ANTINUTRITIONAL AND PHYSICOCHEMICAL PROPERTIES OF FLOURS BLENDED FROM SELECTED TROPICAL TUBERS AND PROCESSED BAMBARA GROUNDNUT (*Vigna subterranean*).

BY

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CERTIFICATION

This is to certify that this project on Antinutritional and Physicochemical properties of flours blended from selected tropical tubers and processed bambara groundnut (*Vigna subterranean*) is the original work approved and carried out by Elochukwu Chinwe, Registration No, 20064567608 under the supervision of Prof.C.I. Iwuoha in the Department of Food Science and Technology, School of Engineering and Engineering Technology, Federal University of Technology, Owerri.

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DEDICATION

This project is dedicated to GOD Almighty for making me to fulfil this programme and to my husband Engr.Emmanuel Elochukwu for his relentless effort and care.

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ABSTRACT

Some selected tropical root and stem tubers (cassava, cocoyam, sweet potato and yam) were dried and processed into flours. The cassava tuber was processed into flour using the high quality grading method. Bambara groundnut was processed to obtain the conventional bambara groundnut flour, bambara groundnut cotyledon flour and the steamed bambara groundnut cotyledon flour. Composite flours were formulated using each of the root tubers and each of the bambara groundnut treatments in the ratio of 100:0, 75:25, 50:50, 25:75, and 0:100. The proximate composition, physicochemical properties and anti-nutritional properties of the blended and unblended flour samples were evaluated. Nine (9) flours selected from the treatments were subsequently used for cake production. Results showed that blending of tuber flours with treated and non treated bambara groundnut flours was found to significantly ($P<0.05$) effect the proximate composition, physicochemical properties and antinutritional composition of the tuber flours. The magnitude of the effect was dependent on the tuber/legume blending ratio. Sensory evaluation of cake from the nine selected flours revealed that the mean score of the overall acceptance of the queen's cake ranged from 3.27 ± 1.62 to 8.29 ± 0.59, with the composite flour from sweet potato and steamed bambara cotyledon at the ratio of 75:25 being generally accepted just as the wheat flour queen's cake.

Key words:
Processed bambara groundnut, tropical tubers, antinutritional factors, physicochemical properties, composite flour, flour ratios.

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CHAPTER 1

INTRODUCTION

Tropical root crops are consumed as subsistence products in the tropical world with about 3 billion people consuming these crops on a fairly regular basis. The most important in terms of tonnage production in developing countries are cassava, potato and sweet potato while other major crops such as yam and cocoyam are important foods in certain areas, their level of production are considerably less (Onwueme and Sinha,1991).The key to efficient storage and utilization is processing.Food processing can be defined as the application of scientific principles to the preservation or modification of food to make safe, appealing products with a uniformly high quality. It also requires the creative imagination of the processor to provide customers with an interesting variety of foods in their diet (Fellows, 1997). Among the tropical tuber crops, cassava (*Manihot esculenta Crantz*) is one of the most important staple food crops grown in tropical Africa. Nigeria is the largest producer of cassava in the world with an output of 44 million tonnes (CBN statistical report, 2004). As a result of its efficient production of food energy, year round availability, tolerance to extreme stress conditions and suitability for present farming and food systems in Africa, cassava is playing a major role in efforts to alleviate the African food crisis. Internally the market for cassava is very bright particularly with the Federal Government policy of

blending of 90% wheat flour with 10% cassava flour. Cassava varieties have been long classified as either bitter (high HCN) with higher than 20mg/ 100g fresh weight of cassava root tubers or sweet types (low HCN) with less than 10mg/100g fresh weight of cassava tubers (Hahn, 1984). The short shelf life of cassava tubers calls for the need of processing into products with longer shelf life. Cassava can be processed into flour, flakes, chips, starch, alcohol, etc. According to Raemaeker (2001) the food value of cassava root is fairly low. Apart from 61% water it contains mainly starch (33.6%), cellulose (2.6%), protein (1.2%), fat (0.4%) and minerals (1.2%). Cassava is often blamed for causing protein deficiency diseases when eaten as a staple food and that is why there is urgent need for fortification.

Yams are among the oldest recorded tropical food crops. Various species of food yams in the genus *Dioscorea* are cultivated in the tropics and sub- tropics (11TA, 1992). The six most economically important species grown as staple foods in Africa are*: D. rotundata* Poir (white guinea yam), D. *cayenensis.* Lam. (yellow yam), *D. alata* L. (water yam), *D. esculenta* (Leur) Burk. (Chinese yam), *D. dumetorum (Kunth*) Pax (bitter yam) and *D. bulbifera* L. (aerial yam) (Onwueme ,1978). These 6 species constitute over 90% of the food yams produced in the tropics. Almost all *Dioscorea spp*. contain bitter alkaloid called dioscorein,which gradually diminished and disappears at maturity in most cultivated varieties (Asiedu, 1997). Yam is

more appreciated in many countries since about 85% of its tuber is edible. This part composed principally of 65-75% H_2O, 15-23% starch, 2.5% protein, 0.5-1.5% fibre, 0.7-2% ash and 0.05-0.2% fat. In addition yam contains 4-12mg /100g ascorbic acid and vitamin B. As far as protein is concerned yam is deficient (Raemaekers, 2001) and that is why there is need for its fortification in order to enrich it.

Sweet potato (*lpomoea batatas*) is another tropical tuber from the genus of *Ipomoea*. There are three main groups of cultivars. These are recognized depending on differences between them in texture, colour and palatability of their tubers. One group has tubers with hard, dry flesh which is often yellow, another has tubers which are coarse, fibrous, unpalatable flesh; while the third has soft tuber which is white or orange water flesh which is sweet when cooked (Cobley, 1976). According to Reamaeker (2001) the water content of this tuberous root varies from 57 to 78% of the fresh weight. The remaining is made up mainly of starch (13-33%), sucrose (2.6-6.0%), reducing sugar (0.3-0.8), minerals (0.8-2.2%) as well as protein (0.8-2.2%) and cellulose (0.9-1.2%). Carotene content of the tubers varies between O and 24mg per 100g of fresh tuber. The ascorbic acid content (vitamin C) varies between 23 and 43mg/100g. The tubers can be processed into flours and the sweet potato flour is easy to store.

Cocoyam (*Colocasia esculenta*) is another tuber crop, which belongs to the family of *Araceae*. Cocoyam as a food provide easily digested starch and contain relatively high levels of protein compared with most root crops although the protein they contain is not adequate on its own and should be supplemented with good protein pulses. There are three major species: 'old' cocoyams, *Colocasia esculenta* and C*olocasis antiquorum* and 'new' *Cocoyams xanthosoma* (Mayhew and Penny, 1988). The skin of cocoyam is known to contain high levels of oxalates. Apart from calcium oxalates other toxins such as saponin are found present in cocoyam and can be removed by prolonged soaking (Irvine, 1979). However taro is never eaten raw. They are either boiled or baked before they are eaten. In Nigeria, cocoyam is a neglected crop and does not compete favorably with other root crops (yams and cassava) in terms of production and consumption because of its high perishability (Onwueme, 1978). Usually farmers helplessly watch their stored cocoyam rot away because routine methods of processing and consumption of cocoyam are inadequate to utilize all the cocoyam produced. It is important to explore industrial uses of cocoyam.

Bambara groundnut(*Voandzeia subterranea*) is a tropical food legume, a member of the family of *fabaceae.* This little known vegetable has the potential to improve nutrition, boost food security, foster rural development and support sustainable land care (National Research Council, 2006). Due to

the high price of meat and fish, much importance is now placed on grain legumes as a source of proteins in all the developing countries. The nutritional value of the legume seeds is restricted by the presence of anti-nutrients such as substances that inhibit the action of pancreatic proteases (trypsin inhibitors), blood-clotting substances (haemagglutinin), polyphenols, phytic acid, cynaogenetic glucosides and flatus factors (Borget,1992) but these antimetabolites has been substantially decreased in many species by selection and breeding (Cobley,1976). Bambara groundnuts are grown primarily for their seeds which may be eaten raw when immature but becomes too hard when mature. When roasted or boiled, even the mature seeds are sweet and pleasant tasting. The seeds are often roasted and ground into flour.

They make a well-balanced food with a caloric value equal to that of a high quality cereal grain (FAO, 1988). As mentioned by Enwere and Hung (1996) the proximate composition of the bambara groundnut seed was found to be 9.7% moisture, 16.6% protein, 5.9% fat, 2.9% ash, 4.9% crude fibre and 64.9% carbohydrates and Purseglove (1991) claims that the above composition of bambara groundnut makes the food legume a complete balanced food. The grain legume are useful sources of thiamine (VitaminB_1) ,carboxylase niacin,(Vitamin B_6) and of calcium. The seed coats are used to identify their varieties. The varieties of bambara groundnut are BBG, BBFG,

BSWH (black seed coat-white hilum), CSCH (cream seed coat-cream hilum) and PSWH (purple speckle on cream seed coat-white hilum. Bambara groundnut is cultivated mainly for local production but seldom on a large scale.

In this project four different root crops (cassava, yam, sweet potato and cocoyam) will be blended with three different bambara groundnut treatments to obtain different ratios of the flour blends. The antinutritional, proximate and physicochemical properties of the flour blends will be determined in order to envisage the proper mixture of the flour blends. This will create room for an improved and fortified mechanism for the use of the above root crops and bambara groundnut. Although studies have been done on composite flour, but they were still interested in the wheat as the major flour in the composite flour thus leaving the wheat flour problem partially solved. For instance. Akinmande *et al.*(2007) produced bread with a flour blend of wheat/tiger nut composite, Agu *et al*.(2007) produced bread with wheat/fluted pumpkin seed flour, Alozie *et al.*(2009) produced bread with wheat/bambara groundnut composite flour, Sanful *et al.*(2010) produced rock cake with a composite flour blend of wheat , cassava and cocoyam and many more ,but these have not really solved the problem of wheat since from the samples produced the ones found more acceptable by the consumers are those in which the percentage of wheat used were between 70 -90%.

In trying to investigate the different flour blends, a number of criteria will be considered in the selection of proper blend. These include:

- The blend with the highest nutritional content.
- The blend with the least quantity of antinutritional factors.
- The blend that will have a longer shelf life.
- The blend that will yield the appropriate physicochemical properties suitable for baking. .

1.1 Statement of the problem

Nigeria is one of the highest producers of most of the tropical root crops, but the greatest problem she is facing is the issue of post harvest losses. A report reveals that the post harvest losses resulting to about 40% of the total harvest products every year are obtained in the country. There are no super storage systems and so one of the ways of reducing these post harvest losses is to process these fresh tropical root crops into diverse flour products for easy storage, transportation and year-round availability. Another problem prevalent in the third world countries is the issue of malnutrition with special attention on protein availability. It has been scientifically declared that bambara groundnut is high in protein quotient particularly in methionine which makes its protein more complete and substantial than any other legume (Yusuf *et al*, 2008).This crop is an assuring crop for the poor people and a great answer to the challenging and devastating problem of malnutrition

which grips the people who are unable to make a healthy nutritious diet. Another problem is the dangers associated with long-time standing practices of the sole use of wheat flour for baking. There is an urgent need now for the creation of diversity of flours for baking in order to combat the food insecurity in the country.

1.2 Objectives

The objectives of this project may be stated as follows:

- To determine the antinutritional and proximate composition as well as physicochemical properties of some tropical tuber flours blended with heat processed bambara groundnut flour.
- To determine the optimum ratio of combination of various tuber flours with treated bambara groundnut flours consistent with low antinutritional composition and optimum physicochemical and nutrient quality.
- To establish the sensory properties of cake made with tuber/bambara groundnut composite flour blended at optimum ratio.

1.3 Justification

Nigeria is a non-wheat producing country and hence relies on wheat producing countries for her wheat need. She spends a lot of money yearly on importation of wheat. Being one of the highest producer of most tropical crops, there is a need to develop a food product of higher nutritional value from a blend of some of these tropical root crops (cassava, yam, sweet potato, and cocoyam) and an indigenous legume (Bambara groundnut) in order to combat the food crisis in the Nation. Fortification of tuber flours with legumes flours will enhance food availability, human capital development, and boost nutrient composition of flours, cost effective since the raw materials are all available in the country, poverty and hunger eradication which will help achieve the aim of food security. This is because flour is consumed by a large segment of the world population in various forms which includes bread, pasta products, cakes, cookies and also in the form of 'fufu' and other products.

The under-utilization of these tropical root crops and bambara groundnut needs to be harnessed. The industrial use of cocoyam, sweet potatoes and bambara groundnut will go a long way in reducing their post harvest losses as well as minimize wheat flour importation.

Successful production of acceptable product with an enhanced shelf life will provoke the root crop and bambara groundnut farmers to increase their production. They will meet both the local and global demands since the products can be transported beyond the shores of the nation. This will lead to employment generation and economic empowerment at the grassroots and boost in the foreign exchange receipts for the country. If the product is accepted, then bambara groundnut will no longer be regarded as a poor man's food but rather it will have an industrial usage.

CHAPTER 2

LITERATURE REVIEW

Legumes are important dietary source of protein calories and other nutrients for humans' population in many developing countries. They have a production cycle which is continuous or semi-continuous and this helps to avoid storage problems and provide increased food security for the poor especially during periods of food shortage. The incidence of protein malnutrition is very prevalent especially in Nigeria where diet is very low in protein. The protein malnutrition coupled with calories deficiency and shortage of other essential nutrients is wide spreading in many developing countries. These protein deficiencies have resulted to decreased rate of resistance to infections and parasitic diseases (Zamora and Field, 1997). The use of legumes for enrichment of local starchy staples should be encouraged since the nutritive values of the starchy staples will be improved (Alozie *et al*.2009).

According to Onimawo *et al.*(1998), legumes are generally classified into two main types viz those containing high protein and high oil content such as soybeans and groundnut, etc and those containing moderate protein and low oil content example bambara

groundnut. Bambara groundnut falls into the second group because it contains 20g/100g protein and 6g/100g fat. It is the legume of interest in this project.

2.1 Bambara Groundnut (*Voandzeia or Vigna subterranea*).

Bambara (also spelled Bambarra) groundnut has many common names such as Congo groundnut, Congo goober, Madagascar groundnut, earth pea, Baffin pea, Njugo bean (S. Africa), Wondrous, Nzama(Malawi), Indhlubu, underground bean (Stephen,1994) and Okpa "Otu anya" Igbo (in Nigeria), etc. is a member of the family *Fabaceae*. The plant originated in West Africa and still a traditional food plant in Africa

Bambara groundnuts are reported to be the third most important leguminous crop south of the Sahara being superseded only by cowpeas and groundnuts. The legume is indigenous to tropical Africa but is now found in Asia, parts of North Australia, South and Central America (Kay,1979). Most of the production is consumed domestically. Bambara groundnuts do not usually enter international trade although there have been several unsuccessful attempts to develop exports to Europe for use as an animal feeding stuff. It has lost importance in many parts of Africa because of the expansion of groundnut production, but in recent years

there has been renewed interest in the crop for cultivation in the arid savanna zones because of its resistance to drought conditions and ability to yield a reasonable crop when grown on poor soils (Kay, 1979). Little work has been done in the agronomy of the crop and its improvement and there is urgent need to develop improved cultivars (Kay, 1979).

The use of this legume is considered in this study because it is underutilized when compared to other legumes (Ihekoronye and Ngoddy, 1985). Bambara is grown extensively in Nigeria (Oguntunde, 1985; Enwere, 1998) but it is one of the lesser utilized legumes in Nigeria (Olapade and Adetuyi, 2007).) The legume is very rich in protein (15%) and it is cheap to procure. Nigeria produces over 100,000 metric tonnes closely followed by Niger with 30, 000 metric tonnes and Ghana with 20, 000 metric tonnes (Asiedu, 1989).

2.1.1 Description

The leguminous crop (Bambara groundnut) is grown for its underground seeds. The entire plant is similar to the common peanut, being a low flat annual with compound leaves of three leaflets. Like the peanut, it forms pods and seeds on or just below the ground (Stephen, 1994). The pods are round, wrinkled and over ½ inch long. Each

contains one or two seeds that are round, smooth and very hard when dried. The seeds are coated with tough, granulated yellow external surface with colours ranging from yellowish- white, clear yellow and redish pink. They are globular or ovoid in structure (Borget, 1992).

2.1.2 Varieties

The seed coats are used to identify their varieties it can vary in colour from white, creamy to dark brown, red or black and may be speckled or patterned with a combination of these colours. With most cultivars there is a marked white hilum which in light coloured seeds is sometimes surrounded by a black or brown eye. The varieties of bambara groundnut are BBG, BBFG, BSWH (black seed coat- white hilum),CSCH (cream seed coat-cream hilum) and PSWH (purple speckle on cream seed coat- white hilum).

2.1.3 Chemical Composition

The ripe seeds contains on the average 10% water, 15-20% protein, 4-9% fat, 50-65% carbohydrates and 3-5% fibre. The proteins of the grain legumes contain relatively more of the essential amino-acids lysine and tryptophan and so usefully complement the amino-

acids supplied by cereals in which the contents of lysine and tryptophan are relatively small. On the other hand the proteins of grain legumes contain relatively small proportions of the sulphur- containing amino acids methionine, cystine / cyestine. Grain legumes are useful sources of thiamine (vitamin B_1), carboxylase, niacin (vitamin B_6) and calcium (Cobley,1976).

According to National Research Council (2006) the seeds contain 14- 24% protein and about 60% carbohydrates. The protein is reported to be higher in essential amino acid methionine than other grain legumes. Bambara groundnut contains 6-12% oil which is less than half of the amount found in peanuts making them not useful as an oil seed crop. According to Purseglove (1991), the ripe seed contains 16-21% protein, 4.5-6.5% fat, 50-60% carbohydrate thus providing a completely balanced food. Little or no work has been done on the improvement of the crop except some sorting and testing of cultivars in Zambia.

Kay(1979) reported the proximate composition of the grain legume as follows: moisture 11%, total carbohydrates 61.7%, fat 6.3%, protein 17.7%, fibre 4.9%, ash 3.3%, thiamine 0.28 mg/100g, riboflavin 0.12mg/100g, niacin 2.1 mg/100g, vitamin A 30 iu/100g, ascorbic acid

1.0mg/100g, calcium 73mg/100g, Iron 7.6mg/100g, phosphorus 0.38g/100g.

The amino- acid content (mg/g N) has been reported as : leucine 494- 510, lysine 400- 430, valine 331- 340, phenylalanine 219- 360, Isoleucine 275-280, threonine 219-240; methionine 113-120, cystine 70-180. The protein is of high biological value because of its relatively high lysine content. The oil contains the following fatty acid: palmitic 19.4%, stearic 11.8%, oleic 24.4%, linoleic 34.2%, arachidic 5.3%; behenic 4.9% (Aykroyd and Doughty, 1964; Oyenuga, 1968).

2.1.4 Anti-nutritional Factors

Bambara groundnut is one of the widely cultivated legumes in Africa (NAS, 1979). Like any other legume it contains some anti-nutritional factors which if not well processed may hinder its digestibility. Antinutrients are chemical substances in food that do not offer nourishment to the body examples are phytic acid, oxalates, tannin and hydrocyanic acid, etc. The effect of these antinutrients in the body depends on the type and the concentration in which it is present in the food material (Chung *et al*. 1998). The antinutritional factors found in legumes are:

- **Protease inhibitor:**

There are found in Soybeans, groundnut, bambara groundnut etc. in fact, all legumes have been found to contain trypsin inhibitor and chymotrypsin inhibitor which leads to hypertrophy of pancrease (Osho *et al*, 1989). It also inhibit the proteolytic activity of the digestive enzyme trypsin and can lead to reduced availability of amino acids and reduced growth (Liener and Kakade ,1980).

- **Hemagglutinins:**

These are also called lectins and are all proteins. Crude raw extracts of hemagglutinins agglutinates the red blood cells of human beings and other animals if injected directly into the blood stream.

- **Flatulence inducing factors**

One of the major constraints to the human consumption of legumes is their ability to produce gas in the gastro-intestinal tract which is referred to as flatulence. The gases produced are carbon (iv) oxide, hydrogen gas and methane gas. Raffinose, starchyose and verbaslose are the oligosaccharides which have been implicated as the causative factors of flatulence (Liener, 1962).

- **Phytic acid**

Phytic acid content of legumes has been known to lower the bio-availability of minerals (Eradma 1979; Deshpand and Charyan, 1984) and inhibits the activity of several enzymes (Singh and Krikorian ,1982).

- **Tannins:**

Tannins are polyhydric phenols. They form insoluble complexes with proteins, carbohydrates and lipids leading to a reduction in digestibility of these nutrients and also inhibit the activities of some enzymes like trypsin, amylase and lipase (Griffiths, 1979).

- **Saponins:**

Saponins when present in large quality in food legumes impact bitter taste to the plant foods (Oakenfull, 1981).

2.1.5 Utilization and Economic Importance

Although bambara seeds are not sold in the world market, they play an important part in the diet of people in several West African countries (Nigeria, Ghana, Togo and Benin) where they are third most vital

commodity after cowpea and groundnut in the national production and consumption statistics (Raemaeker, 2001).

It is eaten in various ways depending on the region. Before maturity the freshly harvested pods are cooked, shelled and eaten as a snack but become too hard when mature (Kay, 1979; Alobo, 1999). The dried seeds are either roasted and eaten as snack or milled into flour and used in the preparation of moin-moin (Olapade *et al*, 2005) analogue called "Okpa" among the Igbo tribe of Nigeria (Enwere, 1998). The commercial canning of the bambara groundnut has been successfully developed in Rhodesia and Ghana (Kay, 1979).

2.2 ROOT CROPS

Root crops are classed as staple foods because they provide the main item of diet for many people. Cassava, yam and cocoyam are among the major root and tuber crops that are widely cultivated in both the tropical and subtropical regions of the world. Roots and tubers contribute about 10% of human food and are the major sources of energy for over 200 million people in Africa (Coursey, 1983).

According to an earlier report by Chandra (1984), China, Nigeria and Brazil are the main producers of root crops. The relative importance

of individual root crop varies both by region and country. Roots and tubers contain over 65% moisture when harvested but lose up to 40% after 2-3 months in storage with cassava roots degrading physiologically after 5 days, these huge losses of roots and tubers after harvest could be as a result of a number of factors such as metabolic losses due mainly to respiration which produces carbon dioxide, water and heat, microbiological attack that result in massive tissue break down, mechanical injury which accelerates the onset of primary deterioration, vascular streaking particularly in cassava and other factors (Onimawo and Egbekun, 1998). Ene (1992) suggested that the key to efficient storage and utilization is processing. The root crops of interest are cassava, yam, cocoyam, and sweet potatoes.

2.2.1 Cassava (*Manihot esculenta)*

Cassava or manioc is a woody shrub of the *Euphorbiaceous* (Spurge family) native to South America that is extensively cultivated as an annual crop in tropical and sub- tropical regions for its edible starchy tuberous root, a major source of carbohydrates. Cassava is called ‘mandioca’ in Portuguese, ‘manioc’ in Afrikaans and Rotuman,

‘tapioca’ in Fijian, manioc in French and ‘manyok’ in Haitian Creole (Bradbury, 2006).

World population of cassavas root was estimated to be 184 million tonnes in 2002; the majority of production is in Africa where 99.1 million tonnes were grown, 51.1 million tonnes were grown in Asia and 32.2 million tonnes in Latin America and the Caribbean (CBN, 2004).

2.2.1. Description

Cassava root is long and tapered with a firm homogenous flesh encased in a detachable rind, about 1mm thick, rough and brown on the outside. A mature cassava tuber (excluding the tail) may range in length from 15- 100cm and weight from 0.5-2.0kg depending on variety and environment (Onwueme, 1978).Tubers grow very rapidly around 4 to 8 months stage, after which they continue to grow more slowly. As they get older they become fibrous, decrease in mass due to loss of water and the starch content increases (Silvestre, 1989).

2.2.1.2 Varieties

Cassava varieties have been long classified as either bitter (high HCN) with higher than 20mg /100g fresh weight of cassava root tubers

or the sweet type (low HCN) with less than 10mg/100g fresh weight of cassava tubers (Hahn, 1984). According to Nnodu and Dixon (1998), the bitter cassava varieties include TMS 305072, NR 8082, NR 8083, 30555, 50395, 90257 and the sweet varieties (low cyanide) include NR series- 84292, 84151, 8420, 84104 as well as TMS series 71762, 30474, 80/00033, 82/00447, 30001 and 4(2) 1425.The newly released varieties by NRCRI Umudike and IITA Ibadan are TME 419,TMS 98/0581, TMS 98/0510,TMS 98/050TMS 97/2205, TMS 96/1632, TMS 92/0057, TMS 92/0325, TMS 98/0002 and NR 87184.

In this project the improved variety being used is TME 419 which is a bitter variety of cassava. According to IITA Ibadan, TME 419 improved variety is high yielding, suitable for food, industry and livestock and it is the most suitable for mixed cropping. It is disease tolerant to cassava mosaic diseases, bacterial blight disease anthracnose, cassava meal bug and green mite.

2.2.1.3 Chemical Composition

The chemical composition of peeled cassava varies with maturity, variety, cultural practices, storage environment and region (Asiedu, 1989). The flesh of the tuber constitutes the greater bulk and consists

essentially of stored starch. The peel comprises of 10-20% of the tuber. The edible flesh portion makes up 80- 90% of the tuber with carbohydrate (CHO) fraction which is mainly starch making up 20-25% of the tuber flesh (Purseglove, 1988).According to Silvestre (1989), the tuber flesh is composed of 35% dry matter, 89% glucids (mainly starch), 1% fat, 2.5% protein, 4.5% fibre and 3% ash but Meuser and Smolink (1980) reported that the water content is 66.2%, 27.5% starch, 0.4% protein,0.2% fat,0.8% minerals and 1.5% dietary fibre. Raemaeker (2001) stated that the food value of cassava roots is fairly low. Apart from 61% water, it contains mainly starch (33.6%), cellulose (2.6%), protein (1.2%), fat (0.4%) and minerals (1.2%).From 1kg of cassava root, 29-33% flour or 20-25% starch can be extracted (Raemaeker,2001).

According to Oyenuga (1968), cassava root contains low amounts of thiamine and riboflavin, fair quantity of niacin, phosphorus and iron. The calcium content is minimal. The protein of cassava root and of the processed product garri is low in methionine, lysine, tryptophan, phenylalanine and tyrosine but high in arginine. The protein of cassava leaves contain higher amounts of these amino acids than that in flesh or processed root. According to IITA Ibadan and NRCRI Umudike the

cassava var.TME 419 takes 10-12 months to mature, the percentage of its dry matter is 39%, garri yield is 23.5% ,starch from the root flour 65.7% ,sugar 4.6%, protein 2.3%, ash 1.55, fibre 1% and amylase percentage of the starch is 18.7%.

2.2.1.4 Anti-nutritional factors

Cyanide is one of the most potent, rapidly acting poisons known. Cyanides inhibit the oxidative processes cells, causing them to die quickly. Because the body rapidly detoxifies cyanide, an adult human can withstand 50-60ppm, for an hour without serious consequences. However exposure to concentrations of 200-500ppm for 30minutes is usually fatal. Apart from death, acute cyanide toxicity at small doses can cause headache, tightness in throat and chest, and muscle weakness. An important factor influencing the use of cassava as a food is toxicity. Cassava contains two cyanogenic glycosides: linamarin and lotaustralin. The former is present in larger quantities usually up to 90% of the total .These hydrolyze in the presence of the endogenous enzyme Linamarase to liberate hydrogen cyanide (HCN) (Wood, 1965).The poisonous cyanogenic glycosides are distributed throughout the tuber. The level is higher in the “bitter” varieties and are at a low level in the “sweet”

varieties (Asiedu, 1989). The distribution of the glucoside within the roots tends to differ in the two cases. A high concentration of the HCN is confined to the skin and outer cortical layer in the sweet and bitter varieties (Oyenuga, 1968). Cyanide has been implicated as the toxic factor that directly or indirectly causes some observed disease in cassava producing and consuming countries. Incidence of ataxic neuropathy and endemic goiter possibly caused by cyanide and its derivatives have been associated with high level of cassava consumption (Cooke and Maduagwu, 1978). In a study, Iwuoha *et al, (*1997) reported that submerged boiling in water for 35 min, followed by sun drying affected up to 81.5% reduction in cyanide content.

2.2.1.5 Utilization and economic importance

The major processed forms of the cassava tuber fall into 4 general categories: Meal, flour, chips and starch (Ihekoronye and Ngoddy, 1985). Meal forms include gari, 'farinha de mandioca' and meal of retted cassava. The meal and flour forms account for the bulk of cassava used for human food while the chips and petted is used for livestock feed in temperate countries (Onwueme, 1978). The cassava starch account for most of the cassava that enters international trade

(Ihekoronye and Ngoddy, 1985). Increased use is being made industrially of cassava starch for the production of sugar, alcohol, adhesive (Kay, 1987). Cassava is also processed to make syrups and monosodium glutamate (MSG), the latter being widely used to enhance the flavor of other processed foods (Mayhew and Penny, 1988). Internally the market for cassava is very bright particularly with the federal government policy of blending 90% wheat flour with 10% cassava flour. Research work on composite flours in bread making has shown that cassava flour can be substituted for up to 20% of the wheat or cereal flours used in baking without significantly changing the final product or the processing methods (Oti and Ukpabi, 2006).

2.2.2 Yam

Yam is a member of the genus *Dioscorea* and produce tubers, bubils of rhizomes that are of economic importance especially as food for man. They are monocots belonging to the family *dioscorea* within order *Dioscoreals*. Ekwu *et al.* (2005) reported that yam is the most staple food in West Africa after cereals. Yam is a major food in west Africa, the Caribbean, the south pacific islands, south- east Asia, India and parts of Brazil (Ihekoronye and Ngoddy, 1985).

2.2.2.1 Description

The edible part of the yam plant is the tuber which varies in shape according to species and the environment it was grown. The tuber *D. rotundata* (white yam) is more or less cylindrical in shape, weight of individual tuber ranging from 200g-50kg. The skin is smooth and brown while the flesh is usually white and firm (Mayhew and Penny, 1988; Asiedu, 1989). The tuber has 3 general morphological section; head, middle and the tail however the tail ends has a high moisture content than the head (Coursey and Walker, 1960) and there is a gradient of increasing percentage of moisture and a decreasing percentage of dry matter from head to tail.

2.2.2.2 Varieties

Yam fall within the genus *Dioscorea,* the economically important species are *Dioscorea rotundata* (white yam), *D. cayenesis* (yellow yam) *D. bulbifera* (aerial yam) and *D. dumetorum* (trifoliate yam) (Ike and Inoni ,2006).The 6 species constitute over 90% of the food yams produced in the tropics (Hahn *et al,* 1987).Of all the *Dioscorea* species *D. rotundata* (white yam) is the most important in west Africa (Odu *et al*, 2004) and widely cultivated in the middle belt of Nigeria because of

its economic value and uses (Degras, 1993). This is the specie used in this project

2.2.2.3 Chemical composition

The chemical composition of yam varies with species and cultivar even within the same cultivars it may vary depending on the environment conditions under which the tuber is produced (Onwueme, 1978). Yam is more appreciated in many countries because about 85% of its tuber is edible .The freshly harvested yam tuber consist of about 70% water, 25% starch, 1-2% protein and traces of sugar and vitamins (Onwueme and Sinha, 1991). According to Raemaeker (2001), the edible part of yam is composed principally of 65-75% water, 15-23% starch, 2.5% protein, 0.5-1.5% fibre, 0.7-2.0% ash and 0.05-2% fat. The starch is more concentrated at the proximal end of the tuber. In addition yam contains 4-12 mg/100g ascorbic acid and the same for vitamin B. As far as amino acids are concerned yam is deficient in tryptophan and sulphur containing amino acids. It contains sufficient quantities of other amino-acids though calcium, iron and phosphorus are among the components of the mineral fraction of the tuber, calcium occurs principally in rhaphides, bundless of crystals of calcium oxalate and

may not be available nutritionally. Most of the carbohydrate is starch and mainly amylopectin (branched- chain starch), amylose occurs as 10 to 28% of the starch and influence the properties of the starch. Sugars are only present in minute quantities (Onwueme, 1978; Ihekoronye and Ngoddy, 1985). Mucilage which exclude when the yam tuber surface is cut are mostly glycoprotein (Onwueme, 1978). Ihekoronye and Ngoddy (1985) further stated that some yams may contain sufficient amounts of polyphenolic compounds. These are important since they are subject to enzymatic oxidation when the tuber is cut, turning it brown. This type of browning presents problems in commercial preparation of yam flours.

2.2.2.4 Anti-nutritional factors

Almost all *Dioscorea spp.* contain a bitter alkaloid called dioscorein which gradually diminishes and disappears at full maturity in most cultivated varieties especially in *Dioscorea rotundata* (white yam). This substance can also be dissipated by cooking or steeping the tubers in water (Asiedu, 1997). The alkaloid dioscrine which is toxic to man and animals is common to certain varieties of yam such as *D. Hispida Dennst* (Asiatic bitter yam), *D. dumentorum* (trifoliate yam) with *D. alata* (water yam) having little toxicity (Onwueme,1978). Wanesundera

(1994) reported a range of 486-781 mg/100g (dry matter) for total oxalate in fresh yam tubers and concluded that it may not constitute a nutritional concern since 50-75% of the oxalate is in water soluble form.

2.2.2.5 Utilization and economic importance

The large proportion of yam produced is marketed as fresh tuber. Only a small proportion or fraction goes to market in processed forms (Onwueme, 1978). Boiled yam is one of the simplest and commonest form in which it is consumed. Boiling with skin still attached allow for the retention of a greater percentage of vitamin C present in the tuber although the vitamin is readily oxidized during boiling (Coursey and Aidoo, 1966; Asiedu, 1989) . The most favoured yam based food in most of west Africa is the pounded dough known as 'Fufu' which is best when prepared from *Dioscorea rotundata* with its high starch viscosity and gelatinization strength (Terry *et al*, 1983).Yam tubers also make good feed for livestock but are not normally used for that purpose because of the availability of much cheaper alternatives (Onwueme, 1978). Other forms in which yam tubers are processed are mashed yam, fried yam, roasted yam and baked yam but the major processed forms in which yam tuber are utilized are as yam flour, yam flakes and yam

chips. Yam is also used in the manufacture of starch but the total amount of yam devoted to this purpose is however quite small and the industry exists only in Philippines (Terry *et al*, 1983). Another industrial product from yam is the production of steriod used in the manufacture of fertility drugs (Ene, 1992). The economic importance of yam lies mostly in its utility as a carbohydrate food for the producing region rather than in any ability to earn foreign exchange.

2.2.3 Cocoyam

Cocoyams are members of a large monocotyledonous family *Aracea.* (Cobley and Steele 1976, Ihekoronye and Ngoddy 1985), Cocoyams are stem tubers and belong to the edible aroid group. The name cocoyam is used in West Africa for both species *Colocasia esculenta* (taro) and *Xanthosoma sagittifolium* (tannia) (Onwueme, 1978). Cocoyam is a neglected crop and does not compete favourably with other root crops (yam and cassava) in terms of production and consumption because of its high perishability (Onwueme,1978).Usually farmers helplessly watch their harvested stored cocoyam rot away because routine method of processing and consumption of cocoyam are inadequate to utilize all the cocoyam produced. Cocoyam production has not been given priority attention in many countries probably because of its unacceptability by the high income countries for both

consumption and other purposes. Annual production of cocoyam in Nigeria is estimated at 26.587 million tonnes, she is the world's largest producer of cocoyam accounting for about 37% of the total world output (FAO, 2006). Most of the crop is grown in southern Nigeria including Anambra state as one of the staple foods. The specie of interest in this project is *Xanthosoma sagittifolium* (tannia).

2.2.3.1 Description

Xanthosoma (tannia) is comparatively a more recent introduction into the West coast of Africa from the West Indian Islands, and it appears to be the more productive of the two types. They grow to a height of between four to Six feet and possess large leaves but their leaves are sagittate in shape, dark green in colour with its basal lobes enjoined. They produce corms, a form of underground stem; the big central corm is surrounded by smaller ones and all of them usually contain good quality carbohydrate which is of great value as food both for man and for beast. The cormels rather than the corms are more commonly used as a vegetable for human consumption (Oyenuga, 1968).

2.2.3.2 Varieties

According to Ihekoronye and Ngoddy (1985), the cocoyam – *Colocasia* (taro) and *Xanthosoma* (tannia) are the two important genera of the family Aracea. The other three genera *Alocasis, Amorphophallus* and *Cyrtosperma* are important as food plants only in the pacific basin of the tropics. Mayhew and Penny (1988) claimed that the part of the cocoyam below the ground is a corm, the three major species: "old" cocoyams; *Colocasia* esculenta**,** *Colocasia antiquorum* and "new" cocoyam; *Xanthosoma*

2.2.3.3 Chemical composition

Nutritionally cocoyam is superior to cassava and yam in their possession of higher protein, mineral and vitamin content as well as easily digestible starch, it is highly recommended for diabetic patients, the aged and the children with allergy and persons with intestinal disorders (Key,1987). According to Oyenuga (1968), the proximate composition of tannia in percentage fresh weight is 70 – 77% moisture content, 17 -26% carbohydrates, 1.3 – 3.7% protein, 0.2 – 0.4% fat, 0.6 – 1.9 crude fibre, 0.6 – 1.3% ash, 2mg/100g riboflavin, 1mg/100g niacin and 9-16mg/100g vitamin C. The nature and constituent of the starch in tannia variety is hard and highly starchy which tends it easily to the preparation of pounded 'fufu' (Ihekoronye and Ngoddy, 1985).

2.2.3.4 Anti-nutritional factors

The undesirable presence of calcium oxalate crystals in taro leaves and tuber (0.1-0.4% fresh, weight) should be noted. These acidic substances are irritating to the digestive tract and have deleterious effects on human nutrition and health particularly by decreasing calicum absorption aiding the formation of Kidney stone. The presence of calicum oxalate crystals in the genera colocasia has been well documented (Nooman & Savage ,1999).

2.2.3.5 Utilization and economic importance

Cocoyam compares favorably with other root and tuber crop in terms of food value and industrial use. The corms and cormels of *Xanthosoma* may be pounded either pure or mixed with yam or cassava and eaten with vegetable soup, they can be boiled or roasted and eaten with palm oil, stem meat or fish. It can also be processed into snack food like cocoyam flakes. It is feasible to develop a number of useful products from cocoyam such as drum-dried flakes, soup thickeners and beverage powder (Oyenuga, 1968).

2.2.4 Sweet potatoes

Sweet potato (*Ipomea batatas*) is a native to the tropical parts of South America and were domesticated there at least 5000 years ago. They are now cultivated throughout tropical and warm temperate regions where there

is sufficient water to support their growth. This tuber crop is an important crop in African. It is seasonally grown and production always leads to seasonal abundance. It is a major food crop in developing countries (Woolfe, 1992).Sweet potato is a minor crop in Nigeria cultivated in a few restricted areas by farmers for their own consumption. According to the food and agriculture organization (FAO, 1988) statistics, the world production in 2004 was 127,000,000 tonnes the majority comes from china, with a production of 105,000,000 tonnes. About half of the Chinese crop is used for livestock .The main commercial producers of sweet potatoes include china, Indonesia, Vietnam, Japan, India and Uganda. According to FAO, production of sweet potato in Nigeria increased from 149,000 metric tonnes in 1961 to 2,468,000 metric tonnes in 2000.

2.2.4.1 Description

Sweet potato (*Ipomoea batatas*) is a dicotyledonous plant that belongs to the family convoloulaceae .Its large, starchy, sweet tasting tuberous roots are an important root vegetable (Purseglove, 1991; Woolfe, 1992).The young leaves and shoots are sometimes eaten as green. This plant is a herbaceous perennial vine, bearing alternate heart shaped or palmate lobed leaves and medium sized sympetalous flowers. The edible tuberous root is long and tapered with a smooth skin whose colour ranges between red ,purple ,brown and white .Its

flesh ranges from white through yellow ,orange and purple (Wikipedia, 2010).

