QUALITY ATTRIBUTES AND STORABILITY OF NOODLES FROM BLEND OF PRO-VITAMIN A CASSAVA (*Manihot esculenta* CRANTZ) AND AFRICAN YAM BEAN (*Sphenostylis stenocarpa* HARMS) FLOURS

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A Thesis in the Department of Food Technology,
Submitted to the Faculty of Technology
in partial fulfilment of the requirements for the Degree of

DOCTOR OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN

MARCH, 2020

ABSTRACT

Noodle, a convenient wheat-based food, is high in carbohydrate but low in protein and vitamin contents. Imported wheat is mostly used to meet the demand for convenience foods preparation in Nigeria. Alternative to wheat, Pro-Vitamin A Cassava (PVAC), a good source of vitamin A and African Yam Bean (AYB), rich in protein content, could be used for noodle production. However, information on utilisation of PVAC and AYB flour mixture for preparation of noodle is sparse. This study was designed to investigate quality and storage attributes of noodles prepared from blend of PVAC and AYB flours.

From preliminary trials, PVAC (cultivar 07/593) and AYB (accession TSs 94) were separately processed into flours using standard procedures. The flour blend of PVAC (60-90%) and AYB (10-40%) were prepared using mixture experimental design. Protein, β-carotene and fat contents of blend were determined by standard methods and used as criteria to select the desirable blend by maximising protein and β-carotene contents, while minimising fat content. Noodles were produced from the desirable blend (100 g) and process optimised using response surface methodology with moisture content (50-60%) and steaming time (1-4 min) as variables. Protein, β-carotene, fat contents, cooking qualities and textural attributes of noodles were analysed using standard methods. Protein quality (protein efficiency, true protein digestibility and feed efficiency) of the noodles was compared with standard diet (casein diet) using male *wistar* rats. Overall acceptability of cooked noodles was determined using 50 panelists and a commercial noodle as control. Samples were stored in Low Density Polyethylene (LDPE) (100 µm) and High Density Polyethylene (HDPE) (150 µm and 200 µm) at ambient condition (27±2^{o}C, 64±2.00%, RH). Colour, moisture content, β-carotene retention, total viable, mould and yeast counts of stored samples were determined at two week intervals over a six-month duration. Data were analysed using ANOVA at $\alpha_{0.05}$.

Protein, β-carotene and fat contents of flour blend were 2.31-10.52%, 3.5-7.60 µg/g and 0.57-1.40%, respectively, while those of optimised blend (70.49%PVAC and 29.51%AYB) were 6.69%, 6.45 µg/g and 0.58%, respectively. The protein, β-carotene, fat contents, cooking yield, cooking loss and cooking time of noodles were 9.25-11.55%, 2.97-4.99 µg/g, 0.88-1.18%, 177.84-209.93%, 6.87-10.80% and 7.20-9.45 min, respectively. Textural properties varied from 1,165 to 2,382 g, 254.50 to 1,082 g and 18.50 to 68.50 g for hardness, chewiness and stickiness, respectively. Protein efficiency, true protein digestibility and feed efficiency of experimental samples (2.24-2.37%, 95.5-97.00% and 0.15-0.20%, respectively) were not significantly different from that of control (casein diet). Overall acceptability varied significantly with commercial noodle having the highest value followed by sample hydrated and steamed at 50% and 1 min. The best packaging material based on colour, moisture content, β-carotene retention and microbiological qualities of the samples was HDPE (200 µm).

Pro-vitamin A cassava-African yam bean noodles of acceptable nutritional, cooking and sensory qualities were produced. High-density polyethylene (200 µm) was suitable for storage of the noodles at tropical ambient condition.

Keywords: Cassava noodles, African yam bean, Beta-carotene, Protein enrichment.

Word count: 485

CERTIFICATION

I certify that this study was carried out by **AJIBOLA, GHANIYAH ODUNOLA** with the matric number 74798 under my supervision, in partial fulfillment of prerequisite for the award of PhD in Food Technology, Faculty of Technology, University of Ibadan, Ibadan.

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DEDICATION

This thesis is devoted to almighty Allah, the most gracious and most merciful for His protection and guidance and Engr. Habeeb Olasunmbo Ajibola for his sacrifice and support throughout the programme.

ACKNOWLEDGMENT

I give utmost acknowledgment and adoration to Almighty Allah, lord of Universe, whose blessings and protection have made me who I am today. I ceaselessly thank him for His mercy over me in concluding this research.

My deepest gratefulness goes to my splendid and relentless supervisor Dr A. A. Olapade for his indefatigable efforts, kindness, encouragements, patience and guidance accorded to me during this programme. May Almighty Allah grant him more strength, knowledge, wisdom and understanding in all his endeavours. I sincerely appreciated the immeasurable effort of the former head of Department, Professor K. O. Falade for his moral support throughout the programme. May the Almighty God elongate your life with good health. My special appreciation goes to our fathers in the Department Professor G. O. Adegoke, Professor O. C. Aworh and all my compassionate, supportive and concern lecturers: Professor R. Akinoso, Dr G. I. Arueya, Dr Olufunke O. Ezekiel, our mama, Dr Phyllis I. Uzo-Peters, Dr A. O. Oladunjoye and Dr Folasade O. Adeboyejo for the insistent backing bestowed on me during my programme.

I am obliged to the entire non-academic staff of Food Technology Department, University of Ibadan among whom are Dr Y. A. Babarinde, Mr. P. O. Ayoola, Mr. M. J. Effiong, Mr. A. O. Austin and Mrs. Sarah Olufunmilayo for their brilliant contributions, support and knowledge impacted during my laboratory analyses and throughout the programme. My profound acknowledgement goes to the following staff of the Interdisciplinary Central Laboratory of University of Ibadan among whom are Mrs. O. O. Balogun, Mr. W. O. Ope and Mr. T. A. Abiola for their backing. I am sincerely indebted to Dr S. M. Omotosho (SMO Consult) for his advice and support in performing some of my analyses.

I am sincerely grateful to the entire staff of Cassava Processing Unit and Genetic Resources Centre of International Institute of Tropical Agriculture, (IITA) for provision of PVAC roots and AYB seeds utilised during the study. I am greatly thankful to Mr. Peter Illuebbey for the relentless support granted to me, Alhaji N. A. Adetoro for his kind gesture showered on me throughout my raw materials sourcing, the use of their equipment and support rendered during comparative sensory evaluation period. I appreciated the efforts of the entire staff of Food and Nutrition Unit of IITA,

most especially the laboratory manager, Mr. Michael Adesokan, Mrs. O. B. Olaniyan, Mr. M. G. Adeniran, Mr. A. S. Akinboade and Mr. J. O. Oyelekan of High Quality Cassava Flour (HQCF) unit for all their support, advice and concern during my raw material sourcing and laboratory analyses. I am highly grateful to Dr W. Awoyale for ensuring and supporting me in granting laboratory space at Food and Nutrition Unit of IITA and his advice throughout the period. I appreciated the efforts of Mr Abiodun Odejayi and Mr. O. O. Oloshunde for their ceaseless support on the use of flash dryer during the programme.

This acknowledgement would not be completed if I failed to show my sincere gratitude to my loving and caring family. I am highly grateful to my caring, loving, selfless and kind hearted husband, Engr Habeeb Olasunmbo Ajibola for being there always, his sacrifice, prayer, moral and financial supports. I also appreciated my supportive children: Ameenah, Khaleelulah, Ja'far and Imran for their understanding, prayer and support.

With deep sense of humility, I appreciate my Father, Alhaji A. A. Akinlabi, Alhaja Yidiat Akinlabi, my brother, Dr Ismail Akinlabi, my lovely and caring sisters Alhaja Fatimah Adio, Alhaja Halimah Olumakin, Dr Mrs Ashia Makinde, and Mrs Kafayah Lamidi and all the entire Akinlabi's family for their prayer and word of encouragement. I am indebted to my uncle Mr. Saliu Kareem for all his prayer throughout the programme. I am indeed thankful for the backing granted to me by the entire Ajibola family most especially Alhaji and Alhaja Ajibola and Evangelist Ogundokun for their prayer. To my late mum, Mrs. Simbiat Akinlabi of blessed memory, may Allah forgive her of her sins and grant her aljanah firdaos.

I am grateful for the support of Professor Ologhobo, Dr O. A. Abu, Dr Esther Akangbe and Mr. S. Arowolo of Animal Science Department during my animal study. My honest appreciation goes to my friends and colleagues among whom are Mrs. Kafayah Adebayo, Mrs. S. Sulaiman, Dr K. K. Olatoye, Mrs. K. Babalola, Dr Abosede Alabi and host of others that assisted towards the accomplishment of this work. I appreciate everyone.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Roots and tubers are essential parts of food in various nations of Africa and other parts of the globe. The best known of the group comprise yam, cocoyam, sweet and irish potatoes, and cassava (Sanni *et al*., 2003). Cassava (*Manihot esculenta* Crantz) belongs to perennial vegetative shrub that is cultivated all over the tropics. It is the fourth very essential energy giving food for common residents in tropics of West as well as Central Africa. Its capability to flourish well after planting and feasibility of its stems have significantly added to its widespread. Therefore, it is being regarded as a way of achieving domestic food safety and increasing food accessibility (Lebot**,** 2009).

According to Aniedu and Omodamiro (2012), millions of Nigerians regardless of ages, genders and geographical locations obtain inadequate vitamin A. To eradicate this menace, Nigerian Government under the Ministry of Health offers vitamin A supplementation from ages six months to fifty-nine months old children during their immunisation periods. Similarly, the Government has authorised enrichment of some foods with vitamin A ever since year 2000. This has necessitated the development of Pro-Vitamin A Cassava (PVAC), that is planned to support the existing efforts of addressing Vitamin A Deficiency (VAD) by supplying vitamin A via a staple food commonly eaten by the populace. This will also increase the accessibility of varieties of vitamin A-based diets in the country.

Noodle is universally acceptable food with high consumption rate. According to World Instant Noodles Association (WINA) (2016), Africa demand for noodle has been increasing with increase in population, however, it is usually produced from imported wheat flour. To reduce over reliance on wheat importation in non-wheat producing country, efforts should be made to utilise our local crops in food

production. Liu *et al*. (2012) opined that noodles could be produced from flours obtained from other indigenous crops. Therefore, it is highly essential to produce noodle from available indigenous crops comprising PVAC and African Yam Bean (AYB).

According to Dickson *et al.* (2012), diets in many African countries mostly comprise of protein, mineral and vitamin-deficient starchy foods. Eyidemir and Hayta (2009) also opined that noodles and new kinds of pasta are good energy giving foods but poor in protein content with good amino acid profile. Based on Abidin *et al*. (2013), cassava flour has a good capacity of replacing imported wheat flour that is generally used for noodle production. However, it is low in protein content; thus, it needs to be fortified with protein rich flour to prepare balance diet.

Legumes are common diets for several people in diverse parts of the globe. Its seeds contain as double as protein content of cereals in percentage and commonly comprise of more stable composition of essential (indispensable) amino acids (Vijayakumari *et al.*, 1997). African yam bean is among the best origins for protein enrichment of carbohydrate diets (Blessing *et al.,* 2013).

1.2 Problem Statement

There is over dependence on utilisation of imported wheat flour in production of noodles. Information on utilisation of AYB compared to other major legumes such as soybean is sparse. To prevent AYB from extinction, its utilisation should be encouraged and extended to fortification of local dishes, snacks and convenience foods. Children and adolescence eat a lot of noodles which are energy dense. Therefore, there is need for improvement to enrich the protein and vitamin of noodles. At present, more companies do voluntary inclusion of vitamin A but we need vitamin A and protein contents. It is against this backdrop that the researcher investigate on the possibility of producing instant noodle, which is a staple food of the populace, especially under-five children, from PVA C and AYB flours.

1.3 Justification of the Study

There is paucity of information on the utilisation of AYB Flour (AYBF) to enrich PVAC flour in noodle production and there has not been enough scientific information on the optimisation of major ingredients of fortified cassava noodle. African yam bean was selected due to its nutrient density that will help to enrich the food. Likewise, its usage will boost utilisation of this under-exploited legume in many food formulations specifically in emergent countries for human feeding (Blessing *et al.*, 2013). According to Verhoef (2010), increasing the constant supply of vitamin A via foodstuff might go a long way in reducing children's death attributed to some common childhood diseases. It was projected that twenty to thirty percent of children, under five years of age's death could be averted, provided they are well nourished on foods with adequate vitamin A and protein (Bellamy, 1998).

1.4 Objectives of the Study

The overall objective of the research was to prepare acceptable noodles from provitamin A fortified cassava-African yam bean flours.

The specific objectives include:

1. Evaluation of chemical, functional and nutritional qualities of pro-vitamin A cassava and African yam bean flour blend.
2. Establishment of processing parameters for preparation of instant noodles from the blend of pro-vitamin A cassava and African yam bean flour.
3. Evaluation of quality attributes of noodles from blend of pro-vitamin A cassava and African yam bean flour.
4. Determination of storage stability of cassava-African yam bean noodles.

CHAPTER TWO

2.0 LITERATURE REVIEW

More than 800 millions people depend on cassava as main basis of their calories (Sowmyapriya *et al.,* 2017). It contributes enormously to worldwide food security and expected to partake more substantial part in forthcoming (Rosenthal and Ort, 2012). It is an essential sustenance crop and chief carbohydrate mostly eaten in numerous ways by people. Thus, it adds meaningfully to food and living of millions of individuals and thousands of producers and marketers all over the globe. This creates the basis for diverse varieties of cassava-based diets in some continents. Furthermore, it is used as an ingredient in production of human diets, feedstuffs and technologically advanced foods (Balagopalan, 2002; Taiwo, 2006).

2.1 History of Cassava

Cassava was made known to Africa in 16th century by the pioneer Portuguese traders (Ohadike, 1981). It belongs to chief humid root crops in numerous lands of the globe (Liu *et al*., 2011). Similarly, it had capability to tolerate the most hostile climatic circumstances which other food crops can not endure. Therefore, it was forecasted to be the least subtle to climatic conditions, drought resistant, can be cultivated nearly anywhere, and is not simply demolished by heavy rains (Jarvis *et al.*, 2012).

It has two common botanical types that are classified based on the cyanoglycoside composition. This categorises the tubers into “sweet” and “bitter” cassava. Sweet type encompasses low cyanoglycoside content (<140 ppm) while, bitter type contains over 140 ppm cyanoglycosides on dry basis. The cyanoglycosides are uniformly spread all over the sweet. On the other hand, cyanoglycosides are mainly situated under cassava peel which is easily detached during peeling of “bitter”, excessive cyanide cassava in cassava processing (Falade and Akingbala, 2008).

These two classifications of cassava: sweet and bitter have been used over the years by several farmers as an indicator of the level of harmfulness of numerous cassava varieties. It has been reported by several researchers that there is a diverse discrepancies in level of cyanoglycosides from various cassava varieties irrespective of their classification as sweet or bitter varieties (Raji *et al*., 2007; CIAT 2007).

2.2 Statistics of Cassava Production

Cassava global production is about 291 million tonnes annually. Africa is providing 55 percent from the world supply and Nigeria's contribution to the global production is up to 36.9 percent of African production. Nigeria is presently producing around 59 million metric tonnes (MT) annually and thus, the leading global production (FAO, 2017). It is largely grown in some tropical countries and is being reserved as produce that can offshoot pastoral industrial development and thereby upsurge revenue for producers, processors and merchants (Echebiri and Edaba, 2008). The global cassava production as at 2017 is displayed in Table 2.1.

2.3 Nutrient Composition of Cassava

Nutritional quality of cassava differs depending on varieties, stage of the plant, topographical setting and ecological situations (Gil and Buitrago, 2002). Its roots and leaves made up of 50% and 6% respectively of an established plant and form the dietary essential portions of plant (Tewe, 2004). Its roots comprise bark, peel and the edible parts. These provide the energy source for plant and the greatest regularly eaten portion in the world. Its edible part comprises 80-90% of entire bulk of tuber, with water making the principal constituent. The nutritional importance of its roots is very essential owing to the fact that they are the most eaten portion in most emergent countries (Harris and Koomson, 2011).

The moisture content of roots ranged from 60.3 to 87.1% (Padonou *et al*., 2005; Zvinavashe *et al*., 2011). Furthermore, it is an important characteristic in shelflife determination of the flour. More than 12% permit microbiologcal deterioration therefore, lower levels are desirable as it does not permit microbial growth. Thus, lengthier shelf life will be reasonably guaranteed (Harris and Koomson, 2011). Its flour has a moisture content that differs from 9.2-12.3% (Charles *et al*., 2005) and

Table 2.1. Global Cassava Cultivation

Country	Quantity of cassava production (MT)	Year
World	291,992,646	2017
Nigeria	59, 485,947	2017
Congo	31,596,046	2017
Thailand	30,973,292	2017
Indonesia	19,046,000	2017
Brazil	18,876,470	2017
Ghana	18,470,762	2017
Angola	11,747,938	2017
Cambodia	10,577,812	2017
Vietnam	10,267,568	2017
Mozambique	8,773,712	2017
Cameroon	5,798,909	2017
Cote d'Ivoire	5,367,000	2017
Tanzania	5,014,624	2017
Malawi	4,960,556	2017
China	4,862,814	2017
Sierra Leone	4,761,385	2017
Benin	4,341,848	2017
India	4,171,000	2017
Paraguay	3,166,800	2017
Philippines	2,807,671	2017

Source: FAO (2017) MT denotes million tonne

11-16.5% (Shittu *et al*., 2007a). The crude protein, lipid, fibre and ash contents of fresh cassava roots were low (0.9, 0.3, 0.5 and 0.4 g/100 g, respectively (Adepoju *et al*., 2010). It is also low in some vitamins and mineral contents (Charles *et al.*, 2005). According to Gil and Buitrago (2002), it contains about 0.5% fat and good source of calcium and vitamin C of about 16-35 mg/100 g and 15-45 mg/100 g, respectively.

According to Zvinavashe *et al.* (2011), cassava plant produces more carbohydrate by mass compare to other principal food crop in the same ecological situations. Its roots are functional energy reserve with high carbohydrate composition of about 32 to 35% and 80 to 90% on fresh and dry basis respectively. Approximately fifty percent of crude protein content of tubers is protein and second half contains permitted amino acids (largely aspartic acids and glutamic) and proten-free ingredients namely nitrite, nitrate and cyanogenic glucosides. Maziya-Dixon *et al.* (2007) opined that cassava is a good source of carbohydrate thus, provides energy, despite it lacks micronutrients. According to Montagnac *et al*. (2009), its roots are lesser in carbohydrate content than sorghum, yellow corn, rice and wheat but higher than potatoes on a 100 g basis.

According to Charles *et al.* (2005), it comprises of 1-2% protein that makes it mainly carbohydrate based food. Due to its deficiency in protein, it is poor basis of a few indispensable amino acids namely tyrosine, methionine, phenylalanine, lysine and tryptophan (Falade and Akingbala, 2010). In view of this, it needs fortification with protein enrich flour in preparation of balanced food. It is equally low in lipid content with about 0.1 to 0.3% on wet mass base and 0.1 to 0.8% (Charles *et al*., 2005) and 0.56% (Padonou *et al*., 2005) on dehydrated mass base.

Tremblay (2013) reported that the presence of insoluble fibre in cassava assists in improving the digestive system of the body by getting rid of the toxins from the intestine to enhance proper functioning of the digestive system. He acknowledged that cassava richness in carbohydrate helps to strengthen the body and regulates the sugar levels in the bloodstream. He also opined that cassava has high vitamin C content that helps in reducing aging, good for heart and lungs, and assists in getting rid of free radicals in the body because of its antioxidant properties.

Cassava roots are good bases of some essential minerals among which are zinc, copper, manganese, iron, magnesium, to mention a few. Furthermore, they have substantial amount of potassium up to 271 mg per 100 g or six percent of recommended daily allowance. They have moderate amount of some vitamin B-complex group among which are folate, thiamine, pantothenic to mention a few (Rudrappa, 2015).

2.4 Cassava Varieties

There are many varieties of both white and yellow-fleshed cassava. The yellow-fleshed cassava is referred to Pro-vitamin A cassava. These varieties are increasing due to continuous ongoing research and development on it. Babatunde (2012) stated that cassava is the greatest essential primary diet in Nigeria based on population of individuals that consume it everyday and large quantity of calorie deliverable from it. According to Kulakow and Egesie (2012), development of cassava varieties is the main productive insight which could enhance the nourishing status of individuals living on cassava-based diets. This will also assist in promoting its utilisation via awareness creation. The recent research on cassava has brought about enrichment of the crop with the advent of new breed of PVAC varieties.

Nigerian administration released first three new yellow-fleshed cassava varieties that could deliver added vitamin A to foods of above 70 million people that consume cassava based food daily (Kulakow *et al.,* 2011). According to Ilona *et al*. (2017), the first three vitamin A cassava varieties with 6–8 ppm total carotenoid content were released in 2011, while the second three varieties with up to 11 ppm were formally released in 2014. These latest breed of PVAC varieties are depicted in Table 2.2.

2.5 Cassava Utilisations

Almost 40% of cassava roots are presently processed into local dishes such as *fufu,* lafun to mention a few. Meanwhile, there are numerous prospects to increase its local utilisation such as utilising it in preparing an array of novel foods, specifically in these dynamic developed communities of the emergent nations (Dufour *et al.,* 2002). Its utilisation patterns differ seriously from one country to another. For instance,

Table 2.2. Permitted Varieties of Vitamin A Cassava Roots in Nigeria

Variety Name	Overall carotenoid content (FW)*	Fresh tuber Yield	Produce Comparative to standard**	Dry matter
TMS 01/1371	+8 ppm	20.1 t/ha	87%	30.7%
TMS 01/1412	+7 ppm	29.8 t/ha	128%	30.1%
TMS 01/1368	+7 ppm	26.7 t/ha	115%	33.4%
TMS 07/0593	+11 ppm	21.5 t/ha	100%	34.6%
TMS 07/0539	+11 ppm	20.3 t/ha	94%	31.9%
TMS 07/0220	+11 ppm	23.1 t/ha	107%	32.7%

* Pro-vitamin A contain about 80% of the overall carotenoid content on wet weight basis-(FW). **Nationwide standard TMS 30572; information from 2011 issues (TMS 01/1371, TMS 01/1412 and TMS 01/1368) derived from 2008/09 and 2009/10 multi-locational tests from seven locations; facts from 2014 issues (TMS 07/0593, TMS 07/0539 and TMS 07/0220) obtained from 2011/2012 and 2012/2013 derived from some locations along eight locations.

`Source: Ilona *et al*. (2017)

Nigerians consumed about 90% of the country production (IITA, 2010). The possibility of adding more value to the crop can be enhanced by formulating more food products from it. For instance, Omodamiro *et al.* (2012) stated the production and acceptability of *fufu* flour made by adopting traditional and odourless method. Similarly, Oparinde *et al.* (2012) reported the acceptability of vitamin A enrich *gari* in Oyo and Imo states. IITA (2011) detailed the production and acceptability of high quality cassava flour (HQCF), *gari*, *fufu* paste and cassava chips.

Globally, cassava utilisation has been innovated and shifted from sustenance farming to large scale production of industrialised products. Moreover, home consumption still accounts for the highest utilisation of the crop (Westby, 2002., UNIDO, 2006). It can also be used in production of varieties of Nigeria foods among which are *gari, fufu,* cassava chips, cassava flour, cassava bread, cassava snacks etc. Based on Scott *et al.* (2000), the overall cassava utilisation is predicted to rise at 1.9 percent annually and foresee to reach over 290 million tonnes by year 2020 in emergent countries. Meanwhile, the maintenance of industrialised progress of cassava is subjected to some extent of the expansion of the utilisation and value addition of the crop to upsurge the in-house demands as well as external markets (Vijayakumar and Boopathy, 2014).

Animal feeds manufacturers are discovering the crop to be an active cheap option to other crops. Its yields create essential ingredients for animal feedstuffs and can be used in formulating feeds for some animals. Some cassava products have created requests in food processing companies. For example, vitamin A enrich cassava flour (HQCF) can be utilised for manufacture of bakery foods and some by-products. Its starch has been utilised extensively in the industry to make foods with physico-chemical characteristics for specific requests such as preparation of lubricants, thickeners, gravies, baby foods, convenient foods and alcoholic drinks (Echebiri and Edaba, 2008).

2.5.1 High quality cassava flour

High quality cassava flour is described as snowy, even, un-fermented and unscented cassava flour that is quickly processed within 24 h from fit cassava roots planted within ten to twelve months after cultivation. This is projected to be utilised as

ingredients in foods and drinks companies to produce biscuits, baby foods, pastas, pies, beverages, binders and thickeners for broths and stews. It can equally be used appropriately in manufacturing of glucose syrup, gums, pastes, paperboard adhesives, fabrics, plywood, broadsheet and pharmaceutical medicines. It has potential application in the production of composite flours with wheat flour and non-wheat flours for production of high quality foods (Dziedzoave *et al.*, 2006).

There is difference between HQCF production and that of fermented cassava flours used for *gari* and other fermented products. The main difference between this traditional cassava flour and HQCF is the absence of fermentation which produces a low pH and acidic taste that are unwanted for industrialised foods. Therefore, production needs a firm obedience to upright manufacturing protocols to be able to acquire high quality end products of appropriate makings. The tubers should be of good quality, with absence of rot and must be harvested within ten months to a year after planting (Dziedzoave *et al.*, 2006). Tubers of over a year after planting minimise flour productivity (Apea-Bah *et al.*, 2011). Therefore, this should be avoided and discouraged in HQCF processing to improve the productivity.

It is a non-wheat flour that is useful in curing of celiac illnesses (Briani *et al.*, 2008). In terms of its quality attributes, it must be free from extraneous material and foreign matter. It should not possess any odour and flavour, portrays the colour representative of variety used and its particle size should be within 250-500µm. This size relies on the cell arrangement and extent of handling which affect the functionalities of flour as well as product quality. It is created to be adequate for manufacturing of various forms of pastries and other fast foods by using it alone or as composite flours (Dziedzoave *et al.*, 2006). Furthermore, it has been used industrially in the manufacture of alcohol such as ethanol and methanol (Ocloo and Ayernor, 2010). These aforementioned utilisations of HQCF depicted its great potential to substitute imported wheat flour.

Owing to its great potential, it creates the simplest entering way to aid the subsistence farmers or small and medium enterprises in the nearest future, and offers prospect to capitalise in other foods (Adebayo *et al.*, 2010). Most administrations of cassava-

cultivating nations are creating struggles to motivate competitive manufacture of cassava into industrialised ingredients for importation replacement and overseas trading incomes (Dziedzoave *et al.,* 2005).

2.5.2 Composite flours

Sanni *et al.* (2004) described composite flours as the name given to wheat flour that has been mixed with gluten free flours such as maize, soybean and cassava. Meanwhile, Seibel (2006) defined it as blend of flours from roots of good source of starch among which are potatoes, yam, cassava; cereals and flours of good source of protein (groundnut, soybean) with or without wheat flour inclusion. From these definitions, inclusion of wheat flour is optional in preparing composite flour. Consumption of wheat based pasta products usually causes imbalance nutrients among the consumers (Shanthi *et al*., 2005). In order to overcome this menace, composite flour can be used to make nutritious pasta products.

Currently, efforts are being aimed to recognise those non-wheat bases which could be utilised in most developing nations to replace wheat in bakery and other convenience foods production. This will promote the saving of overseas exchange by reducing importation of wheat. These gluten free flours can be derived from roots and tubers, cereals and legumes such as potatoes, corn, soybean, sorghum e.t.c (Oladunmoye *et al*., 2010; Oluwamukomi *et al.*, 2011; Alvarenga *et al.*, 2011; Idolo, 2011). This will improve utilisation of our locally grown crops. For instance, the use of composite flours have been extensive and successful in bakery products production. Its use is cost effective and beneficial in developing countries as it boosts utilisation of indigenous crops (Hugo *et al*., 2000).

Composite flours are made from roots and tubers (irish potato and cassava) blended with major legumes (soybeans, cowpea, peas, common beans, chickpeas, lima beans) in addition with under-exploited legumes such as hamburger bean seed (*Mucuna sloanei*), bambara groundnut (*Voandzeia subterranean*), pigeon peas (*Cajanus cajan*)` that stayed underutilised (Arinathan *et al*., 2003). Inclusion of AYBF can also add an immense value. Cassava flour, a healthier complement to gluten flour equated with additional root and tuber crops as established in various studies (Ed*dy et al.,* 2007).

Although, pasta or noodle products like spaghetti and macaroni are not often made from ordinary wheat grain *(Triticum aestivum*) commonly referred to as bread wheat (Sowabhagya and Zakiuddin, 2001). They are made from durum semolina wheat. The use of other cereals for noodle production have been reported with and without wheat incorporation as depicted in Table 2.3. According to Falade and Akingbala (2008), inclusion of cassava flour in production of composite flour for fast foods manufacturing will reduce cost and improve noodles, breakfast cereals, pastries production among others. Instant noodles have been made successfully from cassava flour, but the process has not been developed (Sanni *et al*. 2004; Abidin *et al*. 2013).

2.6 Cassava Utilisation Constraints

Cassava possess several merits that mostly describe its prevalent farming. However, it has several grave restrictions. First and foremost, quick post-harvest deterioration problem of roots after harvesting limits its marketability (Van Oirschot *et al.*, 2000; Lebot, 2009).

The roots possess poor protein content (Adepoju *et al*., 2010). Its poor content in some indispensable micro-nutrients can lead to imbalance diets that can results in "hidden hunger". It is deficient in protein content with very little indispensable amino acid composition. It contains some anti-nutritional factors that are detrimental to human health (Montag*nac et al.,* 2009). For example, its roots and leaves contain linamarin and an insignificant quantity of lotaustralin (Bradbury and Denton, 2010; Mburu e*t al.,* 2012). Many health illnesses that are connected to constant consumption of sub-lethal amounts of cyanogen have resulted in total injury and demise owing to consumption of cyanide from eating of wrongly prepared cassava foods (Adindu and Aproku, 2006; Nhassico *et al.,* 2008; Dufour, 2011). The tolerable amount of cyanide in diets is 10 mg/kg dry mass (FAO/WHO, 2013). Meanwhile, the level lower than 100 mg/kg dry mass was publicised to be safe for cassava chips for nourishing diverse categories of cattle (FAO and IFAD, 2004).

2.7 Global Prevalence of Micronutrients Deficiency

Despite several advances and improvements in child health, malnutrition still remains one of the major public health challenges of the 21st century, especially in developing

Table 2.3. Composite Flours for Manufacture of Biscuits and Noodles Comparable to Full Wheat

Common name	Botanical name	Level of combination (%)	Kinds of products	References
Cassava	*Manihot esculenta*	60% cassava flour, 30% wheat flour and 10% soybean flour.	Noodles	Sanni *et al.* (2004).
		70% cassava flour, 22.5% wheat flour and 7.5% Soybean flour.	Noodles	Sanni *et al.* (2007).
		50% cassava starch, 20% milk powder and 30% soy flour.	Biscuits	Seibel, (2006).
		60% cassava, 15% peanut and 25% wheat flour.	Noodles	Seibel, (2006).
		85.58% cassava flour and 14.42% soybean flour.	Noodles	Okwundu and Aluyor, (2015).
		100% cassava	Biscuits	Oyewole *et al*., 1996
		40% cassava	Biscuits	Omoaka and Bokanga, 1994.
Chick pea	*Cicer arietinum*	50%	Biscuits	Doxastakis *et al*., 2002; Navickis, 1987
Soybean	*Glycine max*	40% soy, 30% maize and 30% wheat	Noodles	Seibel, (2006)
Sorghum/ millet	*Sorghum bicolor*	100% sorghum/millet	Biscuits	Seibel, (2006)
Maize	*Zea Mays*	80% pre-gelatinized maize flour and 20% soy flour.	Noodles	Seibel, (2006)
Breadfruit	*Artocarpus Integrifolia*	15%	Noodles	Olaoye *et al.,* 2006
Cashew apple	*Anacardium Occidentale*	20% replacement for cassava	Biscuits	Ogunjobi and Ogunwolu, 2010
Sorghum	*Sorghum bicolor*	10%	Biscuits	Adebowale *et al.*, 2012

Source: Ohimain (2014)

nations. It destabilises the survival, growth and development of children, and associated with about 35% of all deaths in children under the age of 5 years worldwide. An approximate of 178 million children are stunted and 19 million children have severe acute malnutrition. These conditions are usually associated with micronutrient deficiencies such as vitamin A, iron, zinc and iodine deficiencies (Bhutta *et al*., 2012).

Globally, micronutrient deficiencies are of great public health and socioeconomic importance. They impact about 2 billion people in developing and developed countries. These are silent outbreaks of vitamin and mineral deficiencies that affect people of all genders and ages, as well as specific vulnerable groups (Tulchinsky, 2010). The prevalence of micronutrient deficiencies occur with expectant women and their children under 5 years at the greatest risk (Bailey *et al*., 2015).

Vitamin A deficiency is considered as one of the most common micronutrient deficiencies worldwide, mostly affecting children in developing countries. About 30% of children under 5 years of age are vitamin A deficient (Stevens, 2015). In 2011, a projection of 157,000 children deaths were connected to VAD worldwide (Black *et al*., 2013). Based on WHO (2011) evaluation, over two billion of global population suffered from insufficiency of micronutrients majorly caused by deficient food intake. In lieu of this, efforts should be geared towards fortifying some commonly eaten starchy foods to boost the nutritional status of the consumers.

According to WHO (2015), approximately 250 million preschool children and a substantial proportion of pregnant women are vitamin A deficient. About 250 000 to 500 000 vitamin A-deficient children become blind annually, half of them die within a year of losing their sight.

2.7.1 Importance of vitamin A and precursors

Vitamins are organic compound that are vital for human health, growth, development, reproduction and maintenance, and their deficiencies would impose serious health hazards (Maqbool *et al.*, 2018).

Vitamin A is an indispensable micronutrient for humans that cannot be synthesized in

the body but must be obtained from dietary sources. Beta-carotene (β-carotene) is the major plant source of vitamin A precursor that is characterised by two associated retinyl groups. It contributes to the body's total vitamin A level. Some forms of carotenes such as α and γ also have some vitamin activity. by virtue of each having a single retinyl group (Oruch and Pryme, 2012).

Vitamin A deficiency is the main unrestricted health menace common to more than 75 nations in the emergent world. It can lead to night blindness and Xeropthamia in its early stage, that may later develop to sightlessness (Cuevas *et al*., 2010). In an attempt to relieve this public health menace, enhancement of Pro-vitamin A Carotenoids (PAC) content of some crops was commenced. This was done to the points of producing a considerable influence on dietary and wellbeing status of consumers in those mark African nations, that has VAD occurrence as a public health worry (WHO, 2009).

Supplementation of vitamin A was announced worldwide as a temporary interference to minimise VAD in infant under age five and women after childbirth. In addition, dietary-based strategies are being discovered as a better acceptable and cost-effective approaches (Bouis *et al.,* 2011). Despite the efforts that have been employed to reduce VAD, the problem still persisted in some developing countries. Adopting other strategies to reduce these problems is highly essential. Hence, major crops biofortification with PAC is an evolving approach of addressing vitamin A position of people (Tanumihardjo *et al.*, 2008). This could help in controlling this problem.

According to Cuevas *et al*. (2010), β-carotene is vital for development, reproduction, sight and maintenance of integrity of epithelial tissue. Tumuhimbise *et al*. (2013) opined that β-carotene retention of biofortified cassava is adequate to provide sufficient vitamin A requests. Therefore, the use of this crop would enhance nutritional status of people. Owing to this, there is need to formulate many foods from this recently produced crop to increase its value, improving and extending its utilisation. Cassava, as a major common diet crop, hence, eating of PVAC would assist in controlling VAD, which is called severe communal health issue in most nations of the globe (Sagar *et al.,* 2009; Vimala *et al.,* 2011; Omodamiro *et al.,*

2011).

Vitamin A enriched crops have shown to be an efficient means of turning the tide in contrary to the menace to some extent. Studies have shown that bioavailability of the pro-vitamin A is extraordinary sufficient to impact the nutritional status of individuals with VAD (Tumuhimbise *et al.,* 2013). However, more efforts to reduce this deficiency to the barest minimum need to be promoted as its effects have a huge health, economic and social impact on most developing countries.

Furthermore, micronutrients food enrichment is an effective machinery to minimise micronutrients malnourishment as a dietary-based approach. Among the efforts that had been adopted to reduce malnutrition was the enhancement of nutritional status of *fufu* flour with AYBF. The established combination of flours could be integrated into the food to avert protein malnourishment in most emergent countries where cassava based food are commonly eaten (Blessing *et al*., 2013). *Gari* has also been enriched with AYBF to improve its nutritional quality (Okoye, 2015). Fortification of other cassava based foods is equally essential.

2.8 Vitamin A and its Efficiency

Two dietary bases of vitamin A are well known: preformed retinoids and PAC. The total vitamin A source of an animal can be obtained from the two sources depending on some factors such as nutritional supply, intestinal absorption and metabolic ability to convert PAC to retinoids (Green and Fascetti, 2016). This vitamin is obtained from diet, either as assembled vitamin in animal foods or as a precursor of vitamin A in plant foodstuffs, namely: coloured fruit and vegetables (Tang, 2010).

Vitamin A comprises all-trans-retinol and the family of naturally occurring molecules related with the biological activity of retinol (such as retinal, retinoic acid, retinyl esters), as well as provitamin A carotenoids which are dietary precursors of retinol. Preformed vitamin A is effectively absorbed (70–90%), while β-carotene absorption appears to be extremely variable (5–65%), depending on diet and diet-related factors, genetic characteristics and the health status of the consumer. The intestine is the main tissue where dietary provitamin A carotenoids are converted to retinol (EFSA, 2015).

According to Li *et al.* (2010), the extent of bioconversion of β-carotene to retinol was reported as 7:1. However, La Frano *et al*. (2013) and Phorbee *et al.* (2013) stated 4.5:1 and 6:1 for PVAC foods, respectively. Of the three: β-carotene, alpha carotene and beta cryptoxanthin, β-carotene possess best pro-vitamin A influence; though beta cryptoxanthin and alpha carotene had better bioavailability rate (Burri *et al*., 2011).

Bioavailability is the portion of the eaten nutrients which is accessible for normal functional purposes and preservation. There are numerous ways for determining carotenoid bioavailability with flexible grades of achievement. The simplest technique includes evaluating the serum or plasma response after carotenoid ingestion. This technique is suitable when comparing bioavailability between doses or dietary treatments (Green and Fascetti, 2016).

2.8.1 Method of measuring bioavailability

The best technique of assessing retinol content is employing High Performance Liquid Chromatography (HPLC). It is costly, strictly difficult and usually not accessible in developing nations (De Pee and Dary, 2002). Presently, HPLC is the greatest device for retinol evaluation. Therefore, provision of simple and less expensive procedure for this assessment is required for use in lowly environment. This vitamin is deposited mainly in liver as retinol hence, liver preserves and reveals the real vitamin A position. Though, shortest assessment of liver stocks is impossible. Assessment of serum retinol content is discovered as the situation method of evaluating VAD (WHO, 2009).

2.8.2 Factors affecting bioavailability

Many factors impact on the carotenoid bioavailability among which are:

Food matrix: The type of food matrix in which carotenoids are located determines their bioavailability to a great extent. Processing, such as mechanical homogenization or heat treatment, has the potential to enhance the bioavailability of carotenoids. Processing, such as mechanical homogenization or heat treatment, has the potential to enhance the bioavailability of carotenoids from vegetables (from 18% to a sixfold increase) (Van het Hof *et al*., 2000). For instance, spinach processing method to destroy the diet matrix prior eating enhance the β-carotene bioavailability in individuals (Castenmiller *et al*., 1999).

Vitamin A Position: Existing vitamin A (VA) can influence β-carotene absorption. Therefore, it influences the effectiveness of change of β-carotene into vitamin A so it may compensate for alterations in bioavailability (Green and Fascetti, 2016).

Carotenoid interactions: According to Kostic *et al.* (1995); O'Neill and Thurnham (1998), β-carotene content of food seems to diminish the absorption of many other carotenoids in humans when eaten together, including lutein and lycopene.

Dietary fat: It increases the imbibing of β-carotene because it is needed for creation of the mixed micelles in which β-carotene moves from intestinal lumen to the enterocyte. Furthermore, fat helps in conversion of carotenoids from an aqueous substrate (fruits and vegetables) to solubilization into mixed micelles (Green and Fascetti, 2016). This was in accordance with La Frano *et al.* (2013) in which yellow-fleshed cassava porridge prepared with oil displayed more β-carotene bioavailability in women nourished with the food compared to those nourished with the same meal without oil. The work showed that the newly bred varieties of cassava might be an active part of diet-based contributions of minimising VAD in people who consume this food regularly. It has been gathered that little quantity of oil is enough for effective absorption of functional quantity of β-carotene (Ribaya-Mercado *et al.*, 2007; Davidsson and Haskell, 2011).

Similarly, Pillay *et al*. (2014) stated that processing can enhance carotenoids bioavailability by unsettling the diet medium though, it can as well result in loss of carotenoids. Furthermore, diet preparation by cooking and frying, as well as mastication of food could help in discharging carotenoids in the food through diffusion of water and fat, that will ease the enzymatic ingestion of macromolecules and extraction of carotenoids.

Dietary fibre: It reacts with bile acids to upsurge the fecal evacuation of fats and other fat-miscible compounds such as carotenoids. Furthermore, fibre might entrap carotenoids in the intestinal lumen. Also, parasitic infection might diminish the bioavailability of β-carotene (Green and Fascetti, 2016). Jalal *et al.* (1998) revealed that children established increased absorption of β-carotene from foods when they

were provided with anthelmintic treatment for the intestinal parasite *Ascaris lumbricoides*.

2.9 Legumes

They are essential components of well-adjusted food in most areas of the globe owing to their richness in protein and starch composition. They are eaten locally as full seeds for snacks or as flour after removing their hulls. Rapid development in food companies that continuously requires fresh ingredients attracted scientists to legume ingredients (Adebowale *et al.,* 2009). They are well-known as a cost-effective basis of energy and protein food, especially for emergent countries because of its richness in protein (23-25%) and carbohydrates (50-67%) (Olapade *et al*., (2012).

