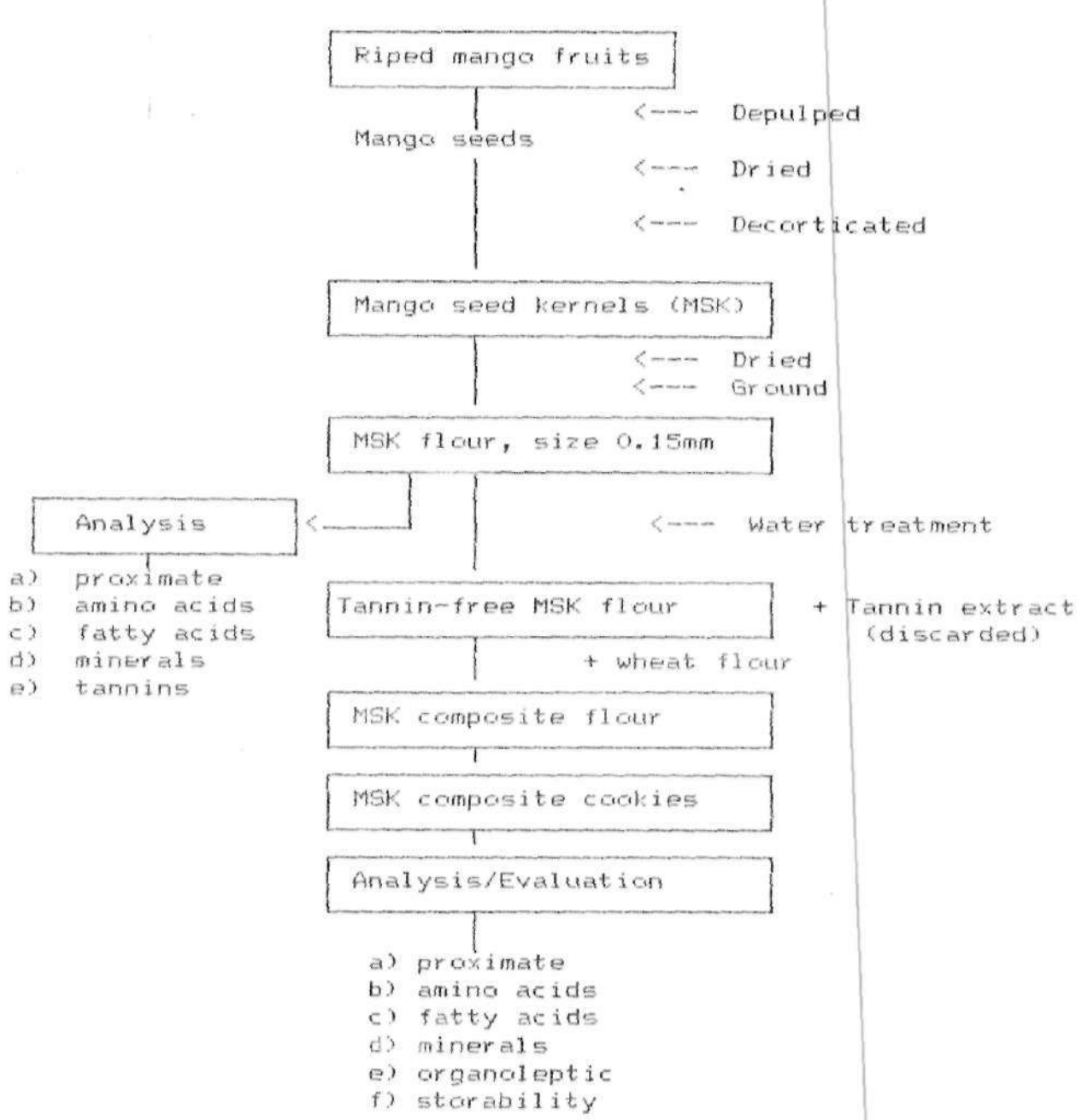
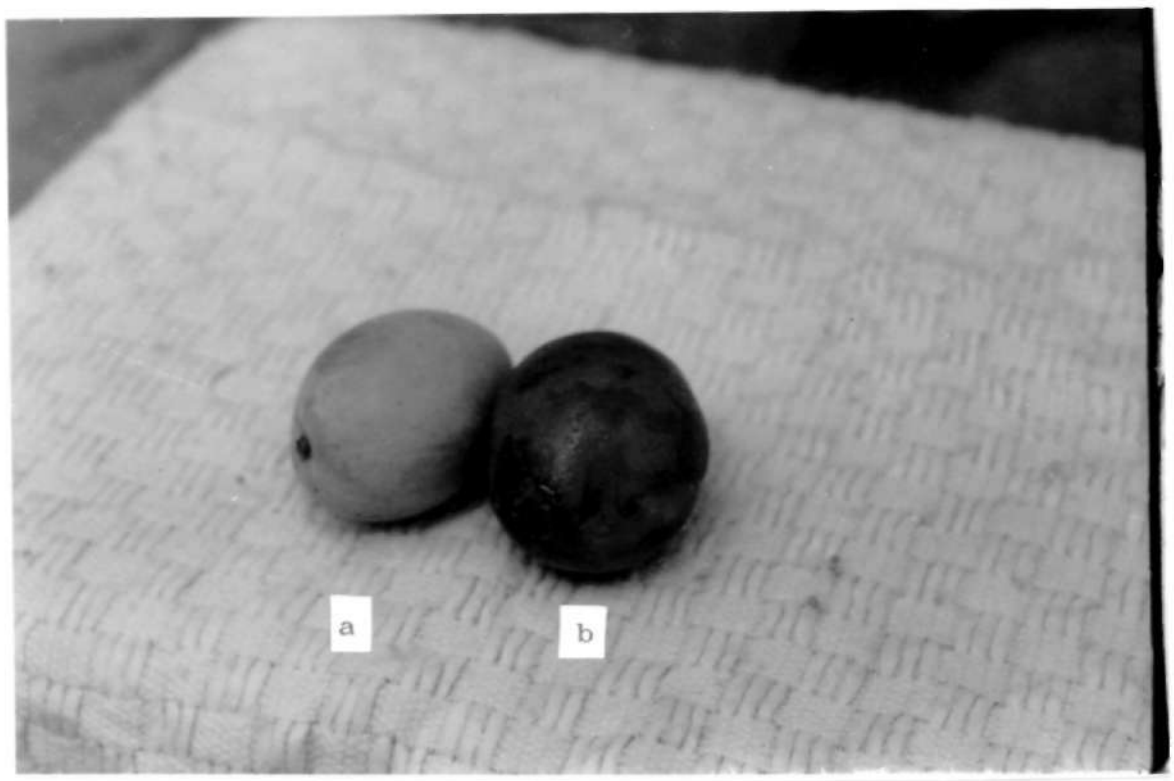


Figure 1: Outline of Experimental Design.


a
b

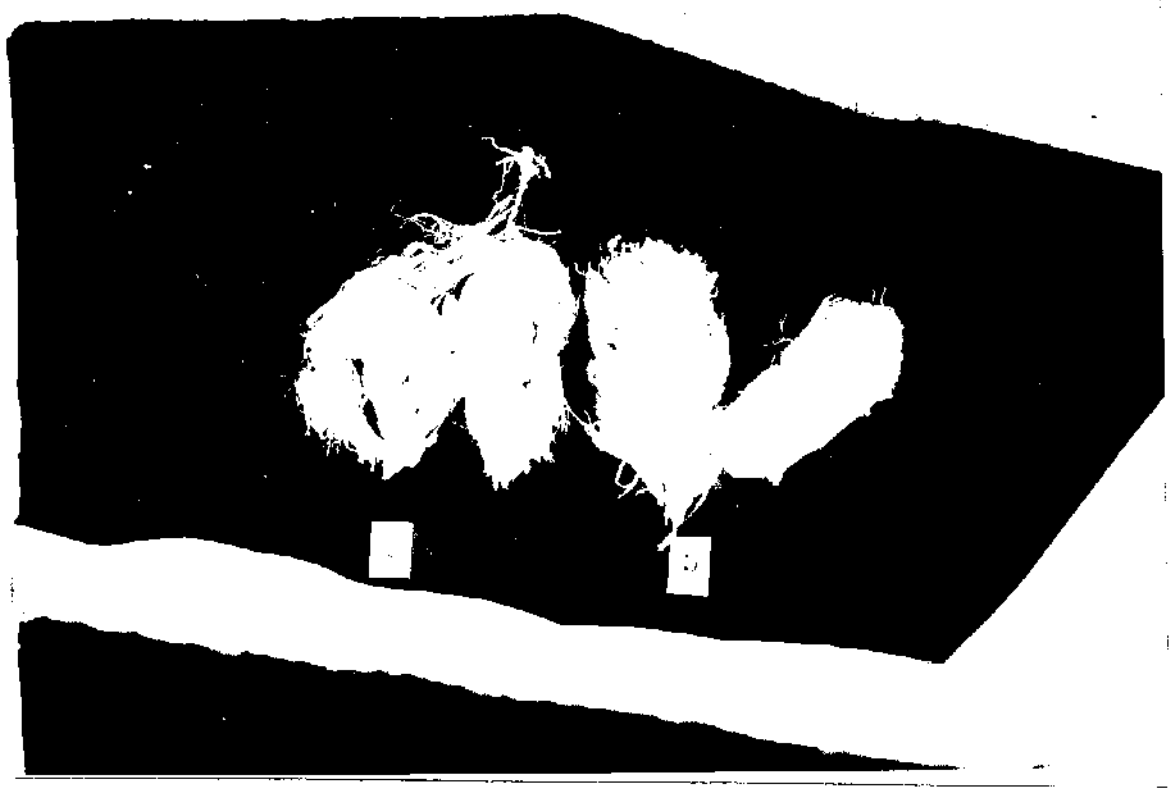


Plate 2: 'Binta sugar' mango seed: split open (a) and whole (b)



Plate 3: Dried 'binta sugar' mango seed kernels



Plate 4: Mixed variety mango seed kernel flour

2.4.2 Reduction of tannin content

The tannin content of the mango seed kernel flour was reduced by a modified method of Dhingra and Kapoor (1985b): A paste of the mango kernel flour was made with distilled water (1:2 w/v) and shaken on a wrist action shaker at medium speed for 2 hours. The water extract was carefully decanted and the residual slurry was dried in the sun for 2 days. During the period of sundrying, samples were removed just before sun set each day to prevent samples from re-absorbing moisture. Dried tannin-free MSK flour samples were stored refrigerated in screw cap plastic containers until required.

2.4.3 PREPARATION OF COOKIES

Cookies were produced according to a recipe based on a modification of Tlusty's (1989) method. In a big bowl was taken 1058g powdered sugar, 769g soft margarine and three medium sized eggs, thoroughly mixed and then, 1000g all purpose wheat flour and about 22.0g baking soda were stirred into the mixture until homogeneity was attained. The mixture (dough) was covered and kept refrigerated for 3 hours. On a lightly floured cloth covered board, the dough was then divided into tiny rolls of about 3/16 inch in thickness, then cut into regular shapes with 2 to 2.5 inch diameter cookie cutters. A light sprinkling of approximately 20 mg of granulated sugar was applied on the cookies before baking in a gas oven set at about 375°C until the edges became light brown. The baking time was approximately 7 minutes. The 10% composite flour was prepared by mixing 100g MSK flour with 900g all purpose

Plate 5: Mango seek kernel (MSK) composite flour cookies.
a = 0% MSK (whole wheat)
b = 20% MSK
c = 30% MSK

wheat flour until homogeneity was attained. The 20 and 30% composite flours were prepared similarly by substituting MSK flour for the all purpose wheat flour as in Table 2. The composite flour were then used to produce 20 and 30% MSK cookies as composite flour cookies using the same procedure and recipe as outlined for all purpose wheat flour except that for every 100g of MSK flour used, 10g reduction in margarine requirement was made to cater for the intrinsic lipid of the MSK.