2.2.4.2 Varieties

Sweet potato (*Ipomoea batatas*) from the genus of *Ipomoea* comprises of several hundred species of which *I.batatas* especially has economic value owing to its edible tubers (botanically speaking these are roots).Several species are grown in India for consumption as spinach other species are grown as ornamental plants. *I. aquatic* is aquatic specie cultivated throughout Asia for its leaves and stems used particularly as spinach. The difference between varieties depends on the shape of the leaves, tubers, colour, size and storage qualities (Raemaeker, 2001).Three main groups of cultivars are recognized depending upon differences in texture, colour and palatability of these tubers. One group has tubers with hard dry flesh which is often yellow ;another has tubers with coarse, fibrous, unpalatable flesh ; while the third has soft tubers with white or orange watery flesh which is sweet when cooked (Cobley, 1976).The specie used for this project was white flesh orange back locally called ‘Odekpe’ in Anambra state

2.2.4.3 Chemical composition

The young leaves of sweet potato serves as a good green vegetable for man and are highly relished by cattle, sheep and goats .The leaves are a valuable

source of proteins (about 25%), ash (about 10%), oil (4%) and low in crude fibre (9%).They are rich in calcium, phosphorus and iron and they form good sources of ascorbic acid, riboflavin, niacin and carotene. The leaves contain 8.1mg of tocopherol (Vitamin E) per 100g. Frequent cuttings of the foliage tend o reduce the yield of the tuber (Oyenuga, 1968).According to Ihekoronye and Ngoddy (1985), sweet potato tubers contain free sugar as well as starch and this gives them their sweet taste. The starch is in readily digestible form being converted to maltose during cooking thus making the sweet potato more sugary than other normal starchy food. Its composition involves 58-81% moisture, 17-43% carbohydrates, 0.18-1.66% fat, 0.45-4.37% crude protein, 0.60-4.54% crude fibre and 0.66-1.98% ash .The tuber is rich in carotene (particularly the yellow varieties), minerals and the B complex vitamins. Vitamin C content is about 19mg/100g. According to Raemaeker (2001), the water content of the tuberous root of sweet potato varies from 57 to 78% of the fresh weight. The remaining is made up mainly of starch (13-33%), sucrose (2.6-6.0%), reducing sugar (0.3-0.8%),minerals (0.8-2.2%) as well as protein (0.8-2.2%) and cellulose (0.9-1.2%).Carotene content of the tubers varies between 0 and 24 mg per 100 g of fresh tuber. The ascorbic acid content (Vitamin C) varies between 23 and 43 mg/100g. In 1992, the center for Science in the public interest compared the nutritional value of sweet potatoes to other vegetables, considering fibre content, complex carbohydrates, protein, vitamin A and C, iron and calcium, the

sweet potato ranked the highest in nutritional value. Sweet potato varieties with dark orange flesh have more beta carotene than those with light coloured flesh and their increased cultivation is encouraged in Africa, where vitamin A deficiency is a serious health problem. Despite the name 'sweet', it may be a beneficial food for the diabetes, as preliminary studies on animals have revealed that it helps to stabilize blood sugar levels and to lower insulin resistance (Wikipedia,2010) .The intensity of the sweet potato's yellow or orange flesh colour is directly correlated to its beta carotene content. The beta carotene in orange fleshed sweet potato which our bodies can use to produce Vitamin A and is therefore called 'Provitamin A' has been reported to be more bioavailable than that from dark green vegetables. The antioxidant activity in sweet potato skin regardless of its colour is almost three times higher than the rest of the tissues (Wikipedia, 2010).

Woofle (1992) reported that sweet potato like the irish potato contains an invertase, a maltogenic amylase and a 'sucrogenic' amylase .The proteins of sweet potato are of high biological value containing many essential amino acid. He further stated that there is a globulin name 'ipomoein' in sweet potato. This globulin accounts for 68% of sweet potato protein. Sweet potato has been identified to contain endogenous amylase enzyme. This amylase cause starch degradation during cooking and their control results in the best combination of saccaharification and physical properties in the preparation of

processed product. The potential of sweet potato roots particularly its intrinsic amylase enzyme may increase the diastatic activity of the composite flour and consequently increase loaf volume if utilized in composite bread (Hageniamana *et al*. 1992).

2.2.4.4 Anti-nutritional factors

Wang and Yeh (1996) found inhibitors of the pancreatic proteolytic enzyme Kallikrein to be present in potato and since then it has been said that the potato could contain protease inhibitor (trypsin inhibitor).

2.2.4.5 Utilization and economic importance

Sweet potato is consumed throughout the year as fresh boiled root; it can be roasted, fried and dried into chips or traditionally processed into low quality flour primarily for domestic use and to a lesser extent for sale in rural markets (Woolfe, 1992). The Industrial processing of sweet potatoes has not been developed greatly in tropical Africa but they may be used as thickening agents in canning, in sauces, in production of starch, glucose syrup and alcohol (Mayhew and Penny ,1988)

2.3 FLOUR

Flour is the key ingredient used in baking technology. The most important flours used in most important foods in European and North American culture is the wheat flour and is the defining ingredient in most European styles of bread and pastries. Regulations in many countries require that wheat flour be enriched to replace the micronutrients lost in the production of refined flour. Flour by definition contains a high proportion of starch which are complex carbohydrates also known as polysaccharides. Wheat and some other flours also contain proteins called gluten. When dough made with wheat flour is kneaded, the gluten molecules cross-link to form a sub-microscopic network that gives the dough an elastic structure. This allows the retention of gas bubbles in the intact structure, resulting in an aerated final product with a soft texture, desirable for breads, cakes and the like. According to Scade (1975), wheat can be roughly divided into 'hard' and 'soft' the term referring to the nature of the starchy portion or endosperm of the grain. In hard wheat the endosperm feels dry and is difficult to compress. The endosperm from soft wheat has a mealy consistency and can be easily squeezed by hand to form a solid mass. The term "Strong flour means a flour capable of yielding large loaves of good texture and at the same time absorbing comparatively large quantities of water, thus giving a high yield of bread from each sack of flour. Very strong wheat is blended by the miller

with weak or soft wheat to produce flour with particular or desirable bread making characteristics. Nearly all English wheat are 'soft' or weak, producing flours more suitable for biscuit and cake making than for bread production. Hard flour is high in gluten with a certain toughness that holds its shape well once baked while soft flour is comparatively low gluten and so results in finer texture. In this project the type of flour of interest is the composite flour. Composite flour initially referred to mixture of wheat flour with cereal flour or legumes for making of bread and bakery products. However, this term can also be used in regard to mixture of two or more non-wheat flours like roots and tubers, legumes or other cereals and fruit flours. The uses of non wheat cereals like millet, sorghum, maize and legumes like soy-bean, breadfruit etc has nutritional advantages in bakery products since without their inclusion, most bakery products from wheat flour will be low in quantity and quality of protein as well as poor in minerals and vitamins (Alozie *et al*. 2009). Idowu *et al*.(1996) in the study on the use of cocoyam flour as composite flour with wheat flour in bread and biscuit production revealed that up to 10% and 80% substitution with cocoyam flour produced acceptable bread and biscuit respectively. Mepba *et al.*(2007) in the feasibility study of partially replacing wheat flour with plaintain flour in bread and biscuit making found that acceptable breads and biscuits can be formulated from wheat-plaintain composite flour using up to 80:20(w/w)% and 60:40(w/w)% ratios of wheat: plantain flour as maximum acceptable

levels of substitution for bread and biscuit respectively. Okpala and Chinyelu (2011) in the study of the physicochemical, and organoleptic evaluation of cookies from pigeon pea (Cajanus cajan) and cocoyam (Xanthosoma sp.) flour blends revealed that cookies produced from 20% pigeon pea flour and 80% cocoyam flour compared favourably with cookies produced from wheat. Okpala and Okoli (2011) in the study of the nutritional evaluation of cookies produced from pigeon pea, cocoyam and sorghum flour blends revealed that the cookies with minimum protein content of 10% were similar to the casein diet in maintenance, weight, food intake, digested nitrogen, nitrogen balance, biological value and net protein utilization when fed to albino rats.

There are various types of composite flour available in Nigeria but the one of interest here is the tropical root crop/indigenous legume (bambara groundnut). The final product of interest is cake which is one of the common confectioneries in Nigeria.

2.3.1 Technology of cake baking

According to Scade (1975) the main ingredients necessary in the construction of a cake are fats flour, sugar and egg other ingredients that may be added are milk products, flavour, fruits etc. Cakes are soft bakery products produced by baking a batter containing flour, sugar, baking powders and beaten eggs with or without shortenings (IFIS, 2005). According to Hermes (1999), when baking a cake most bakers aim to create a fluffy cake with tender crumb. As cake flour is milled it is heavily bleached not only to make it white but to break down the protein in the flour .Typically cake flour is around 7% much lower than other flours; bread flour for example has twice that amount of protein. He further stated that cake is a form of food that is usually sweet and often baked. This is one of the major snacks in the fast food industries mostly loved by women and children. Cakes can be classified based on their appropriate accompaniment such as coffee cakes, ginger cake, coconut cakes or based primarily an ingredient and cooking technique such as Christmas cake, rock cake and queen's cake. The type of cake produced in this project is the queen's cake.

CHAPTER 3

MATERIALS AND METHODS

3.1 MATERIALS

The materials include bitter Cassava (var.TME 419) that was purchased from the National Root and Crop Research Institute (NRCRI) Umudike, Sweet potatoes (white fleshed), Cocoyam *(Xanthosoma sagittifolium*) and Yam (*Dioscorea rotundata*) and Bambara groundnut variety were purchased from the open market at Umudike and identified in the research institute at Umudike.

3.2 EQUIPMENT AND CHEMICAL REAGENTS

3.2.1. Equipment

The equipment used for this study was obtained from the laboratory of the Department of Food Science and Technology and the Crop Science laboratory of the Federal University of Technology, Owerri and the main laboratory of the NRCRI Umudike and the biochemistry laboratory of the Kogi State University.

3.2.2 Chemicals

Chemical reagents used for the project was that of analytical grade and as prescribed by the official methods of analysis.

3.3 METHODS

3.3.1. Production of Samples

3.3.1.1 Production of root tuber flours

Healthy, mature, firm, freshly harvested tubers were used. These tubers include cassava, sweet potatoes, cocoyam and yam. They were washed to remove sands and soil debris and other impurities. They were then peeled to remove the stalks, wooden tip and peels and then washed again to avoid any form of contamination. They were cut in chunks and immersed in 1% solution of sodium metabisulphite, for 25 minutes. They were sliced into thin slices of 5mm and placed in an oven to dry, after drying they were milled and sieved with a sieve of aperture size of 0.2µm to obtain their respective flour This is represented in Fig. 3.1and 3.2 .

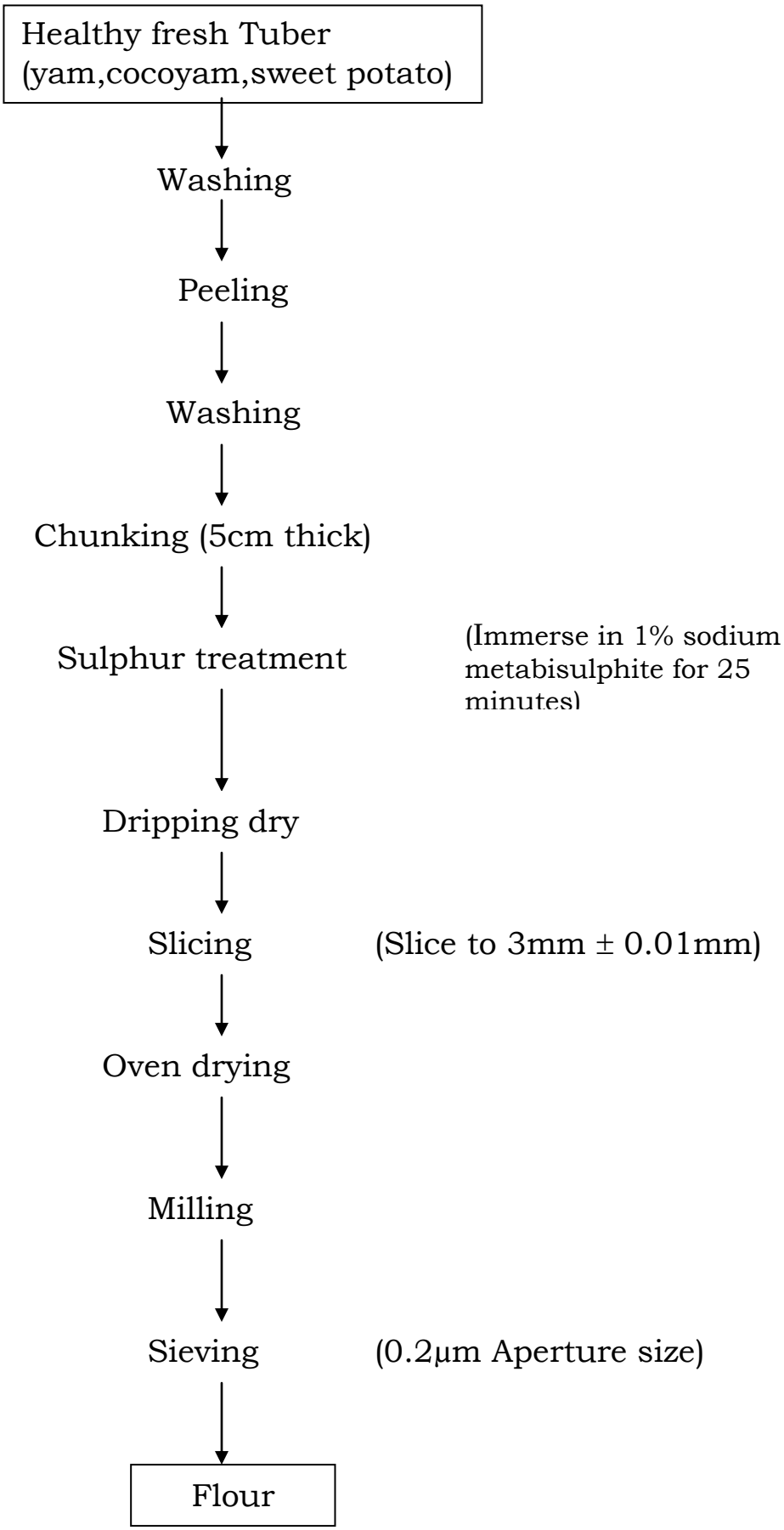


Fig 3.1: **Production Flow Diagram of Tubers**

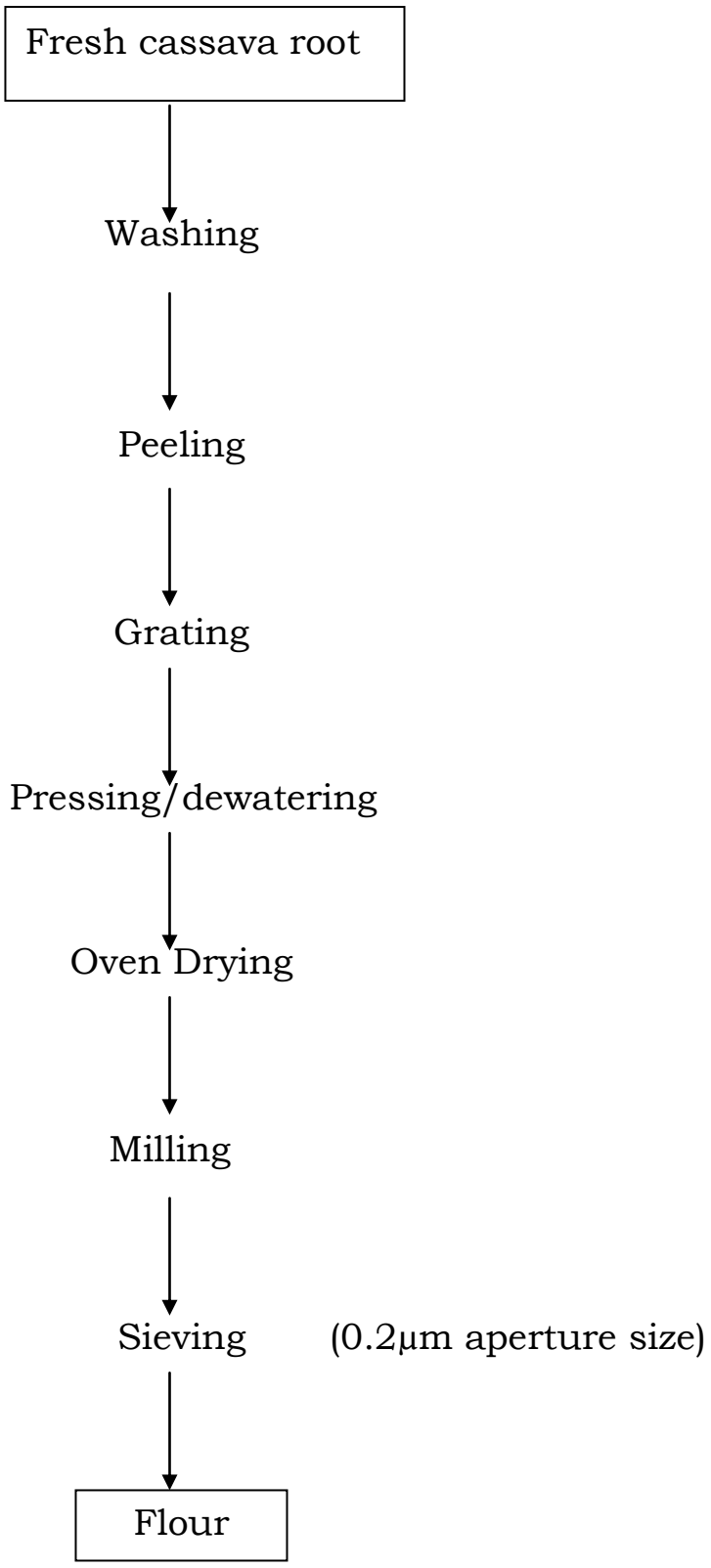


Fig 3.2: Flow diagram for the production of high quality cassava flour

CASSAVA FLOUR

YAM FLOUR

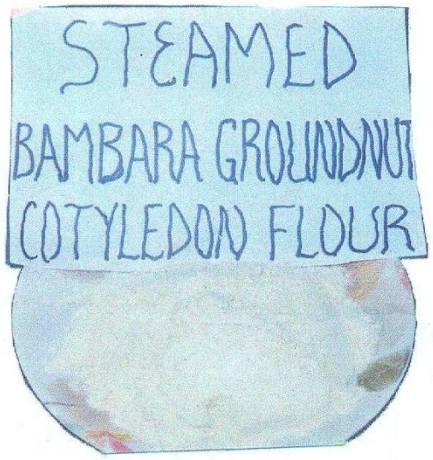
COCOYAM FLOUR

SWEET POTATO FLOUR

Plate 3.1 : Flour samples from root tuber flours

CONVENTIONAL BAMBARA GROUNDNUT FLOUR

BAMBARA GROUNDNUT COTYLEDON FLOUR



STEAMED BAMBARA GROUNDNUT COTYLEDON FLOUR

Plate 3.2 : Flour samples from bambara groundnut flours

3.3.1.2 Production of bambara groundnut flours

Bambara groundnut seeds were graded, cleaned and divided into three equal batches. One batch was without treatment, but was dehulled as practiced by the local bambara groundnut flour producers. They were dried and milled into flour. In the second batch, the cotyledon was be obtained by boiling the raw whole seed in water for 25 minutes, cooled and then the seed coat was removed (decorting).They were in turn dried and milled into flour. In the third batch the raw bamabara groundnut seed was heated, boiled for 25 minutes, dehulled , then steamed for 20 minutes, then dried and milled into flour. .

3.3.1.3 Production of root crop-bambara groundnut flour blend

The root tubers (cassava, sweet potatoes, yam and cocoyam) flour varieties and the different treated bambara groundnut flours were blended together in 5 different blending ratios of the form in Table 3.1

TABLE 3.1 FIVE BLENDED RATIOS

Root Tuber (Cassava, Sweet Potatoes, Yam, Cocoyam) flour	Bambara Groundnut Flour
100	0
75	25
50	50
25	75
0	100

Proximate analysis, physicochemical analysis and antinutritional analysis was carried out on the raw samples, pre-treated samples and the flour blend ratios. The sensory evaluation was carried out on the samples selected based on the results of the proximate, physicochemical properties and antinutritional properties.

3.3.2 Proximate Analysis

Proximate composition covered the determination of sample qualities in terms of protein, fat, fibre, ash, moisture content /dry matter and carbohydrates. The 47 samples generated were subjected to these analyses. The test parameters were determined as follows:

3.3.2.1 Determination of moisture content of flour samples

The gravimetric method (AOAC, 1990; James, 1995) was used. Each flour sample (2g) was weighed into dried moisture cans of known masses. The samples were dried in the oven at 105^{o}C for 3 hours in the first instance. They were cooled in a desiccators and reweighed. The samples in the cans were returned to the oven for further drying. Drying, cooling and weighing were done at hourly interval until a constant weight was obtained. The moisture content was calculated as a percentage, the ratio of moisture loss to the weight of samples analyzed. The formula below was used in the calculation

$$\%\text{Moisture content} = \frac{100(w_2 - w_3)}{}$$

$$w_2 - w_1$$

Where w_1 = wt of sample moisture can

w_2 = wt of can + sample before drying

w_3 = wt of can + sample after drying to constant weight

Note: % Dry matter = 100 - % moisture content

3.3.2.2 Ash determination

This was done by the furnace incineration gravimetric method discussed variously by Pearson (1976) and James (1995).

A measured weight of the various flour samples (2g) were weighed into porcelain crucibles of known masses. The crucibles containing the samples were heated gently in an oven to reduce the moisture and then transferred into the muffle furnace heated at 550^{o}C. Burning was done at 550^{o}C until the samples became white gray ash. With the aid of a pair of tongs, the burnt sample in each crucible was carefully transferred to a dessicator and allowed to cool before each of them was reweighed. By difference, the weight of ash was obtained as a percentage of the sample analyzed. Calculation was as follows:

$$\% \text{ Ash} = \frac{w_2 - w_1}{\text{Wt of sample}} \times \frac{100}{1}$$

Where w_1 = wt of empty crucible
W_2 = wt of crucible + ash

3.3.2.3 Crude fat determination

The crude fat content of the samples was determined using (A.O.A.C 1990) method. A 250ml soxhlet flask was washed and dried in the oven at the temperature of 105^{o}C for 3 minutes. The flask was cooled in a desiccator and weighed. A measured weight of each sample (2g) was placed in ash less filter paper, carefully wrapped and clipped and put into the soxhlet extractor. Some 200ml of petroleum ether was transferred into the flask. The soxhlet apparatus was assembled and the top closed with cotton wool to prevent solvent loss evaporation. The flask was placed on the heating mantle and heated to 80^{o}C and fat extracted for 4h.The filter paper with the spent sample was removed from the extractor and the solvent distilled out and recovered. The crude fat left in the flask was cooled in the desiccator at room temperature and weighed. The difference mass was calculated as percentage crude fat content.

$$\% \text{ Fat} = \frac{\text{weight of fat}}{\text{weight of sample}} \times \frac{100}{1}$$

3.3.2.4 Crude fibre determination

The crude fibre content was determined by Weende method as described by James 1995. Sample (2g) was defatted with petroleum ether using soxhlet

extractor. The defatted sample was dried in the oven and transferred into 500ml conical flask. 200ml of 1.25% H_2SO_4 was used to digest the sample for 30 minutes. Under reflux it was filtered with a white musclin cloth and washed with boiling water till the washing was neutral to litmus paper. The residue was transferred back to the conical flask and digested for another 30 minutes under reflux with 200ml of 40% NaOH .it was filtered and washed with boiling water until the washing water became neutral to litmus paper. The residue was transferred into a crucible of known mass and dried in the oven at 105^oC to constant mass . The dried residue was ashed in the muffle furnace for 4h at 550^oC, cooled in the desiccators and weighed.

Calcualation:

Mass of Crucible = Wg

Mass of crucible + residue before ashing =W_1g

Mass of crucible + residue after ashing =W_2g

Mass of crude fibre $(W_1 - W_2)$g

$$\% \text{ crude fibre} = \frac{(W_1 - W_2)g}{2} \times \frac{100}{1}$$

3.3.2.5 Determination of protein

Protein was determined by the kjeldahl method (James 1995). The total N_2 was determined and the factor 6.25 was used to multiply to obtain the protein. Procedure: Each sample (0.5g) was boiled in 10mls of conc. H_2SO_4 in the

presence of selenium catalyst. Boiling was done under a fume cupboard until a clear solution was obtained. The digest was diluted to 100ml in a vol.flash and 10ml portion of it was mixed with equal volume of 45% NaOH solution. The mixture was distilled in a kjeldahl unit and the distillate was collected into 10ml of 4% boric acid solution containing 3 drops of mixed indicator (methyl red and bromocresol green).A total of 50ml distillate was collected and titrated against 0.02N H_2SO_4 solution .Titration was done from green to deep red end point. A reagent blank was treated as discussed above but without sample. It was also titrated. The N_2 content and hence the protein was calculated as shown below:

% Protein = $\%N_2 \times 6.25$

$$\% N_2 = \frac{100}{10} \times \frac{14 \times N}{1000} \times \frac{Vf}{Va} \times T - BLK$$

where

W = wt of sample (g)

N = Normality of titrate

Vf = Total volume of extract

Va = Volume of extract distilled

T = Titre of sample

BLK = Titre of reagent blank

3.3.2.6 Carbohydrate determination

Carbohydrate content of the flour samples were determined by difference. It was assumed that vitamins and minerals occurred in minute quantities. The ash, crude fibre, protein and moisture content were summed up together and subtracted from 100% to give the carbohydrate (CHO)

% CHO = 100 - (sum of % fat, protein, ash, moisture and crude fibre)

3.3.4 Physicochemical Analysis

Functional properties have been defined as those characteristics that govern the behaviour of nutrients in food during processing, storage and preparation as they affect food quality and acceptability (Onwuka, 2005) This can also be described as any property (except nutritional) of a food component that affects its utilization. The flour samples were subjected to the following physico-chemical analysis: the pH, water absorption capacity and the oil absorption capacity, swelling index, gelling point and boiling point.

3.3.4.1 pH determination

The pH was determined using the glass electrode method. Slurries were made by dispersing 2g of each flour sample in 10mlof deionized water and allowed to incubate at room temperature for 30 minutes. The pH was measured electronically on a Metrolim Herisan Precision pH meter, read using a glass

electrode containing potassium chloride electrolyte. The instrument was calibrated with a standard buffer solution of pH 4, pH 7 and pH 9 and allowed to stabilize for 15 minutes. After the electrode was inserted into the suspension and the pH was then read off.

3.3.4.2 Swelling index

The swelling index was determined using the method according to Ukpabi and Ndimele (1990). Sample (5g) was transferred into a clean, dry, 10ml graduated cylinder. The sample was leveled and volume noted and then the sample was transferred into a 100ml measuring cylinder, about 100ml of water at room temperature was added into the measuring cylinder and then allowed to stand for one hour. The volume of the swollen material was recorded. This was repeated in duplicate. The swelling index of the flour was calculated as multiple of the original volume

3.3.4.3 Determination of water/ oil absorption capacity

For water / oil absorption capacity the method described by Abbey and Ibeh (1988) was followed. Each sample (1g) was weighed into a conical graduated centrifuge tube .Using a waring whirl mixer the sample and 10ml distilled water or oil were mixed thoroughly for 30 seconds. The sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 3500rpm

for 30 minutes. The volume of free water or oil (the supernatant) was read directly from the graduated centrifuge tube.

Note: Absorption capacity is expressed as grams of oil or water absorbed (or retained) per gram of sample.

Calculation: the amount of oil or water absorbed (total minus free) is multiplied by its density for conversion to grams.

3.3.4.4 Determination of gelatinization and boiling points

The method of Narayana and Narasinga–Rao (1982) was adopted to determine the gelling and boiling temperatures of the samples. Each sample (2g) was dissolved in 25ml of distilled water in a beaker and stirred. A thermometer was clamped onto a retort stand with its bulb submerged in the beaker. The beaker was stirred with the stirring rod until the sample gelled. The means of duplicate determination was determined and the varying boiling points of the samples were also recorded.

3.3.5 Anti-Nutritional Factors' Analysis

Antinutrients are chemical substances in food that do not offer nourishment to the body e.g. alkaloid, tannins, phytic acid, cyanogenic glycoside, hemagglutinin, saponin, trypsin inhibitor, oxalates etc. The effect of these anti-nutrients in the body depends on the type and concentration in which it is present in the food material

3.3.5.1 Determination of alkaloid

Alkaloid determination was done using the alkaloid precipitation gravimetric method described by Harborne (1973). Each sample (5g) was mixed with 100mls of 10% acetic acid in ethanol. This mixture was allowed to stand for 4 hr at room temperature after which it was filtered through whafman No 42 filter paper. The filtrate was reduced to a quarter of its volume by evaporating over a steam bath. The concentrated extract was treated with drop-wise addition of conc. ammonia hydroxide until full turbidity was observed. The alkaloid precipitates were recovered by filtration using weighed filter paper. The residue (ppt) in the filter paper was washed with 1% NH_4OH solution dried in the oven of 100^0C for 30 minutes and weighed after cooling in a dessicator. The alkaloid content was calculated as percentage of the sample analysed:

$$\% \text{ Alkaloid} = \frac{100}{W} \times W_2 - W_1$$

Where W = wt of sample

W_1 = wt of empty filter paper

W_2 = wt of filter paper and alkaloid ppt

3.3.5.2 Determination of tannin

This was done using Folin Dennis spectrophotometer method described by Pearson (1976). Each sample (2g) was dispersed in 50ml of distilled water and shaken for 30minutes before it was filtered through whafman No.42 filter paper. The residue was washed further with the distilled water until 100ml filtrate was obtained. Meanwhile standard tannic acid solution was prepared and diluted to a chosen concentration (0.1mg / ml).An aliquot of the extract from each sample (5ml) as well as equal volume (5ml) of the standard solution and 5ml of distilled water were dispensed into separate 50ml volume flask to serve as sample standard and reagent blank respectively. Process volume (1ml) of the folin Dennis reagent was added to each of the flask followed by 2.5ml of saturated sodium carbonate solution. After mixing well, the content of each flask was added up to 50ml with distilled water and they were incubated for 90 minutes at room temperature before their respective absorbance were read in a spectrophotometer. Readings were taken with reagent blank of zero and at a wavelength of 760 nm. The tannin content of each sample was calculated using the formula below:

$$\% \text{ Tannin} = \frac{100}{W} \times \frac{au}{as} \times c \times \frac{Vf}{Va} \times D$$

Where w = wt of sample

au = absorbance of test sample

as = absorbance of standard tannin solution

c = concentration of standard tannin

Vf = Total extract volume (50ml)

Va = Volume of extract analyzed (5ml)

D = Dilution factor where necessary

3.3.5.3 Determination of saponins

The method of Obadoni and Ochuku (2001) as described by Okwu (2004) was employed. Each sample (5g) was boiled in 200ml of 20% ethanol for 4 hours at 55^0C in a water bath. It was filtered through wharf man filter and the residue was re-extracted with another 200ml of the 20% ethanol solution. The extracts were pooled together and concentrated by evaporation over a steam bath until 40ml was left. The concentrated extract was treated with 20ml of diethyl ether in a separating funnel and shaken very well and allowed to form partitions. The aqueous layer was recorded and treated with 60ml of n-butanol and then washed with two portion 10ml each of 5% aqueous sodium chloride. It was finally evaporated to dryness over a steam bath, dried to constant weight in the oven and the percentage saponin was calculated as shown below:

$$\% \text{ Saponin} = \frac{W_2 - W_1}{W} \times \frac{100}{1}$$

Where W = wt of sample analyzed

W_1 = wt of empty evaporation dish

W_2 = wt of evaporation dish + saponin extract

3.3.5.4 Determination of phytic acid

The phytic acid was determined using the procedure by Lucas and Markakas as described by Akinmutimi (2006). This entails the weighing of 2g of each sample into 250 ml conical flask. Solution (100ml) of 2% concentrated hydrochloric acid was used to soak each sample in the conical flask for 3 h. This was filtered through a double layer of hardened filter papers. Each filtrate (50ml) was placed in 250ml beaker and 107ml of distilled water was added in each case to give proper acidity. Solution (10ml) of 0.3% ammonium thiocyanate solution was added into each solution as indicator. This was titrated with standard iron, chloride solution which contained 0.000195g iron per ml. The end point was slightly brownish yellow which persisted for 5 minutes. The percentage phytic acid was calculated using the formula:

$$\% \text{ Phytic acid} = P \times 1.19 \times 100$$

Where P = titre value x 0.000195g

3.3.5.5 Determination of cyanogenic glycosides

This was done by AOAC (1984) method. Each dry flour sample (1.0g) was weighed into a 250ml round bottomed flask, add calcium and disperse in 200mls of distilled water let it stand for 2 h (Autolysis was conducted with apparatus completely connected for distillation). An antifoaming agent (silicon oil or tannic acid) was added before distillation. In the steam

distillation 150-170ml of distillate was collected in a 250ml conical flask containing 20ml of 2.5% NaOH. To 100ml of the distillate containing cyanogenic glycoside, 8ml of 6N NH_4OH and 2ml of 5 % KI was added, mixed and titrated with 0.02 N silver nitrate ($AgNO_3$) using a micro-burette against a black background. Permanent turbidity indicates end point

Cyanogenic glycoside content of sample was calculated thus :

Cyanogenic glycoside mg/100g

$$= \frac{\text{Titre value(ml)} \times 1.08\text{(g)} \times \text{extract vol (ml)} \times 100}{\text{Aliquot vol (ml)} \times \text{sample wt (g)}}$$

3.3.5.6 Determination of trypsin inhibitor

The trypsin activity (TIA) assay discussed here is the spectrophotometric method described by Arntifield *et al*, (1985). Each sample (1.0g) was dispersed in 50ml of 0.5M NaCl.The mixture was stirred for 30 min at room temperature and centrifuged. The supernatants were filtered through whatman No. 41 filter paper. The filtrate (extract) is used for the assay. Standard trypsin was prepared using N- α – Bensoyl – DL arginine – P – nitroanilide (BAPA).To 10ml of the substrate in a test tube 2.0ml of the standard trypsin solution was added. A blank was prepared with 10ml of the same substrate in a test tube but with no extract added. The contents of the test tubes were allowed to stand for at least 5 min and then measured spectrophotometrically

at 410nm,wavelength .One trypsin unit inhibited (TIU) is equal to an increase fo 0.01 in absorbance unit at 410nm .

The trypsin inhibitor activity is expressed as the number of trypsin units inhibited (TIU) per unit weight (g) of the sample analyzed .

Thus:

$$\text{TIU/mg} = \frac{\text{Absorbance of sample}}{\text{Absorbance of standard}} \times 0.01F$$

$$\text{TUI /mg} = \frac{b - a}{0.01} \times F$$

Where b = absorbance of test sample solution

a = absorbance of the blank (control)

F = experimental factor given by

$F = 1/w \times Vf/Va \times D$

Where w = weight of sample

Vf = total volume of extract

Va = volume of extract used in the assay

D = dilution factor (if any)

3.3.5.7 Determination of oxalates

The dye method modified by Munro and Bassir (1969) was used for the extraction. Each dry sample (5.0g) was extracted 3 times by warming (40-50^{o}C) and stirring with magnetic stirrer for 1 hour in 200ml of 0.3N HCl .

The combined extract is diluted to 100ml with water and used for total oxalate estimation.

For oxalate estimation, 5.0ml of extract was made alkaline with 1.0ml of 5N ammonium hydroxide. This was made acid to phenolphthalein (2 or 3 drops of this indicator added excess acid decolorizes solution) by drop wise addition of glacial acetic acid. 1.0ml of 5% $CaCl_2$ was then added and the mixture allowed to stand for 3 hours after which it was then centrifuged at 3000rpm for 15 minutes. The supernatants were discarded and the precipitates washed 3 times with hot water with thorough mixing and centrifuging each time. Then to each tube 2.0ml of 3N H_2SO_4 was added and then precipitates dissolved by warming in a water bath (70-80 ^{0}C). The content of each tube was then titrated with freshly prepared 0.01N K_2MnO_4 . Titration was carried out at ordinary temperature until the pink colour appears throughout the solution. This was allowed to stand until the solution was colourless. The solution was then warmed to 70-80 ^{0}C and titration was continued until a pink colour persists for at least 30 seconds.

Calculation was done as follows:

$$\frac{T \times (Vme)(Df) \times 10^5}{(ME) \times Mf} \text{ (mg /100g)}$$

Where T is the titre value of $KMnO_4$ **(**ml)

Vme is the volume-mass equivalent (i.e. 1cm^3 of 0.05m $KMnO_4$ solution is equivalent to 0.00225g anhydrous oxalic acid),

Df is the dilution factor V_T/A (2.4 where V_T is the total volume of titrate (300ml) and A is the aliquot used (125ML),

ME is the molar equivalent of $KMnO_4$ in oxalate ($KMnO_4$ redox reaction)

mf is the mass of flour used

3.2.7.8 Determination of hemagglutinin

The method of determination of hemagglutinin was by spectrophotometric method as described by Onwuka (2005). Sample (0.5g of each) was dispersed in a 10ml normal saline solution buffered at pH 6.4 with a 0.01M phosphate buffer solution. It was allowed to stand at room temperature for 30 minutes and then centrifuged to obtain the extract. To 0.1ml of the extract diluent in a test tube, 1ml of trypsinized (20% trypsin solution has be added) cow blood was added. The control was mounted with the test-tube containing only the red blood cells. Allow both tubes to stand for 4 hours at room temperature 1ml of normal saline was added to all the test tubes and allowed to stand for 10 minutes after which the absorbance was read at 620nm..The test tubes containing only the blood cells and normal saline serves as the blank. The result was expressed as hemagglutinin unit per milligram of the sample

HUI/mg = (b – a) x f

$$F = \frac{1}{W} \times \frac{V_f}{V_a} \times D$$

w = 0.5g

V_f = 8

V_a = 0.1

D = 1

a = 0 (as blank)

Where b = absorbance of test sample solution

a = absorbance of the standard

F = experimental factor, given by

$$F = \frac{1}{w} \times \frac{V_f}{V_a} \times D$$

Where w = weight of sample

Vf = total volume of extract

Va = volume of extract used in the assay

D = dilution factor (if any)

Spectrophotometer used: Agilent uv/visible spectrophotometer with 1cm path length

3.3.6 Sensory Analysis

Samples were selected based on high swelling index, low gelling point, low water absorption capacity, high fiber content, appropriate proximate composition when compared to the conventional wheat flour .In this selection of blends ,the blends were selected based on the highest mean score from the statistical analysis for the maximal requirement and the least mean score for the minimal requirement. The selected composite flour samples were used in the production of queen's cake.

3.3.6.1 Cake production process

The creaming method of cake production by Hermes (1999) was used for the cake production .The selected samples and the conventional wheat flour which served as the control were used for the queen's cake production.(Fig. 3.3). All the ingredients were properly weighed. To 100g of sample flour 75g of sugar, 75g of fat and 2 eggs were used. The sugar and fat were creamed together in a bowl using a wooden spoon with a circular motion until soft, white and creamy mixture was achieved .The beaten eggs were added by degrees continuing the creaming between each addition, once the mixture began to curdle a little flour was added to make it smooth. This mixing with the addition of flour was continued until the weighed ingredients were exhausted. The final mixture was soft enough to drop from the spoon. This was then placed in greased patty tins and baked in fairly hot oven at temperature 140-180^{o}C for 20 minutes. They were removed from the tins and placed on cooling racks to cool.