According to Alozie *et al*. (2009), leguminous plants play an essential role in human nutrition by providing a significant amount of food in developing countries. They along with cereals, roots and vegetables constitute the staple foods and rank next to cereal as basis of human foods. They provide much of the required protein to the fruitarian population. Butt and Batool (2010) reported that legumes have high protein quality thus, have the potential to fight malnutrition in the emergent countries. This can be achieved by ensuring that they form part of daily diets.

Food-safety and sustainability is a crucial global concern in current eras. Most indigenous diets of Africa that have potential of reducing nutritional deficiency are often abandoned and not consumed (Adewale and Odoh, 2013). One of the primary challenges of food security is abandonment of most possible food security harvests in most developing countries. Nigeria is among the African nations that is blessed with diversities of legumes which are vital for food safety (Saka *et al.,* 2004; Saka *et al.,* 2007).

African yam bean belongs to neglected bean of humid and sub-humid parts of globe that enticed investigation in current periods (Azeke *et al.,* 2005). It belongs to one of those crops with remarkable nutritional potentials (Adewale and Odoh, 2013). It ranks well among neglected crops and can contribute to food security if its genetic resources are saved for utilisation in breeding and improvement (Adewale *et al.,* 2012). Furthermore, it is broadly used for many food processing and has potential for

complementing protein requirement of numerous families (Ajayi, 2011). Its protein concentrate is widely utilised in fortification of starchy foods (Eneche, 2005).

2.10 Agronomy of African Yam Bean

African yam bean is an essential produce in most African countries that is usually planted to offer two eatable foods, the tuber and the seeds (Olasoji *et al.*, 2011). It is highly adjustable crop having the ability of producing on acidic and extremely leaked sandy soils (Oagile *et al.*, 2012). It was cultivated for this study and its plant with the seeds in cobs were shown in Appendix 1 and Appendix 2. Its planting period usually begins after stabilisation of the rain between fifth and seventh month of the year in Nigeria and Ghana (Okpara and Omaliko, 1995; Klu *et al*., 2001). It displays hypogeal sprouting that happens between four and seven days after planting. Its seeds of between two and three are spread at the base of piles of main crops (Adewale, 2011).

In Nigeria and Ghana, it is cultivated as an insignificant produce in varied relationship with other crops particularly, cassava and yam (Amoatey *et al.*, 2000; Saka *et al.*, 2007). Its lonely planting is rare, frequently planted sideways with yams to portion similar stake for backing (Amoatey *et al*., 2000; Ibeawuchi *et al.*, 2007). It produces pods, extremely rich in protein seeds and capable of growing in fringe regions where additional pulses cannot boom (Enwere, 1998). It has the possibility of meeting the constantly growing protein demands of the people (Yusufu *et al*., 2013).

It is a dynamic plant, which turns and rises to altitudes of around 3 m. Owing to its potential of climbing to such height, it requires staking. It has slightly woody pod that contains between twenty to thirty seeds depending on the length and maturity of pod during harvesting. It reaches its full maturity at around 170 days of planting (Klu *et al*., 2001). Its seed types are numerous with variation in dimension, shape and the colour of the seed coat. There exists variation in colour of the seed coat that ranges from brown to reddish brown, white to many shades of cream, grey and black to mention a few. Most common seed shapes include round/spherical, oval/ellipsoidal, oblong and rhomboid. Significant differences existed among the accessions on the basis of their dimensions, breadths and their ratios (Adewale *et al*., 2010).

The length of the seed was lengthier than its breadth and width but the variation between seed breadth and thickness was irregular. This was in agreement with the work of Ajibola and Olapade (2016). Meanwhile, there were consistent and foreseeable connection among the seed length, breadth and thickness. These seeds measurements are essential in determining the shape of the crop (Adewale *et al*., 2010). The source and types of some of AYB seeds varieties were depicted in Table 2.4.

2.10.1 Geographical distribution of African yam bean

African yam bean belongs to leguminous crop that is often cultivated in most West African countries (Ajayi, 2011). It endures wide geographic, climatic and edaphic ecosystems that lies between the scopes of 15 ºN to 15 ºS and 15 ºW to 40 ºE of the continent. Its cultivation is common to both southern and northern parts of Nigeria (Adewale *et al.*, 2008). The accessibility of hereditary properties of the produce is endangered by its abandonment as well as under-utilisation which will have an aggressive effect on its cultivation (Adewale and Dumet, 2009). Meanwhile, Adewale (2011) reported that extensive investigation of its hereditary properties in Africa might offer guarantee for its prospect hereditary enhancement. Therefore, efforts to explore on its genetic resources and utilisation should be appreciated most especially in the emergent nations.

2.11 Nutritional and Medicinal Importance of the Crop

African yam bean is a multipurpose leguminous plant, appreciated for its richness in protein tubers, seeds and leaves that are utilised as spinach (Oagile *et al.,* 2012). Its seeds have rich dietary profile with great quantity of food composition among which are energy giving food, protein rich food, fat and additional nutrients like other major leguminous crops. Processing significantly minimised its anti-nutritional content with insignificant consequence on the nutritional value. In lieu of its nutrient accessibility, small anti-nutritional composition and mineral content, its intake most importantly cooked seeds might aid to fight the consequence of malnutrition mostly encountered in northern part of Nigeria and emergent nations worldwide (Ndidi *et al*., 2014).

Its seeds are good in vitamins and minerals especially vitamin B and C, dietary fibre, but deficient in saturated fat, sodium, and cholesterol (American Society of

Table 2.4. Profile and Colour of Some Accessions of African Yam Bean Seeds

Accession Name	Source/Area	Seed Skin Colour	Seed Shape
TSs1	Nigeria /Calabar	Tan	Spherical Rhombus
TSs3	Nigeria	Tan	Spherical
TSs4	Enugu	Brown	Ovoid
TSs7	Nigeria /Umuchite	Greyish Brown	Ovoid / globose
TSs10	Obuduigota	Cocoa-coloured (speckled)	Ovoid/ globose
TSs11	Nigeria	Creamy white	Globose
TSs63	Nigeria	Tan	Ovoid
TSs65	Zaria	Coffee	Ovoid
TSs82	Nigeria	Tan	Ovoid/ rhomboid
TSs84	Nigeria	Tan	Ovoid/ globose
TSs90	Ikot-Ekpene	Tan black (speckled)	Ovoid/ globose
TSs94	Ikot-Ekpene	Brown	Ovoid
TSs104A	Unknown	Cocoa-coloured (speckled)	Ovoid
TSs104B	Unknown	Greenish white	Globose
TSs111	Nigeria Ikot-Ekpene	Tan	Globose
TSs112	Nigeria	Tan	Globose
TSs119	Unknown	Tan	Globose
TSs130	Unknown	Tan (speckled)	Ovoid/rhomboid

Source: Popoola *et al.* (2011)

Agronomy, 2007). Similarly, it is good in additional minerals among which are iron, potassium and phosphorus (Ajibade *et al.* , 2005). Its tubers and seeds contain protein contents that varied from 11 to 19% and 21 to 29% respectively with up to 50% energy giving food commonly starch (Eromosele *et al.,* 2008). Both seeds and tubers have protein contents higher than other leguminous products (Azeke *et al.,* 2005) except soybeans. Its protein content comprises above 32% indispensable amino acids, of which leucine and lysine form the majority (Onyenekwe *et al*., 2000). According to Ekop (2006), it comprises of all amino acids found in plant protein.

Its lysine and methionine composition are stated to be greater than those obtained in other legumes such as cowpea and pigeon pea to mention a few (Uguru and Madukaife, 2001). These amino acids composition were similar or superior to that of soybeans (Yetunde *et al.,* 2009). Its protein content compared well with those of other African root crops and contain up to ten times as much as protein content of cassava roots while, its indispensable proteins and those of soybeans are comparable (Norman and Cunningham, 2006).

Its medicinal significance has overextended to the extent that epidemiological researches have testified that legume eating is substantially and inversely connected with circulatory illness hazard (Flight and Clifton, 2006; Nagarajan, 2010; Hutchins *et al.,* 2012). This might enhance its consumption especially by health concern consumers. The proximate and fatty acid composition of the seed accessions were significantly different (Adeyeye *et al.,* 1999). The significant difference in their proximate composition was validated by Ameh (2007).

2.12 Constraints to African Yam Bean Utilisation

Some circumstances have adversely predisposed the yield and adequacy of crop among farmers, buyers and researchers. The most common of these is the characteristic toughness of seed coat (Ene-Obong and Okoye, 1993). Adebowale *et al*. (2009) reported AYB as an under-utilised crop owing to its little social honour and deficient of complete data on its compositional examination. Other limitations to its farming and consumption comprise of occurrence of anti-nutrients, extended cooking period (Fasoyiro *et al*., 2006) and poor seed productivity (Saka *et al*., 2004). One of

main restrictions hindering its wide-spread utilisation is the presence of anti-nutrients (Akinmutimi *et al.,* 2006). Azeke *et al*. (2005) itemised the results of anti-nutritional contents of three of its accessions namely black, marble and white accessions as displayed in Table 2.5. It was discovered that there were significant differences among the accessions particularly in their cyanogenic glycosides.

Nwosu *et al*. (2012) stated some limitations such as reduced swelling ability in its matured seeds, production of black liquid during cooking and difficulty in dehulling of its dry seeds. The aforemention drawbacks can discourage its use for some food products that need dehulling e.g moi-moi and akara. Other problems connected with the crop include flatulence and beany off flavour which can also have influence on its consumption and acceptability rate. Agbenorhevi *et al.* (2007) opined that researches have revealed numerous processing techniques such as soaking, autoclaving, fermentation, recurrent boiling and enzyme treatments do have reductive effect on anti-nutritional factors which include oligosaccharides and thus boost the bean protein digestibility. Nevertheless, the degree of oligosaccharides loss varied owing to varietal alterations that affect the inherent composition and extent of absorption. It was observed that most processing methods do control the flatulence associated with beans meal.

2.12.1 Anti-nutritional factors

They are compounds that reduce the nutrient utilisation of plants or plant products used as human foods and play a vital role in determining the use of plants for humans (Gemede and Ratta, 2014). They are undesirable components in legumes that could hinder utilisation of essential minerals including calcium, magnesium, iron and zinc etc. They interfere with their absorption and utilisation and thereby contribute to mineral deficiency (Vasagam and Rajkumar, 2011; Qayyum *et al*., 2012). They are generally toxic and may negatively affect the nutrient value of seeds by impairing protein digestibility and mineral availability. However, they are heat labile and hence may be inactivated by processing methods involving heat generation (Ndidi *et al*., 2014). Cyanogenic glycoside, hemagglutinin, saponin, protease inhibitor, oxalates, phytates and anti-vitamins are good examples (Onwuka, 2005).

2.13 Noodles

They are foods with tiny and extended size that can be cut into desired size. They are

Table 2.5. Anti-nutritional Composition of Three Varieties of AYB Seeds

Anti-nutrients	Quantity
α-amylase inhibitor	(6-12.6) AIU/g
Trypsin inhibitor	(0.68-3.04) TIU/mg
Tannins	(0.92-19.5) mg/g
Phytic acid	(4.51-7.37) mg/g
Cyanogenic glucoside	(37-225 mgHCN/kg

Source: Azeke *et al*. (2005)

made mainly from flour and water to make unrisen dough that is generally prepared in a boiling water. They are common as well as widely accepted by people because of their convenience to cook (Gotoh *et al.,* 2007). Sanni *et al*. (2005a) defined noodles as tiny food prepared from combination of flours, water and eggs through extrusion process. According to Chen *et al*. (2011); Li *et al*. (2012), requests for nutritious diets have improved and have influenced the noodle manufacturing in the sense that quite a huge number of noodle producers had established nutritionally improved noodles by incorporating native constituents. Many studies have exposed the essential of substitutive ingredient that might impact the noodle unit operations and final quality.

Based on Gulia *et al*. (2014), healthiness worries associated with the eating of instant noodles are regularly ascribed to greater quantity of fat in it. Approaches to decrease this problem could be established and approved in eradicating the difficulties and diminish the connected hazards. However, the recent trends in production of healthy food has provided the opportunity of developing numerous foods of good health properties. In lieu of this, noodle industry is facing a trial of releasing novel and well-designed instant noodle with reduced level of fat, salt and replacement of wheat flour with nutritious indigenous flour (Heo *et al*., 2013).

2.13.1 Noodle consumption pattern

Food consumption pattern not only influence the individual well-being but also have repercussion on the society as a whole (Hawarlin, 2007). Noodles are internationally recognised food due to its global acceptability and enjoyment by the consumers. This has placed the noodle-associated company in second leading, after bread (Jayasena *et al.,* 2008). For instance, based on WINA (2011), from 2007 to 2010 Nigeria was among the top five fastest growing countries in instant noodle consumption. It has thus become the largest instant noodle market in Africa, consuming 1.67 billion meals in 2010 which is equivalent to 0.9 meal/person /month.

Based on WINA (2011), noodle world market has been inreasing tremendously. For instance, India reached 3,260 millions packets. Regardless of age, area and gender, instant noodles are valued and eaten as a global food. This has made Nigeria to be placed as the 12th leading consumer globally with 1,540 millions packets. Its global demand has been estimated to be nearly 100 billion servings (WINA, 2015). Gulia *et*

al. (2014) reported that worldwide rise in instant noodles consumption has popularised it. This was attributed to its characteristics among which are affordability, easy to cook to mention a few.

2.13.2 Gluten-free noqdles

Currently, there is a rising awareness for non-wheat products due to the rapid rise in number of celiac patients. Celiac illness is a gastral condition that harms the villi, tinyhair such as protrusions in the small intestine which absorb nutrients owing to the immune system response to gluten (Crockett, 2009). Researches have endorsed non-wheat based foods as an appropriate cure for people with celiac illness, wheat bigotry and wheat incompatible responses (Gaesser and Angadi, 2012; Alvarez and Boye, 2014). Moreover, broad researches have been conducted on advance of novel kinds of noodles to enhance its functional fitness, welfares among which is edible gum addition (Choy *et al*., 2012).

Many categories of these noodles are made from wheat, while other kinds are prepared from diverse kinds of non-wheat starches or flours, include canna starch, maize starch, rice and buck wheat flours (Tan *et al.,* 2009). Consumption of noodles had brought about extensive reliance on wheat in most non-wheat manufacturing countries. Notwithstanding, feeding on wheat might be a source of food intolerance and sensitivity among which are immune system reaction, wheat intolerance (Rosell *et al.*, 2014) to some people. This among others has led to a growing request of non-wheat foodstuffs.

With this development, production of novel kinds of noodles from gluten free flours will be promoted and prioritised by the noodle producers. However, numerous studies have been conducted on non-wheat noodles with the use of diverse kinds of flours (Inglett *et al.,* 2005; Yadav *et al*., 2011; Heo *et al*., 2013). It was observed that rice flour appeared to be the finest substitute for noodle owing to its tiny size that will enhance noodle textural properties. Flours obtained from other indigenous crop can also be used for manufacture of non wheat noodles (Liu *et al*., 2012). For instance, Nwabueze and Anoruoh (2009) made noodles from cassava mosaic disease-resistant varieties flours. Likewise, composite flour was prepared from amaranth and cassava starch to prepare non-wheat pasta (Fiorda *et al*., 2013). Therefore, utilisation of gluten-free flours is highly significant to decrease importation of wheat, improve the

health of the consumers and promoting new product development that would boost the economy of the country.

2.13.3 Instant noodle manufacture

Instant noodles are produced from blend of flours, water, alkaline salt and other extra ingredients. It is eaten worldwide because of its unique properties among which are affordability, easy cooking, ready to eat, generally acceptable taste to mention a few (Yu, 2003). There are non-fried noodles that are usually vended with sachets of flavouring comprising the oil. They may be soaked in hot water for two to five minutes and parboiled type could be warmed prior eating from the pack. A portion of noodle is good in carbohydrate and fat, poor in fibre, vitamins and minerals (Lee, 2009).

Noodles are eaten in over 80 countries and this made it a worldwide recognised food. This is because noodle industry delivers 95.4 billion portions yearly to customers worldwide. Its requests are on the increase as depicted in Figure 2.1. China is the first position in noodles eating, while Japan and Vietnam ranked second and third position in the world (WINA, 2011). The industry has various types of noodles, though, instant noodles are the most expanding in the segment owing to their ease to cook and expediency (Kyaw, 2007).

2.13.4 Quality of instant noodles

The principal constituents of noodles comprising flour, water, salt and alkaline salt (usually carbonates of sodium and potassium). These ingredients offer adequate roles and characteristics to ensure production of high quality food (Choy, 2011). Alkaline salts are part of the significant ingredients which affect the quality attributes of native noodles. It adds to the improvement and production of preferred yellow colour (Asenstorfer *et al.*, 2006). Incorporation of additional ingredients can contribute to the production of high quality noodle. For example, egg powder addition helps in resisting high breakage and ensure good cooking quality. This brings about greater water absorption capacity and reduction in cooking loss. In addition, starch addition develops good look, outward softness and good mouth feel (Konik *et al.,* 2006).

In evaluating flour for noodle preparation, there are three significant quality characteristics to be considered: processability, noodle colour and texture. Noodle procedure is principally significant in the current manufacturing production. Each kind

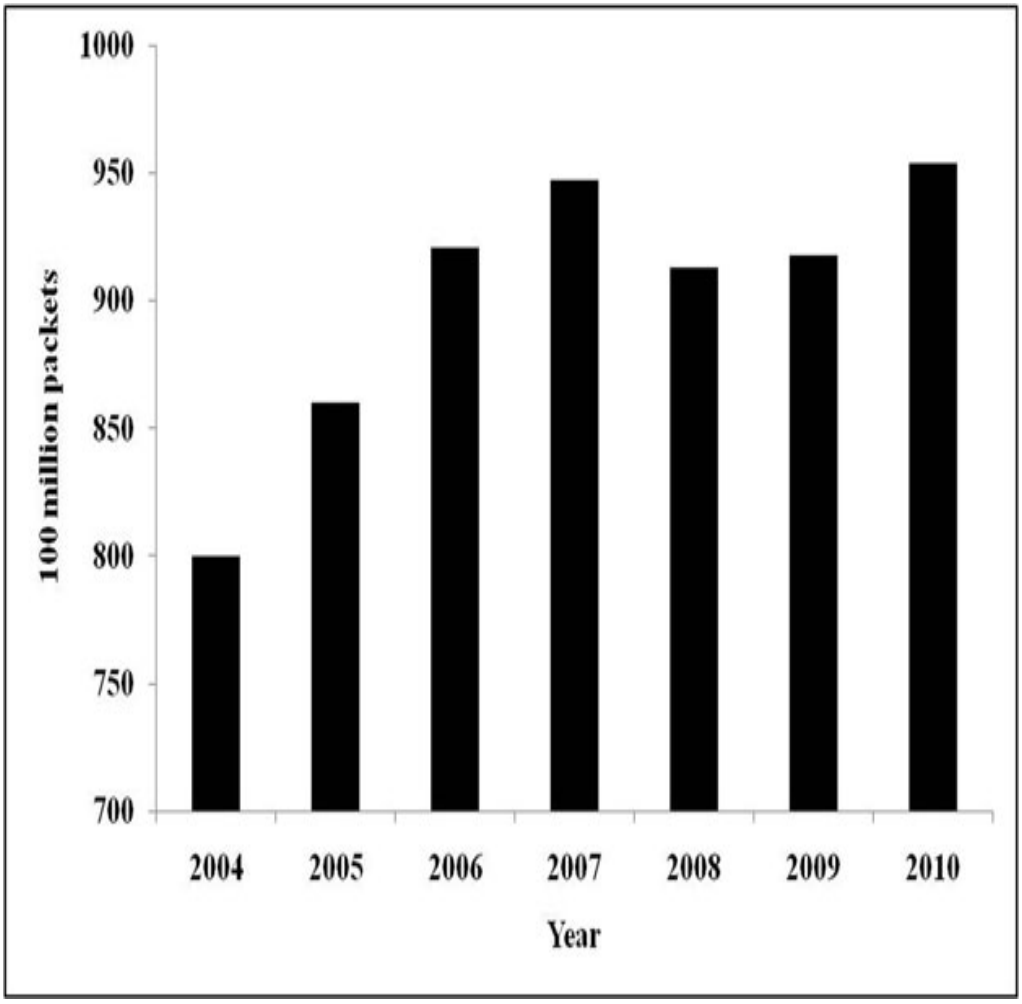


Figure 2.1: Global Feeding Statistics of Noodles

Source: WINA (2011)

of noodle has its own exceptional colour and texture attributes. Flour colour, protein and ash composition, yellow colour and enzyme action are indispensable influences accountable for the colour of noodle (Hou, 2001). Colour is known as the principal factor of pasta and noodle marketability (Li *et al.*, 2012). One of the main problems with new noodles and pasta is their endangered to browning. Therefore, it is required and highly essential to minimise this browning to improve their sensory attributes (Asenstorfer *et al*., 2010). This could be achieved by further processing of fresh noodle into a shelf stable food.

Flour characteristics are equally essential parameters to be thought of in producing high quality instant noodle. For instance, flour of high protein content affected the noodle colour brightness, reduce fat absorption, strong and flexible texture of cooked noodles. In lieu of this, protein quantity and quality were the main features that associated adversely with fat content of noodles (Park and Baik, 2004a). Nutrient composition of noodles differs broadly subject to the kind, quality and amount of essential ingredients as well as handling technique (Hatcher, 2001). For example, protein composition of wheat flour is very important in cooking and sensory attributes of noodles (Fu, 2008, Hou, 2011).

Besides, most noodles are produced from flours comprising 8-10% protein content. Generally, production of high quality noodles require flours of 7 to 9.5% protein for bag type and 11.5 to 12% for cup type. Moreover, flours of low protein are inappropriate for achieving textural firmness or taste compared to those prepared from flour (>10%) protein. This is because flour of low protein can not efficiently improve the preferred protein matrix during mixing and compressing. Therefore, flour containing low protein content needs fortification with protein rich flour so as to enhance noodle sensory quality (Choy, 2011).

Instant noodles are usually enriched to increase their nutritional value (Gulia *et al.*, 2014). The objective of incorporating indigenous proteins to noodle and its related products are to improve nutritional quality and maintaining tough dough arrangement (Maforinbo *et al*., 2008). By and large, noodle makers choose flour of low gelatinization temperature that consequences in rapid water absorption when cooking

(Fu, 2008). Widjaya (2010) opined that noodles essential quality characteristics include texture, colour, cooking qualities as well as microstructural properties. These qualities parameters were impacted by the raw materials used, preparations and handling. According to Hatcher *et al*. (1999), many ingredients among which are starch, water, protein and edible gum display essential role in description of noodle textural properties.

Noda *et al*. (2006) stated that noodle quality can be generally analysed using textural properties and other essential features of the cooked noodles among which are smoothness, firmness and elasticity among others. Furthermore, the characteristics of good quality noodles include bright colour with no or little evident of staining, good flavour, acceptable shelf life without noticeable microbiological deterioration and have good textural properties (Fu, 2008). In lieu of this, noodles quality is naturally determined based on colour, appearance, texture, taste, hardness, cooking loss and sensory evaluation.

2.13.4.1 Noodle textural properties

Texture is a vital characteristic in consumer decision making when purchasing food. It is referred to the physical appearance of the arrangement of foods on the basis of their response to pressure (Razzaq *et al*., 2012). These characteristics are the greatest thoughtful features of appraising quality and customers acceptability of boiled noodles (Hung-Chia *et al*., 2011). This assessment is an imitation of the stroke of chins by reducing bite-size part of diets two times. The resultant force-time curve obtained is utilised in deriving some textural properties. Therefore, it is usually well-known that this property is the greatest criterion in evaluating general superiority of boiled noodles (Dziki and Laskowski, 2005; Manthey and Dick, 2012).

Appropriate assessment of noodle cooking quality needs observation of numerous factors. The use of taste panellists can also be adopted in evaluating noodle cooking quality, but these are strenuous and unreasonable especially once large quantities of noodles need to be assessed (Smewing, 1997; Borneo and Aguirre, 2008; Wood, 2009). Considering these limitations, numerous methods such as the use of equipment

have been established which effectively evaluate cooked noodle textural features (Oh *et al.,* 1983; Brennan *et al*., 2004). Structural and textural attributes of noodles are susceptible to numerous issues and major important of these properties are the uncooked materials, dough and drying circumstances (Zweifel *et al.,* 2003).

According to Ross (2006), instrumental methods offer uniformity in assessing essential automated and other physical characteristics that help in evaluating the texture of food. These frequently relate reasonably simple alteration geometrics to food samples in an hygienic test site location. These are generally adopted in evaluating noodle texture solely or to supplement sensory evaluation test. Extensive embracing of this method offers the researchers with an appropriate and affordable technique to assess alterations in automated properties as a consequence of variations in ingredients, preparation or environments. In addition, many studies have stated that these two main methods of analyses linked together.

Sensory evaluation is very specific, strenuous and costly. Consequently, faster and additional precise approaches suitable for noodles are required. However, instrumental methods are cheaper and not time consuming compare to sensory tests. It has been noted that the use of instrument in evaluating noodle texture is dependable and convenient substitute assessment to sensory method. Texture profile analysis (TPA) technique is generally applied to measure the noodle texture using a texture analyser because the method collects large amounts of data related to the noodle texture at once. However, this method is usually connected to serious sensory features that permit some level of consumer acceptability (Yu, 2003).

2.13.4.2 Microstructural characteristics of noodles

The importance of microstructural properties in noodle quality cannot be overemphasised. According to Gulia *et al*. (2014), dough and noodles microstructure have been investigated so as to comprehend the influence of ingredients and processing variables on the noodle quality. Scanning Electronic Microscopy (SEM) analysis confirmed the modifications in noodles microstructure (Sun *et al.,* 2019). According to Sung and Stone (2005) in their work on microstructural studies of pasta and starch pasta, it was opined that numerous trivial holes were apparent on exterior of

the dry pasta that might allow diffusion of water into the internal part of pasta when cooking.

2.13.5 Instant noodle unit operations

According to Hou (2001), notwithstanding the big differences in preparation, dimension, noodles shape and procedure to make the strands is extraordinarily not changing for varied kinds of noodles. The quality of noodles is affected by quantity of uncooked constituents namely flour, water, salt and handling situations among which are mixing time, sheeting, steaming and frying. Noodles are usually in two forms: steamed and air dried (instant dry noodle) and steamed and fried (instant fried noodle). It is essential to highlight and explain these processing steps.

2.13.5.1 Dough mixing

Instant noodle preparation starts with this step and the magnitude of blending has a serious effect on superiority. It is usually done in a flat or upright blender. The flat blender is usually employed in the commercial setting as it yields superior blending outcomes (Hou, 2001). Reasonable blending speed can be embraced to avert gluten collapse and denaturation of wheat protein, particularly in wheat based flours (Huang, 1996). Other ingredients apart from flour are pre-dissolved in warm water. This mixing differs from four min (Yu and Ngadi, 2004; Park and Baik, 2004b) to twenty min (Yahata *et al.* , 2006). Bui and Small (2008) opined that ingredients were mixed intermittently for one to four min to form dough. According to Kim (1996a), mixing of ingredients allows smooth moisture delivery among flour particles, food components and other organic ingredients. This gives rise to development of dough with a consistent interior structure.

The recommended water holding capability in noodle preparation is around thirty to thirty-eight percent based on mass of the flour. Substantial deterioration in textural features rises with rise in water holding ability (Edwards *et al*., 1996; Hatcher *et al*., 1999; Park and Baik, 2002). However, Kumar and Prabhasankar (2015) used 40-45% for their noodle formulation. Based on preliminary study in this research, it has been observed that water holding ability is determined by the kind of flour to be used since dissimilar flours have dissimilar water absorption capacity. Water retention ability determines quantity of water require to form dough. According to Widjaya (2010), the

rate of water absorption considerably influences the shelf life features of foods. For instance, lesser water absorption aids in reducing noodle discolouration and minimises the quantity of water to remove in final frying or drying method.

Hydrocolloids addition is the most essential strategy established to imitate the features of wheat in non-wheat foods (Moore *et al*., 2006; Lazaridou *et al.*, 2007; Arendt *et al*., 2008; Alvarenga *et al.*, 2011; Ho and Noor Aziah, 2013). They enhance water absorption features of noodles when cooking, regulate the consistency and general "taste" of end product and decrease oil absorption ability when frying of noodles. This is because they are hydrophilic thus, possess high water absorption capacity (Yu and Ngadi, 2006).

Additional ingredients such as stabilisers and food colours could be included. The best commonly used stabilisers in instant noodles production comprising guar gum, carboxyl methyl cellulose to mention a few. These are usually added at 0.1 to 0.5% (Moore *et al*., 2006; Lazaridou *et al*., 2007; Arendt *et al*., 2008; Alvarenga *et al*., 2011; Ho and Noor Aziah, 2013). Furthermore, utilisation of xanthan gum improves the dough uniformity and dough cohesiveness (Lazaridou *et al*., 2007). In the meantime, mixtures of varied amount of salt (0-2%) and alkaline salts (0.1-0.3%) were achieved as the best ranges for the aforemention ingredients (Widjaya, 2010).

2.13.5.2 Dough resting

This unit operation permits dough to rest for a period of about 20 to 40 min before compressing into flat shape. It fast-tracks additional incorporation of water into flour and permits thorough mixture of water in dough system. It helps elasticity of dough development, yields smoother and less varied dough (Hou, 2001). According to Crosbie and Ross (2004), researches have revealed that relaxed dough possess a better constant protein medium, less cavity and less protein shrinkage above the compressed exteriors than unrested ones.

2.13.5.3 Sheeting

This involves compressing of dough to make constant dough, that is folded and passed over successive moves. This step is meant to attain a fine compress dough of chosen width, constant and uniform gluten matrix of compress dough (Gulia *et al.*, 2014). It is essential for noodle dough to be adequately firm to tolerate compressing, but should

not be too strong to tear or crack the dough. Therefore, acceptable strong elasticity of dough and stretching are needed in dough of all noodles. Decent flattening of dough stretching confirms that compressing dough should not be diminished during continuous move. Flour of rich protein content with firm gluten needs compression movement to attain needed last sheet width (Choy, 2011).

Compressing, size reduction and removal of water from noodles are perplexing when water absorption departs for about two to three percent from the optimal amount. Inadequate water results in no constant rigid dough and fewer stretching noodle, however excessive water consequences into dough gumminess thus, management problem rises in preparation (Hatcher *et al*., 2008).

2.13.5.4 Cutting

The compressed dough is divided into noodle strands of wanted dimension using a narrow cutter. Thickness and shape of strands are affected by slitting moves. This could either be square or round shape based on numerous slitters used. For instant noodle processing, noodle strands are constantly served into roving conveyor that travels gentlier than slitting reels on it. Strands are divided into needed dimension using cutter (Gulia *et al.*, 2014). There exist many sizes of noodles that are varied from 1.0-7.5 mm and the drying and cooking time are affected by the thickness and dimension of the strands (Crosbie and Ross, 2004). Metal blocks are used to cut the size of noodle strands into desired shape and the strands obtained are exposed to steaming, frying or drying and finally packaging (Choy, 2011). For extruded noodles, the size and shape of noodle filaments are usually formed by the extruder die.

2.13.5.5 Extrusion

Extrusion processing is one of the new physical processing method employed in food technology for production of various novel foods among which are noodles, pasta products, complementary foods, texturized vegetable proteins, snacks and convenience foods (Aworh, 2014). It is presently adopted in foods production and grouped into two kinds namely: cold extrusion and hot extrusion. Cold extrusion is the non-cooking type of extrusion that converts the food into similar consistent extrudates without cooking, while hot extrusion is the cooking type that involves high temperature short period that cooks the food ingredients using mixture of heat, automated cutting and force (Rizvi *et*

al., 1995; Nwabueze and Iwe, 2008). Non-cooking extrusion involves low heat of dehydrating convenience foods among which are pasta and other noodle products which Nigerians are usually conversant with and willingly consume (Nwabueze *et al.*, 2007). It is cheap and affordable technique that requires low level of energy in its procedure.

2.13.5.6 Steaming

This is an essential procedure in producing instant noodles. It involves great grade of starch gelatinisation that is essential in manufacture of instant noodles. The noodle filaments are taken to a steam compartment to parboil them by subjecting them to a temperature of 100 ^{o}C for 1-5 min. This procedure is essential and rely on the preliminary moisture content of noodle, quantity of force, steaming temperature and time. Adequate steaming is highly important in production of high quality noodles. Insufficient steaming produce a stiff central noodle that will be difficult to cook well, while over steaming produce soft and gummy noodles (Gulia *et al*., 2014). Pronyk *et al*. (2008) opined that superheating steaming at high temperature is being used to moderately heat, rapidly dry and making an instant noodle without frying.

Steaming time was testified to influence the final physical properties of the product. Too much steaming seems to produce uneven drying and resulted in development of tough and gummy appearance. Meanwhile, inadequate steaming makes the noodles to become delicate and predisposed it to breakage (Kubomura, 1998). For instance, Bui and Small (2008) steamed noodles for 2 min. Furthermore, Fu (2008) reported that instant fried noodle is produced by constant steaming and frying procedure that gelatinises the starch and rapidly drying it, while instant dried noodles are not fried but oven dried after steaming.

2.13.5.7 Drying/Frying

This processing step depends on the type of noodle to be produced. Production of an instant dried noodles require drying process, while instant fried noodles involve frying. According to Gulia *et al*. (2014), hot air is applied in drying noodle filaments to produce instant dried noodles. Though, instant fried noodles are chosen to hot-air instant noodles which require lengthier cooking time. Low fat content of instant dried

noodle creates good-looking and heathier product. This is because elimination of oil from noodles will lessen health worries of fat content that will provide consumer with appropriate and fit food product.

Acceptability of instant dried noodle depend mostly on producing good textural properties and eating quality. Elongated dehydration time may be the basis of contraction in noodle structure and this will impact on cooking time and final texture. Rancidity of noodles can be minimised by removing frying to achieve an extended shelflife. Non-fried instant noodles are now gaining acceptance particularly where consumer's consciousness of healthy foods is common and may be an issue (Choy, 2011). According to Aluyor and Okwundu (2015), oven drying is a better drying method than frying for all noodle samples from the standpoint of nutritional value. Dietary fat can be regulated by oven-drying food samples rather than frying in oil.

2.13.5.8 Classification of noodles

There are numerous strategies used in noodle classification but the greatest common methods are two: based on processing procedures and kinds of raw materials used. On the basis of processing procedures, noodles are grouped into fresh, dry, cooked, steamed and instant types. Similar main processing steps are adopted for all noodle types. Noodles that are sold instantly after production are called fresh noodles. These are generally sprinkled with good flour instantly next to cutting so as to avoid sticking together. They can be treated more by aeriation, boiling, steaming and cooking in hot water. Dehydrated noodles can be manufactured from uncooked fresh noodles that had experienced an organised aeriation procedure. Meanwhile, boiled noodles are immersed in boiled water to parboil it and steamed noodles can be prepared by exposing fresh noodles to vapour. Instant noodles are made by exposing the noodles to vapour and dehydrating either by deep frying or oven drying process depending on the desired instant noodle (Choy, 2011).

Fried instant noodles: Frying of noodles minimises its moisture content to about two to five percent, while air dry noodles has a moisture content of around eight to twelve percent. Heating when frying or hot air aeriation gelatinises starch to achieve a permeable texture that enhances rehydration procedure during cooking. Most instant

noodles are fried owing to the fact that hot air aeriation consequences in irregular drying that affect the quality of end product. However, fried noodles has 15-20% fat content compared to a peak of 3% fat content in air-dried noodles. This high fat content of fried noodle made it vulnerable to oxidation that results in rancidity which has health concerns (Gulia *et al*., 2014).

Heated-air dried instant noodles: These are dehydrated in heated air at about 70-80 °C. The merits of these products comprising low fat content and longer shelf life. Nevertheless, low productivity, poor taste and poor texture are features that make these products less familiar comparing to instant fried noodles. Meanwhile, instant fried noodles are common owing to its lesser preparation period, reduced water replenishment period, delicious taste and good texture (Yu, 2003). The processing steps for the production of diverse kinds of noodles are depicted in Figure 2.2.

2.13.5.9 Packaging

Marsh and Bugusu (2007) opined that packaging plays a substantial part in predicting food storage stability of the end product. Correct choice of containers and the machineries of keeping the product quality during transportation, storage and distribution are essential. Some of the common food packaging materials adopted in most food industries comprising glass, metals, paper and paperboards and plastic containers. It offers safety from the main kinds of exterior influences: physical, chemical and biological (Gulia *et al*., 2014).

Polyethylene and polypropylene packaging materials have an effective mixture of properties comprising plasticity, strength, weightlessness, steadiness, moisture and chemical resistance and simple processing. They can be reuse and recycle (Marsh and Bugush, 2007). They are usually used for bag noodles, while polyester are used for cup noodles. Noodles are generally packed in a non-transparent green or reddish yellow bag (Gulia *et al*., 2014). Hou (2011) opined that the quality of packaging materials is very essential in noodles packaging. This is because it protects and preserves the noodles during storage period without hosting extra toxins that are detrimental to

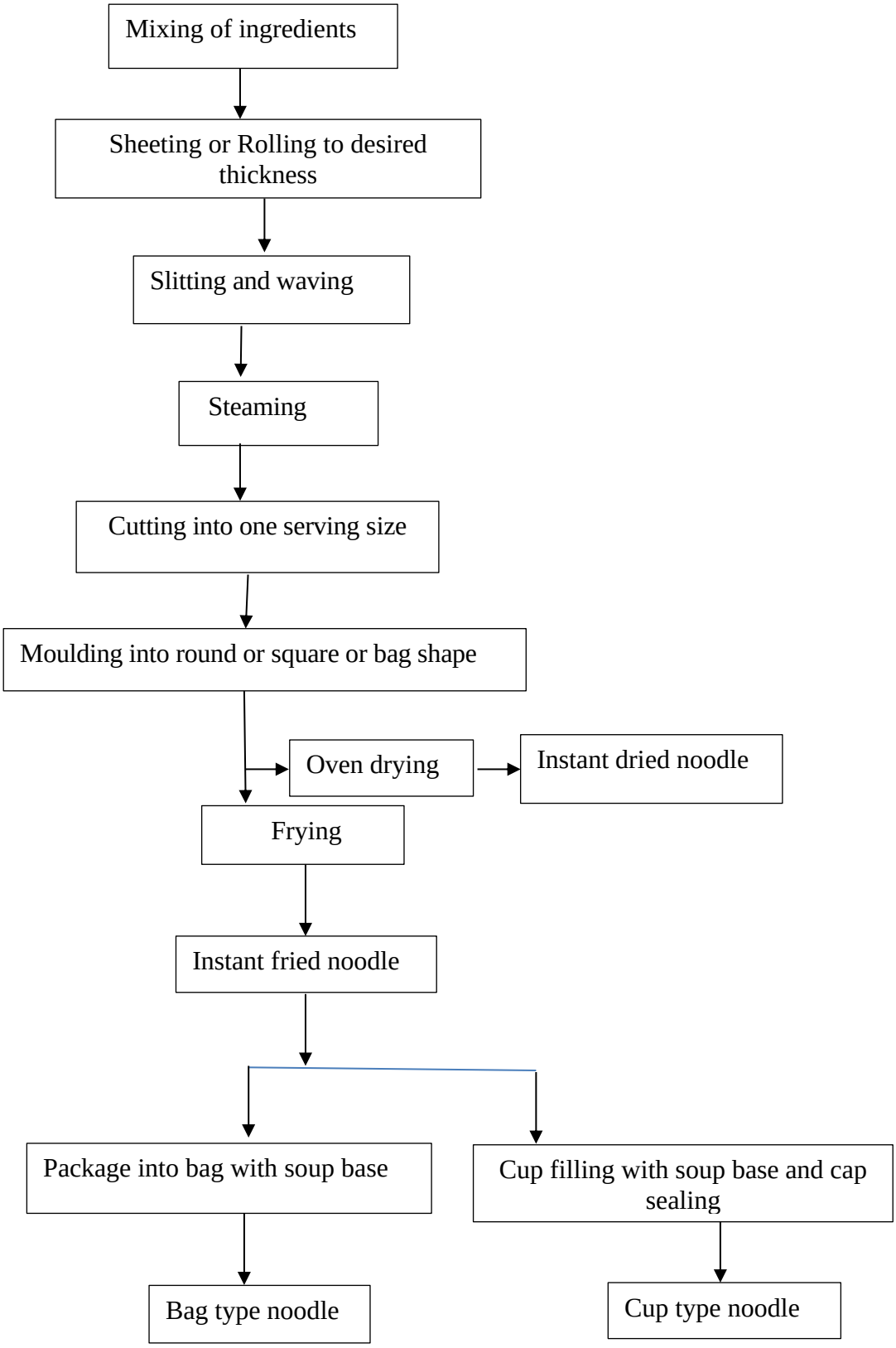


Figure 2.2: Production and Grouping of Instant Noodles

Source: Kim (1996b)

consumers. In lieu of this, appropriate packaging performs an important role in prolonging the product shelf life. Therefore, its importance cannot be overemphasised in the food industries.

2.14 Optimisation Techniques

Optimisation method is used to enhance the performance of a scheme and upsurge productivity without increasing the price. Response Surface Methodology (RSM) is unique of the essential procedures in optimisation method. It is a collection of arithmetical and numerical methods suitable for developing, enhancing and boosting procedures (Garayo and Moreira, 2002). It has an essential application in designing, developing and formulating of novel products as well as improving an existing products (Idowu, 2013). It is a quicker and less costly technique for collecting research outcome than traditional technique. RSM has effectively been used for development and optimisation of cereal products (Thakur and Saxena 2000; Chakraborty *et al*. 2011; Vijayakumar and Boopathy 2014). Its efficiency in optimisation of quantity of raw materials, preparations and handling situations in Food Technology from uncooked to the end of foods among which are dry cassava mass (Gan *et al*., 2007) cannot be overemphasized.