Cookies in air-tight plastic containers were kept frozen (-18°C) until required. Samples of cookies are shown in plate 5.

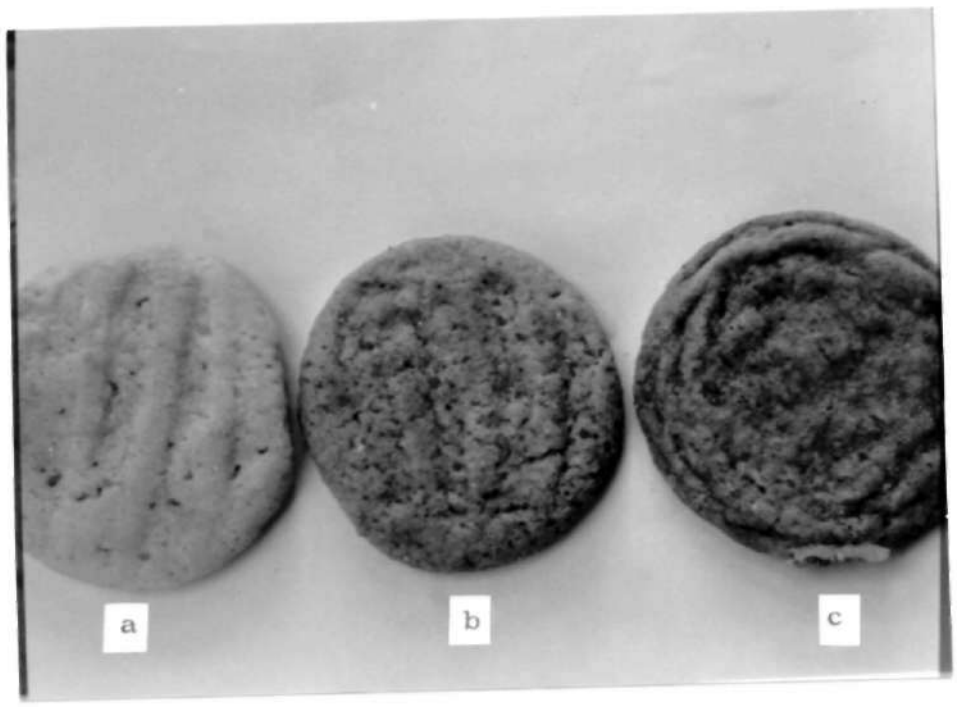


Plate 5: Mango seek kernel (MSK) composite flour cookies.
a = 0% MSK (whole wheat)
b = 20% MSK
c = 30% MSK

Table 2: Proportion of mango seed kernel (MSK) and wheat flours in the composite flour.

Percentage of the MSK flour in composite	Quantity (g) of: All Purpose Wheat flour(A)	Mango Seed Kernel flour(B)
0	1000	0
10	900	100
20	800	200
30	700	300

Each portion of A is mixed with the corresponding portion of B to make the composite flour.

2.5 SENSORY EVALUATION

Sensory evaluation was carried out based on the methods of Gacula (1975), Jackson (1981), Watts *et al.* (1989) and Rutledge and Hudson (1990). Two panels were employed for the sensory evaluation. A taste panel was used for the product-oriented testing, while another panel, essentially a pilot consumer panel was employed for the consumer-oriented testing. The taste panel, comprising of 12 panelists was constituted from the staff and postgraduate students of the Department of Biochemistry, Ahmadu Bello University, Zaria. The panelists were selected and further trained on their individual ability to discriminate between and detect differences in flavour, odour and texture of cookies and similar snack products. The panelists were divided into two groups of 6 each and each group sat at different times (of approximately 30 minutes apart) but on the same days. Panel sittings were held in an air-conditioned, well lit, and comfortable room. At each sitting, one set of samples was given to each panelist at 10 minutes interval. Each panelist was supplied with lukewarm (37 - 40°C) water for mouth rinsing in between sample tasting. To enhance odour and flavour detection, all samples were warmed at 50°C just before serving. Each set of samples presented to each panelist consisted of five coded and one uncoded (control) samples. One of the coded samples was also a control. The control sample served as standard to which all the other coded samples were compared.

The quality of the coded samples relative to the control was rated on an evaluation sheet using seven point hedonic scale for

odour, flavour, appearance, texture and colour (Appendix 1a). In the scale, the point 7 was defined as much better (compared to control) and 1 as much poorer (Appendix 1a). A seven point hedonic scale was used for flavour type which varied from 7 for Bean like to 2 for foreign and 1 for unclassified (Appendix 1a)

The consumer panel consisted of 56 untrained randomly recruited post-primary and undergraduate students that were able to read the product ballot forms (Appendix 1b). Cookies prepared from a composite flour of 0, 10, 20 and 30% MSK flour were labelled with random three-digit numbers and presented to each panelist. The panelists scored the samples on a 7-point hedonic scale were 7 represented extreme likeness and 1 represented extreme dislike. Cookie acceptability was deduced from analysis (ANOVA) of the panel scores.

2.6 PROXIMATE ANALYSIS

Mango seed kernel flour and MSK composite flour cookies were analysed for moisture, caloric energy, ash, protein, fat, fibre and total carbohydrate. Protein content was determined by the improved micro-kjeldahl method (AOAC, 24.027, 1980) while moisture, ash and lipid contents were also determined by the official methods of analysis (AOAC, 24.003a, 24.004a and 24.005a, 1980). Total carbohydrate was determined by difference. All parameters were determined in triplicate, except otherwise stated.

2.7 FAT CONTENT AND FAT CHARACTERISTICS

The fat content was determined by extracting 5.0g of the sample with diethyl ether in a soxhlet apparatus and the melting point (Cc1-25), the iodine value by Wijs method (Cd 1-25), the acid value (Cd 3a-63) and the saponification number (cd 3-25) of the fat were determined as in the AOCS (1979).

2.8 CHEMICAL ASSAYS

2.8.1 TANNIN CONTENT

The tannin contents of samples were determined as catechin equivalent by the rapid method of Burns (1971) using vanillin hydrochloric acid. Exactly 500mg deffated sample was transferred into a centrifuge tube with 10 ml of 1% v/v HCl (S.G 1.18): methanol mixture, shaken for 20 minutes on a wrist action shaker then centrifuged at 5000g for 10 minutes. The aliquot was transferred into a 25ml volumetric flask. Another 5ml of the 1% HCl-methanol solution was added to the centrifuge tube and shaken for 20 minutes, centrifuged at 5000g for 10 minutes then the aliquot added to the first extract. The volume was made up to 25ml with the 1% HCl-methanol solution and mixed well.

Aliquots (1.0ml) of the extract was added slowly to 5.0ml of freshly prepared (1:1 v/v) mixture of 8% v/v HCl in methanol and 1% w/v vanillin in methanol in a test tube. The test-tubes containing 1.0ml each of different concentrations (0.2-1.0mg) of catechin in methanol were treated similarly as standards along with the extract. Sample blanks were equally set by adding 5.0ml

of 4% v/v HCl in methanol to 1.0ml aliquot of the vanillin-HCl reagent. After 20 minutes, absorbance readings were taken at 500nm against the reagent blank in a spectronic 20 spectrophotometer.

Standard curve (Appendix 2) was prepared by plotting the average absorbance readings of the duplicate determinations of the standard catechin concentrations. Blank absorbance was substracted from the sample absorbance, then the resultant absorbance values were converted into concentrations of catechin per ml and the percent catechin equivalent (C.E) was calculated as:

$$\% \text{ C.E} = \frac{a \times b \times 100}{c \times d}$$

Where a = mg catechin per ml, determined from appendix 2
b = final volume of extract in ml.
c = volume of extract taken in ml.
d = weight of sample extracted in gm.

2.8.2 FATTY ACID COMPOSITION

The raw and processed mango seed kernels as well as the composite flour cookies were analysed for fatty acid composition. Samples were ground into powder and steam distilled according to AOAC (1980) method. The oil obtained was methylated using the method of Luddy *et al.* (1968). Essentially, the method involved taking 1.0g oil or fat in a 250ml round bottomed flask and adding 50ml of the mixture of methanol: toluene: H_2SO_4 (S.G 1.84); (20: 10: 1 by volume) then refluxed for 90 minutes. The mixture was extracted with 50ml hexane then washed thrice with 100ml distilled water before drying over anhydrous Na_2SO_4. Extract was

concentrated on a rotary evaporator. The methylated oils were analyzed by means of gas chromatography (GC) and gas chromatography- mass spectrometry (GC-MS) (Appendix 4).

Gas chomatography was carried out in a Hewlett-Packard 5890 gas chromatograph equipped with either a split-splitters injector plus a DB-5 Column (30m x 0.32mm id) or an 'on column' injector plus a supelcowax 10M (30m) were used. The carrier gas was helium and the flow rate was 1.5ml per minute. The oven temperature was programmed from 150°C with a 4 min. initial hold and then 5°C per minute increase to a final temperature of 250°C. The injection volume was 0.5ul.

For the combined GC-MS, the GC was coupled to a VG Masslab 12-250 mass spectrometer operating at 70 eV and an ion source temperature of 200°C. Spectra were recorded every 0.65 (between Mass 50 and 450). The identity of each compound was determined by comparison with work data bank of Richard (1992).

2.8.3 AMINO ACID ANALYSES

Sample (100mg) of either the defatted kernel flour or defatted cookies was hydrolyzed with 6M HCl in a 250ml round bottomed flask fitted with a reflux condenser for 24 hours. After removing the acid in a rotary evaporator, the residue was dissolved in citrate butter (pH. 2.0) and filtered. Then aliquots (10ul) of the hydrolysate were analysed in duplicate for amino acid content using an automatic amino acid analyser (Technicon Instruments Co. Ltd., England; Appendix 3).

To facilitate quantitation of tryptophan, another set of samples were hydrolyzed using 5N barium hydroxide in place of acid hydrolysis according to the method of Slump and Schrender (1969). Aliquots of the filtered hydrolysate (1.0ml) were pipetted into each test tube containing 4.0ml of a solution of a 1:1 v/v mixture of 270mg $FeCl_2 6H_2O$ dissolved in 0.5ml distilled water then diluted to 1 litre with glacial acetic acid and 30N sulphuric acid. The mixture was shaken vigorously and the colour developed for 15min at 65°C, then cooled rapidly. The absorbance of the solution at 545nm was read on a spectronic 20 spectrophotometer (Villegas and Mertz, 1971). Tryptophan was quantified by reference to a standard curve prepared using pure L-tryptophan as standard.

2.8.4 DETERMINATION OF MINERAL CONTENT

The mineral contents of the mango seed kernel flour and cookies were determined using atomic absorption spectrophotometry (Perkin Elmer £703) as in AOAC (1980). The mineral elements quantitated were calcium, magnesium, sodium, zinc, iron, copper and potassium.

Two grammes of the ground sample was digested with 115ml of a mixture of HNO_3 (SG 1.57), H_2SO_4 (SG 1.84) and $HClO_4$, (7:8:8 by volume). Then the cooled digest was diluted with 50 ml distilled deionized water, filtered through a whatman £5 filter paper and made up to 100 ml with distilled deionized water, in a glass volumetric flask. This final solution was used for atomic absorption spectrophotometry. Phosphorus was determined spectrophotometrically by the vanadomolybdate method as in AOAC (1980).