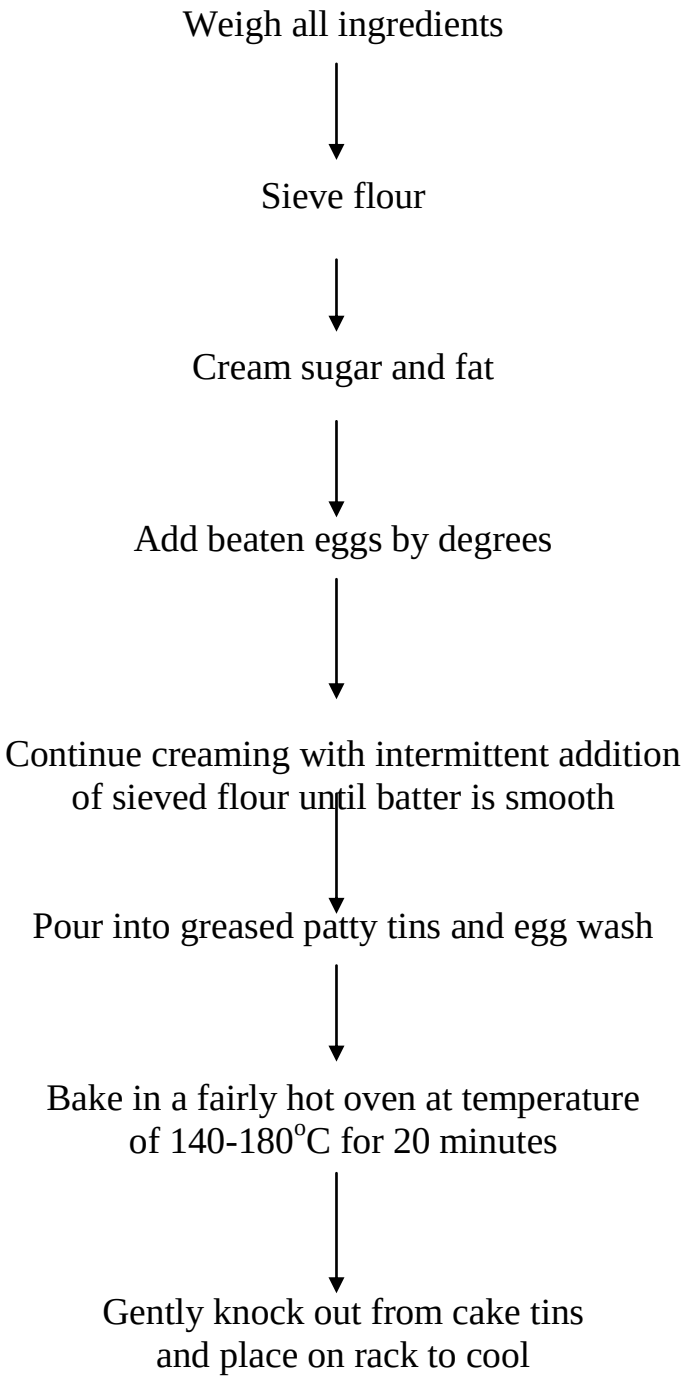


Fig. 3.3 Flow chart for the preparation of queen's cake

3.6.6.2 Sensory evaluation

Sensory evaluation of the queen's cake was conducted using fifteen semi-trained panelists that were familiar with quality attributes of queen's cake. Samples were presented in identical container with different coding. Nine point hedonic scale as described by Ihekoronye and Ngoddy (1985) was used ranging from like extremely (9) to dislike extremely (1).Each cake sample was rated for colour, aroma, taste, texture, overall acceptance. Samples were rated along side the control sample (100%) wheat flour for comparison.

3.3.7 Statistical Analysis of Data

The values of the proximate composition, physicochemical properties and antinutritional properties as affected by bambara groundnut treatments and the root tuber type were statistically analyzed by fitting them into a TFT (4) x BGT (3) x TFB (5) factorial experimental design (Table 3.2) and analysis of variance (ANOVA) was carried out according to Nwachukwu and Egbulonu (2000) and SAS (1999). Mean separation was done using the Fisher LSD to determine the significant differences at 5% level. Also subjected to ANOVA were the data obtained from sensory quality analysis. The design of experiment for the proximate, antinutritional and physicochemical analysis is represented at the Table 3.2 below:

Table 3.2 Factorial Design of Experiments

A	B_1	B_2	B_3	C
A_1	$A_1B_1C_1$	$A_1B_2C_1$	$A_1B_3C_1$	C_1
	$A_1B_1C_2$	$A_1B_2C_2$	$A_1B_3C_2$	C_2
	$A_1B_1C_3$	$A_1B_2C_3$	$A_1B_3C_3$	C_3
	$A_1B_1C_4$	$A_1B_2C_4$	$A_1B_3C_4$	C_4
	$A_1B_1C_5$	$A_1B_2C_5$	$A_1B_3C_5$	C_5
A_2	$A_2B_1C_1$	$A_2B_2C_1$	$A_2B_3C_1$	C_1
	$A_2B_1C_2$	$A_2B_2C_2$	$A_2B_3C_2$	C_2
	$A_2B_1C_3$	$A_2B_2C_3$	$A_2B_3C_3$	C_3
	$A_2B_1C_4$	$A_2B_2C_4$	$A_2B_3C_4$	C_4
	$A_2B_1C_5$	$A_2B_2C_5$	$A_2B_3C_5$	C_5
A_3	$A_3B_1C_1$	$A_3B_2C_1$	$A_3B_3C_1$	C_1
	$A_3B_1C_2$	$A_3B_2C_2$	$A_3B_3C_2$	C_2
	$A_3B_1C_3$	$A_3B_2C_3$	$A_3B_3C_3$	C_3
	$A_3B_1C_4$	$A_3B_2C_4$	$A_3B_3C_4$	C_4
	$A_3B_1C_5$	$A_3B_2C_5$	$A_3B_3C_5$	C_5
A_4	$A_4B_1C_1$	$A_4B_2C_1$	$A_4B_3C_1$	C_1
	$A_4B_1C_2$	$A_4B_2C_2$	$A_4B_3C_2$	C_2
	$A_4B_1C_3$	$A_4B_2C_3$	$A_4B_3C_3$	C_3
	$A_4B_1C_4$	$A_4B_2C_4$	$A_4B_3C_4$	C_4
	$A_4B_1C_5$	$A_4B_2C_5$	$A_4B_3C_5$	C_5

KEY: A_i= Root Tuber Flours. i = 1-4 (cassava, yam, cocoyam, sweet potato)

B_j= Bambara groundnut Treatments. j=1-3 (conventional, cotyledon, steamed cotyledon)

C_k= Blend Ratios. k = 1-5 (TTF:BGF) = (100:0.75:25,50:50,25:75,0:100).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS

Table 4.1a Data from Proximate Composition of Tropical Tuber Flours Blended with Treated Bambara groundnut flours

Sample code	%Moisture	%Protein	%Fat	%Flbre	%Ash	%CHO	Energy(kJ)	%Dry matter
$A_1B_1C_1$	12.82	1.45	1.67	0.55	0.30	83.21	353.67	87.18
$A_1B_1C_2$	13.46	4.04	3.60	1.10	0.59	77.21	357.40	86.54
$A_1B_1C_3$	12.83	9.38	5.35	1.45	0.59	70.40	367.27	87.17
$A_1B_1C_4$	10.52	11.08	5.97	1.80	1.74	68.89	373.67	89.48
$A_1B_1C_5$	11.96	14.80	6.20	1.95	2.52	62.57	365.28	88.04
$A_1B_2C_1$	12.82	1.45	1.67	0.55	0.30	83.21	353.67	87.18
$A_1B_2C_2$	12.37	4.65	3.17	1.10	1.25	77.46	356.97	87.63
$A_1B_2C_3$	11.36	8.81	4.04	1.30	1.48	73.01	363.64	88.64
$A_1B_2C_4$	11.11	10.88	4.99	2.00	2.46	62.56	362.67	88.89
$A_1B_2C_5$	9.60	16.65	7.86	0.90	2.48	62.51	387.38	90.40
$A_1B_3C_1$	12.82	1.45	1.67	0.55	0.30	83.21	353.67	87.18
$A_1B_3C_2$	12.42	5.69	2.69	0.80	0.55	77.85	358.37	87.58
$A_1B_3C_3$	12.33	12.44	5.03	2.85	1.37	65.98	358.95	87.67
$A_1B_3C_4$	12.55	13.90	6.61	2.45	1.50	59.39	367.05	87.45
$A_1B_3C_5$	9.83	16.83	8.87	0.80	1.96	61.71	394.11	90.17
$A_2B_1C_1$	12.32	5.08	1.06	0.75	1.31	79.48	347.78	87.68
$A_2B_1C_2$	12.08	5.67	1.26	0.95	1.39	78.65	348.62	87.92
$A_2B_1C_3$	12.01	8.87	1.52	1.05	1.60	74.95	348.96	87.79
$A_2B_1C_4$	11.25	12.15	5.16	1.15	2.34	67.95	366.84	88.75
$A_2B_1C_5$	11.96	14.80	6.20	1.95	2.52	62.57	365.28	88.04
$A_2B_2C_1$	12.32	5.08	1.06	0.75	1.31	79.48	347.78	87.68
$A_2B_2C_2$	9.73	7.50	2.67	1.60	2.13	76.37	359.51	90.27
$A_2B_2C_3$	12.38	12.95	4.62	1.30	2.28	66.47	359.26	87.62
$A_2B_2C_4$	11.07	13.61	6.36	0.90	2.46	65.60	374.08	88.93
$A_2B_2C_5$	9.60	16.65	7.86	0.90	2.48	62.51	387.38	90.40
$A_2B_3C_1$	12.32	5.08	1.06	0.75	1.31	79.48	347.78	87.68
$A_2B_3C_2$	10.44	12.40	2.61	1.15	1.75	71.65	359.69	89.56
$A_2B_3C_3$	11.65	15.69	4.93	1.55	1.82	64.36	364.57	88.35
$A_2B_3C_4$	10.36	16.57	7.11	1.65	1.85	62.46	380.11	89.64
$A_2B_3C_5$	9.83	16.83	8.87	0.80	1.96	61.71	394.11	90.17
$A_3B_1C_1$	11.54	3.97	1.57	1.20	2.61	79.12	346.49	88.46
$A_3B_1C_2$	10.80	8.59	3.33	1.40	2.07	73.81	359.57	89.20
$A_3B_1C_3$	11.53	11.90	5.39	1.30	1.75	68.13	368.63	88.47
$A_3B_1C_4$	10.14	14.30	6.18	1.35	2.34	65.69	375.58	89.86
$A_3B_1C_5$	11.96	14.80	6.20	1.95	2.52	62.57	365.28	88.04
$A_3B_2C_1$	11.54	3.97	1.57	1.20	2.61	79.12	346.49	88.46
$A_3B_2C_2$	11.25	6.56	2.03	1.30	2.13	76.73	351.43	88.75
$A_3B_2C_3$	9.71	12.70	3.55	1.40	1.82	70.82	366.03	90.29
$A_3B_2C_4$	11.91	16.30	5.70	1.40	1.88	62.81	367.74	88.09
$A_3B_2C_5$	9.60	16.65	7.86	0.90	2.48	62.51	387.38	90.40
$A_3B_2C_5$	9.64	16.60	7.84	0.97	2.48	62.47	386.84	90.36
$A_3B_2C_5$	9.56	16.70	7.88	0.83	2.48	62.55	387.92	90.44
$A_3B_3C_1$	11.54	3.97	1.57	1.20	2.61	79.12	346.49	88.46
$A_3B_3C_2$	12.18	7.82	2.92	1.70	2.28	73.10	349.96	87.82
$A_3B_3C_3$	10.34	7.56	5.06	1.60	2.27	73.17	368.46	89.66
$A_3B_3C_4$	12.34	12.36	6.74	1.80	2.36	64.40	367.52	87.66
$A_3B_3C_5$	9.83	16.83	8.87	0.80	1.96	61.71	394.11	90.17
$A_4B_1C_1$	11.52	2.84	1.18	1.90	0.79	81.77	349.06	88.48
$A_4B_1C_2$	9.60	7.09	2.24	0.80	2.32	77.95	360.32	90.40
$A_4B_1C_3$	11.34	7.78	3.45	1.25	2.42	73.76	357.21	88.66
$A_4B_1C_4$	11.51	12.66	3.80	1.35	2.94	67.74	355.80	88.49
$A_4B_1C_5$	11.96	14.80	6.20	1.95	2.52	62.57	365.28	88.04
$A_4B_2C_1$	11.52	2.84	1.18	1.90	0.79	81.77	349.06	88.48
$A_4B_2C_2$	10.71	9.43	3.57	1.60	1.40	73.29	363.01	89.29
$A_4B_2C_3$	10.93	10.24	5.24	1.40	1.48	70.71	370.96	89.07
$A_4B_2C_4$	10.42	11.86	5.73	1.20	1.87	68.92	374.69	89.58
$A_4B_2C_5$	9.60	16.65	7.86	0.90	2.48	62.51	387.38	90.40
$A_4B_3C_1$	11.52	2.84	1.18	1.90	0.79	81.77	349.06	88.48
$A_4B_3C_2$	10.69	10.27	4.72	1.40	1.23	71.69	370.32	89.31
$A_4B_3C_3$	10.90	12.74	6.89	1.20	1.63	66.64	379.53	89.10
$A_4B_3C_4$	10.44	14.84	7.37	1.10	2.05	64.20	382.49	89.56
$A_4B_3C_5$	9.83	16.83	8.87	0.80	1.96	61.71	394.11	90.17

*Means of triplicate determinations

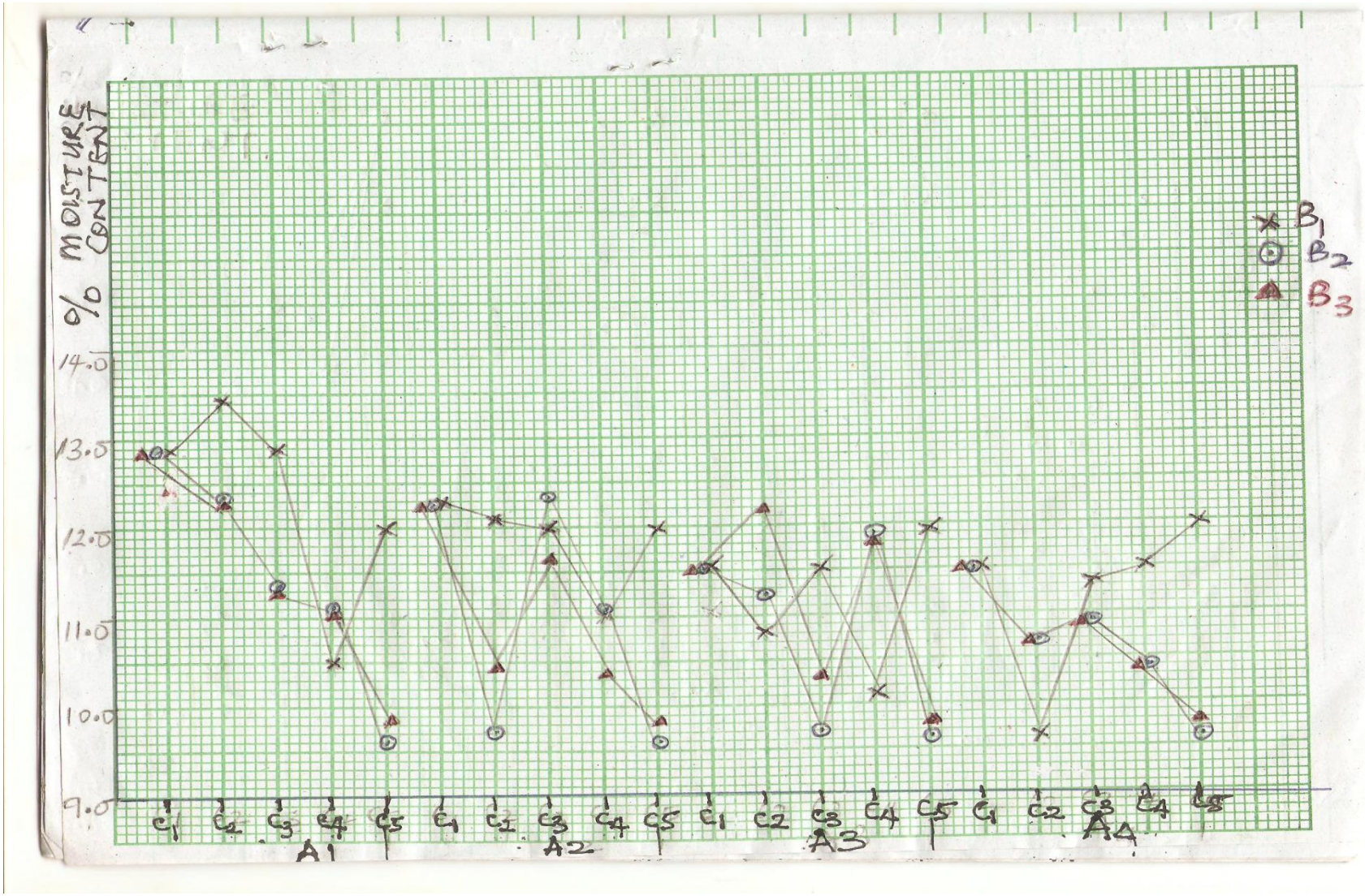


Fig.4.1: Effect of blend ratios on the percentage moisture content of flours selected from tropical tuber flours and treated bambara groundnut flours

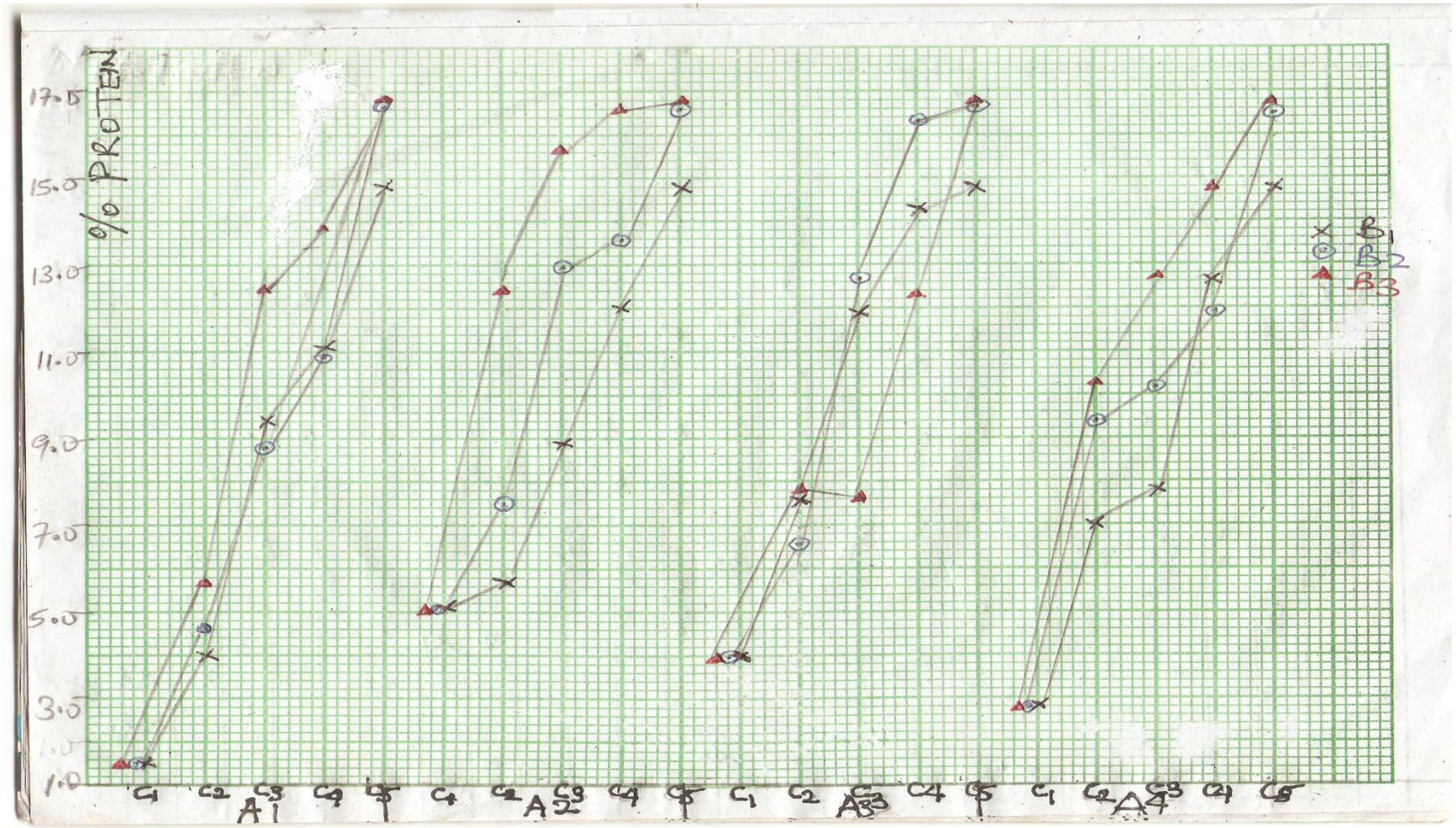


Fig.4.2: Effect of blend ratios on the percentage protein content of flours selected from tropical tuber flours and treated bambara groundnut flours

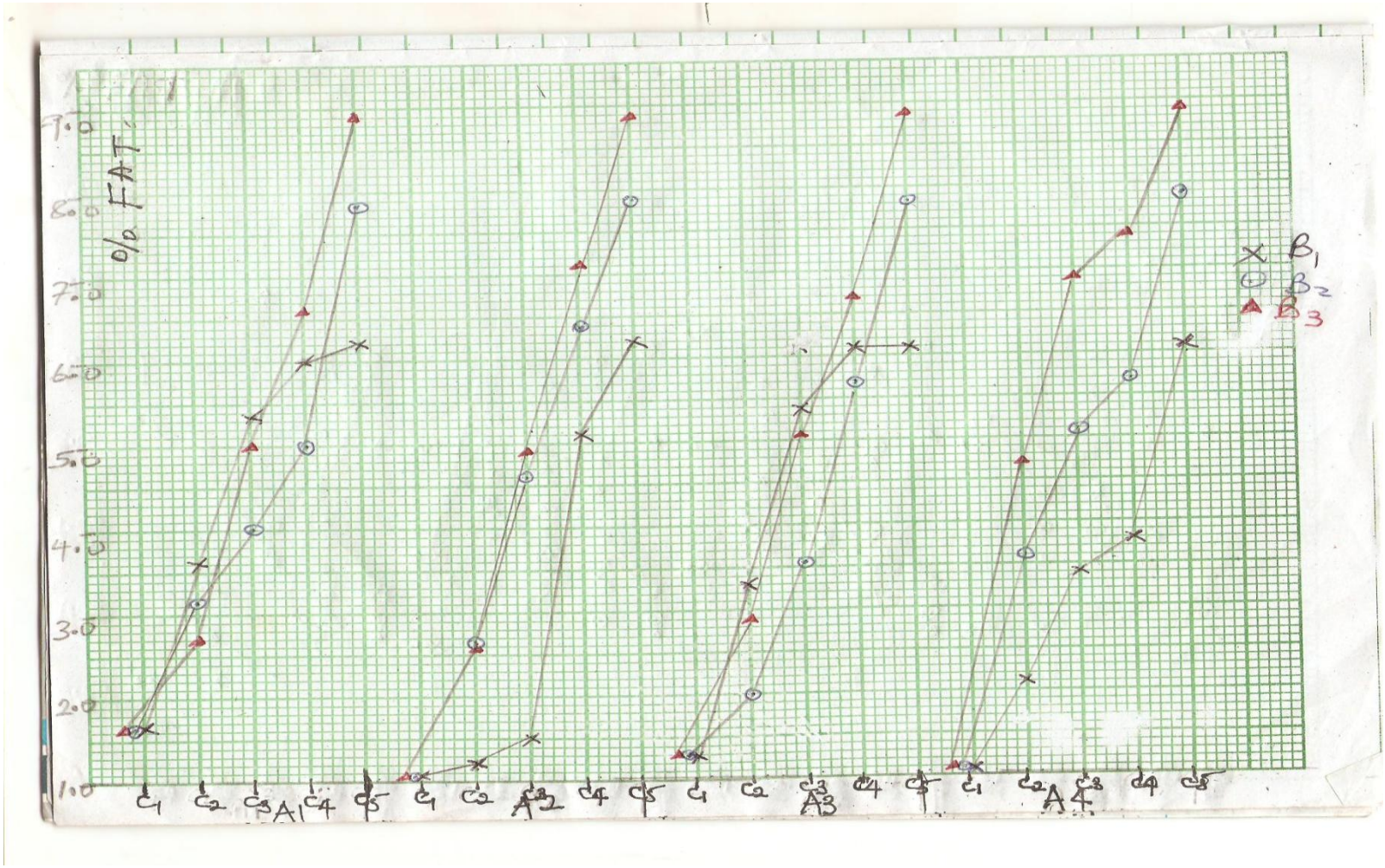


Fig.4.3: Effect of blend ratios on the percentage fat content of flours selected from tropical tuber flours and treated bambara groundnut flours

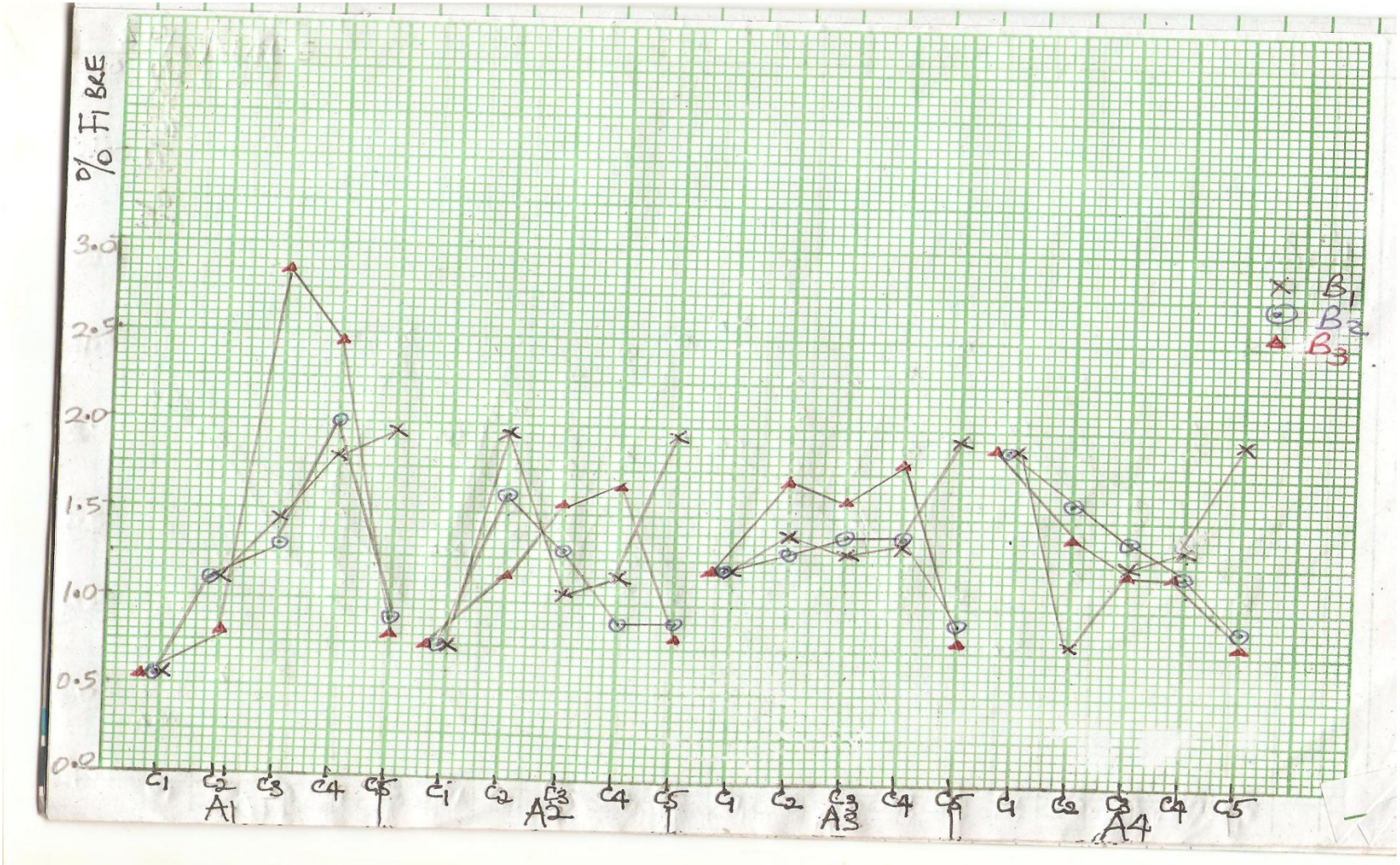


Fig.4.4: Effect of blend ratios on the percentage fibre content of flours selected from tropical tuber flours and treated bambara groundnut flours

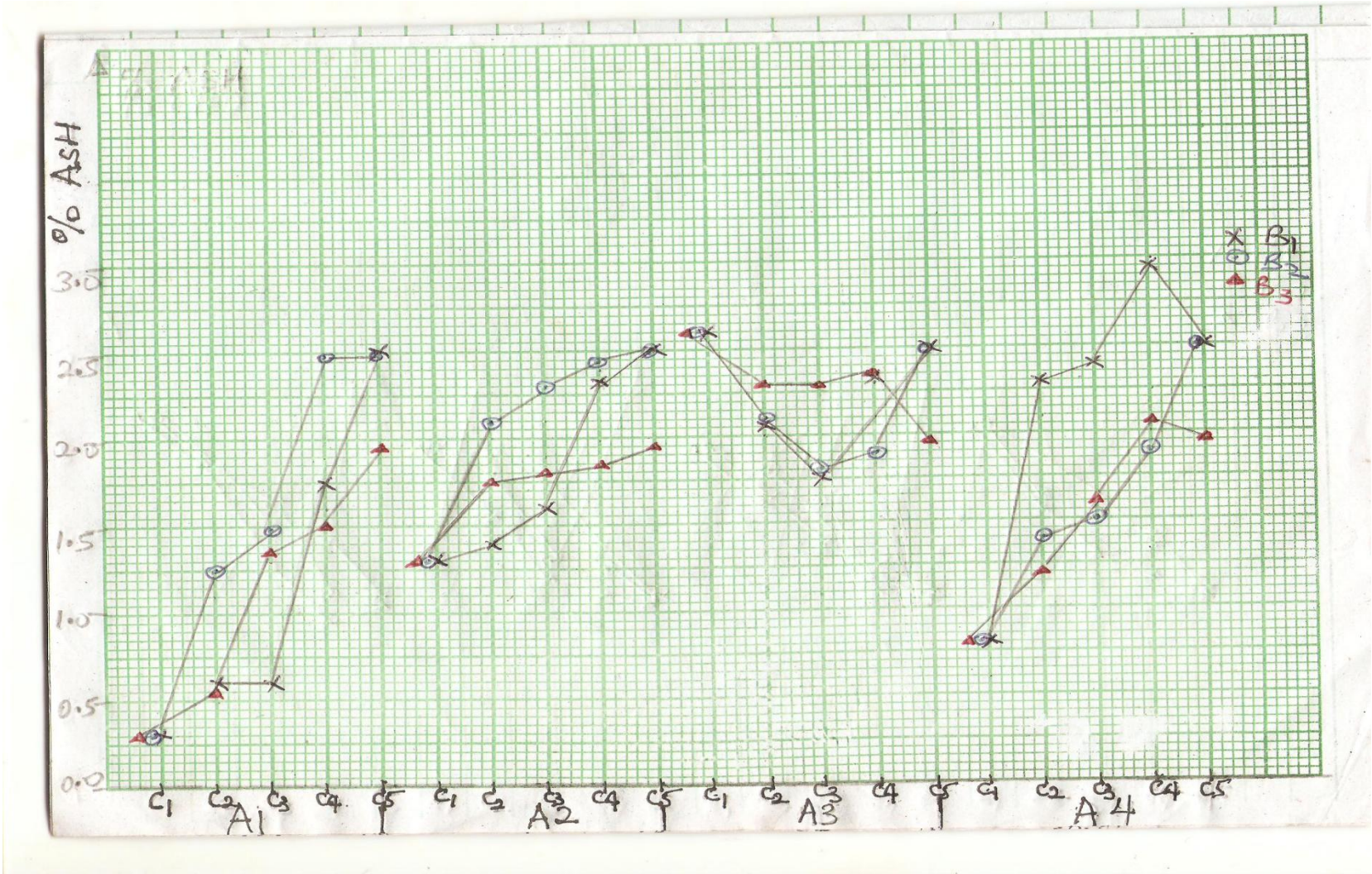


Fig.4.5: Effect of blend ratios on the percentage ash content of flours selected from tropical tuber flours and treated bambara groundnut flours

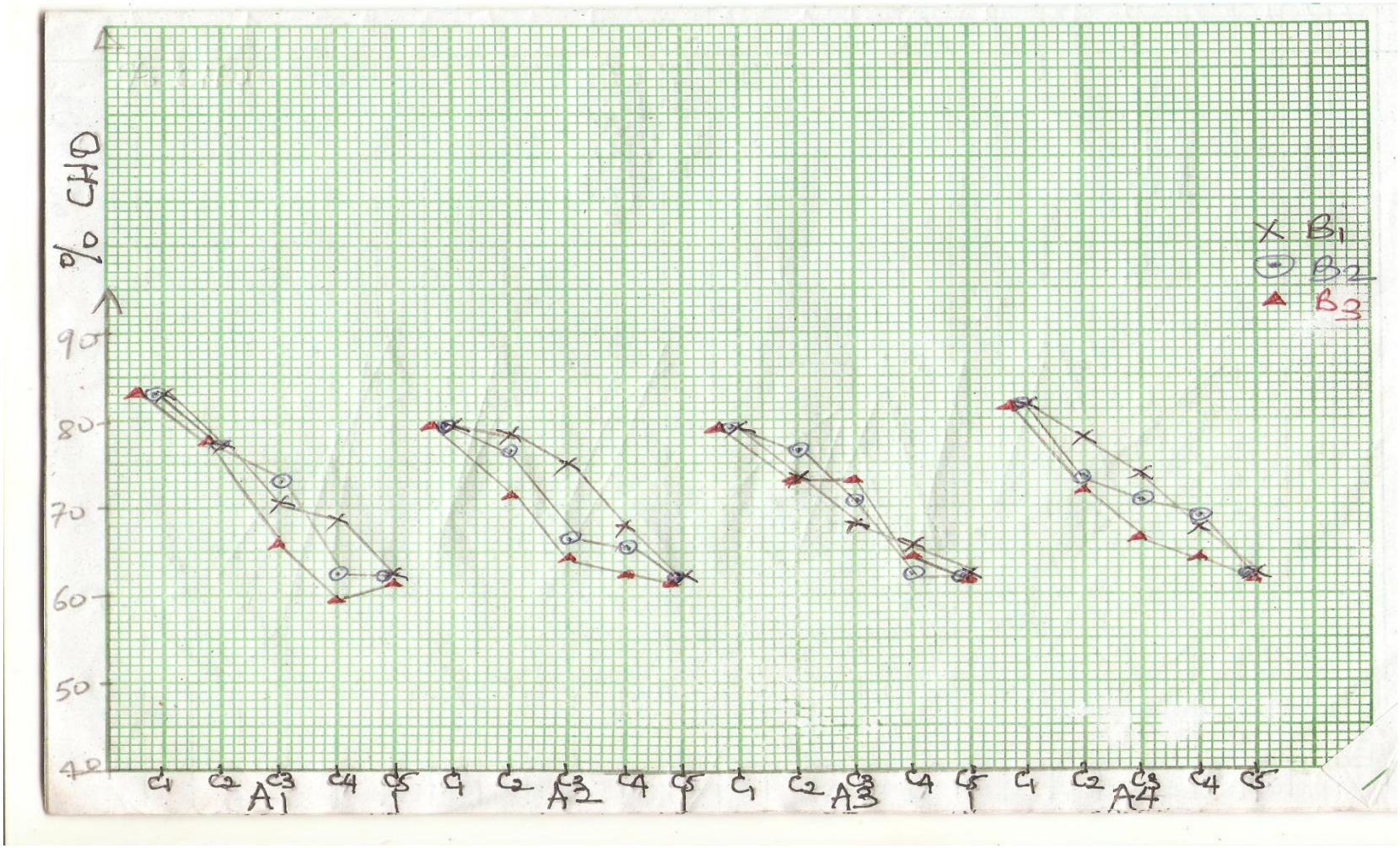


Fig.4.6: Effect of blend ratios on the percentage carbohydrate content of flours selected from tropical tuber flours and treated bambara groundnut flours

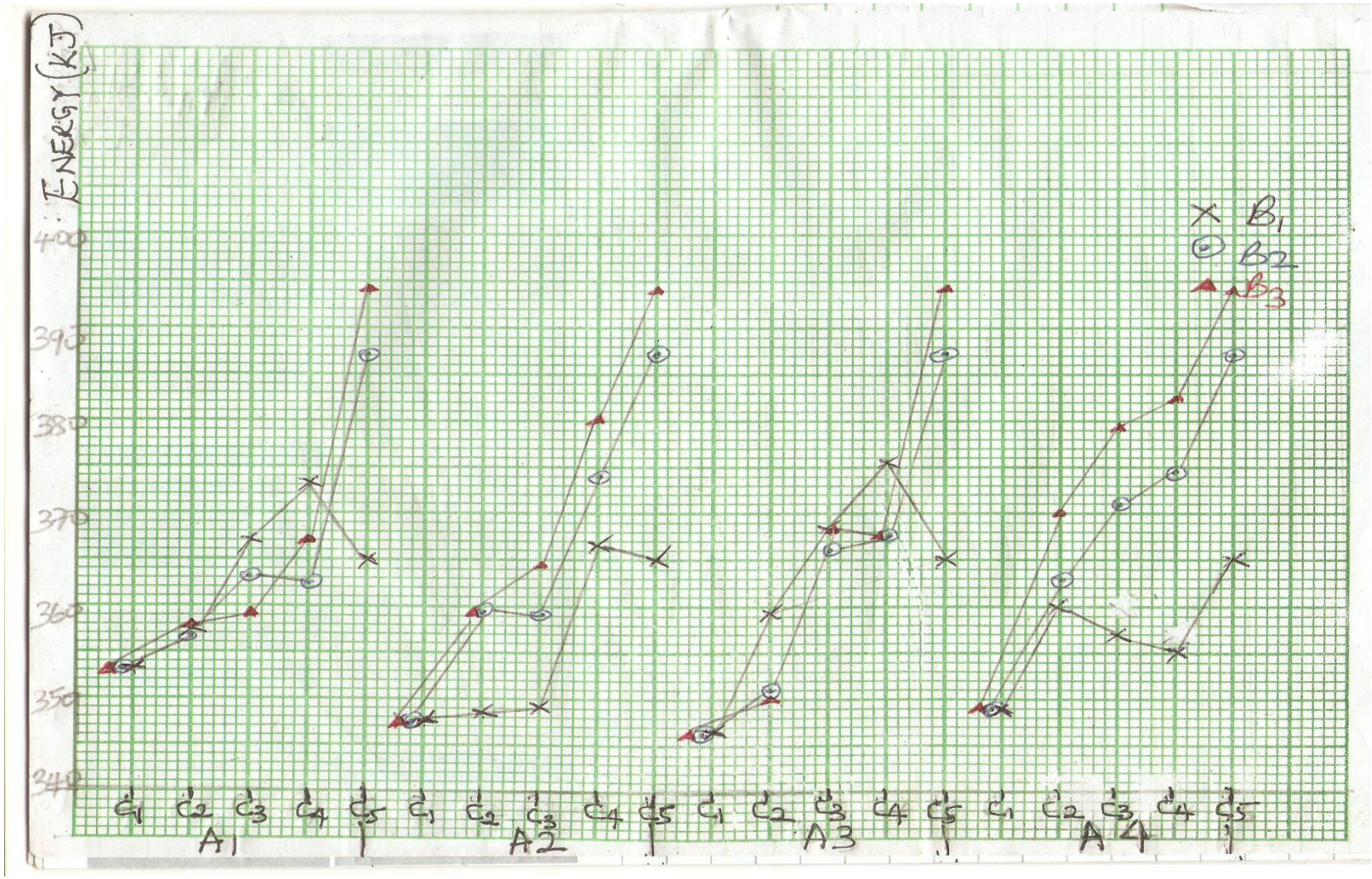


Fig.4.7: Effect of blend ratios on the energy content of flours selected from tropical tuber flours and treated bambara groundnut flour