2.15 Importance of Thermal Properties

They are heat associated properties that impact the manner a particular food substance permit or disallow the passage of heat. These include thermal conductivity, thermal diffusivity, specific heat capacity among others (Oyerinde and Olalusi, 2011). Choosing a precise dimension technique to describe thermal properties requirements depend on: sample information such as its geometry, size and sample preparation procedure, comprehending of fundamentals and processes of testing method and understanding of possible sources of mistakes that might impact the final results. (Zhao *et al*., 2016).

The dimension procedures of thermophysical properties is grouped into two classes: stable state and transient (momentary) methods. A typical example of momentary technique is the line heat source procedure. It is quick, relevant to nonconvective diet and natural ingredients due to minimal moisture loss from the food. In lieu of this, this technique is popularly used by the investigators in evaluating the heat properties of

food and natural ingredients compared to stable state techniques. Instance of transient evaluation of thermal conductivity of many food ingredients is being newly described by Opoku *et al*. (2006).

Some of the example of steady state measurement of thermophysical properties include parallel conductance method, comparative technique; radial heat flow method and absolute technique (Zhao *et al*., 2016). Presently, there have been no information on the thermal properties of instant noodles. Therefore, line heat method was adopted in this work to assess thermophysical properties of noodles.

2.16 Moisture Sorption Isotherm

Moisture sorption isotherm (MSI) of food is define as the heat transfer connection that existed in between the water activity (a_w) and equilibrium moisture content (EMC) of food product at continuous temperature and pressure. Its awareness and comprehension are highly essential in Food Technology and Engineering in designing and optimisation of aeriation machineries, designing of bundles, forecasting of quality, steadiness, storage stability and for computing moisture alterations that might occur when storing (Andrade *et al.*, 2011). It is grouped into two: adsorption and desorption beneficial in production design such as drying procedure, choosing a suitable and these procedures are heat and water activity dependent. This information are apparatus and packaging food material and forecasting of storage stability throughout shelf life and shipping (Kaymak-Ertekin and Gedik, 2004; Chowdhury *et al*., 2006; Samapundo *et al.*, 2007; Tunc and Duman, 2007).

According to Sobowale *et al*. (2017), sorption isotherms are valued implements for researchers, owing to its efficient usage in predicting likely fluctuations in organic materials. Adsorption isotherm information can be used as a storage guide, while the desorption isotherm data can be used for drying analysis. Many researches investigating the sorption performance of foods have stated the utilisation of saturated salt solutions compared to acid solutions for moistness control. Static gravimetric technique is usually chosen and adopted for determining moisture sorption isotherm of foods. This is owing to its ability to measure accurately the drying weight of food samples and their environment, reduction of temperature variability amid samples and their environments or origin of water vapour, among other merits (Aviara *et al.*, 2006).

Water vapour sorption isotherms are graphical plots of equilibrium moisture content achievable by food materials when kept under a constant temperature but classic outline of the isotherm reveals the manner which water binds to the system. Stronger water particle contacts produce a lower aw, that makes the product more stable, while the weaker water molecule interactions generate higher aw, that disposed the product to deterioration thus, the produce turn into unbalanced (Fabra *et al.,* 2009). This showed that moisture movement affect the condition of the food such as chemical and physical situation of foods. These will greatly impact on the shelf life of the food.

2.16.1 Water activities in foods

Water activity (a_w) is one of the greatest essential considerations in Food Technology as it is connected with the amount of water present in food for various reactions among which are physical, chemical, biochemical reactions and microbiological growth. Therefore, water activity is directly related to storage stability of foods. The connection between water activity and equilibrium moisture content of the products on steady temperature is referred to moisture sorption isotherm (Abramovic and Klofutar, 2006).

2.16.2 Moisture sorption isotherm models

There are many recommended mathematical models to explain MSI. Some of which were established with an hypothetical basis of explaining adsorption mechanisms (Raji and Ojediran, 2011; Blahovec and Yanniotis, 2009; Van der Zanden and Goossens, 2004; Mathlouthi and Rogé, 2003) however, others are simplification of intricate models (Yan *et al*., 2008). The greatest popular models usually utilised to explain sorption isotherm of food include the Langmuir, Oswin, Brunauer-Emmett-Teller (BET), Smith, Halsey, Iglesias-Chirife, Henderson, Peleg and Guggenheim-Anderson-de Boer (GAB) models (Sahin and Gülüm, 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Sources of Materials

Pro-vitamin A cassava tubers from newly improved cultivar (070593) and twenty five varieties (TSs 1, TSs 9, TSs 10, TSs 23, TSs 24, TSs 33, TSs 48, TSs 49, TSs 57, TSs 61, TSs 69, TSs 82, TSs 84, TSs 86, TSs 89, TSs 93, TSs 94, TSs 95, TSs 96, TSs 101, TSs 109, TSs 111, TSs 116, TSs 125 and TSs 137) of AYB seeds were collected from Cassava Processing Unit and Genetic Resources Centre of International Institute of Tropical Agriculture (IITA) Ibadan (Plates 3.1 and 3.2). Edible gum (Xanthan gum), ascorbic acid, pure analytical grade of sodium and potassium carbonates were purchased from a chemical store, while iodised salt was bought from Bodija market in Ibadan. Other noodle-making ingredients were kept dry and sealed in low-density polyethylene bags on a shelf prior to usage. African yam bean seed varieties were screened by analysing their protein, phytate and tannin contents.

3.2 Physico-Chemical Properties of Cassava Roots and African Yam Bean Seeds

3.2.1 Determination of colour of cassava roots and African yam bean seeds

The colour of peeled and grated cassava roots and milled African yam bean seeds were determined using Konica Minolta Chroma metre of model CR-410 (Japan). This apparatus was standardised using white tiles. The three dissimilar colour attributes: *L**, *a** and *b** were noted. The *L** determines brightness of which the highest value denote lighter, while *a** determines the equilibrium between redness and greenness of samples that displayed in positive and negative numbers respectively. The *b** designates the equilibrium between yellowness (+) and blueness (-). As *a** and *b** values nearer to zero, it shows reduced concentrated colour, while values far away from zero correspond to more concentrated colour.

From the finely grated cassava roots and milled African yam bean seeds, 15 g of each

Plate 3.1 Provitamin A Cassava Variety (070593)

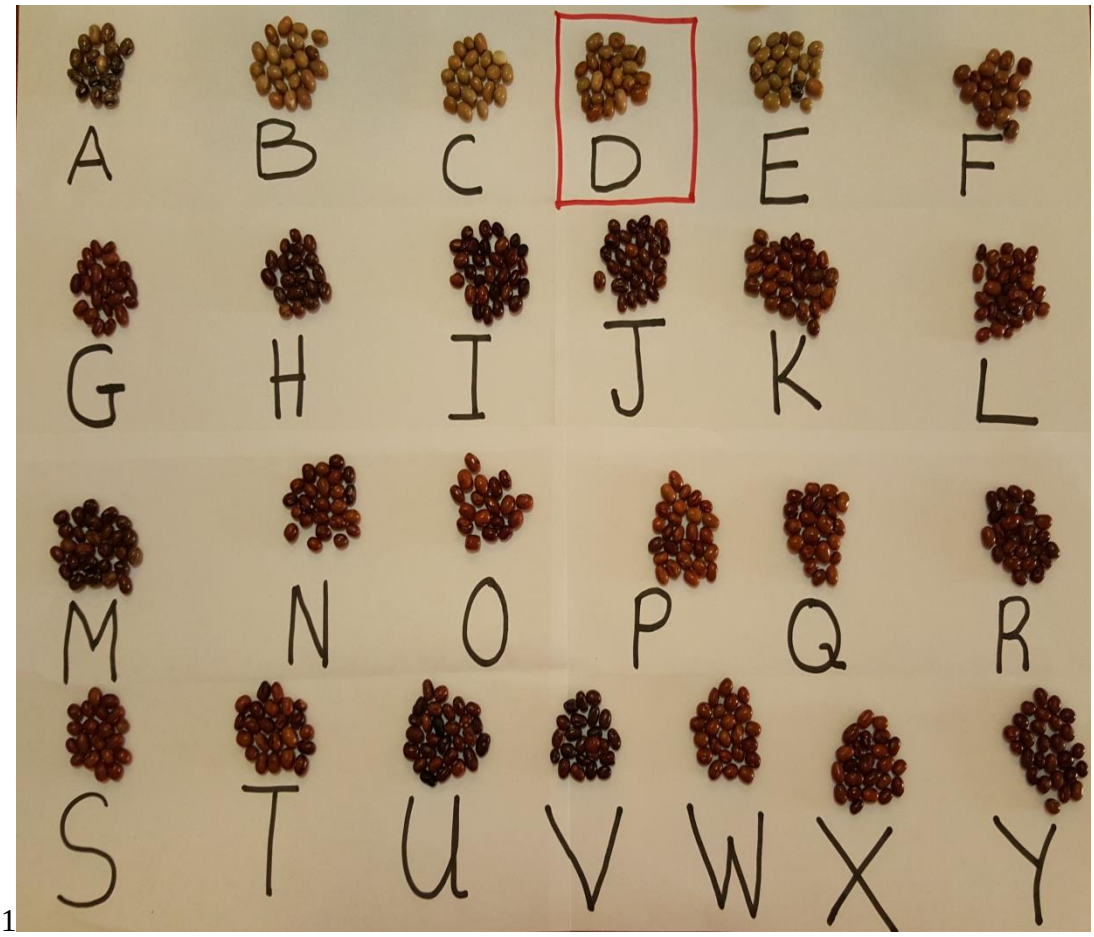
1 

Plate 3.2 African Yam Bean Accessions

A=TSs 56, B=TSs 61, C=TSs 93, D =TSs 94, E=TSs 116, F=TSs 1, G=TSs 9, H=TSs 10, I=TSs 23, J=TSs 24, K=TSs 33, L=TSs 48, M=TSs 49, N=TSs 69, O=TSs 82, P=TSs 84, Q=TSs 86, R=TSs 89, S=TSs 95, T=TSs 96, U=TSs 101 V=TSs 109, W=TSs 111, X=TSs 125, Y=TSs 137.

sample was weighed into a resealable transparent bag. The lightness and yellowness were determined via transparent bag. The samples were evaluated three times (n=3) by placing the measuring head in an haphazard manner to diverse positions on top of the sample (Choy, 2011).

3.2.2 Determination of proximate composition of cassava roots and African yam bean seeds

3.2.2.1 Determination of moisture and dry matter contents of cassava roots and African yam bean seeds

Technique of AOAC (2005) was adopted for analysing moisture and dry matter composition of cassava roots and African yam bean seeds. From each sample, three grams was measured using OHAUS weighing balance (model PA214, OHAUS corporation, Switzerland, USA) into a known weighed clean waterless can. This was put in a Fisher Scientific Isotemp^{R} Oven (model 655F, USA) and dried between a temperature of 103 and 105 ^{o}C for about 16 to 24 h until constant weight was obtained. This was cooled in a dessicator, weighed and recorded. Change in mass was noted as moisture as shown.

$$\% \text{ Moisture content} = \left(\frac{M_1 - M_2}{M_1 - M_0}\right) \times 100 \quad \text{.....3.1}$$

% Dry matter (DM) = 100-MC

Where M_0 =mass of empty can

M_1 = mass of can and wet sample

M_2 = mass of can and dry sample

Note that $M_1 - M_0$ = mass of sample prepared for drying

3.2.2.2 Determination of ash content of cassava roots and African yam bean seeds

This was investigated as reported by AOAC (2005) technique. Crucible was washed, dried, cooled in desiccator and weighed. Three grammes of mash cassava roots and milled African yam bean seeds were separately weighed in a crucible of identified weight. The crucible with each sample was placed in a Vulcan^{TM} furnace of model 3-1750 to burn off all the organic constituents at 550 ^{o}C for 6 h. The crucible with

sample was removed, cooled in desiccator and weighed. Residue weight after incineration was noted and ash content was expressed as:

$$\% \text{ Ash content } = \frac{W3 - W1}{W2 - W1} \times 100 \ldots\ldots 3.2$$

Let W_1 = Mass of crucible, W_2 = Mass of crucible + sample prior ashing and W_3 = Mass of crucible + sample after ashing.

3.2.2.3 Determination of crude protein of cassava roots and African yam bean seeds

Kjeldahl technique was followed in evaluating crude protein content of cassava roots and twenty-five accessions of AYB with the use of FOSS Kjeltec^{TM} protein analyser (2300 model, Sweden) followed the procedure of AOAC (2005) with minor amendments. The modifications included addition of 12 ml of concentrated H_2S0_4 instead of 4 ml. Each sample of 0.15 g was weighed into digestion tube, a tablet of Kjeldahl catalyst and 12 ml of undiluted H_2S0_4 were poured. The combination was positioned in Tecator digestion block predetermined at 420 ^oC and digested for 1 h. Blank was prepared and treated similarly. Digestion tubes were detached from digestion slab and permitted to cool to room temperature.

Addition of forty percent sodium hydroxide and application of heat were done automatically. Ammonia (NH_3) was liberated out and received in a percentage of boric acid receiver solution comprising bromocresol green indicator. The mass of sample to analyse was typed with the use of system keyboard. Tubes containing blank sample and those of samples' digests were positioned in distillating unit of the system one by one. The distillation and titration were performed automatically as programmed. The percentage of total nitrogen was displayed at the end of each analysis. This was used in calculating percentage crude protein as stated:

% Protein = % Nitrogen x 5.8

5.8 was used as a conversion factor.

3.2.2.4 Determination of crude fat of cassava roots and African yam bean seeds

An automated method of Soxtec system HT2 was used to determine the crude fat following the technique of AACC (2005). From each sample, three grams was weighed, moved into hygienic thimbles, stuck lightly with cotton wool and injected in FOSS Soxtec^{TM} (8000, FOSS Analytical Co., Ltd, Suzhou, China) extraction unit. Clean pre-weighed extraction cups comprising of 70 ml of petroleum ether were inserted into the apparatus and the thimbles comprising of the samples were lowered into it. The apparatus was turned on and the extraction was done automatically. At the completion of the extraction, the cups were detached and dehydrated in kiln for 20-30 min at 105 ^{o}C to get rid of residual hexane. These were cooled and weighed.

$$\% \text{ Fat} = \frac{[(\text{mass of cup} + \text{oil}) - \text{mass of empty cup}]}{\text{mass of sample}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

3.2.2.5 Determination of crude fibre of cassava roots and African yam bean seeds

Crude fibre content of cassava roots and African yam bean seeds were determined using FOSS Fibertec^{TM} (2010, FOSS Analytical Co., Ltd, Suzhou, China) as shown in Appendix 12. The equipment was turned on and heat was applied to it for 30 min to warm it. The reagents were prepared and weights of the empty crucibles were taken. About 0.5 g of celite and 1 g of sample were weighed into labelled crucibles. These crucibles containing samples and celite were inserted into the apparatus and few drops of anti-foaming agent was added. Acid and alkaline hydrolyses were performed automatically one after the other. This was followed by washing and draining off the acids and alkali from the samples with the use of hot water. The crucibles with samples were removed, dried for 12 h at 105 ^{o}C, cooled and weighed. These were ashed, chilled and re-weighed. Crude fibre content of samples were investigated as displayed.

$$\% \text{ Crude fibre} = \frac{(A-B)}{\text{weight of sample}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

Let A = mass of dried sample, B = mass of ashed sample

3.2.2.6 Determination of total carbohydrate of cassava roots and African yam bean seeds

Total carbohydrate content of each sample was determined by deducting other food components from 100 as specified by Koua *et al*. (2012).

$$\text{Carbohydrate} = 100 - \%(\text{Moisture} + \text{Ash} + \text{Fat} + \text{Protein}) \ldots \ldots\ldots\ldots 3.5$$

3.2.3 Determination of anti-nutritional factors of twenty-five accessions of African yam bean seeds

3.2.3.1 Determination of tannin content of African yam bean seeds

Technique of Fagbemi *et al.* (2005) was modified to analyse the tannin content of twenty-five accessions of AYB seeds with minor amendment. The modification include the use of 1% HCl in methanol instead of 70% acetone. Five millimetres of 99% methanol was poured into 0.5 g of milled seeds. The mixture was shaken to agitate uniformly for 2 min with the use of vortex mixer and centrifuged at 3,000 revolution per minute for ten minutes.

A millimetre of liquid above the sediment was stirred with 0.5 ml Folin Ciocalteau reagent. Similarly, 0.5 millimetre of 20% sodium carbonate and eight millimetres of distilled water were poured into the mixture. Thirty minutes of minimum time was permitted to develop colour and absorbance was read at 760 nm using Genesys UV-visible spectrophotometer of model 10S. Curves of tannic acid in blank and standard were plotted alongside absorbance. The tannin composition was estimated as mg tannic acid equivalent from a line regression equation obtained from a standardisation curve. The sample tannin content was then read from the curve.

3.2.3.2 Determination of phytate content of African yam bean seeds

Phytate contents of AYB seeds accessions were determined using the technique of AOAC (2005). A gram of each accession of AYB seeds was milled, dissolved in 25 ml of trichloroacetic acid (TCA) and gently shook in an orbital shaker for 3 h. The extract was removed by centrifuging at 2000 rpm for 15 min. Ten millimetres of liquid above the sediment was poured into quantifying tube and 4 ml of iron III chloride was added. This was boiled in water bath for 45 min, centrifuged and poured out. The residue was cleaned twice by dissolving in 25 ml of 3% TCA. This was

heated in water bath for 10 min, centrifuged and the residue was cleaned with purified water. This was dissolved in 5 ml of purified water, 2 ml of 1.5 N NaoH was added and mixed. The volume was increased to 30 ml with purified water.

The combination was boiled in water bath for 30 min, filtered hot into 100 ml container and the residue was dissolved with 40 ml of hot 3.2 N trioxonitrate v acid. The fiter paper was cleaned with water, cooled to room temperature and diluted to the mark. From the aliquot, 0.5 ml was weighed into another 100 ml flask, diluted to 70 ml with water. The absorbance of this was read at 470 nm of Genesys UV-visible spectrophotometer of model 10S. The phytate content was obtained from a line regression equation obtained from a standardisation curve. The sample phytate was then read from the curve

3.3 Sample Preparation

3.3.1 Processing of cassava flour

The PVAC roots were prepared into flours within 24 h of harvesting. Processing of HQCF based on description of Aniedu and Omodamiro (2012) was adopted as displayed in Figure 3.1 with slight amendment. Cassava roots of 10-12 months maturity were harvested, sorted and peeled. The peeled roots were washed, grated and dewatered with the use of 50 ton pressing equipment as shown in Appendix 10. The wet cake obtained were pulverised to reduce the size and increase the surface area. The pulverised wet cake were dried using Niji Lukas flash dryer at a temperature of 130 ^{o}C for 20 s residence time as depicted in Appendix 11. The cassava flour were milled, sieved and allowed to cool prior packaging. The modification involved the use of flash dryer for drying instead of sun drying on a raised platform.

3.3.2 Processing of African yam bean seeds into flour

African yam bean seeds of TSs 94 was chosen because of its highest protein content among the screened varieties. This was prepared into flour followed the technique of Nwosu *et al*. (2011) as displayed in Figure 3.2 with minor alterations. Seeds were manually cleaned to discard unwanted materials like residue, diseased seeds to mention a few. Sorted seeds were weighed and soaked in water of seed to water ratio 1:3 for 24 h. Excessive water was removed and seeds were simmered for 10 min at

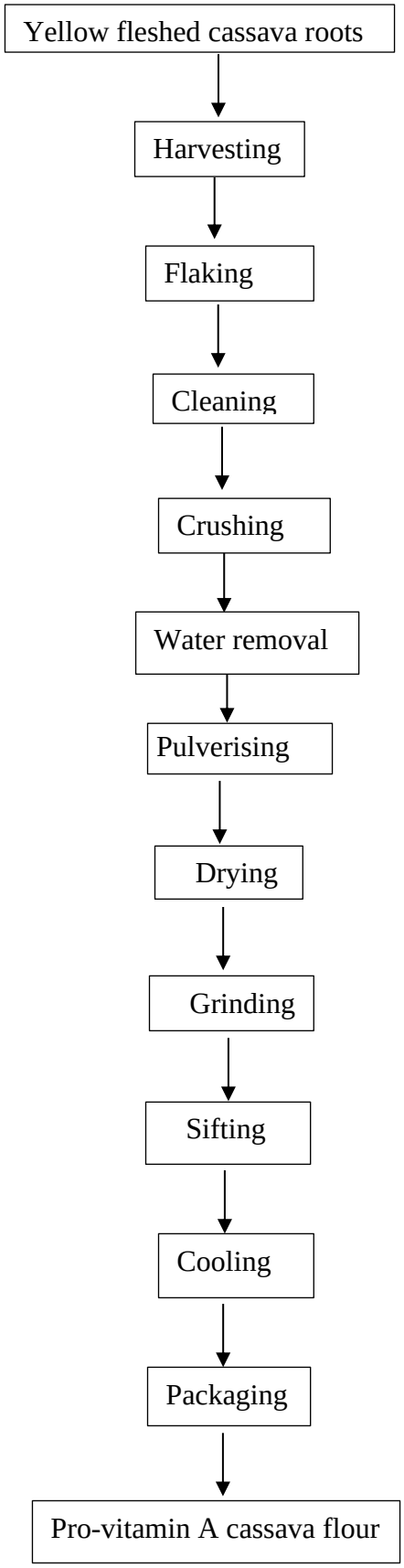


Figure 3.1: Production of Pro-vitamin A Cassava Flour

Source: Aniedu and Omodamiro (2012)

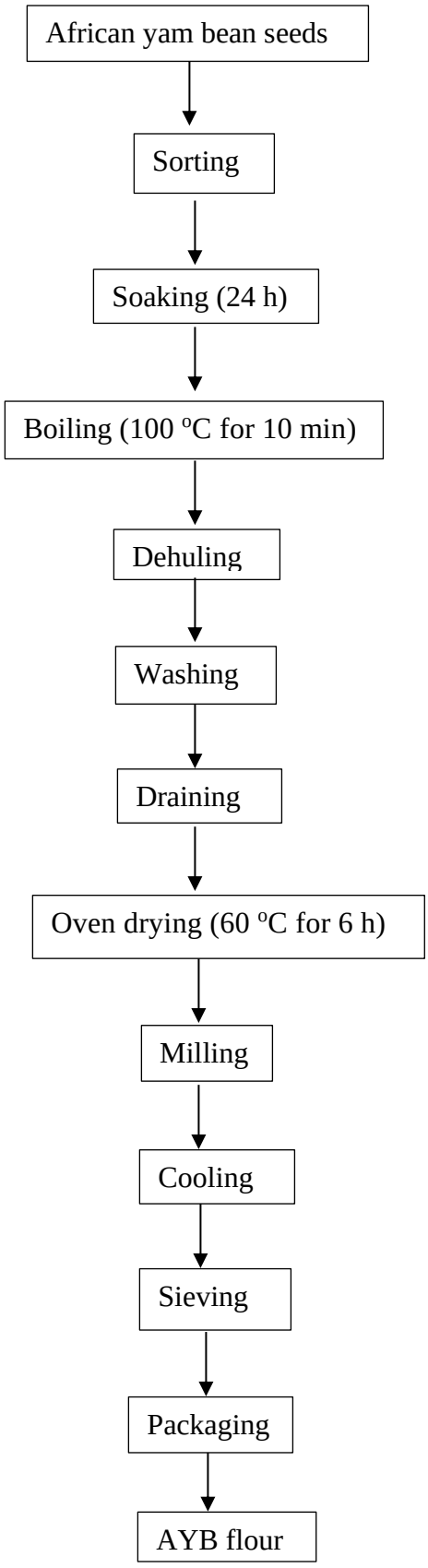


Figure 3.2: Production of African Yam Bean Flour
Source: Nwosu *et al*. (2011)

100 ^{o}C. These were chilled and manually dehulled by using hands to rub the seeds together. The dehulled seeds were washed to detach the coats from seeds, drained and dried in a Fisher Scientific Isotemp^{R} furnace at 60 ^{o}C for 6 h. These were pulverised, cooled, sieved and wrapped in low density polyethylene bag. The modification involved difference in boiling duration.

3.4 Experimental Design

Response Surface Methodology (RSM) of mixture design was adopted in attainment of required flour blend for cassava-African yam bean noodles with the use of Design Expert software. This was done by choosing the two major ingredients as independent variables: Pro-vitamin A Cassava Flour (CF) and AYBF ranged from 60-90% and 10-40% respectively. The chosen criteria were to maximise the protein and β-carotene contents, while minimising the fat content of the blend.

These blend were quantified and thoroughly blended with the use of Bajaj grinder mixer (model GX 10 DLX, Bajaj Electrical Limited Mumbai, India) for 1 min to obtain similar mixtures. The central point of design was performed five times to estimate reproducibility of the process. Each variable was coded at five levels: -1.414, -1, 0, +1 and +1.414. The coded and uncoded variables with their corresponding values were displayed in Table 3.1.

3.5 Chemical Compositions of Cassava-African Yam Bean Flour Blend

3.5.1 Proximate composition of cassava-African yam bean flour blend

Procedure of AOAC (2005) was followed in determining the moisture, dry matter, ash and protein content of samples as explained in sections 3.2.2.1, 3.2.2.2 and 3.2.2.3. Techniques of AACC (2005), AOAC (1990) and Koua *et al*. (2012) were adopted in determining fat, crude fibre and carbohydrate compositions of cassava-African yam bean flour blend as specified in 3.2.2.4, 3.2.2.5 and 3.2.2.6 respectively. Similarly, the method of FAO (2002) was used in determining total energy contents of cassava-African yam bean flour blends as depicted.

$$\text{Total energy } = [(4 \times \text{Protein}) + (4 \times \text{Carbohydrate}) + (9 \times \text{Fat})]\text{Kcal/g} \ldots 3.6$$

Table 3.1: Independent Variables with their Coded and Uncoded Values

Variables		-α	-1	0	+1	+α
AYBF	Coded	-1.414	-1	0	+1	+α
	Actual	3.79	10	25	40	46.21
CF	Coded	-1.414	-1	0	+1	+α
	Actual	29.64	40	65	90	100.36

CF: AYBF, CF=Pro-vitamin A cassava flour and AYBF=African yam bean flour.

3.5.2 Extraction and determination of carotenoids

3.5.2.1 Sample preparation of cassava roots

Cassava roots were peeled, shared equally into four portions via two vertical slices from one end to other to attain four segments. The two opposite segments were unwanted, while the other segments were diced, crushed then, homogenised using laboratory pestle and mortar to attain an homogenous mass as reported by Carvalho *et al.* (2012). Ten grams of the homogenous mass was weighed into mortar and 30 ml of acetone was poured into it. This was allowed to stand for twenty minutes and 3 g of celite was poured into the sample to aid the extraction. Pestle was used to crush the sample thrice for about 5 min each time and acetone was added to the sample at each crushing time until it was fully extracted. This was filtered with the use of suction via a Buchner funnel containing filter paper connected to the pump to aid the filtration.

The aliquot was conveyed to 500 ml separation chimney holding forty millimetres of petroleum ether. The container was rinsed with acetone to ensure the removal of all the extract. The acetone was removed by careful washing via gentle addition of distilled water into the extract. The process was recurring for four times till no residual solvent left. The lower portion, being water was removed and upper part was cautiously transferred via little funnel holding cotton wool and anhydrous sodium sulphate for discarding residual water. This was added to 25 ml mark with petroleum ether, permitted to settle for some time then, its absorbance was noted at 450 nm on Genesys 10S spectrophotometer. Total carotenoid content was determined as displayed:

$$\text{Total carotenoid } (\mu\mathbf{g/g}) = \frac{(\mathbf{A \times volume\ (ml) \times 10^4})}{(\mathbf{A^{1\%}1cm \times sample\ weight\ (g)})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.7$$

Let A = absorbance, volume = entire quantity of extract (25 ml), $A^{1\%}1$ cm = absorption constant of βeta-carotene in petroleum ether (2592).

3.5.2.2 Extraction and determination of carotenoid content of flour blend

The procedure of Carvalho *et al*. (2012) was followed with minor amendment to extract and determine the carotenoid contents of flours and flour blend. The amendment includes the use of different sample weight and solvent volume. From flour blend, 10 g of each blend was weighed into mortar, purified water was poured to

soak the flour blend for 5 min. After soaking, the method of cassava roots processing of carotenoid extraction and determination as explained in section 3.4.4.1 was followed.

3.5.2.3 Identification and evaluation of beta-carotene and isomers

Carvalho *et al*. (2012) technique was followed with slight alteration to determine βeta-carotene, its trans and cis isomers of flours and flour blend. Fifteen millimetres of extract was transferred into concentrator container and concentrated at 40 ^{o}C for 25 min. in TurboVap® LV concentration workstation (Caliper Life Sciences, U.S.A.). The concentrated extract was thinned with one millimetre of dichloroethane and one millimetre of methanol. This was stirred with vortex mixer and conveyed to a 2-ml amber flask of HPLC apparatus (Agilent 1200 series, Perkin Elmer, USA) as depicted in Appendix 13. The instrument was turned on and produced corresponding chromatograph of each sample. The value obtained from the chromatograph was input into the equation to obtain the β-carotene and its isomers contents.

$$C = \frac{A_X * C_S \ (\mu g/ml) * V \ (ml)}{A_S * S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.8$$

Let A_X = highest area of carotenoid, C_S = normal concentration, A_S = normal area, V= entire capacity of extract and S = weight of sample in gram.

3.5.3 Physico-chemical properties of flour blend

3.5.3.1 Titratable acidity and pH of blend

Ten grams of each blend was weighed into a cup, ninety millimetres of purified water was poured and stirred carefully. The combination was left for sixty minutes at room temperature. The pH of the blend was determined using pH metre of Hanna instrument with model number H12211 (Romania, Europe). This was done thrice by inserting the pH metre into each combination. The pH value was displayed and noted. A twenty-five millimetres of the mixture was taken for determination of total titratable acidity. Two to three drips of phenolphthalein indicator was poured into the mixture. This was titrated with 0.1 N sodium hydroxide till final point distinguished by change in colour to pink. Quantity of sodium hydroxide used was multiplied by 0.09 to get the percentage titratable acidity in form of lactic acid (Eriksson *et al*., 2014).

3.5.3.2 Starch and sugar composition of blend

These were analysed by following AOAC (2005) procedures. Sample was smoothly milled, 0.020 gram of it was weighed into centrifuge cylinder. A millimetre of 95% ethanol was poured on the sample to wet it, two millimetres of purified water and ten millimetres of hot ethanol were also poured. This combination was vortexed, then centrifuged with the use of centrifuge of Ivan Sorvall Incorporation with model number GLC-1 at 2000 revolution per minute for 10 min. The liquid above deposit was emptied to be used for evaluation of free sugar whereas, deposit was utilised for determination of starch. To the deposit, 7.5 millimetres of perchloric acid was poured and permitted to stand for sixty minutes. Purified water was added till twenty-five millimetre mark and sieved via muslin cloth.

From the filtrate, 0.05 ml was measured and purified water was poured to obtain a millimetre mark. Colour was developed after adding 0.5 millimetre of (5% phenol) and 2.5 millimetre of concentrated tetraoxosulphate (vi) acid. It was stirred, cooled to room temperature and absorbance was noted using Genesys UV-VIS spectrophotometer of (model 10S, USA) at a wavelength of 490 nm. Furthernore, purified water was added to supernatant taken for sugar determination to obtain twenty millimetre mark. From this, 0.2 millimetre was scooped and purified water was added to obtain a millimetre mark. Afterwards, 0.5 millimetre of (5% phenol) and 2.5 millimetres of concentrated tetraoxosulphate (vi) acid.were poured. This was mixed properly using vortex mixer to ensure thorough mixing, cooled to room temperature and absorbance was noted at a wavelength of 490 nm of the same equipment.

Homogenous mixture of simple monosaccharide sugar was made by weighing 0.01 g of D-glucose in 100 millimetre volumetric container. This was dissolved and purified water was added to 100 millimetre mark. Out of standard homogenous mixture, 0.1, 0.2, 0.3, 0.4 and 0.5 ml of it (100 μg/ml glucose) was poured into test tubes. Purified water was poured into each test tube upto a millimetre mark.This corresponded to 10, 20, 30, 40 and 50 mg glucose per ml. To this, 0.5 millimetre of five percent phenol and 2.5 millimetres of concentrated tetraoxosulphate (vi) acid.was poured, properly stirred, cooled and absorbance was noted at 490 nm. Normal simple monosaccharide sugar curve of absorbance versus concentration was plotted to determine intercept and slope which are needed in computing sugar and starch composition as shown in equations (3.9) and (3.10) correspondingly.

$$\% \text{ Sugar} = \frac{[\text{Absorbance} - \text{Intercept x Dilution factor x volume }]}{\text{sample weight x gradient x 10,000}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.9$$

Let dilution factor = 5; volume = 20; gradient = 0.0055 and intercept = 0.0044.

$$\% \text{ Starch} = \frac{[\text{absorbance} - \text{intercept x dilution factor x volume x 0.9 }]}{\text{sample weight x gradient x 10,000}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.10$$

Let dilution factor = 5; volume = 25; gradient = 0.0055 and intercept =0.0044.

3.5.3.3 Determination of amylose composition of blend

The technique of Mohana *et al*. (2007) was employed in determination of amylose composition of flour mixtures. From flour mixtures, 0.1 g was weighed into test tube, a millimetre of 95% ethanol was poured to wet the sample, then nine millimetres of 1 N sodium hydroxide was poured. The test tube was concealed and the contents were properly stirred. This was boiled in Thelco water bath (model 83, USA), for ten minutes for starch gelitinisation and permitted to cool to room temperature. One millimetre was scooped from extract and diluted to ten millimetre using nine millimetres of purified water. From this, 0.5 ml was scooped from the diluents, 0.1 millimetre of acetic acid and 0.2 millimetre of iodine solution were poured into the aliquot. Purified water of 9.2 ml was poured to reach a ten millimetre mark. The combination was permitted to stand for twenty minutes for colour development, properly mixed with the use of vortex mixer and absorbance was noted at 620 nm on Genesys UV-VIS spectrophotometer of model 10S. Thus, amylose composition was analysed according to equation (3.11), whereas amylopectin was estimated by deducting amylose content from 100.

$$\% \text{ Amylose} = \frac{\%\text{amylose of standard} \times \text{Absorbance of sample}}{\text{Absorbance of standard}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.11$$

$$\text{The amylopectin content} = 100 - \%\text{Amylose content}$$

3.5.4 Determination of mineral content of blend

Mineral compositions of blend were investigated by adopting dry ashing based on

technique reported by AOAC (2005). From the flour mixtures, two grams was weighed into clean and dried crucible of known mass. This was arranged in an oven of 550 ^{o}C for 6 h, cooled and its ashes were melted in ten millimetres of 10% HCl. Purified water was poured to ensure the combination reach 25 ml mark of the measuring cylinder. The sample ash solution was introduced into atomic absorption spectrophotometer of model 210VGP to determine iron, calcium, copper, magnesium and zinc. Potassium and sodium were analysed using Jenway flame photometre, while phosphorus was determined with the use of visible spectrophotometry through ammonium phosphovanadomolybdate.

3.6 Determination of Colour of Flours and their Blend

Colour of flours and their blend were investigated with the use of Konica Minolta Chroma metre with model number CR-410 as described in section 3.2.1.

3.7 Determination of Pasting Properties of Blend

Pasting properties were investigated according to technique of AACC (2005) by means of Rapid Visco Analyser (RVA) with model number RVA-4C, Newport Scientific, Warriewood, Australia). The moisture content of each blend was analysed and recorded into the attached computer to generate the corresponding mass of sample and quantity of purified water needed for the analysis. The sample was weighed into container and corresponding weight of purified water was added to the sample. Plastic paddle was introduced into the container containing the sample and water, carefully shaken to dissolve the sample and introduced into the RVA equipment. The mixture was mixed at 960 rpm for initial 10 sec next at 160 rpm throughout the analysis. The mixture was boiled from 50 to 95 ^{o}C in 3 min 45 sec for a waiting period of 150 sec. followed by cooling to 50 ^{o}C in 225 sec with 120 sec waiting period.

The speed of boiling and refrigerating was at the frequency of 11.25 ^{o}C/min and the entire series was finalised in 13 min. The following pasting parameters: peak viscosity, breakdown viscosity, trough, final viscosity, setback viscosity, pasting temperature (^{o}C) and peak time (min) were noted with the use of computer connected to the equipment. These viscosities were stated in centipoises (cp) and were converted to rapid visco unit (RVU).

3.8 Evaluation of Functional Properties of Blend

3.8.1 Water and oil absorption capacities of blend

Water and oil absorption capacities of blend were analysed following the technique of Isah *et al.* (2015) with minor amendment. The amendment involved the omission of heating in a water bath. A gram of flour blend was measured into already weighed centrifuge. Ten millimetres of purified water or oil was poured as case may be. The blend was properly stirred, permitted to rest for about ten minutes prior centrifuging at 6000 rpm for fifteen minutes. Supernatant was separated by decanting liquid above the residue. Mass of centrifuge with residue was recorded.

$$\text{Water/Oil absorption capacity} = \frac{\text{Mass of container and residue} - \text{Mass of container}}{\text{Mass of sample}} \quad \ldots\ldots 3.12$$

3.8.2 Packed density of the blend

Packed and loose densities of flour mixtures were determined as reported by the technique of Appiah *et al*. (2011). From each flour blend, ten grams was weighed and poured into 100 millimetres quantifying tube to record the volume. This was placed and patted judiciously on a laboratory bench till constant sample volume was reached and noted. The packed and loose densities were determined

`

$$\text{Packed density (g/ml)} = \frac{\text{Mass of sample}}{\text{Volume of Sample after patter}} \times 100 \quad \ldots\ldots 3.13$$

$$\text{Loose density (g/ml)} = \frac{\text{Mass of sample}}{\text{Volume of Sample prior patter}} \times 100 \quad \ldots\ldots 3.14$$

3.8.3 Dispersibility of the flour blend

The technique of Kulkarni *et al*. (1991) was followed. Ten grams of sample was poured in 100 millimetres of quantifying container. Purified water was poured to reach the mark. This was shaken vigorously to ensure all the flour samples were thoroughly mixed and permitted to stand for 3 h. Sediment was measured and the volume was taken away from 100. The result was recorded as percentage dispersibility.

3.8.4 Swelling and solubility index determination of the blend

The improved technique of Riley *et al.* (2006) was implemented. A gram of flour

blend was poured into known weight of centrifuge container. Fifteen millimetres of purified water was poured and stirred mildly at little speed for about 5 min. This combination was boiled in thermostatic water bath of 80 ^{o}C for 40 min with constant mixing to avoid lump development. This was permitted to cool and separated at 2,200 rpm for 20 min in separator. The fluid above the sediment was transferred instantly into previously weighed container and oven dried at about 100 ^{o}C till a constant mass was attained. This was cooled and weighed. Mass of residue was weighed and noted.

$$\text{Swelling power (\%)} = \frac{\text{Mass of residue}}{\text{mass of sample}} \times 100 \quad \text{.....3.15.}$$

$$\text{Solubility index (\%)} = \frac{\text{Weight of soluble}}{\text{Sample weight}} \times 100 \quad \text{.....3.16.}$$

3.8.5 Foaming capacity of the blend

The procedure of Onwuka (2005) was used in determining the foaming capacity. Two grams of sample was measured into quantifying tube, fifty millimetres of purified water was poured into it and the volume was recorded. The combination was stirred and shook well for lather development. At about 30 s of mixing, the entire volume was noted and proportion rise in capacity was recorded.

$$\text{Foaming capacity (\%)} = \frac{\text{Volume after agitation} - \text{volume prior agitation}}{\text{Volume after agitation}} \times 100 \quad \text{.....3.17.}$$

3.8.6 Least gelation concentration of blend

Technique of Sathe *et al*. (1982) was employed to determine least gelation concentration (LGC) of flour mixture. Ten suspensions of 2-20% (w/w) of flour mixture were made using purified water. Each suspension was poured in test tube, boiled in water bath for 1 h and quickly chilled beneath flowing water. The test tubes with the contents were chilled more at 4 °C for 2 h. The test tubes with the contents were removed and upturned. The concentration at which the contents did not drop is known as least gelation concentration.

3.9 Determination of Anti-nutritional Factors of Flour Blend

3.9.1 Determination of hydrogen cyanide content

The procedure of Essers *et al*. (1993) was followed to determine hydrogen cyanide content. Fifteen grams of flour blend was measured and standardised with 125 millimetres of 0.1 M orthophosphoric acid. The homogenate was separated by removing the liquid above sediment. From extract, 0.1 ml was taken and treated with linamarin stock to obtain entire cyanogenic potential. Additional test was performed using 0.1 ml of the extract nevertheless 0.1 ml of 0.1M phosphate buffer (pH 6.0) was utilised to provide non-glucosidic cyanogenic potential. The third investigation was performed using 0.6 ml of the extract, this was poured into 3.4 ml of McIlvaine buffer (pH 4.5). The free cyanogen was obtained by appropriate agitation ofthe mixture using 0.2 ml of 0.5% chloramin T and 0.8 ml of colour component. A normal arc was achieved by plotting absorbance values in vertical-axis and normal concentration values in horizontal-axis: linamarin = 125 ml/(0.01093 x sample weight); Non-glucosidic cyanogen = 125 ml/(0.03176 x sample weight);
permitted cyanide = 125 ml/(0.04151 x sample weight).

3.9.2 Determination of tannin content of the blend

The technique of Fagbemi *et al.* (2005) was modified to analyse the tannin composition with minor amendment. The modification include the use of 99% methanol instead of 70% acetone. Five millimetres of 1% HCl in methanol was poured into 0.5 g of flour mixture. Combination was shaken to agitate uniformly for 2 min with the use of vortex mixer and centrifuged at 3,000 revolution per minute for ten minutes.

A millimetre of liquid above the sediment was stirred with 0.5 ml Folin Ciocalteau reagent. Similarly, 0.5 millimetre of 20% sodium carbonate and eight millimetres of purified water were poured to the combination. Minimum of thirty minutes was permitted to change colour and absorbance was noted at 760 nm by means of Genesys UV-visible spectrophotometer of model 10S. Curve of tannic acid in blank and standard was plotted alongside absorbance. The tannins composition was estimated as mg tannic acid equivalent from a line regression equation obtained from a standardisation curve. The sample tannin content was then read from the curve.