2.9 MOISTURE SORPTION ISOTHERM

The concept of equilibrium moisture content is important in the study of food preservation. The minimum moisture content under which a food product can be preserved is influenced by the ambient equilibrium moisture content. Hence, the aim of drying foodstuffs is to lower its moisture content in order to reduce chemical and biochemical reactions to the minimum and to prevent the growth of spoilage microrganisms (Achoba *et al.* 1991; Labuza *et al.* 1970). When a food product is exposed to an atmosphere of uniform relative humidity and constant temperature for defined period of time, the intergranular relative humidity (RH) reaches constant value known as equilibrium relative humidity (ERH). A plot of the moisture content of the product at equilibrium against the ERH or water activity, a_w (note, a_w = RH/100), is known as the moisture sorption isotherm (Denloye and Ade-John, 1985)

The sorption isotherm of the cookies were therefore investigated to evaluate their storability potential. The method of Screedharan *et al.* (1985) as employed by Achoba *et al.* (1991) was adopted. Freshly prepared cookies (7.5-10.9g) were dried to constant weight for 12 hours in a vacuum oven at 60°C, and 25mmHg pressure. The equilibrium moisture content (EMC) of these products at relative humidity (RH) values ranging from 10 to 95% were determined by storing samples placed on metal gauze in desiccators at 25 or 30±1°C. Constant RH was maintained with sulphuric acid - water mixtures (Table 3) as in Stokes and Robinson (1949). The samples were weighed at 24 hour intervals until constant weights

were obtained usually within 15 days. A plot of percent moisture content versus percent RH was made as the adsorption isotherm.

2.10 STATISTICAL ANALYSIS

Data were mostly expressed as the mean ± SD and analysed by one-way analysis of variance (ANOVA) (Zar, 1984). If the ANOVA indicated significance ($P<0.05$), Fisher's least significant difference (LSD) test for multiple comparison was applied.

Table 3: Equilibrium relative humidity mixtures of H_2SO_4 (S.G. 1.84) and water for the attainment of various relative humidities at 25°C.

% Relative Humidity	Aqueous Tension (mm Hg)	% H_2SO_4
100	23.76	0.0
95	22.57	11.02
90	21.38	17.91
85	20.19	22.88
80	19.00	26.79
75	17.82	30.14
70	16.63	33.09
65	15.44	35.80
60	14.25	38.35
55	13.07	40.75
50	11.85	43.10
45	10.69	45.41
40	9.50	47.71
35	8.31	50.14
30	7.31	52.01
25	5.94	55.01
20	4.75	57.76
15	3.56	60.80
10	2.38	64.45
5	1.19	69.44

Concentrations of H_2SO_4 expressed as percentage of anhydrous solute (H_2SO_4; (S.G 1.84) by weight.

Source: Stokes and Robinson (1949)

CHAPTER THREE

3.0 RESULTS AND DISCUSSION

3.1 MANGO FRUIT AND MANGO SEED KERNEL

The mango pulp constituted 68.1-70.4% total fruit weight (Table 4a). The whole kernel and seed kernel consited of 18-19% and 10% of fruit respectively. The 'binta sugar' cultivar which is the most popular and apparently the aboundant in Nigeria is in terms of fruit weight less than half of the weight of the large sized Gboko mango, also known as 'paparanda' (Table 4a). This differences in fruit size do not appear to affect the proportion of the seed kernel, which on the average constituted 10% of fruit weight irrespective of cultivar. Hence, it was decided that the mixed variety MSK be studied. The effect of location on the mango fruit sizes of these two cultivars was not considered because fruit sizes varied significantly ($p<0.05$) even on the same mango tree.

3.1.1 PROXIMATE COMPOSITION

The proximate nutrient composition of mixed varieties of mango seed kernel (MSK), from various locations in Nigeria are shown in Table 4. From the results, location has no significant ($P>0.05$) effect on the protein, fibre and ash contents of MSK. However, location has significant ($P<0.05$) effects on the moisture and carbohydrate contents. Idah MSK contained the highest level of fat that differed significantly ($P<0.05$) from that of Makurdi with the lowest fat content. Apart from the Indian "Amini" variety of MSK which has fat content (12.6%) comparable to Nigerian MSK, all

Table 4a: Proportions of different parts of mango fruits(gm)

cultivar	total Wt.	Skin	Pulp	Kernel		
				Total	Outer Coat	Seed Kernel
Binta sugar	148.6	18.8 (12.6)	101.2 (68.1)	28.6 (19.3)	13.2 (8.9)	15.4 (10.4)
Paparanda	342.6	35.3 (10.3)	241.2 (70.4)	62.4 (18.2)	28.4 (8.3)	34.3 (10.0)

Each value is a mean of 8 determinations.
Values in parenthesis indicate the percentage of whole fruit.

Table 4b: Proximate composition (% dry weight) of sundried mango seed kernels obtained from different locations

Parameter	Idah	Kaduna	Zaria	Makurdi .	Mean±SD
Moisture	45.8±0.94[a]	43.2±0.20[c]	41.3±0.50[bc]	47.4±0.60[bd]	44.4±2.72
Crude protein	5.9±0.10	5.6±0.30	5.6±0.34	6.0±0.20	6.0±0.39
Fat	13.7±1.68[b]	13.0±0.85	13.2±0.34[b]	11.4±0.72[a]	12.8±0.98
Fibre	1.9±0.12	2.1±0.12	1.9±0.12	2.1±0.06	2.0±0.10
Ash	1.9±0.50	2.0±0.05	2.1±0.25	1.9±0.10	2.0±0.08
Carbohydrate[‡]	32.7±1.79[aceg]	36.3±1.25[bceg]	37.9±0.94[adfg]	33.3±0.97[aegh]	33.0±2.47
Energy (Kcal/g)	4.2±0.20	4.4±0.25	4.5±0.22	4.4±0.20	4.4±0.12

Each value is a mean of 4 determinations ± SD
Values with different superscript in a row differ significantly ($P<0.05$)
‡ Carbohydrate was determoned by difference

other Indian Mango varieties have comparatively lower fat content (Van Pee *et al.* 1981).

There are two varieties of mangoes in Nigeria which are easily distinguishable by the fruit size; the smaller sweet mango fruit locally called "Binta Sugar" is common and widespread hence the most popular while the one with larger fruit which is commonly found in the middle belt area of Nigeria is equally abundant and locally called "Gboko Mango" (or "paparanda"). In terms of kernel size, these two varieties do not differ. However, the effect of variety on proximate composition of these two mango varieties is shown in Table 5. The Nigerian Binta sugar MSK differed significantly ($P<0.05$) in terms of fat content when compared to the Nigerian large sized MSK from the same source. Both source and variety therefore affect fat content of the MSK. This observation agrees with the report of Van Pee *et al.* (1981) who investigated the effect of variety on the MSK fat. Van Pee *et al.* (1981) showed that 13 different mango varieties from India had MSK fat contents of between 6.8 - 12.6% on moisture free basis. These workers did not assay for other proximate nutrients hence it is impossible to relate the varietal differences in fat content to other proximate parameters such as carbohydrate and protein. The significant difference conferred on the carbohydrate content of the MSK as a result of variety may be related to the variations in the fat content because the carbohydrate content was estimated by difference.

A high caloric energy value (mean = 4.4 Kcal/g) obtained from the Bomb calorimetric assay of the MSK showed no significant

difference (P>0.05) arising from either variety or source (Table 4). However from the carbohydrate content and the caloric energy value obtained, any snack food derived from the MSK should theoretically supplement the energy needs of the consumers. For instance, the World Health Organization recommended daily energy intake (RDI) for children aged 1-3, 4-6, and 7-9 years are 1360, 1830 and 2190 Kcal respectively (WHO, 1974); hence these children would theoretically meet their respective RDI for energy if they consume any snack product(s) containing 309, 416 and 498g of MSK respectively.

Table 5: The proximate composition of the kernel seed of two popular varieties of mango.

Parameter	MSK Variety Binta sugar (Kaduna)	Paparanda (Kaduna)
Moisture	46.2±0.82	46.4±0.32
Crude Protein	6.0±0.15	5.6±0.35
Fat	12.6±0.35[a]	11.3±0.48[b]
Fibre	1.8±0.21	2.0±0.05
Ash	2.0±0.15	2.0±0.05
Carbohydrate*	33.2±0.92[a]	34.7±0.17[b]

Each value is a mean of 4 determinations ± SD.
Values with different superscript in a row differ significantly ($P<0.05$)
* Carbohydrate was determined by difference

A critical assessement of the proximate nutrient content of the Nigerian mixed variety MSK became a logical thing to do in this study because the nutrient variations were not significant for all nutrients determined (Tables 4 & 5) and it is obvious too that any commercial or large scale application of MSK for purposes of food or feed would naturally involve mixed variety MSK because of the logistics of separating the MSK according to variety and source.

The mixed variety MSK which contained 6.0% protein, 12.8% fat, 2.0% fibre, 2.0% ash and 33.0% carbohydrate (Table 4) apparently holds a great deal of utilizable nutrients especially with respect to the protein level. These values are within the range reported for Asian mango seed kernels by several workers (Mittal and Singh, 1979; Anisur-Rahman, 1981; Dhingra and Kapoor, 1985b; Augustin and Ling, 1987). However, it is important to note that the protein values reported by these workers and in the present study use the factor of 6.25 for converting nitrogen content to crude protein. Though this provided the basis for the comparision of the present findings to the previous works, it must be acknowledged that plant materials contain some non-protein nitrogenous substances such as amines, purines, pyrimidines, nucleosides, alkaloids, porphyrins and non-proteinogenic amino acids (Haard, 1985). Hence the protein values may not entirely be due to proteins *per se*. In addition, tannins also limit the availability of proteins in foods. Some workers (Okai and Aboagye,1990; Das *et al.* 1988) have shown the limitations to the use of the MSK for food or feed due to its tannin contents.

3.1.2 Tannin Content

Variety and source of the MSK do not have significant effect on tannin content but the level of maturity of the seed kernel does (Table 6). Premature MSK had very high levels of tannin that differed significantly ($P<0.05$) when compared to the matured MSK (Table 6). Although there are no published information on the effect of the stage of maturity of the mango fruit on the tannin content of the corresponding MSK, Makkar and Singh (1991) showed that tannin levels in oak leaves depended on the level of maturity of the leaves. It is therefore both advisable and desirable to avoid the use of premature MSK for food or feed because tannin are heat-stable and the high levels of this antinutritional factor in MSK could pose nutritional problems resulting from protein indigestibility. The major problems associated with tannins in food is protein indigestibility caused by the formation of soluble and insoluble tannin-protein complexes as well as tannin induced enzyme inactivation (Van Buren and Robinson, 1969; Feeney, 1969; Tamir and Alumont, 1969; Milic *et al.* 1972; Eggum and Christensen, 1975; Makkar and Singh, 1991). Treatments that could reduce or remove the tannins in the MSK is therefore of immense nutritional benefit.

The loss of tannins on treatment of MSK flour with water is shown in Table 7. Treatment of MSK flour with water at 25°C (ambient temperature water) does not seem to achieve significant ($P>0.05$) tannin removal. However, effective and significant ($P<0.05$) removal of tannin was effected when the MSK flour was treated with water at 70°C for 30 minutes; whereas Dhingra and

Kapoor (1985b) reported effective tannin removal only on water treatment of MSK flour at 80°C for 20 minutes. Consequently tannin removal or considerable reduction of this antinutritional compound makes the incorporation of MSK flour into foods or feeds viable.

Table 6: Tannin Content of different mango seed kernels.

Description of Mango seed kernel	Tannin (%)
Makurdi, Binta Sugar (Premature Kernels)	1.27 ± 0.09
Matured MSK:	
Makurdi, Binta Sugar	0.42 ± 0.04[b]
Kaduna, Binta sugar	0.39 ± 0.02[b]
Kaduna, Paparanda	0.36 ± 0.04[b]
Zaria, Mixed	0.41 ± 0.03[b]
Idah, Mixed	0.32 ± 0.06[b]

Each value is a mean of 4 determinations ± SD

Values with different superscript in a column differ signifantly ($P < 0.05$).