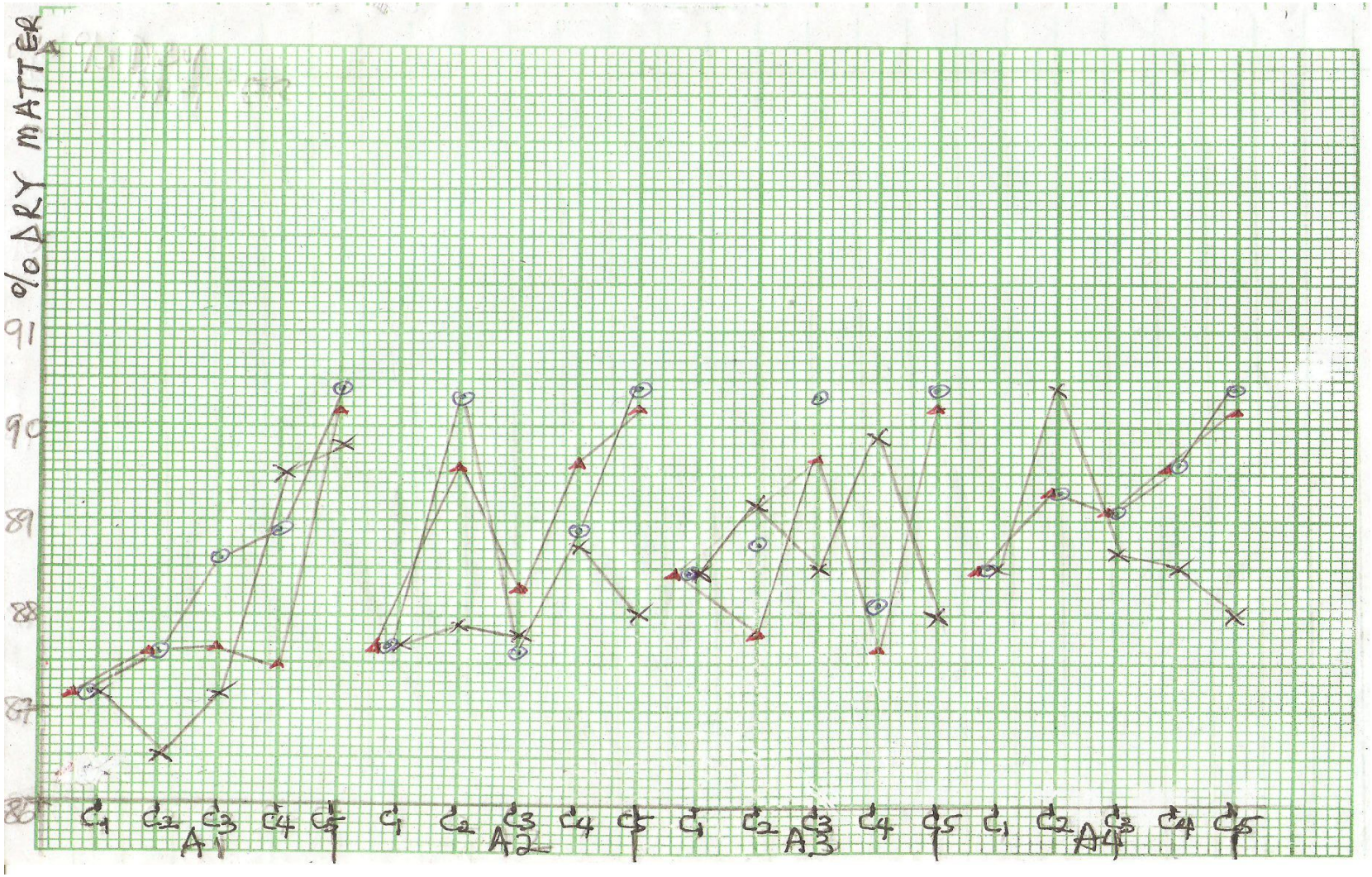


Fig.4.8: Effect of blend ratios on the percentage dry matter content of flours selected from tropical tuber flours and treated bambara groundnut flour

Table 4.1b Data from Physicochemical Properties of Tropical Tuber Flours Blended with Treated Bambara groundnut flours

Sample code	Swelling index (g/ml)	Oil absorption capacity (g/cm^3)	Water absorption capacity (g/cm^3)	Gelling temp.(^{o}C)	Boiling temp.(^{o}C)	pH
$A_1B_1C_1$	1.06	1.54	1.10	74.50	79.00	6.20
$A_1B_1C_2$	1.06	1.56	1.20	70.00	75.50	6.20
$A_1B_1C_3$	1.08	1.29	1.05	78.00	82.00	5.90
$A_1B_1C_4$	1.07	1.46	1.20	67.50	81.00	6.40
$A_1B_1C_5$	1.06	1.77	0.60	78.50	85.00	6.30
$A_1B_2C_1$	1.06	1.54	1.00	74.50	79.00	6.20
$A_1B_2C_2$	1.06	1.78	1.80	78.00	84.00	6.20
$A_1B_2C_3$	1.15	1.46	1.51	84.50	90.50	6.30
$A_1B_2C_4$	1.07	1.11	1.60	82.00	94.50	6.40
$A_1B_2C_5$	1.13	1.75	2.00	89.50	97.50	6.50
$A_1B_3C_1$	1.06	1.54	1.00	74.50	79.00	6.20
$A_1B_3C_2$	1.50	1.76	2.00	78.00	84.00	6.30
$A_1B_3C_3$	1.39	1.53	1.55	88.00	94.00	6.20
$A_1B_3C_4$	1.32	1.76	1.90	93.00	98.00	6.15
$A_1B_3C_5$	1.20	1.79	2.00	92.00	96.00	6.50
$A_2B_1C_1$	1.23	1.50	2.10	76.50	87.50	6.30
$A_2B_1C_2$	1.61	0.73	1.80	70.00	82.00	6.30
$A_2B_1C_3$	1.40	0.92	1.70	75.50	85.50	6.50
$A_2B_1C_4$	1.33	0.72	0.95	78.00	90.50	6.50
$A_2B_1C_5$	1.06	1.77	0.60	78.50	85.00	6.30
$A_2B_2C_1$	1.23	1.50	2.00	76.50	87.50	6.30
$A_2B_2C_2$	1.40	1.84	2.00	81.00	97.50	6.40
$A_2B_2C_3$	1.29	1.84	2.13	84.00	92.00	6.20
$A_2B_2C_4$	1.28	1.48	1.40	86.00	94.00	6.20
$A_2B_2C_5$	1.13	1.75	2.00	89.50	97.50	6.50
$A_2B_3C_1$	1.24	1.50	2.00	76.50	87.50	6.30
$A_2B_3C_2$	1.14	1.29	1.40	75.50	78.50	6.20
$A_2B_3C_3$	1.17	1.47	1.40	68.00	78.50	6.30
$A_2B_3C_4$	1.09	1.46	2.40	80.50	82.50	6.20
$A_2B_3C_5$	1.20	1.79	2.00	92.00	96.00	6.50
$A_3B_1C_1$	1.31	1.34	1.50	85.50	93.00	6.50
$A_3B_1C_2$	1.27	1.38	1.40	80.50	86.50	6.10
$A_3B_1C_3$	1.04	1.29	1.25	73.00	79.00	6.40
$A_3B_1C_4$	1.07	1.28	1.20	82.00	89.00	6.40
$A_3B_1C_5$	1.06	1.77	0.60	78.50	85.00	6.30
$A_3B_2C_1$	1.31	1.34	1.50	85.50	93.00	6.50
$A_3B_2C_2$	1.13	1.66	1.38	80.00	85.50	6.10
$A_3B_2C_3$	1.16	1.47	1.20	82.00	92.00	6.40
$A_3B_2C_4$	1.10	1.09	1.40	79.00	90.00	6.20
$A_3B_2C_5$	1.13	1.75	2.00	89.50	97.50	6.50
$A_3B_3C_1$	1.31	1.34	1.50	85.50	93.00	6.50
$A_3B_3C_2$	1.03	1.29	1.43	87.00	96.00	6.40
$A_3B_3C_3$	1.25	1.30	1.35	78.00	97.50	6.40
$A_3B_3C_4$	1.13	1.46	1.58	86.00	96.00	6.40
$A_3B_3C_5$	1.20	1.79	2.00	92.00	96.00	6.50
$A_4B_1C_1$	1.79	1.65	2.00	84.00	90.00	6.20
$A_4B_1C_2$	1.19	0.73	2.60	79.00	92.50	6.40
$A_4B_1C_3$	1.09	0.92	1.94	84.00	88.00	6.40
$A_4B_1C_4$	1.17	0.91	1.00	85.50	92.00	6.50
$A_4B_1C_5$	1.06	1.77	0.60	78.50	85.00	6.30
$A_4B_2C_1$	1.79	1.65	2.00	84.00	90.00	6.20
$A_4B_2C_2$	1.04	1.28	1.35	77.50	86.00	6.30
$A_4B_2C_3$	1.06	1.38	1.20	80.00	95.00	6.40
$A_4B_2C_4$	1.15	1.10	1.40	85.00	95.00	6.20
$A_4B_2C_5$	1.13	1.75	2.00	89.50	97.50	6.50
$A_4B_3C_1$	1.79	1.65	2.00	84.00	90.00	6.20
$A_4B_3C_2$	1.15	1.10	1.62	78.00	82.00	6.30
$A_4B_3C_3$	1.11	1.29	1.60	86.50	96.00	6.30
$A_4B_3C_4$	1.19	1.47	1.60	89.00	97.00	6.00
$A_4B_3C_5$	1.20	1.79	2.00	92.00	96.00	6.50

Mean of duplicate determinations

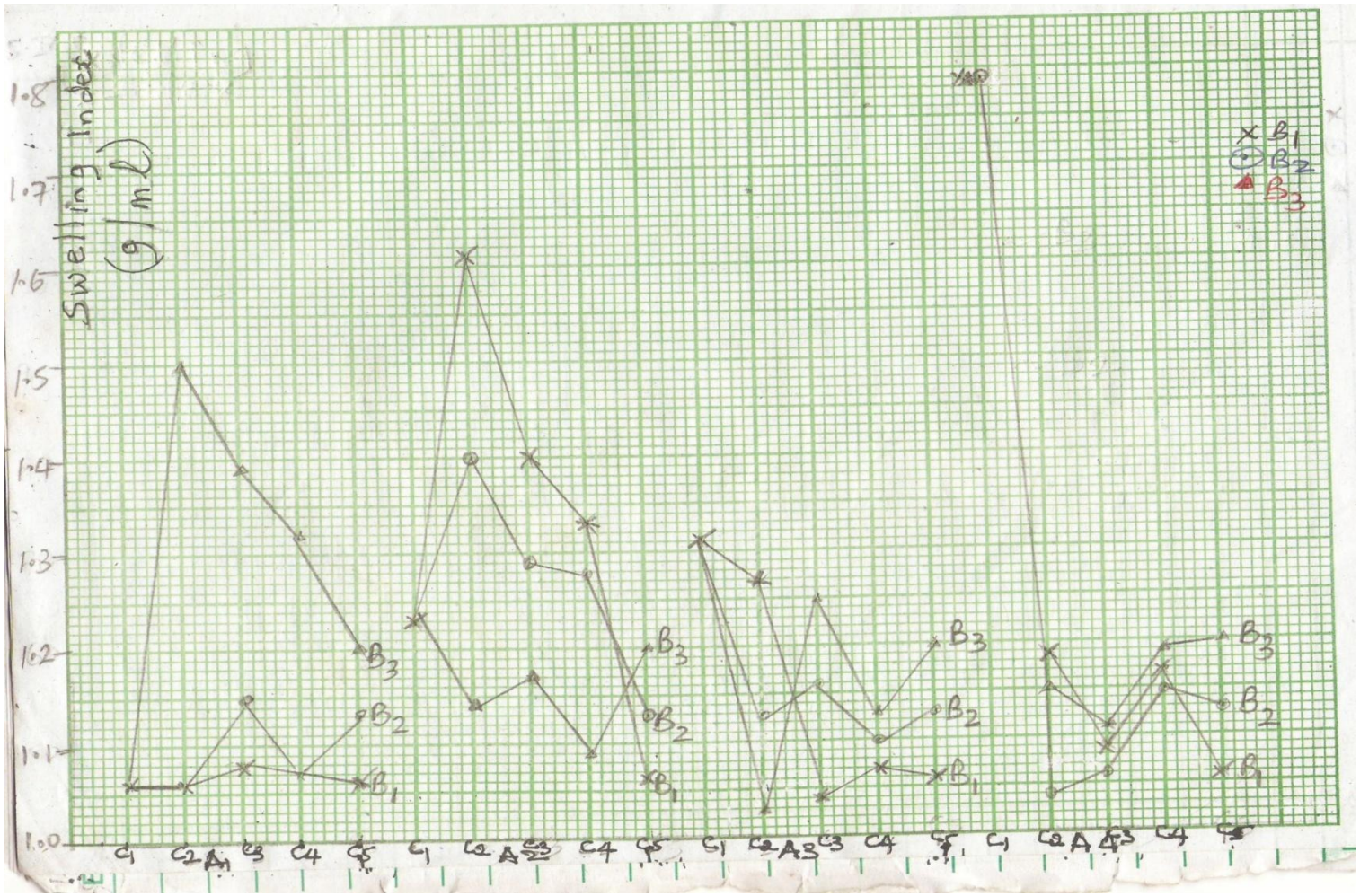


Fig.4.9: Effect of blend ratios on the swelling index of flours selected from tropical tuber flours and treated bambara groundnut flours

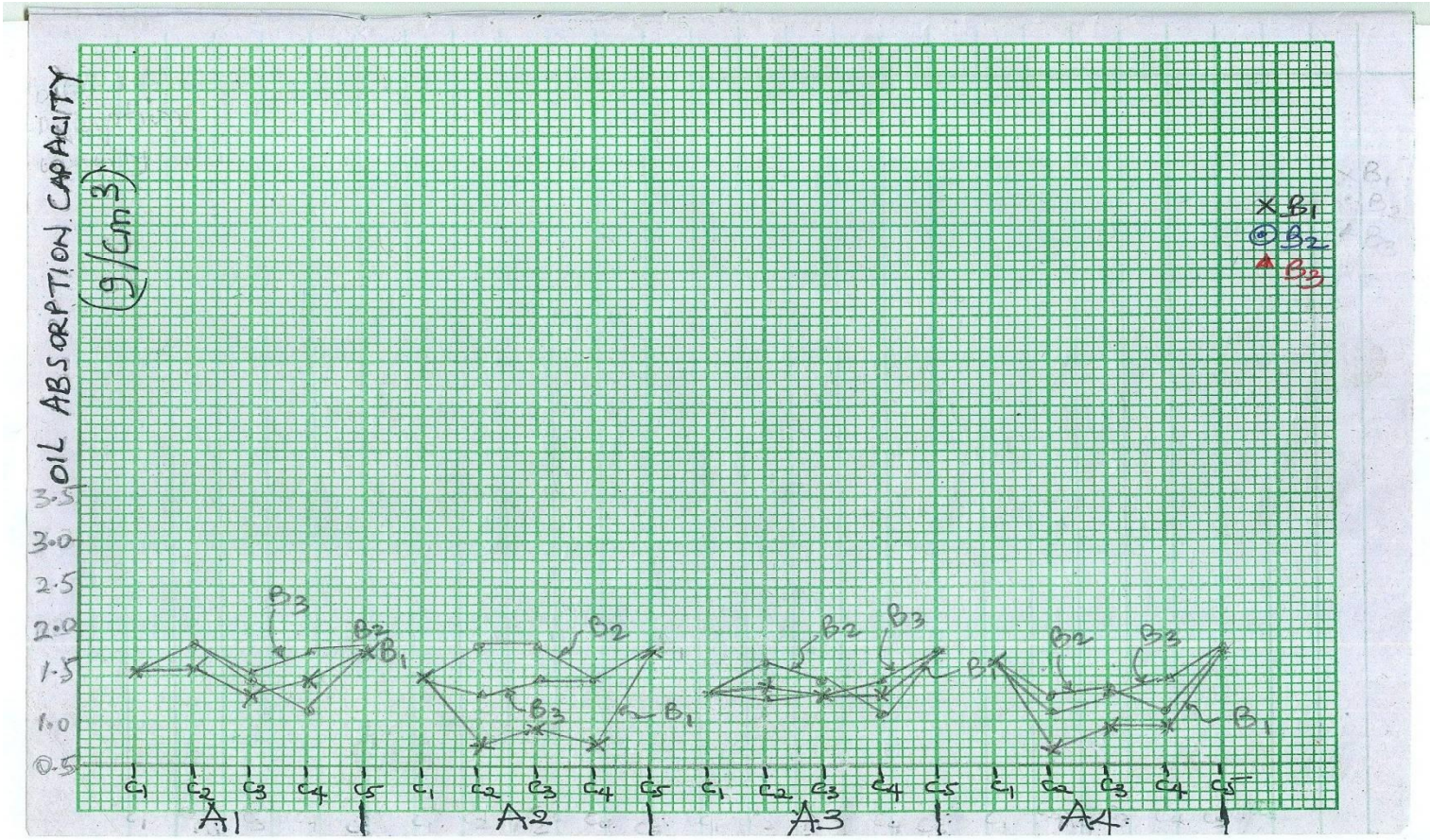


Fig.4.10: Effect of blend ratios on the oil absorption capacity of flours selected from tropical tuber flours and treated bambara groundnut flours

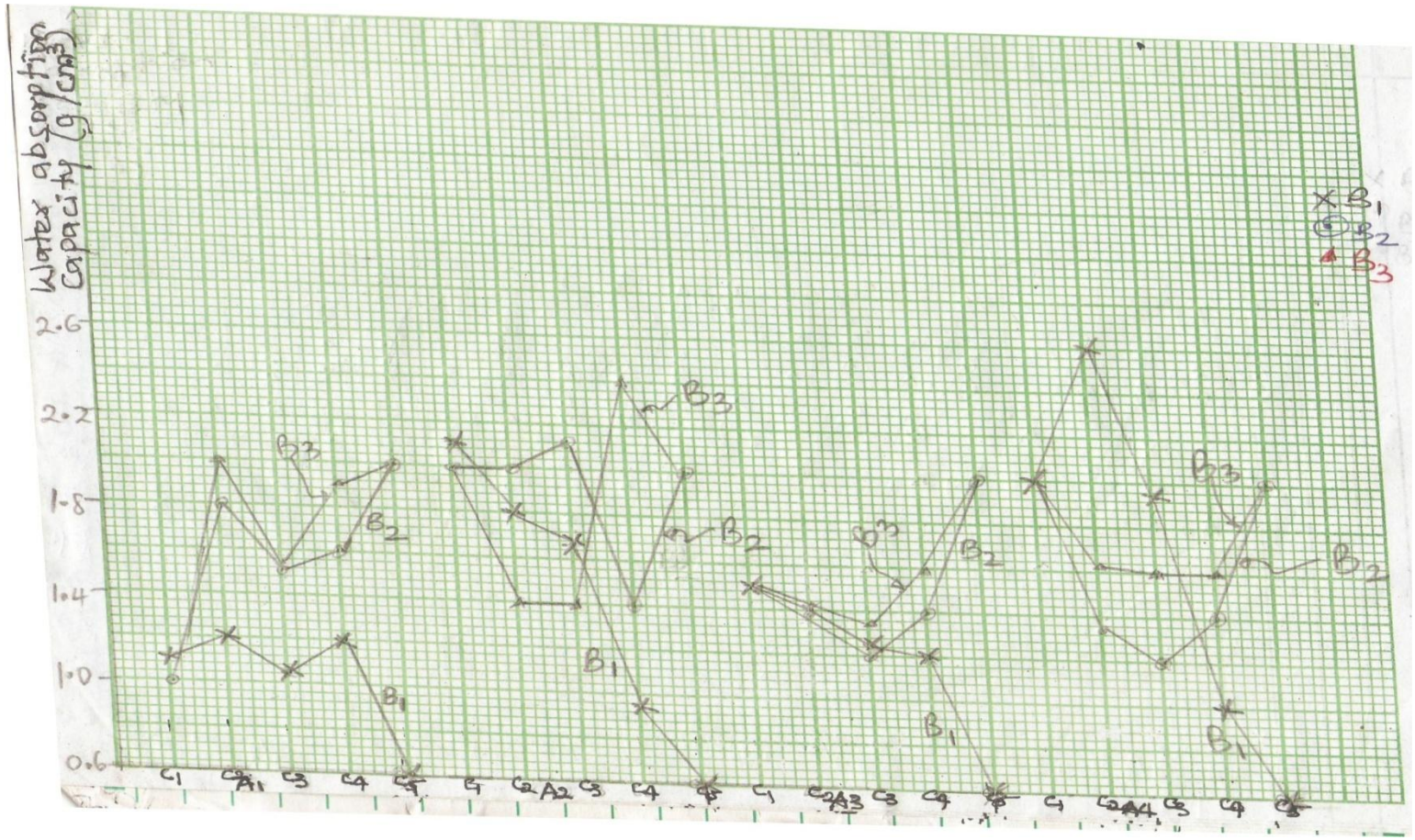


Fig.4.11: Effect of blend ratios on the water absorption capacity of flours selected from tropical tuber flours and treated bambara groundnut flours

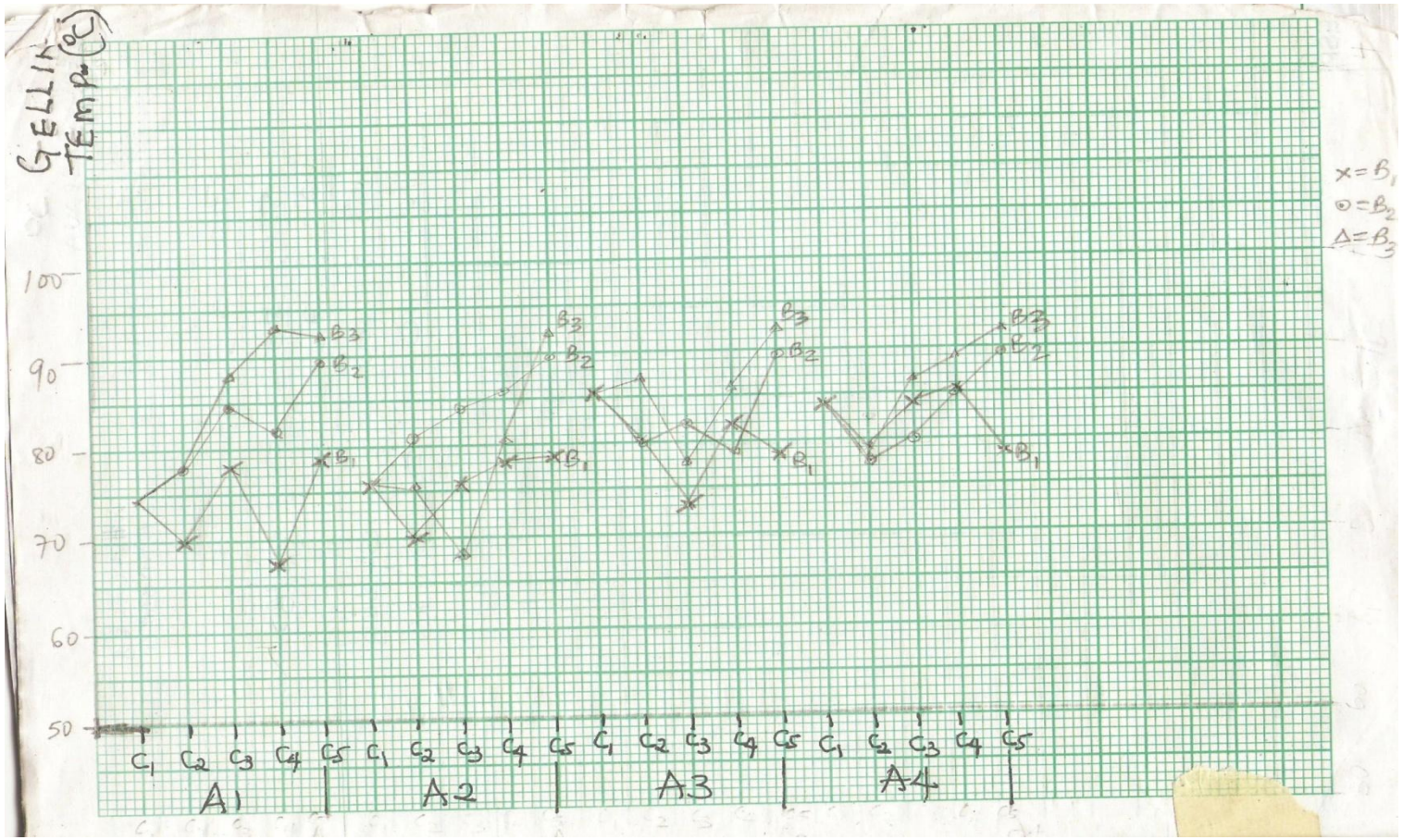


Fig.4.12: Effect of blend ratios on the gelling temperature of flours selected from tropical tuber flours and treated bambara groundnut flour

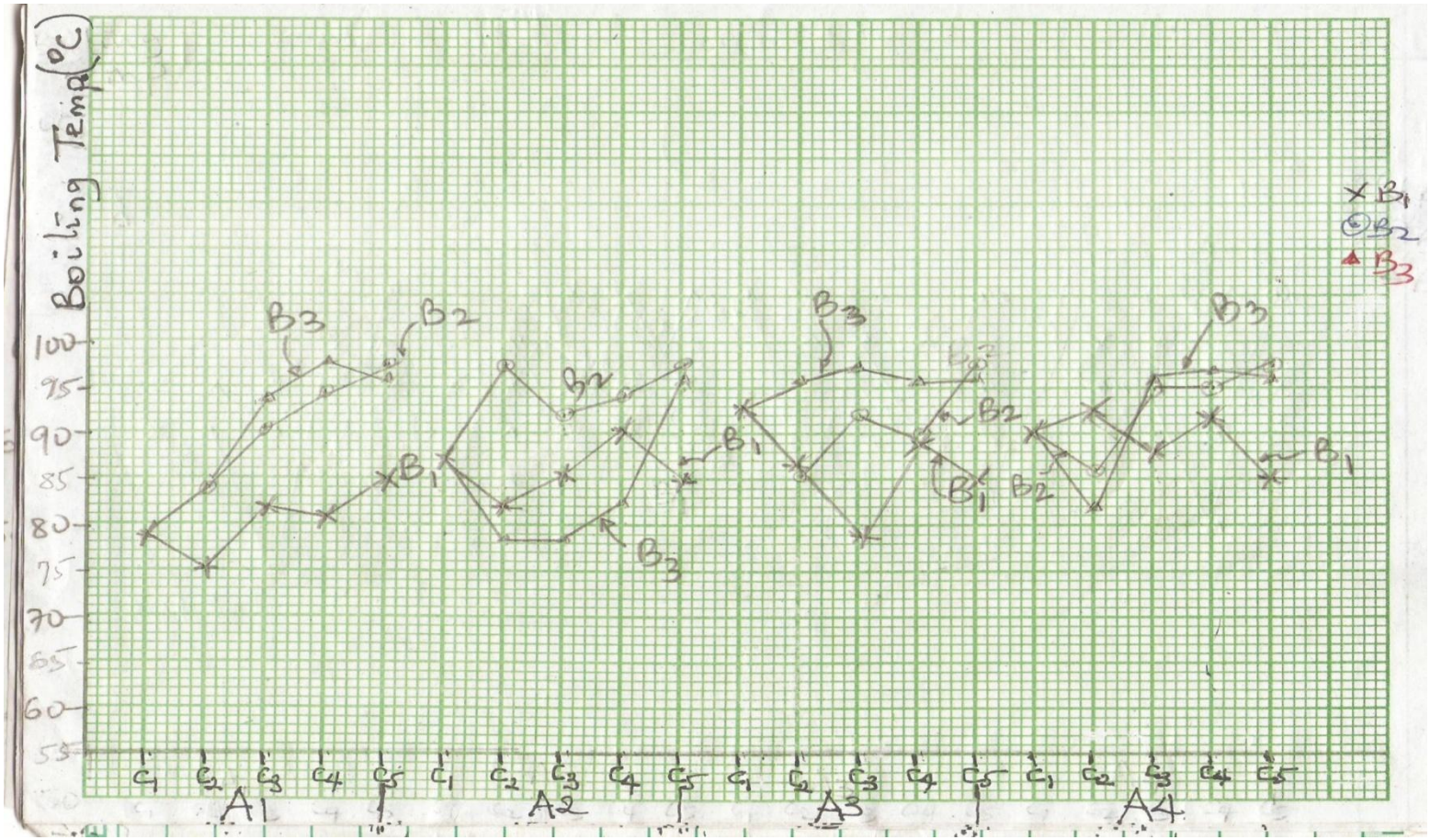


Fig.4.13: Effect of blend ratios on the boiling temperature of flours selected from tropical tuber flours and treated bambara groundnut flours

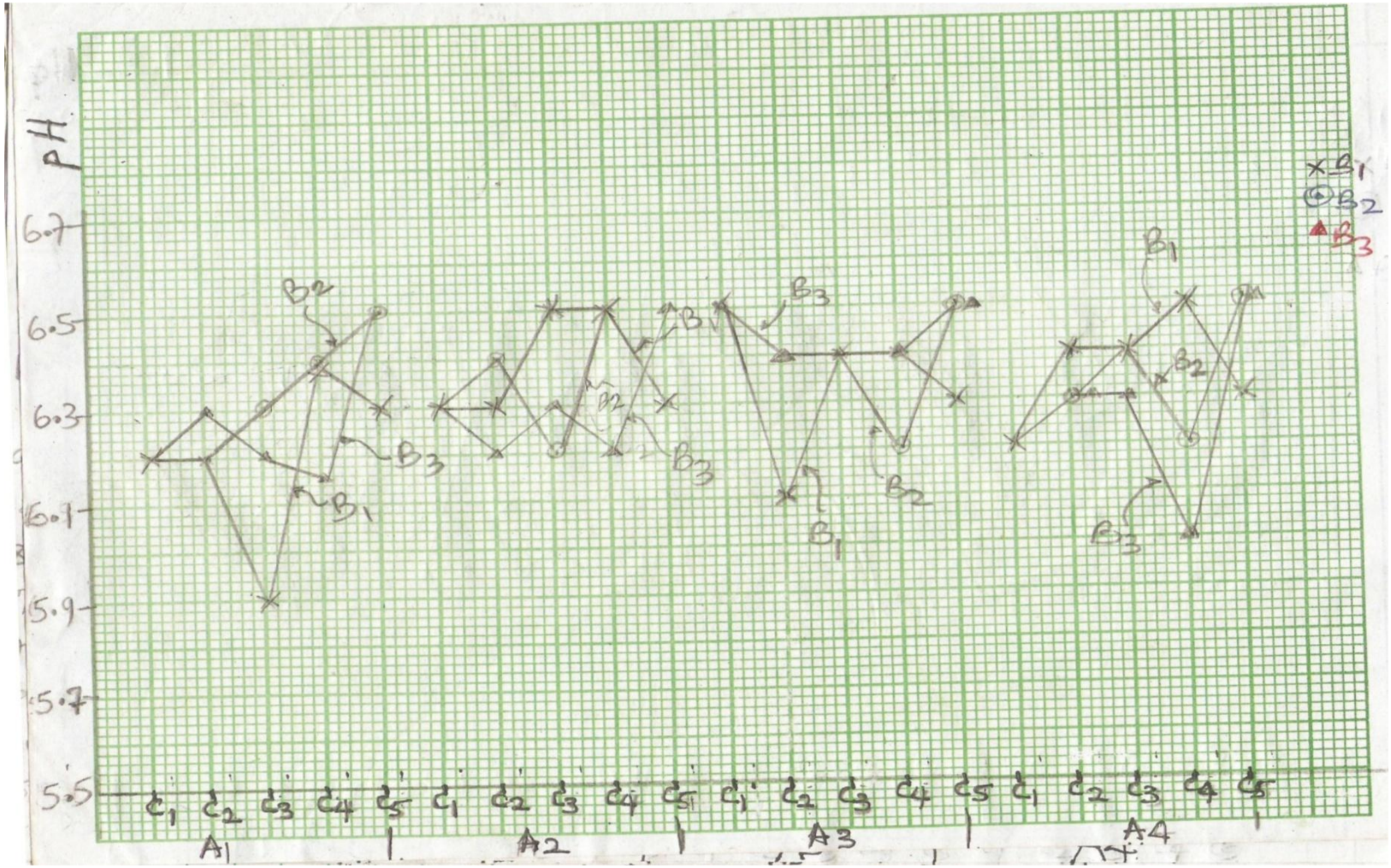


Fig.4.14: Effect of blend ratios on the pH of flours selected from tropical tuber flours and treated bambara groundnut flours

Table 4.1c Data from Antinutritional Properties of Tropical Tuber Flours Blended with Treated Bambara groundnut flours

Sample code	Alkaloid (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Oxalate (mg/100g)	HCN (mg/ 100g)	Trypsin inhibitor Tui/mg	Hema-gglutinin Hui/mg	Phytic acid(mg/ 100g)
$A_1B_1C_1$	1.51	1.92	2.33	3.88	9.51	27.40	1.71	0.196
$A_1B_1C_2$	1.19	2.19	1.14	3.23	4.04	20.46	ND	0.157
$A_1B_1C_3$	0.87	2.16	1.57	3.09	3.26	20.95	ND	0.162
$A_1B_1C_4$	0.83	1.92	1.84	2.98	2.26	19.46	ND	0.206
$A_1B_1C_5$	0.81	1.83	4.88	3.71	0.87	21.46	12.64	0.243
$A_1B_2C_1$	1.51	1.92	2.33	3.88	9.51	27.40	1.71	0.196
$A_1B_2C_2$	1.19	1.15	2.55	3.35	3.88	40.95	ND	0.184
$A_1B_2C_3$	1.41	1.11	3.00	3.07	3.03	34.70	ND	0.189
$A_1B_2C_4$	1.51	1.08	3.09	1.52	1.72	27.50	ND	0.279
$A_1B_2C_5$	1.71	1.59	3.09	1.51	0.63	32.91	ND	0.369
$A_1B_3C_1$	1.51	1.92	2.33	3.88	9.51	27.40	1.71	0.196
$A_1B_3C_2$	1.74	1.01	2.20	4.11	3.47	19.18	ND	0.199
$A_1B_3C_3$	2.02	1.44	2.89	4.08	2.60	22.67	4.80	ND
$A_1B_3C_4$	2.49	1.91	3.22	4.23	2.15	39.78	ND	0.258
$A_1B_3C_5$	3.01	2.06	4.40	2.45	0.62	17.54	ND	0.184
$A_2B_1C_1$	1.03	2.24	2.33	3.79	0.62	39.89	ND	0.183
$A_2B_1C_2$	1.09	1.30	2.44	3.34	0.83	33.80	1.10	0.345
$A_2B_1C_3$	2.01	1.47	2.29	3.51	0.87	32.25	ND	0.420
$A_2B_1C_4$	2.09	2.08	2.01	3.78	0.77	36.01	ND	0.475
$A_2B_1C_5$	0.81	1.83	4.88	3.71	0.87	21.46	12.60	0.243
$A_2B_2C_1$	1.03	2.24	2.33	3.79	0.62	39.89	ND	0.183
$A_2B_2C_2$	1.01	2.02	1.19	1.86	0.92	31.59	ND	0.306
$A_2B_2C_3$	1.19	1.80	1.39	1.23	0.66	28.13	ND	0.298
$A_2B_2C_4$	1.36	1.61	1.49	1.01	0.70	26.86	2.08	0.237
$A_2B_2C_5$	1.71	1.49	3.09	1.51	0.63	32.91	ND	0.369
$A_2B_3C_1$	1.03	2.24	2.33	3.79	0.62	39.89	ND	0.183
$A_2B_3C_2$	2.41	2.19	1.18	2.44	0.89	43.22	ND	0.251
$A_2B_3C_3$	2.31	1.58	1.21	2.41	0.65	31.40	ND	0.239
$A_2B_3C_4$	2.01	1.80	1.27	2.01	0.62	27.99	ND	0.207
$A_2B_3C_5$	3.01	2.06	4.40	2.45	0.62	17.54	ND	0.184
$A_3B_1C_1$	2.72	2.24	2.59	6.12	1.92	18.71	ND	0.331
$A_3B_1C_2$	2.09	2.31	2.01	5.09	1.57	32.15	2.46	0.320
$A_3B_1C_3$	1.76	2.31	2.26	3.22	1.09	34.75	3.44	0.290
$A_3B_1C_4$	1.51	2.23	2.66	3.09	0.92	30.54	10.56	0.245
$A_3B_1C_5$	0.81	1.83	4.88	3.71	0.87	21.46	12.64	0.243
$A_3B_2C_1$	2.72	2.24	2.59	6.12	1.92	18.71	ND	0.331
$A_3B_2C_2$	2.17	2.26	2.18	5.25	1.41	26.34	ND	0.250
$A_3B_2C_3$	1.69	2.23	2.28	4.41	1.01	30.10	ND	0.346
$A_3B_2C_4$	1.49	2.17	2.43	3.74	0.86	37.22	ND	0.403
$A_3B_2C_5$	1.71	1.49	3.09	1.51	0.63	32.91	ND	0.369
$A_3B_3C_1$	2.72	2.24	2.59	6.12	1.92	18.71	ND	0.331
$A_3B_3C_2$	2.95	1.80	2.70	5.11	1.37	41.25	ND	0.290
$A_3B_3C_3$	3.03	1.51	3.01	4.37	1.02	30.56	1.36	0.263
$A_3B_3C_4$	3.13	1.31	3.34	3.57	0.81	38.27	0.40	0.105
$A_3B_3C_5$	3.01	2.06	4.40	2.45	0.62	17.54	ND	0.184
$A_4B_1C_1$	2.71	1.36	3.59	3.87	0.54	24.71	ND	0.232
$A_4B_1C_2$	1.21	1.80	2.32	1.96	0.66	23.83	0.72	0.260
$A_4B_1C_3$	1.06	2.01	2.64	2.09	0.76	26.59	1.76	0.450
$A_4B_1C_4$	0.84	2.22	2.96	3.95	0.81	27.72	1.91	0.487
$A_4B_1C_5$	0.81	1.83	4.88	3.71	0.87	21.46	12.64	0.243
$A_4B_2C_1$	2.71	1.36	3.59	3.87	0.54	24.71	ND	0.232
$A_4B_2C_2$	2.22	2.17	3.27	3.09	0.51	26.39	ND	0.214
$A_4B_2C_3$	1.91	2.16	2.91	2.34	0.58	28.69	ND	0.211
$A_4B_2C_4$	1.61	2.01	2.71	2.18	0.58	35.46	1.91	0.025
$A_4B_2C_5$	1.71	1.49	3.09	1.51	0.63	32.91	ND	0.369
$A_4B_3C_1$	2.71	1.36	3.59	3.87	0.54	24.71	ND	0.232
$A_4B_3C_2$	2.01	1.66	2.37	3.63	0.55	20.76	ND	0.215
$A_4B_3C_3$	2.42	2.44	2.51	3.01	0.57	37.37	ND	0.263
$A_4B_3C_4$	2.88	2.01	2.69	2.78	0.60	38.94	ND	0.275
$A_4B_3C_5$	3.01	2.06	4.40	2.45	0.62	17.54	ND	0.183