3.9.3 Determination of phytate content of the blend

Phytate content of flour blend were analysed using the technique of AOAC (2005) as explained in section 3.2.3.2 for AYB seeds.

3.10 Microstructural Characterisation of Flours and Flour Blend

Pro-vitamin A cassava and AYB flours were scanned based on the technique reported by Widjaya (2010). This was done to assess change in alterations of the arrangement and morphology of carbohydrate particles before and after fortification. The microstructure of the flours and the optimised flour blend were determined by using INSPECT Scanning Electron Microscope (model S 50, Netherland) as exhibited in Appendix 14. A gram of flour sample was placed into silver stub using a conductive adhesive and observed with the use of small vacuum mode (10 kV), pressure 0.5 Torr and spot size 5.

3.11 Model Fitting and Verificaation of Flour Blend

The independent variables (factors) and dependent variables (responses) were analysed statistically by means of design expert (version 6.0.6) (Stat-Ease Inc., Minneapolis). The results of factors (A and B) on the responses was modelled by polynomial response surface model. The suitability of the models was assessed via coefficient of determination (R^2), adjusted (adj-R^2) and the analysis of variance (ANOVA). Models were verified by analysing in the laboratory the β-carotene, protein and fat composition of desirable blend as obtained in optimum solution by the software. These experimental values of responses were equated with their projected values to obtain percentage of agreement.

3.12 Preparation of Noodles from Flour Blend

Two processing parameters: steaming time and hydration level were optimised using the ranges of 1-3 min and 50-56%, respectively as obtained from preliminary work to prepare the noodles. This experimental design is depicted in Table 3.2. These mixtures were adopted in preparing the noodles and wrapped in a low density polyethylene container before commencement of laboratory analysis. The water quantity requirement in forming homogenous dough and attaining the established hydration level was established with the use of Akinoso *et al*. (2006) technique as depicted.

Table 3.2: Experimental Design of the Noodle

Runs	Hydration (%)	Steaming Time (min.sec)
1	50	1
2	48.76	2
3	56	3
4	53	2
5	50	3
6	53	0.59
7	53	3.41
8	56	1
9	53	2
10	53	2
11	53	2
12	53	2
13	57.24	2

HL=hydration level (%), ST=Steaming time (min.sec)

$$Q = \frac{A(b-a)}{100-b} \quad \text{.....3.18}$$

Let Q be the quantity of water to be added, A is sample original mass, b is % hydration to form dough and 'a' is original moisture content of feed.

The approaches of Oladunmoye *et al*. (2014) and Widjaya (2010) were adopted to obtain the quantity of other ingredients to be added to form the dough. For instance, for every 100 g of each flour mixture, 0.1 g of sodium and potassium carbonates, 0.5 g of both ascorbic acid and xanthan gum and 1.5 g of iodised salt were weighed. These were added, mixed with warm water and the mixture was evenly mixed with flour blend to obtain a smooth dough. This research adopted the method of Nwabueze and Anoruoh (2009) with slight modifications for noodle preparation as exhibited in Figure 3.3. The modifications include the use of CF, fortification with AYBF and steaming method adopted.

The mixing and resting time of Widjaya (2010) were adopted. The flour blend and other ingredients were evenly mixed with warm water as deternined for 5 min to form smooth and homogenous dough. This was wrapped in a high density polyethylene bag to prevent surface drying and rested for 30 min. Rested dough was compressed for one minute prior feeding into SIMAC Pastamatic 1000 cold extruder (Italy) as shown in Plate 3.3 and extruded through a circular shaped instant noodle die of 2 mm diameter. The extrudates were steamed as determined, submerged in cold water for 2 min, drained and spread on a tray at room temperature to air dry for 4 h before oven drying at 55 ^{o}C for 5 h. These were cooled and packaged in low density polyethylene bag.

3.13 Evaluation of Chemical composition of Noodles

3.13.1 Proximate composition of noodles

The moisture, dry matter and ash contents of cassava-African yam bean noodles were determined following the technique of AOAC (2005) as depicted in sections 3.2.2.1 and 3.2.2.2. Crude protein and fat contents of noodles were analysed using FOSS Kjeltec^{TM} 2300 protein analyser and automated method of Soxtec system HT2, respectively as

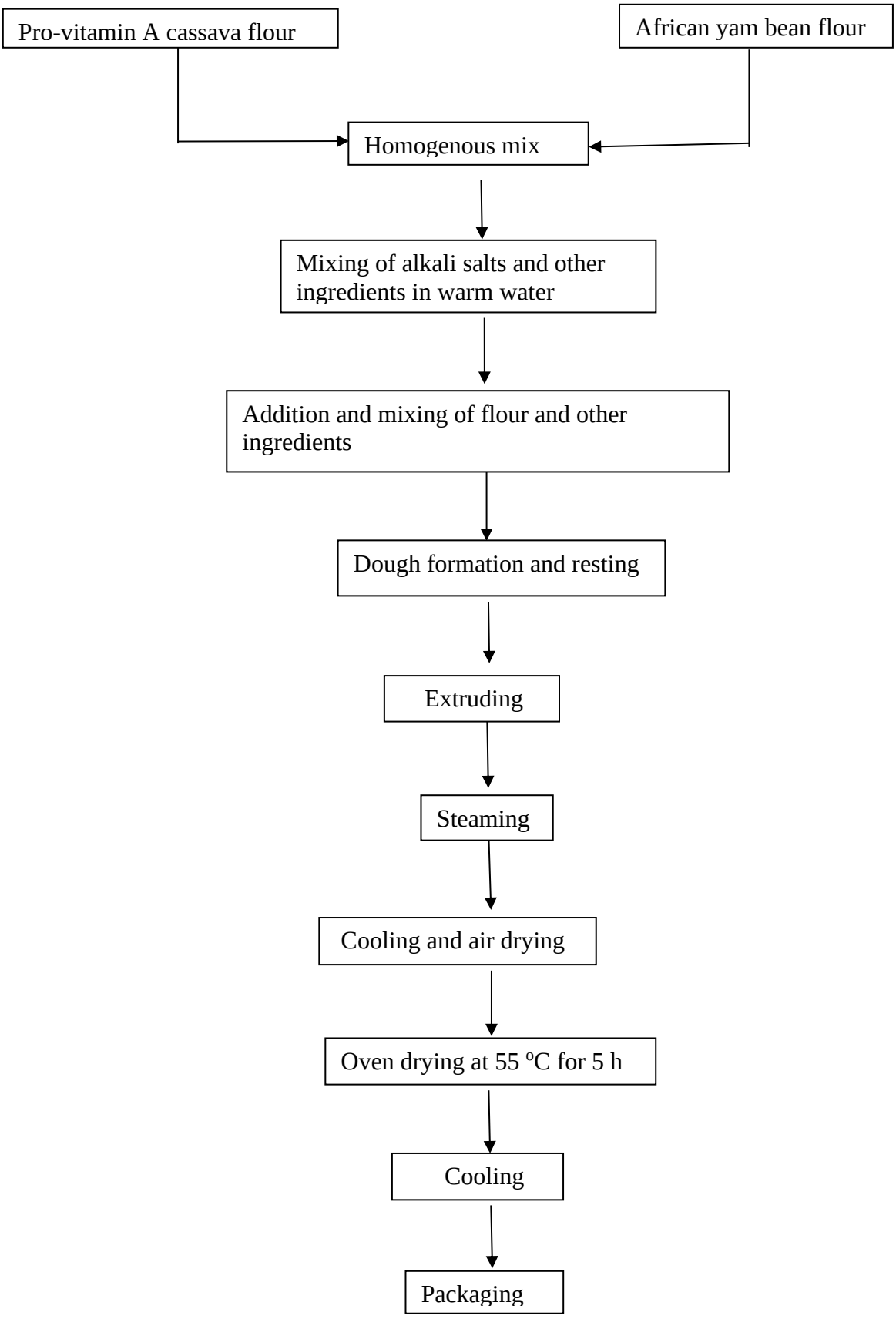


Figure 3.3: Production of Pro-vitamin A Cassava-African Yam Bean Noodle

Plate 3.3: SIMAC Pastamatic Cold Extruder

described by AACC (2005) method 46-12.01 with minor amendments as stated in sections 3.2.2.3 and 3.2.2.4. Crude fibre compositions of samples were determined by employing FOSS Fibertec^{TM} 2010 equipment as discussed in section 3.2.2.5. The total carbohydrate and total energy contents of noodles were estimated by difference as stated by Koua *et al.* (2012) and FAO (2002) as aforementioned in equations (3.5) and (3.6) respectively.

3.13.2 Determination of mineral compositions of the noodles

Mineral compositions of noodles were investigated by dry ashing technique as stated by AOAC (2005) with slight amendments. This was done by introducing the sample ash solution into Atomic Absorption Spectrophotometer of model 210VGP to determine iron, calcium, copper, magnesium and zinc. Potassium and sodium were determined by Jenway flame photometry, whereas the phosphorus was investigated by visible spectrophotometry through ammonium phosphovanadomolybdate.

3.13.3 Determination of overall carotenoid and beta carotene of the noodles

The total carotenoid and β-carotene contents of cassava-African yam bean noodles and commercial noodles coded 510 (Indomie), 511 (Dangote) and 512 (Golden penny) were determined following the procedure of Carvalho *et al*. (2012) with slight amendment as described in sections 3.4.4.2 and 3.4.4.3 correspondingly.

3.14 Determination of Colour of Noodles

Colour of noodles was investigated with the use of Konica Minolta Chroma metre of (model CR-410, Japan) as described by Choy (2011) as explained in 3.2.1.

3.15 Determination of Anti-nutritional Factors of Noodles

3.15.1 Determination of hydrogen cyanide of noodles

Hydrogen cyanides of noodles were investigated by employing the procedure of Essers *et al*. (1993) with slight amendment as discussed in 3.9.1 for flour blend determination.

3.15.2 Determination of tannin content of noodles

Tannin contents of cassava-AYB noodles were investigated as stated by Fagbemi *et al.* (2005) with slight amendments as shown in 3.8.2 for flour blend.

3.15.3 Determination of phytate content of noodles

Phytate contents of cassava-AYB noodles were assessed using the technique as stated by AOAC (2005) as shown in 3.2.3.2 for AYB seeds.

3.16 Determination of Amino Acid Compositions of Noodles

Amino acid compositions of noodles were analysed based on procedure reported by Benitez (1989). Noodle samples were dried to a constant mass and fats were removed with the use of chloroform and methanol combination in proportion of 2:1. Two grams of noodles was weighed into thimble and extracted for 5 h in soxhlet extraction unit (AOAC, 2005). This was hydrolysed, vapourised on rotary evaporator and introduced into Applied Biosystems PTH amino acid analyser of (model 120 A, Applied Biosystems Inc., California, USA) as shown in Appendix 15.

From the defatted samples, 1 g of each sample was hydrolysed according to technique explained by Glew *et al*. (2005). This was done by putting sample in a glass ampoule, adding 7 ml of 6 N HCl to it, tightly closed with bursen burner flame and incubated at 110 ^{o}C for 24 h. Nitrogen was injected into the vessel to eject oxygen and evade likely oxidation of a few amino acids through hydrolysis e.g. methionine and cysteine. Vessel was permitted to cool prior destroying at tip and the content was clarified to eliminate humins. Deposit was vapourised to dryness with the use of rotary evaporator at 40 ^{o}C for 1 h. This was molten using 5 ml of acetate buffer of pH 2.0 and kept in flexible sample flasks, that were preserved in freezer. From sample hydrolysate, 6 ml was introduced into the cartridge of the amino acid analyser that was aimed to detach and examine free acidic, neutral and basic amino acids. An integrator was coupled with analyser which calculated the highest part relative to concentration of each amino acids.

3.17 Physical and Cooking Quality of the Noodles

3.17.1 Determination of best cooking time

The best cooking time of noodles was investigated based on technique of Chillo *et al.* (2008) with minor amendments. From each noodle sample, five grams was weighed and cooked in 150 millimetres of purified water. For every 30 sec, a strand of noodles was detached, positioned and pressed within the double simple microscope slides. Cooking time was obtained at the time that uncooked central portion just disappeared

which matched to the time of identical colour appearance.

3.17.2 Determination of cooking yield and cooking loss

The cooking yield and cooking loss of noodles were investigated based on Chillo *et al.* (2008) as displayed in equation 3.19 and 3.20 respectively. Five grams of noodle was put in 150 millimetres of hot water and cooked in beaker to its best cooking time as determined. This was drained and allowed to cool for 120 sec. The cooled noodle was then reweighed and the result was noted as percentage increase on cooking. Cooking loss was determined by weighing quantity of firm material wasted to cooking water at room temperature. This was performed by pouring the remaining cooking water into a can of known weight, positioned in furnace at 105 °C and vaporised to dryness. Remainder was determined and stated as proportion of initial weight of the sample. For optimum cooking yield and loss, this method was performed thrice and the mean values were obtained.

$$\text{Cooking yield} = \frac{\text{Mass of cooked noodle} - \text{Mass of dried noodle}}{\text{Mass of dried noodle}} \times 100 \quad \text{.....3.19.}$$

$$\text{Cooking loss} = \frac{\text{Mass of dried residue in cooking water}}{\text{Mass of dried noodle}} \times 100 \quad \text{…….....3.20.}$$

3.18 Determination of Textural Profiling of the Noodles

Noodles were prepared for texture profile determination by employing AACC International Accepted Procedures 66-50 AACC (2000) and Oh *et al*. (1983). This was done by cooking 15 g of noodle in 300 ml of hot water up to its predetermined best cooking time. Cooked noodle was rinsed instantly using running water for 60 s, filtered and put in sample holder for 10 min after cooking prior inserting into Texture profile analyser (model TVT-300XPH, Sweden). This apparatus was standardised prior the analysis with the use of 2 kilograms load cell and return trigger route of 15 mm. This apparatus was shown in Appendix 17.

The backgrounds was performed as follows: mode circumstance measured force in compression; pre-test speed, test speed and post-test speed were all adjusted to 2.0 mm/sec; tension was on 75%; and 45 mm canister probe was utilised. The noodles were packed in a sample holder as closely as possible to one another prior placing on

the analyser. The .apparatus was turned on and the measurements was taken for each sample. The following noodle parameters were determined: hardness, chewiness, stickiness, cohesiveness, adhesiveness, springiness, stinginess and resilience. The results of these parameters were generated automatically. The noodle hardness in (g) was obtained from the top of the graph that was also denoted by the peak force.

3.19 Thermal Properties of the Noodles

The KD2 Pro-Thermal Properties Analyser (Decagon Devices Inc. Washington, USA) as shown in Appendix 16 was employed in investigating thermal properties of noodles based on the technique reported by Mahapatra *et al.* (2013). It is handy field and workshop apparatus that employed the momentary line hotness source technique. It has length and diameter of 30 mm and 1.28 mm respectively, and 6 mm arrangement double needle SH-1 sensor that investigated the thermal properties. The KD2 analyser probe was introduced into the sample holder containing packed and well compacted sample. It was switched on and thermal properties including resistivity, thermal conductivity, thermal diffusivity, specific heat capacity and product temperature were measured and displayed.

3.20 Microstructural Characterisation of the Noodles

Noodles were scanned based on the technique reported by Widjaya (2010). The assessment of microstructure of dried noodles was analysed by employing INSPECT Scanning Electron Microscope of model S 50 (FEI Company, Hillsboro, US). A gram amount of noodle strands was positioned into a silver stub with the use of hand glove and inspected employing low vacuum mode (10 kV), pressure 0.5 Torr and spot size 5. Outer surfaces of noodle strands were viewed under 150x, 500x and 1000x magnification.

3.21 Model Fitting and Verification of the Noodles

Response Surface Methodology of central composite design was utilised to create and enhance models for cyanogenic glycoside, cooking quality, textural properties and colour of noodles. The criteria for optimising these noodles include minimising cyanogenic glycoside, cooking loss, chewiness, stickiness while maximising the cooking yield and yellowness. The independent variables (factors) and dependent

variables (responses) were analysed statistically employing design expert (version 6.0.6). This was perform to create predictive models for the noodles.

Models were verified by analysing in the laboratory the values of the responses using the optimum hydration level and steaming time obtained by the software. The results of the responses were compared with their predicted values to obtain the percentage of agreement.

3.22 Sensory Evaluation of the Noodles

The noodles were cooked and served to fifty trained women staff of Cassava Processing Unit of IITA to compare sensory attributes of two optimised cassava-African yam bean noodles and commercial noodle. Chosen panellists were also trained for creating the awareness on the purposes of the research, chosen sensory attributes and procedures for assessing the noodles. A 9 point hedonic scale was utilised in ranking noodles for taste, flavour, colour, stickiness, chewiness and overall acceptability of which 9 signifies like tremendously and 1 signifies hate tremendously and 5 signifies neither like nor hate.

3.23 Determination of Adsorption Isotherm of the Noodles

The gravimetric technique in different temperatures (20-40 ^{o}C) and relative humidity conditions a_w (0.11-0.86) was used to generate the adsorption data of noodle samples as stated by Shittu *et al*. (2015) with minor amendments. Eight soaked saline mixtures of lithium chloride, potassium acetate, magnesium chloride, potassium carbonate, magnesium nitrate, sodium nitrite, sodium chloride and potassium chloride were used to retain individual relative humidity in desiccators. These corresponding water activities (a_w) were dispensed into the desiccators. For the adsorption isotherm, the dried samples (2 g ± 0.01 g) each was weighed into moisture pans and placed in each desiccator representing each salt. The experiment was performed at ambient conditions (27.0±2 ^{o}C, 64±2%).

A small cotton wool was dipped in chloroform and positioned above the wire gauze in each desiccator to prevent fungal activity. Little quantity of grease was scrubbed on edge of each desiccator's lid to prevent air from entering. These desiccators with the samples were positioned in an incubator to sustain the needed temperatures (28 ^{o}C and

35 ^{o}C). Each sample was weighed every two days with the use of digital weighing balance until constant weight is obtained in three consecutive recordings, then the sample was said to assume the equilibrium (±0.01 g). The EMC was then calculated from the moisture adsorption isotherms graph of the samples. Each sample was represented twice for the analyses.

3.24 Storage Studies of Cassava-African Yam Bean Noodles

The noodle samples were weighed and packaged into three different packaging materials: low density polyethylene of 100 microgauge, high density polyethylene of 150 microgauge and 200 microgauge respectively. These were wrapped and stored at room temperature to evaluate storage stability of noodles in packaging materials for twenty four weeks at interval of two weeks. Physical, microbiological and chemical analyses such as colour, moisture, total viable count, mould count, yeast count, total β-carotene and total carotenoids of these samples were determined at two weeks interval.

3.25 Microbiological Analysis of the Noodles

Appropriate nutrient agar (NA) and potato dextrose agar (PDA) were weighed and dissolved with equivalent quantity of distilled water as derived from agar containers to prepare the agar. These were sterilised along with test tubes, distilled water and other glass wares at 121 ^{o}C for fifteen min in an autoclave prior the commencement of the analyses. The two freshly prepared optimised noodle samples were milled and their microbiological analyses (total viable count, mould and yeast counts) were analysed immediately after production and during storage at two weeks interval in three different packaging materials.

3.25.1 Total viable count

Serial dilutions were performed from 1 g of pulverised noodle melted in 10 ml of purified water. This was done by taking one millimetre from the melted sample into another sterilised test-tube holding nine millimetres of distilled water to make ten millimetres. These samples were serially diluted with continuation of this process to obtain 10^{-6} for each sample. Pour plate method was adopted in evaluating the total viable count of the noodle sample. This was done by pouring one millimetre of appropriate dilution into hygienic petri dishes and about 15 ml of freshly prepared nutrient agar was added, spread and permitted to solidify. Petri dishes were later

upturned and incubated at 37 ^{o}C for 24 h. These were done thrice for each sample and the mean counts for the triplicate sample were recorded as the mean bacterial count of the sample (Ikuomola and Eniola, 2010).

3.25.2 Total mould and yeast count

About 0.3 g of chloraphenicol powder was poured into sterilised PDA to prevent bacteria development for yeast count. After serial dilution, the pour plate and spread procedures were adopted. This was done by taking 1 ml of each diluents, poured it on a petridish and discharged about 15 ml of freshly prepared PDA into the petri dishes for mould and yeast count. The petri dishes were permitted to solidify and inverted prior incubating at 37 ^{o}C for 48 h for mould and yeast count. Mean count of triplicate sample was noted as total mould and total yeast count as the case may be.

3.26 Animal Studies of Cassava African Yam Bean Noodles

The experiment was conducted in agreement with National Institutes of Health (NIH) procedures for maintenance and use of laboratory animals as described by Akah *et al*. (2009). Proposal was written, accepted and approval was given by Animal Care Use and Research Ethics Committee (ACUREC) at Department of Veterinary Medicine, University of Ibadan, Ibadan. Forty male weanling wistar rats with average initial weight 40-55 g of four weeks old were obtained from a reputable breeder. Prior to the commencement of experimental feeding phase, all the rats were fed with stabilising diets for a duration of 5 days. Each rat was individually housed in screened bottom metabolic cage. These rats were reweighed and haphazardly distributed into five treatment groups of eight rats per group. The weight difference among the groups was ±1.5 g. These groups include casein, carrot based, two experimental diets and basal diet.

The casein diet is the standard protein source that also comprised of corn starch, glucose, sucrose and non vitamin A vegetable oil as the energy sources, non nutritive cellulose and egg shell for dietary fibre and dicalcium phosphate (DCP) for minerals. Carrot diet is the positive control diet that contain carrots that has been estimated and mixed with other ingredients to attain both equalised β-carotene and protein content as depicted. Carrot is chosen because it is very high in beta carotene content among the human foods (Górnicki and Kaleta, 2007). The basal diet is a nitrogen-free diet

that has similar composition to carrot diet with the exception of carrot and casein. The two experimental diets consist of PVAC-AYB noodle mixed with nitrogen-free diet to achieve both isonitrogenous and equalised β-carotene content as shown.

Groups were given the diets as prepared and depicted in Table 3.3 and water was given in *adlibitum* (Ani *et al*., 2012; Akande *et al*., 2014). Dietary intake was weighed and noted daily, while the weights of rats were noted twice per week during feeding period. All rats were examined everyday to examine the signs of toxicity and likely weight loss. Similar level of cleanliness was continued during the twenty-one days of the experiment. This period is said to be acceptable and nutritionally adequate to observe biochemical alterations that may come up in animal tissues. Faecal sample from each group was collected, air dried, oven dried at 105 ^{o}C for 24 h and milled before commencing on laboratory analysis. Urine was obtained from each group in small urine bottle, that comprised of 1 ml of concentrated tetraoxosulphate vi acid to trap the nitrogen**.**

3.26.1 Protein quality evaluation

The feed efficiency ratio (FER), protein efficiency ratio (PER), net protein utilisation (NPU) and true protein digestibility (TD) were investigated as reported by Famakin *et al*. (2016) as depicted. The biological value (BV) was estimated based on technique of Abiose *et al*. (2015).

$$\text{Feed Efficiency Ratio (FER)} = \frac{\text{Weight gained}}{Feed\ intake} \text{----------3.21}$$

$$\text{Protein Efficiency Ratio (PER)} = \frac{\text{Weight gained}}{Protein\ intake} \text{----------3.22}$$

$$\text{Net protein utilisation (NPU)} = \frac{\text{Ni}-(\text{Nf1}-\text{Nf2})-(\text{Nu1}-\text{Nu2})}{Ni} \times 100 \text{ ----------3.23}$$

$$\text{True protein digestibility (TD)} = \frac{\text{Ni}-(\text{Nf1}-\text{Nf2})}{Ni} \times 100 \text{----------3.24}$$

$$\text{Biological value (BV)} = \frac{(\text{Nf1}-\text{Nf2})-(\text{Nu1}-\text{Nu2})\times 100}{Ni-(Nf1-\text{Nf2})} \text{----------3.25}$$

Table 3.3: Rat Feed Composition for Animal Study (g/kg)

Diets	Casein diet	Carrot diet	END 1	END 2	Nitrogen-free diet
Corn Starch	431.50	401.50	63.50	37.50	542.50
Casein	111.10	111.00	0	0	0
Sucrose	150	150	5	5	150
Glucose	150	150	5	5	150
NNC	15	15	15	15	15
Egg shell	20	20	20	20	20
Vegetable oil	100	100	3	3	100
Carrot	0	30	0	0	0
END 1	0	0	866	0	0
END 2	0	0	0	892	0
DCP	15	15	15	15	15
Salt	2.50	2.50	2.50	2.50	2.50
Vitamin premix	5	5	5	5	5
Total	1000.10	1000.00	1000.00	1000.00	1000.00
Protein (g/kg)	99.99	100.20	100.02	99.90	0
Energy (Kcal/kg)	3063.84	3014.69	3304.40	3352.71	3114.33
Calcium (g/kg)	7.89	7.88	7.72	7.71	7.91
Phosphorus (g/kg)	7.68	7.61	6.70	6.64	7.95
Beta-carotene	0	2.22	2.21	2.45	0

NNC means non-nutritive cellulose, END 1 means experimental noodle diet 1, END 2 means experimental noodle diet 2 and DCP means dicalcium phosphate.

Let Ni be the nitrogen intake of the experimental diet.

N_{f1} = faecal nitrogen excreted while on experimental diet.

N_{f2} = faecal nitrogen excreted while on nitrogen-free diet

Nu_1 = urinary nitrogen for the experimental diet.

Nu_2 = urinary nitrogen for the nitrogen-free diet.

3.26.2 Determination of haematological parameters of the studied animals

Blood sample was collected from two rats out of the entire rats prior the commencement of the experiment for haematological analysis to serve as baseline. This was also collected from each group at eleventh day of feeding (mid-period) and at twenty-one day of feeding by tail puncturing. The blood was collected in ethylene diamine tetracetic acid (EDTA) containers for haematological assay and plain containers for biochemical examination. At the end of the experiment after starvation for about 12 h, five rats were taken from each group, weighed and sacrificed humanely for haematological, serum biochemistry mineral examination and histopathological. The following haematological indices were determined as stated by Famakin *et al*. (2016).

Pack cell volume (PCV): This was investigated by separating the blood sample in heparinised capillary cylinder of haematocrit micro-centrifuge at 3000 rpm for thirty minute. Reading was taken and centrifuged again for about five minute until two similar consecutive reading were obtained.

Red blood cell (RBC): This was assessed with the use of normal salt as a diluting fluid to evaluate haemoglobin content (Hb) and red blood cell (RBC) count following cyanomethaemoglobin technique. Neutrophil, Lymphocytes, Monocytes, Eosinophils, White blood cell (WBC) and Platelets were assessed with the use of Sysmex Automated Haematology analyzer of model KX-21N (Sysmex Corporation, Bellport, USA). Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), and Mean Corpuscular Haemoglobin Concentration (MCHC) were also determined as depicted:

$$MCV = \frac{PCV}{RBC} \text{----------} 3.26$$

$$MCH = \frac{Hb}{RBC} \times 10 \text{----------} 3.27$$

$$MCHC = \frac{Hb}{PCV} \times 100 \text{----------} 3.28$$

3.26.3 Determination of serum biochemistry and minerals

Blood was collected in plain bottle, permitted to clot and separated at 3500 revolution per minute for ten minutes. This was poured and used for biochemical and mineral determination such as globulin, albumin, ratio, total protein, alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), urea and creatinine. Randox commercial kits (Randox laboratories, England, UK) was employed for these analyses. This was done by following the manufacturer's procedure on the kits.

3.26.4 Histopathological analysis

Kidney and lung were separated from the rats. Evaluation and exposure of organs to histopathological analysis was performed after slides fixation as detailed in procedure of Adesiji (1999). Organs were fixed in 10% formalin solution, slides were labelled and secured at 54 °C overnight on hot plate. These slides went through sequence of stages for Haematoxylin and Eosin staining procedure. These organs were inspected under a light microscope at 400X magnifications. Some toxicological lesions were inspected (Asyura *et al*., 2016).

3.27 Bioavailability Study

3.27.1 Samples preparation and storage

The two experimental noodles and carrot based diets were prepared underneath gold fluorescent light to avoid photo-oxidation and isomerisation as reported by Phorbee *et al*. (2013). They were later kept in dark bags prior analysis.

3.27.2 Determination of beta carotene content of diets

Carotenoid and β-carotene contents of two experimental noodles and carrot based diets were investigated following the method of Carvalho *et al*. (2012) as explained in 3.4.4.2 with minor amendment. The amendment involved the addition of 5% potassium hydroxide for saponification to discard substantial matrix interfering from

high level of fats that might be in the samples prior the analysis **(**Schweigert *et al*. 2000; Rodriguez-Amaya, 2016a; Rodriguez-Amaya, 2016b).

3.27.3 Evaluation of plasma beta carotene of fed rats

Plasma obtained from rat fed with PVAC-AYB noodles were kept in a freezer prior analysis. The technique of Tan *et al*. (2017) was employed to evaluate plasma beta carotene (PBC) content of rats fed with two experimental PVAC-AYB noodles and carrot based diets. From preserved serum, 0.2 ml was pipetted into sterilised quantifying beakers. This was extracted twice with 0.8 ml of hexane. Extracts were dried beneath a moderate stream of nitrogen at 35 ^{o}C, altered with 0.1 ml reconstitution solution that contained ethanol and butylated hydroxytoluene in ratio 80 to 20 v/v.

This was separated and clear supernatants were moved into amber autosampler vials. The β-carotene departed via the column, exit entirely other portions absorbed above the column. Petroleum ether was poured to wash the column to certify entire elimination of β-carotene. The colourless of eluate indicated full elution. The extract was added to 25 ml column, concentrated and injected into HPLC to analyse. Samples were analysed beneath golden bright light to avoid photo-oxidation and isomerization.

3.28 Statistical Analyses

Most analyses were performed thrice and data obtained were analysed statistically. The mean and standard deviation were obtained as data were exposed to one-way analysis of variance (ANOVA) adopting Statistical Package for Social Sciences (SPSS) (version 20, 2013). Averages were compared and separated by adopting Duncan's New Multiple Range Test (DNMRT) at 95% confidence level. Design expert (version 6.0.6) was also utilised for data analyses.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Physico-Chemical Properties of Cassava Roots and African Yam Bean Seeds

Protein, phytate and tannin contents of twenrty-five accessions of AYB are shown in Table 4.1 with values varied from 19.84 to 26.68%, 1.29 to 3.95 mg/g and 0.14 to 0.58 mg/g, respectively. The crude protein were lower than the values reported by Abioye *et al.* (2015) for nine varieties of AYB seeds with values ranging from 28.63 to 30.43%. However, the phytate and tannin contents obtained in this work fell below those stated by Onuoha *et al.* (2017) for six varieties of AYB seeds with values ranging from 21.3 to 31.4 mg/g and 10.1 to 14.3 mg/g, respectively.

Pro-vitamin A cassava (07/593) was selected based on its highest dry matter content among the newly introduced varieties, while AYB (TSs 94) was selected due to its maximum protein content of the screened accessions. The colour and proximate composition of PVAC roots and chosen AYB were displayed in Table 4.2 with values ranging between 78.95 and 85.56 for lightness, while 37.20 and 13.50 were obtained for yellowness, respectively. The lightness of peeled cassava roots obtained in this study compared with 72.43 to 81.19 as reported by Ladeira *et al*. (2013). However, its yellowness value were higher than the range stated by the same researchers with values ranging from 14.08 to 16.29.

Proximate composition of cassava roots compared well with Montgnac *et al*. (2009) with values ranging from 45.9 to 85.3%, 0.3 to 3.5%, 0.03 to 0.5%, 0.4 to 1.7%, 25.3 to 35.7% and 0.1 to 3.7% for moisture, protein, fat, ash, carbohydrate and fibre contents, respectively. Likewise, protein content obtained also compared well with those of cassava varieties stated by Manano *et al*. (2017) with values 0.74 to 1.51. The fat and fibre contents of the chosen AYB compared with those stated by Fasoyiro *et al.* (2006) with values ranging from 1.47 to 4.96% and 1.92 to 7.21%, respectively. Meanwhile, the ash and carbohydrate contents compared with Ojuederie and Balogun (2017) for AYB seeds with values varied from 1.1 to 3.8% and 50.9 to 62.5%,

Table 4.1 Protein, Phytate and Tannin Contents of 25 Accessions of AYB Seeds

Accession number	Protein (%)	Phytate (mg/g)	Tannin (mg/g)
TSs 1	$24.27\pm0.09_{d}$	$1.64\pm0.00_{fg}$	$0.37\pm0.00_{c}$
TSs 9	$23.54\pm0.13_{ef}$	$1.38\pm0.01_{g}$	$0.49\pm0.01_{b}$
TSs 10	$23.78\pm0.21_{e}$	$1.57\pm0.03_{fg}$	$0.58\pm0.02_{a}$
TSs 23	$26.34\pm0.21_{ab}$	$1.73\pm0.01_{f}$	$0.33+0.02_{de}$
TSs 24	$21.03\pm0.52_{mn}$	$1.69\pm0.01_{f}$	$0.45\pm0.00_{b}$
TSs 33	$23.22\pm0.09_{fg}$	$2.69\pm0.02_{d}$	$0.2\pm0.01_{i}$
TSs 48	$24.88\pm0.21_{c}$	$2.95\pm0.1_{c}$	$0.31\pm0.01_{def}$
TSs 49	$25.55\pm0.09_{b}$	$3.1\pm0.01_{bc}$	$0.2\pm0.00_{i}$
TSs 57	$22.72\pm0.19_{ij}$	$3.95\pm0.03_{a}$	$0.49\pm0.06_{b}$
TSs 61	$23.94\pm0.1_{de}$	$2.4\pm0.07_{e}$	$0.32\pm0.1_{def}$
TSs 69	$25.64\pm0.13_{b}$	$3.94\pm0.05_{a}$	$0.34\pm0.02_{cd}$
TSs 82	$22.26\pm0.21_{jk}$	$2.29\pm0.01_{e}$	$0.14\pm0.00_{j}$
TSs 84	$23.05\pm0.16_{gh}$	$2.36\pm0.02_{e}$	$0.21\pm0.00_{i}$
TSs 86	$21.15\pm0.16_{i}$	$2.38\pm0.01_{e}$	$0.27\pm0.01_{fg}$
TSs 89	$24.18\pm0.13_{d}$	$3.11\pm0.01_{bc}$	$0.21\pm0.01_{i}$
TSs 93	$24.27\pm0.12_{d}$	$2.79\pm0.03_{cd}$	$0.31\pm0.03_{def}$
TSs 94	$26.68\pm0.04_{a}$	$1.71\pm0.05_{f}$	$0.24\pm0.01_{i}$
TSs 95	$19.84\pm0.08_{p}$	$3.15\pm0.01_{bc}$	$0.26\pm0.01_{gh}$
TSs 96	$23.34\pm0.16_{fg}$	$2.3\pm0.01_{e}$	$0.14\pm0.1_{j}$
TSs 101	$22.14\pm0.13_{l}$	$3.0\pm0.02_{c}$	$0.23\pm0.00_{hi}$
TSs 109	$20.68\pm0.21_{o}$	$3.3\pm0.03_{b}$	$0.28\pm0.01_{fg}$
TSs 111	$22.49\pm0.13_{jk}$	$2.38\pm0.031_{e}$	$0.31\pm0.01_{def}$
TSs 116	$23.95\pm0.03_{de}$	$1.29\pm0.05_{h}$	$0.17\pm0.02_{j}$
TSs 125	$22.67\pm0.12_{ij}$	$2.27\pm0.01_{e}$	$0.21\pm0.04_{i}$
TSs 137	$22.99\pm0.16_{gh}$	$3.15\pm0.08_{bc}$	$0.3\pm0.01_{ef}$

Values are means of triplicte ± standard deviation.

Table 4.2: Physico-chemical Properties of Cassava Roots and African Yam Bean Seeds

Samples Samples	Lightness	Yellowness	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	CHO (%)	Dry matter (%)	Crude fibre (%)
Cassava	78.95±0.71	37.22±0.10	0.76±0.40	0.26±0.02	68±0.00	1.08±0.05	30.29±0.20	32.39±0.00	0.57±0.05
AYB	85.56±0.71	13.5±0.71	26.69±0.15	1.5±0.71	8.5±0.71	3.5±0.71	59.81±0.1	91.45±0.71	5.4±0.71

AYB: Raw African yam bean seeds, CHO: Carbohydrate. Values are means of triplicate ± standard deviation.

respectively.

4.2 Response Surface Methodology of Flour Blend

The experimental design produced thirteen flour blend with five central points of which their properties were presented on Table 4.3. Nutritional qualities of these blend were presented.

4.3 Chemical Properties of Cassava-African Yam Bean Flour Blend

4.3.1 Proximate composition of blend

Proximate compositions of flour blend are presented on Table 4.4. Significant differences existed in flour blend proximate compositions. Moisture contents of mixtures varied from 8.12 to 11.72%. African yam bean flour had maximum moisture, whereas 90CF:10AYBF had minimum. These values equated well with the values ranging from 8 to 14% reported by Iwe *et al.* (2016) and lower than 13% highest endorsed by Standard Organization of Nigeria (SON) as stated by Sanni *et al.* (2005b). According to Maziya-Dixon *et al*. (2005), lesser moisture content confers greater shelf life stability on flour.

Fat contents of blend were in the range of 0.54 to 1.99%. African yam bean flour had the maximum fat content, whereas CF had minimum. The range of values obtained in this work fell below those reported by Iwe *et al*. (2016) for rice, AYB and brown cowpea composite flour with values ranging from 1.64 to 5.79%. Reason for this low fat content might be that tubers, cereals and legumes keep their energy in form of starch other than fats and these less fat contents is advantageous as this guarantees lengthier shelf life of flours (Reebe *et al*., 2000).

Protein contents of flours and flour mixtures varied from 1.89 to 19.6%. African yam bean flour had maximum protein content, whereas sample CF had minimum. Substantial increase in protein composition was noted in the flours as level of AYBF inclusion increased in the blend. This increase was expected because AYBF is a protein-rich flour. This increase compared with those reported by Idowu (2013) for snack produced from maize and AYB seeds flour blend.

Ash contents of flour mixtures varied from 1.29 to 2.07% with sample 50CF:50 AYBF

Table 4.3: Experimental Design of Flour Blend with their Responses

Treatments	Samples CF:AYBF	Beta carotene (µg/g)	Fat (%)	Protein (%)
1	94.49:5.51	7.61	0.75	2.31
2	90:10	6.68	0.73	2.88
3	80.06:19.94	6.37	0.66	5.08
4	80:20	6.82	1.00	5.03
5	72.22:27.78	6.59	0.58	6.48
6	72.22:27.78	6.57	0.58	6.54
7	72.22:27.78	6.58	0.58	6.02
8	72.22:27.78	6.58	0.58	6.35
9	72.22:27.78	6.61	0.58	6.48
10	69.23:30.77	6.77	0.83	6.17
11	58.45:41.55	3.50	1.04	9.17
12	54.25:45.75	5.90	1.40	9.77
13	50:50	4.69	1.05	10.52

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF:African yam bean flour.

Table 4.4: Proximate Compositions of Cassava-African Yam Bean Flour Blend

Samples CF:AYBF (%)	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	Crude fibre (%)	Carbohydrate (%)	Total Energy (Kcal/g)
94.49:5.51	$8.35\pm0.24_{fg}$	$0.73\pm0.07_{ef}$	$2.31\pm0.13_{j}$	$1.75\pm0.02_{bcd}$	$4.01\pm0.18_{cde}$	$86.90\pm0.34_{a}$	$363.12\pm1.04_{ab}$
90:10	$8.12\pm0.09_{g}$	$0.75\pm0.04_{de}$	$2.88\pm0.06_{i}$	$1.77\pm0.06_{bc}$	$4.26\pm0.19_{bcd}$	$86.49\pm0.19_{b}$	$364.19\pm0.14_{ab}$
80.06:19.94	$8.61\pm0.16_{ef}$	$0.86\pm0.04_{d}$	$5.03\pm0.10_{h}$	$1.80\pm0.01_{b}$	$4.76\pm0.27_{b}$	$83.74\pm0.15_{c}$	$370.92\pm0.66_{a}$
80:20	$8.95\pm0.09_{de}$	$1.00\pm0.05_{c}$	$5.08\pm0.16_{h}$	$1.76\pm0.01_{bc}$	$4.98\pm0.06_{b}$	$83.17\pm0.15_{d}$	$360.21\pm0.58_{b}$
72.22:27.78	$9.77\pm0.18_{bc}$	$0.59\pm0.04_{h}$	$6.54\pm0.10_{e}$	$1.70\pm0.01_{bcd}$	$4.53\pm0.33_{bc}$	$81.39\pm0.21_{g}$	$357.04\pm0.86_{bcd}$
72.22:27.78	$9.53\pm0.27_{cd}$	$0.57\pm0.03_{h}$	$6.48\pm0.19_{e}$	$1.68\pm0.06_{cd}$	$4.20\pm0.34_{bcd}$	$81.75\pm0.41_{fg}$	$358.01\pm0.96_{bc}$
72.22:27.78	$9.62\pm0.09_{c}$	$0.58\pm0.01_{h}$	$6.02\pm0.10_{g}$	$1.70\pm0.02_{bcd}$	$3.61\pm0.50_{e}$	$82.09\pm0.18_{ef}$	$357.62\pm0.42_{bcd}$
72.22:27.78	$9.79\pm0.07_{bc}$	$0.61\pm0.05_{gh}$	$6.35\pm0.16_{ef}$	$1.72\pm0.01_{bcd}$	$4.35\pm0.30_{c}$	$81.53\pm0.13_{g}$	$357.00\pm0.45_{bcd}$
72.22:27.78	$9.17\pm0.02_{d}$	$0.56\pm0.03_{h}$	$6.48\pm0.10_{e}$	$1.78\pm0.01_{b}$	$4.19\pm0.14_{bcd}$	$82.01\pm0.08_{ef}$	$359.01\pm0.23_{b}$
69.23:30.77	$9.55\pm0.04_{cd}$	$0.82\pm0.06_{d}$	$6.17\pm0.10_{fg}$	$1.77\pm0.006_{bc}$	$4.17\pm0.13_{bcd}$	$81.69\pm0.16_{fg}$	$358.82\pm0.32_{b}$
58:45.41.55	$10.13\pm0.08_{b}$	$1.04\pm0.03_{c}$	$9.17\pm0.13_{d}$	$1.98\pm0.03_{a}$	$4.32\pm0.10_{c}$	$77.86\pm0.13_{i}$	$355.87\pm0.31_{d}$
54.25:45:75	$8.87\pm0.41_{ef}$	$1.40\pm0.06_{b}$	$9.77\pm0.10_{c}$	$1.76\pm0.02_{bc}$	$4.47\pm0.15_{bc}$	$78.20\pm0.47_{h}$	$364.48\pm1.78_{ab}$
50:50	$9.77\pm0.18_{bc}$	$1.05\pm0.04_{c}$	$10.52\pm0.10_{b}$	$2.06\pm0.04_{a}$	$5.09\pm0.06_{a}$	$76.60\pm0.17_{j}$	$357.91\pm0.60_{bc}$
00:100	$11.72\pm0.63_{a}$	$1.99\pm0.02_{a}$	$19.6\pm0.15_{a}$	$2.07\pm0.02_{a}$	$2.90\pm0.18_{f}$	$64.62\pm0.27_{k}$	$354.79\pm1.64_{e}$
100:00	$9.87\pm0.05_{bc}$	$0.54\pm0.02_{i}$	$1.89\pm0.03_{k}$	$1.29\pm0.05_{e}$	$0.80\pm0.04_{g}$	$86.98\pm0.16_{a}$	$358.06\pm0.24_{bc}$

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF: African yam bean flour. Values are average of three replicates ± standard deviation. Average values with different subscript within column are significantly ($p \leq 0.05$) different.

had maximum, whereas CF had least. These values were in the ranges reported by Chilungo (2013) for baked wheat products supplemented with cassava and pigeon pea flours.with values ranging from 0.57 to 2.50% and fell within the acceptable limit of SON (2004) of 3% maximum reported for cassava flour as stated by Sanni *et al.* (2015). Crude fibre contents of flours and their mixtures ranged from 0.80 to 5.09% with the maximum value noted in sample 50CF:50AYBF, while sample CF had the minimum value. These ranges were lesser than those stated by Iwe *et al*. (2016) of 0.95-6.27%. This might due to difference in their ingredients composition

The carbohydrate contents of flours and their mixtures ranged from 76.60 to 86.98%. Sample CF had the maximum carbohydrate, while sample AYBF had the minimum. Sample CF and sample 94.49CF:5.51AYB were not significantly different in their carbohydrate contents. It was revealed that as AYBF quantity was increasing in the flour blend, the carbohydrate composition was reducing. This compared with Okoye *et al*. (2017). The reason might be that AYBF had lower carbohydrate content compared to CF. The total energy contents of the flours and their blend were ranged from 354.79 to 370.92 kcal/g. Sample 80.06CF:19.94AYB had highest total energy, while AYBF had the lowest. This compared well with values ranging from 346.89 to 372.75 kcal/g reported by Ohizua *et al*. (2017).