Table 7: Effect of water temperature on the tannin content of mango seed kernel (MSK) flour

Temperature of MSK: Water paste (1:2w/v) (°C)	Treatment Period (Hours) 0.5	1	24
25	0.43 ± 0.04[a]	0.42 ± 0.02[a]	0.39 ± 0.03[a]
60	0.30 ± 0.03[a]	0.28 ± 0.04[a]	0.25 ± 0.06[a]
70	0.03 ± 0.01[b]	0.04 ± 0.01[a]	0.03 ± 0.01[a]
80	0.04 ± 0.01[b]	0.04 ± 0.01[a]	0.03 ± 0.01[a]

Each value is a mean of 4 determinations ± SD

Values with different superscripts in a column differ significantly ($P<0.05$)

3.1.3 Fat Content and fatty acid composition of MSK.

Crude fat extract of the mixed variety MSK was of very faint yellow colour, smooth and free from granules but solid at room temperature. The mean melting point for Nigerian MSK fat was 40.3 ±1.1°C. Van Pee *et al.* (1981) reported slightly yellow colours for Indian MSK fat but obtained melting points ranging from 30.5 to 35.8°C which were lower than that obtained in this study. The small diferences in the melting points between the varieties of MSK studied in this report and the Asiantic MSK may be due to the slight differences in their contents of unsaturated fatty acids as well as the chain length of the fatty acid. For instance, Van Pee *et al.* (1981) reported the fatty acid composition of the M'Vuazi II variety of MSK as 6.0% palmitic (16:0), 32.2% stearic (18:0), 55.0% oleic (18:1), 5.0% linoleic (18:2), 0.6% linolenic (18:3) and 1.2% arachidic (20:0) whereas the values obtained from this study for mixed variety MSK are correspondingly 6.6, 46.1, 40.0, 4.0, 0.4 and 2.3% respectively in addition to the presence of 0.4% behenic acid (22:0) (Table 9). This variation in unsaturated fatty acids may account for the small difference in the iodine value amongst varieties. Again Van Pee *et al.* (1981) reported iodine value (Wijs) of 57.7 for M'Vuazi II MSK fat while that of the mixed variety MSK is 42.5 (Table 8).

Generally, irrespective of source and variety, stearic and oleic acids constitute about 84% of the fatty acids in MSK fat. Other quantifiable fatty acids were in decreasing order, palmitic (5.9%), linoleic (4.8%), arachidic (2.4%), behenic(0.6%) and linolenic (0.4%) (Table 9). These findings are in agreement with

the data published for Asiatic Mango varieties (Van Pee *et al.* 1981, Dhingra and Kapoor, 1985a and Narrasimha-Char and Azeemoddin, 1989) and that of Egyptian MSK fat (Moharram and Moustafa, 1982).

Table 8: Biochemical characteristics of mango seed kernel (MSK) fat

	MSK variety		
	Binta sugar	Idah mixed	Zaria mixed
Iodine value(Wijs)	38.6	42.5	40.2
Acid value(mg KOH/g fat)	3.8	4.2	3.9
Saponification number (mg KOH/g fat)	189.0	191.0	190.0
Melting point (C)	39.2	40.3	40.0

Values are averages of 2 determinations.

Table 9: Fatty acid composition of mango seed kernel (MSK) fat

Fatty acids (mol %)	Kaduna Binta Sugar	Idah Mixed variety	Zaria Mixed variety
12.0	-	tr	tr
14.0	-	tr	tr
15.0	-	-	tr
16.0	5.9	6.6	6.0
16.1	-	tr	tr
17.0	-	tr	tr
18.0	46.3	46.1	46.0
18.1	37.6	40.0	40.0
18.2	4.8	4.0	4.4
18.3	0.4	0.4	0.4
19.0	-	tr	tr
20.0	2.4	2.3	2.4
20.1	tr	tr	tr
22.0	0.6	0.4	0.6
23.0	tr	tr	-
24.0	-	tr	-

Values are averages of 2 determinations
tr=trace amount present.
- Not detected

A Hewlett-Packard model 5890 gas chromatograph coupled to a VG Masslab 12-250 mass spectrometer was used to assay for fatty acids. Detection was by flame ionization after elution through a DB-5 column (30m by 0.32 mm id) packed with 10% SP-2330 on 100-200 mesh chromosorb (Supelco Inc. Switzerland). Injection volume was 0.5 ul while gas flow rate was 1.5 ml/minute. The initial oven temperature of 150°C was held for 4 minutes then increased at 5°C per minute to a final temperature of 250°C.

However, the striking difference between these previous studies and the current finding appears to be the quantifiable level of behenic acid detected and a host of other fatty acids that occurred in trace amounts. These are dodecanoic(12:0), tetradecanoic(14:0), pentadecanioc (15:0), 9,hexadecenoic(16:1), heptadecanoic (17:0), hexadecanoic (19:0), 5,eicosenoic (20:1), tricosanoic (23:0) and tetracosanoic (24:0) acids; all accounting for usually less than 0.3% of total fatty acids in the MSK fat.

The high level of stearic acid fraction of MSK fat suggests possibility of its incorporation into chocolate and other confectionery products to improve the desired stability especially in hot climates. From this study, it is apparent that mango kernel fat may be substituted for shea butter since it is the high stearic acid (30 to 40%) component of shea butter that makes it an important commercial fat in the confectionery industry. Hence, the extraction of mango kernels collected in centres where mango fruits are processed or produced in large quantities may be of some economic interest.

3.1.4 Amino acid composition

The amino acid composition of the Binta sugar MSK variety and the mixed MSK are shown in Table 10. Except for methionine, phenylalanine and valine, all the essential amino acids were higher in the Nigerian MSK than those of the FAO Reference protein. However, when the amino acids were compared with those of whole egg protein, leucine and tryptophan were present at comparable or higher values while isoleucine, lysine, methionine,

phenylalanine, valine and histidine occurred in lesser amounts. Generally no significant (P>0.05) differences exist in the amino acid contents of the Binta sugar MSK when compared to the mixed variety MSK except for the occurrence of proline in the mixed MSK which also had significantly (P<0.05) lower level of glutamic acid when compared to Binta sugar MSK. The essential amino acid index of the Binta sugar and the mixed variety mango seed kernels were 67 and 72 respectively. These values are within the range of published reports (Dhingra and Kapoor, 1985a and Augustin and Ling, 1987) and equally show that MSK protein is of good quality.

Table 10: Amino acid composition (g/100 g protein) of Mango seed kernel (MSK) as compared to standard proteins [a]

Amino acid	Binta sugar MSK (Kaduna)	Mixed MSK (Idah)	Whole egg Protein	FAO Reference Protein
Isoleucine	3.8	4.6	6.2	4.2
Leucine	7.9	8.8	8.8	4.8
Lysine	4.4	5.3	6.9	4.2
Methionine	1.8	1.8	3.3	2.2
Phenylalanine	2.0	1.9	5.7	2.8
Tryptophan	2.0	2.1	1.5	1.4
Valine	3.7	3.8	6.8	4.2
Histidine	1.5	1.5	2.4	
Arginine	3.4	3.6		
Threonine	4.4	4.3		
Alanine	6.6	6.9		
Aspartic acid + Asparagine	12.0	11.3		
Glutamic acid + Glutamine	8.5	2.9		
Glycine	8.3	8.0		
Serine	7.0	7.1		
Tyrosine	1.8	1.8		
Proline	-	3.4		

Values are averages of 2 determinations
a FAO (1970).
- Not detected.

3.1.5 Mineral Contents of the MSK

The content of some minerals in the mixed variety MSK is shown in Table 11. Although the values for most of the minerals studied are low, the potassium and phosphorus contents are appreciably high. Phosphate, together with calcium and fluoride play significant role in the development of hard tissues while potassium is a component of soft tissue (Stare and Williams, 1984). Copper did not occur at any detectable level in MSK. Previous authors had not made the attempt to determine the mineral content of MSK. It is noted that such an exercise is necessary especially as there are reports of the utilization of MSK meals in the feeding of chicks (Reddy, 1987; Patle, 1980 and el-Alaily *et al.* 1976), calves and milk cows (Reddy and Prasad, 1985; Patel *et al.* 1970 and 1971) and Sprague Dawley rats (Okai and Aboagye, 1990). These reports indicated that substitution of about 20% MSK or washed MSK meals into animal feed rations resulted into normal feed utilization as evidence by both growth and organ examination. The importance of minerals especially phosphorus to growing animals is well known while the levels of these minerals in feed stuff is of practical importance in animal ration formulation.

Table 11: Levels of some mineral ions (mg/100g sample) in mango seed kernel (MSK) flour.

Mineral	mixed MSK (IDAH)	mixed MSK (ZARIA)	mixed MSK (KADUNA)
Calcium	47.0 ± 1.1	49.0 ± 1.0	48.0 ± 1.2
Magnesium	98.0 ± 2.1	100.2 ± 1.8	80.0 ± 1.2
Zinc	1.3 ± 0.1	2.1 ± 0.2	1.2 ± 0.2
Manganese	1.6 ± 0.2	2.0 ± 0.2	1.8 ± 0.1
Iron	10.5 ± 0.2	9.5 ± 0.2	11.0 ± 0.3
Copper	0.0	0.0	0.0
Potassium	345.0 ± 2.4	360.0 ± 1.2	365.0 ± 1.0
Sodium	2.8 ± 0.1	3.0 ± 0.2	3.0 ± 0.1
Phosphorus	140.4 ± 1.2	130.0 ± 1.3	128.0 ± 1.2

Each value is a mean of 6 determinations ± SD.

3.2.0 Mango Seed Kernel (MSK) Composite Flour Cookies

The two different types of cookie produce from the composite flour (wheat: MSK) are shown in plate 5. The whole-wheat cookie (Plate 5a) was used as standard. The traditional Indian snack foods like chikenpea flour based "pakora", and the wheat flour based "mattar" or "patrantha" have had their original flour replaced with between 20 and 30% MSK flour without adverse effect on the acceptability of the products (Dhingra and Kapoor, 1985a and 1985b). The MSK composite cookies represent a bold attempt at converting waste materials of the mango fruit (MSK) into edible products. It is important to note that cookies, like other similar snacks are not only convenient and handy but serve as a ready supply of energy and nutrients to children who incidentally are confronted with the problem of inadequate energy supplies especially in developing nations.

Considering the present findings on the nutrient composition of the MSK, incorporation of the cheap and abundant MSK flour into some popular snack foods should contribute meaningfully to the nutrient and energy needs of children. The limitations to the use of MSK in snack foods are the tannin content of the MSK as well as the cultural and taste factors that usually hinder the acceptability of novel foods. The cultural limitation is easily eliminated because children are yet to have established permanent food culture. Besides, children generally have the ability to acquire new tastes in foods. However, the tannin content of MSK is of nutritional importance as it limits the protein digestibility and nutrient availability of MSK based snacks. Hence, the presence

of tannin in foods targetted at children may aggravate the problem of protein energy malnutrition. Consequently, the removal of tannin from MSK and the use of such MSK flour in the formulation of various snack foods is not just desirable but relevant to the problem of PEM.

3.2.1 Proximate Composition of MSK composite flour cookies.

The proximate composition of the different cookie produced from MSK flours is shown in Table 12. There are virtually no differences ($P>0.05$) between the nutrient composition of the various MSK substituted cookies.This was expected in view of the fact that fat, the only nutrient that would have varied, was balanced by making adjustments for the intrinsic fat of the MSK. Apart from the indigenous Indian snack products, in which partial substitution of the flour had been made with MSK flour, there are no published information on wheat:MSK composite flour snacks. Hence, this report is a pioneering effort towards the complete utilization of MSK. The cookies made with 30% MSK flour had slightly lower protein but a little higher fibre contents when compared to the 20% MSK composite cookies. However, these differences were not statistically significant ($P>0.05$). The energy values were higher for all the cookies (5.4 kcal/gm) formulated when compared to the MSK flour (4.4 kcal/gm) (Tables 4 and 5) possibly because of the high fat content of the cookies.