* Mean of duplicate determinations

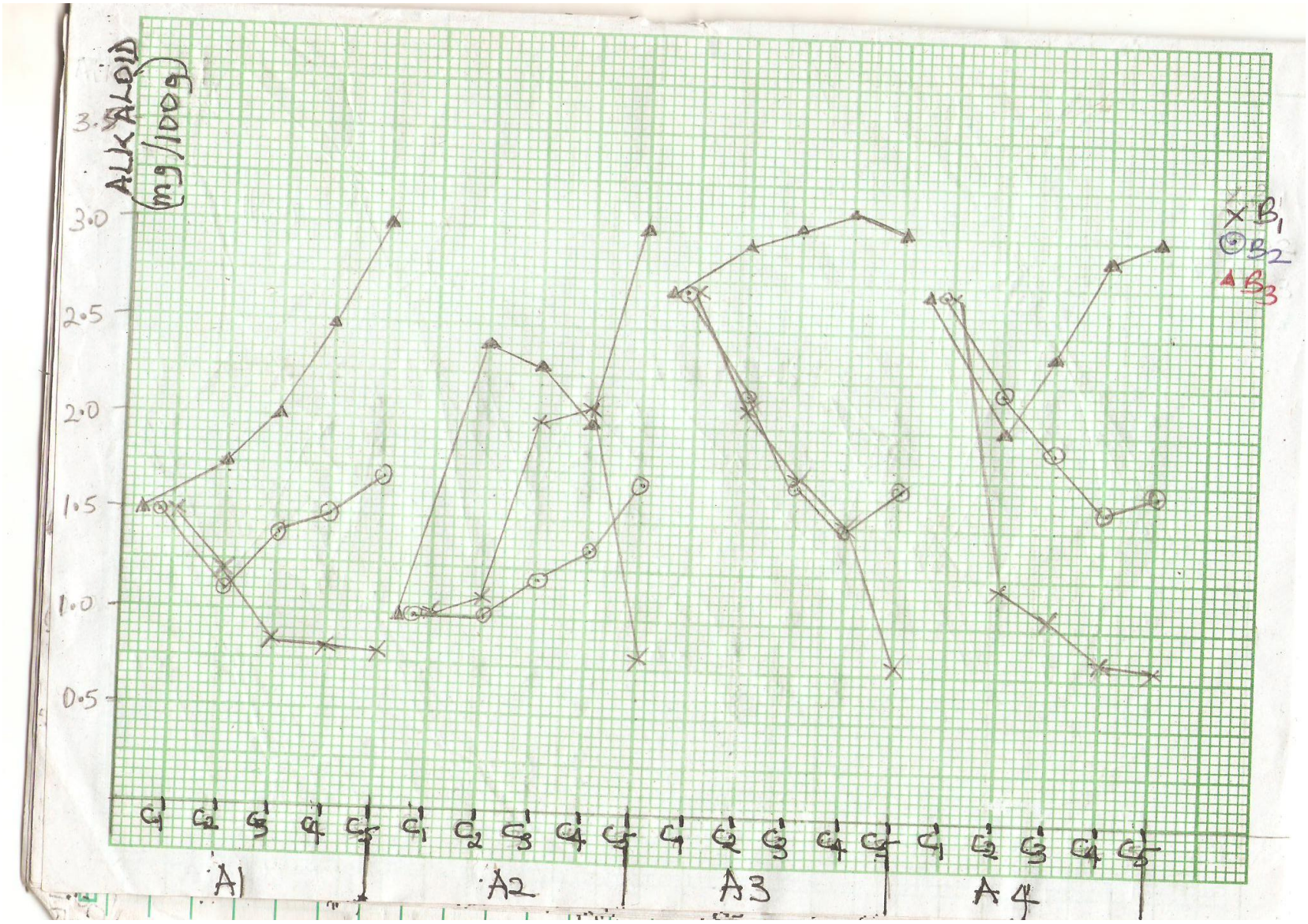


Fig.4.15: Effect of blend ratios on the alkaloid content of flours selected from tropical tuber flours and treated bambara groundnut flours

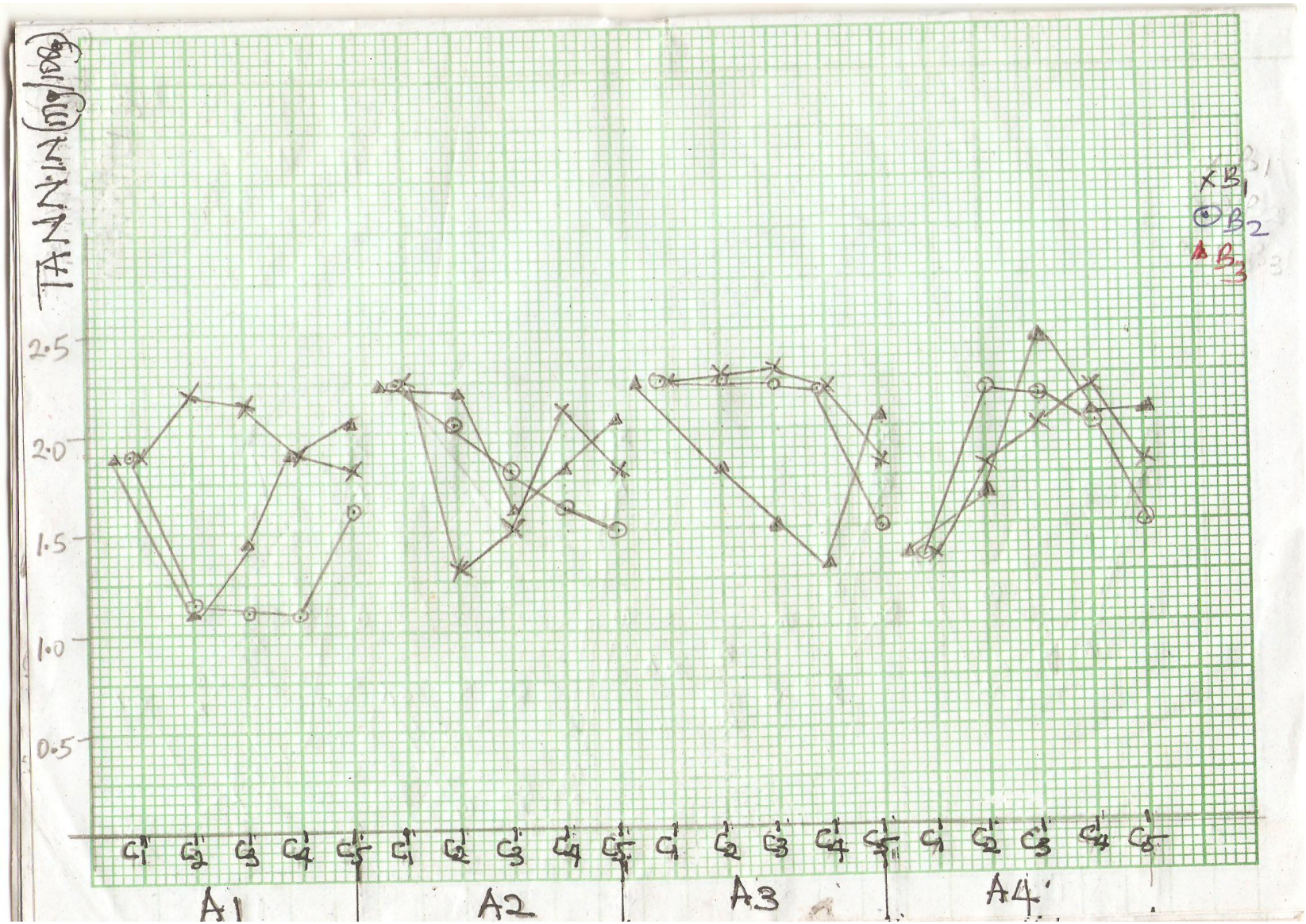


Fig.4.16: Effect of blend ratios on the tannin content of flours selected from tropical tuber flours and treated bambara groundnut flours

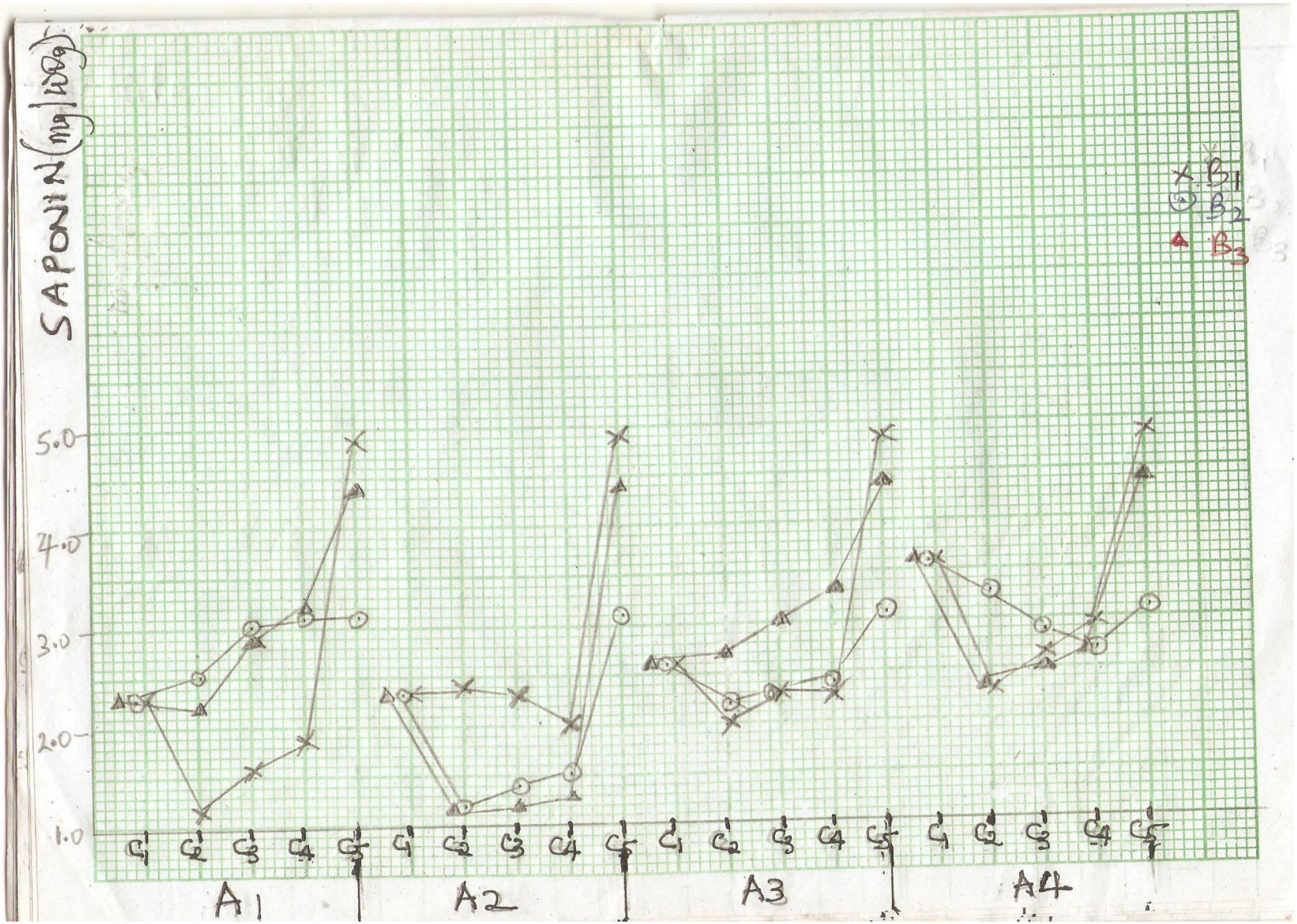


Fig.4.17: Effect of blend ratios on the saponin content of flours selected from tropical tuber flours and treated bambara groundnut flours

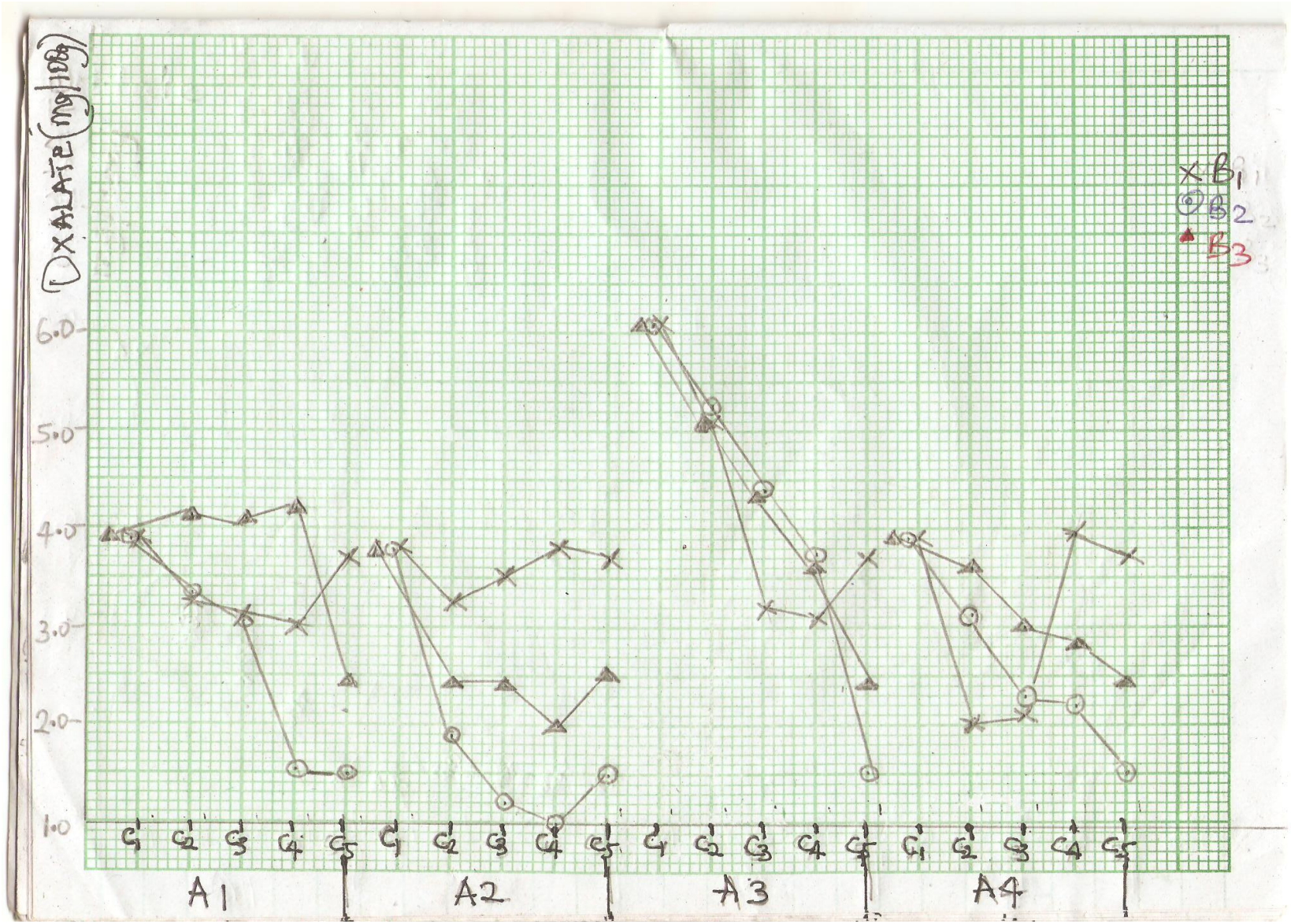


Fig.4.18: Effect of blend ratios on the oxalate content of flours selected from tropical tuber flours and treated bambara groundnut flours

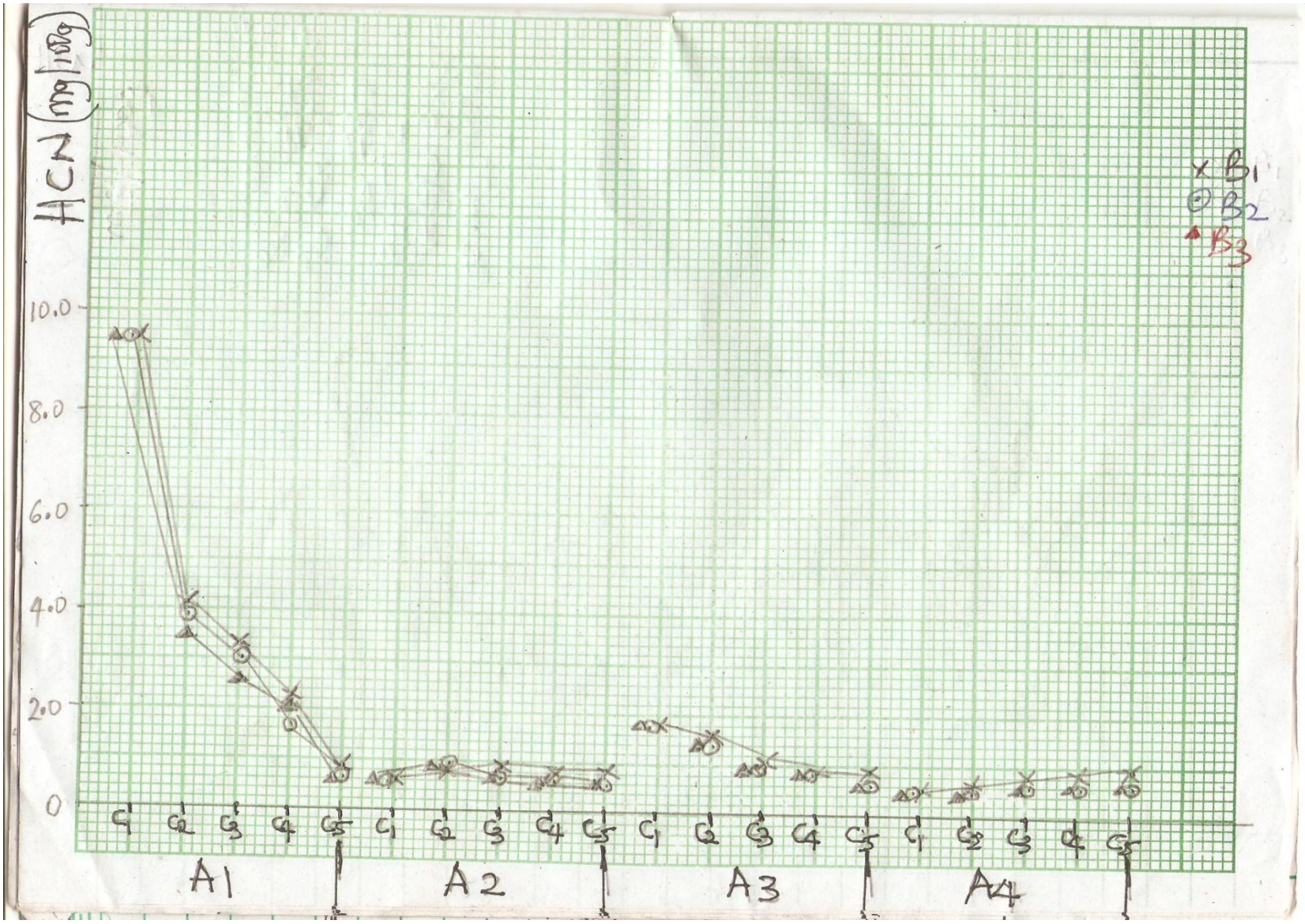


Fig.4.19: Effect of blend ratios on the hydrocyanic acid (HCN) content of flours selected from tropical tuber flours and treated bambara groundnut flours

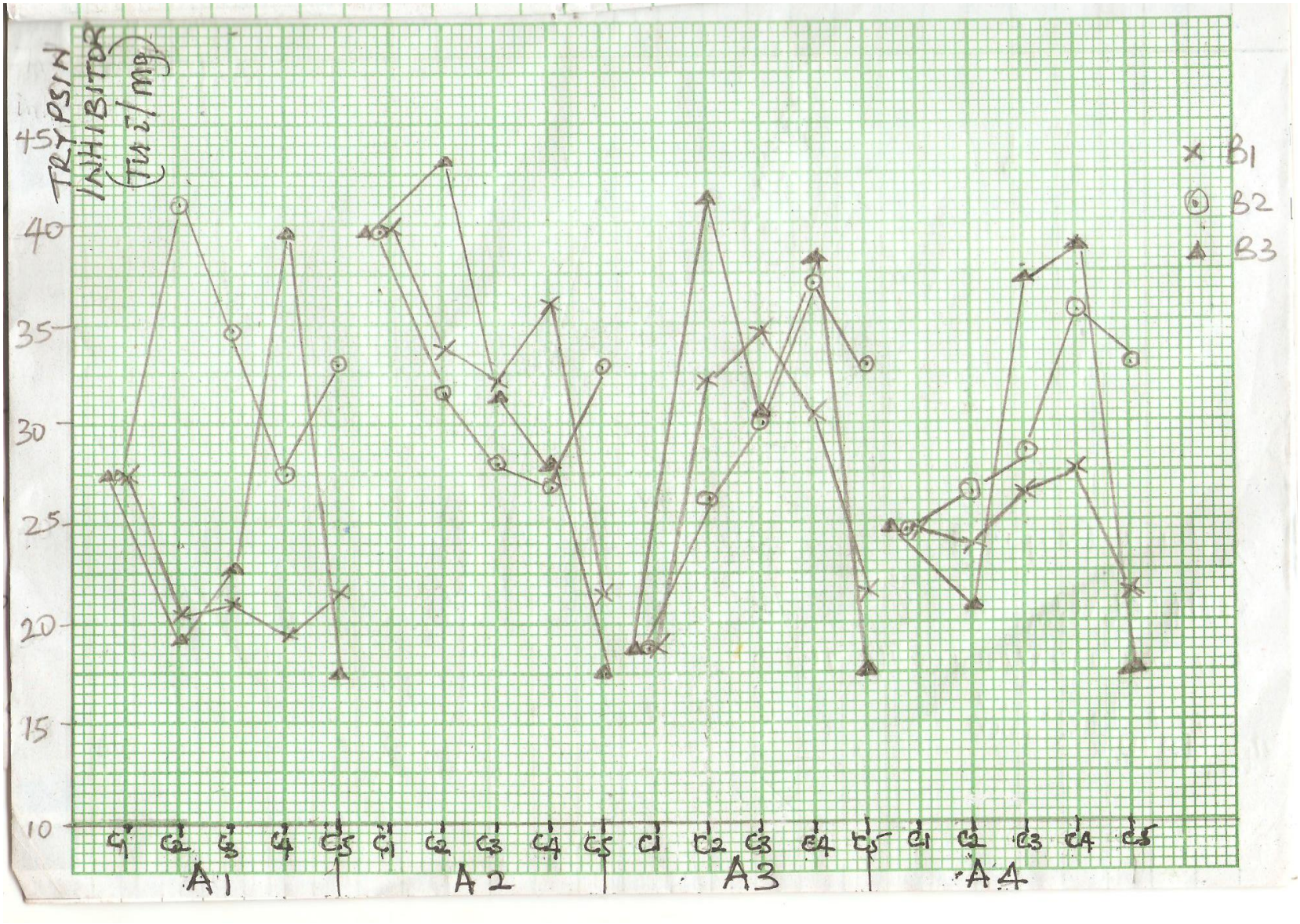


Fig.4.20: Effect of blend ratios on the trypsin inhibitor content of flours selected from tropical tuber flours and treated bambara groundnut flours

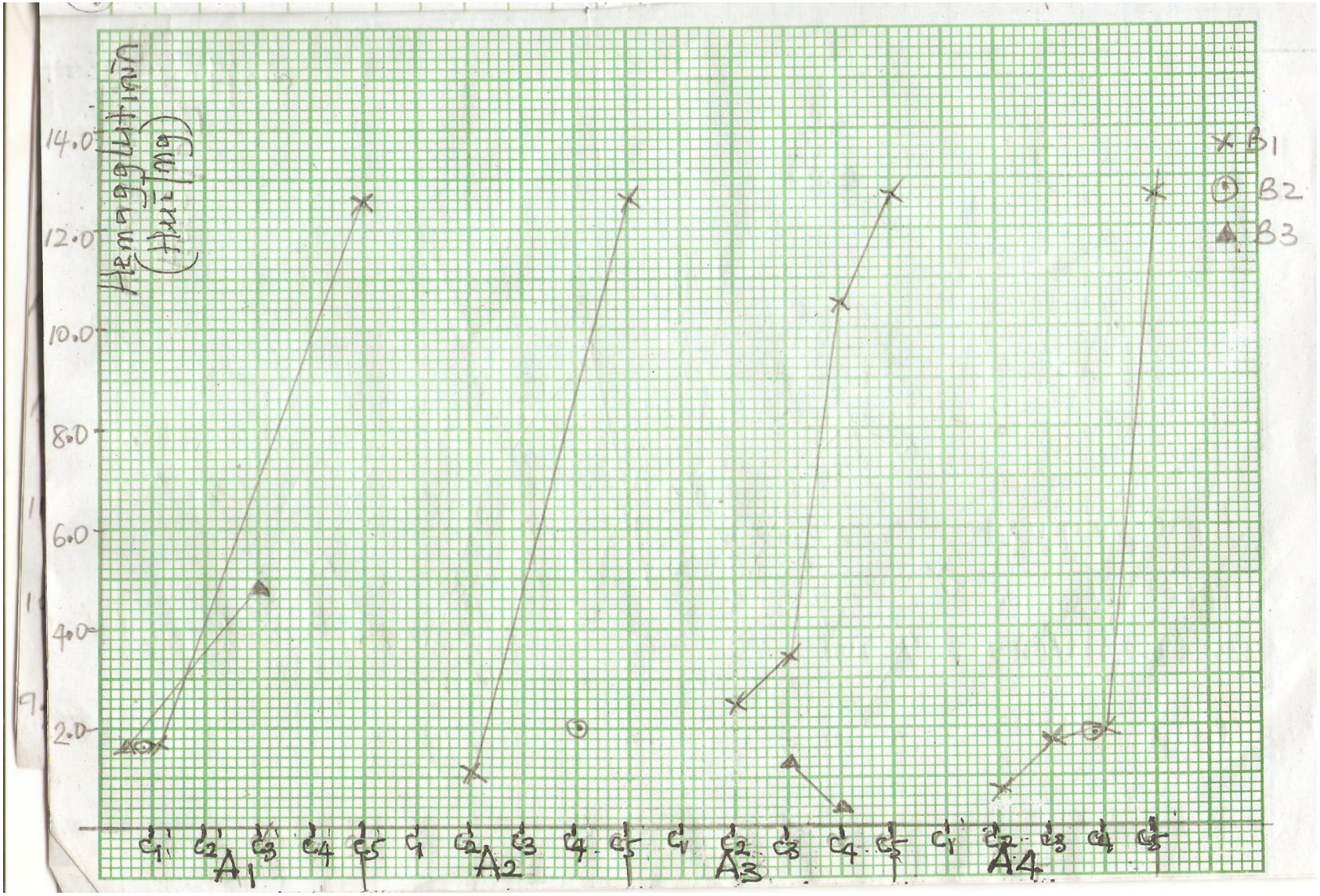


Fig.4.21: Effect of blend ratios on the hemagglutinin content of flours selected from tropical tuber flours and treated bambara groundnut flours

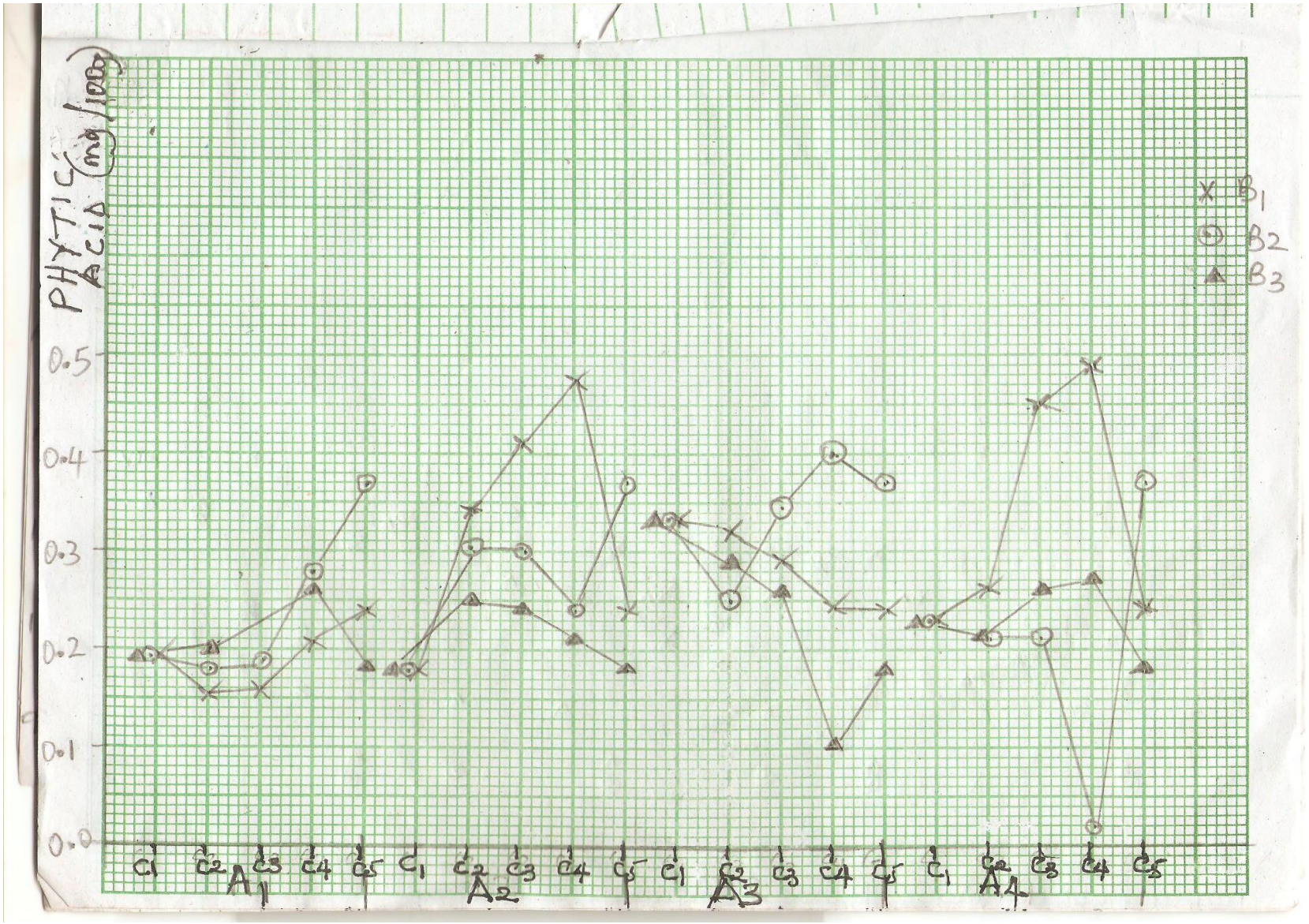


Fig.4.22: Effect of blend ratios on the phytic acid content of flours selected from tropical tuber flours and treated bambara groundnut flours

KEY:

$A_1B_1C_1$ = Cassava / Conventional bambara groundnut flour at ratio 100:0

$A_1B_1C_2$ = Cassava / Conventional bambara groundnut flour at ratio 75:25

$A_1B_1C_3$ = Cassava / Conventional bambara groundnut flour at ratio 50:50

$A_1B_1C_4$ = Cassava / Conventional bambara groundnut flour at ratio 25:75

$A_1B_1C_5$ = Cassava / Conventional bambara groundnut flour at ratio 0:100

$A_1B_2C_1$ = Cassava / bambara groundnut cotyledon flour at ratio 100:0

$A_1B_2C_2$ = Cassava / bambara groundnut cotyledon flour at ratio 75:25

$A_1B_2C_3$ = Cassava / bambara groundnut cotyledon flour at ratio 50:50

$A_1B_2C_4$ = Cassava / bambara groundnut cotyledon flour at ratio 25:75

$A_1B_2C_5$ = Cassava / bambara groundnut cotyledon flour at ratio 0:100

$A_1B_3C_1$ = Cassava / steamed bambara groundnut cotyledon flour at ratio 100:0

$A_1B_3C_2$ = Cassava / steamed bambara groundnut cotyledon flour at ratio 75:25

$A_1B_3C_3$ = Cassava / steamed bambara groundnut cotyledon flour at ratio 50:50

$A_1B_3C_4$ = Cassava / steamed bambara groundnut cotyledon flour at ratio 25:75

$A_1B_3C_5$ = Cassava / steamed bambara groundnut cotyledon flour at ratio 0:100

$A_2B_1C_1$ = Yam / Conventional bambara groundnut flour at ratio 100:0

$A_2B_1C_2$ = Yam / Conventional bambara groundnut flour at ratio 75:25

$A_2B_1C_3$ = Yam / Conventional bambara groundnut flour at ratio 50:50

$A_2B_1C_4$ =Yam / Conventional bambara groundnut flour at ratio 25:75

$A_2B_1C_5$ = Yam / Conventional bambara groundnut flour at ratio 0:100

$A_2B_2C_1$ = Yam / bambara groundnut cotyledon flour at ratio 100:0

$A_2B_2C_2$ =Yam / bambara groundnut cotyledon flour at ratio 75:25

$A_2B_2C_3$ = Yam / bambara groundnut cotyledon flour at ratio 50:50

$A_2B_2C_4$ = Yam / bambara groundnut cotyledon flour at ratio 25:75

$A_2B_2C_5$ = Yam / bambara groundnut cotyledon flour at ratio 0:100

$A_2B_3C_1$= Yam / steamed bambara groundnut cotyledon flour at ratio 100:0

$A_2B_3C_2$ = Yam / steamed bambara groundnut cotyledon flour at ratio 75:25

$A_2B_3C_3$ = Yam / steamed bambara groundnut cotyledon flour at ratio 50:50

$A_2B_3C_4$ = Yam / steamed bambara groundnut cotyledon flour at ratio 25:75

$A_2B_3C_5$ = Yam / steamed bambara groundnut cotyledon flour at ratio 0:100

$A_3B_1C_1$ = Cocoyam /Conventional bambara groundnut flour at ratio 100:0

$A_3B_1C_2$=Cocoyam /Conventional bambara groundnut flour at ratio 75:25

$A_3B_1C_3$ =Cocoyam /Conventional bambara groundnut flour at ratio 50:50

$A_3B_1C_4$ =Cocoyam /Conventional bambara groundnut flour at ratio 25:75

$A_3B_1C_5$ = Cocoyam /Conventional bambara groundnut flour at ratio 0:100

$A_3B_2C_1$ = Cocoyam / bambara groundnut cotyledon flour at ratio 100:0

$A_3B_2C_2$ = Cocoyam / bambara groundnut cotyledon flour at ratio 75:25

$A_3B_2C_3$ = Cocoyam / bambara groundnut cotyledon flour at ratio 50:50

$A_3B_2C_4$ = Cocoyam / bambara groundnut cotyledon flour at ratio 25:75

$A_3B_2C_5$ = Cocoyam / bambara groundnut cotyledon flour at ratio 0:100

$A_3B_3C_1$ = Cocoyam / steamed bambara groundnut cotyledon flour at ratio 100:0

$A_3B_3C_2$ = Cocoyam/ steamed bambara groundnut cotyledon flour at ratio 75:25

$A_3B_3C_3$ = Cocoyam / steamed bambara groundnut cotyledon flour at ratio 50:50

$A_3B_3C_4$ = Cocoyam / steamed bambara groundnut cotyledon flour at ratio 25:75

$A_3B_3C_5$ = Cocoyam / steamed bambara groundnut cotyledon flour at ratio 0:100

$A_4B_1C_1$ = Sweet potato / Conventional bambara groundnut flour at ratio 100:0

$A_4B_1C_2$ = Sweet potato / Conventional bambara groundnut flour at ratio 75:25

$A_4B_1C_3$ = Sweet potato / Conventional bambara groundnut flour at ratio 50:50

$A_4B_1C_4$ = Sweet potato / Conventional bambara groundnut flour at ratio 25:75

$A_4B_1C_5$ = Sweet potato / Conventional bambara groundnut flour at ratio 0:100

$A_4B_2C_1$ = Sweet potato and/ bambara groundnut cotyledon flour at ratio 100: 0

$A_4B_2C_2$ = Sweet potato / bambara groundnut cotyledon flour at ratio 75:25

$A_4B_2C_3$= Sweet potato / bambara groundnut cotyledon flour at ratio50:50

$A_4B_2C_4$ = Sweet potato / bambara groundnut cotyledon flour at ratio 25:75

$A_4B_2C_5$ = Sweet potato / bambara groundnut cotyledon flour at ratio 0:100

$A_4B_3C_1$= Sweet potato / steamed bambara groundnut cotyledon flour at ratio 100:0

$A_4B_3C_2$ = Sweet potato / steamed bambara groundnut cotyledon flour at ratio 75:25

$A_4B_3C_3$ = Sweet potato / steamed bambara groundnut cotyledon flour at ratio 50:50

$A_4B_3C_4$ = Sweet potato / steamed bambara groundnut cotyledon flour at ratio 25:75

$A_4B_3C_5$ = Sweet potato / steamed bambara groundnut cotyledon flour at ratio 0:100

Table 4.1.1 Proximate composition of Tropical Tuber Flour Samples

Tropical Tuber Variety	COMPOSITION (%) *							
	Moisture content	Crude protein	Fat	Fibre	Ash	Carbohydrates	Energy (kJ)	Dry matter
Cassava	12.82±.02[a]	1.45±.04[d]	1.67±.04[a]	0.55±.05[d]	0.30±.04[d]	83.21±.07[a]	353.67±.29[a]	87.180±.02[c]
Yam	12.32±.04[b]	5.08±.02[a]	1.06±.02[d]	0.75±.05[c]	1.31±.06[b]	79.48±.07[c]	347.78±.38[c]	87.680±.04[b]
Cocoyam	11.54±.02[c]	3.97±.10[b]	1.57±.03[b]	1.20±.02[b]	2.61±.20[a]	79.12±.03[d]	346.49±.79[d]	88.460±.02[a]
Sweet potato	11.52±.02[c]	2.84±.04[c]	1.18±.02[c]	1.90±.04[a]	0.79±.03[c]	81.77±.07[b]	349.06±.26[b]	88.480±.02[a]
LSD[1]	0.0499	0.110	0.054	0.079	0.143	0.118	1.00	0.0499

* Values are means ± Standard deviation (SD) from 3 determinations

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P= 0.05

Table 4.1.2 Proximate composition of Flour Samples as affected by Tropical Tuber Variety

Tropical Tuber Variety	COMPOSITION (%) *							
	Moisture content	Crude protein	Fat	Fibre	Ash	Carbohydrates	Energy (kJ)	Dry matter
Cassava	11.92±1.15[a]	9.54±5.98[d]	4.63±2.20[a]	1.34±0.71[a]	1.29±0.81[d]	71.28±8.43[a]	364.90±11.79[b]	88.08±1.15[d]
Yam	11.29±1.02[b]	11.26±4.50[a]	4.16±2.67[c]	1.15±0.39[b]	1.90±0.44[b]	70.25±6.99[c]	363.45±14.62[d]	88.71±1.02[c]
Cocoyam	11.08±0.91[c]	10.55±4.65[b]	4.57±2.34[b]	1.36±0.30[a]	2.25±0.30[a]	70.19±6.48[c]	364.09±14.19[c]	88.92±0.91[b]
Sweet potato	10.83±0.73[d]	10.25±4.69[c]	4.63±2.47[a]	1.38±0.39[a]	1.78±0.68[c]	71.13±7.00[b]	367.22±14.02[a]	89.17±0.73[a]
LSD[1]	0.0262	0.019	0.014	0.0356	0.023	0.0557	0.2181	0.0269

* Values are means ± SD from 45 samples

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P = 0.05

Table 4.1.3 Proximate composition of Flour Samples as affected by Bambara Groundnut (BGN) Treatments

BGN Treatment	COMPOSITION (%) *							
	Moisture content	Crude protein	Fat	Fibre	Ash	Carbohydrates	Energy (kJ)	Dry matter
Conventional bambaragroundnut flour	11.66±0.91[a]	9.30±4.36[c]	3.88±1.20[c]	1.36±0.43[a]	1.86±0.78[a]	71.95±6.79[a]	359.90±8.72[c]	88.34±0.91[c]
Bambaragroundnut cotyledon flour	10.98±1.06[c]	10.57±5.16[b]	4.43±2.31[b]	1.23±0.37[b]	1.88±0.63[a]	70.92±7.12[b]	365.81±13.46[b]	89.02±1.06[a]
Steamed bambaragroundnut cotyledon flour	11.21±1.05[b]	11.33±5.27[a]	5.18±2.73[a]	1.34±0.60[a]	1.68±0.60[b]	69.27±7.59[c]	369.03±16.28[a]	88.79±1.05[b]
LSD[1]	0.0227	0.0164	0.0121	0.0309	0.0199	0.05	0.1889	0.0233