4.3.2 Total carotenoid and beta carotene of flours, blend and products

The total carotenoid and beta carotene compositions of roots, intermediate products (grated and pressed cassava mash), flours and flour mixtures were depicted in Table 4.5**.** The total carotenoid contents of the roots, intermediate products and flour blend varied from 8.71 to 13.75 µg/g with flash dried and sun dried cassava flours having the highest and the least contents, respectively. Meanwhile, carotenoid was not detected in AYBF. The values obtained in this study fell within the range stated by Oliveira *et al*. (2010) for bitter yellow cassava with values ranged from 1.97 to 16.33 µg/g. Although, Chavez *et al*. (2007) reported total carotenoid contents of 10-22 µg/g. These variations might also be due to the alterations in the types of varieties used by the researchers.

Sun dried cassava flour had the least carotenoid content. This might due to the undesirable effect of sunlight on carotenoid retention. Vimala *et al.* (2011) stated that

Table 4.5: Total Beta Carotene and Carotenoid Contents of Flour Blend

Samples CF:AYBF	Beta-Cryptoxanthin (µg/g)	13-cis (µg/g)	Trans (µg/g)	9-cis (µg/g)	Total Beta Carotene (µg/g)	Total Carotenoid (µg/g)
Root	0.00_{k}	1.26_{g}	2.48_{h}	1.32_{g}	5.06_{l}	8.71_{m}
Grated	1.41_{a}	2.89_{a}	6.49_{a}	4.10_{a}	13.49_{a}	9.7_{l}
Pressed	1.23_{b}	2.80_{b}	6.14_{b}	3.99_{b}	12.93_{b}	8.46_{n}
Flash dried CF	0.75_{e}	2.14_{c}	4.06_{c}	1.94_{d}	8.13_{c}	13.75_{a}
Cabinet dried CF	0.75_{e}	1.54_{e}	3.91_{d}	1.93_{d}	7.37_{e}	11.90_{e}
Sun dried CF	0.95_{c}	1.67_{d}	3.68_{e}	1.66_{e}	6.88_{f}	2.23_{o}
AYBF	ND	ND	ND	ND	ND	ND
94.49:5.51	0.86_{d}	1.71_{d}	3.76_{e}	2.13_{c}	7.61_{d}	13.73_{a}
90:10	0.76_{e}	1.51_{e}	3.28_{f}	1.89_{d}	6.67_{ghi}	11.95_{de}
80.06:19.94	0.97_{c}	1.46_{ef}	2.97_{g}	1.93_{d}	6.36_{j}	12.46_{c}
80:20	0.74_{ef}	1.54_{e}	3.34_{f}	1.93_{d}	6.82_{fg}	13.60_{b}
72.22:27.78	0.63_{g}	1.39_{f}	3.29_{f}	1.89_{d}	6.57_{hi}	11.53_{g}
72.22:27.78	0.64_{g}	1.39_{f}	3.29_{f}	1.91_{d}	6.59_{hi}	11.77_{f}
72.22:27.78	0.63_{g}	1.39_{f}	3.28_{f}	1.91_{d}	6.58_{hi}	10.97_{k}
72.22:27.78	0.64_{g}	1.39_{f}	3.29_{f}	1.90_{d}	6.57_{hi}	11.45_{h}
72.22:27.78	0.63_{g}	1.39_{f}	3.30_{f}	1.91_{d}	6.61_{hi}	11.59_{g}
69.23:30.77	0.73_{f}	1.50_{e}	3.36_{f}	1.91_{d}	6.76_{fgh}	11.37_{i}
58:45.41.55	0.41_{j}	0.78_{i}	1.73_{j}	0.99_{h}	3.50_{m}	12_{d}
54.25:45:75	0.59_{h}	1.25_{g}	2.99_{g}	1.53_{f}	5.90_{k}	11.88_{e}
50:50	0.49_{i}	0.99_{h}	2.36_{i}	1.32_{g}	4.69_{l}	11.26_{j}

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF: African yam bean flour and ND: not detected. Values are means of triplicate ± standard deviation, Average values of dissimilar subscript within column are significantly ($p \leq 0.05$) different.

retention of carotenoids in varied processing procedures assists in evaluating the best method for attaining food products of greater nutritional value. The total β-carotene contents obtained in this work varied from 3.50 to 13.49 µg/g. Grated cassava roots had highest, while sample 58:45CF.41.55AYB had the least. Samples were significantly ($p \leq 0.05$) different in their overall β-carotene and carotenoid contents.

4.3.3 Physico-chemical composition of flour blend

Physico-chemical composition of flour blend are displayed in Table 4.6. The pH and titratable acidity of blend ranged from 5.92 to 6.87 and 0.17 to 0.25%, respectively. Sample 50CF:50AYBF had maximum pH, whereas AYBF had minimum. Similarly, sample 54.25CF:45.75AYBF had maximum titratable acidity, whereas CF had minimum. These values compared with acceptable range characteristic of HQCF as stated by Dziedzoave *et al*. (2005) and Dziedzoave *et al.* (2006) of (6-7) and (< 0.25) for pH and titratable acidity respectively. It was observed that there was increase in pH of mixtures as level of AYBF inclusion increased.

Starch and sugar compositions varied from 65.54 to 82.52% and 3.37 to 4.87%, respectively. These values were comparable to those stated by Chijioke *et al.* (2016) with values ranged from 37.74 to 94.96% and 1.76 to 10.83%, respectively. Amylose and amylopectin compositions varied from 17.66 to 22.07% and 77.93 to 82.34%, respectively. Sample 94.49CF:5.51AYBF had highest amylose content, whereas AYBF had least. The range of values obtained in this work were comparable to those reported by Iwe *et al*. (2016) with values ranged from 17.13 to 28.07%. Likewise, AYBF had highest amylopectin, while samples CF and 94.49CF:5.51AYBF had the least. Tukomane *et al.* (2007) opined that amylose content is an essential determinant of functional property of flour and starches. According to Shittu *et al*. (2007b), flours of high amylose composition are best for noodle manufacture.

4.3.4 Mineral compositions of the flour blend

The mineral compositions of flour combinations are displayed on Table 4.7. Calcium contents of flour mixtures ranged from 97.35 to 231 mg/kg with sample 58.45CF:41.55AYBF having the highest, while CF having the least. The calcium contents of blend increased as quantity of AYBF increased. Magnesium contents of

Table 4.6: Physico-chemical Properties of the Blend

Samples CF:AYBF (%)	Sugar (%)	Starch (%)	Amylose (%)	Amylopectin (%)	Titratable acidity (%)	pH
94.49:5.51	$4.68\pm0.03_{b}$	$75.57\pm0.26_{ef}$	$22.07\pm0.15_{a}$	$77.93\pm0.15_{e}$	$0.17\pm0.01_{e}$	$5.92\pm0.02_{e}$
90:10	$4.52\pm0.06_{bc}$	$74.03\pm0.29_{ef}$	$20.71\pm0.27_{b}$	$79.29\pm0.27_{cd}$	$0.18\pm0.01_{e}$	$6.02\pm0.02_{e}$
80.06:19.94	$3.93\pm0.03_{de}$	$73.18\pm0.51_{f}$	$19.07\pm0.26_{d}$	$80.93\pm0.26_{b}$	$0.21\pm0.01_{c}$	$6.41\pm0.08_{d}$
80:20	$3.89\pm0.02_{de}$	$72.82\pm0.11_{f}$	$18.97\pm0.09_{d}$	$81.03\pm0.09_{b}$	$0.19\pm0.01_{d}$	$6.41\pm0.01_{d}$
72.22:27.78	$3.62\pm0.05_{ef}$	$78.48\pm0.02_{d}$	$18.12\pm0.09_{e}$	$81.88\pm0.09_{ab}$	$0.20\pm0.01_{cd}$	$6.56\pm0.02_{bc}$
72.22:27.78	$3.75\pm0.03_{e}$	$78.12\pm0.2_{d}$	$18.07\pm0.25_{e}$	$81.93\pm0.25_{ab}$	$0.19\pm0.01_{d}$	$6.47\pm0.06_{c}$
72.22:27.78	$3.57\pm0.05_{ef}$	$77.27\pm0.36_{de}$	$18.02\pm0.06_{e}$	$81.98\pm0.06_{ab}$	$0.19\pm0.02_{d}$	$6.49\pm0.08_{c}$
72.22:27.78	$3.79\pm0.23_{e}$	$77.52\pm0.85_{de}$	$17.97\pm0.2_{e}$	$82.03\pm0.2b_{ab}$	$0.18\pm0.01_{e}$	$6.43\pm0.02_{d}$
72.22:27.78	$3.73\pm0.05_{e}$	$77.17\pm0.26_{de}$	$18.15\pm0.04_{e}$	$81.85\pm0.04_{ab}$	$0.19\pm0.04_{d}$	$6.54\pm0.05_{bc}$
69.23:30.77	$3.49\pm0.04_{f}$	$79.52\pm0.14_{c}$	$20.27\pm0.27_{bc}$	$79.73\pm0.27_{c}$	$0.24\pm0.01_{ab}$	$6.63\pm0.10_{b}$
58.45:41.55	$4.11\pm0.1_{d}$	$80.78\pm0.29_{b}$	$21.67\pm0.12_{ab}$	$78.33\pm0.12_{d}$	$0.25\pm0.01_{a}$	$6.73\pm0.13_{ab}$
54.25:45.75	$4.25\pm0.03_{cd}$	$81.26\pm0.29_{ab}$	$21.56\pm0.08_{ab}$	$78.44\pm0.08_{d}$	$0.24\pm0.09_{ab}$	$6.73\pm0.07_{ab}$
50:50	$4.39\pm0.03_{c}$	$82.52\pm0.28_{a}$	$19.74\pm0.22_{c}$	$80.26\pm0.22_{bc}$	$0.23\pm0.09_{b}$	$6.87\pm0.18_{a}$
00:100	$3.37\pm0.06_{g}$	$65.54\pm0.29_{g}$	$17.66\pm0.11_{f}$	$82.34\pm0.11_{a}$	$0.13\pm0.03_{f}$	$5.58\pm0.05_{f}$
100:00	$4.87\pm0.08_{a}$	$76.32\pm0.17_{e}$	$22.00\pm0.24_{a}$	$78.00\pm0.24_{e}$	$0.11\pm0.02_{g}$	$6.01\pm0.03_{e}$

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF: African yam bean flour. Values are means of three replicate ± standard deviation. Average values with different subscript in column are significantly ($p\leq0.05$) different.

Table 4.7: Mineral Contents of the Blend

Samples CF:AYBF	Magnessium (mg/kg)	Calcium (mg/kg)	Zinc (mg/kg)	Iron (mg/kg)
94.49:5.51	$22.45\pm0.35_{j}$	$188.45\pm0.35_{l}$	$2.17\pm0.01_{g}$	$10.2\pm0.14_{j}$
90:10	23.01 ± 0.35i	$192.2\pm0.14_{j}$	$2.23\pm0.01_{g}$	$10.6\pm0.15_{ij}$
80.06:19.94	$23.44\pm0.35_{h}$	196±0.14i	$2.25\pm0.03_{g}$	$11.2\pm0.14_{i}$
80:20	$23.79\pm0.5_{g}$	$204.95\pm0.07_{h}$	$2.28\pm0.26_{g}$	$11.9\pm0.14_{h}$
72.22:27.78	$24.54\pm2.4_{de}$	$213.2\pm0.42_{e}$	$2.95\pm0.04_{ef}$	$13.35\pm0.35_{ef}$
72.22:27.78	$24.09\pm0.42_{f}$	$209.6\pm0.42_{g}$	$2.8\pm0.02_{f}$	$13.05\pm0.21_{efg}$
72.22:27.78	$24.49\pm0.42_{e}$	$211.95\pm0.35_{f}$	$3.05\pm0.02_{ef}$	$13.4\pm0.14_{ef}$
72.22:27.78	$24.71\pm0.21_{d}$	$216.45\pm0.92_{d}$	$3.13\pm0.03_{e}$	$13.6\pm0.28_{ef}$
72.22:27.78	$24.41\pm2.33_{e}$	$211.9\pm1.70_{f}$	$2.99\pm0.01_{ef}$	$13.2\pm0.14_{efg}$
69.23:30.77	25.9 ± 0.28**b**	$225\pm0.28_{b}$	$3.64\pm0.03_{cd}$	$15.35\pm0.35_{c}$
58:45.41.55	$26.93\pm0.28_{a}$	$231.55\pm0.35_{a}$	$3.87\pm0.03_{c}$	$17\pm0.42_{b}$
54.25:45:75	$24\pm0.00_{f}$	$211\pm0.01_{f}$	$3\pm0.02_{ef}$	$12.5\pm0.71_{gh}$
50:50	$25.2\pm0.42_{c}$	$221.55\pm0.21_{c}$	$3.52\pm0.04_{d}$	$14.5\pm0.42_{d}$
00:100	$23.47\pm0.21_{h}$	$189.55\pm0.21_{l}$	$53.6\pm0.28_{a}$	$48.7\pm0.28_{a}$
100:00	$10.77\pm0.28_{k}$	$97.35\pm0.35_{m}$	$18.7\pm0.28_{b}$	$12.75\pm0.21_{fg}$

CF: Provitamin A cassava flour, AYBF: African yam bean flour. Values are means of triplicate ± standard deviation. Average values of dissimilar subscript in column are significantly ($p\leq0.05$) different.

mixtures varied from 10.77 to 26.93 mg/kg with sample 58.45CF:41.55AYBF having the highest, while CF having the least. The zinc and iron contents of the blend ranged from 2.17 to 53.6 mg/kg and 10.2 to 48.17 mg/kg, respectively. The iron contents obtained were greater than those stated by Adeola *et al*. (2017) with values ranging from 1.14-7.84 mg/kg. The flour blend were significantly ($p \leq 0.05$) different in their mineral compositions.

4.4 Impact of Processing on Colour Variations of Flours and their Blend

The colour of flour impacts on the acceptabilility of end product and uniquenes of numerous flour criteria desired by consumers (Widjaya, 2010). Table 4.8 depicted the impact of processing on the colour of PVAC, its flour, intermediate products, AYB and flour blend. Variations in colour of flour blend and in-between products varied from 78.61 to 88.64 for l*, -2.27 to 4.23 for a* and 23.83 to 37.21 for b* values. Pulverised cassava mash had greatest lightness (l*), whereas AYBF had lowest. The values of l* and a* were lesser than those reported by Tharise *et al*. (2014) with values ranging from 95.02 to 97.10 and -0.73 to -1.13, but the b* values were higher with value ranging from 5.66 to 10.01. The brightness of milled cassava mash and pressed cassava were not significantly ($p \geq 0.05$) different from each other.

Yellowness (b*) of PVAC roots was highest whereas AYBF had least yellowness. This might be owing to the occurrence of carotenoid content in PVAC tubers. It was revealed that yellowness concentration was diminishing as level of AYBF inclusion was increasing. Reduction of yellowness of the blend might be as a result of influence of distribution of pigments among which are carotenoids and xanthophyll occurrence in CF with AYBF. Samples were significantly ($p \leq 0.05$) different based on their yellowness except samples 54.25CF:45.75AYBF and 50CF:50AYBF.

4.5 Pasting Properties of the Blend

Pasting properties of flours and their blend are portrayed in Table 4.9. There were significant ($p \leq 0.05$) differences in pasting properties of the blend. The range of values obtained in this study compared with the ranges stated by Adeola *et al*. (2017) with values 5.34-307.20 RVU, 9.05-572.92 RVU and 3.71-265.67 RVU for trough, final viscosity and setback values, respectively. Iwe *et al*. (2016) opined that pasting property is a guide employed in forecasting the capability of food in making paste

Table 4.8: Colour Variations of Flour Blend, Roots and Intermediate Products

Samples CF:AYBF (%)	Lightness (l*)	Redness (a*)	Yellowness (b*)
94.49:5.51	$80.45\pm0.18_{d}$	$-1.14\pm0.3_{e}$	$31.29\pm0.13_{c}$
90:10	$80.35\pm0.08_{d}$	$-1.42\pm0.07_{g}$	$30.35\pm0.33_{de}$
80.06:19.94	$80.23\pm0.12_{d}$	$-1.46\pm0.11_{gh}$	$30.3\pm0.07_{de}$
80:20	$79.94\pm0.16_{d}$	$-1.56\pm0.07_{ghij}$	$30.37\pm0.21_{de}$
72.22:27.78	$79.67\pm0.03_{de}$	$-1.50\pm0.01_{ghi}$	$30.12\pm0.11_{e}$
72.22:27.78	$79.54\pm0.15_{de}$	$-1.48\pm0.04_{ghi}$	$30.18\pm0.38_{e}$
72.22:27.78	$79.99\pm0.02_{d}$	$-1.45\pm0.10_{gh}$	$30.17\pm0.03_{e}$
72.22:27.78	$79.78\pm0.05_{de}$	$-1.47\pm0.10_{ghi}$	$29.89\pm0.46_{e}$
72.22:27.78	$79.99\pm0.04_{d}$	$-1.62\pm0.08_{ghij}$	$30.03\pm0.04_{e}$
69.23:30.77	$79.89\pm0.08_{d}$	$-1.37\pm0.11_{f}$	$29.71\pm0.16_{e}$
58.45:41.55	$79.67\pm0.23_{de}$	$-1.68\pm0.08_{ij}$	$29.87\pm0.56_{e}$
54.25:45.75	$79.56\pm0.26_{de}$	$-1.79\pm0.11_{j}$	$28.88\pm0.26_{f}$
50:50	$79.70\pm0.41_{de}$	$-1.65\pm0.12_{hij}$	$28.27\pm0.12_{f}$
00:100	$78.61\pm0.69_{e}$	$-1.89\pm0.13_{k}$	$23.84\pm0.12_{h}$
100:00	$81.36\pm1.59_{c}$	$-2.27\pm0.05_{l}$	$26.57\pm0.33_{g}$
Root	$78.73\pm0.64_{e}$	$4.23\pm0.08_{a}$	$37.21\pm0.05_{a}$
Grated	$86.88\pm1.46_{b}$	$1.57\pm0.36_{b}$	$35.67\pm1.16_{b}$
Pressed	$88.63\pm0.73_{a}$	$0.83\pm0.02_{c}$	$31.10\pm0.36_{c}$
Pulverised	$88.64\pm0.69_{a}$	$0.31\pm0.01_{d}$	$30.92\pm0.26_{cd}$

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF: African yam bean flour. Values are means of triplicates determination ± standard deviation. Average values with different subscript within column are significantly ($p\leq0.05$) different.

Table 4.9: Pasting Properties of Flour Blend

Samples CF:AYBF (%)	Peak Viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (min.s)	Pasting Temp (^oC)
94.49:5.51	$514.50\pm0.71_{b}$	$206.5\pm0.71_{b}$	$308.00\pm0.00_{b}$	$303.04\pm1.47_{cd}$	$119.25\pm2.95_{a}$	$4.23\pm0.05_{i}$	$72.65\pm0.00_{de}$
90:10	$494.38\pm1.83_{c}$	$183.79\pm1.47_{e}$	$310.58\pm3.30_{b}$	$296.50\pm3.54_{d}$	$89.50\pm3.54_{e}$	$4.47\pm0.00_{h}$	$72.20\pm0.71_{ef}$
80.06:19.94	$407.92\pm4.95_{e}$	$175.79\pm0.18_{fg}$	$232.13\pm4.77_{c}$	$287.21\pm0.30_{e}$	$111.42\pm0.47_{b}$	$4.53\pm0.00_{gh}$	$72.55\pm0.07_{de}$
80:20	$421.21\pm8.78_{d}$	$199.75\pm3.54_{c}$	$221.46\pm5.24_{d}$	$320.92\pm5.66_{b}$	$121.17\pm2.12_{a}$	$5.13\pm0.00_{ef}$	$72.92\pm0.60_{cde}$
72.28:27.22	$341.96\pm4.66_{j}$	$179.08\pm0.59_{f}$	$162.88\pm4.07_{g}$	$281.83\pm1.53_{e}$	$102.75\pm0.94_{d}$	$5.23\pm0.05_{de}$	$72.55\pm0.00_{de}$
72.28:27.22	$363.38\pm0.88_{h}$	$188.50\pm0.24_{d}$	$174.88\pm0.65_{f}$	$296.96\pm0.77_{d}$	$105.67\pm2.95_{bc}$	$5.20\pm0.00_{de}$	$72.80\pm0.28_{de}$
72.28:27.22	$384.75\pm6.36_{f}$	$197.92\pm1.06_{c}$	$186.83\pm5.30_{e}$	$307.13\pm7.01_{c}$	$109.21\pm5.95_{bc}$	$5.17\pm0.05_{ef}$	$73.03\pm0.60_{cde}$
72.28:27.22	$374.38\pm1.47_{g}$	$185.92\pm0.47_{de}$	$188.50\pm0.83_{e}$	$296.25\pm1.65_{d}$	$110.33\pm1.06_{bc}$	$5.13\pm0.01_{ef}$	$73.20\pm0.28_{cde}$
72.28:27.22	$364.00\pm3.42_{h}$	$173.88\pm0.18_{g}$	$190.13\pm3.59_{e}$	$285.33\pm3.65_{e}$	$111.46\pm3.83_{b}$	$5.10\pm0.05_{ef}$	$73.40\pm0.07_{bcd}$
69.23:30.77	$333.13\pm2.30_{j}$	$162.42\pm1.89_{h}$	$170.71\pm0.41_{f}$	$266.04\pm1.12_{f}$	$103.63\pm3.01_{cd}$	$5.00\pm0.03_{fg}$	$73.05\pm0.64_{cde}$
58:45.41.55	$252.04\pm0.18_{l}$	$166.04\pm4.18_{h}$	$86.00\pm4.01_{h}$	$229.63\pm1971_{h}$	$63.58\pm5.89_{f}$	$5.33\pm0.00_{cd}$	$73.83\pm0.53_{bc}$
54.25:45.75	$265.63\pm5.72_{k}$	$182.79\pm1.00_{e}$	$82.83\pm4.71_{h}$	$245.04\pm3.48_{g}$	$62.25\pm2.47_{f}$	$5.23\pm0.14_{c}$	$74.30\pm0.07_{b}$
50:50	$214.66\pm0.24_{m}$	157.58±1.53i	57.08±1.30i	$203.17\pm4.01_{i}$	$45.58\pm2.48_{g}$	$5.50\pm0.05_{b}$	$74.25\pm0.00_{b}$
00:100	$10.00\pm1.41_{n}$	$9.00\pm1.41_{j}$	$1.00\pm0.00_{j}$	$20.00\pm1.41_{j}$	$10.50\pm0.71_{h}$	$7.33\pm0.02_{a}$	$82.33\pm0.00_{a}$
100:00	$569.37\pm0.53_{a}$	$225.83\pm0.47_{a}$	$343.54\pm0.06_{a}$	$346.75\pm2.00_{a}$	$120.92\pm2.48_{a}$	$4.23\pm0.01_{j}$	$71.35\pm0.71_{f}$

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF: African yam bean flour. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscript in column are significantly ($p\leq0.05$) different.

once exposed to heating.

The peak viscosities of flours and their blend varied from 10.00 to 569.37 RVU with CF had the highest, while AYBF had the least. Significant decrease was noted in peak viscosity, breakdown viscosity and setback value as level of AYBF increased. This diminish in viscosities of composite flours might be due to existence and exchanges of food ingredients namely fat and protein in AYBF. It is the highest viscosity attained throughout heating and a guide of capability of starch-based foods to rise prior their physical collapse (Sanni *et al.,* 2006; Adebowale *et al.*, 2008).

Trough viscosity varied from 9.00 RVU to 225.83 RVU with CF having the greatest, while AYBF had the least. Trough viscosity is the least viscosity achieved at constant temperature stage of Rapid Visco Analyser (RVA). It is the pasting property which evaluates the capability of paste to repel collapse throughout cooling (Danbaba *et al*., 2012). Breakdown viscosity of flour blend varied from 1.00 to 343.54 RVU with CF having the greatest breakdown viscosity, while AYBF had the lowest. Values obtained from this study were higher than those stated by Iwe *et al*. (2016) with values ranging from 22.08-106.75 RVU. This might due to the dissimilarities in the composition of their flour blend. Breakdown viscosity is an index of the stability of the starch and a measure of the comfort with which the swollen granules can be collapsed (Kaur *et al.*, 2007).

Final viscosity of the blend varied from 20.00 to 346.75 RVU. Sample AYBF had the highest final viscosity, whereas CF had the least. Values obtained in this study compared with range of values stated by Adeola *et al*. (2017) with values ranging from 9.00 to 572.92 RVU. Final viscosity is the ability of blend to tolerate boiling and shear strain which is often met in processing and essential matter for numerous methods particularly those needing steady paste and little retrogradation. This property exposes the ability to make gelatinous paste following cooking and refrigerating (Adebowale *et al*., 2008). The setback viscosity of blend varied from 10.5 to 121.17 RVU. It was noted that the flour blend with the least quantity of AYBF (94.49CF:5.51AYBF) had peak setback value. Peak setback viscosity indicated that the texture of the food that would be formed from the blend with lesser AYBF

experienced degradation quicker compared with the blend with large quantity of AYBF.

Peak time of flours and their blend varied from 4.23 to 7.33 min with AYBF having the maximum peak time, whereas CFhad the least. Peak time is the period requires to cook the sample. The pasting temperatures of flours and their blend varied from 71.35 to 82.33 ^{o}C. Samples were significantly different in their pasting temperatures except samples 54.25CF:45.75AYBF and 50CF:50AYBF. However, samples CF and AYBF were significantly different from their blend in terms of their pasting properties.

It was noted that the pasting temperature of both flours and their blend were lower than boiling temperature. This proposing that the samples will make paste in boiling water lower than boiling point and thus, suggesting cost saving in the food industry. Based on the report of Olapade and Akinyanju (2014), pasting temperature describes the stability of other components in the formulation as well as visualising the energy requirement for the preparation. Adebowale *et al.* (2008) stated that high pasting temperature showed the ease of paste formation.

4.6 Functional Properties of the Blend

The functional properties of flours and their blend are presented in Table 4.10. Water absorption capacities of the flours and their blend varied from 1.75 to 2.00 g/g of which sample AYBF had maximum water absorption capability, while CF had the minimum. The values obtained in this study compared with range reported by Adeola *et al.* (2017) with values ranging from 1.64 to 3.9 g/g. It was observed that as AYBF increased in the blend, water absorption ability also increased. This property measured capability of flour to absorb water.

Oil absorption capacities of the flours and their blend varied from 0.95 to 1.15 g/g of which 94.49CF:5.51AYBF had maximum oil absorption, whereas 69.23CF:30.77AYBF had minimum. The values obtained in this work compared with the range stated by Ohizua *et al*. (2017) with values 0.9-1.5 g/g. This property measures the ability of flours to absorb oil.

Packed density of flours and their blend varied from 0.60 to 0.97 g/ml with AYBF

Table 4.10: Functional Properties of Flour Blend

Sample Code CF:AYBF (%)	Water Absorption (g/g)	Oil Absorption (g/g)	Packed density (g/ml)	Loose density (g/ml)	Dispersibility (%)
94.49:5.51	$1.8\pm0.14_{abc}$	$1.15\pm0.07_{abc}$	$0.66\pm0.01_{def}$	$0.40\pm0.01_{ef}$	$60.00\pm2.65_{g}$
90:10	$1.86\pm0.00_{ab}$	$1.1\pm0.00_{bcd}$	$0.60\pm0.04_{f}$	$0.41\pm0.03_{def}$	$67.33\pm0.76_{bc}$
80.06:19.94	$1.85\pm0.01_{7ab}$	$1\pm0.00_{cde}$	$0.64\pm0.0_{2def}$	$0.43\pm0.02_{cde}$	$64.17\pm1.89_{de}$
80:20	$1.85\pm0.10_{ab}$	$0.95\pm0.07_{de}$	$0.65\pm0.06_{def}$	$0.47\pm0.06_{c}$	$62.5\pm0.5_{efg}$
72.22:27.78	$1.85\pm0.07_{ab}$	$1\pm0.14_{cde}$	$0.68\pm0.05_{de}$	$0.44\pm0.03_{cde}$	$64.33\pm1,16_{de}$
72.22:27.78	$1.85\pm0.07_{ab}$	$1\pm0.00_{cde}$	$0.67\pm0.00_{de}$	$0.41\pm0.00_{def}$	$63.67\pm0.58_{e}$
72.22:27.78	$1.85\pm0.00_{ab}$	$0.98\pm0.04_{cde}$	$0.63\pm0.00_{ef}$	$0.38\pm0.01_{f}$	$65.00\pm1.00_{cde}$
72.22:27.78	$1.89\pm0.00_{ab}$	$1.15\pm0.07_{ab}$	$0.65\pm0.02_{def}$	$0.40\pm0.01_{ef}$	$64.67\pm0.58_{de}$
72.22:27.78	$1.88\pm0.04_{ab}$	$1.05\pm0.07_{cde}$	$0.67\pm0.02_{de}$	$0.40\pm0.03_{ef}$	$66.83\pm0.76_{bcd}$
69.23:30.77	$1.95\pm0.07_{ab}$	$0.95\pm0.07_{de}$	$0.68\pm0.03_{de}$	$0.44\pm0.01_{cde}$	$63.83\pm1.53_{e}$
58:45.41.55	$1.92\pm0.07_{ab}$	$1\pm0.00_{cde}$	$0.68\pm0.05_{de}$	$0.45\pm0.01_{cd}$	$68.67\pm3.06_{b}$
54.25:45:75	$1.93\pm0.14_{ab}$	$1\pm0.14_{cde}$	$0.70\pm0.01_{d}$	$0.44\pm0.01_{cde}$	$63.33\pm1.26_{ef}$
50:50	$1.97\pm0.35_{ab}$	$1\pm0.00_{cde}$	$0.81\pm0.04_{c}$	$0.54\pm0.03_{b}$	$67.67\pm0.58_{b}$
0:100	$2\pm0.28_{a}$	$0.9\pm0.14_{e}$	$0.97\pm0.03_{a}$	$0.75\pm0.03_{a}$	$73.33\pm1.53_{a}$
100:0	$1.75\pm0.07_{bc}$	$1.3\pm0.00_{a}$	$0.88\pm0.02_{b}$	$0.42\pm0.03_{cdef}$	$61.00\pm1.00_{fg}$

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF: African yam bean flour. Values are means of three replicates ± standard deviation. Average values of dissimilsr subscript within column are significantly ($p\leq0.05$) different.

having maximum value, whereas 90CF:10AYBF had the minimum. These values compared with ranges stated by Adeola *et al*. (2017) with values ranging 0.58 to 1.05 g/ml. Report on food packed density is not only vital to food manufacturers in packaging and management of powdery foods, but it is likewise necessary by food technologists in production of some foods (Kulkarni *et al.,* 1996; Malomo *et al.,* 2012). This could be used in assessing handling requirement namely the kind of wrapping materials suitable for storing and transporting food ingredients (David *et al.,* 2015).

Loose density and dispersibility of flour blend varied from 0.38 to 0.75 g/ml and 60.00 to 73.33% respectively. Sample AYBF had highest loose density and dispersibility, whereas 72.22CF:27.78AYBF had lowest loose density. Moreover, CF and 94.49CF:5.51AYBF had lowest dispersibility. The values of dispersibility obtained in this work compared with ranges stated by Ohizua *et al.* (2017) with 52 to 79%. All the flours have sensibly greater dispersibility, which connotes the comfort of reconsititution to make fine constant dough throughout the mixing (Adebowale *et al*., 2008).

Swelling power capacity of flours and flour blend varied from 1.62 to 4.85 as depicted in Table 4.11. These were investigated within the range of temperature 50 to 90 ^{o}C. It was revealed that there was rise in swollenness capacity as temperature increased. This indicates that swelling power is temperature dependent as stated by Ikegwu *et al.* (2010). Although, there was reduction in swelling power of blend at temperature between 70 and 80 ^{o}C. This was equally stated by Lawal *et al*. (2011).

Foaming capability and stability of flour blend varied from 5.63 to 9.9% as presented in Table 4.12. Sample 94.49CF:5.51AYBF had the maximum foaming capacity, while 72.22CF:27.78AYBF had minimum. The values obtained in this research corresponded to the range stated by Ohizua *et al*. (2017) with values 2.01 to 12.88%. Asif-Ul-Alam *et al*. (2014) opined that the foaming capacity determined the capability of flour to froth that is reliant on the occurrence of protein particles that reduce the exterior pressure of water. Foam stability was studied for eighty minutes at twenty minutes break. It was noted that foam stability of samples was diminishing with

Table 4.11: Swelling Power at Various Temperatures

Samples codes	Temperatures ^{o}C				
CF:AYBF	50	60	70	80	90
94.49:5.51	$1.85\pm0.01_{c}$	$2.5\pm o.21_{a}$	$2.9\pm0.00_{b}$	$2.85\pm0.14_{ab}$	$4.6\pm0.28_{b}$
90:10	$1.87\pm0.01_{c}$	$2.45\pm0.35_{ab}$	$2.85\pm0.35_{b}$	$2.8\pm0.07_{ab}$	$4.55\pm0.07_{b}$
80.06:19.94	$1.78\pm0.01_{cd}$	$2.33\pm0.00_{ab}$	$2.72\pm0.00_{c}$	$2.67\pm0.07_{b}$	$4.08\pm0,14_{cd}$
80:20	$1.82\pm0.01_{c}$	$2.35\pm0.07_{ab}$	$2.75\pm0.21_{c}$	$2.68\pm0.14_{b}$	$4.15\pm0.14_{cd}$
72.22:27.78	$1.76\pm0.04_{cd}$	$2.01\pm0.13_{cd}$	$2.5\pm0.64_{cd}$	$2.59\pm0.42_{c}$	$3.75\pm0.28_{de}$
72.22:27.78	$1.77\pm0.03_{cd}$	$2\pm0.00_{cd}$	$2.4\pm0.14_{cd}$	$2.61\pm0.21_{bc}$	$4\pm0.14_{ed}$
72.22:27.78	$1.76\pm0.02_{cd}$	$1.95\pm0.07_{cd}$	$2.30\pm0.28_{d}$	$2.53\pm0.14_{cde}$	$3.8\pm0.28_{de}$
72.22:27.78	$1.74\pm0.01_{cd}$	$1.92\pm0.07_{cd}$	$2.45\pm0.07_{cd}$	$2.6\pm0.35_{bc}$	$3.65\pm0.07_{e}$
72.22:27.78	$1.82\pm0.06_{c}$	$1.98\pm0.07_{cd}$	$2.7\pm0.14_{c}$	$2.58\pm0.14_{c}$	$3.91\pm0.14_{d}$
69.23:30.77	$1.67\pm0.11_{d}$	$1.86\pm0.14_{d}$	$2.52\pm0.14_{cd}$	$2.45\pm0.07_{d}$	$3.89\pm0.14_{d}$
58:45.41.55	$1.60\pm0.03_{e}$	$1.95\pm0.07_{bcd}$	$2.7\pm0.14_{c}$	$2.65\pm0.07_{bc}$	$3.97\pm0.07_{cd}$
54.25:45:75	$1.62\pm0.03_{e}$	$2.15\pm0.21_{c}$	$2.75\pm0.35_{c}$	$2.72\pm0.07_{b}$	$4.2\pm0.07_{c}$
50:50	$1.72\pm0.08_{cd}$	$2.35\pm0.14_{ab}$	$3.25\pm0.35_{a}$	$3.1\pm0.14_{a}$	$4.85\pm0.07_{a}$
00:100	$2.08\pm0.07_{b}$	$2.25\pm0.07_{b}$	$2.45\pm0.07_{cd}$	$2.25\pm0.21_{e}$	$4\pm0.00_{cd}$
100:00	$2.21\pm0.01_{a}$	$2.55\pm0.35_{a}$	$3\pm0.28_{b}$	$2.92\pm0.28_{ab}$	$4.7\pm0.28_{b}$

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF: African yam bean flour. Values are means of three replicate ± standard deviation. Average values with dissimilar subscript in column are significantly ($p\leq0.05$) different.

Table 4.12: Foaming Capacity and Stability of Flour Blend

Sample CF:AYBF	Foaming capacity (%)	Foaming stability (20 min)	Foaming stability (40 min)	Foaming stability (60 min)	Foaming stability (80 min)
94.49:5.51	$9.9\pm1.24_{a}$	$6.3\pm1.19_{a}$	$5.41\pm0.07_{a}$	$3.61\pm0.05_{a}$	$1.81\pm0.02_{a}$
90:10	$6.54\pm1.24_{ab}$	$4.67\pm1.27_{ab}$	$4.67\pm1.27_{ab}$	$1.87\pm0.03_{ab}$	$1.85\pm0.00_{a}$
80.06:19.94	$6.54\pm1.24_{ab}$	$4.68\pm1.39_{ab}$	$2.81\pm1.36_{bc}$	$1.87\pm0.03_{ab}$	ND
80:20	$8.25\pm1.19_{ab}$	$5.51\pm0.07_{ab}$	$2.75\pm1.26_{bc}$	$1.82\pm2.57_{ab}$	$0.91\pm1.29_{a}$
72.22:27.78	$5.63\pm2.52_{b}$	$4.76\pm1.28_{ab}$	$2.81\pm1.26_{bc}$	$1.85\pm2.62_{ab}$	$0.93\pm1.31_{a}$
72.22:27.78	$6.54\pm1.24_{ab}$	$4.67\pm1.27_{ab}$	$4.63\pm1.31_{ab}$	$2.80\pm1.28_{a}$	$1.87\pm0.03_{a}$
72.22:27.78	$6.54\pm1.24_{ab}$	$4.71\pm1.21_{ab}$	$2.82\pm1.25_{bc}$	ND	ND
72.22:27.78	$6.54\pm1.24_{ab}$	$4.72\pm1.34_{ab}$	$3.74\pm0.05_{abc}$	$1.86\pm0.01_{ab}$	$1.86\pm0.01_{a}$
72.22:27.78	$5.63\pm2.52_{b}$	$4.67\pm1.27_{ab}$	$4.63\pm1.32_{ab}$	$2.79\pm1.29_{a}$	$0.94\pm1.32_{a}$
69.23:30.77	$5.66\pm0.00_{b}$	$3.77\pm0.00_{b}$	$2.83\pm1.33_{bc}$	ND	ND
58:45.41.55	$6.55\pm1.24_{ab}$	$4.67\pm1.27_{ab}$	$3.74\pm0.05_{abc}$	$1.87\pm0.03_{ab}$	$0.93\pm1.31_{a}$
54.25:45:75	$8.25\pm1.19_{ab}$	$5.51\pm0.07_{ab}$	$3.67\pm0.04_{abc}$	$2.75\pm1.27_{a}$	ND
50:50	$6.54\pm1.24_{ab}$	$3.74\pm0.05_{b}$	$1.87\pm0.02_{c}$	ND	ND
0:100	$8.25\pm1.19_{ab}$	$5.51\pm0.07_{ab}$	$3.67\pm0.04_{abc}$	$1.84\pm0.02_{ab}$	$0.93\pm1.31_{a}$
100:0	$7.41\pm0.00_{ab}$	$5.56\pm0.00_{ab}$	$4.63\pm1.32_{ab}$	$2.78\pm1.31_{a}$	$0.93\pm1.31_{a}$

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF: African yam bean flour and ND: not detected. Values are means of three replicate ± standard deviation. Average values of dissimilar subscript within column are significantly different ($P\leq0.05$).

increase in period.