As a result of the tannin removal profile to which the MSK flour was subjected before its incorporation into the cookies, the tannin assay of these cookies showed no detectable levels of this

antinutritional component of the MSK. Therefore, these tannin-free MSK based cookies would be an acceptable snack for children and should in principles supplement their energy and nutrient needs.

Table 12: Proximate composition of wheat-mango seed kernel (MSK) composite flour cookies

Proximate parameter	Proportion (%) of MSK flour in cookie flour		
	0	20	30
Moisture	4.1±0.43	3.7±0.40	3.7±0.40
Crude protein	5.1±0.40	5.1±0.37	5.0±0.37
Fat	18.6±2.47	19.8±2.02	18.1±1.77
Fibre	0.2±0.03	0.2±0.02	0.4±0.01
Ash	0.9±0.20	0.8±0.01	0.9±0.08
Carbohydrate+	71.2±1.25	70.5±1.10	72.4±1.30
Energy	5.5±0.25	5.3±0.14	5.4±+0.20

Each value is a mean of 4 determinations ± SD

\+ Carbohydrate was determined by difference

3.2.2 Fatty acid composition of cookie fat

The fatty acid composition of the MSK flour substituted cookies are shown in Table 13. The fatty acids in both the 20% and 30% MSK composite flour cookies, in decreasing order of proportion are oleic (18:1), myristic (14:0), stearic (18:0), linoleic (18:2), palmitic (16:0), lauric (12:0), arachidic (20:0) and linolenic (18:3) acids. Butter contains only between 0.5 to 3.0% linoleic acid (Heimann, 1980) while soft margarine depending on the fatty acid components of the vegetable oil from which it is produced, usually contains high levels of slightly shorter chain fatty acids and low levels of unsaturated longer chain fatty acids (Nawar, 1985). It is therefore not surprising that whereas oleic and stearic acids constituted the major fatty acids in MSK fat (Table 8), the cookie oils are predominantly (73%) myristic and oleic acids with stearic, linoleic and palmitic constituting about 20%. The differences in the fatty acid compositions of the MSK fat and the cookie oils appear to be a direct consequence of the margarine used in the preparation of the cookies. It is noted that the levels of oleic acid is high in both the MSK fat and cookie oil extracts.

Table 13: Fatty acid composition (mol %) of mango seed kernel (MSK) composite flour cookie fats.

	Proportion (%) MSK in cookie	
Fatty acid	20%	30%
Lauric(12:0)	2.1	2.2
Myristic(14:0)	36.2	27.2
Palmitic(16:0)	4.0	4.0
Stearic(18:0)	10.3	7.8
Oleic(18:1)	36.9	35.5
Linoleic(18:2)	8.6	8.4
Linolenic(18:3)	0.4	0.4
Arachidic(20:0)	1.6	1.6

Values are averages of 2 determinations

A Hewlett-Packard model 5890 gas chromatograph coupled to a VG Masslab 12-250 mass spectrometer was used to assay for fatty acids. Detection was by flame ionization after elution through a DB-5 column (30m by 0.32 mm id) packed with 10% SP-2330 on 100-200 mesh chromosorb (Supelco Inc. Switzerland). Injection volume was 0.5 ul while gas flow rate was 1.5 ml/minute. The initial oven temperature of 150°C was held for 4 minutes then increased at 5°C per minute to a final temperature of 250°C.

3.2.3 Amino Acid Composition

The amino acid composition of the cookies (Table 14) shows a pattern of occurrence that is similar to that of the MSK protein except that almost all amino acids occurred at lesser amounts in the cookies than in the MSK. Wheat with protein content of 12% contains albumins, globulins, gliadins and glutenins as storage proteins with the last two constituting about 80-85% of the endosperm protein (Haard, 1985). The major amino acids are glutamate, proline, lysine, trytophan and to a lesser extent, cystine, arginine and histidine (Heimann, 1980). The short baking time (8 minutes) not withstanding, the high temperature (375°C) at which these cookies were baked coupled with the dilution of the wheat flour with MSK and other cookie ingredients and interactions such as Maillard's reactions may account for the low levels of amino acids in the MSK cookies.

All the essential amino acids were present in the cookies albeit at levels that are generally lower than those of whole egg protein (FAO, 1957) or FAO Reference protein (FAO, 1970). Since cookies are quite appealing to growing children, it is envisaged that, depending on the quantity consumed, there exists, theoretically though, the possibility for these children to ingest appreciable levels of the essential amino acids necessary for their growth and development. Again, apart from alanine and proline, appreciable levels of other nonessential amino acids (Table 14) occur in the MSK substituted cookies.

Table 14: Amino acid composition of mango seed kernel (MSK) composite cookies (g/100g protein).

Amino acid	Proportion (%) of MSK flour in cookie flour:		
	0	20	30
Isoleucine	2.3	2.1	2.0
Leucine	4.2	2.9	2.8
Lysine	3.1	2.5	2.2
Methionine	0.7	0.9	0.8
Phenylalanine	2.2	2.2	2.2
Tryptophan	1.2	1.2	1.2
Valine	3.0	2.2	2.0
Histidine	2.8	1.7	1.8
Arginine	1.0	2.0	2.0
Threonine	2.2	2.9	2.7
Alanine	-	-	-
Aspartic acid + Asparagine	4.0	4.4	4.0
Glutamic acid + Glutamine	4.8	6.2	6.0
Glycine	2.8	2.6	2.6
Serine	4.8	4.8	4.6
Tyrosine	3.0	2.1	2.0
Proline	3.5	-	-

Values are averages of 2 determinations

- Not detected.

3.2.4 Mineral Content

Table 15 shows the mineral content of the MSK composite flour cookies. The ash contents of these cookies are low when compared to those of the MSK flour. Correspondingly the levels of the minerals, except sodium, are lower in the cookies when compared to their levels in the MSK flour (Table 11). However, this difference is not significant ($P>0.05$).

The high level of sodium in the cookies appear to be a direct consequence of the baking soda in these cookies. Since previous reports on the MSK and its products did not cover mineral contents, it is not possible to relate the current findings on the mineral contents of these cookies to other published work.

The absence of copper in the cookies is expected as both the MSK flour and wheat equally lacked copper (Tables 11 and 15).

Table 15: Contents of some mineral ions (mg/100g) in the mango seed kernel (MSK) composite flour cookies

Mineral	Proportion (%) of MSK flour in cookie:		
	0 (All wheat)	20	30
Calcium	15.0±1.0	30.0±2.4	32.0±2.0
Magnesium	12.8±1.1	14.0±0.5	15.0±1.5
Zinc	1.1±0.1	1.0±0.1	1.1±0.1
Manganese	0.3±0.1	0.3±0.1	0.3±0.1
Iron	3.8±0.3	3.8±0.2	4.0±0.3
Copper	0	0	0
Potassium	48.0±2.1	60.0±3.0	59.8±3.2
Sodium	366.0±3.2	366.0±2.4	376.0±5.1
Phosphorus	367.0±2.2	47.3±2.0	50.0±2.4

Each values is a mean of 6 determinations ± SD

3.2.5 Sensory Attributes

The sensory evaluation result is shown in Table 16. Apart from flavour type, all other sensory attributes were assessed relative to the control. A score of 4.0 is adjudged as being comparable to the control. Scores higher than 4.0 and up to 7.0 were rated as either slightly better (5.0) or much better (7.0) while scores lower than 4.0 were regarded as either slightly poorer (3.0) or much poorer (1.0) than the control.

The all wheat cookies used as control was scored 5.57 corresponding to a flavour type that is closer to butter-like (6.0) than nut-like (5.0). The 20% MSK cookie had butter-like flavour. The 30% MSK cookie also had a score of 5.92; indicating that the flavour type is equally closer to butter-like than nut-like. Comparatively, there was no significant difference ($P>0.05$) between the flavour scores of the different types of cookies (Table 16).

At 20% substitution of MSK flour into wheat, odour was not significantly affected in the resultant cookies (Table 16). When the level of substitution was increased to 30%, the odour differed significantly ($P<0.05$) between the 30% MSK cookies and the control and also between the 30% and 20% MSK cookies.

Although odour alone is not a sole determinant of product quality, composite flour having levels above 20% of MSK flour in such products must take cognisance of the deterioration in odour. It is expected that the use of flavouring agents such as vanilla could enable the masking of the odour of products containing over 20% of MSK flour.

The taste score of the 20% MSK cookies was slightly higher (4.67) than that of the control cookies (Table 16). This difference was not significant (P>0.05). As in odour, substitution at 30% of MSK flour into wheat lowered the taste score of the resultant cookies by about 20%, although the difference was not significant (P>0.05).

The mango seed kernel flour had a characteristic light brown colour as opposed to wheat flour which is whitish in colour. A direct consequence of the colour difference between the MSK and wheat flours is shown in the colour ratings (Table 16). The colour of the MSK cookies (20 & 30%) differed significantly (P<0.05) from the colour of the all wheat cookie. The appearance rating too followed the same pattern as the colour rating. Notwithstanding the colour rating of the MSK cookies, the light brown colour conferred on them a better cookie colour than the whitish all-wheat cookie. The MSK cookies therefore possess an inherent advantage, in terms of colour and appearance, over the all wheat cookie. It appears that there is a strong relationship between colour and appearance because panelists showed preference for the usual brownish colour of MSK cookies.

Table 16: Sensory attributes of mango seed kernel (MSK) composite flour cookies

Sensory Parameter[a]	Proportion (%) of MSK in cookie flour: 0 All wheat (control)	20	30
Flavour	5.57±0.50	6.00±0.78	5.92±0.76
Odour	4.00±0.00[a]	4.33±0.85[b]	3.11±0.57[a]
flavour (taste)	4.00±0.00	4.67±0.94	3.75±1.16
Appearance	4.00±0.00[a]	5.92±0.76[b]	5.73±0.99[b]
Texture	4.00±0.00	4.00±1.08	3.46±0.78
Colour	4.00±0.00[a]	5.27±0.62[b]	5.25±1.42[b]

Each value is a mean of 12 determinations ± SD.

Values with different superscripts in a row differ significantly ($P<0.05$)

a Sensory parameters were rated on a 7-point hedonic scale (Appendix 1)

The texture of the MSK cookies (20 and 30%) were comparable to that of the control (Table 16). The slight difference in texture between the 30% MSK cookie and the other cookies was not significant ($P>0.05$). The brownish colour of the MSK cookies is, native to and characteristic of MSK flour and, an advantage over the whitish coloured wheat.

The consumer acceptance rating of the 0,10,20 and 30% MSK cookies give mean hedonic scores of 5.5±0.98, 5.4±1.17, 5.6±1.03 and 5.5±0.94 repectively. A summary of the statistical analysis (ANOVA) of these results is presented in appendix 1c. The calculated F-ratio value for panelist was 1.38 while the tabular value was 1.32, indicating a significant difference ($P<0.05$) in the panelist scores of the cookie varieties. This observation is consistent with the fact that the consumer panel was untrained. However, the calculated F-ratio for treatment was 0.40 compared to the tabular value of 2.61. Hence no significant difference ($P>0.05$) among the mean hedonic scores of the four cookie varieties. Therefore consumers showed equal likeness for the 0% (whole wheat), 10, 20 and 30% MSK cookies. Whereas, the results of the consumer testing should not be used to predict the performance of the MSK cookies in the market place, it is important to note that the MSK flour appears to have a potential as non-wheat component of composite flour in cookie making.