* Values are means ± SD from 60 samples

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P= 0.05

Table 4.1.4 Proximate composition of Flour Samples as affected by Tuber – Bambara groundnut Blending Ratio

Tuber Flour:Bambaragroundnut Ratio (TTF: BGF)	COMPOSITION (%) *							
	Moisture content	Crude protein	Fat	Fibre	Ash	Carbohydrates	Energy (kJ)	Dry matter
100:0	12.05±0.56[a]	3.34±1.37[e]	1.37±0.26[e]	1.10±0.53[d]	1.25±0.88[e]	80.90±1.70[a]	349.22±2.73[e]	87.95±0.56[e]
75:25	11.31±1.15[c]	7.48±2.35[d]	2.90±0.86[d]	1.24±0.30[c]	1.59±0.61[d]	75.48±2.51[b]	357.95±5.74[d]	88.69±1.15[c]
50:50	11.44±0.87[b]	10.92±2.44[c]	4.59±1.30[c]	1.47±0.46[b]	1.71±0.48[c]	69.87±3.39[c]	364.46±7.56[c]	88.55±0.87[d]
25:75	11.13±0.79[d]	14.18±2.15[b]	5.98±0.97[b]	1.51±0.43[a]	2.15±0.39[b]	65.05±2.89[d]	370.69±7.31[b]	88.87±0.79[b]
0:100	10.46±1.08[e]	16.09±0.93[a]	7.64±1.12[a]	1.22±0.53[c]	2.32±0.26[a]	62.26±0.40[e]	382.26±12.50[a]	89.54±1.08[a]
LSD[1]	0.0293	0.0212	0.0156	0.0398	0.0257	0.0645	0.2438	0.0301

* Values are means ± SD from 36 samples
Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$
1. Least Significant Difference @ P = 0.05

Table 4.1.5 Physicochemical Properties of Tropical Tuber Flour Samples

Tropical Tuber Variety	Physicochemical Properties					
	Swelling index(g/ml)	OAC (g/cm^3)	WAC (g/cm^3)	Gelling Temp.(^oC)	Boiling Temp.(^oC)	pH
Cassava	1.06±0.00^d	1.54±0.01^b	1.10±0.14^c	74.50±0.71^c	79.00±0.00^d	6.20±0.01^c
Yam	1.23±0.01^c	1.50±0.00^c	2.10±0.14^a	76.50±0.71^b	87.50±0.71^c	6.30±0.00^b
Cocoyam	1.31±0.00^b	1.34±0.01^d	1.53±0.04^b	85.50±0.71^a	93.00±1.41^a	6.50±0.04^a
Sweet potato	1.79±0.00^a	1.65±0.01^a	2.00±0.00^a	84.00±0.00^a	90.00±0.00^b	6.20±0.00^c
LSD[1]	0.01	0.0169	0.099	1.70	2.20	0.05

* Values are means ± Standard deviation (SD) from 3 determinations

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P= 0.05

Table 4.1.6 Physicochemical Properties of Tuber Flour Samples as affected by Bambara Groundnut Flour Addition

Tropical Tuber Variety	Physicochemical Properties					
	Swelling index(g/ml)	OAC (g/cm^s)	WAC (g/cm^3)	Gelling Temp.(^oC)	Boiling Temp. .(^oC)	pH
Cassava	1.15±0.14[d]	1.57±0.20[a]	1.43±0.45[c]	80.17±7.67[c]	86.60±7.60[c]	6.26±0.15[d]
Yam	1.25±0.14[b]	1.44±0.37[b]	1.72±0.48[a]	79.20±6.48[d]	88.13±6.26[b]	6.33±0.12[b]
Cocoyam	1.17±0.10[c]	1.43±0.21[b]	1.42±0.33[c]	82.93±4.90[b]	91.27±5.33[a]	6.37±0.14[a]
Sweet potato	1.26±0.27[a]	1.36±0.34[c]	1.66±0.49[b]	83.77±4.42[a]	91.47±4.67[a]	6.31±0.14[c]
LSD[1]	0.0038	0.0041	0 .0234	0.3334	0.3127	0.0005

* Values are means ± SD from 30 samples
Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$
1. Least Significant Difference @ P = 0.05

Table 4.1.7 Physicochemical Properties of Flour Samples as affected by Bambara Groundnut (BGN) Treatment

BGN Treatment	Physicochemical Properties					
	Swelling Index(g/ml)	OAC (g/cm^3)	WAC (g/cm^3)	Gelling Temp. (^oC).	Boiling Temp.(^oC).	pH
Conventional bambaragroundnut flour	1.20±0.20^b	1.31±0.37^c	1.31±0.55^c	77.88±5.04^c	85.65±4.80^c	6.32±0.15^b
Bambaragroundnut cotyledon flour	1.19±0.17^c	1.52±0.24^a	1.64±0.35^b	82.88±4.56^b	91.78±5.19^a	6.33±0.13^a
Steamed bambaragroundnut cotyledon flour	1.23±0.17^a	1.52±0.21^b	1.72±0.33^a	83.80±7.16^a	90.68±7.12^b	6.32±0.14^c
LSD[1]	0.0033	0.0036	0.0202	0.2887	0.2708	0.0004

* Values are means ± SD from 30 samples
Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$
1. Least Significant Difference @ P = 0.05

Table 4.1.8 Physicochemical properties of Flour Samples as affected by Tuber –Bambara groundnut Blending Ratio

Tuber Flour:Bambaragroundnut Ratio (TTF: BGF)	Physicochemical Properties					
	Swelling index(g/ml)	OAC (g/cm^3)	WAC (g/cm^3)	Gelling Temp.(^oC)	Boiling Temp.(^oC)	pH
100:0	1.35±0.28[a]	1.50±0.11[b]	1.63±0.42[b]	80.13±4.83[c]	87.38±5.36[d]	6.30±0.13[a]
75:25	1.21±0.19[b]	1.36±0.37[c]	1.67±0.39[a]	77.88±4.56[d]	85.83±6.49[e]	6.27±0.10[e]
50:50	1.18±0.12[c]	1.34±0.25[d]	1.49±0.31[d]	80.13±5.80[c]	89.17±6.43[c]	6.31±0.15[b]
25:75	1.16±0.09[d]	1.27±0.29[e]	1.47±0.39[d]	82.79±6.29[b]	91.63±5.31[b]	6.30±0.15[d]
0:100	1.13±0.06[e]	1.77±0.02[a]	1.53±0.68[c]	86.67±6.00[a]	92.83±5.70[a]	6.43±0.10[a]
LSD[1]	0.0042	0. 0046	0 .0261	0 .3727	0.3497	0.0005

* Values are means ± SD from 24 samples

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P = 0.05

Table 4.1.9 Antinutritional Properties of Tropical Tuber Flour Samples

Tropical Tuber Variety	Antinutritional Properties							
	Alkaloid (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Oxalate (mg/100g)	HCN (mg/100g)	Trypsin inhibitor (Tui/mg)	Hemagg-ulutinin(Hui /mg	Phytic Acid (mg/100g)
Cassava	1.52±0.00^{b}	1.92±0.02^{b}	2.33±0.04^{c}	3.88±0.01^{b}	9.51±0.01^{a}	27.40±3.61^{b}	1.71±0.01^{a}	0.20±0.01^{c}
Yam	1.03±0.04^{c}	2.24±0.02^{a}	2.33±0.04^{c}	3.79±0.01^{c}	0.62±0.01^{c}	39.89±1.34^{a}	0.00±0.00^{b}	0.18±0.00^{c}
Cocoyam	2.72±0.02^{a}	2.24±0.04^{a}	2.59±0.01^{b}	6.12±0.03^{a}	1.92±0.03^{b}	18.71±2.90^{b}	0.00±0.00^{b}	0.33±0.01^{a}
Sweet potato	2.71±0.01^{a}	1.36±0.01^{c}	3.59±0.01^{a}	3.87±0.01^{b}	0.54±0.02^{d}	24.71±7.49^{b}	0.00±0.00^{b}	0.23±0.00^{b}
LSD[1]	0.061	0.065	0.082	0.05	0.056	12.376	0.020	0.024

* Values are means ± Standard deviation (SD) from 3 determinations

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P = 0.05

Table 4.1.10 Antinutritional Properties of Tropical Tuber Flour Samples as affected by blending with Bambara Groundnut Flour

Tropical Tuber Variety	Antinutritional Properties							
	Alkaloid (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Oxalate (mg/100g)	HCN (mg/100g)	Trypsin inhibitor (Tiu/mg)	Hemagg-ulutinin(Hui /mg	Phytic Acid (mg/100g)
Cassava	1.55±0.59^{d}	1.68±0.41^{c}	2.72±0.96^{c}	3.26±0.85^{b}	3.80±3.09^{a}	26.65±8.28^{b}	1.50±3.31^{b}	0.20±0.08^{c}
Yam	1.61±0.65^{c}	1.86±0.31^{b}	2.26±1.11^{d}	2.71±1.00^{d}	0.73±0.12^{c}	32.18±7.47^{a}	1.05±3.21^{d}	0.27±0.09^{a}
Cocoyam	2.23±0.70^{a}	2.01±0.33^{a}	2.87±0.79^{b}	4.26±1.37^{a}	1.20±0.45^{b}	28.61±8.83^{b}	2.06±3.98^{a}	0.29±0.08^{a}
Sweet potato	1.99±0.75^{b}	1.86±0.34^{b}	3.17±0.72^{a}	2.95±0.82^{c}	0.62±0.11^{d}	27.45±7.21^{b}	1.26±3.19^{c}	0.26±0.11^{b}
LSD[1]	0.0086	0 .0147	0.0107	0.0094	0.0088	2.62	0.2032	0 .0146

* Values are means ± SD from 30 samples

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P = 0.05

Table 4.1.11 Antinutritional Properties of Flour Samples as affected by Bambara Groundnut (BGN) Treatment

BGN Treatment	Antinutritional Properties							
	Alkaloid (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Oxalate (m/100g)	HCN (mg/100g)	Trypsin inhibitor (Tui/mg)	Hemagg-ulutinin(Hui unit/mg	Phytic Acid (mg/100g)
Conventional bambaragroundnut flour	1.39±0.63^{c}	1.95±0.30^{a}	2.82±1.15^{b}	3.59±0.88^{a}	1.69±2.03^{a}	26.75±7.21^{b}	3.71±5.11^{a}	0.29±0.10^{a}
Bambaragroundnut cotyledon flour	1.68±0.47^{b}	1.78±0.41^{c}	2.58±0.64^{c}	2.84±1.43^{c}	1.55±2.05^{b}	30.81±6.48^{a}	0.28±0.69^{b}	0.27±0.10^{b}
Steamed bambaragroundnut cotyledon flour	2.47±0.58^{a}	1.83±0.37^{b}	2.85±1.01^{a}	3.46±1.05^{b}	1.52±2.02^{c}	28.61±10.02^{ba}	0.41±1.12^{b}	0.21±0.07^{c}
LSD[1]	0.0075	0.0128	0.0092	0.0082	0.0076	2.266	0.176	0.0127

* Values are means ± SD from 40 samples

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P = 0.05

Table 4.1.12 Antinutritional Properties Flour Samples as affected by Tuber – Bambara groundnut Blending Ratio

Tuber Flour: Bam-baragroundnut Ratio (TTF: BGF)	Antinutritional Properties							
	Alkaloid (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Oxalate (mg/100g)	HCN (mg/100g)	Trypsin inhibitor (Tui/mg)	Hemagg-ulutinin(Hui /mg	Phytic Acid (mg/100g)
100:0	1.99±0.76^{a}	1.94±0.37^{a}	2.71±0.53^{b}	4.41±1.00^{a}	3.15±3.79^{a}	27.68±8.52^{b}	0.43±0.76^{d}	0.24±0.05^{c}
75:25	1.77±0.62^{d}	1.82±0.44^{c}	2.13±0.65^{e}	3.54±1.14^{b}	1.67±1.30^{b}	29.99±9.01^{ba}	0.36±0.74^{d}	0.25±0.06^{bc}
50:50	1.81±0.61^{c}	1.85±0.41^{b}	2.33±0.62^{d}	3.07±0.93^{c}	1.34±0.98^{c}	29.84±6.79^{ba}	0.95±1.61^{c}	0.26±0.12^{ba}
25:75	1.81±0.72^{c}	1.86±0.35^{b}	2.48±0.67^{c}	2.90±1.01^{d}	1.07±0.60^{d}	32.15±7.07^{a}	1.40±2.94^{b}	0.27±0.13^{a}
0:100	1.84±0.92^{b}	1.80±0.23^{d}	4.12±0.77^{a}	2.56±0.92^{e}	0.71±0.12^{e}	23.97±7.37^{c}	4.21±6.11^{a}	0.27±0.08^{ba}
LSD[1]	0.0096	0.0185	0.0119	0.0105	0.0098	2.9258	0.2272	0.0164

* Values are means ± SD from 24 samples

Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$

1. Least Significant Difference @ P = 0.05

Table 4.1.13 Mean Scores of Sensory Evaluation of Cake Sample from Flour Blends

Cake sample code	Sensory Attributes				
	General appearance	Aroma	Taste	Texture	Overall acceptance
A	6.47 ± 1.25^{b}	5.60 ± 2.67^{b}	5.87 ± .070^{b}	6.13 ±1.41^{a}	6.07±1.49^{c}
B	6.53 ± 1.30^{b}	6.60 ± 1.99^{a}	7.60 ± 0.99^{a}	6.87 ±1.55^{a}	7.60± 0.91^{a}
C	7.20 ± 1.32^{a}	6.13 ± 1.92^{b}	6.47 ± 2.29^{a}	6.00 ±2.36^{a}	6.26 ±1.30^{b}
D	7.47 ± 1.36^{a}	6.40 ± 1.64^{a}	6.93 ± 1.58^{a}	6.33 ±1.76^{a}	6.40 ±1.59^{b}
E	7.33 ± 1.18^{a}	6.00 ± 2.27^{b}	6.47 ± 2.19^{a}	6.07 ±2.25^{a}	7.13 ±0.99^{b}
F	6.27 ± 1.49^{b}	6.40 ± 1.96^{a}	6.47 ±2.10^{a}	5.47 ±1.73^{b}	6.60±1.12^{b}
G	4.27 ± 2.05^{c}	3.93 ±2.02^{c}	2.20 ± 1.01^{c}	3.60 ± 1.84^{c}	3.27±1.62^{d}
H	6.73 ± 2.12^{a}	5.87 ± 2.47^{b}	6.53 ± 2.07^{a}	5.47 ±1.81^{b}	6.27±2.08^{b}
I	6.73 ± 2.02^{a}	4.00 ± 2.39^{c}	5.07 ± 1.53^{b}	4.87 ± 1.99^{b}	5.33±1.16^{c}
J(control)	8.13 ± 0.83^{a}	8.13 ± 0.52^{a}	7.93 ± 0.70^{a}	8.13±0.59^{a}	8.20±0.56^{a}
LSD	1.59	1.92	1.85	2.15	0.93

* Values are means ± Standard deviation (SD) from 15 determinations .Means not followed by the same letters along the column are significantly different @ $P \leq 0.05$.

A = Cake made from sweet potato flour blend with conventional Bambara groundnut flour 50:50

B = Cake made from sweet potato flour blend with steamed Bambara groundnut cotyledon flour 75:25

C = Cake made from cassava flour blend with Bambara groundnut cotyledon flour 75:25

D = Cake made from cassava flour blend with Bambara groundnut cotyledon flour 50:50

E = Cake made from yam flour blend with conventional Bambara groundnut flour 50:50

F = Cake made from cocoyam flour blend with Bambara groundnut cotyledon flour 50:50

G = Cake made from yam flour blend with conventional Bambara groundnut flour 75:25

H = Cake made from cocoyam flour blend with steamed Bambara groundnut cotyledon flour 50:50

I = Cake made from sweet potato flour blend with conventional Bambara groundnut flour 25:75

J = Cake made from wheat flour (control).

SWEET POTATO BLENDED WITH CONVENTIONAL BAMBARA GROUNDNUT FLOUR 50%: 50%

SWEET POTATO BLENDED WITH STEAMED BAMBARA GROUNDNUT COTYLEDON FLOUR 75% : 25%

CASSAVA FLOUR BLENDED WITH BAMBARA GROUNDNUT COTYLEDON FLOUR 75%:25%

CASSAVA FLOUR BLENDED WITH BAMBARA GROUNDNUT COTYLEDON FLOUR 50%:50%

YAM FLOUR BLENDED WITH CONVENTIONAL BAMBARA GROUNDNUT FLOUR 50%:50%

COCOYAM FLOUR BLENDED WITH BAMBARA GROUNDNUT COTYLEDON FLOUR 50%:50%

YAM FLOUR BLENDED WITH CONVENTIONAL BAMBARA GROUNDNUT FLOUR 75%:25%

COCOYAM FLOUR BLENDED WITH STEAMED BAMBARA GROUNDNUT COTYLEDON FLOUR 50%:50%

SWEET POTATO FLOUR BLENDED WITH CONVENTIONAL BAMBARA GROUNDNUT FLOUR 25%:75%

WHEAT FLOUR (100%) (CONTROL)

Plate 4.1 Queen's cake samples produced from root tuber flour-bambara groundnut flour blends and 100% wheat flour

4.2 DISCUSSION

4.2.1 Changes in the Proximate Composition of Flour Samples

The result of the analysis of the proximate composition of the flour samples are presented in Table 4.1.1.The proximate composition was affected by 3 main factors which are the tuber type, the bambara groundnut treatments and the tuber: bambara groundnut blend ratios. The data on Table 4.1a showed the means of triplicate determinations obtained from the analysis conducted and Figure 4.1 to 4.8 represents the graphical presentation of the table. The proximate composition of the control tropical tuber flour samples was shown on Table 4.1.1. One way analysis of variance (ANOVA) (Appendix II) showed that the means of most of the measured parameters varied significantly ($P < 0.05$) with the exception of cocoyam and sweet potato in which there were no significant difference in their percentage moisture and dry matter.

Table 4.1.2 reveals the proximate composition of treated flour samples as affected by tropical tuber variety. Three way analysis of variance (ANOVA) (Appendix III) showed that the means of most of the measured parameters varied significantly ($P < 0.05$) with the exception of the fat, fibre and carbohydrate which showed no significant difference ($P>0.05$) in their content in some of the treated tropical tuber varieties. Results from this study showed that blending the tuber flours with the various bambara groundnut

treatments reduced the moisture content of the control tropical tuber flour samples. (Table 4.1.1 via Table 4.1.2). This implies that tuber flours have more residual moisture than the legume flours and this affected the moisture content of the treated flours. The moisture content of food powders goes a long way in suggesting the shelf life of the product. The moisture content of any food material is of significance to shelf life, packaging and general acceptability (Sefa-Dedeh and Saalia, 1997;Okaka and Okaka 2001).The reduction in moisture content of any food during production helps to enhance its suitability and adaptability for further use in food formulations (Enesminger *et al.* 1995). However all the flour samples fall below the minimum limit (15%) of moisture content for flours (Ihekoronye and Ngoddy,1985).

There was a significant increase in the percentage protein of the tropical tuber flour varieties with blending of various treated bambara groundnut flours, with the yam flour variety having the highest protein percentage increase. A previous study carried out by Abasiekong *et al.* (2010) showed that increase in percentage protein was a function of supplementation of flours using bambara groundnut. There was a significant difference ($P< 0.05$) in the percentage protein of the treated flour samples as affected by tropical tuber varieties. Therefore in the choice of blends with the highest protein percentage yam stands a better choice.

From Table 4.1.2 above it was observed that there was an increase in percentage fat of all the treated flour samples, with the flour samples containing the cassava and sweet potato varieties showing no significant difference among their means. According to Olapade and Adetuyi (2001), the fat content of bambara groundnut flour is generally high compared to other non-oil seed legumes (5.03-9.00%). This factor must be the contributory factor to the high percentage fat of the treated flour samples. It is desirable to use blends with the lowest fat content, in order to reduce rancidity in the stored product.

The fibre content of the tuber flours blended with treated bambara groundnut flours showed no significant difference ($P<0.05$) in cassava, cocoyam and sweet potato varieties (Table 4.1.2). When compared to the sample means of the control samples on Table 4.1.1, the same trend in protein was observed , but the significant increase in the percentage fibre of the treated flour samples was common to the treated flour samples containing cassava, yam and cocoyam flours but a decrease was obtained in the flour containing the sweet potato. The higher content of crude fibre in bambara groundnut may be responsible for the marginal increases observed in the treated flours. This high fibre content may contribute to bulk, encourage bowel movement, (discouraging constipation and piles), lowers blood cholesterol and helps prevent cancer of the colon (Hung *et al.* 2004).

There was a significant difference ($P<0.05$) in the percentage ash content of the treated flour varieties (Table 4.1.2) .When compared to the control tuber flours, it was observed that there was a significant increase with the exception of the tuber flour sample containing cocoyam where there was a slight decrease in the ash content. These increases may be due to addition effects. This may also be due to complementary roles as reported by Linemann (1988) and Akpapunam and Darbe (1994).The ash content represents the total mineral content in foods and thus serves as a viable tool for nutritional evaluation (Lieniel,2002).

The percentage carbohydrates content was high in the control tropical tuber flour samples with cassava having the highest carbohydrates percentage (83.21%) which was significantly different ($P<0.05$) from other samples. Table 4.1.2 reveals a significant decrease in the percentage carbohydrate of the treated tropical tuber varieties although yam and cocoyam were not significantly different at the same level. This corresponds with the work done by Akubor *et al.* (2000) who reported that the carbohydrate content of the maize bambara groundnut '*apula*' blends decreased with increase in the level of bambara groundnut probably due to dilution effect. The energy content of the treated tropical tuber varieties ranged between 363.45kJ and 367.22kJ were significantly different ($P<0.05$). This indicates a significant increase from the control tuber varieties on Table 4.1.1. The same trend was observed

in the percentage dry matter. These increases may also be due to addition effects.

Table 4.1.3 showed the proximate composition of the flour samples as affected by the Bambara groundnut treatments. Three way analysis of variance conducted reveals that there was significant differences ($P<0.05$) in the measured parameters with the exception of the fibre content (of the conventional bambara groundnut flour and steamed bambara groundnut cotyledon flour) and ash content (of the conventional bambara groundnut flour and bambara groundnut cotyledon).The moisture content of all fall within the acceptable limit of dry flour products (10-15%).There was significant increase in percentage protein from the conventional bambaragroundnut flour (9.30%) to the bambaragroundnut cotyledon flour (10.55%) and finally to the steamed bambaragroundnut cotyledon flour (11.33%).This could be attributed to the concentration of the intact proteins. This result is consistent with the report of Nti (2009) which stated that dehulling increased the protein content of bambara groundnut flours. The fat value was highest in flour samples with steamed bambara groundnut cotyledon flours and least with the conventional bambara groundnut flours. This might have resulted from the total removal of the hull portion and concentration of the endosperm. The increase in the fat and protein percentages of the flour samples with bambara groundnut cotyledon and

steamed bambara groundnut cotyledon corresponds with a previous study in Linseed carried out by Schlamb *et al.* (1955) , Mandokhot *et al.* (1979) and Reichert *et al.*(1986) which stated that dehulling of legumes significantly concentrates major components like oil and proteins. The conventional bambara groundnut flours were dehulled using the conventional dehulling separation loss which is a function of specific gravity between the light and heavy particles while in hot dehulling it involves the use of heat in order to achieve the desired moisture equilibrium before cracking can be done. Although all the samples were dehulled, the hot dehulling gave a more refined flour due to the complete absence of the hulls than the conventional dehulling which could still contain some residual hulls and this also could account for the differences in the proximate characteristics.

From Table 4.1.3 above it was observed that dehulling of the bambara groundnut decreased the neutral fibre content of the flour samples but on heat steaming the bambara groundnut cotyledon the fibre content increases ue to the intact fibre content. This shows that dehulling of the bambara groundnut which entailed the removal of some bran and the outer layer of the seed has resulted to its decrease in fibre content of the treated flour samples These results fall within those reported for some legumes (Ramulu and Udayasekhara 1997, Abdelnour, 2001) who found that two rates of dehulling reduced the fibre content of pearl millet from 1.1% to 0.75% and 0.55% . The

fibre content of the conventional bambara groundnut flour and the steamed bambara groundnut flour reveals no level of significance (P<.0.05). The steaming process might have concentrated the intact fibre . The dehulling process did not cause a significant difference in the ash content of the conventional bambara groundnut and bambara groundnut cotyledon flour samples may be due to the short time boiling of the raw bambara groundnut seed before dehulling but a significant decrease was observed in the steamed bambara groundnut cotyledon flour samples. This might be as a result of leaching out of minerals during the hot air steaming process. The carbohydrates percentage (Table 4.1.3) reveals that the blends with conventional bambara groundnut flour have the highest carbohydrate content (71.95%) and this was significantly different (P<0.05) from other samples. The carbohydrates values are dependent on the values of other proximate components since it was determined by difference not chemically.

Table 4.1.3 also showed that flour samples containing the steamed bambara groundnut cotyledon flours are of higher energy value and are significantly different (P<0.05) from other samples. This can be attributed to their high content of proteins and fats which are contributory factors in the calculation of energy values of food.

Table 4.1.4 above showed that the proximate composition of flour samples as affected by tuber: bambara groundnut blending ratio. The results showed

that there were significant differences (P<0.05) in the proximate content of all the blends with exception in the fibre content of blend ratios of 75:25 and 0:100 which reveal no significant difference. The protein, fat, ash, and energy of the flour blend ratios significantly increased with increase in the levels of bambara groundnut in the blends while that of the carbohydrate decreased with increase in the levels of bambara groundnut.

4.2.2 Changes in the Physicochemical Properties of Flour Samples

The physicochemical properties of the flour blends were evaluated using swelling index, oil absorption capacity, water absorption capacity, gelling temperature, boiling temperature and pH.The data on Table 4.1b represents the means of duplicate determinations obtained when these analysis were conducted on the flour samples and Figure 4.9 to 4.14 reveals the graphical presentation.

Table 4.1.5 above showed that the physicochemical properties of the control flour samples differ significantly (P<0.05) from each tuber variety with the exception of water absorption capacity (of yam and sweet potato) and the gelling temperature (of cocoyam and sweet potato) which were not significantly different. Sweet potato tuber variety had the highest swelling index, oil absorption capacity and water absorption capacity. Cassava had the least gelling temperature and boiling temperature. The pH of the tropical

tuber flours all fall within the range of 6.20-6.50 which implies that they are slightly alkaline in nature.

Table 4.1.6 above showed that the physicochemical properties of the treated flour samples are affected by the various bambara groundnut flour addition. There were significant differences ($P<0.05$) in the swelling index of the blended flour samples of the tropical tuber varieties with the sweet potato variety having the highest swelling index. Sanni *et al.* (2005) reported that the swelling index of granules reflect the extent of associative forces within the granule, therefore the higher the swelling index, the lower the associative forces. High swelling capacity has been reported as part of the criteria for a good quality product (Achinewhu *et al.* 1998).The swelling index of the control flour samples on Table 4.1.5 of the yam, cocoyam and sweet potato tuber varieties were higher than that of the blended flour samples on Table 4.1.6.This could be attributed to the highly associative starch granule that is relatively resistant to swelling that is introduced by the addition of the bambara groundnut flours.

Oil absorption capacity is the ability of the flour proteins to physically bind fat by capillary attraction, and is of great importance since fat acts as a flavor retainer and also increase the mouth feel of foods especially bread and other baked foods (Kinsella, 1976). From Table 4.1.5 and 4.1.6 it was observed that the oil absorption capacity from flour samples from yam and sweet potato

tuber varieties decreased with the addition of bambara groundnut flour while that of cocoyam and cassava experienced an increase in the oil absorption capacity. Blended tuber flours from yam and cocoyam were not significantly different ($P<0.05$) from each other and this implies that the adddition of bambara groundnut flours did not significantly affect the oil absorption capacity of the yam and cocoyam flours.

Table 4.1.6 also showed that the water absorption capacity of the treated samples from cassava tuber variety had an increase from the control flour samples while in the other tuber varieties there was a decrease. There were significant differences ($P<0.05$) in the water absorption capacity of the treated flour samples of the tropical tuber varieties with the flour sample from the yam tuber variety having the highest water absorption capacity. Table 4.1.2 showed that flour samples from yam tuber varieties had the highest protein content. Dev and Quensil (1988) reported that protein subunits have more water binding site (increase in the number of hydrophilic groups which are the primary site in water binding proteins). The effect of interaction of protein and starch (carbohydrates) on water absorption had been reported by previous works (Chauham and Bain, 1985; Bhattacharya *et al.* 1986; Iwe, 2000; Rampersad *et al.* 2003).The differences in water absorption may be due to starch damage arising from the milling process and the water binding properties of the bambara groundnut flour proteins (Meredith, 1969;

Akpapunam and Darbe, 1994). The water absorption capacity of food materials is an index of the maximum amount of water it can take up and retain hence determine the energy and nutrient dense of a food (Levin *et al*. 1993). Niba *et al.* (2001) also stated that water absorption capacity is important in bulking and consistency of products as well as baking applications. Good water absorption and retention also suggest better performance in texture of comminuted meats and baked products (Okezie and Bello, 1988).

Table 4.1.6 also showed that the addition of bambara groundnut flour caused an increasing effect on cassava and yam tuber flours and a decreasing effect on the cocoyam and sweet potato tuber flours in terms of gelling temperatures. There were significant differences ($P<0.05$) in the gelling temperature of the treated flour samples with flour samples from the yam variety having the least gelatinization temperature while that of sweet potato tuber variety was the highest. This could be attributed to its carbohydrate content. High amylose starch requires high temperatures for gelatinization and gives short bodied paste that form firm opaque gel on cooling (Lawal *et al*.2004). Gelatinization affects digestibility and texture of starch containing foods (Richard *et al.* 1991; Lawal *et al.* 2004). The boiling temperatures of the treated flour samples showed that there was no significant differences ($P<0.05$) in boiling temperatures of treated flour samples from the cocoyam

and sweet potato tuber varieties. Table 4.1.6 showed also that the boiling temperatures of treated flours from the cassava and yam tuber varieties had increased over that of the control on Table 4.1.5.The treated flour samples from the cassava and the yam tuber varieties had the least boiling temperatures which are more preferrable in order to reduce energy cost and damage of heat labile nutrients.

Table 4.1.7 showed that the different types of treatment of the bambara groundnut are significantly different ($P<0.05$) in the measured parameters. In the swelling index it was observed that flour samples with steamed bambara groundnut cotyledon flour had the highest swelling index. The same trend was observed in the oil absorption capacity and in the water absorption capacity. This confirms the works of Ghavidel and Pradash, (2006) which stated that dehulling improves the certain functional properties of legumes. In the same Table it was shown that the treated samples containing the steamed bambara groundnut cotyledon flour had the highest gelling temperature. Sathe *et al.* (1982) associated the gel formation of leguminous flour to the relative ratios of the different constituents (proteins, carbohydrates and lipids) that make up the legumes. According to Enujiugha (2006) high gelatinization temperature will require more energy consumption to cook and hence the gel strength would be weak and undesirable.

Table 4.1.8 presented the physicochemical properties of the treated flour samples as affected by tuber flour/bambara groundnut blending ratios (TTF: BGF). Results showed that there were significant differences ($P<0.05$) in the swelling index, oil absorption capacity, boiling temperature and pH of the test samples. The swelling index of the blended flour samples decreased significantly ($P<0.05$) with increase in the level of the bambara groundnut in the blends. This confirms the work of Ihekoronye and Ngoddy (1985) which attributes swelling index to the starch content. In the same Table it was observed that the tuber flour: bambara groundnut flour ratio of 0:100 had the highest oil absorption capacity, gelling temperatures and boiling temperatures. This makes this ratio of blending unstable for economic use. The water absorption capacity reveals that the TTF: BGF in the ratios of 50:50 and 25:75 are not significantly different ($P<0.05$) and the ratio of 75:25 had the highest water absorption capacity, lowest boiling temperature and gelling temperature when all the tuber flour blends were considered.

4.2.3 Changes in the Antinutritional Properties of Flour Samples

The means of duplicate determinations obtained when these analysis were conducted based on the level of antinutritional factors in the control and the treated flour samples are shown in Table 4.1c while Figure 4.15 to 4.22 showed the graphical presentation of the table. The antinutritional factors analyzed were the alkaloid, tannin, saponin, oxalate, hydrocyanic acid, trypsin inhibitor, hemaggulutinin and the phytic acid. Table 4.1.9 showed the antinutritional properties of the untreated (unblended) tropical tuber flours (control). Generally there were significant differences ($P<0.05$) among the sample means in some of the measured parameters.

Alkaloid content was lowest in the yam tuber flour (1.03mg/g) and highest in cocoyam flour sample (2.72mg/g) (Table 4.1.9).On treating these tuber flours it was observed on Table 4.1.10 that there was a significant increase ($P<0.05$) in the alkaloid content of the treated flour samples of cassava and yam while there was a decrease in the flour samples containing cocoyam and sweet potato with treated flour samples of cocoyam having the highest alkaloid content (2.23mg/g) and that of cassava being the least (1.55mg/g) . According to Wikipedia (2010), alkaloid is a naturally occurring nitrogenous organic molecule that has a pharmacological effect on humans and animals although the recommended lethal dose should be 150-169mg per kg body weight.

Table 4.1.9 above showed that the tannin content of the yam and cocoyam sample flours are not significantly different (P<0.05), and they contain the highest tannin content (2.24mg/g) among the tropical tuber flours investigated. Sweet potato had the least tannin content (1.36mg/g).The treated tropical tuber flours on Table 4.1.10 above revealed that there were significant differences (P<0.05) among the tuber flours although the treated yam and sweet potato flour samples were not significantly different The table also showed that the treated flour samples with the treated cocoyam flour samples had the highest tannin content (2.01mg/g) while the treated cassava flour sample had the least tannin content (1.68mg/g).The increase and decrease in the tannin content of the treated tropical flour under investigation can be ascribed to the treatment undergone by these tuber flours. According to Tannin and Tannin Sources (1989), tannin occurs in nearly every plant from all over the world in all climates. The presence of tannin in foods sometimes gives it dark colour due to its reaction with iron. It can provoke astringent reactions in the mouth and make the food unpalatable. Tannins reduce the digestibility of protein by inhibiting the digestive enzymes. However polyphenols such as tannins have anticancer properties so drinks such as green tea that contain large amounts of these compounds might be good for the health of some people despite their antinutrient properties (Chung *et al*. 1998).

Sweet potato had the highest saponin content (3.59mg/g) as shown on Table 4.1.9 and is significantly different ($P<0.05$) from other flour samples although the saponin content of yam and cassava were not significantly different and they contain the least saponin content (2.33mg/g) among the tuber flour investigated. Table 4.1.10 above showed that on treating these tuber flours there was a significant increase in the saponin content of the treated flours containing the cassava and cocoyam tuber flours and a decrease in the flour samples containing yam and sweet potato. The treated sweet potato flour had the highest saponin content (3.17mg/g) while the treated yam flour had the least saponin content (2.26mg/g). However Merck (1976) reported that saponins are practically non toxic to man when taken orally. Oakenfull *et al.* 1979 and Topping *et al.* 1980 also stated that saponins have a number of advantages of which the most interesting is that it can lower plasma cholesterol concentration.

According to Table 4.1.9 above in terms of oxalate, cocoyam tuber flour had the highest level of oxalate (6.12mg/g) among the tropical tuber flour investigated and the tuber flour containing the least oxalate was yam (3.79mg/g). The result shows that among the major tropical tubers cocoyam has the highest level of oxalate. There were significant differences ($P<0.05$) among the sample means of the level of oxalate of all the tropical tuber flours. Table 4.1.10 above showed that in all the treated tuber flours there was

a significant decrease ($P<0.05$) in the sample means of their oxalate content due to the treatments undergone by these tuber flours. The interest in the toxicity of oxalates arose because of instances of several fatal human poisoning following the eating of larger quantities of leaves of certain plants known to contain larger amounts of oxalates and occurrence of calcium oxalate in the majority cases of human kidney stones. Oxalate can form complexes with most essential trace elements therefore making the unavailable for enzymatic activities and other metabolic processes. Consumption of large doses of oxalic acid causes corrosive gastroenteritis, shock, convulsive symptoms, low plasma calcium, high plasma oxalate and renal damage (Eneobong,2001).Considering the amount of oxalate in the control and treated flour samples none of them could possibly be toxic under meal portion since the safe level in man is 15-30g per food consumed.

Hydrocyanic acid content was highest in the cassava flour (9.51mg/kg) and lowest in the sweet potato flour (0.54mg/kg).However all the cyanide values of the control and treated flour samples were generally lower than the safe level (10mg/kg) recommended by food and agricultural organization (FAO) and world health organization (Adindu *et al.* 2003). There was a significant difference ($P<0.05$) in hydrocyanic acid content of the tropical tuber flours. Table 4.1.10 above showed a significant decrease in the hydrocyanic acid content of the treated flours although slight increase was observed in the

treated tuber flours of yam and sweet potato from 0.62mg/kg,0.54mg/kg to 0.73mg/kg,0.62mg/kg respectively. There were significant differences ($P<0.05$) in hydrocyanic acid content of all the treated tropical tuber flours. The lethal dose of hydrocyanic acid as reported by Eneobong (2001) was 35mg per body weight. On the other hand, Burn (1971) reported that the body has a way of detoxifying small doses of cyanide in food by converting it to thiocyanide which is excreted in the urine. However traces of cyanide in food are of immense importance since it helps to convert inactive form (hydroxycobalamine) to active form (cyanocobalamine). Aremu (1991) estimated that the per capita daily intake of hydrocyanate in Nigeria was 8mg almost 90% of which is from garri alone

Table 4.1.9 above also showed that the trypsin inhibitor content was lowest in cocoyam flour (18.71Tui/g) and highest in yam flour (39.89Tui/g) and there were significant differences ($P<0.05$) between yam flour and the other tropical tuber flours. Table 4.1.10 showed that there was a significant increase ($P<0.05$) in trypsin inhibitor content of the cocoyam and sweet potato flours mixed with treated bambara groundnut flours while the blends of cassava and yam flours with same legume witnessed a significant decrease. The same table also showed that the treated yam flours had the highest level of trypsin inhibitor (32.18Tui/mg).According to Taylor and Francis (2009), it has been established that sweet potato shows trypsin inhibitor activity (TIA)

ranging from 90% inhibition in some varieties to 20% in others and that there is a significant correlation between trypsin inhibitor and the protein content of the sweet potato variety. This also corresponds with the discovery in this work that treated yam flour which had the highest protein percentage also had the highest content of trypsin inhibition. Heating to 90^{o}C for several minutes inactivates trypsin inhibitors. According to Fadahunsi (2009) trypsin inhibition activity decreased by 22.1% after soaking for 24 hours and further decreased to 72% after boiling for 45 minutes. Akanji *et al.* (2003) reported that trypsin inhibitor causes drop in trypsin level (amino acid) and decrease in protein digestibility leading to slower animal growth.

Table 4.1.9 above showed that hemagglutinin was detected only in the cassava tuber flour (1.71Hui/mg) while in the other samples it was negligible. On treating the tuber flours as shown on Table 4.1.10 it was observed that hemagglutinin was detected in all the flour samples and they were significantly different ($P<0.05$) from one another. Treated cocoyam flour had the highest hemagglutinin (2.06Hui/mg) content while the treated yam flour had the least (1.05Hui/mg).This implies that these treatments had fully introduced this antinutritional factor into the flour samples.