4.7 Anti-nutritional Factors of Flour Blend

Anti-nutritional factors of flour blend are depicted on Table 4.13. The hydrogen cyanide and phytate composition of the blend ranged from 3.47 to 10.32 mg/kg and 1.08 to 2.45 mg/g respectively. Sample 94.49CF:5.51AYBF had maximum hydrogen cyanide, while sample AYBF had minmum. Hydrogen cyanide compositions of flours and their blend were significantly different except samples 94.49CF:5.51AYBF and 90CF:10AYBF that were not significantly different from each other. It was shown that hydrogen cyanide content of blend reduced as the quantity of AYBF inclusion increased in the blend. The HCN values fell within a tolerable limit of 10 mg HCNeqv/kg of cassava flour as recommended by the Food and Agriculture Organisation of the United Nations and World Health Organisation, FAO/WHO (2013) and the African Organisation of Standards, ARSO (2012).

Sample AYBF had the highest phytate and tannin compositions, while sample 94.49CF:5.51AYBF had the least phytate. The tannin compositions of blend ranged from 0.11 to 0.82 mg/g with sample CF had minimum. It was noted that tannin and phytate contents increased as the quantity of AYBF addition increased in the blend. There were significant ($p \leq 0.05$) differences in phytate and tannin compositions of flours and flour blend. The samples' hydrogen cyanide, phytate and tannin contents were lower than permissible levels of 50 mg/kg, 250-500 mg/100 g and 20 mg/g, respectively as stated by Ndidi *et al*. (2014).

4.8 Microstructural Properties of Flours and Flour Blend

Micrographs of AYBF, CF and their optimised flour blends are presented on Plates 4.1, 4.2 and 4.3, respectively. It was observed that AYBF had a predominantly segregated oval shape with the presence of etching. Information on their pore structure revealed that flours were characterised by homogenously dispersed pores of different sizes. Cassava flour had predominantly oval shapes with insignificant round shapes that were clustered together. This compared with Soetikno *et al.* (2017) and Putri *et al.* (2011) that detected irregular shapes in cassava flour. Their pore structure were also categorised by evenly spread of different sizes.

Table 4.13: Anti-nutritional Compositions of Flour Blend

Samples CF:AYBF (%)	HCN (mg/kg)	Phytate (mg/g)	Tannin (mg/g)
94.49:5.51	$10.32\pm0.14_{a}$	$1.08\pm0.10_{i}$	$0.11\pm0.01_{h}$
90:10	$10.18\pm0.35_{a}$	$1.37\pm0.07_{gh}$	$0.22\pm0.01_{g}$
80.06:19.94	$9.41\pm0.22_{b}$	$1.42\pm0.12_{g}$	$0.24\pm0.01_{fg}$
80:20	$9.39\pm0.15_{b}$	$1.55\pm0.17_{fg}$	$0.26\pm0.01_{f}$
72.22:27.78	$8.81\pm0.35_{c}$	$1.95\pm0.10_{e}$	$0.26\pm0.03_{f}$
72.22:27.78	$9.45\pm0.47_{b}$	$2.00\pm0.10_{de}$	$0.24\pm0.01_{fg}$
72.22:27.78	$8.88\pm0.38_{c}$	$2.09\pm0.20_{cde}$	$0.22\pm0.01_{g}$
72.22:27.78	$9.51\pm0.46_{b}$	$2.07\pm0.14_{cde}$	$0.21\pm0.01_{g}$
72.22:27.78	$8.69\pm0.40_{c}$	$1.89\pm0.15_{e}$	$0.25\pm0.02_{f}$
69.23:30.77	$8.21\pm0.22_{d}$	$1.69\pm0.10_{f}$	$0.37\pm0.02_{d}$
58:45.41.55	$6.22\pm0.27_{fg}$	$2.24\pm0.07_{bc}$	$0.34\pm0.01_{e}$
54.25:45:75	$7.31\pm0.27_{ef}$	$2.44\pm0.06_{b}$	$0.45\pm0.03_{c}$
50:50	$7.99\pm0.14_{e}$	$2.20\pm0.10_{cd}$	$0.63\pm0.02_{b}$
0:100	$3.47\pm0.05_{g}$	$2.55\pm0.11_{a}$	$0.82\pm0.01_{a}$
100:0	$6.76\pm0.28_{f}$	$1.38\pm0.07_{gh}$	$0.34\pm0.01_{e}$

CF:AYBF, CF: Pro-vitamin A cassava flour, AYBF denotes African yam bean flour. Values are means of three replicate ± standard deviation. Average values of dissimilar subscript in column are significantly different ($P\leq0.05$).

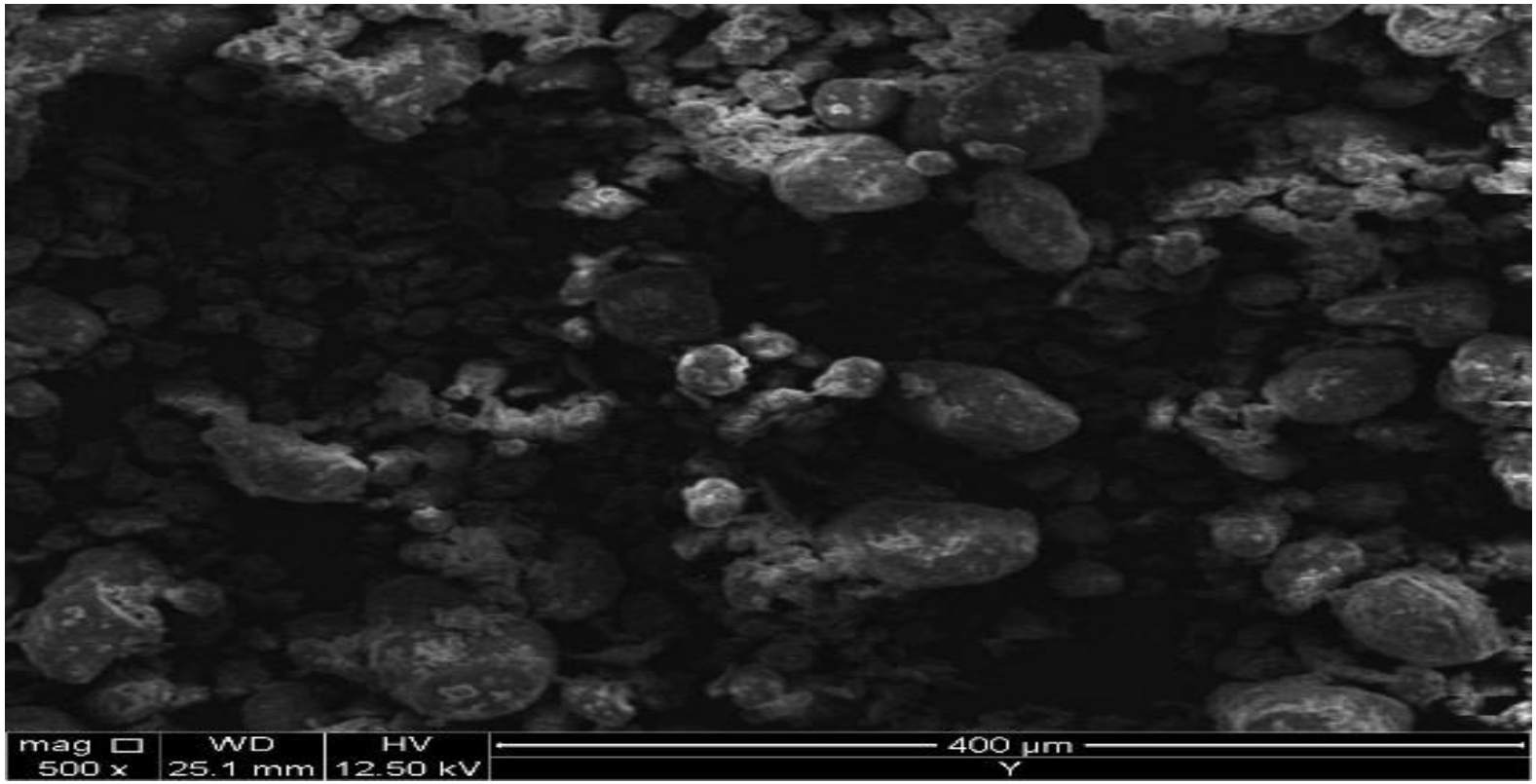


Plate 4.1: Micrograph of African Yam Bean Flour (x500 Magnification)

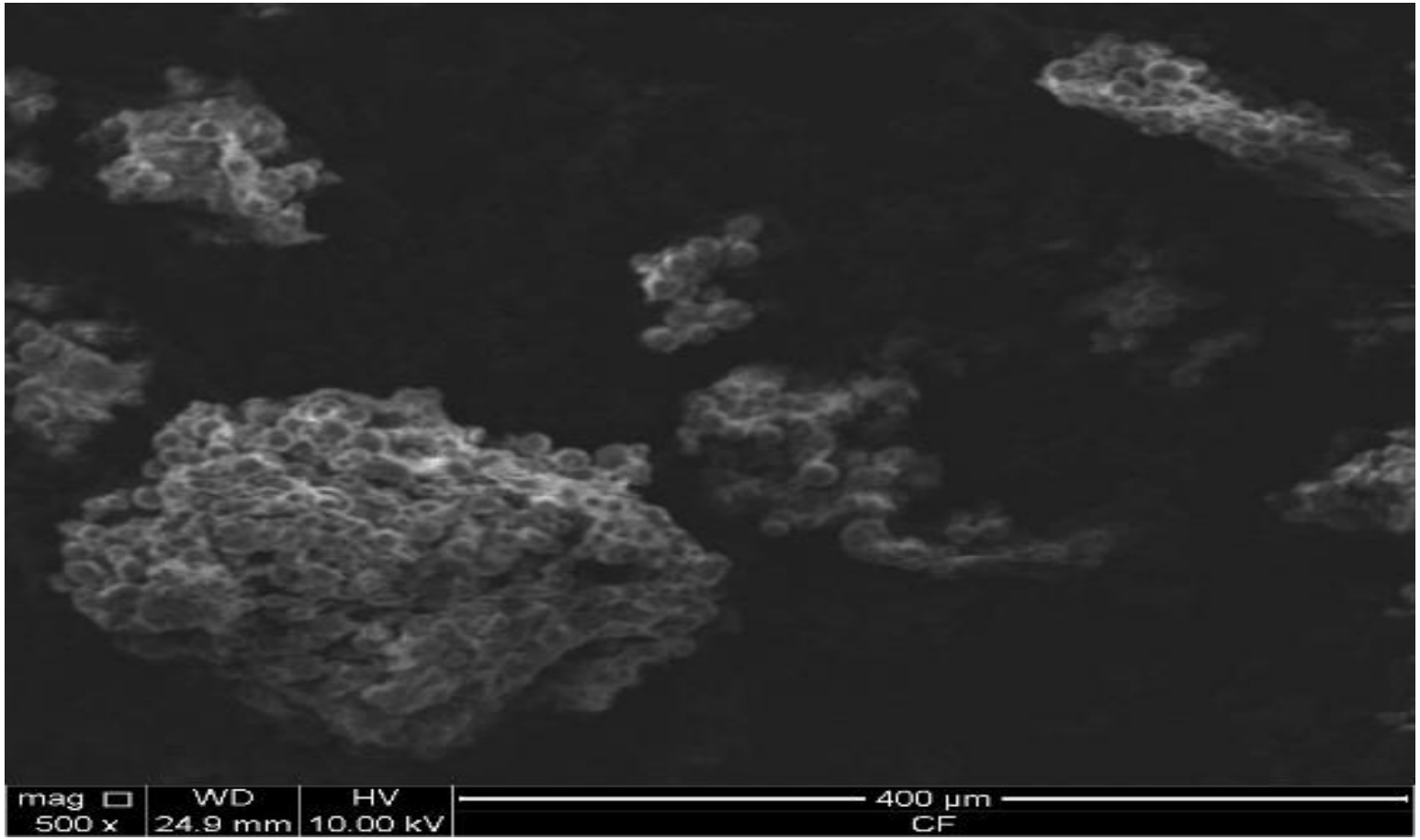


Plate 4.2: Micrograph of Pro-vitamin A Cassava Flour (x500 Magnification)

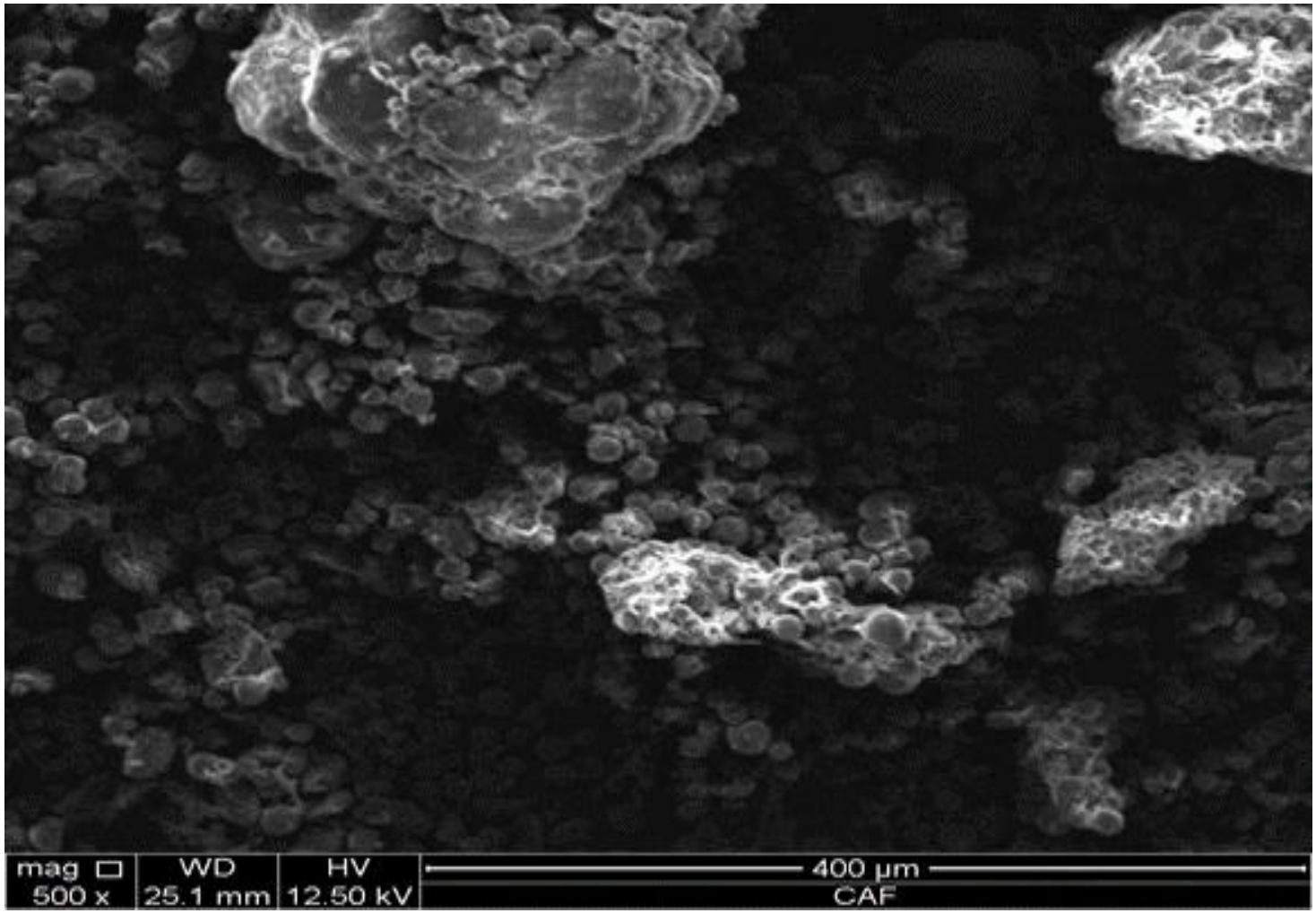


Plate 4.3: Micrograph of Optimised Cassava-African Yam Bean Flour Blend (x500 Magnification)

The optimised flour blends combined the structures of both flours with oval shapes in the presence of pasted portion. Their pore structure revealed that the flours were categorised by evenly dispersed pores of the same sizes. Rough surface and eroded starch granules were observed. This was due to corrosion and enzymatic hydrolysis of cassava starch granules that happened mostly on exterior of cassava starch particles. Furthermore, the micrographs of the two flours and their blend showed the structural difference among the three flours. This was corroborated by Soetikno *et al.* (2017) that revealed that cassava flour particles had a distinct morphology after modifications.

4.9 Predictive Models and Models Verification of Flour Blend

The polynomial response surface models provided the equations that report and predict the link between independent variables (CF and AYBF) and their chosen responses: β-carotene, protein and fat contents within a specified range. The predicted equations for the responses and coefficient of determination (R^2) were shown in Table 4.14. It was observed that R^2 for all the responses were greater than 85%, signifying significant models. The difference between predicted values of desirable blend and experimental values was depicted in Table 4.15.

4.10 Determination of Cassava-African Yam Bean Noodles Quality

4.10.1 Impact of processing parameters on proximate composition of noodles

Proximate compositions of cassava-African yam bean noodles and commercial noodle are presented on Table 4.16. Noodles were significantly ($p \leq 0.05$) different in their proximate compositions which revealed the consequence of difference in hydration level and steaming time. The moisture contents of the noodles varied from 5.67-9.54%. Sample 53:2 had highest moisture, while sample 510 had the least. These values compared with the ranges stated by Chijioke *et al.* (2016) with values ranging from 3.69 to 11.46%. These values compared well with recommended moisture content for air dried noodles of below 14% reported by Codex Alimentarius Commission, CAC (2006).

The ash contents of noodles varied from 1.84 to 3.04% with sample 53:2 had maximum ash content, whereas sample 510 had the minimum. The values obtained in

Table 4.14: Predicted Equations for the Responses

Responses	Equations	R^2 (Coefficient of determination)
Beta carotene	$Y=6.59+0.54A-0.76B+0.18A^2-0.73B^2+0.56AB$	0.9360
Protein	$Y=6.38-1.64A+2.31B+0.42A^2-0.43B^2-0.55AB$	0.9904
Fat	$Y=0.58-0.17A+0.049B+0.2A^2+0.13B^2+0.057AB$	0.8525

A= Pro-vitamin A cassava flour, B= African yam bean flour

Table 4.15: Experimental and Predicted Values of Flour Blends

Variables	CF (%)	AYBF (%)	Beta-carotene (µg/g)	Protein (%)	Fat (%)
Predicted values	70.52	29.48	6.46	6.68	0.58
Experimental values	70.52	29.48	5.74	7.15	0.69
Percentage of agreement			88.85	92.96	81.03
Percentage of deviation			11.15	7.04	18.97

CF: Pro-vitamin A cassava flour and AYBF: African yam bean flour

Table 4.16: Proximate Composition of the Noodles

Samples codes HL:ST	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Crude fibre (%)	Carbohydrate (%)
50:1	$8.64\pm0.01_{c}$	$2.67\pm0.00_{b}$	$11.55\pm0.42_{ab}$	$0.88\pm0.11_{de}$	$2.83\pm0.05_{d}$	$76.26\pm0.54_{b}$
48.76:2	$8.67\pm0.38_{c}$	$2.67\pm0.47_{b}$	$11.36\pm0.41_{ab}$	$1.07\pm0.1_{bc}$	$3.20\pm0.08_{ab}$	$76.23\pm1.36_{cd}$
56:3	$8.84\pm0.16_{bc}$	$2.5\pm0.24_{bc}$	$11.22\pm0.46_{b}$	$1.09\pm0.03_{bc}$	$2.18\pm0.05_{g}$	$76.35\pm0.52_{cd}$
53:2	$8.68\pm0.04_{c}$	$2.57\pm0.00_{bc}$	$10.26\pm0.41_{bcd}$	$1.08\pm0.04_{bc}$	$2.84\pm0.08_{d}$	$77.41\pm0.49_{b}$
50:3	$8.07\pm0.13_{e}$	$2.67\pm0.00_{b}$	$11.70\pm0.62_{a}$	$1.16\pm0.07_{b}$	$2.63\pm0.06_{e}$	$76.4\pm0.56_{c}$
53:0.59	$9.13\pm0.11_{b}$	$2.33\pm0.00_{ab}$	$10.56\pm0.83_{bc}$	$1.18\pm0.08_{b}$	$2.49\pm0.09_{f}$	$76.8\pm1.01_{cd}$
53:3.41	$9.21\pm0.01_{b}$	$1.84\pm0.23_{d}$	$10.15\pm0.41_{bcd}$	$1.14\pm0.02_{bc}$	$2.63\pm0.03_{e}$	$77.66\pm0.18_{c}$
56:1	$8.58\pm0.04_{cd}$	$2.17\pm0.23_{c}$	$10.08\pm0.21_{cd}$	$1.09\pm0.06_{bc}$	$3.41\pm0.05_{a}$	$78.08\pm0.01_{b}$
53:2	$8.64\pm0.14_{c}$	$2.75\pm0.35_{b}$	$9.98\pm0.42_{cd}$	$0.93\pm1.14_{bcd}$	$3.41\pm0.05_{a}$	$77.7\pm0.77_{b}$
53:2	$9.54\pm0.14_{a}$	$2.25\pm0.55_{b}$	$10.05\pm0.62_{cd}$	$0.97\pm0.21_{bcd}$	$3.33\pm0.05_{ab}$	$77.19\pm0.33_{b}$
53:2	$8.7\pm0.09_{c}$	$2.5\pm0.00_{bc}$	$10.02\pm0.21_{cd}$	$1.01\pm0.04_{bcd}$	$3.32\pm0.04_{ab}$	$77.77\pm0.15_{b}$
53:2	$8.68\pm0.09_{c}$	$2.5\pm0.24_{bc}$	$9.95\pm0.42_{de}$	$0.92\pm0.16_{bcd}$	$3.1\pm0.05_{b}$	$77.95\pm0.42_{b}$
57.24:2	$8.91\pm0.03_{bc}$	$2.00\pm0.01_{c}$	$9.25\pm0.21_{f}$	$0.88\pm0.21_{de}$	$3.44\pm0.04_{a}$	$78.92\pm0.44_{a}$
510	$5.67\pm0.05_{f}$	$3.04\pm0.03_{a}$	$9.89\pm0.02_{de}$	$4.95\pm0.12_{a}$	$0.49\pm0.03_{h}$	$76.46\pm0.23_{c}$

HL=hydration level (%), ST=steaming time (min), 510: Commercial noodle. Values are means of three replicates ± standard deviation. Average values of dissimilar subscript within column are significantly ($p\leq 0.05$) different.

this work were more than those reported by Akanbi *et al*. (2011) with values ranging from 1.3 to 2.3% for breadfruit-starch wheat composite noodles. Samples prepared at hydration level of between 53 and 57.24% at steaming time of between 1 and 3 min were not significantly ($p \geq 0.05$) different in their ash compositions.

The protein contents of noodles varied from 9.25 to 11.70% with sample 50:3 having the maximum protein content, while sample 57.24:2 had the minimum. As the hydration level was increasing, the protein contents of the samples were diminishing. It was observed that steaming duration did not have a profound influence on protein compositions of the noodles.

The fat contents of noodles varied from 0.88 to 4.95% with sample 510 having the maximum fat content, while samples 57.24:2 and 50:1 had the minimum. Crude fibre contents of noodles varied from 0.49 to 3.44% with sample 57.24:2 having the maximum crude fibre, while sample 510 had the minimum. The carbohydrate contents of noodles ranged from 76.23 to 78.92% with sample 57.24:2 having the highest carbohydrate content, while 53:0.59 had the least. It was observed that steaming at 2 min was found to increase carbohydrate contents of the samples except at hydration level of 48.76%.

4.10.2 Effect of processing parameters on mineral composition

Mineral compositions of cassava-African yam bean noodles were displayed on Table 4.17. Noodles were significantly ($p<0.05$) different in their phosphorus, calcium, sodium and potassium contents. Phosphorus contents of cassava-African yam bean noodles ranged from 0.32 to 0.99 mg/100 g with noodle coded 53:2 having the highest phosphorus content, while sample 53:0.59 had the least. It was noted that hydration level and steaming duration ranging from 53% to 50% at 2 min to 1 min, resulted in reduction in phosphorus contents. Likewise, a further reduction of hydration level to 48.76% at 2 min steaming time resulted in reduction of phosphorus content. Further increase in hydration level to 57.24% at the same steaming period caused a pronounced loss in phosphorus composition of noodles.

Calcium contents of samples varied from 101.65 to 141.5mg/kg with sample 50:1 having the highest calcium content, while sample 50:3 had the least. Increasing the

Table 4.17: Mineral Composition of Cassava-African Yam Bean Noodles

Samples HL:ST	Phosphorus (mg/kg)	Calcium (mg/kg)	Magnessium (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)	Iron (mg/kg)	Zinc (mg/kg)
50:1	$0.91\pm0.14_{d}$	$141.5\pm2.12_{a}$	$167.10.21_{a}$	$37.55\pm0.07_{cd}$	$47.35\pm1.4_{d}$	$16.8\pm0.14_{e}$	$46.17\pm0.01_{c}$
48.76:2	$0.97\pm0.54_{b}$	$108.4\pm0.14_{d}$	$119.6\pm0.14_{d}$	$46.98\pm0.88_{ab}$	$48.34\pm1.77_{c}$	$19.6\pm0.14_{a}$	$46.5\pm0.14_{c}$
56:3	$0.86\pm0.47_{e}$	$121.95\pm0.21_{b}$	$148.6\pm0.28_{b}$	$42.98\pm0.23_{b}$	$34.64\pm0.23_{g}$	$18.8\pm0.14_{b}$	$47.6\pm0.42_{b}$
53:2	$0.97\pm0.25_{b}$	$106.4\pm0.14_{ef}$	$118.2\pm0.14_{e}$	$40.37\pm0.38_{bcd}$	$52.71\pm0.59_{a}$	$18.35\pm0.21_{bc}$	$44.4\pm0.14_{d}$
50:3	$0.62\pm0.07_{g}$	$101.65\pm0.21_{h}$	$114.7\pm0.14_{g}$	$26.57\pm0.45_{e}$	$36.67\pm0.15_{e}$	$16\pm0.28_{f}$	$40\pm0.28_{h}$
53:0.59	$0.32\pm0.14_{i}$	$105.25\pm0.21_{fg}$	$112.85\pm0.07_{h}$	$53.44\pm1.78_{a}$	$29.44\pm0.26_{j}$	$16.45\pm0.21_{ef}$	$41.65\pm0.07_{g}$
53:3.41	$0.7\pm0.11_{f}$	$104.8\pm0.14_{g}$	$116.45\pm0.21_{f}$	$34.95\pm0.21_{d}$	$34.66\pm0.2_{g}$	$16.8\pm0.14_{e}$	$43.6\pm0.14_{ef}$
56:1	$0.96\pm0.09_{bc}$	$112.7\pm0.28_{c}$	$121.7\pm0.28_{c}$	$40.69\pm0.26_{bcd}$	$36.26\pm0.11_{ef}$	$17.6\pm0.42_{d}$	$48.55\pm0.35_{a}$
53:2	$0.99\pm0.27_{a}$	$105.95\pm0.21_{efg}$	$118\pm0.14_{e}$	$39.99\pm0.27_{bcd}$	$52.16\pm0.2_{ab}$	$18.25\pm0.21_{bc}$	$44.45\pm0.21_{d}$
53:2	$0.91\pm0.18_{d}$	$106.05\pm0.21_{efg}$	$118.05\pm0.35_{e}$	$40.44\pm0.12_{bcd}$	$52.00\pm0.31_{ab}$	$17.85\pm0.21_{cd}$	$44.05\pm0.21_{de}$
53:2	$0.95\pm0.07_{bc}$	$106.15\pm0.21_{efg}$	$117.95\pm0.21_{e}$	$39.94\pm0.20_{bcd}$	$49.79\pm0.15_{bc}$	$18.45\pm0.35_{b}$	$44.25\pm\pm0.21_{d}$
53:2	$0.97\pm0.07_{b}$	$106.75\pm0.07_{e}$	$117.95\pm0.21_{e}$	$40.42\pm0.15_{bcd}$	$50.73\pm1.12_{b}$	$18.25\pm0.21_{bc}$	$44.55\pm0.21_{d}$
57.24:2	$0.47\pm0.21_{h}$	$108.55\pm0.35_{d}$	$116.45\pm0.35_{f}$	$20.12\pm0.37_{f}$	$32.49\pm0.19_{h}$	$15.35\pm0.35_{g}$	$43.35\pm0.35_{f}$

HL=hydration level (%), ST=steaming time (min). Values are means of three replicates ± standard deviation.

Average values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

steaming time of noodles at 53% hydration level from 59 sec to 2 min resulted in increase in the calcium content of noodle. A loss in calcium content of the noodle was showed that steaming time above 2 min at 53% hydration level resulted in reduced calcium content whereas reduction of hydration level from 53% to 48.76% resulted in increase in calcium content. Magnesium content of samples ranged from 112.85 to 167.1 mg/kg with sample 50:1 having maximum magnesium content, while sample 53:0.59 had the minimum. It was observed that increasing the steaming time at 53% hydration level resulted in increase in magnesium contents of noodles. However, this was in contrary to noodles hydrated at 50%.

Potassium contents of the noodles varied from 20.12 to 53.44 mg/kg with sample 53:0.59 having the maximum, while 57.24:2 had the minimum. There was reduction in potassium content of the noodles as steaming time increased from 59 s to 3.41 min at 53% hydration level. Likewise, increasing the hydration level from 53% to 57.24% at 2 min steaming time caused decrease in potassium content of noodles. The values of potassium contents obtained in this study matched with the range reported by Xu *et al.* (2017) with values ranging from 7.6 to 312.96 mg/kg.

Sodium contents of noodles varied from 29.44 to 52.71mg/kg with sample 53:2 having highest sodium content, while 53:0.59 had the least. It was revealed that increase in hydration level to 50% regardless of steaming duration resulted in reduction of sodium contents. Similarly, a steaming duration above 59 s resulted in increase in sodium contents at 50% hydration level. The iron comtents of the noodle varied from 15.35 to 19.6 mg/kg with sample 48.76:2 having the highest, while sample 57.24:2 had the least. The zinc contents of the noodles varied from 40.00 to 48.55 with sample 56:1 having the highest, while sample 50:3 had the least.

4.10.3 Impact of processing parameters on overall carotenoid and beta carotene

The total beta carotene and total carotenoid contents of cassava-African yam bean noodles varied from 2.85 to 4.99 µg/g and 5.61 to 8.15 µg/g, respectively as displayed in Table 4.18. Noodles were significantly different ($P<0.05$) in their total beta carotene and total carotenoid compositions. Sample 48.76:2 having maximum total beta carotene and total carotenoid contents of the noodles, while sample 53:3.41 had the minimum. However, the total beta carotene and carotenoid content of sample 510

Table 4.18: Total Beta Carotene and Carotenoid Contents of the Noodles

Samples HL:ST	13 Cis (µg/g)	Trans (µg/g)	9 Cis (µg/g)	Total Beta carotene (µg/g)	Total Carotenoid (µg/g)
50:1	$0.81\pm0.08_{de}$	$1.59\pm0.01_{de}$	$0.78\pm0.00_{ef}$	$3.18\pm0.06_{d}$	$5.88\pm0.06_{g}$
48.76:2	$1.22\pm 0.02_{a}$	$2.55\pm0.02_{a}$	$1.21\pm0.04_{b}$	$4.99\pm0.08_{a}$	$8.15\pm0.12_{b}$
56:3	$0.72\pm0.04_{e}$	$1.50\pm0.07_{h}$	$0.75\pm0.10_{ef}$	$2.97\pm0.21_{de}$	$5.78\pm0.07_{g}$
53:2	$0.80\pm0.09_{de}$	$1.83\pm0.00_{d}$	$0.85\pm0.00_{de}$	$3.49\pm0.08_{c}$	$6.42\pm0.01_{e}$
50:3	$0.80\pm0.09_{de}$	$1.53\pm0.00_{h}$	$0.76\pm0.04_{ef}$	$3.09\pm0.06_{de}$	$6.27\pm0.08_{f}$
53:0.59	$0.84\pm0.02_{de}$	$1.47\pm0.01_{h}$	$0.73\pm0.00_{ef}$	$3.03\pm0.03_{de}$	$6.21\pm0.01_{f}$
53:3.41	$0.80\pm0.01_{de}$	$1.36\pm0.01_{i}$	$0.69\pm0.02_{f}$	$2.85\pm0.05_{e}$	$5.61\pm0.03_{j}$
56:1	$0.73\pm0.06_{e}$	$1.64\pm0.04_{e}$	$0.83\pm0.07_{e}$	$3.19\pm0.16_{d}$	$5.87\pm0.06_{g}$
53:2	$1.04\pm0.12_{bc}$	$1.88\pm0.00_{c}$	$0.96\pm0.08_{cd}$	$3.89\pm0.04_{b}$	$7.38\pm0.04_{c}$
53:2	$1.02\pm0.01_{bc}$	$2.11\pm0.01_{b}$	$0.99\pm0.02_{c}$	$4.13\pm0.02_{b}$	$7.04\pm0.04_{d}$
53:2	$0.94\pm0.07_{cd}$	$2.04\pm0.03_{b}$	$0.97\pm0.03_{cd}$	$3.95\pm0.01_{b}$	$7.03\pm0.01_{d}$
53:2	$0.97\pm 0.00_{c}$	$2.01\pm0.02_{b}$	$0.98\pm0.01_{c}$	$3.97\pm0.03_{b}$	$6.81+0.02_{d}$
57.24:2	$0.90\pm0.02_{cd}$	$1.73\pm0.06_{e}$	$0.85\pm0.04_{de}$	$3.47\pm0.12_{c}$	$6.47\pm0.01_{e}$
500	$1.12\pm0.02_{ab}$	$2.54\pm0.01_{a}$	$1.31\pm0.02_{a}$	$5.14\pm0.02_{a}$	$8.96\pm0.03_{a}$
510	ND	ND	ND	ND	ND

HL=hydration level (%), ST=steaming time (min), CF=pro-vitamin A cassava flour, 500: validated optimised blend, 510: commercial noodle and ND: not detected. Values are means of three replicates ± standard deviation. Average values of dissimilar subscript within column are significantly ($p\leq0.05$) dissimilar.

was not detected.

At hydration level 56%, the total beta carotene contents of noodles reduced as the steaming duration increased but their total carotenoid contents were not significantly ($p \geq 0.05$) different. Steaming duration had a substantial influence on noodles quality at hydration level 53%. As the steaming period increased from 0.59 min to 2 min, both total beta carotene and total carotenoids contents of noodles improved. Moreover, it was observed that as steaming period rose to 3.41 min. both total beta carotene and total carotenoid contents diminished. This showed that steaming duration longer than 2 min had a detrimental effect on both total beta carotene and total carotenoid of cassava-African yam bean noodles. This result compared with Bui and Small (2008) that steamed noodles for 2 min.

Similarly, as the hydration level increased from 48.76% to 53%, there was reduction in carotenoids contents of the samples. This might due to the influence of moisture content on carotenoids content of the sample. This showed that as hydration level increased, both total beta carotene and carotenoid contents of the noodles reduced.

4.11 Colour Variations of Dried Noodles

The colour of uncooked cassava-African yam bean noodles and commercial noodle are presented on Table 4.19. The values varied from 73.75 to 89.24 for l*, -1.85 to 1.52 for a* and 14.98 to 18.56 for b* with sample 510 having the most lightness (l*), while sample 53:2 had the least. Similarly, sample 50:1 having the most intense yellowness (b*) colour and sample 510 had the least. Cassava-African yam bean noodles were significantly ($p \leq 0.05$) different from commercial noodle owing to their l*, a* and b*. The dissimilarities could be as a result of difference in their ingredients. The b* values obtained in this research compared with the ranges reported by Widjaya (2010) with values 11.0 to 21.8. Moreover, l* obtained in this work were lesser than those stated by the same researcher with values 77.3 to 83.7.

4.12 Anti-nutritional Contents of Cassava-African Yam Bean Noodles

The anti-nutritional contents of noodles are presented on Table 4.20. Noodles were significantly ($p \leq 0.05$) different in their tested anti-nutritional factors. Samples' phytate, tannin and hydrogen cyanide were below the acceptable limits based on

Table 4.19: Colour Variations of Experimental and Commercial Noodles

Samples HL:ST	Lightness (l*)	Redness (a*)	Yellowness (b*)
50:1	$77.59\pm0.17_{cd}$	$0.62\pm0.08_{e}$	$18.56\pm0.07_{a}$
48.76:2	$76.50\pm0.34_{de}$	$0.92\pm0.11_{d}$	$17.29\pm0.16_{cd}$
56:3	$75.63\pm1.16_{efg}$	$0.58\pm0.13_{e}$	$18.17\pm0.25_{b}$
53:2	$74.72\pm0.82_{ghi}$	$1.10\pm0.06_{c}$	$16.19\pm0.06_{hi}$
50:3	$75.41\pm0.10_{efgh}$	$0.26\pm0.01_{f}$	$17.94\pm0.03_{b}$
53:0.59	$76.06\pm0.10_{ef}$	$(-)0.43\pm0.02_{g}$	$17.35\pm0.00_{cd}$
53:3.41	$73.75\pm0.27_{i}$	$1.52\pm0.02_{a}$	$17.45\pm0.09_{c}$
56:1	$78.02\pm1.43_{c}$	$0.54\pm0.05_{e}$	$16.91\pm0.11_{ef}$
53:2	$75.23\pm0.42_{fgh}$	$1.38\pm0.24_{ab}$	$16.68\pm0.25_{fg}$
53:2	$74.15\pm0.60_{hi}$	$1.13\pm0.03_{c}$	$15.91\pm0.27_{i}$
53:2	$74.67\pm0.49_{ghi}$	$1.27\pm0.10_{bc}$	$16.36\pm0.19_{gh}$
53:2	$74.44\pm0.24_{ghi}$	$1.39\pm0.09_{ab}$	$16.61\pm0.10_{fg}$
57.24:2	$79.33\pm0.82_{b}$	$1.35\pm0.10_{ab}$	$17.08\pm0.53_{de}$
510	$89.24\pm0.76_{a}$	$(-)1.85\pm0.09_{h}$	$14.98\pm0.14_{j}$

HL=hydration level (%), ST=steaming time (min), 510=indomie noodle. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscript in column are significantly ($p\leq0.05$) different.

Table 4.20: Anti-nutritional Factors of the Noodles

Samples HL:ST	HCN (mg/kg)	Phytate (mg/g)	Tannin (mg/g)
50:1	$0.6\pm0.02_{g}$	$1.34\pm0.05_{a}$	$0.68\pm0.01_{a}$
48.76:2	$1.01\pm0.08_{d}$	$1\pm0.04_{fg}$	$0.64\pm0.02_{b}$
56:3	$1.31\pm0.03_{b}$	$1.08\pm0.05_{def}$	$0.34\pm0.01_{h}$
53:2	$0.89\pm0.03_{e}$	$0.9\pm0.00_{g}$	$0.6\pm0.02_{bc}$
50:3	$1.8\pm0.04_{a}$	$1.28\pm0.05_{b}$	$0.6\pm0.00_{bc}$
53:0.59	$0.9\pm0.01_{e}$	$1\pm0.04_{fg}$	$0.37\pm0.01_{gh}$
53:3.41	$1.20\pm0.02_{c}$	$1.01\pm0.05_{efg}$	$0.35\pm0.01_{h}$
56:1	$0.9\pm0.02_{e}$	$1.14\pm0.04_{cde}$	$0.4\pm0.02_{g}$
53:2	$0.73\pm0.04_{f}$	$1.14\pm0.05_{cde}$	$0.51\pm0.02_{f}$
53:2	$0.7\pm0.01_{f}$	$1.04\pm0.09_{def}$	$0.55\pm0.04_{de}$
53:2	$0.98\pm0.03_{d}$	$1.07\pm0.04_{def}$	$0.56\pm0.01_{cd}$
53:2	$0.7\pm0.02_{f}$	$1.01\pm0.05_{efg}$	$0.52\pm0.02_{ef}$
57.24:2	$0.73\pm0.04_{f}$	$0.97\pm0.00_{fg}$	$0.48\pm0.00_{f}$

HL=hydration level (%), ST=steaming time (min). Values are means of three replicates ± standard deviation, Average values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

Ndidi *et al*. (2014) that reported the maximum tolerable limit in man as varied from 2.5 to 5 mg/g for phytate, 20 mg/g for tannin and 50 mg/kg for hydrogen cyanide.

4.13 Amino Acids Profile of the Noodles

Amino acids contents of flours, optimised flour blend, cassava-African yam bean noodles and commercial noodle were presented on Tables 4.21, 4.22, 4.23 and Table 4.24, respectively. Details of the amino acid contents were as follows: leucine 0.74-7.74 g/100 g, isoleucine 2.57-4.15 g/100 g, lysine 3.34-5.82 g/100 g, methionine 0.84-1.31 g/100 g, phenylalanine 3.34-4.42 g/100 g, threonine 2.7-7.87 g/100 g, valine 3.03-4.05 g/100 g, histidine 1.92-2.57 g/100 g, tryptophan 0.79-1.23 g/100 g, proline 2.83-3.93 g/100 g alanine 3.57-4.58 g/100 g, cysteine 0.8-1.31 g/100 g, tyrosin 2.48-3.5 g/100 g, arginine 5.08-7.25 g/100 g, aspartic acid 6.5-8.41 g/100 g, glutamic acid 10.37-12.92 g/100 g, glycine 3.24-4.44 g/100 g and serine 2.99-3.61 g/100 g. Glutamic acid content had maximum value followed by aspartic acid while, tryptophan had the minimum.