3.2.6 Sorption Isotherm of Cookies

In an attempt to predict the storability of the MSK cookies the sorption isotherms shown in Figures 2 and 3 were obtained at

25 and 30°C respectively. The isotherms have the usual sigmoidal shape, showing gradual increases in equilibrium moisture content (EMC) at low relative humidity (RH) values (10-45%) at both temperatures. However, at RH values above 65%, slopes of the isotherms are much steeper, indicating large increases in EMC per

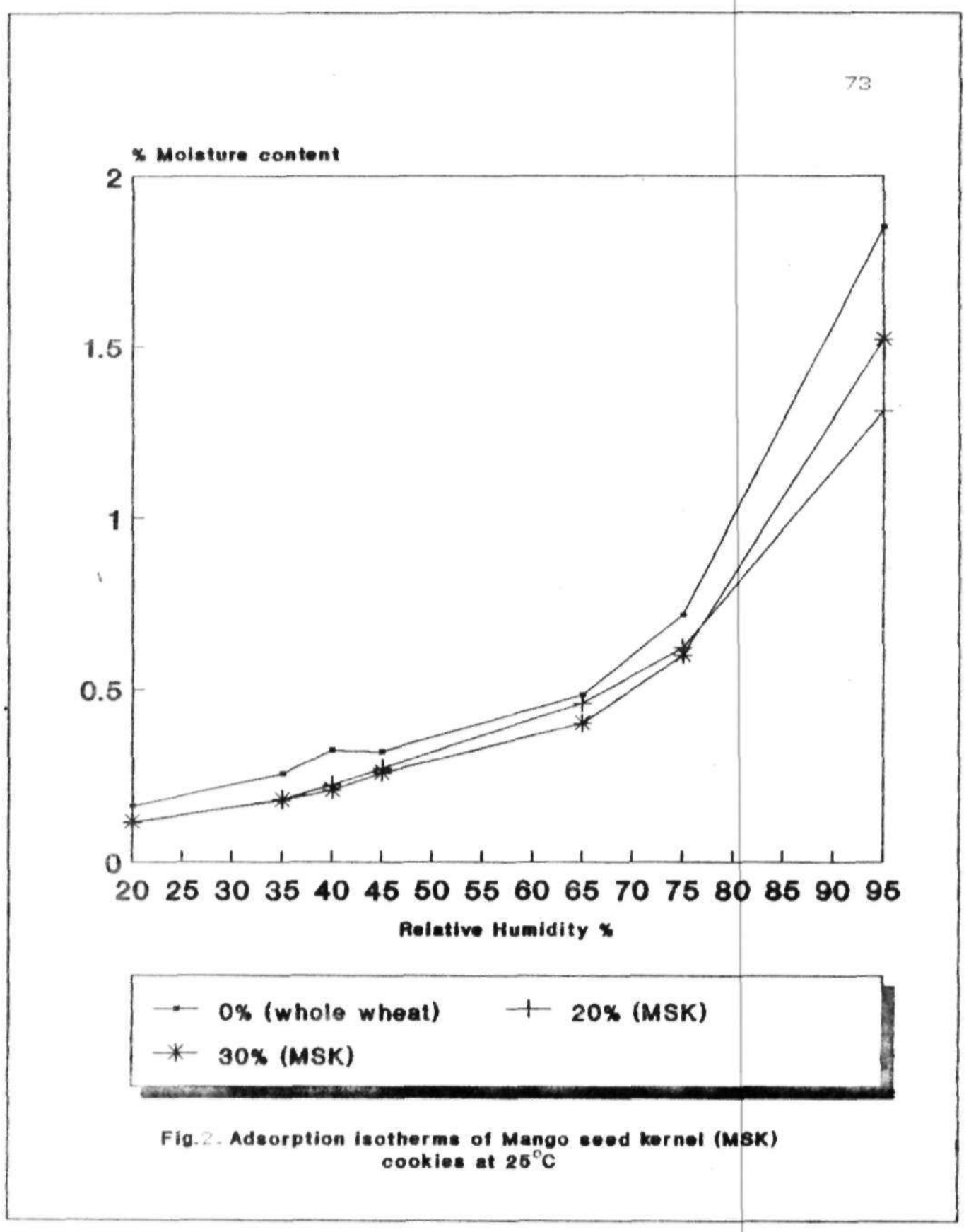


Fig.2. Adsorption isotherms of Mango seed kernel (MSK) cookies at 25°C

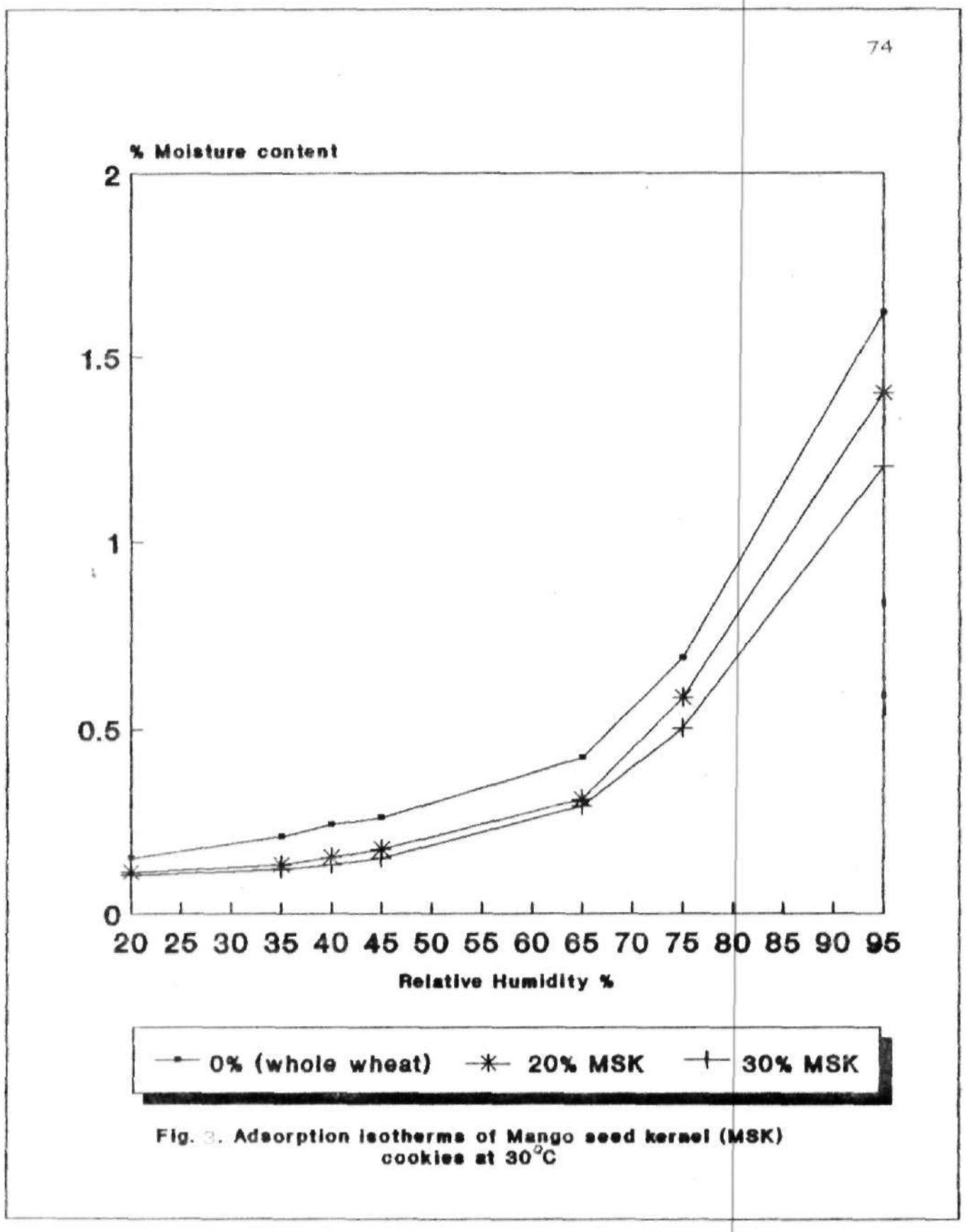


Fig. 3. Adsorption isotherms of Mango seed kernel (MSK) cookies at 30°C

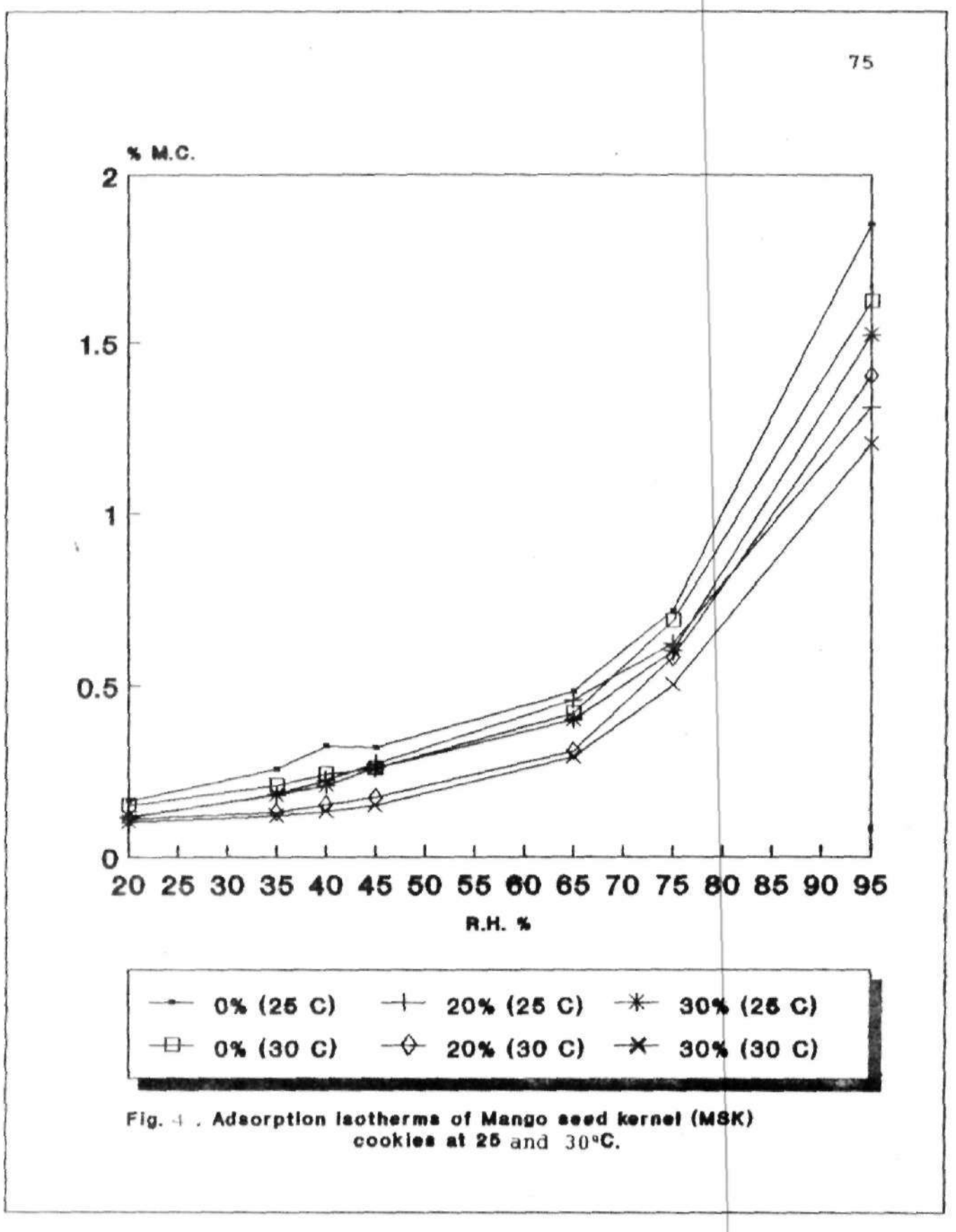


Fig. 4 . Adsorption isotherms of Mango seed kernel (MSK) cookies at 25 and 30°C.

unit increase in RH. These observations suggest that fluctuations in temperature and environmental RH will greatly affect the storability of the cookies. There is a shift to lower EMC as the temperature increases at a given RH value (Figure 4). This observation is consistent with the findings on most foods (Fennema, 1985; Achoba *et al.* 1991).