All the tropical tuber flour samples under investigation contained some levels of phytic acid as shown on Table 4.1.9 with the cocoyam flour sample having the highest (0.33mg/g) content of phytic acid and yam flour sample had the

least content of phytic acid (0.18mg/g).When these tuber flours were treated the result on Table 4.1.10 showed that the phytic acid content of yam and cocoyam were not significantly different ($P<0.05$) from each other but were significantly different at the same level from other treated sample flours. Treated flour samples from cocoyam had the highest phytic acid content (0.29mg/g) while the least was the treated cassava flour sample (0.20mg/g). This confirms the work of Taylor (1982) which stated that cassava, cocoyam and yam contain phytates and processing into fermented foods will reduce the phytate level of these root crops sufficiently to nullify its adverse effect. McCance and Widdowson (1955) determined the phytic acid content of 64 foodstuffs and found that 20-60% of the phytate are found in cereals and are excreted by human being unchanged in the feaces. Deshpande *et al.* (1982) stated that the maximum tolerable dose of phytate in the body is 250-500mg/100g.Warnick (1997) observed that foods with greater than 19mg/100g phytic acid composition showed low iron diffusibility. Research has traditionally focused on its structure that gives it the ability to bind minerals, protein and starch and the resulting lower absorption of these elements. However recent research has shown that phytic acid has many health benefits. Phytic acid has antioxidant, anticancer hypocholestroemic acid and lypolipidemic effects (phytochemicals) at a regulated dosage (Wikipedia, 1988).

Table 4.1.11 above showed that the antinutritional factors of the flour samples as affected by the bambara groundnut treatments. Generally there were significant differences ($P<0.05$) among the sample means of the tested parameters. Alkaloid content was lowest in the flour samples containing the conventional bambara groundnut flour (1.39mg/g) and highest in the flour samples containing the steamed bambara groundnut cotyledon flour (2.47mg/g).The result showed that total dehulling caused a significant increase of alkaloid in the flour samples containing the bambara groundnut cotyledon flour and the steamed bambara groundnut cotyledon flour This is in agreement with the work of Deshpande *et al.*(1982) who observed that dehulling can increase certain antinutritional factors such phytic acid, trypsin inhibitor and alkaloid of certain beans. This could be as a result of the location of these antinutritional factors which could be intact in the cotyledons of the certain beans.

Tannin content was lowest in the flour samples containing the bambara groundnut cotyledon flour (1.78mg/g) and highest in the flour samples containing the conventional bambara groundnut flour (1.95mg/g).This result shows that proper dehulling by first boiling the seed of the legume in use caused a significant decrease ($P<0.05$) in the tannin content. This implies that the tannins are mainly present in the seed coat of the bambara groundnut legume. This conforms to the work of *Ekpo et al.*(2008) which stated that

hydrozable tannin are water soluble and disperses in hot water due to its leaching out .This shows that during boiling, some of the hydrozable tannins in the bambara groundnut seed has been leached out. Udensi *et al.* (1999) reported that most of the antinutritional factors are heat labile, boiling could therefore inactivate the heat sensitive antinutritional factors. According to Ferruzi *et al.* (2009), cooking in water is more effective in reducing tannins than other treatments. Deshpande *et al.* (1982) stated that the removal of seed coats lowered the tannin content of beans by 68-95%. The increment of the tannin content of the flour samples containing the steamed bambara groundnut cotyledon flour can be attributed to the heat steaming which might have compounded the tannins in the bambara groundnut cotyledon.

Saponin content was lowest in the flour samples containing the bambara groundnut cotyledon flour (2.58mg/g) and highest in the flour samples containing the steamed bambara groundnut cotyledon (2.85mg/g).This conforms to the work of Reichert *et al.* (1986) which stated that abrasive dehulling of legumes to flour ranging from 85.2 to 98.8% reduced the saponin content to a low level concentration. The flour samples containing the steamed bambara groundnut cotyledon had the highest saponin content due to the concentration of the group B saponins which are located in the cotyledon. According to Kerwin 2004, there are two types of saponins in soybeans : group A saponins which are located in the germ and produces

undesirable astringent taste typical of some soy products and group B saponins which are found in both the soybean germ and cotyledons and these have the health promoting properties.

Oxalate content was lowest in the flour samples containing the bambara groundnut cotyledon flour (2.84mg/g) and highest in the flour samples containing the conventional bambara groundnut flour (3.59mg/g).The result showed that proper dehulling caused a significant reduction in the oxalate content.

Hydrocyanic acid content was lowest in the flour samples containing the steamed bambara groundnut cotyledon flour (1.52mg/kg) and highest in the flour samples containing the conventional bambara groundnut flour (1.69mg/kg).There was a significant decrease ($P<0.05$) in hydrocyanic acid content due to boiling, dehulling and steaming of the bambara groundnut legume. Chakraborty and Eka (1978), reported that hydrocyanic acid content of wheat *Triticum spp.* to be 81.36mg.However Edet (2005) reported that there was no hydrocyanic acid observed in his studies on some bread samples in Uyo metropolis.

Trypsin inhibitor content was high in the flour samples containing the bambara groundnut cotyledon flour (30.81Tui/mg) and the steamed bambara groundnut cotyledon flours (28.61Tui/mg) and low in the flour samples

containing the conventional bambara groundnut flour. This also tallies with the work of Deshpande *et al.* (1982) who observed that dehulling can increase certain antinutritional factors such phytic acid, trypsin inhibitor and alkaloid of certain beans. According to Obizoba and Egbuna (1991) fermentation process reduced the TIA and polyphenol levels in the cotyledons of two Nigerian varieties of bambara groundnut. According to Wikipedia (2010), trypsin inhibitors are chemicals that reduce the availability of trypsin an enzyme essential to nutrition of many animals including humans.

Hemagglutinin content of the flour samples containing the conventional bambara groundnut flours was high (3.71Hui/mg) and significantly different ($P<0.05$) from the sample flours containing bambara groundnut cotyledon flour (0.28Hui/mg) and steamed bambara groundnut cotyledon flour (0.41Hui/mg). According to Wikipedia (2009), hemagglutinin are substances that cause red blood cells to agglutinate examples include antibodies, blood group antigens, autoimmune factors (such as Rh factors) and lectins. According to Onwuka (2006), combination of soaking and boiling at various levels on the detoxification of trypsin inhibitor, cyanogenic glycoside, hemagglutinin, alkaloid and tannin in pigeon pea and vegetable cowpea were more potent than soaking or boiling alone.

Phytic acid content was low in the flour samples containing the steamed bambara groundnut cotyledon flour (0.21mg/g) and high in the flour samples containing the conventional bambara groundnut flour (0.29mg/g).The result shows that boiling to dehull and the steaming of the cotyledon caused a reduction in the phytic acid content .This agrees with the report of Opoku *et al*.(2003) which observed that soaking and cooking can eliminate or reduce the phytic acid content in legumes (pigeon pea and mung beans).According to Eneobong and Obizoba (1996) decrease in phytate and tannin occurs as a result of leaching of phytate and tannin into the soaking water.

Table 4.1.12 above showed the antinutritional properties of flour samples as affected by the tropical tuber flour : bambara groundnut blending ratios. Alkaloid content indicates the ratio of tuber flour: bambara groundnut of 75:25 was the lowest (1.77mg/g) while that of 100:0 had the highest alkaloid content (1.99mg/g).This indicates that both the tuber flours and the legume flours contain high level of alkaloids but the tuber flours contribute the higher percentage. The alkaloid content of the blends was significantly different ($P<0.05$) although that of 50:50 and 25:75 of tuber flour: bambara groundnut flour showed that they were not significantly different. The tannin content of the blend ratios revealed that there was a significant decrease in the ratio with increase in the level of substitution with bambara groundnut although the ratio of 0:100 tuber flour: bambara groundnut flour did not also follow the

trend. The tannin content of the blends was significantly different (P<0.05) although that of 50:50 and 25:75 of tuber flour: bambara groundnut flour showed that they were not significantly different. Tannin was lowest in the ratio 0:100 (1.80mg/g) and highest in the ratio 100:0 (1.94mg/g) of tuber flour: bambara groundnut. This indicates that the tropical tuber crops used had a higher percentage of tannin than the legume used. The saponin content showed that ratio of 75:25 tuber flour : bambara groundnut was lowest (2.13mg/g) and highest in the ratio 0:100 (4.12mg/g).This indicates the bambara groundnut (legume) had a higher saponin content than the tropical tubers. There were significant differences (P<0.05) in the saponin content of the blend ratios. Oxalate was lowest in the blend ratio of 0:100 (2.56mg/g) and highest in the ratio of 100:0 (4.41mg/g) tuber flour: bambara groundnut .This shows that oxalates are mostly found in tropical tubers than in legumes. There were significant differences (P<0.05) in the oxalate content of the blend ratio. The hydrocyanic acid content of the blend ratios on the same table showed that the ratio of 0:100 had the lowest content (0.71mg/kg) and the highest content was found in the ratio of 100:0 (3.15mg/kg) tuber flour: bambara groundnut. This implies that the contributory factor in the level of hydrocyanic acid in the blend ratio was the tropical tubers used. Trypsin inhibitor content was lowest in the ratio 0:100 (23.97Tui/mg) and highest in the ratio 25:75 (32.15Tiu/mg) tuber flour: bambara groundnut. The results reveal that ratio 75:25 and 50:50 were not significantly different from each

other and from ratios 100:0 and 25:75 of the blend ratio of tuber flour: bambara groundnut. This showed that the level of trypsin inhibitor in the blend ratio was affected by the tropical tubers and the legumes. Hemagglutinin content was lowest in the ratio of 75:25 (0.36Hui/mg) and highest in the blend ratio of 0:100 (4.21Hui/mg) tuber flour: bambara groundnut .This showed that the main contributor of hemagglutinin in the blend ratios was the bambara groundnut flours. Phytic acid was lowest in the ratio of 100:0 (0.24ug/g) and is significantly different from other blend ratios while the highest is the ratio of 25:75 and 0:100 (0.27ug/g) tuber flour: bambara groundnut. This indicates that the tropical tubers and the bambara groundnut contain phytic acid but it is higher in legumes.

The possibility now exists to eliminate antinutrients entirely using genetic. engineering but since these compounds may also have beneficial effects, such genetic modification could make the foods more nutritious but not improve people's health (Welch and Graham, 2004).

4.2.4 Sensory Evaluation of Cake Samples from Flour Blends.

Result of sensory evaluation presented on Table 4.1.8 showed that there were no significant difference ($P<0.05$) in the general appearance of the control (cake sample J) queen's cake to the queen's cake from cake sample D,E,C,H and I, but the general appearance of cake sample A,G,B and F were significantly different from the control. The odor of the queen's cake from the control was different although it was not significantly different from cake samples of B, F and D. The panelists commented that cake samples of G and I had strong beany odor and this can be attributed to the use of the conventional bambara groundnut flour which had not undergone any form of heat treatment. Being an edible product the taste of the product will be great interest since the general appearance of most of the products is acceptable. The taste of queen's cake from samples J, B, D, H, C,E and F, were found to be 88.1%, 84.4%, 77%, 72.5% and 71.9% (for cake samples C,E and F) respectively, this indicates that even though the panelist prefer the queen's cake from the control which was from wheat flour they found the taste of the other cake samples to be quite good. The percentages were calculated by making the taste score point the subject of the formula of the 9-points scale and converting to percentages .The worst taste as commented by the panelists was from sample G which they complained had a bitter taste The texture of the whole wheat queen's cake was not significantly different ($P<0.05$) from

the queen’s cake from samples of B, D,A, E and C but was different from cake samples F,H,I and G. The panelist suggested the use of flours used in the production of the cake samples F,H and I be used for biscuit production because of the crispy nature and nutty aroma exhibited from these samples . The mean score of the overall acceptance ranged from 3.27±1.62 to 8.29± 0.56 with sample J having the highest mean score and sample G having the least mean score. The difference in the means of samples J and B were not significantly ($P<0.05$). Thus generally the cake sample from sample B which was the flour blend of sweet potato and steamed bambara groundnut cotyledon flour was generally accepted just as the wheat flour cake.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The use and importance of selected legume in combination with certain root tubers in boosting the nutrient (especially protein) content of baked products cannot be over–emphasized. The results obtained from the analysis has shown that it is feasible to use bambara groundnut flour in combination with root tuber flours like sweet potato in production of pastries like cakes, biscuits etc. From the study it was observed that cake product of acceptable quality can be obtained from various tuber flours (sweet potato, cassava and cocoyam) and treated bambara groundnut flours (dehulled bambara groundnut cotyledon flours and steamed bambara groundnut cotyledon flours) at the ratios of 75:25 and 50:50 of tuber flour type: bambara groundnut treatments. The optimum quality of cake product was obtained from the blend ratio of 75:25 of sweet potato flour to steamed bambara groundnut. The study also reveals that tuber flours such as cassava, yam. cocoyam and sweet potato are low in proteins and fat content and its combination with legumes such as bambara groundnut will enhance the nutritional content of the products derived from them. Hence is an ideal source of promoting the dietary protein for human consumption. The blending of the tuber flours and the leguminous flours also reveals a decrease

in the carbohydrate content of the blend ratios with increase in the substitution levels of the bambara groundnut flours although the energy level was on the increase. It was also observed that the swelling capacity of the flour blends decreased with increase in bambara groundnut flour in the blend.

This research has also revealed that boiling, soaking, dehulling , steaming and drying helped partially in eliminating some antinutritional factors like tannin, oxalate, hydrocyanic acid and hemagglutinin. The blending of the tuber flours with bambara groundnut flours at the ratios tested increased the level of antinutrients such trypsin inhibitor and hemagglutinin in some flour blends. The organoleptic analysis conducted on this research work indicated that on the average, the cake produced from almost all the blends were acceptable by the consumer.

5.2 RECOMMENDATIONS

Nigeria is one of the largest producers of most of these root tuber crops in the African continent, but in the area of export of the products from these tuber crops the country is lacking when compared to Ghana which is the second largest producer of yam tubers after Nigeria but is the highest exporter of yam food products. This research reveals that more cultivation of legumes like bambara groundnut will be of great importance when more consumer products are generated from it. The consumption of the resultant product will go a long way in ensuring that there is an increased intake of good quality protein and fiber among Nigerians in an acceptable food medium with a resultant effect of increased utilization of bambara groundnut thus reducing importation of wheat and reduction of weight problem where low calorie and high fiber diet of foods is desirable.

It has been suggested that these root tubers and legumes should be given more of the above treatments before use thus rendering them non toxic. More research can be done to assess the effect of germination process on the antinutrients content of bambara groundnut as a means of improving their use and acceptability by the entire masses. In the production of the root tuber flours it is of great importance that the issues of enzymic and non - enzymic browning are prevented as this will affect the acceptability of the final product.

There are many other legumes which can be used also to combat this issue of protein malnutrition which is prevalent in our country. From this work we highly recommend the use of root tuber flours like sweet potato flour in combination with legume flour like that of bambara groundnut in a desirable proportion in bakeries and households for easy accessibility and better living economic purposes.

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APPENDICES

APPENDIX 1.
ONE-WAY ANALYSIS OF VARIANCE (ANOVA) PROCEDURES SUMMARY

Table Formatting the Data from One-Factor Experimental Design

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	X_{11}	X_{12}	X_{13}	X_{14}
2	X_{21}	X_{22}	X_{23}	X_{24}
3	X_{31}	X_{32}	X_{33}	X_{34}
Total	T_{k1}	T_{k2}	T_{k3}	T_{k4}
Mean	X_{k1}	X_{k2}	X_{k3}	X_{k4}

$$T_{ki} = \sum_{i=1}^{k} X_{ki}$$

ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab})at P=0.05
Among Columns(SSC*)	SSC	(k-1)	MSC=SSC/(k-1)	F_c=MSC/MSE	F{(k-1),k(r-1)}
Error(Within)	SSE	k(r-1)	MSE=SSE/(k{r-1})		
Total	SST	(n-1)			

* $T_n = T_1 + T_2 + \ldots + T_k = \sum \sum kX_{ij}$ I

$$CT = (T_n)^2/rk \quad \text{II}$$

$$SST = \sum_{j=1}^{r}\sum_{i=1}^{k} X_{ij}^2 - \left(\sum_{j=1}^{r}\sum_{i=1}^{k} X_{ij}\right)^2/rk \quad \text{III}$$

$$SSC = \left(\sum_{i=1}^{k} T^2_i\right)/r - CT \quad \text{IV}$$

$$SSE = SST - SSC \quad \text{V}$$

If $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ {(k-1), k(r-1)} then the effect due to source of variation is significant. Thus the resultant factor means will have to be separated further using Fisher's LSD (least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)} \quad \text{VI}$$

$$SEM©=SEM(k)=\sqrt{(2\times MSE/r)} \quad \text{VII}$$

SEM→Standard error of mean.

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{\ 0.05,}$, then significant difference exists between those two means of a factor in question. Superscripts or subscripts are used to symbolize the differences.

APPENDIX II

Table 3: One – way ANOVA on Proximate Composition of Tropical Tuber Flour Samples

Table 3.1: Moisture Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	12.82	12.32	11.54	11.52
2	12.80	12.28	11.52	11.54
3	12.84	12.36	11.56	11.50
Total	38.46	36.96	34.62	34.56
Mean	12.82	12.32	11.54	11.52

Table 3.1.1 **ANOVA TABLE**

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated (F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between samples	3.6204	3	1.2068	1724	4.07
Error(Within)	0.0056	8	0.0007		
Total	3.626	11			

*****

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ {(k-1), k(r-1)} then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(8)_{0.05} \times \sqrt{(2 \times 0.0007/3)}$$

$$= 2.31 \times 0.02160 = 0.05$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor 0.05 in question. Superscripts are used to symbolize the differences.

$$\bar{A}_1 - \bar{A}_2 = 12.82 - 12.32 = 0.50 > 0.05$$

$$\bar{A}_1 - \bar{A}_3 = 12.82 - 11.54 = 1.28 > 0.05$$

$$\bar{A}_1 - \bar{A}_4 = 12.82 - 11.52 = 1.30 > 0.05$$

$$\bar{A}_2 - \bar{A}_3 = 12.32 - 11.54 = 0.78 > 0.05$$

$$\bar{A}_2 - \bar{A}_4 = 12.32 - 11.52 = 0.80 > 0.05$$

$$\bar{A}_3 - \bar{A}_4 = 11.54 - 11.52 = 0.02 < 0.05$$

The results can be shown by using letters to indicate differences:

A_1 , A_2 , A_3 , A_4
12.82a, 12.32b, 11.54c, 11.52c

Table 3.2: Crude Protein Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	1.45	5.08	3.97	2.84
2	1.49	5.10	3.87	2.80
3	1.41	5.06	4.07	2.88
Total	4.35	15.24	11.91	8.52
Mean	1.45	5.08	3.97	2.84

Table 3.2.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated (F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	21.739	3	7.2465	2131.32	4.07
Error(Within)	0.027	8	0.0034		
Total	21.767	11			

***** Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ {(k-1), k(r-1)} then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(8)_{0.05} \times \sqrt{(2 \times 0.0034/3)}$$

$$= 2.31 \times 0.0.04761 = 0.1099 = 0.11$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_2 - \bar{A}_1 = 5.08 - 1.45 = 3.63 > 0.11$$

$$\bar{A}_2 - \bar{A}_3 = 5.08 - 3.97 = 1.11 > 0.11$$

$$\bar{A}_2 - \bar{A}_4 = 5.08 - 2.84 = 2.24 > 0.11$$

$$\bar{A}_3 - \bar{A}_4 = 3.97 - 2.84 = 1.13 > 0.11$$

The results can be shown by using letters to indicate differences:

A_2	A_3	A_4	A_1
5.08a,	3.97b,	2.84c,	1.45d

Table 3.3: Crude Fat Content of Tropical Tuber Flour samples

Sample Size	cassava (A_1)	yam(A_2)	cocoyam(A_3)	sweet- potato (A_4)
1	1.67	1.06	1.57	1.18
2	1.63	1.04	1.54	1.20
3	1.71	1.08	1.60	1.16
Total	5.01	3.18	4.71	3.54
Mean	1.67	1.06	1.57	1.18

Table 3.3.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated (F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	0.7866	3	0.2622	317.82	4.07
Error(Within)	0.0066	8	0.000825		
Total	0.7932	11			

*Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(8)_{0.05} \times \sqrt{(2 \times 0.000825/3)}$$

$$= 2.31 \times 0.02345 = 0.05417$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_1 - \bar{A}_2 = 1.67 - 1.06 = 0.61 > 0.0542$$

$$\bar{A}_1 - \bar{A}_3 = 1.67 - 1.57 = 0.10 > 0.0542$$

$$\bar{A}_1 - \bar{A}_4 = 1.67 - 1.18 = 0.48 > 0.0542$$

$$\bar{A}_3 - \bar{A}_4 = 1.57 - 1.18 = 0.39 > 0.0542$$

The results can be shown by using letters to indicate differences:

A_1	A_3	A_4	A_2
1.67a,	1.57b,	1.18c,	1.06d

Table 3.4: Crude Fibre Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet- potato(A_4)
1	0.55	0.75	1.20	1.90
2	0.60	0.80	1.18	1.94
3	0.50	0.70	1.22	1.86
Total	1.65	2.25	3.60	5.68
Mean	0.55	0.75	1.20	1.91

Table 3.4.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated (F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	3.225	3	1.075	614.28	4.07
Error(Within)	0.014	8	0.00175		
Total	3.239	11			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(8)_{0.05} \times \sqrt{(2 \times 0.00175/3)}$$

$$= 2.31 \times 0.003415 = 0.079$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_4 - \bar{A}_3 = 1.90 - 1.20 = 0.70 > 0.079$$

$$\bar{A}_4 - \bar{A}_2 = 1.90 - 0.75 = 1.15 > 0.079$$

$$\bar{A}_4 - \bar{A}_1 = 1.90 - 0.55 = 1.35 > 0.079$$

$$\bar{A}_3 - \bar{A}_2 = 1.20 - 0.75 = 0.45 > 0.079$$

$$\bar{A}_3 - \bar{A}_1 = 1.20 - 0.55 = 0.65 > 0.079$$

$$\bar{A}_2 - \bar{A}_1 = 0.75 - 0.55 = 0.20 > 0.079$$

The results can be shown by using letters to indicate differences:

A_4	A_3	A_2	A_1
1.90a,	1.20b,	0.75c,	0.55d

Table 3.5: Ash Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet- potato(A_4)
1	0.30	1.31	2.61	0.79
2	0.34	1.37	2.80	0.82
3	0.26	1.25	2.41	0.76
Total	0.90	3.93	7.82	2.37
Mean	0.30	1.31	2.61	0.79

Table 3.5.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated (F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	8.917	3	2.97233	515.81	4.07
Error(Within)	0.0461	8	0.005763		
Total	8.963	11			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD
(Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(8)_{0.05} \times \sqrt{(2 \times 0.005763/3)}$$

$$= 2.31 \times 0.0620 = 0.143$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_3 - \bar{A}_2 = 2.61 - 1.31 = 1.30 > 0.143$$

$\bar{A}_3 - \bar{A}_4 = 2.61\text{-}0.79 = 1.82 > 0.143$

$\bar{A}_3 - \bar{A}_1 = 2.61 - 0.30 = 2.31 > 0.143$

$\bar{A}_2 - \bar{A}_4 = 1.31 - 0.79 = 0.52 > 0.143$

$\bar{A}_2 - \bar{A}_1 = 1.31 - 0.30 = 1.01 > 0.143$

$\bar{A}_4 - \bar{A}_1 = 0.79 - 0.30 = 0.49 > 0.143$

The results can be shown by using letters to indicate differences:

A_3	A_2	A_4	A_1
2.61a,	1.31b,	0.79c,	0.30d

Table 3.6: Carbohydrates Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	83.21	79.48	79.12	81.77
2	83.14	79.41	79.09	81.70
3	83.28	79.55	79.15	81.84
Total	249.63	238.44	237.36	245.31
Mean	83.21	79.48	79.12	81.77

Table 3.6.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated (F_{cal})	Variance Ratio Tabulated(F_{tab})at P=0.05
Between Samples	33.8331	3	11.2777	2891.72	4.07
Error(Within)	0.0312	8	0.0039		
Total	33.8642	11			

*Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD

(Least significant difference) Test (procedure).

$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$

$= LSD(k)_{0.05} = t(8)_{0.05} \times \sqrt{(2 \times 0.0039/3)}$

$= 2.31 \times 0.05099 = 0.118$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_1 - \bar{A}_2 = 83.21 - 79.48 = 3.73 > 0.118$$

$$\bar{A}_1 - \bar{A}_3 = 83.21 - 79.12 = 4.09 > 0.118$$

$$\bar{A}_1 - \bar{A}_4 = 83.21 - 81.77 = 1.44 > 0.118$$

$$\bar{A}_4 - \bar{A}_2 = 81.77 - 79.48 = 2.29 > 0.118$$

$$\bar{A}_4 - \bar{A}_3 = 81.77 - 79.12 = 2.65 > 0.118$$

$$\bar{A}_2 - \bar{A}_3 = 79.48 - 79.12 = 0.36 > 0.118$$

The results can be shown by using letters to indicate differences:

A_1	A_4	A_2	A_3
83.21a,	81.77b,	79.48c,	79.12d

Table 3.7: Energy Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	353.67	347.78	346.49	349.06
2	353.19	347.40	345.70	348.80
3	353.15	348.16	347.28	349.32
Total	1060.01	1043.34	1039.47	1047.18
Mean	353.34	347.78	346.49	349.06

Table 3.7.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated (F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	79.042332	3	26.3474	330.046	4.07
Error(Within)	2.260338	8	0.28254		
Total	81.3027	11			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD
(Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05\,=}\, t(8)_{0.05} \times \sqrt{(2 \times 0.28254/3)}$$

$$= 2.31 \times \sqrt{0.18836} = 1.00$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_1 - \bar{A}_2 = 353.67 - 347.78 = 5.89 > 1.00$$

$$\bar{A}_1 - \bar{A}_3 = 353.67 - 346.49 = 7.18 > 1.00$$

$$\bar{A}_1 - \bar{A}_4 = 353.67 - 349.06 = 4.61 > 1.00$$

$$\bar{A}_4 - \bar{A}_2 = 349.06 - 347.78 = 1.28 > 1.00$$

$$\bar{A}_4 - \bar{A}_3 = 349.06 - 346.49 = 2.57 > 1.00$$

$$\bar{A}_2 - \bar{A}_3 = 347.78 - 346.49 = 1.29 > 1.00$$

The results can be shown by using letters to indicate differences:

A_1	A_4	A_2	A_3
353.67a,	349.06b,	347.78c,	346.49d

Table 3.8: Dry matter Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	87.18	87.68	88.46	88.48
2	87.20	87.72	88.48	88.46
3	87.16	87.64	88.44	88.50
Total	261.54	263.04	265.38	265.44
Mean	87.18	87.68	88.46	88.48

Table 3.8.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	3.6204	3	1.2068	1724	4.07
Error(Within)	0.0056	8	0.0007		
Total	3.626	11			

*

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(8)_{0.05} \times \sqrt{(2 \times 0.0007/3)}$$

$$= 2.31 \times 0.0216 = 0.05$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_4 - \bar{A}_1 = 88.48 - 87.18 = 1.30 > 0.435$$

$$\bar{A}_4 - \bar{A}_2 = 88.48 - 87.68 = 0.80 > 0.435$$

$$\bar{A}_4 - \bar{A}_3 = 88.48 - 88.46 = 0.02 < 0.435$$

$$\bar{A}_3 - \bar{A}_1 = 88.46 - 87.18 = 1.28 > 0.435$$

$$\bar{A}_3 - \bar{A}_2 = 88.46 - 87.68 = 0.78 > 0.435$$

$$\bar{A}_2 - \bar{A}_1 = 87.68 - 87.18 = 0.50 > 0.435$$

The results can be shown by using letters to indicate differences:

A_4 ,	A_3 ,	A_2 ,	A_1
88.48a,	88.46a,	87.68b,	87.18c

Table 4: One–way ANOVA on Physicochemical Properties of Tropical Tuber Flour Samples

Table 4.1: Swelling Index Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	1.06	1.22	1.31	1.79
2	1.06	1.23	1.31	1.79
Total	2.12	2.45	2.62	3.58
Mean	1.06	1.225	1.31	1.79

Table 4.1.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated (F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	0.5897	3	0.1966	14979	6.59
Error(Within)	0.0000525	4	0.000013125		
Total	0.5898	7			

*Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.000013125/2)}$$

$$= 2.78 \times 0.00362 = 0.01$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_4 - \bar{A}_1 = 1.79 - 1.06 = 0.73 > 0.01$$

$$\bar{A}_4 - \bar{A}_2 = 1.79 - 1.23 = 0.56 > 0.01$$

$$\bar{A}_4 - \bar{A}_3 = 1.79 - 1.31 = 0.48 > 0.01$$

$$\bar{A}_3 - \bar{A}_1 = 1.31 - 1.06 = 0.25 > 0.01$$

$$\bar{A}_3 - \bar{A}_2 = 1.31 - 1.23 = 0.08 > 0.01$$

$$\bar{A}_2 - \bar{A}_1 = 1.23 - 1.06 = 0.17 > 0.01$$

The results can be shown by using letters to indicate differences:

A_4 ,	A_3 ,	A_2 ,	A_1
1.79a,	1.31b,	1.23c,	1.06

Table 4.2: Oil Absorption Capacity Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet- potato(A_4)
1	1.54	1.50	1.33	1.65
2	1.53	1.50	1.34	1.64
Total	3.07	3.00	2.67	3.29
Mean	1.535	1.50	1.335	1.645

Table 4.2.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	0.0988375	3	0.032945	893.42	6.59
Error(With in)	0.0001475	4	0.000036875		
Total	0.0989875	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.000036875/2)}$$

$$= 2.78 \times 0.00607 = 0.0169 = 0.02$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_4 - \bar{A}_1 = 1.65 - 1.54 = 0.11 > 0.02$$

$$\bar{A}_4 - \bar{A}_2 = 1.65 - 1.50 = 0.15 > 0.02$$

$$\bar{A}_4 - \bar{A}_3 = 1.65 - 1.34 = 0.31 > 0.02$$

$$\bar{A}_1 - \bar{A}_2 = 1.54 - 1.50 = 0.04 > 0.02$$

$$\bar{A}_1 - \bar{A}_3 = 1.54 - 1.34 = 0.02 = 0.02$$

$$\bar{A}_2 - \bar{A}_3 = 1.50 - 1.34 = 0.16 > 0.02$$

The results can be shown by using letters to indicate differences:

A_4 ,	A_1 ,	A_2 ,	A_3
1.65a,	1.54b,	1.50c,	1.34

Table 4.3: Water Absorption Capacity Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	1.00	2.00	1.50	2.00
2	1.10	2.01	1.51	2.00
Total	2.10	4.01	3.01	4.00
Mean	1.05	2.005	1.505	2.00

Table 4.3.1 **ANOVA TABLE**

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	1.2583	3	0.4194	328.94	6.59
Error(Within)	0.0051	4	0.001275		
Total	1.2634	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD
(Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.001275/2)}$$

$$= 2.78 \times 0.0993 = 0.10$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_2 - \bar{A}_1 = 2.10 - 1.10 = 1.00 > 0.10$$

$$\bar{A}_2 - \bar{A}_3 = 2.10 - 1.53 = 0.57 > 0.10$$

$$\bar{A}_2 - \bar{A}_4 = 2.10 - 2.00 = 0.10 = 0.10$$

$$\bar{A}_4 - \bar{A}_1 = 2.00 - 1.10 = 0.90 > 0.10$$

$$\bar{A}_4 - \bar{A}_3 = 2.00 - 1.53 = 0.47 > 0.10$$

The results can be shown by using letters to indicate differences:

A_2 ,	A_4 ,	A_3 ,	A_1
2.10a,	2.00a,	1.53b ,	1.10c

Table 4.4: Gelling (^oC) Temperature of Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	75	76	85	84
2	74	77	86	84
Total	149	153	171	168
Mean	74.5	76.5	85.5	84

Table 4.4.1 **ANOVA TABLE**

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	177.375	3	59.125	157.67	6.59
Error(Within)	1.500	4	0.375		
Total	178.875	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.375/2)}$$

$$= 2.78 \times 0.6124 = 1.70$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_3 - \bar{A}_1 = 85.50 - 74.50 = 11.00 > 1.70$$

$$\bar{A}_3 - \bar{A}_2 = 85.50 - 76.50 = 9.00 > 1.70$$

$$\bar{A}_3 - \bar{A}_4 = 85.50 - 84.00 = 1.50 < .1.70$$

$$\bar{A}_4 - \bar{A}_1 = 84.00 - 74.50 = 9.50 > 1.70$$

$$\bar{A}_4 - \bar{A}_2 = 84.00 - 76.50 = 7.50 > 1.70$$

$$\bar{A}_2 - \bar{A}_1 = 76.50 - 74.50 = 2.00 > 1.70$$

The results can be shown by using letters to indicate differences:

A_3 ,	A_4 ,	A_2 ,	A_1
85.50a,	84.0a,	76.50b ,	74.50c

Table 4.5: Boiling Temperature (^oC) of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	79	87	92	90
2	79	88	94	90
Total	158	175	186	180
Mean	79	87.5	93	90

TABLE 4.5.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	217.375	3	72.4583	115.93	6.59
Error(Within)	2.500	4	0.625		
Total	219.875	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD

(Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.625/2)}$$

$$= 2.78 \times 0.79057 = 2.20$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_3 - \bar{A}_1 = 93.00 - 79.00 = 140 > 2.20$$

$$\bar{A}_3 - \bar{A}_2 = 93.00 - 87.50 = 5.50 > 2.20$$

$$\bar{A}_3 - \bar{A}_4 = 93.00 - 90.00 = 3.00 > .2.20$$

$$\bar{A}_4 - \bar{A}_1 = 90.00 - 79.00 = 11.0 > 2.20$$

$$\bar{A}_4 - \bar{A}_2 = 90.00 - 87.50 = 2.50 > 2.20$$

$$\bar{A}_2 - \bar{A}_1 = 87.50 - 79.00 = 8.50 > 2.20$$

The results can be shown by using letters to indicate differences:

A_3 ,	A_4 ,	A_2 ,	A_1
93.00a,	90.00b,	87.50c ,	79.00d

Table 4.5: pH of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	6.20	6.30	6.50	6.20
2	6.21	6.30	6.55	6.20
Total	12.41	12.6	13.05	12.4
Mean	6.205	6.30	6.525	6.2

Table 4.5.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	0.13885	3	0.04628	142.4	6.59
Error(With in)	0.0013	4	0.000325		
Total	0.14015	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD

(Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.000325/2)}$$

$$= 2.78 \times 0.01803 = 0.05$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_3 - \bar{A}_1 = 6.50 - 6.20 = 0.30 > 0.05$$

$\bar{A}_3 - \bar{A}_2 = 6.50 - 6.30 = 0.20 > 0.05$

$\bar{A}_2 - \bar{A}_1 = 6.30 - 6.20 = 0.10 > .0.05$

$\bar{A}_2 - \bar{A}_4 = 6.30 - 6.20 = 0.10 > 0.05$

$\bar{A}_4 - \bar{A}_1 = 6.20 - 6.20 = 0.00 < 0.05$

The results can be shown by using letters to indicate differences:

A_3 ,	A_2 ,	A_4 ,	A_1
6.50a,	6.30b,	6.20c ,	6.20c

Table 5: One– way ANOVA on the Antinutritional Properties of Tropical Tuber Flour Samples

Table 5.1: Alkaloid Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	1.52	1.00	2.70	2.70
2	1.52	1.05	2.73	2.72
Total	3.04	2.05	5.43	5.42
Mean	1.52	1.025	2.715	2.71

Table 5.1.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	4.39225	3	1.4641	3082.32	6.59
Error(With in)	0.0019	4	0.000475		
Total	4.39415	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD

(Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.000475/2)}$$

$$= 2.78 \times 0.0,0218 = 0.061$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_3 - \bar{A}_1 = 2.72 - 1.52 = 1.20 > 0.06$$

$$\bar{A}_3 - \bar{A}_2 = 2.72 - 1.03 = 1.69 > 0.06$$

$$\bar{A}_3 - \bar{A}_4 = 2.72 - 2.71 = 0.01 < 0.06$$

$\bar{A}_4 - \bar{A}_1 = 2.71 - 1.52 = 1.19 > 0.06$

$\bar{A}_4 - \bar{A}_2 = 2.71 - 1.03 = 1.68 > 0.06$

$\bar{A}_1 - \bar{A}_2 = 1.52 - 1.03 = 0.49 > 0.06$

The results can be shown by using letters to indicate differences:

A_3 ,	A_4 ,	A_1 ,	A_2
2.72a,	2.71a,	1.52b ,	1.03c

Table 5.2: Tannin Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	1.93	2.22	2.21	1.36
2	1.90	2.25	2.26	1.35
Total	3.83	4.47	4.47	2.71
Mean	1.915	2.235	2.235	1.355

Table 5.2.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	1.0336	3	0.3445	626.36	6.59
Error(Within)	0.0022	4	0.00055		
Total	1.0358	7			

*

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD

(Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.00055/2)}$$

$$= 2.78 \times \ 0.02345 = 0.065 = 0.07$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_3 - \bar{A}_1 = 2.24 - 1.92 = 0.32 > 0.07$$

$$\bar{A}_3 - \bar{A}_2 = 2.24 - 2.24 = 0.00 < 0.07$$

$$\bar{A}_3 - \bar{A}_4 = 2.24 - 1.36 = 0.88 > 0.07$$

$$\bar{A}_2 - \bar{A}_4 = 2.24 - 1.36 = 0.88 > 0.07$$

$$\bar{A}_2 - \bar{A}_1 = 2.24 - 1.92 = 0.32 > 0.07$$

$$\bar{A}_1 - \bar{A}_4 = 1.92 - 1.36 = 0.56 > 0.07$$

The results can be shown by using letters to indicate differences:

A_3 ,	A_2 ,	A_1 ,	A_4
2.24a,	2.24a,	1.92b ,	1.36c

Table 5.3: Saponin Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	2.30	2.36	2.60	3.60
2	2.35	2.30	2.58	3.58
Total	4.65	4.66	5.18	7.18
Mean	2.325	2.33	2.59	3.59

Table 5.3.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	2.1628375	3	0.720945	835.9	6.59
Error(With in)	0.00345	4	0.0008625		
Total	2.16629	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD

(Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.0008625/2)}$$

$$= 2.78 \times 0.0294 = 0.082$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_4 - \bar{A}_1 = 3.59 - 2.33 = 1.26 > 0.08$$

$$\bar{A}_4 - \bar{A}_2 = 3.59 - 2.33 = 1.26 > 0.08$$

$$\bar{A}_4 - \bar{A}_3 = 3.59 - 2.59 = 1.00 > 0.08$$

$$\bar{A}_3 - \bar{A}_2 = 2.59 - 2.33 = 0.26 > 0.08$$

The results can be shown by using letters to indicate differences:

A_4 ,	A_3 ,	A_2 ,	A_1
3.59a,	2.59b,	2.33c ,	2.33c

Table 5.4: Oxalate Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	3.87	3.78	6.10	3.88
2	3.88	3.80	6.14	3.86
Total	7.75	7.58	12.24	7.74
Mean	3.875	3.79	6.12	3.87

Table 5.4.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	7.77254	3	2.59085	8274.83	6.59
Error(Within)	0.0012525	4	0.0003131		
Total	7.77379	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD
(Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.0003131/2)}$$

$$= 2.78 \times 0.0177 = 0.0492 = 0.05$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_3 - \bar{A}_1 = 6.12 - 3.88 = 2.24 > 0.05$$

$$\bar{A}_3 - \bar{A}_2 = 6.12 - 3.79 = 2.33 > 0.05$$

$$\bar{A}_3 - \bar{A}_4 = 6.12 - 3.87 = 2.25 > .0.05$$

$$\bar{A}_1 - \bar{A}_2 = 3.88 - 3.79 = 0.09 > 0.05$$

$$\bar{A}_1 - \bar{A}_4 = 3.88 - 3.87 = 0.01 < 0.05$$

$$\bar{A}_4 - \bar{A}_2 = 3.87 - 3.79 = 0.08 > 0.05$$

The results can be shown by using letters to indicate differences:

A_3 ,	A_1 ,	A_4 ,	A_2
6.12a,	3.88b,	3.87b ,	3.79c

Table 5.5: HCN Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	9.50	0.61	1.94	0.52
2	9.52	0.63	1.90	0.55
Total	19.02	1.24	3.84	1.07
Mean	9.51	0.62	1.92	0.535

Table 5.5.1 **ANOVA TABLE**

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	110.4031375	3	36.801	89106.54	6.59
Error(Within)	0.0016525	4	0.000413		
Total	110.40478	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD

(Least significant difference) Test (procedure).

$$LSD©_{0.05}=LSD(k)_{0.05}=t(DF_E)_{0.05}\times\sqrt{(2\times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.000413/2)}$$

$$= 2.78 \times 0.0203 = 0.056 = 0.06$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_1 - \bar{A}_2 = 9.51 - 0.62 = 8.89 > 0.06$$

$$\bar{A}_1 - \bar{A}_3 = 9.51 - 1.92 = 7.59 > 0.06$$

$$\bar{A}_1 - \bar{A}_4 = 9.51 - 0.54 = 8.97 > 0.06$$

$$\bar{A}_2 - \bar{A}_4 = 0.62 - 0.54 = 0.08 > 0.06$$

$$\bar{A}_3 - \bar{A}_2 = 1.92 - 0.62 = 1.30 > 0.06$$

$$\bar{A}_3 - \bar{A}_4 = 1.92 - 0.54 = 1.38 > 0.06$$

The results can be shown by using letters to indicate differences:

A_1 ,	A_3 ,	A_2 ,	A_4
9.51a,	1.92b,	0.62c ,	0.54d

.