The total indispensable and dispensable amino acids of noodles are presented on Table 4.25. These ranged from 27 to 33.67 g/100g and 41.02 to 46.28 g/100g. It was observed that these values for most experimental noodles were higher than commercial noodle. This was corroborated with Xu *et al.* (2017) that reported that potato noodles had higher amino acids than commercial noodle. This might due to the presence of nonwheat flour in composition of the noodles. The values of alanine, cysteine and arginine obtained in this work compared with ranges reported by Ogunmodimu *et al*. (2015) with values 3.48-6.15 g/100 g, 0.62-1.42 g/100 g and 4.25-7.92 g/100 g, repectively. Sample AYBF was significantly ($p \leq 0.05$) different from others based on their leucine and alaninie composition.

Similarly, sample CF was significantly different in terms of its leucine, isoleucine, threonine, lysine, tryptophan, proline, glutamic acid and glycine contents. Sample 510 was also significantly different based on its cysteine, alanine, and arginine contents. The percentage of essential amino acid obtained from cassava-African yam bean noodles were in ranges of 31.55 to 41.24% as shown. Sample 53:3.41 having the maximum value, whereas sample 510 had the minimum from the noodle samples and

Table 4.21: Indispensable Amino Acids of the Noodles (g/100 g protein)

Samples HL:ST	Leucine	Iso-leucine	Phenylalanine	Valine	Threonine
50:1	$5.66\pm0.08_{gh}$	$3.46\pm0.16_{bc}$	$3.85\pm0.06_{abcd}$	$3.45\pm0.21_{cde}$	$3.04\pm0.06_{defg}$
48.76:2	$7.74\pm0.29_{a}$	$4.15\pm0.22_{a}$	$4.17\pm0.13_{ab}$	$4.04\pm0.16_{a}$	$3.47\pm0.04_{b}$
56:3	$6.06\pm0.15_{efg}$	$3.39\pm0.13_{bcd}$	$3.34\pm0.08_{d}$	$3.27\pm0.17_{de}$	$2.7\pm0.01_{h}$
53:2	$6.16\pm0.7_{defg}$	$2.68\pm0.47_{e}$	$3.54\pm0.00_{bcd}$	$3.77\pm0.33_{abcd}$	$3.23\pm0.06_{bcde}$
50:3	$6.34\pm0.22_{cde}$	$3.31\pm0.1_{bcd}$	$3.46\pm0.13_{cd}$	$3.03\pm0.17_{e}$	$2.85\pm0.05_{gh}$
53:0.59	$6.74\pm0.13_{cd}$	$3.21\pm0.08_{bcd}$	$3.94\pm0.06_{abcd}$	$4.05\pm0.11_{a}$	$3.36\pm0.04_{bc}$
53:3	$6.89\pm0.12_{bc}$	$3.48\pm0.09_{bc}$	$4.42\pm0.11_{a}$	$3.99\pm0.06_{ab}$	$2.97\pm0.04_{efg}$
56:1	$6.99\pm0.15_{bc}$	$3.02\pm0.10_{cde}$	$4.32\pm0.09_{a}$	$3.93\pm0.06_{abc}$	$2.92\pm0.03_{fgh}$
53:2	$5.43\pm0.08_{h}$	$2.99\pm0.25_{cde}$	$3.77\pm0.69_{abcd}$	$3.67\pm0.43_{abcd}$	$3.32\pm0.33_{bc}$
53:2	$5.51\pm0.78_{gh}$	$3.10\pm0.13_{bcde}$	$3.95\pm0.06_{abcd}$	$3.85\pm0.13_{abc}$	$3.38\pm0.01_{bc}$
53:2	$5.74\pm0.78_{fgh}$	$2.95\pm0.09_{de}$	$3.86\pm0.56_{abcd}$	$3.96\pm0.02_{abc}$	$3.04\pm0.06_{defg}$
53:2	$5.84\pm0.42_{fgh}$	$3.16\pm0.21_{bcde}$	$4.23\pm0.16_{a}$	$3.95\pm0.02_{abc}$	$3.31\pm0.11_{bcd}$
57.24:2	$5.63\pm0.08_{gh}$	$3.26\pm0.17_{bcd}$	$4.39\pm0.2_{a}$	$3.48\pm0.2_{bcde}$	$3.87\pm0.18_{a}$
510	$6.06\pm0.15_{efgh}$	$3.08\pm0.09_{bcde}$	$3.46\pm0.13_{cd}$	$3.92\pm0.12_{abc}$	$3.18\pm0.06_{cdef}$
500	$6.64\pm0.22_{cd}$	$3.55\pm0.1_{b}$	$4.03\pm0.06_{abc}$	$3.93\pm0.06_{abc}$	$3.22\pm0.04_{bcde}$
CF	$0.74\pm0.08_{i}$	$2.57\pm0.11_{f}$	$3.53\pm0.06_{abcd}$	$3.5\pm0.09_{cde}$	$3.12\pm0.06_{cde}$
AYBF	$7.26\pm0.23_{b}$	$3.27\pm0.33_{bcd}$	$4.3\pm0.62_{a}$	$3.81\pm0.54_{abc}$	$3.31\pm0.22_{bcd}$

HL = hydration level (%), ST = steaming time (min), AYBF: African yam bean flour, CF: Pro-vitamin A cassava flour, 500: Optimised flour blend, 510: Commercial noodle. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p \leq 0.05$) different.

Table 4.22: Indispensable Amino Acid of the Noodles (g/100 g protein)

Samples HL:ST	Methionine	Lysine	Histidine	Tryptophan
50:1	$1.14\pm0.04_{bcd}$	$4.76\pm0.17_{bcd}$	$2.30\pm0.04_{bc}$	$0.9\pm0.06_{ab}$
48.76:2	$1.31\pm0.07_{a}$	$4.51\pm0.31_{bcde}$	$2.1\pm0.02_{bcdef}$	$0.94\pm0.07_{ab}$
56:3	$1.12\pm0.04_{bcde}$	$3.81\pm0.25_{def}$	$1.97\pm0.02_{ef}$	$0.87\pm0.06_{ab}$
53:2	$1.20\pm0.04_{abc}$	$4.23\pm0.43_{bcdef}$	$2.19\pm0.02_{bcde}$	$0.9\pm0.06_{ab}$
50:3	$1.19\pm0.02_{abcd}$	$4.09\pm0.24_{cdef}$	$2.21\pm0.03_{bcde}$	$0.89\pm0.03_{ab}$
53:0.59	$1.16\pm0.05_{abcd}$	$5.20\pm0.24_{ab}$	$2.57\pm0.03_{a}$	$0.98\pm0.01_{ab}$
53:3.41	$0.93\pm0.42_{f}$	$5.82\pm0.17_{a}$	$2.12\pm0.03_{bcdef}$	$1.23\pm0.04_{a}$
56:1	$1.22\pm0.02_{ab}$	$5.79\pm0.24_{a}$	$2.33\pm0.05_{b}$	$1.1\pm0.14_{ab}$
53:2	$0.91\pm0.15_{f}$	$3.86\pm1.18_{def}$	$2.01\pm0.04_{def}$	$1.04\pm0.32_{ab}$
53:2	$1.03\pm0.13_{def}$	$4.29\pm0.45_{bcdef}$	$1.92\pm0.24_{f}$	$0.85\pm0.02_{b}$
53:2	$1.17\pm0.11_{abcd}$	$5.18\pm0.51_{ab}$	$2.24\pm0.32_{bcd}$	$1.06\pm0.28_{ab}$
53:2	$1.04\pm0.07_{cdef}$	$4.75\pm0.01_{bcd}$	$2.11\pm0.01_{bcdef}$	$1.17\pm0.16_{ab}$
57.24:2	$0.89\pm0.03_{f}$	$4.94\pm0.24_{abc}$	$2.06\pm0.03_{cdef}$	$1.15\pm0.07_{ab}$
510	$0.97\pm0.03_{ef}$	$3.34\pm0.22_{f}$	$2.28\pm0.03_{bc}$	$0.92\pm0.04_{ab}$
500	$1.17\pm0.04_{abcd}$	$4.95\pm0.10_{abc}$	$2.35\pm0.06_{b}$	$1.02\pm0.04_{ab}$
CF	$0.84\pm0.04_{f}$	$3.49\pm0.21_{ef}$	$1.98\pm0.03_{bcde}$	$0.79\pm0.05_{c}$
AYBF	$0.9\pm0.02_{f}$	$5.19\pm0.8_{ab}$	$2.39\pm0.09_{b}$	$1.06\pm0.26_{ab}$

HL = hydration level (%), ST = steaming time (min), AYBF: African yam bean flour, CF : Pro-vitamin A cassava flour, 500: Optimised flour blend, 510: Commercial noodle. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p \leq 0.05$) different.

Table 4.23: Dispensable Amino Acid Profile of the Noodles (g/100 g protein)

Samples HL:ST	Proline	Alanine	Glutamic acid	Glycine	Tyrosine
50:1	$2.99\pm0.07_{cdef}$	$3.57\pm0.06_{g}$	$10.94\pm0.05_{f}$	$4.03\pm0.07_{cde}$	$3.05\pm0.06_{abc}$
48.76:2	$3.93\pm0.05_{a}$	$4.47\pm0.1_{ab}$	$12.50\pm0.04_{ab}$	$3.99\pm0.04_{cde}$	$2.55\pm0.76_{c}$
56:3	$3.43\pm0.04_{b}$	$3.75\pm0.05_{defg}$	$11.49\pm0.1_{de}$	$3.25\pm0.07_{g}$	$3.03\pm0.09_{abc}$
53:2	$3.2\pm0.08_{bcdef}$	$3.79\pm0.21_{defg}$	$12.37\pm0.33_{g}$	$3.24\pm0.16_{g}$	$2.92\pm0.24_{abc}$
50:3	$2.83\pm0.02_{f}$	$3.68\pm0.05_{fg}$	$11.33\pm0.05_{ef}$	$3.48\pm0.05_{g}$	$3.05\pm0.06_{abc}$
53:0.59	$3.32\pm0.05_{bcd}$	$3.87\pm0.06_{def}$	$12.28\pm0.04_{bc}$	$3.94\pm0.04_{cdef}$	$3.02\pm0.1_{abc}$
53:3	$3.34\pm0.02_{bcd}$	$3.99\pm0.06_{cde}$	$12.58\pm0.02_{ab}$	$4.24\pm0.04_{ab}$	$2.9\pm0.03_{abc}$
56:1	$3.4\pm0.09_{b}$	$3.92\pm0.06_{def}$	$12.92\pm0.04_{a}$	$4.44\pm0.04_{a}$	$3.24\pm0.04_{ab}$
53:2	$3.15\pm0.43_{bcdef}$	$3.66\pm0.1_{9fg}$	$12.24\pm0.36_{bc}$	$3.95\pm0.35_{cdef}$	$3.01\pm0.12_{abc}$
53:2	$3.24\pm0.07_{bcd}$	$3.69\pm0.06_{fg}$	$12.15\pm0.28_{bc}$	$3.81\pm0.01_{def}$	$3.01\pm0.12_{abc}$
53:2	$3.2\pm0.36_{bcdef}$	$3.72\pm0.32_{efg}$	$12.43\pm0.62_{abc}$	$4.17\pm0.15_{bcd}$	$2.92\pm0.24_{abc}$
53:2	$3.35\pm0.14_{bcd}$	$3.74\pm0.08_{defg}$	$12.48\pm0.19_{ab}$	$4.1\pm0.07_{bcd}$	$3.14\pm0.18_{abc}$
57.24:2	$3.29\pm0.09_{bcd}$	$3.65\pm0.06_{fg}$	$12.61\pm0.05_{ab}$	$4.23\pm0.06_{ab}$	$2.89\pm0.05_{bc}$
510	$2.97\pm0.11_{def}$	$4.22\pm0.1_{bc}$	$11.56\pm0.03_{de}$	$3.26\pm0.06_{g}$	$3.26\pm0.02_{ab}$
500	$3.83\pm0.04_{a}$	$4.53\pm0.13_{a}$	$11.93\pm0.04_{cd}$	$3.96\pm0.05_{cdef}$	$3.50\pm0.08_{a}$
CF	$2.86\pm0.03_{ef}$	$4.58\pm0.04_{a}$	$12.74\pm0.05_{a}$	$3.88\pm0.08_{ef}$	$2.48\pm0.04_{e}$
AYBF	$3.25\pm0.29_{bcde}$	$4.02\pm0.11_{cd}$	$12.46\pm0.14_{bc}$	$4.17\pm0.16_{bcd}$	$3.27\pm0.49_{ab}$

HL= hydration level (%), ST = steaming time (min), AYBF: African yam bean flour, CF: Pro-vitamin A cassava flour, 500: optimised flour blend and 510: Commercial noodle. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p \leq 0.05$) different.

Table 4.24: Dispensable Amino Acids Profile of the Noodles (g/100 g protein)

Samples HL:ST	Cysteine	Serine	Aspartic acid	Arginine
50:1	$1.19\pm0.04_{abcde}$	$3.18\pm0.09_{abc}$	$7.53\pm0.04_{d}$	$5.1\pm0.09_{ef}$
48.76:2	$1.29\pm0.02_{ab}$	$2.99\pm0.01_{c}$	$8.41\pm0.03_{a}$	$6.15\pm0.1_{b}$
56:3	$1.01\pm0.02_{ef}$	$3.36\pm0.06_{abc}$	$6.5\pm0.01_{g}$	$5.82\pm0.05_{bcd}$
53:2	$1.15\pm0.09_{abcdef}$	$3.45\pm0.00_{abc}$	$7.22\pm0.62_{bc}$	$5.08\pm0.12_{ef}$
50:3	$1.13\pm0.03_{abcdef}$	$3.61\pm0.05_{a}$	$6.69\pm0.02_{f}$	$5.37\pm0.1_{def}$
53:0.59	$1.23\pm0.06_{abcd}$	$3.25\pm0.06_{abc}$	$8.04\pm0.04_{b}$	$5.89\pm0.06_{bcd}$
53:3	$1.1\pm0.01_{bcdef}$	$3.42\pm0.68_{abc}$	$7.96\pm0.03_{b}$	$5.86\pm0.01_{bcd}$
56:1	$1.31\pm0.05_{a}$	$3.14\pm0.06_{abc}$	$7.92\pm0.01_{bc}$	$6.15\pm0.06_{b}$
53:2	$0.97\pm0.18_{f}$	$3.29\pm0.16_{abc}$	$7.21\pm0.04_{bc}$	$5.68\pm0.72_{bcde}$
53:2	$1.18\pm0.04_{abcde}$	$3.1\pm0.18_{bc}$	$7.23\pm0.16_{bc}$	$5.29\pm0.42_{def}$
53:2	$1.06\pm0.04_{cdef}$	$3.27\pm0.12_{abc}$	$7.24\pm0.06_{bc}$	$5.64\pm0.5_{bcdef}$
53:2	$1.11\pm0.02_{bcdef}$	$3.32\pm0.08_{abc}$	$7.47\pm0.04_{d}$	$5.7\pm0.09_{bcde}$
57.24:2	$1.01\pm0.03_{ef}$	$3.21\pm0.05_{abc}$	$7.49\pm0.01_{d}$	$5.53\pm0.09_{cdef}$
510	$0.8\pm0.03_{g}$	$3.55\pm0.06_{ab}$	$7.79\pm0.03_{c}$	$7.25\pm0.1_{a}$
500	$1.05\pm0.06_{def}$	$3.61\pm0.05_{a}$	$7.81\pm0.04_{c}$	$5.64\pm0.05_{bcdef}$
CF	$1.13\pm0.04_{abcdef}$	$3.53\pm0.04_{ab}$	$7.43\pm0.02_{d}$	$5.98\pm0.06_{bc}$
AYBF	$1.24\pm0.21_{abc}$	$3.6\pm0.29_{a}$	$7.88\pm0.26_{bc}$	$5.72\pm0.18_{bcd}$

HL = hydration level (%), ST= steaming time (min), AYBF:African yam bean flour, CF: Pro-vitamin A cassava flour, 500: Optimised flour blend and 510: Commercial noodle. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscript in column are significantly ($p \leq 0.05$) different.

Table 4.25: Total Indispensable and Dispensable Amino Acids of the Noodles

Samples HL:ST	TEAA (g/100g protein)	TNEA (g/100g protein)	TAA (g/100g protein)	PEAA (%)
50:1	28.56	41.58	70.14	40.72
48.76:2	32.43	46.28	78.71	41.2
56:3	26.53	41.64	68.17	38.92
53:2	27.9	41.02	68.92	40.48
50:3	27.37	41.17	68.54	39.93
53:0.59	31.21	44.84	76.05	41.03
53:3.41	31.85	45.39	77.24	41.24
56:1	31.62	45.44	77.06	41.03
53:2	27	43.16	70.16	38.48
53:2	27.88	42.86	70.74	39.41
53:2	30.2	44.35	74.55	40.51
53:2	29.56	44.41	73.97	39.96
57.24:2	33.67	43.91	77.58	43.40
510	27.21	44.66	71.87	37.86
500	30.86	45.86	76.72	40.22
CF	20.56	44.61	65.17	31.55
AYBF	31.49	45.61	77.1	40.84

HL=Hydration level (%): ST=steaming time (min), 510= commercial noodle, AYBF: African yam bean flour, CF: Pro-vitamin A cassava flour, 500: Optimised flour blend, TEAA: Total indispensable amino acid, TNEAA: Total dispensable amino acids and PEAA: Percentage essential amino acids.

sample CF had the lowest of all samples tested. Values obtained in this work suggested that experimental noodles have balanced of amino acid composition and therefore, adequate for human consumption. According to Zuraini *et al*. (2006), amino acids are essential constituents for curing, vital in protein manufacture procedures and any insufficiency in these vital ingredients will distress the recovery process of the affected individual. Therefore, its importance are enormous to both adults and children.

The effect of hydration level and steaming time were investigated. It was observed that, at 48.76% hydration level for 2 min steaming time, the amino acids such as leucine, iso-leucine, phenylalanine, threonine, glutamic acid, cysteine, aspartic acid and arginine contents were improved. At hydration level and steaming time of 50% at 3 min and 50% at 1 min respectively, reduction in some amino acid contents were noted. Increasing the hydration level and steaming time to 53% at 3.41 min resulted in improvement of amino acid contents of the noodle.

Reduction of steaming time to 2 min at the same hydration level resulted in reduction of amino acid composition except glutamic acid. It was noted that sample prepared at hydration level 53% of steaming time 59 s resulted in improvement of most amino acid contents except iso-leucine, phenylalanine, proline, alanine, tyrosine and serine. It was revealed that increasing hydration level beyond 53% at either 2 min or 3 min steaming time resulted in reduction of most amino acid contents except noodles hydrated at 57.24%. This suggested that both hydration level and steaming duration impacted on amino acid composition.

4.14 Physical and Cooking Quality of Cassava-African Yam Bean Noodles

The cooking qualities of noodles were shown in Table 4.26. The cooking yields of noodles varied from 177.84 to 209.93% respectively with sample 56:3 having the highest and sample 50:3 had the least. These cooking yields were within those stated by Omeire *et al*. (2015) with values ranging from 115.6 to 213.55%. The highest cooking yield was obtained at 3 min steaming time which was in agreement with that of Widjaya (2010) that achieved its highest cooking yield at short steaming times of 3 min. The cooking loss obtained in this study were in the range of 6.87-10.8% with

Table 4.26: Cooking Quality of the Noodles

Samples Hl:ST	Cooking loss (%)	Cooking time (min.sec)	Cooking yield (%)
50:1	$7.68\pm0.13_{def}$	$9.45\pm0.11_{a}$	$185.74\pm2.15_{bcd}$
48.76:2	$8.76\pm0.34_{bc}$	$9.06\pm0.06_{a}$	$189.3\pm8.95_{bc}$
56:3	$7.17\pm0.01_{fg}$	$7.5\pm0.07_{c}$	$209.93\pm1.15_{a}$
53:2	$8.89\pm0.21_{bcd}$	$8.02\pm0.6_{c}$	$197.57\pm6.9_{ab}$
50:3	$8.58\pm0.11_{efg}$	$7.43\pm0.02_{c}$	$177.84\pm2.15_{de}$
53:0.59	$7.58\pm0.28_{efg}$	$8.13\pm0.11_{b}$	$186.95\pm2.11_{bcd}$
53:3.41	$7.96\pm0.24_{de}$	$7.2\pm0.07_{c}$	$181.73\pm8.4_{cd}$
56:1	$10.8\pm0.5_{a}$	$8.28\pm0.18_{b}$	$186.42\pm1.36_{bcd}$
53:2	$8.8\pm0.3_{bcd}$	$8.34\pm0.32_{b}$	$201.95\pm1.83_{ab}$
53:2	$8.17\pm0.28_{def}$	$9.17\pm0.06_{a}$	$208.96\pm1.69_{a}$
53:2	$8.42\pm0.69_{bc}$	$8.38\pm0.30_{b}$	$205\pm6.51_{a}$
53:2	$8.77\pm0.28_{cde}$	$8.32\pm0.18_{b}$	$202.39\pm7.04_{a}$
57.24:2	$9.06\pm0.43_{b}$	$9.19\pm0.06_{a}$	$196.61\pm9.3_{ab}$
510	$6.87\pm0.14_{g}$	$8.48\pm0.16_{b}$	$197.41\pm2.54_{ab}$

HL = hydration level (%), ST = steaming time (min),

510: Commercial noodle. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

sample 510 having the least, while 56:1 had the highest. These values were in agreement with Croatian Official Regulation (1991) that stated that cooking loss should not be greater than 12% and compared with ranges reported by Omeire *et al.* (2015) with values ranging from 3.44 to 22.32%. Cooking loss is the soluble portions of starch and non-starch polysaccharides that escape into cooking water that make the water becomes cloudy and concentrated.

Rayas-Duarte *et al.* (1996) opined that accumulation of non-gluten thinned the strength of gluten. This led to structure interruption that caused more leaching out of noodles into cooking water thereby, leading to high cooking loss in fortified noodles. It was observed that the absence of gluten in fortified noodle might weaken the noodle structure since gluten provides viscoelastic structure to noodle and this resulted in higher cooking loss as compared to commercial noodle. This was corroborated by Susanna and Prabhasankar (2013) that reported gluten free pasta having greater cooking loss than *Triticum durum* pasta.

The cooking time of noodles varied from 7.2 to 9.45 min with sample 50:1 having the maximum cooking time, whereas sample 53:3 had the least. The cooking time obtained in this work were greater than those reported by Choy (2011) with values ranging from 2.15 to 5.30 min. Meanwhile, Rosa-Sibakov *et al*. (2016) stated 9 min and 10 min cooking periods for 100% faba bean pasta and wheat pasta respectively.

The impact of hydration level and steaming time were investigated on cooking quality of noodles. It was revealed that as hydration level rose from 48.76% to 53% at 2 min steaming time, there was increase in cooking yield with no significant difference in cooking loss. Moreover, at hydration level 56% of 1 min steaming time, a high cooking loss was noted. This might be attributed to inadequate steaming that resulted in high loss of noodle strands during cooking. As the steaming time increased to 3 min at the same hydration level cooking loss was significantly reduced which led to a significant increase in cooking yield.

However, at 50% hydration level, an increase in steaming period from 1 min to 3 min resulted in significant loss in cooking yields that led to increase cooking loss of noodles. It was revealed that at 53% hydration level, as the steaming time increased

from 0.59 sec to 2 min, there was increase in cooking yield. A further increase in steaming time to 3.41 min resulted in decrease in cooking yield of the noodle. Overall, it was revealed that both hydration level and steaming time had a significant influence on noodle quality.

4.15 Textural Properties of the Noodles

Textural properties that include firmness, springiness, stickiness, cohesiveness, stinginess, adhesiveness, chewiness and resilience of the noodles are depicted in Table 4.27 and Table 4.28. These properties varied from 810.5 to 2382 g, 0.49 to 0.85, -68.5 to (-18.5), 0.39 to 0.75, 8.04 to 16.7, 56.8 to 823.75, 254.5 to 1082 g and 0.1 to 0.3, respectively. Noodles' hardness were significantly different except samples 50:1, 48.76:2 and 56:3 that were not significantly different based on their hardness. Sample 56:1 having the maximum values for hardness and chewiness whereas, sample 56:3 had the least hardness of the PVAC-AYB noodles. Meanwhile, sample 510 had minimum hardness of all the noodles.

Hardness, cohesiveness and resilience values obtained in this work were lesser than those stated by Vandarkuzhali and Narayanasamy (2015) with values 1531.55-2507.62 g, 0.35-0.43 and 0.16-0.19, respectively. According to Sozer *et al*. (2007) the larger the hardness, the higher will be the adhesiveness and chewiness of cooked noodles. This was in support with Chen (2009) that reported that foods with hard and strong texture need extra chewing force and movements prior swallowing. Vandarkuzhali and Narayanasamy (2015) reported that significant increase in hardness of pasta might be owing to increase in protein content and decreased in water uptake. This could be the reason why the experimental noodles had higher hardness values compared to commercial noodle as displayed. Similar result was observed for the pasta products with added chickpea and quinoa flours.

The chewiness values obtained in this work were lesser than those stated by Jayasena *et al.* (2008) and Vandarkuzhali and Narayanasamy (2015) with values ranging from 944 to 1104 g and 422.15 to 750.14 g, respectively. These dissimilarities might due to variations in ingredients of the noodles. The springiness values of the noodles varied from 0.49 to 0.68. The values obtained in this work were lesser than those stated by Laleg *et al*. (2016) with values ranging from 0.75 to 0.97. Experimental noodles and

Table 4.27: Textural Properties of the Noodles

Samples HL:ST	Hardness (g)	Springiness	Stickiness (g)	Cohesiveness
50:1	$1186\pm69.3_{f}$	$0.58\pm0.04_{de}$	$(-)18.5\pm2.12_{g}$	$0.5\pm0.21_{f}$
48.76:2	$1176.5\pm47.38_{f}$	$0.53\pm0.02_{ef}$	$(-)26.5\pm0.71_{f}$	$0.43\pm0.02_{gh}$
56:3	$1165.5\pm65.76_{f}$	$0.49\pm0.01_{f}$	$(-)28\pm1.41_{f}$	$0.39\pm0.01_{h}$
53:2	$1896\pm154.15_{cd}$	$0.6\pm0.03_{cd}$	$(-)42.5\pm3.54_{e}$	$0.66\pm0.01_{b}$
50:3	$1446.5\pm23.34_{e}$	$0.68\pm0.01_{a}$	$(-)30\pm2.83_{fg}$	$0.58\pm0.04_{de}$
53:0.59	$1784\pm31.11_{d}$	$0.64\pm0.02_{c}$	$(-)53.5\pm2.12_{bcd}$	$0.59\pm0.02_{cde}$
53:3.41	$1959.5\pm103.95_{cd}$	$0.5\pm0.02_{f}$	$(-)48\pm2.83_{de}$	$0.75\pm0.03_{a}$
56:1	$2382.5\pm113.84_{a}$	$0.85\pm0.01_{b}$	$(-)68.5\pm2.12_{a}$	$0.62\pm0.01_{bcd}$
53:2	$2128\pm216.38_{bc}$	$0.61\pm0.02_{cd}$	$(-)52\pm2.83_{cd}$	$0.57\pm0.04_{de}$
53:2	$2053.5\pm105.36_{bc}$	$0.63\pm0.01_{cd}$	$(-)56\pm1.41_{bc}$	$0.55\pm0.01_{e}$
53:2	$2033.5\pm36.06_{c}$	$0.61\pm0.02_{cd}$	$(-)55\pm1.41_{bc}$	$0.48\pm0.01_{f}$
53:2	$2281\pm155.56_{ab}$	$0.62\pm0.05_{cd}$	$(-)57.5\pm7.78_{b}$	$0.56\pm0.01_{e}$
57.24:2	$2082.5\pm21.92_{bc}$	$0.6\pm0.01_{cd}$	$(-)54.5\pm2.12_{bc}$	$0.46\pm0.02_{fg}$
510	$810.5\pm84.15_{g}$	$0.62\pm0.01_{cd}$	$(-)19.5\pm0.71_{g}$	$0.63\pm0.01_{bc}$

HL = hydration level (%), ST= steaming time (min). 510 : Commercial noodle. Values are means of triplicate ± standard deviation. Average values of dissimilar subscript within the column are significantly ($p\leq0.05$) different..

Table 4.28: Textural Properties of Cassava-African Yam Bean Noodles

Samples HL:ST	Stinginess (mm)	Adhesiveness (J)	Chewiness (g)	Resilience
50:1	$8.04\pm0.08_{f}$	$56.8\pm0.71_{i}$	$305.5\pm9.19_{e}$	$0.2\pm0.00_{a}$
48.76:2	$9.43\pm0.93_{ef}$	$100.8\pm5.94_{h}$	$261.5\pm12.02_{e}$	$0.2\pm0.00_{a}$
56:3	$10.32\pm0.59_{e}$	$107.85\pm4.31_{h}$	$254.5\pm77.08_{e}$	$0.1\pm0.00_{a}$
53:2	$13.65\pm0.43_{c}$	$501.15\pm11.24_{c}$	$821.5\pm10.61_{b}$	$0.1\pm0.00_{a}$
50:3	$11.12\pm1.2_{de}$	$146.05\pm4.88_{g}$	$543.5\pm28.99_{d}$	$0.1\pm0.00_{a}$
53:0.59	$14.48\pm0.76_{c}$	$391.95\pm5.73_{d}$	$691.5\pm31.82_{c}$	$0.1\pm0.00_{a}$
53:3.41	$12.11\pm0.17_{d}$	$278.00\pm1.98_{e}$	$753.5\pm54.44_{bc}$	$0.1\pm0.00_{a}$
56:1	$16.23\pm0.28_{ab}$	$823.75\pm22.70_{a}$	$1082\pm11.31_{a}$	$0.1\pm0.00_{a}$
53:2	$15.19\pm0.16_{abc}$	$596.38\pm20.54_{c}$	$791\pm22.63_{b}$	$0.1\pm0.00_{a}$
53:2	$15.05\pm0.28_{bc}$	$673.15\pm28.78_{b}$	$800.35\pm6.44_{b}$	$0.1\pm0.00_{a}$
53:2	$14.48\pm1.72_{c}$	$662.4\pm34.22_{b}$	$777.8\pm16.69_{b}$	$0.1\pm0.00_{a}$
53:2	$16.7\pm0.07_{a}$	$690.85\pm13.36_{b}$	$775\pm38.18_{b}$	$0.1\pm0.00_{a}$
57.24:2	$14.29\pm0.14_{c}$	$256.4\pm5.37_{e}$	$610.5\pm21.92_{d}$	$0.1\pm0.00_{a}$
510	$9.8\pm0.59_{e}$	$83.45\pm4.17_{hi}$	$301\pm25.46_{e}$	$0.3\pm0.00_{a}$

HL= hydration level (%), ST= steaming time (min). 510 = commercial noodle. Values are means of three replicate ± standard deviation. Average values of dissimilar subscript within column are significantly different.

4.16 Thermal Properties of the Noodles

Thermal properties of cassava-African yam bean noodles and commercial noodle were displayed in Table 4.29. Diffusivity, resistivity, conductivity, specific heat capacity and temperature of experimental and commercial noodle ranged from 0.09 to 0.12 mm^2 /s, 598 to 692 $^oCcm/W$, 0.145 to 0.17 W/mk, 1.318 to 1.819 MJ/m^3k and 32.69 to 34.3 ^oC, respectively. Sample 510 was significantly ($p \leq 0.05$) different from other noodles based on their diffusivity and specific heat capacity.

Steaming time had no significant ($p \geq 0.05$) difference on temperature of testing. Meanwhile, as hydration level was increasing, specific heat capacity of noodles was reducing and the temperature was increasing as depicted in samples 48.76:2 and 53:2. The thermal conductivity obtained in this work compared well with those reported by Oyerinde and olalusi (2011) for *gari* with values ranging from 0.06 to 0.24 W/mk. However, the specific heat capacity obtained in this work were lower than those reported by the same researchers with values ranging from 2.01 to 4.14 kj/kgk.

4.17 Microstructural Properties of the Noodles

The microstructural properties of cassava-African yam bean noodles and commercial noodle were presented on Plate 4.4 to Plate 4.11. It was observed that no two samples have the same microstructure and there were clear morphological alterations among the noodle samples. These changes might be ascribed to variations in hydration levels and steaming time of the noodles due to the facts that all the noodles were prepared from similar ingredients and processing steps. This was supported by Widjaya (2010) that stated that commercial noodle exhibited dissimilar microstructure and showing more unevenness compared to experimental noodles. This might be as a consequence of changes in their constituents, formulations and processing steps employed during production.

4.17.1 Effect of hydration on microstructural properties of the noodles

Some noodles were steamed at the same time but hydrated differently, while some were hydrated similarly but steamed differently. Several starch granules were observed on external surface of noodle samples. At hydration level of 50% at 1 min steaming time (50:1), the sample was pasted and had pores. As the hydration level increased to 56% (56:1) at the same steaming time, disappearance of pasted structure and

Table 4.29. Thermal Properties of the Noodles

Sample code HL:ST	Diffusivity (mm^2/s)	Resistivity ($^oCcm/W$)	Thermal Conductivity (W/mk)	Specific heat Capacity	Temperature (^oC)
50:1	$0.09\pm0.00_{bc}$	$618.20\pm7.07_{cd}$	$0.16\pm0.02_{abc}$	$1.74\pm0.01_{bcd}$	$34.01\pm0.16_{ab}$
48.76:2	$0.09\pm0.01_{bc}$	$621.70\pm0.00_{bcd}$	$0.15\pm0.00_{abcd}$	$1.74\pm0.05_{bcd}$	$33.62\pm0.23_{bc}$
56:3	$0.09\pm0.00_{bc}$	$685\pm11.31_{a}$	$0.14\pm0.04_{d}$	$1.62\pm0.09_{cde}$	$34.00\pm0.00_{ab}$
53:2	$0.09\pm0.01_{bc}$	$670.55\pm9.83_{ab}$	$0.16\pm0.03_{abc}$	$1.71\pm0.03_{bcd}$	$33.79\pm0.3_{ab}$
50:3	$0.09\pm0.00_{bc}$	$684.55\pm42.64_{a}$	$0.15\pm0.01_{abcd}$	$1.61\pm0.06_{de}$	$33.95\pm0.19_{ab}$
53:0.59	$0.09\pm0.00_{bc}$	$681.10\pm5.66_{ab}$	$0.15\pm0.01_{abcd}$	$1.63\pm0.08_{cde}$	$32.71\pm0.36_{d}$
53:3.41	$0.10\pm0.00_{b}$	$598.45\pm21.00_{d}$	$0.17\pm0.06_{a}$	$1.75\pm0.03_{b}$	$33.05\pm0.22_{d}$
56:1	$0.09\pm0.00_{bc}$	$599.50\pm33.23_{d}$	$0.17\pm0.09_{a}$	$1.82\pm0.11_{a}$	$33.00\pm0.00_{d}$
53:2	$0.09\pm0.02_{bc}$	$608.70\pm12.02_{cd}$	$0.16\pm0.04_{abc}$	$1.73\pm0.04_{bcd}$	$34.30\pm0.54_{a}$
53:2	$0.09\pm0.03_{bc}$	$681.10\pm14.85_{ab}$	$0.14\pm0.03_{d}$	$1.67\pm0.08_{de}$	$34.23\pm0.13_{ab}$
53:2	$0.09\pm0.01_{bc}$	$655.45\pm21.71_{abc}$	$0.15\pm0.05_{bcd}$	$1.69\pm0.04_{bcd}$	$34.11\pm0.19_{ab}$
53:2	$0.09\pm0.03_{bc}$	$692.05\pm17.47_{a}$	$0.14\pm0.004_{d}$	$1.63\pm0.02_{cde}$	$34.16\pm0.17_{ab}$
57.26	$0.09\pm0.02_{bc}$	$649.15\pm35.99_{abc}$	$0.15\pm0.01_{abcd}$	$1.70\pm0.06_{bcd}$	$34.04\pm0.14_{ab}$
500	$0.09\pm0.01_{bc}$	$690.45\pm1.63_{a}$	$0.14\pm0.00_{d}$	$1.55\pm0.01_{e}$	$33.14\pm0.48_{cd}$
510	$0.12\pm0.04_{a}$	$676.65\pm1.34_{ab}$	$0.15\pm0.00_{cd}$	$1.32\pm0.05_{f}$	$32.69\pm0.01_{d}$

HL = hydration level (%), ST = steaming time (min), 500 : Optimised cassava African yam bean flour blend and 510 : Commercial noodle. Values are means of three replicates ± standard deviation.

Average values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

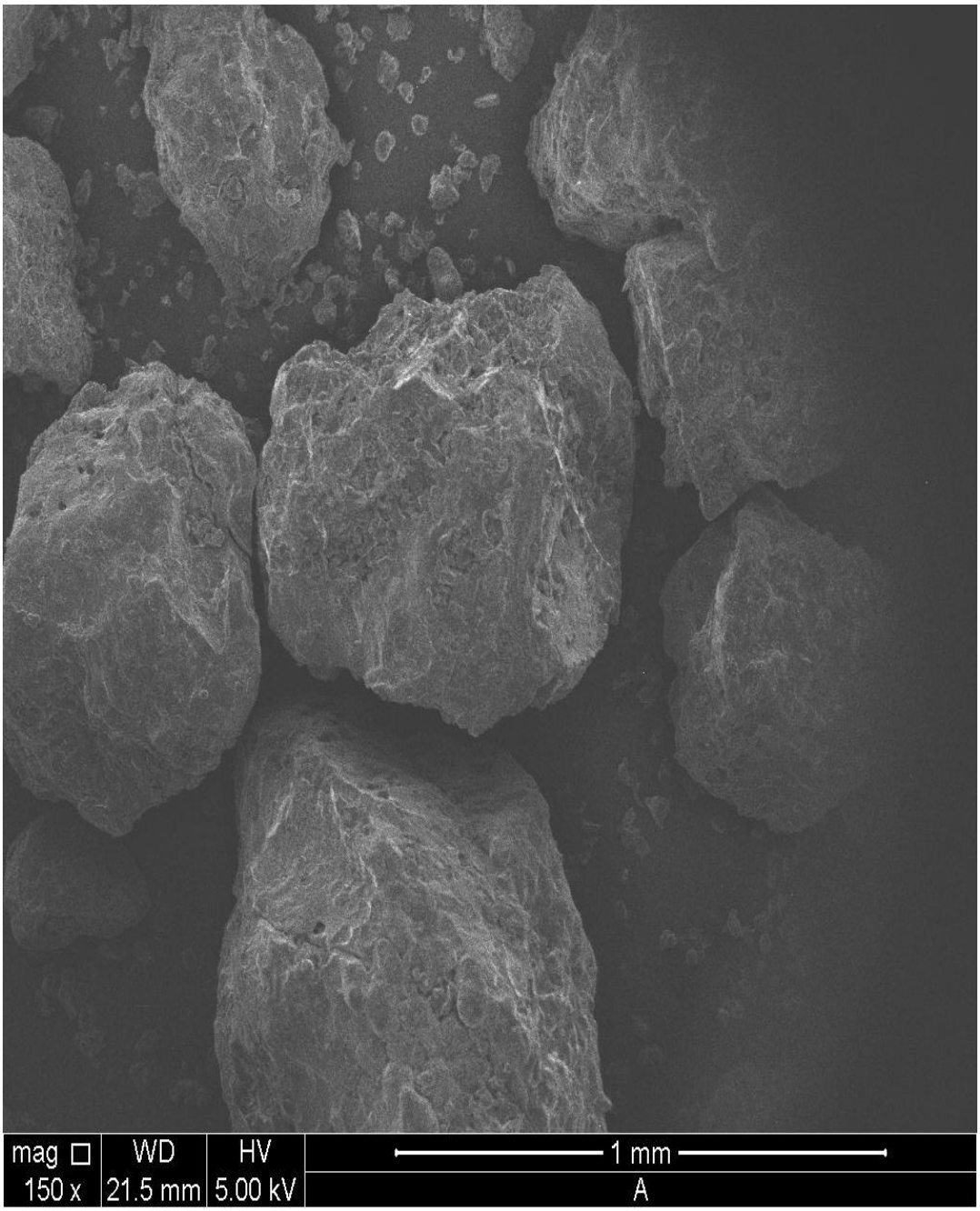


Plate 4.4: Micrograph of Sample 50:1 (x150 Magnification) .

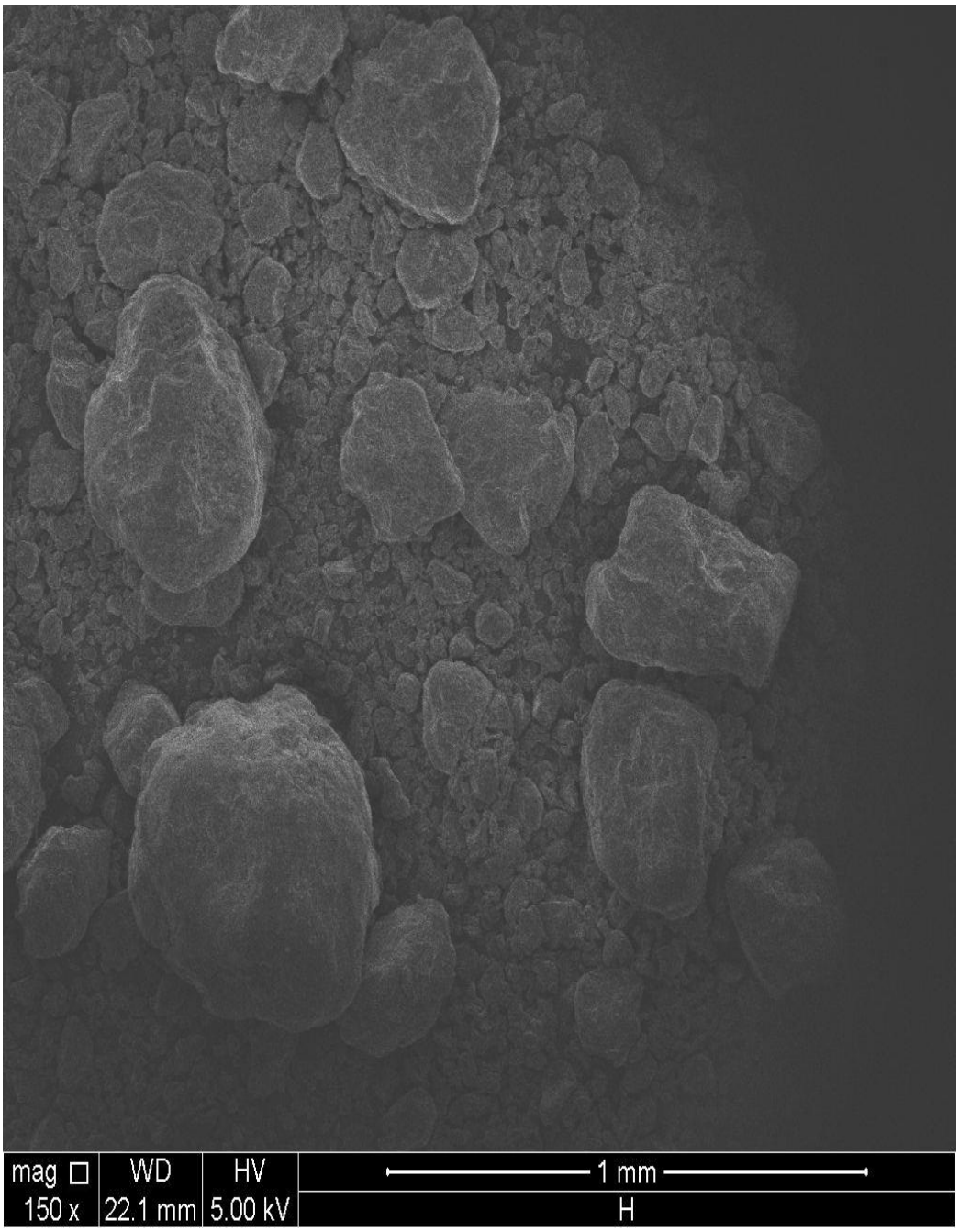


Plate 4.5: Micrograph of Sample 56:1 (x150 Magnification).