At a particular RH and a given temperature, there is a shift to lower EMC as the level of substitution of MSK increases (Figures 2 and 3). This observation suggests that the 20% MSK cookies have higher storability prospect than the 30% MSK cookies. Again, Fennema (1985) defined the monolayer moisture content of foods as " the moisture that corresponds to the maximum amount of water that can be very strongly bound to dry matter". At 25°C the monolayer moisture contents, calculated using the equation of Brunauer *et al.* (1938), decrease with increase in substitution levels of MSK (Table 17). This implies that shelf-life of the cookies will decrease as the level of substitution of MSK into cookies increases, because product cannot tolerate much water or humidity.

Table 17: Effect of level of mango seed kernel (MSK) flour on the BET* monolayer moisture content of cookies.

Percentage of MSK in cookie flour.	monolayer moisture content (M_1) ($gH_2O/100g$ dry sample)
0	21.8
20	18.4
30	13.3

Values are averages of 2 determinations.

* Brunauer, Emmet and Teller (Brunauer *et al.* 1938)

The cookies became mouldy on the 5th and 14th days of storage at 95% & 75% RH respectively. The major fungal contaminants were *Aspergillus flavus*. The proliferation of mould at 75 and 95% RH is as a consequence of the high moisture content of the cookies. This is in consonance with the report of Beauchat (1981) who in the grouping of various common microorganisms and the range of water activity permitting their growth in the different foods, categorised country-style cookies as low moisture foods that would only be free of microbial proliferation at water activity (a_w) range of 0.20 to 0.50. This study has therefore corroborated the reports of Labuza *et al.* (1970 and 1972) and Fennema (1985) in establishing that food stability and water activity are closely related especially in low-moisture foods.

CHAPTER FOUR:

CONCLUSION AND SUGGESTIONS

4.1 CONCLUSION

It is a fact that the most compelling problem of developing nations is food and nutrition. Food and nutrition problems readily translate into malnutrition and the attendant diseases especially for the high risk groups in the population. Hence, pregnant and lactating women and particularly children are easy victims of protein energy malnutrition (PEM). Research efforts and policies aimed at solving the problem of food and nutrition as well as PEM particularly among children have focussed on various options among which cheap but abundant local food sources of nutrients are the least recogized.

The Mango (*Magnifera indica*) seed kernel (MSK) is an unutilized but abundant agricultural produce in several developing countries especially Nigeria where the mango tree grows all over the country. Efforts made to incorporate MSK into some traditional Indian snack foods (Dhingra and Kapoor 1985b) revealed some of the nutritional potentials as well as the limitations (Okai and Aboagye, 1990: Das *et al*. 1988) to the use of MSK in human food.

Only the fat and carbohydrate contents of the MSK appeared to vary significantly ($P<0.05$) with the specie or source of the MSK. Nutrient variations as a consequence of source or specie of the MSK was generally not significant ($P>0.05$). Hence, commercial or large scale application of MSK for purposes of food or feed would

naturally involve mixed variety MSK because of the logistics of separating the MSK according to variety and source.

The results of this work agreed with and confirmed earlier reports (Dhingra and Kapoor, 1985a; Augustin and Ling, 1987) that the MSK is rich in proximate nutrients. The total carbohydrate content (33.0%) and the high caloric energy (4.4 Kcal/gm) of the MSK reveal the potential of this agricutural product as a caloric supplement especially in children. With a protein and fat contents of 6.0 and 12.8% on moisture free basis respectively, MSK holds great deal of potential as a source of these nutrients because all the essential amino acids (eaa) were present (except for phenylalanine, methionine and valine) at levels comparable to the FAO Reference protein (FAO, 1970). Stearic and oleic acids both constitute about 84% of the fatty acids in the MSK fat. The high level of stearic acid fraction (46.3%) in the MSK makes it a potentially important commercial fat in the confectionery industry. However, a striking difference between previous studies (Van Pee *et al.* 1981; Moharran and Moustafa, 1982) and the current finding appears to be the quantifiable level (0.6%) of behenic acid (22:0) detected.

Although, calcium, magnesuim, zinc, manganese, iron and sodium were low in the MSK, the levels of potassium and phosphorus were 356.7 and 132.8mg/100g respectively, indicating that the MSK is a rich source of these minerals which are known to play structural roles in the development of soft and hard tissues respectively.

The occurrence of tannins in MSK was circumvented by the effective and significant ($P<0.05$) removal of this antinutritional factor by treating the MSK flour with water at 70°C for 30 minutes. Tannin free MSK flour was substituted at 20 and 30% levels into wheat as composite flour for making cookies; a convenient snack food that may appeal greatly to children.

The composite cookies with 5.3 Kcal/g energy and 70.5% moisture free carbohydrate should in principle supplement the energy needs of children. Other nutrients theoretically derivable from the MSK cookies are protein (5.1%) and fat (19.8%). All the essential amino acids were present in the cookies albeit at levels that were lower than those of whole egg (FAO, 1957) or FAO Reference protein (FAO, 1970).

Therefore, depending on the quantity consumed, the MSK cookies could possibly supply reasonable levels of nutrients especially the amino acids and energy required by growing children. Although previous reports on the MSK and its products did not cover minerals contents, the levels of the minerals in the MSK cookies appeared to be of a similar pattern to their occurrence in the MSK except the significantly ($P<0.05$) higher level of sodium in the cookies which is a direct consequence of the baking soda in the cookie recipe.

The light brown 20% MSK cookies were not just preferred to the whitish whole wheat (control) cookies in terms of colour but were rated comparable and acceptable in terms of overall acceptability by the sensory evaluation panel. Children are

therefore likely to show similar preference for the MSK cookies because of this inherent light brown colour of the MSK.

The MSK cookies, as low moisture foods, easily pick up moulds at high relative humidities (75% and above). Hence, fluctuations in environmental RH and temperature do adversely affect the storability of the cookies. Despite the similarities in the sorption isotherms of the cookies compared to those of other snack foods (Fennema, 1985; Achoba, *et al.* 1991) the monolayer moisture contents of the MSK cookies, decreased with increase in the levels of MSK in the cookies. This implies that the shelf-life of the cookies will decrease as the level of substitution of MSK into cookies increases because the product cannot tolerate much water or humidity.

The results of this study have confirmed that the mango seed kernel is a cheap, abundant and locally available source of several nutrients. Hence, not withstanding the limitations of its tannin content and the cultural inhibitions, on substitution of washed MSK into convenient snack foods, appreciable levels of some nutrients and energy would be derived especially by the vulnerable group.

As a pioneer study in Nigeria, these findings should generate awareness necessary for the industrial and fuller nutritional utilization of the MSK.

4.2 SUGGESTIONS

Lack of high precision equipments such as GC-MS, HPLC, Amino acid Analyzer e.t.c. appeared to have placed serious limitations to the scope of this work. Consequently, effect of storage on the nutrient composition of both the MSK and the MSK cookies were not investigated. For instance, the fatty acid profile of foods are known to change on storage (Nawar, 1985) and such changes not only provide explanation for the development of rancidity in oily foods but also determine shelf-life.

The investigation of more varieties of the MSK, different substitution levels of the MSK into cookies and the development of other snack foods as well as animal feeds could not be carried out in the present study because the foreign laboratories could only accept limited number of samples.

One major restraint to the utilization of novel foods is the bioavailability of its nutrients. Increasing dietary MSK (above 20% levels) decreased growth rate, blood glucose and plasma protein concentrations, caused hypercholesterolaemia and pathological changes in the tissues of chicks (Das *et al.* 1988), rats (Geetha and Devi, 1986), milch cows (Patel *et al.* 1970), ruminants (Punj, 1988) and pigs (Gupta, 1988). These pathologies are ascribed to the tannin content of MSK.

Despite the removal of tannins from the MSK in this study, there is yet the need to undertake animal studies on the tannin free MSK and its products to determine bioavailability of the MSK nutrients and their efficiency in promoting growth and development without deleterious pathological effects.

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APPENDIX 1a

DEPARTMENT OF BIOCHEMISTRY
AHMADU BELLO UNIVERSITY, ZARIA

ORGANOLEPTIC EVALUATIONB SHEET

Initial of Panelist: _____ Date:_____

1.	SCORE	FLAVOUR TYPE	A	B	C	D	E	F
	7	Bean-like	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	6	Butter-like	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	5	Nut-like	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	4	Seed-like	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	3	Raw	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	2	Foreign	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	1	Unclassified	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

2a	SCORE	ODOUR DESCRIPTION	A		B		C	D	
	7	Much better	[]	[]	[]	[]	[]	[]	
	6	Better	[]	[]	[]	[]	[]	[]	
	5	Slightly better	[]	[]	[]	[]	[]	[]	
	4	Comparable	[]	[]	[]	[]	[]	[]	
	3	Poorer	[]	[]	[]	[]	[]	[]	
	2	Much poorer	[]	[]	[]	[]	[]	[]	
	1	Extremely poor	[]	[]	[]	[]	[]	[]	

2b	SCORE	ODOUR (TASTE) DESCRIPTION	A	B	C	D	E	F
	7	Much better	[]	[]	[]	[]	[]	[]
	6	Better	[]	[]	[]	[]	[]	[]
	5	Slightly better	[]	[]	[]	[]	[]	[]
	4	Comparable	[]	[]	[]	[]	[]	[]
	3	Poorer	[]	[]	[]	[]	[]	[]
	2	Much poorer	[]	[]	[]	[]	[]	[]
	1	Extremely poor	[]	[]	[]	[]	[]	[]

3	SCORE	APPEARANCE RATING	A	B	C	D	E	F
	7	Much better	[]	[]	[]	[]	[]	[]
	6	Better	[]	[]	[]	[]	[]	[]
	5	Slightly better	[]	[]	[]	[]	[]	[]
	4	Comparable	[]	[]	[]	[]	[]	[]
	3	Poorer	[]	[]	[]	[]	[]	[]
	2	Much poorer	[]	[]	[]	[]	[]	[]
	1	Extremely poor	[]	[]	[]	[]	[]	[]

4	SCORE	TEXTURE	A	B	C	D	E	F
	7	Much better	[]	[]	[]	[]	[]	[]
	6	Better	[]	[]	[]	[]	[]	[]
	5	Slightly better	[]	[]	[]	[]	[]	[]
	4	Comparable	[]	[]	[]	[]	[]	[]
	3	Poorer	[]	[]	[]	[]	[]	[]
	2	Much poorer	[]	[]	[]	[]	[]	[]
	1	Extremely poor	[]	[]	[]	[]	[]	[]

5	SCORE	COLOUR RATING	A	B	C	D	E	F
	7	Much better	[]	[]	[]	[]	[]	[]
	6	Better	[]	[]	[]	[]	[]	[]
	5	Slightly better	[]	[]	[]	[]	[]	[]
	4	Comparable	[]	[]	[]	[]	[]	[]
	3	Poorer	[]	[]	[]	[]	[]	[]
	2	Much poorer	[]	[]	[]	[]	[]	[]
	1	Extremely poor	[]	[]	[]	[]	[]	[]

Appendix 1b

Department of Biochemistry
Ahmadu Bello University, Zaria

Ballot for Cookie Products Hedonic Test Using 7-Point Scale

Name/Initial_____
Date:_____

Please look at and taste each sample of cookies in order from left to right as shown on the ballot. Indicate how much you like or dislike each sample by checking the appropriate phrase under the sample code number.