Table 5.6: Trypsin Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	24.85	38.94	20.76	19.41
2	29.95	40.83	16.66	30.00
Total	54.80	79.77	37.42	49.41
Mean	27.4	39.885	18.71	24.705

Table 5.6.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	476.7037	3	158.901	8.02	6.59
Error(Within)	79.2701	4	19.8175		
Total	555.9738	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 19.8175/2)}$$

$$= 2.78 \times 4.452 = 12.376 = 12.38$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_2 - \bar{A}_1 = 39.89 - 27.40 = 12.49 > 12.38$$

$$\bar{A}_2 - \bar{A}_3 = 39.89 - 18.71 = 21.18 > 12.38$$

$$\bar{A}_2 - \bar{A}_4 = 39.89 - 24.71 = 15.18 > 12.38$$

$$\bar{A}_1 - \bar{A}_3 = 27.40 - 18.71 = 8.69 < 12.38$$

$\bar{A}_1 - \bar{A}_4 = 27.40 - 24.71 = 2.69 < 12.38$

$\bar{A}_4 - \bar{A}_3 = 24.71 - 18.71 = 6.00 < 12.38$

The results can be shown by using letters to indicate differences:

A_2 ,	A_1 ,	A_4 ,	A_3
39.89a,	27.40b,	24.71b	18.71b

Table 5.7: Hemagglutinin Content of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_3)	sweet potato(A_4)
1	1.70	0.00	0.00	0.00
2	1.72	0.00	0.00	0.00
Total	3.42	0.00	0.00	0.00
Mean	1.71	0.00	0.00	0.00

Table 5.7.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	4.38615	3	1.46205	29241	6.59
Error(Within)	0.0002	4	0.00005		
Total	4.38635	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD (Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.00005/2)}$$

$$= 2.78 \times 0.00707 = 0.02$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_1 - \bar{A}_2 = 1.71 - 0.00 = 1.71 > 0.02$$

$$\bar{A}_1 - \bar{A}_3 = 1.71 - 0.00 = 1.71 > 0.02$$

$$\bar{A}_1 - \bar{A}_4 = 1.71 - 0.00 = 1.71 > .0.02$$

The results can be shown by using letters to indicate differences:

A_1 ,	A_2 ,	A_3 ,	A_4
1.71a,	0.00b,	0.00b,	0.00b

Table 5.8: Phytic acid of Tropical Tuber Flour samples

Sample Size	cassava(A_1)	yam(A_2)	cocoyam(A_4)	sweet potato(A_4)
1	0.186	0.186	0.325	0.232
2	0.206	0.180	0.337	0.231
Total	0.392	0.366	0.662	0.463
Mean	0.196	0.183	0.331	0.2315

Table 5.8.1 ANOVA TABLE

Source of Variation	Sum of Squares(SS)	Degree of Freedom(df)	Mean Square(MS)	Variance Ratio Calculated(F_{cal})	Variance Ratio Tabulated(F_{tab}) at P=0.05
Between Samples	0.026905	3	0.008968	123.43	6.59
Error(With in)	0.000290625	4	0.000072656		
Total	0.027196	7			

Since $F_{cal} \geq F_{tab\ (P\text{-}0.05)}$ then the effect due to source of variation is significant. Thus the resultant factor means was separated further using Fisher's LSD

(Least significant difference) Test (procedure).

$$LSD©_{0.05} = LSD(k)_{0.05} = t(DF_E)_{0.05} \times \sqrt{(2 \times MSE/r)}$$

$$= LSD(k)_{0.05} = t(4)_{0.05} \times \sqrt{(2 \times 0.000072656/2)}$$

$$= 2.78 \times 0.00852 = 0.024$$

If any $X_{kl} - X_{k2} \geq LSD\ (k)_{0.05,}$, then significant difference exists between those two means of the factor in question. Superscripts are used to symbolize the differences.

$$\bar{A}_3 - \bar{A}_1 = 0.33 - 0.20 = 0.13 > 0.024$$

$$\bar{A}_3 - \bar{A}_2 = 0.33 - 0.18 = 0.15 > 0.024$$

$$\bar{A}_3 - \bar{A}_4 = 0.33 - 0.23 = 0.10 > 0.024$$

$$\bar{A}_4 - \bar{A}_1 = 0.23 - 0.20 = 0.03 > 0.024$$

$$\bar{A}_4 - \bar{A}_2 = 0.23 - 0.18 = 0.05 < 0.024$$

$$\bar{A}_1 - \bar{A}_2 = 0.20 - 0.18 = 0.020 > 0.024$$

The results can be shown by using letters to indicate differences:

A_3 ,	A_4 ,	A_1 ,	A_2
0.33a,	0.23b,	0.20c ,	0.18c

APPENDIX III

THREE-WAY ANALYSIS OF VARIANCE (ANOVA) PROCEDURES SUMMARY

APPENDIX II THE COMPUTATIONAL FORMULAE/EUATION AND TABLES OF STATISCAL PARAMETERS

TABLE FORMATTING THE DATA FROM THREE-FACTOR EXPERIMENTAL DESIGN

A =Tuber Flour Type (TFT)	C=Test Flour Blend (TFB) TF:BG	Bambara Groundnut Treatments (BGT)				
		Whole seed (B1)	Cotyledon (B2)	Steamed cotyledon (B3)	Total	Mean
A1=BCR	C1=100:0	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C2=75:25	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C3=50:50	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C4=25:75	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C5=0:100	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	Total	T_{ABij}	T_{ABij}	T_{ABij}	T_{Ai}	X_{Ai}
A2=WYT	C1=100:0	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C2=75:25	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C3=50:50	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C4=25:75	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C5=0:100	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	Total	T_{ABij}	T_{ABij}	T_{ABij}	T_{Ai}	X_{Ai}
	A3=WCY	C1=100:0	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}
		C2=75:25	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}
	C3=50:50	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C4=25:75	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C5=0:100	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	Total	T_{ABij}	T_{ABij}	T_{ABij}	T_{Ai}	X_{Ai}
A4=WSP	C1=100:0	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C2=75:25	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C3=50:50	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C4=25:75	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	C5=0:100	X_{ijk}	X_{ijk}	X_{ijk}	T_{ACik}	
	Total	T_{BCjk}	T_{BCjk}	T_{BCjk}	T_{ck}	X_{Ai}
Total	C1=100:0	T_{BCjk}	T_{BCjk}	T_{BCjk}	T_{ck}	X_{CK}
	C2=75:25	T_{BCjk}	T_{BCjk}	T_{BCjk}	T_{ck}	X_{CK}
	C3=50:50	T_{Bj}	T_{Bj}	T_{Bj}	T_{n}	X_{CK}
	C4=25:75	T_{BCjk}	T_{BCjk}	T_{BCjk}	T_{ck}	X_{CK}
	C5=0:100	T_{BCjk}	T_{BCjk}	T_{BCjk}	T_{ck}	X_{CK}
	Total	T_{Bj}	T_{Bj}	T_{Bj}	T_{n}	X_{CK}
	Mean	X_{Bj}	X_{Bj}	X_{Bj}		X_{n}

APPENDIX IV

General Anova Table For Named Test Parameter From Three Factor Completely Randomized Design.

Source of variation	SS	DF	MS	F_{cal}	F_{tab} (p=0.05)
A(TFT)	SSA	(a-1)	MSA=SSA/(a-1)	FA=MSA/MSE	$F[D^F_A, D^F_E]$
B(BGT)	SSB	(b-1)	MSB=SSB/(B-1)	FB=MSB/MSE	$F[D^F_B, D^F_E]$
C(TF:BG)	SSC	(c-1)	MSC=SSC/(c-1)	FC=MSB/MSE	$F[D^F_C, D^F_E]$
A×B	SS(AB)	(a-1)(b-1)	MS(AB)=SS(AB)/{(a-1)(b-1)}	FAB=MS(AB)MSE	$F[D^F_{AB}, D^F_E]$
A×C	SS(AC)	(a-1)(c-1)	MS(AC)=SS(AC)/{(a-1)(c-1)}	FAC=MS(AC)MSE	$F[D^F_{AC}, D^F_E]$
B×C	SS(BC)	(b-1)(c-1)	MS(BC)=SS(BC)/{(b-1)(c-1)}	FBC=MS(BC)/MSE	$F[D^F_{BC}, D^F_E]$
Error	SSE	(a-1)(b-1)(c-1)	MS=SSE/{(a-1)(b-1)(c-1)}		
Total	SST	abc-1			

$$CT=T_n{}^2/abc=\left[\sum_{i=l}^{a}\sum_{j=l}^{b}\sum_{k=l}^{c} X_{ijk}\right]^2/abc$$

$$SST=\sum_{i=l}^{a}\sum_{j=l}^{b}\sum_{k=l}^{c} X_{ijk}{}^2 - CT$$

$$SSA=\sum_{i=l}^{a} T_{Ai}{}^2/bc - CT$$

$$SSB=\sum_{j=l}^{b} T_{Bi}{}^2/ac - CT$$

$$SSC=\sum_{k=l}^{c} T_{ck}{}^2/ab - CT$$

$$SS(AB)=\sum_{i=l}^{a}\sum_{j=l}^{c} T_{ABij}{}^2/c - SSA - SSB - CT$$

$$SS(AC) = \sum_{i=1}^{a} \sum_{k=1}^{c} T_{ACik}^2/ab - SSA - SSC - CT$$

$$SS(BC) = \sum_{i=1}^{b} \sum_{k=1}^{c} T_{BCjk}^2/a - SSB - SSC - CT$$

$$SSE = SST - SSA - SSB - SSC - SS(AB) - SS(AC) - SS(BC)$$

If $F_{cal} \geq F_{tab}$ (p=0.05) then the effect due to source of variation(A,B or C,with reference to the main factors) is significant. Thus the resultant factor means will have to be separated further using Fisher's LSD (least significant difference) Test (procedure).

$$LSD(CCV)_{0.05} = LSD(A)_{0.05} = t(DF_E) \times \sqrt{(2 \times MSE/bc)}$$

$$SEM(CCV) = SEM(A) = \sqrt{(2 \times MSE/bc)}$$

SEM→Standard error of mean.

$$LSD(SSC)_{0.05} = LSD(B)_{0.05} = T(DF)_{0.05} \times \sqrt{(2 \times MSE/ac)}$$

$$SEM(TSD) = SEM© = \sqrt{(2 \times MSE/ab)}$$

If any $X_{Aj1} - X_{Aj2} \geq LSD(A)\ 0.05$ or $X_{Bj1} - X_{Bj2} \geq LSD(B)_{0.05}$ or $X_{CK1} - X_{CK2} \geq LSD(C)_{0.05}$, significant difference exists between those two means of a factor in question. Superscripts or subscripts are used to symbolize the differences.

APPENDIX V

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 180

Dependent Variable: Moisture content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	14.27141444	7.13570722	1813.14	<.0001
ratio	4	47.09202556	11.77300639	2991.45	<.0001
flour sample	3	29.28480167	9.76160056	2480.36	<.0001
treatment*ratio	8	34.36724111	4.29590514	1091.56	<.0001
flour sample* treatment	6	5.18208333	0.86368056	219.46	<.0001
flour sample*ratio	12	31.51635667	2.62636306	667.34	<.0001
flour sample*treatment*ratio	24	31.00328333	1.29180347	328.24	<.0001
Model	59	192.7172061	3.2663933	829.97	<.0001
Error	120	0.4722667	0.0039356		
Corrected Total	179	193.1894728			

R-Square	Coeff Var	Root MSE	moisture Mean
0.997555	0.556172	0.062734	11.27961

t Tests (LSD) for moisture

Least Significant Difference 0.0227
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	11.65533	60	B1
B	11.20600	60	B3
C	10.97750	60	B2

Least Significant Difference 0.0293
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	12.05000	36	C1
B	11.44250	36	C3
C	11.30750	36	C2
D	11.13472	36	C4
E	10.46333	36	C5

Least Significant Difference 0.0262
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	11.92000	45	A1
B	11.28800	45	A2
C	11.07800	45	A3
D	10.83244	45	A4

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 180

Dependent Variable: Protein content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	125.706070	62.853035	30461.9	<.0001
ratio	4	3794.339770	948.584943	459734	<.0001
flour sample	3	68.825720	22.941907	11118.9	<.0001
treatment*ratio	8	44.742230	5.592779	2710.56	<.0001
flour sample*treatment	6	110.770570	18.461762	8947.54	<.0001
flour sample*ratio	12	140.696030	11.724669	5682.39	<.0001
flour sample*treatment*ratio	24	168.088330	7.003680	3394.35	<.0001
Model	59	4453.168720	75.477436	36580.3	<.0001
Error	120	0.247600	0.002063		
Corrected Total	179	4453.416320			

R-Square	Coeff Var	Root MSE	protein Mean
0.999944	0.436741	0.045424	10.40067

t Tests (LSD) for protein

Least Significant Difference 0.0164
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	11.328000	60	B3
B	10.571500	60	B2
C	9.302500	60	B1

Least Significant Difference 0.0212
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	16.09333	36	C5
B	14.17583	36	C4
C	10.92167	36	C3
D	7.47750	36	C2
E	3.33500	36	C1

Least Significant Difference 0.019
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	11.262000	45	A2
B	10.553333	45	A3
C	10.247333	45	A4
D	9.540000	45	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 180

Dependent Variable: Fat content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	51.4867600	25.7433800	22917.0	<.0001
ratio	4	879.3307000	219.8326750	195697	<.0001
flour sample	3	7.0120550	2.3373517	2080.73	<.0001
treatment*ratio	8	28.2064400	3.5258050	3138.70	<.0001
flour sample* treatment	6	31.3030000	5.2171667	4644.36	<.0001
flour sample*ratio	12	17.3228200	1.4435683	1285.08	<.0001
flour sample*treatment*ratio	24	27.8144000	1.1589333	1031.69	<.0001
Model	59	1042.476175	17.669088	15729.2	<.0001
Error	120	0.134800	0.001123		
Corrected Total	179	1042.610975			

R-Square	Coeff Var	Root MSE	fat Mean
0.999871	0.745494	0.033516	4.495833

t Tests (LSD) for fat

Least Significant Difference 0.0121
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	5.181500	60	B3
B	4.429500	60	B2
C	3.876500	60	B1

Least Significant Difference 0.0156
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	7.643333	36	C5
B	5.976667	36	C4
C	4.589167	36	C3
D	2.900000	36	C2
E	1.370000	36	C1

Least Significant Difference 0.014
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	4.632000	45	A4
A	4.626000	45	A1
B	4.568667	45	A3
C	4.156667	45	A2

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 180

Dependent Variable: Fibre content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	0.62175000	0.31087500	42.63	<.0001
ratio	4	4.49675000	1.12418750	154.17	<.0001
flour sample	3	1.57737500	0.52579167	72.11	<.0001
treatment*ratio	8	12.82450000	1.60306250	219.85	<.0001
flour sample *treatment	6	0.81325000	0.13554167	18.59	<.0001
sample flour*ratio	12	15.44325000	1.28693750	176.49	<.0001
flour sample*treatment*ratio	24	4.52550000	0.18856250	25.86	<.0001
Model	59	40.30237500	0.68309110	93.68	<.0001
Error	120	0.87500000	0.00729167		
Corrected Total	179	41.17737500			

R-Square	Coeff Var	Root MSE	fibre Mean
0.978750	6.530880	0.085391	1.307500

t Tests (LSD) for fibre

Least Significant Difference 0.0309
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	1.35750	60	B1
A	1.34000	60	B3
B	1.22500	60	B2

Least Significant Difference 0.0398
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	1.51250	36	C4
B	1.47083	36	C3
C	1.23750	36	C2
C	1.21667	36	C5
D	1.10000	36	C1

Least Significant Difference 0.0356
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	1.37667	45	A4
A	1.36333	45	A3
A	1.34333	45	A1
B	1.14667	45	A2

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 180

Dependent Variable: Ash content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	1.49128778	0.74564389	245.37	<.0001
ratio	4	26.78669222	6.69667306	2203.66	<.0001
flour sample	3	21.03404667	7.01134889	2307.21	<.0001
treatment*ratio	8	2.51321778	0.31415222	103.38	<.0001
flour sample* treatment	6	5.93107667	0.98851278	325.29	<.0001
flour sample*ratio	12	19.16323667	1.59693639	525.50	<.0001
flour sample*treatment*ratio	24	4.97844000	0.20743500	68.26	<.0001
Model	59	81.89799778	1.38810166	456.78	<.0001
Error	120	0.36466667	0.00303889		
Corrected Total	179	82.26266444			

R-Square	Coeff Var	Root MSE	ash Mean
0.995567	3.054831	0.055126	1.804556

t Tests (LSD) for ash

Least Significant Difference 0.0199
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	1.87850	60	B2
A	1.85883	60	B1
B	1.67633	60	B3

Least Significant Difference 0.0257
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	2.32000	36	C5
B	2.14917	36	C4
C	1.70917	36	C3
D	1.59278	36	C2
E	1.25167	36	C1

Least Significant Difference 0.023
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	2.24667	45	A3
B	1.90067	45	A2
C	1.77822	45	A4
D	1.29267	45	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 180

Dependent Variable: CHO content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	219.720254	109.860127	5742.65	<.0001
ratio	4	8303.185536	2075.796384	108507	<.0001
flour sample	3	44.461188	14.820396	774.70	<.0001
treatment*ratio	8	116.009051	14.501131	758.01	<.0001
flour sample* treatment	6	117.180657	19.530109	1020.89	<.0001
flour sample*ratio	12	194.292820	16.191068	846.35	<.0001
flour sample*treatment*ratio	24	328.466060	13.686086	715.40	<.0001
Model	59	9323.315566	158.022298	8260.20	<.0001
Error	120	2.295667	0.019131		
Corrected Total	179	9325.611233			

R-Square	Coeff Var	Root MSE	cho Mean
0.999754	0.195602	0.138313	70.71161

t Tests (LSD) for cho

Least Significant Difference 0.05
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	71.94950	60	B1
B	70.91833	60	B2
C	69.26700	60	B3

Least Significant Difference 0.0645
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	80.89500	36	C1
B	75.48472	36	C2
C	69.86667	36	C3
D	65.04833	36	C4
E	62.26333	36	C5

Least Significant Difference 0.0577
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	71.27800	45	A1
B	71.13311	45	A4
C	70.24600	45	A2
C	70.18933	45	A3

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 180

Dependent Variable: Energy content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	2575.26683	1287.63342	4717.59	<.0001
ratio	4	22646.01758	5661.50439	20742.4	<.0001
flour sample	3	365.65238	121.88413	446.55	<.0001
treatment*ratio	8	3529.04646	441.13081	1616.20	<.0001
flour sample*treatment	6	1441.48880	240.24813	880.21	<.0001
flour sample*ratio	12	1373.63358	114.46946	419.39	<.0001
flour sample*treatment*ratio	24	1435.80131	59.82505	219.18	<.0001
Model	59	33366.90694	565.54080	2072.01	<.0001
Error	120	32.75320	0.27294		
Corrected Total	179	33399.66014			

R-Square	Coeff Var	Root MSE	energy Mean
0.999019	0.143168	0.522440	364.9141

t Tests (LSD) for energy

Least Significant Difference 0.1889
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	369.03417	60	B3
B	365.80850	60	B2
C	359.89950	60	B1

Least Significant Difference 0.2438
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	382.2567	36	C5
B	370.6867	36	C4
C	364.4558	36	C3
D	357.9494	36	C2
E	349.2217	36	C1

Least Significant Difference 0.2181
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	367.2178	45	A4
B	364.8958	45	A1
C	364.0927	45	A3
D	363.4500	45	A2

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 180

Dependent Variable: Dry_matter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	14.42970778	7.21485389	1734.11	<.0001
ratio	4	47.15515222	11.78878806	2833.46	<.0001
flour sample	3	29.27986000	9.75995333	2345.83	<.0001
treatment*ratio	8	34.39956444	4.29994556	1033.50	<.0001
flour sample* treatment	6	5.28703000	0.88117167	211.79	<.0001
flour sample*ratio	12	31.74605667	2.64550472	635.85	<.0001
flour sample*treatment*ratio	24	30.72965333	1.28040222	307.75	<.0001
Model	59	193.0270244	3.2716445	786.35	<.0001
Error	120	0.4992667	0.0041606		
Corrected Total	179	193.5262911			

R-Square	Coeff Var	Root MSE	dry_matter Mean
0.997420	0.072704	0.064502	88.71922

t Tests (LSD) for dry_matter

Least Significant Difference 0.0233
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	89.02250	60	B2
B	88.79400	60	B3
C	88.34117	60	B1

Least Significant Difference 0.0301
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	89.53667	36	C5
B	88.86500	36	C4
C	88.69250	36	C2
D	88.55194	36	C3
E	87.95000	36	C1

Least Significant Difference 0.0269
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	89.16733	45	A4
B	88.92200	45	A3
C	88.70756	45	A2
D	88.08000	45	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Swelling Index

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	0.04368500	0.02184250	403.25	<.0001
ratio	4	0.67972500	0.16993125	3137.19	<.0001
flour sample	3	0.28076250	0.09358750	1727.77	<.0001
treatment *ratio	8	0.13609000	0.01701125	314.05	<.0001
flour sample* treatment	6	0.40419500	0.06736583	1243.68	<.0001
flour sample*ratio	12	1.89777500	0.15814792	2919.65	<.0001
flour sample*treatment*ratio	24	0.40313000	0.01679708	310.10	<.0001
Model	59	3.84536250	0.06517564	1203.24	<.0001
Error	60	0.00325000	0.00005417		
Corrected Total	119	3.84861250			

R-Square	Coeff Var	Root MSE	swelling Mean
0.999156	0.610139	0.007360	1.206250

t Tests (LSD) for swelling

Least Significant Difference 0.0033
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	1.232250	40	B3
B	1.199500	40	B1
C	1.187000	40	B2

Least Significant Difference 0.0042
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	1.347083	24	C1
B	1.212083	24	C2
C	1.180000	24	C3
D	1.162083	24	C4
E	1.130000	24	C5

Least Significant Difference 0.0038
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	1.259000	30	A4
B	1.249333	30	A2
C	1.166333	30	A3
D	1.150333	30	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: 0il absorption capacity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	1.15923167	0.57961583	9032.97	<.0001
ratio	4	3.66969167	0.91742292	14297.5	<.0001
flour sample	3	0.71459583	0.23819861	3712.19	<.0001
treatment*ratio	8	1.67639333	0.20954917	3265.70	<.0001
flour sample* treatment	6	1.02516167	0.17086028	2662.76	<.0001
flour sample*ratio	12	1.43957500	0.11996458	1869.58	<.0001
flour sample*treatment*ratio	24	0.73318000	0.03054917	476.09	<.0001
Model	59	10.41782917	0.17657338	2751.79	<.0001
Error	60	0.00385000	0.00006417		
Corrected Total	119	10.42167917			

R-Square	Coeff Var	Root MSE	0il absorption Mean
0.999631	0.552283	0.008010	1.450417

t Tests (LSD) for oil

Least Significant Difference 0.0036
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour
A	1.524000	40	B2
B	1.515750	40	B3
C	1.311500	40	B1

Least Significant Difference 0.0046
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	1.766667	24	C5
B	1.503750	24	C1
C	1.364583	24	C2
D	1.343333	24	C3
E	1.273750	24	C4

Least Significant Difference 0.0041
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	1.573000	30	A1
B	1.435333	30	A2
B	1.434000	30	A3
C	1.359333	30	A4

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Water absorption capacity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	3.76982167	1.88491083	920.59	<.0001
ratio	4	0.70599667	0.17649917	86.20	<.0001
flour sample	3	2.17588917	0.72529639	354.24	<.0001
treatment*ratio	8	9.21920333	1.15240042	562.83	<.0001
flour sample*treatment	6	1.33489833	0.22248306	108.66	<.0001
flour sample*ratio	12	3.69145667	0.30762139	150.24	<.0001
flour sample*treatment*ratio	24	3.54964333	0.14790181	72.24	<.0001
Model	59	24.44690917	0.41435439	202.37	<.0001
Error	60	0.12285000	0.00204750		
Corrected Total	119	24.56975917			

R-Square	Coeff Var	Root MSE	Water absorption Mean
0.995000	2.907275	0.045249	1.556417

t Tests (LSD) for water

Least Significant Difference 0.0202
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	1.71725	40	B3
B	1.64250	40	B2
C	1.30950	40	B1

Least Significant Difference 0.0261
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	1.66583	24	C2
B	1.62500	24	C1
C	1.53333	24	C5
D	1.48917	24	C3
D	1.46875	24	C4

Least Significant Difference 0.0234
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	1.71833	30	A2
B	1.66067	30	A4
C	1.42667	30	A1
C	1.42000	30	A3

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Gelling Temperature

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	812.816667	406.408333	975.38	<.0001
ratio	4	1086.800000	271.700000	652.08	<.0001
flour sample	3	427.766667	142.588889	342.21	<.0001
treatment*ratio	8	537.100000	67.137500	161.13	<.0001
flour sample* treatment	6	418.583333	69.763889	167.43	<.0001
flour sample*ratio	12	706.066667	58.838889	141.21	<.0001
flour sample*treatment*ratio	24	599.833333	24.993056	59.98	<.0001
Model	59	4588.966667	77.779096	186.67	<.0001
Error	60	25.000000	0.416667		
Corrected Total	119	4613.966667			

R-Square	Coeff Var	Root MSE	Gelling Temperature Mean
0.994582	0.791859	0.645497	81.51667

t Tests (LSD) for geling

Least Significant Difference 0.2887
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	83.8000	40	B3
B	82.8750	40	B2
C	77.8750	40	B1

Least Significant Difference 0.3727
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	86.6667	24	C5
B	82.7917	24	C4
C	80.1250	24	C3
C	80.1250	24	C1
D	77.8750	24	C2

Least Significant Difference 0.3334
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	83.7667	30	A4
B	82.9333	30	A3
C	80.1667	30	A1
D	79.2000	30	A2

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Boiling Temperature

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	853.0166667	426.5083333	1163.20	<.0001
ratio	4	806.6166667	201.6541667	549.97	<.0001
flour sample	3	515.8666667	171.9555556	468.97	<.0001
treatment*ratio	8	484.9833333	60.6229167	165.34	<.0001
flour sample*treatment	6	671.3833333	111.8972222	305.17	<.0001
flour sample*ratio	12	622.3833333	51.8652778	141.45	<.0001
flour sample*treatment*ratio	24	803.6166667	33.4840278	91.32	<.0001
Model	59	4757.866667	80.641808	219.93	<.0001
Error	60	22.000000	0.366667		
Corrected Total	119	4779.866667			

R-Square	Coeff Var	Root MSE	Boiling Temperature Mean
0.995397	0.677579	0.605530	89.36667

t Tests (LSD) for boiling

Least Significant Difference 0.2708
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	91.7750	40	B2
B	90.6750	40	B3
C	85.6500	40	B1

Least Significant Difference 0.3497
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	92.8333	24	C5
B	91.6250	24	C4
C	89.1667	24	C3
D	87.3750	24	C1
E	85.8333	24	C2

Least Significant Difference 0.3127
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	91.4667	30	A4
A	91.2667	30	A3
B	88.1333	30	A2
C	86.6000	30	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: pH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	0.00123500	0.00061750	741.00	<.0001
ratio	4	0.40383667	0.10095917	121151	<.0001
flour sample	3	0.18940250	0.06313417	75761.0	<.0001
treatment*ratio	8	0.53177333	0.06647167	79766.0	<.0001
flour sample* treatment	6	0.22330500	0.03721750	44661.0	<.0001
flour sample*ratio	12	0.52977667	0.04414806	52977.7	<.0001
flour sample*treatment*ratio	24	0.43705333	0.01821056	21852.7	<.0001
Model	59	2.31638250	0.03926072	47112.9	<.0001
Error	60	0.00005000	0.00000083		
Corrected Total	119	2.31643250			

R-Square	Coeff Var	Root MSE	pH Mean
0.999978	0.014442	0.000913	6.320750

t Tests (LSD) for pH

Least Significant Difference 0.0004
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	6.3250000	40	B2
B	6.3200000	40	B1
C	6.3172500	40	B3

Least Significant Difference 0.0005
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	6.4333333	24	C5
B	6.3083333	24	C3
C	6.3000000	24	C1
D	6.2954167	24	C4
E	6.2666667	24	C2

Least Significant Difference 0.0005
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	6.3733333	30	A3
B	6.3333333	30	A2
C	6.3133333	30	A4
D	6.2630000	30	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Alkaloid content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	25.08697167	12.54348583	44931.9	<.0001
ratio	4	0.68981333	0.17245333	617.74	<.0001
flour sample	3	9.39445583	3.13148528	11217.3	<.0001
treatment*ratio	8	10.81363667	1.35170458	4841.93	<.0001
flour sample*treatment	6	2.24756167	0.37459361	1341.83	<.0001
flour sample*ratio	12	9.80044000	0.81670333	2925.50	<.0001
flour sample*treatment*ratio	24	4.36493000	0.18187208	651.48	<.0001
Model	59	62.39780917	1.05758999	3788.38	<.0001
Error	60	0.01675000	0.00027917		
Corrected Total	119	62.41455917			

R-Square	Coeff Var	Root MSE	Alkaloid content Mean
0.999732	0.905884	0.016708	1.844417

t Tests (LSD) for alkaloid

Least Significant Difference 0.0075
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	2.468750	40	B3
B	1.678000	40	B2
C	1.386500	40	B1

Least Significant Difference 0.0096
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	1.990000	24	C1
B	1.840000	24	C5
C	1.812500	24	C4
C	1.806250	24	C3
D	1.773333	24	C2

Least Significant Difference 0.0086
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	2.232333	30	A3
B	1.987333	30	A4
C	1.605000	30	A2
D	1.553000	30	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Dependent Variable: Tannin content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	0.63741167	0.31870583	391.85	<.0001
ratio	4	0.25015833	0.06253958	76.89	<.0001
flour sample	3	1.68983000	0.56327667	692.55	<.0001
treatment*ratio	8	1.85712167	0.23214021	285.42	<.0001
flour sample* treatment	6	2.45079500	0.40846583	502.21	<.0001
flour sample*ratio	12	5.14496167	0.42874681	527.15	<.0001
flour sample*treatment*ratio	24	3.90483833	0.16270160	200.04	<.0001
Model	59	15.93511667	0.27008672	332.07	<.0001
Error	60	0.04880000	0.00081333		
Corrected Total	119	15.98391667			

R-Square	Coeff Var	Root MSE	Tannin content Mean
0.996947	1.538103	0.028519	1.854167

t Tests (LSD) for tannin

Least Significant Difference 0.0128
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	1.952500	40	B1
B	1.831750	40	B3
C	1.778250	40	B2

Least Significant Difference 0.0165
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	1.935000	24	C1
B	1.862083	24	C4
B	1.850417	24	C3
C	1.821667	24	C2
D	1.801667	24	C5

Least Significant Difference 0.0147
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	2.014333	30	A3
B	1.861667	30	A4
B	1.861333	30	A2
C	1.679333	30	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Saponin content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	1.72523167	0.86261583	2017.81	<.0001
ratio	4	60.50102500	15.12525625	35380.7	<.0001
flour sample	3	13.01728250	4.33909417	10149.9	<.0001
treatment*ratio	8	12.94103500	1.61762938	3783.93	<.0001
flour sample*treatment	6	7.58261500	1.26376917	2956.19	<.0001
flour sample*ratio	12	7.47612167	0.62301014	1457.33	<.0001
flour sample*treatment*ratio	24	6.04511833	0.25187993	589.19	<.0001
Model	59	109.2884292	1.8523463	4332.97	<.0001
Error	60	0.0256500	0.0004275		
Corrected Total	119	109.3140792			

R-Square	Coeff Var	Root MSE	Saponin content Mean
0.999765	0.751061	0.020676	2.752917

t Tests (LSD) for saponin

Least Significant Difference 0.0092
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	2.850250	40	B3
B	2.824500	40	B1
C	2.584000	40	B2

Least Significant Difference 0.0119
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	4.121667	24	C5
B	2.708750	24	C1
C	2.475417	24	C4
D	2.330000	24	C3
E	2.128750	24	C2

Least Significant Difference 0.0107
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	3.167667	30	A4
B	2.867000	30	A3
C	2.722000	30	A1
D	2.255000	30	A2

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Used 120

Dependent Variable: oxalate Oxalate content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	12.97098667	6.48549333	19505.2	<.0001
ratio	4	49.50748667	12.37687167	37223.7	<.0001
flour sample	3	41.69090250	13.89696750	41795.4	<.0001
treatment*ratio	8	17.46441333	2.18305167	6565.57	<.0001
flour sample*treatment	6	10.42256000	1.73709333	5224.34	<.0001
flour sample*ratio	12	20.78922667	1.73243556	5210.33	<.0001
flour sample*treatment*ratio	24	12.90937333	0.53789056	1617.72	<.0001
Model	59	165.7549492	2.8094059	8449.34	<.0001
Error	60	0.0199500	0.0003325		
Corrected Total	119	165.7748992			

R-Square	Coeff Var	Root MSE	Oxalate content Mean
0.999880	0.553248	0.018235	3.295917

t Tests (LSD) for oxalate

Least Significant Difference 0.0082
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	3.591250	40	B1
B	3.459250	40	B3
C	2.837250	40	B2

Least Significant Difference 0.0105
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	4.413750	24	C1
B	3.538333	24	C2
C	3.069167	24	C3
D	2.903333	24	C4
E	2.555000	24	C5

Least Significant Difference 0.0094
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	4.258333	30	A3
B	3.263333	30	A1
C	2.953667	30	A4
D	2.708333	30	A2

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Hydrocyanic Acid content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	0.7166600	0.3583300	1235.62	<.0001
ratio	4	85.1466383	21.2866596	73402.3	<.0001
flour sample	3	202.1112167	67.3704056	232312	<.0001
treatment*ratio	8	0.3138067	0.0392258	135.26	<.0001
flour sample*treatment	6	0.1502933	0.0250489	86.38	<.0001
flour sample*ratio	12	196.7915417	16.3992951	56549.3	<.0001
flour sample*treatment*ratio	24	0.5587733	0.0232822	80.28	<.0001
Model	59	485.7889300	8.2337107	28392.1	<.0001
Error	60	0.0174000	0.0002900		
Corrected Total	119	485.8063300			

R-Square	Coeff Var	Root MSE	HCN Mean
0.999964	1.073393	0.017029	1.586500

t Tests (LSD) for HCN

Least Significant Difference 0.0076
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	1.694500	40	B1
B	1.547000	40	B2
C	1.518000	40	B3

Least Significant Difference 0.0098
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	3.146250	24	C1
B	1.673333	24	C2
C	1.341250	24	C3
D	1.066667	24	C4
E	0.705000	24	C5

Least Significant Difference 0.0088
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	3.803000	30	A1
B	1.195333	30	A3
C	0.725000	30	A2
D	0.622667	30	A4

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Trypsin inhibitor

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	330.117947	165.058973	6.43	0.0030
ratio	4	919.432567	229.858142	8.95	<.0001
flour sample	3	537.209389	179.069796	6.97	0.0004
treatment*ratio	8	1024.021653	128.002707	4.99	<.0001
flour sample* treatment	6	411.653413	68.608902	2.67	0.0230
flour sample*ratio	12	1770.185473	147.515456	5.75	<.0001
flour sample*treatment*ratio	24	1381.147687	57.547820	2.24	0.0061
Model	59	6373.768129	108.029968	4.21	<.0001
Error	60	1540.403650	25.673394		
Corrected Total	119	7914.171779			

R-Square	Coeff Var	Root MSE	Trypsin inhibitor Mean
0.805361	17.63957	5.066892	28.72458

t Tests (LSD) for trypsin

Least Significant Difference 2.2663
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	30.810	40	B2
B A	28.611	40	B3
B	26.752	40	B1

Least Significant Difference 2.9258
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	32.148	24	C4
B A	29.990	24	C2
B A	29.843	24	C3
B	27.675	24	C1
C	23.967	24	C5

Least Significant Difference 2.6169
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	32.184	30	A2
B	28.612	30	A3
B	27.453	30	A4
B	26.649	30	A1

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Hemaggulutinin

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	301.7473267	150.8736633	974.31	<.0001
ratio	4	243.1297533	60.7824383	392.52	<.0001
flour sample	3	16.8619800	5.6206600	36.30	<.0001
treatment*ratio	8	605.8781067	75.7347633	489.08	<.0001
flour sample*treatment	6	57.3512600	9.5585433	61.73	<.0001
flour sample*ratio	12	55.0407533	4.5867294	29.62	<.0001
flour sample*treatment*ratio	24	98.2161067	4.0923378	26.43	<.0001
Model	59	1378.225287	23.359751	150.85	<.0001
Error	60	9.291100	0.154852		
Corrected Total	119	1387.516387			

R-Square	Coeff Var	Root MSE	Hemaggulutinin Mean
0.993304	26.77559	0.393512	1.469667

t Tests (LSD) for Hemaggulutinin

Least Significant Difference 0.176
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	3.71100	40	B1
B	0.41350	40	B3
B	0.28450	40	B2

Least Significant Difference 0.2272
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	4.2133	24	C5
B	1.4042	24	C4
C	0.9467	24	C3
D	0.4275	24	C1
D	0.3567	24	C2

Least Significant Difference 0.2032
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	2.0573	30	A3
B	1.5047	30	A1
C	1.2623	30	A4
D	1.0543	30	A2

The GLM Procedure

Class	Levels	Values
flour sample	4	A1 A2 A3 A4
treatment	3	B1 B2 B3
ratio	5	C1 C2 C3 C4 C5

Number of Observations Read 120

Dependent Variable: Phytic acid

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
treatment	2	0.12060335	0.06030167	75.20	<.0001
ratio	4	0.01662895	0.00415724	5.18	0.0012
flour sample	3	0.12956949	0.04318983	53.86	<.0001
treatment*ratio	8	0.19836765	0.02479596	30.92	<.0001
flour sample*treatment	6	0.12514598	0.02085766	26.01	<.0001
flour sample*ratio	12	0.18666605	0.01555550	19.40	<.0001
flour sample*treatment*ratio	24	0.25958035	0.01081585	13.49	<.0001
Model	59	1.03656182	0.01756884	21.91	<.0001
Error	60	0.04811550	0.00080192		
Corrected Total	119	1.08467732			

R-Square	Coeff Var	Root MSE	phytic acid Mean
0.955641	11.08673	0.028318	0.255425

t Tests (LSD) for phytic

Least Significant Difference 0.0127
Means with the same letter are not significantly different.

t Grouping	Mean	N	treatment
A	0.286500	40	B1
B	0.267875	40	B2
C	0.211900	40	B3

Least Significant Difference 0.0164
Means with the same letter are not significantly different.

t Grouping	Mean	N	ratio
A	0.266708	24	C4
B A	0.265125	24	C5
B A	0.260833	24	C3
B C	0.249083	24	C2
C	0.235375	24	C1

Least Significant Difference 0.0146
Means with the same letter are not significantly different.

t Grouping	Mean	N	flour sample
A	0.286700	30	A3
A	0.274700	30	A2
B	0.259233	30	A4
C	0.201067	30	A1