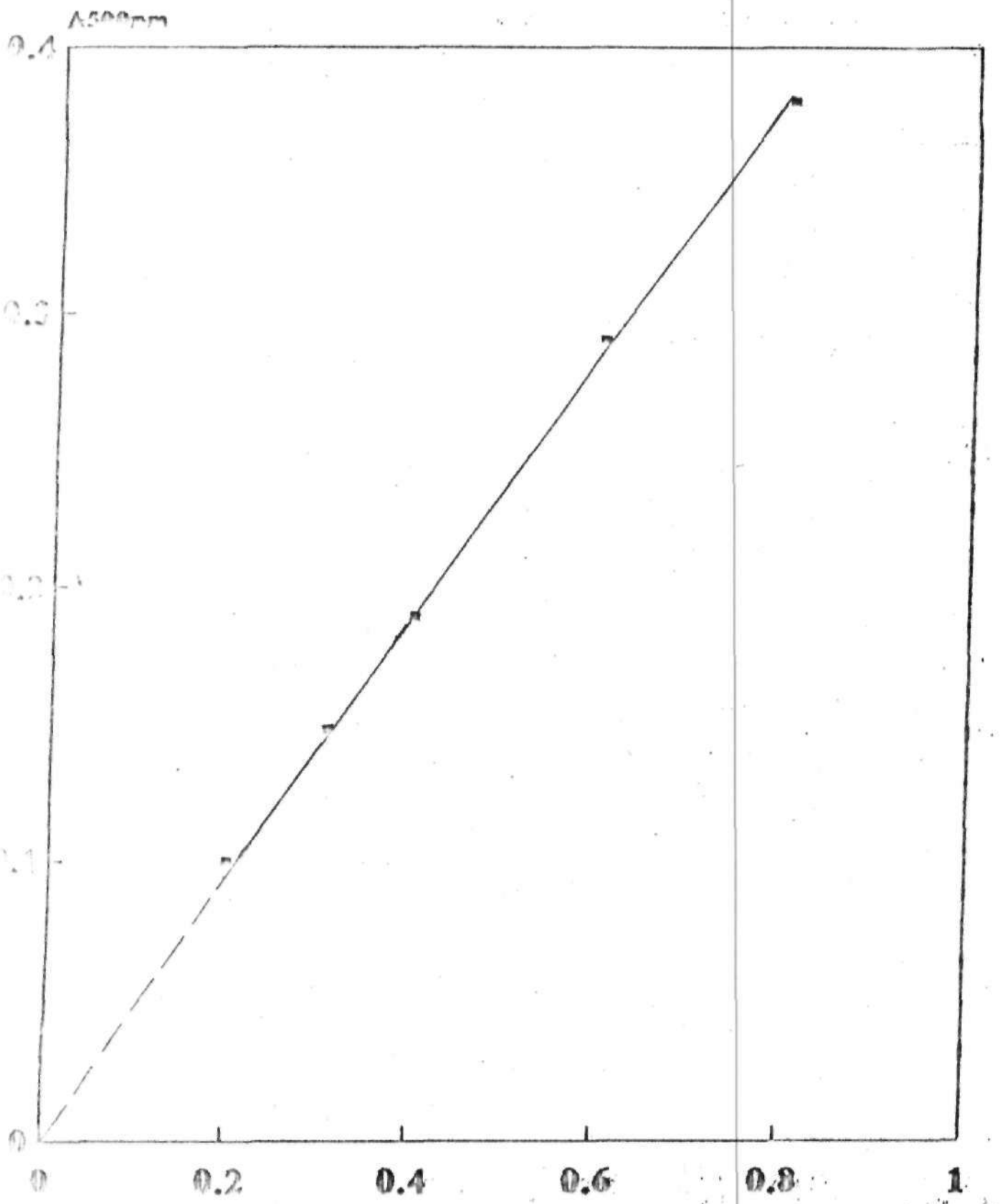
Code_____	Code_____	Code_____	Code_____
____ Like extremely	____ Like extremely	____ Like extremely	____ Like extremely
____ Like very much	____ Like very much	____ Like very much	____ Like very much
____ Like slightly	____ Like slightly	____ Like slightly	____ Like slightly
____ Neither like nor dislike	____ Neither like nor dislike	____ Neither like nor dislike	____ Neither like nor dislike
___ Dislike slightly	___ Dislike slightly	___ Dislike slightly	___ Dislike slightly
___ Dislike very much	___ Dislike very much	___ Dislike very much	___ Dislike very much
___ Dislike extremely	___ Dislike extremely	___ Dislike extremely	___ Dislike extremely
Comments:	Comments:	Comments:	Comments:

Appendix 1c

ANOVA Table for the Hedonic Testing of Cookies

Source of variation	df	SS	MS	F ratio Calculated	Tabular(P<0.05)
Total	223	242			
Treatment	3	1.2	0.40	0.40	2.61
Panelist	55	75.7	1.38	1.38	1.32
Error	165	165.1	1.00		

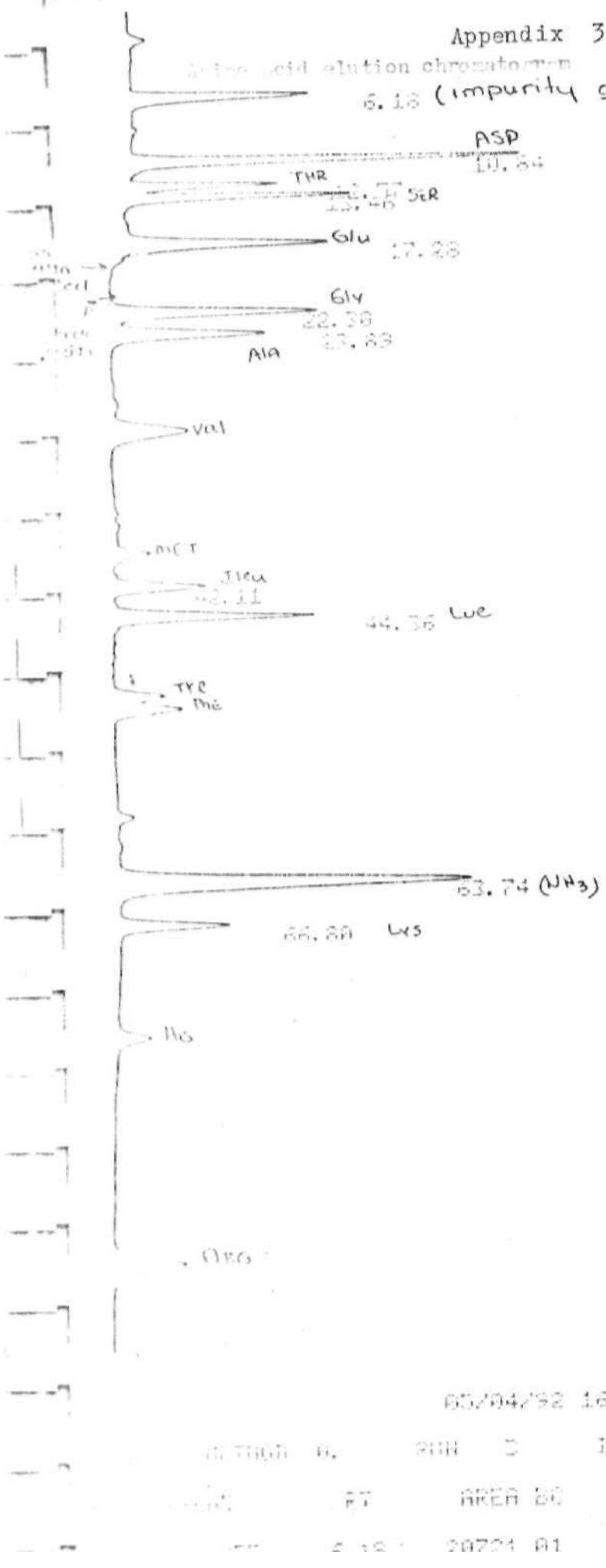
Appendix 2



Standard Curve for the estimation of tannin as catechin equivalent

Appendix 3

Amino acid elution chromatogram



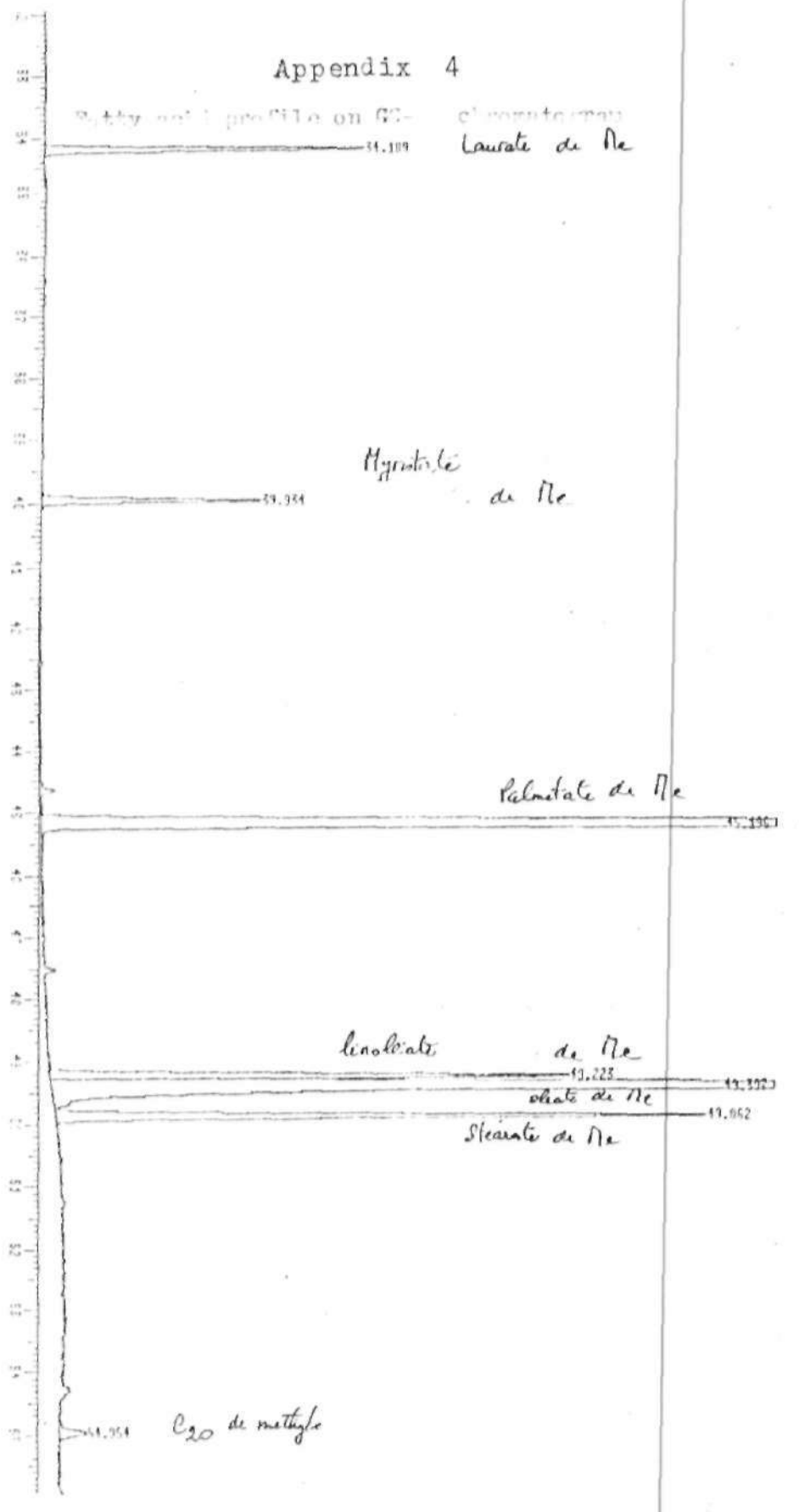
05/04/92 16:50:08 CH= "A" FS= 1.

METHOD A. RUN 3 INDEX 3

PT AREA %

6.18 20721 81

Appendix 4



End of plot. Time = 0.15 to 55.35 minutes Chart speed = 1.35 cm/min