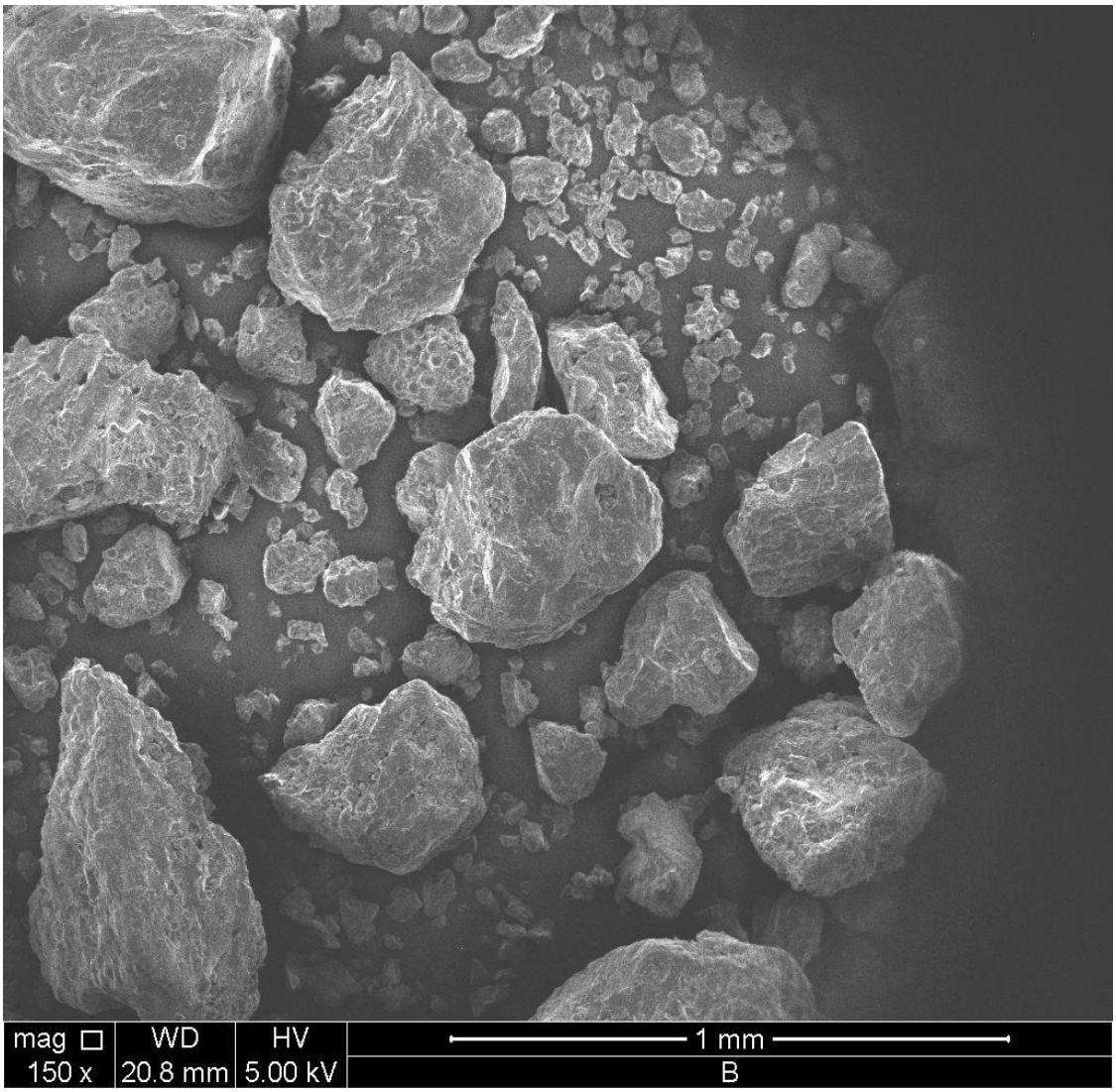


Plate 4.6: Micrograph of Sample 48.76:2 (x150 Magnification).

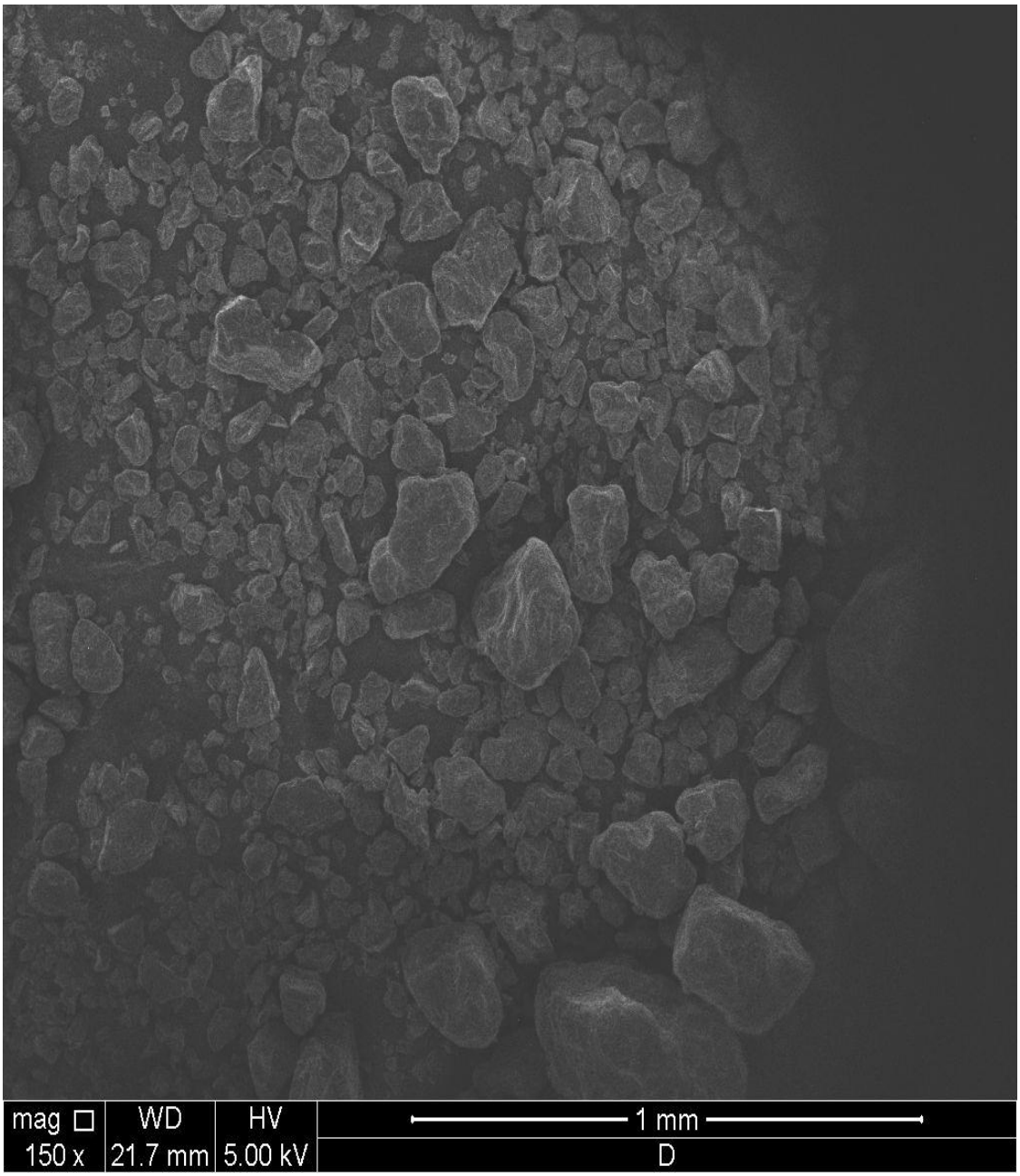


Plate 4.7: Micrograph of Sample 53:2 (x150 Magnification).

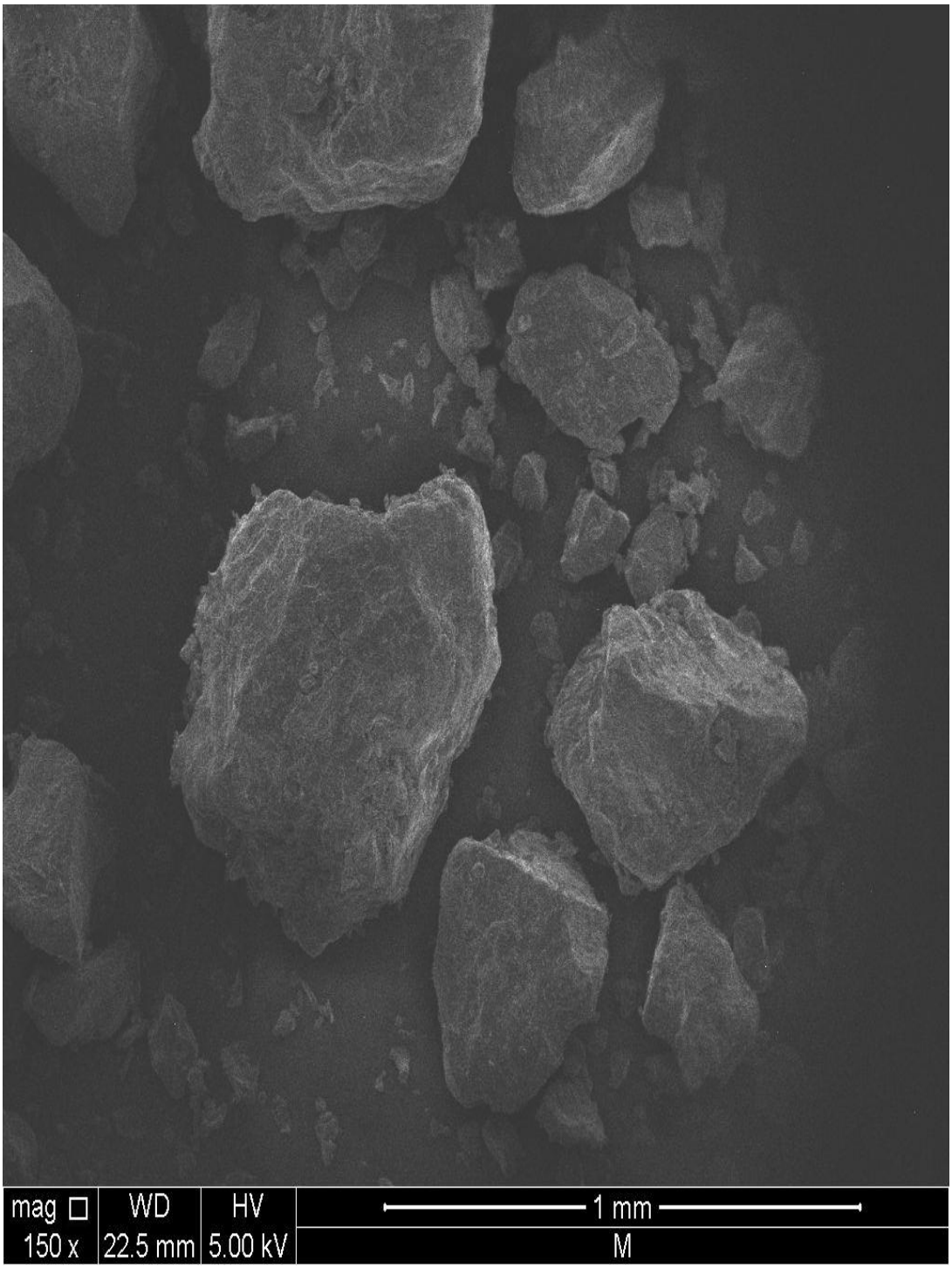


Plate 4.8: Micrograph of Sample 57.24:2 (x150 Magnification).

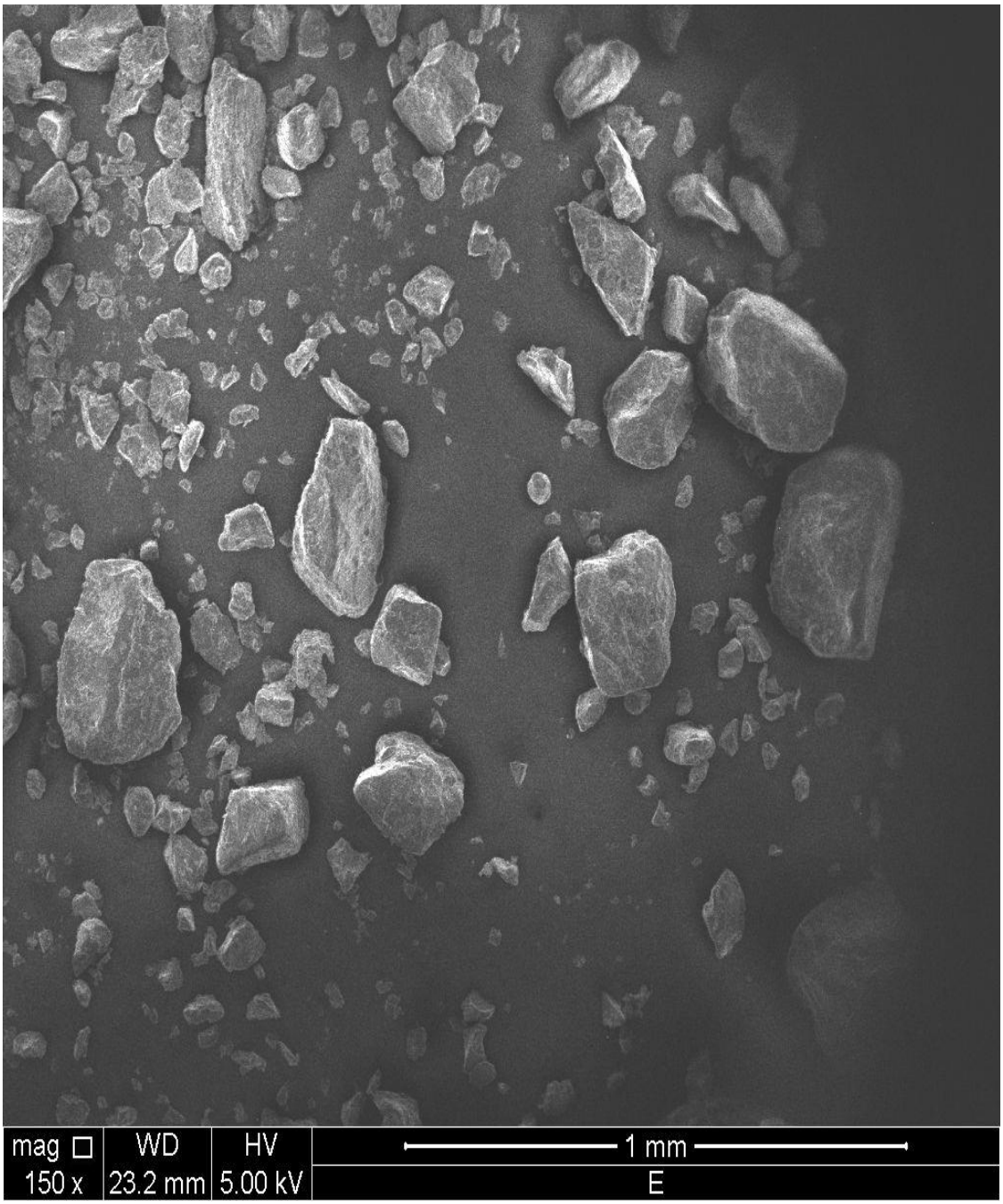


Plate 4.9: Micrograph of Sample 50:3 (x150 Magnification).

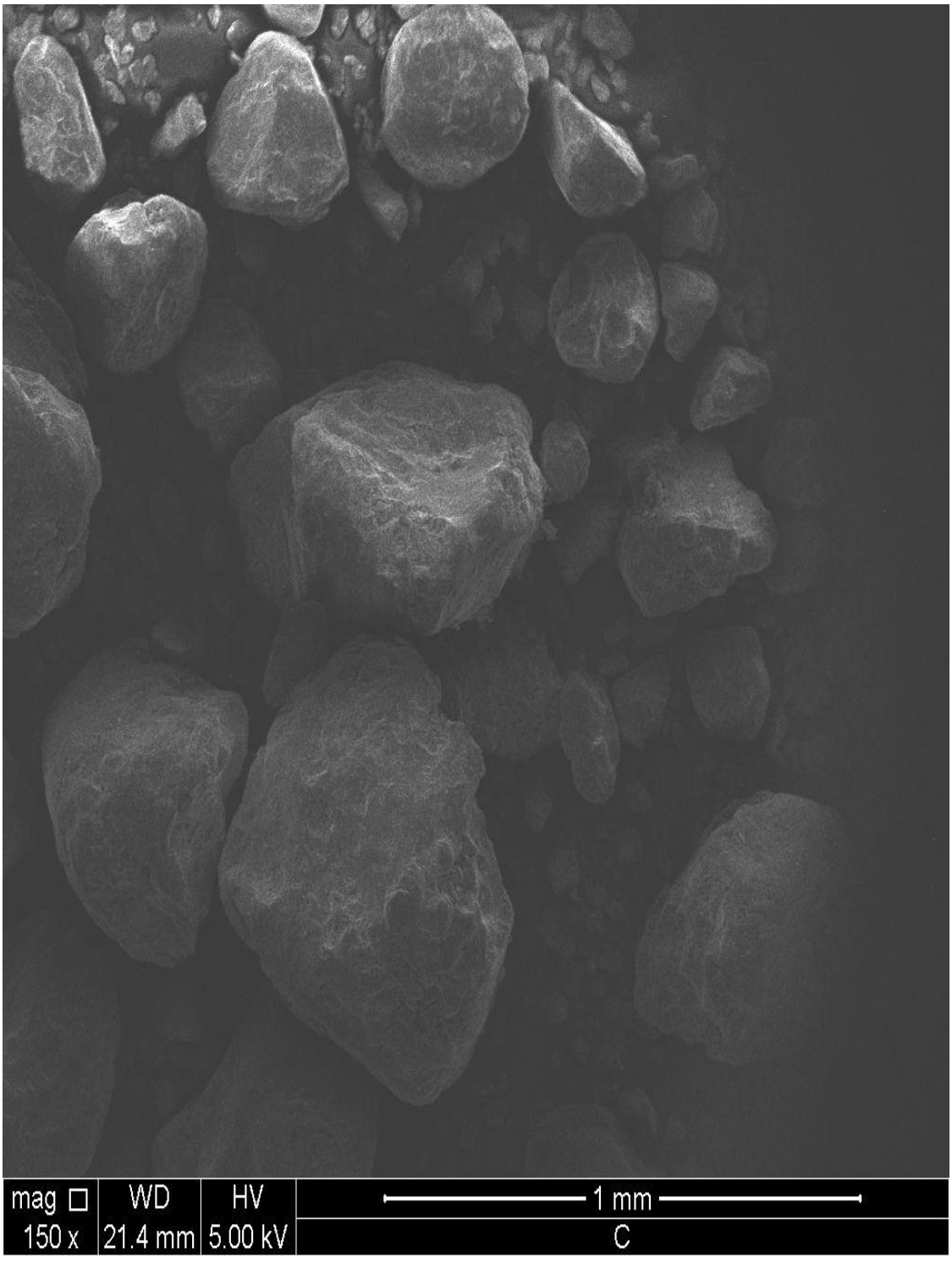


Plate 4.10: Micrograph of Sample 56:3 (x150 Magnification).

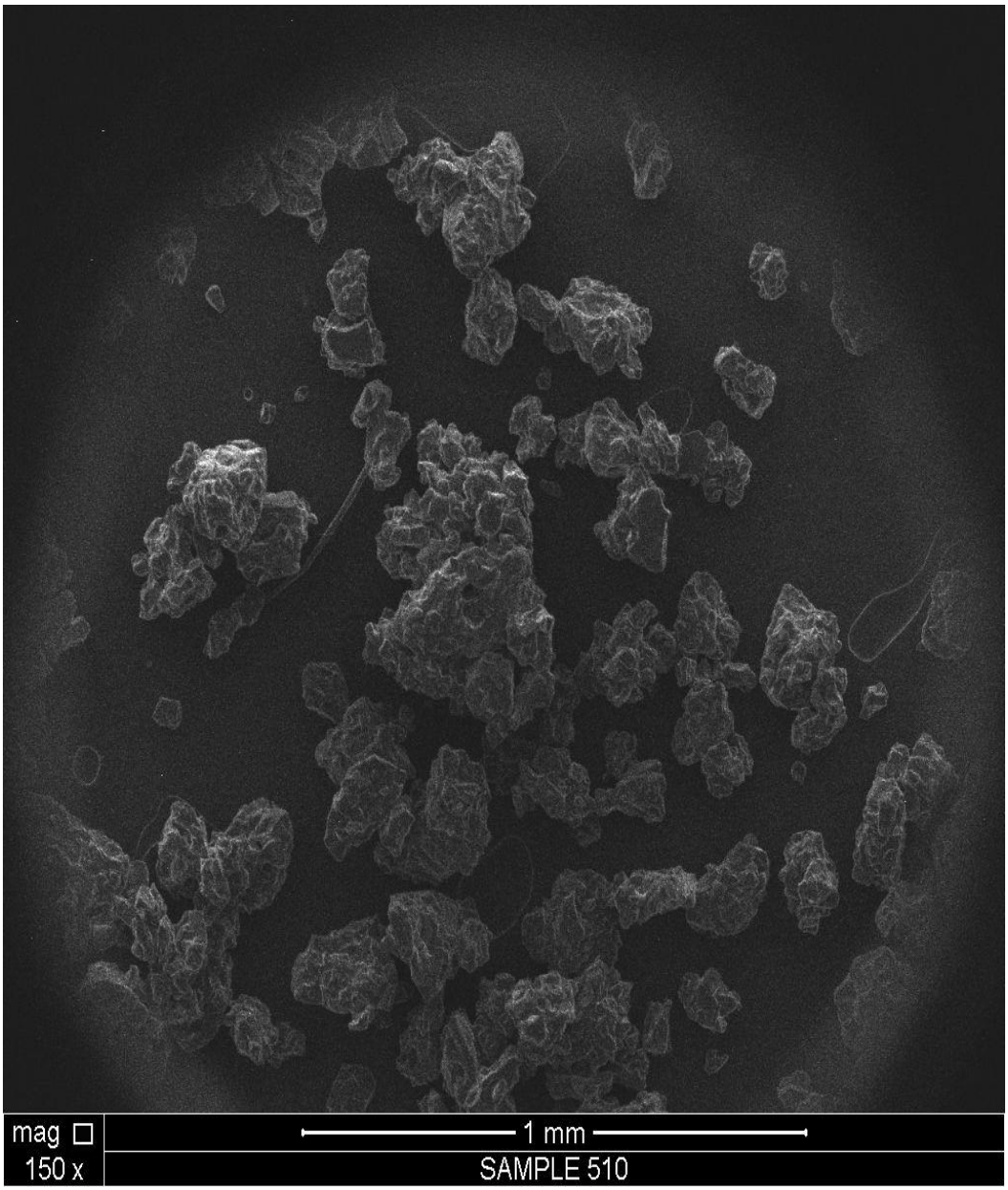


Plate 4.11: Micrograph of Indomie Noodle (x150 Magnification)

segregation of irregular shapes with pores were observed. Similarly, as the hydration level increased from 48.76% to 53% at 2 min steaming time, there was disintegration of starch granules, formation of more irregular shapes and disappearance of pasted structure.

On further increase in hydration level to 57.24% the starch granules become pasted and fewer pores was noted. At 50% hydration level of 3 min steaming time, segregated pasted structure was evident. As the hydration level increases to 56% at the same steaming time, pasted structure was compact and fewer pores were noted. This revealed the impact of hydration level on microstructural properties of noodles. Plate 4.11 was different from all the experimental noodles. This might be attributed to difference in their ingredients during preparation. These results were corroborated with Widjaya (2010) that reported how different formulations as well as processing parameters impacted on the structural differences observed in the noodles.

4.17.2 Effect of steaming duration on microstructural properties of the noodles

Some noodles were hydrated similarly but differed in their steaming time. The micrographs of these noodles were represented in Plates 4.12 to Plate 4.18. It was revealed that samples possessed dissimilar morphology. As the steaming time increased from 1 min to 3 mn, pasted structure was segregated and appearance of irregular shapes were evident as shown in aforementioned plates. Likewise, as the steaming time increased from 59 s to 2 min, there were more disintegration of starch granules and formation of more irregular shapes such as oblong and truncated edges were noted as depicted in Plate 4.15 and Plate 4.16. Increase in steaming time from 2 min to 3.41 min resulted in larger shape of the granules and there was occurrence of pasted structure. This might be attributed to longer steaming that gelatinised the starch granules thereby increasing the shape**.**

4.18 Predictive Models and Optimum Conditions of Noodles

The actual experimental combinations of processing parameters with their responses was shown on Table 4.30. The coefficient of determination, R^2, adjusted R^2, F-value, lack of fit (LoF) and adequate precision of responses were displayed on Table 4.31. It was revealed that coefficients of determination, R^2 for all responses were greater than

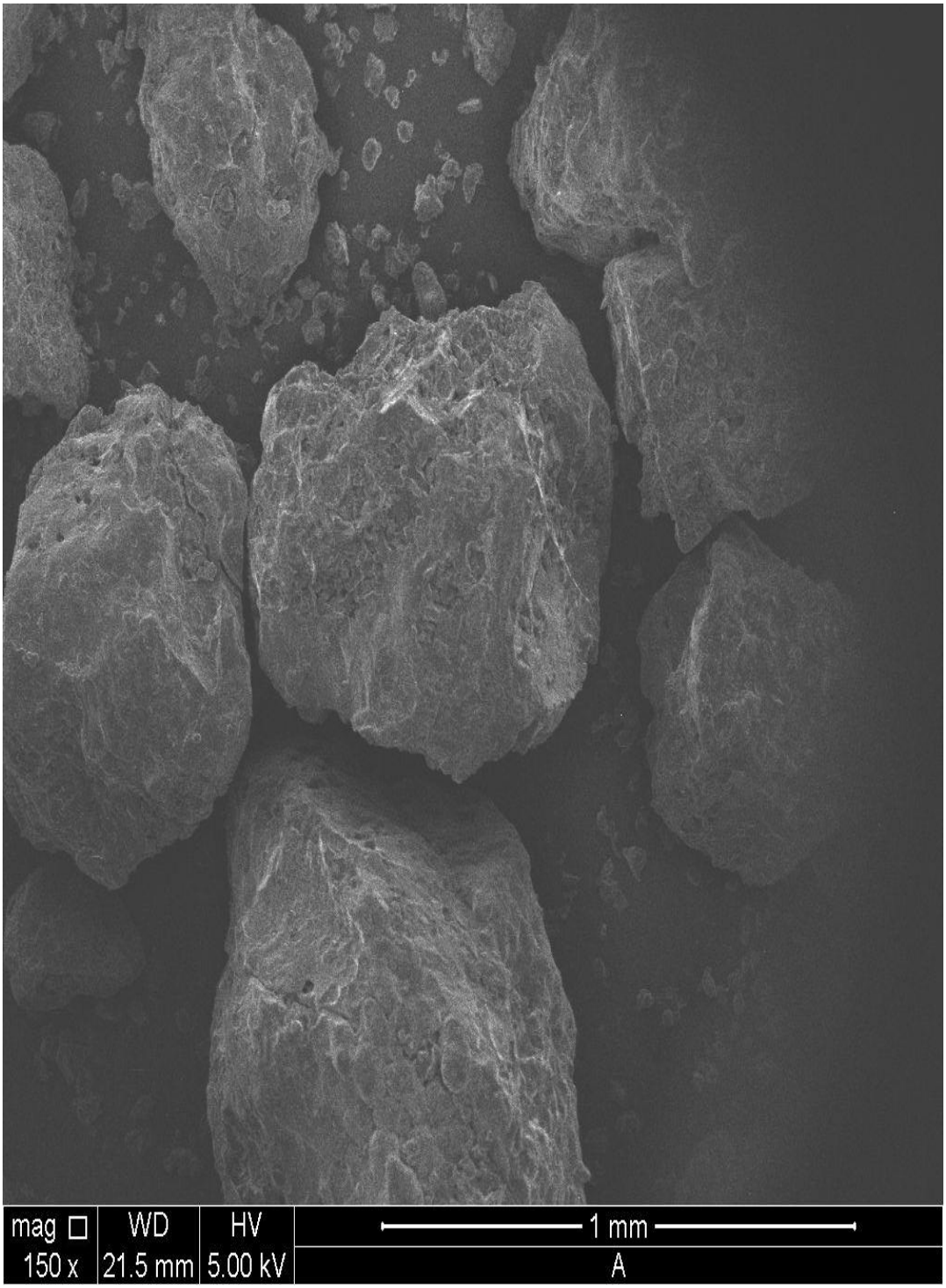


Plate 4.12: Micrograph of Sample 50:1 (x150 Magnification)

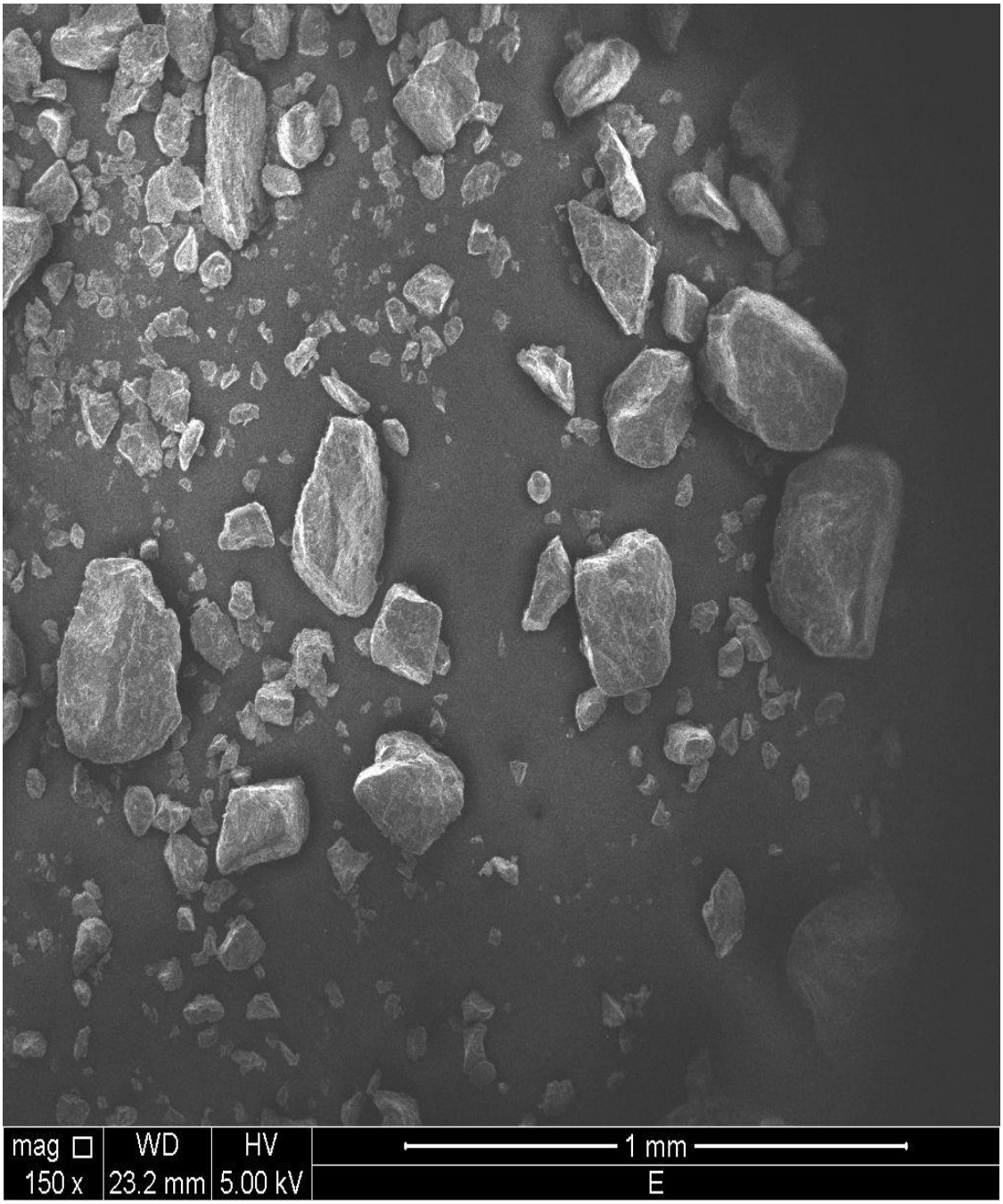


Plate 4.13: Micrograph of Sample 50:3 (x150 Magnification)

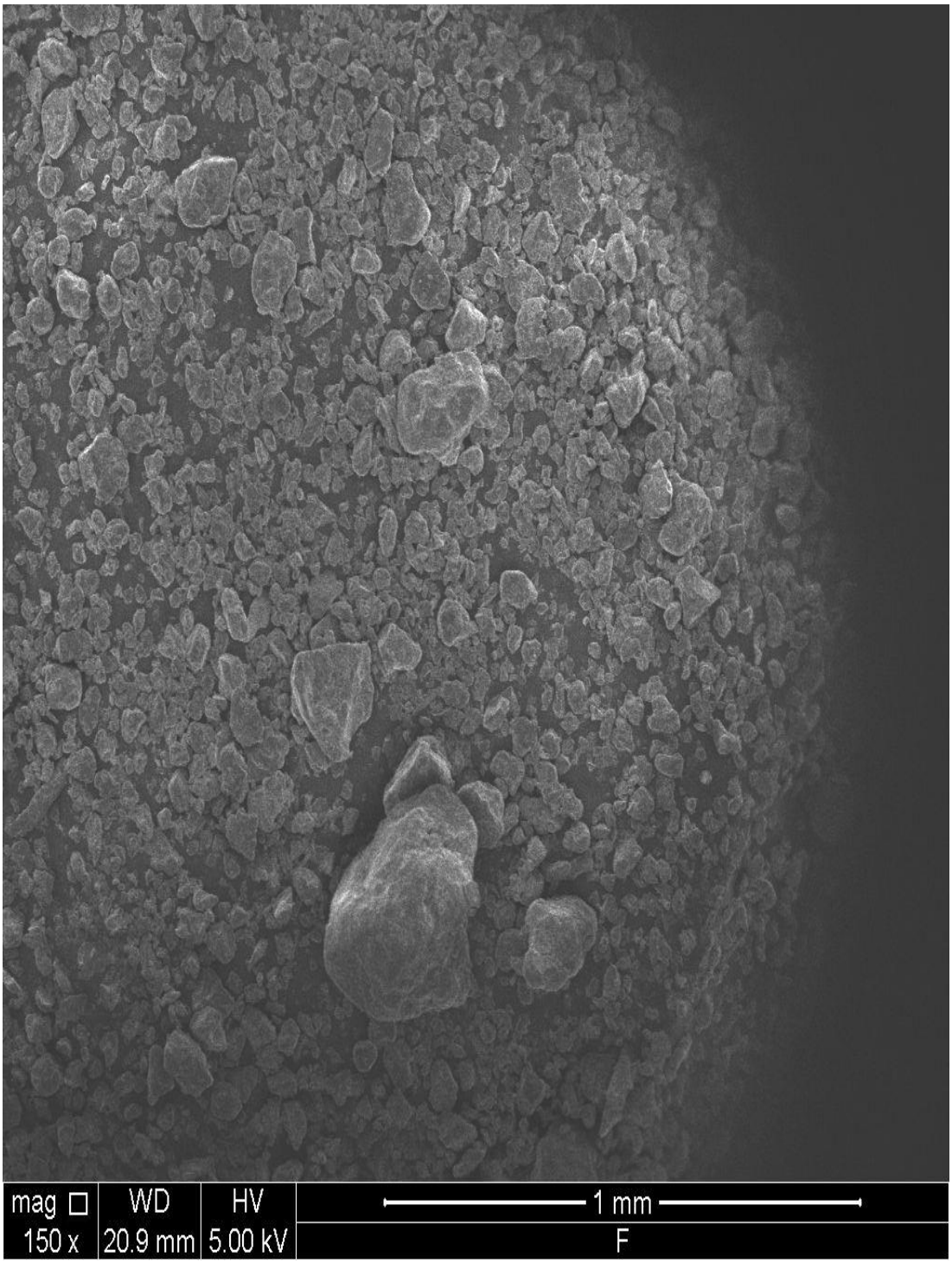


Plate 4.14: Micrograph of Sample 53:0.59 (x150 Magnification).

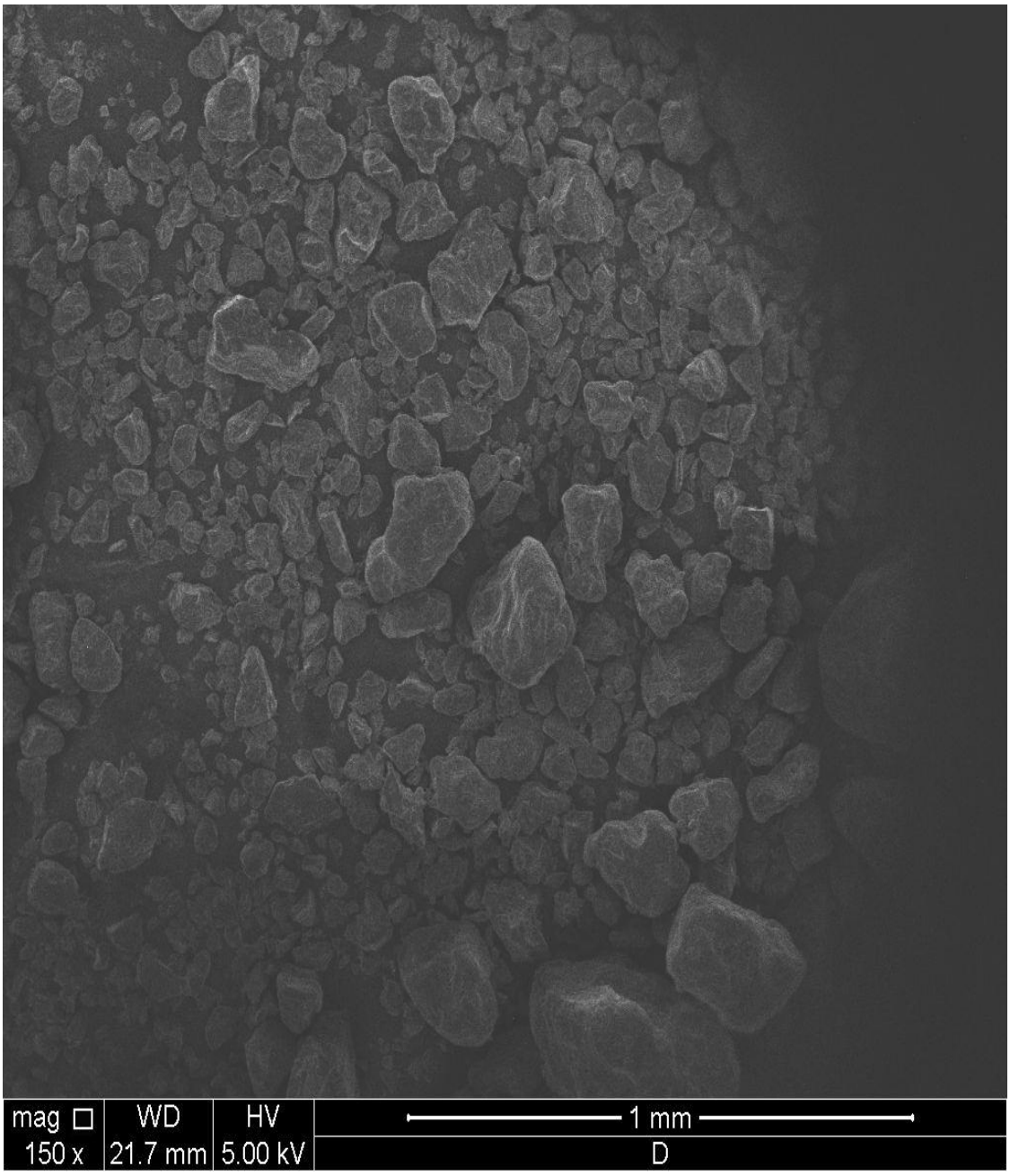


Plate 4.15: Micrograph of Sample 53:2 (x150 Magnification).

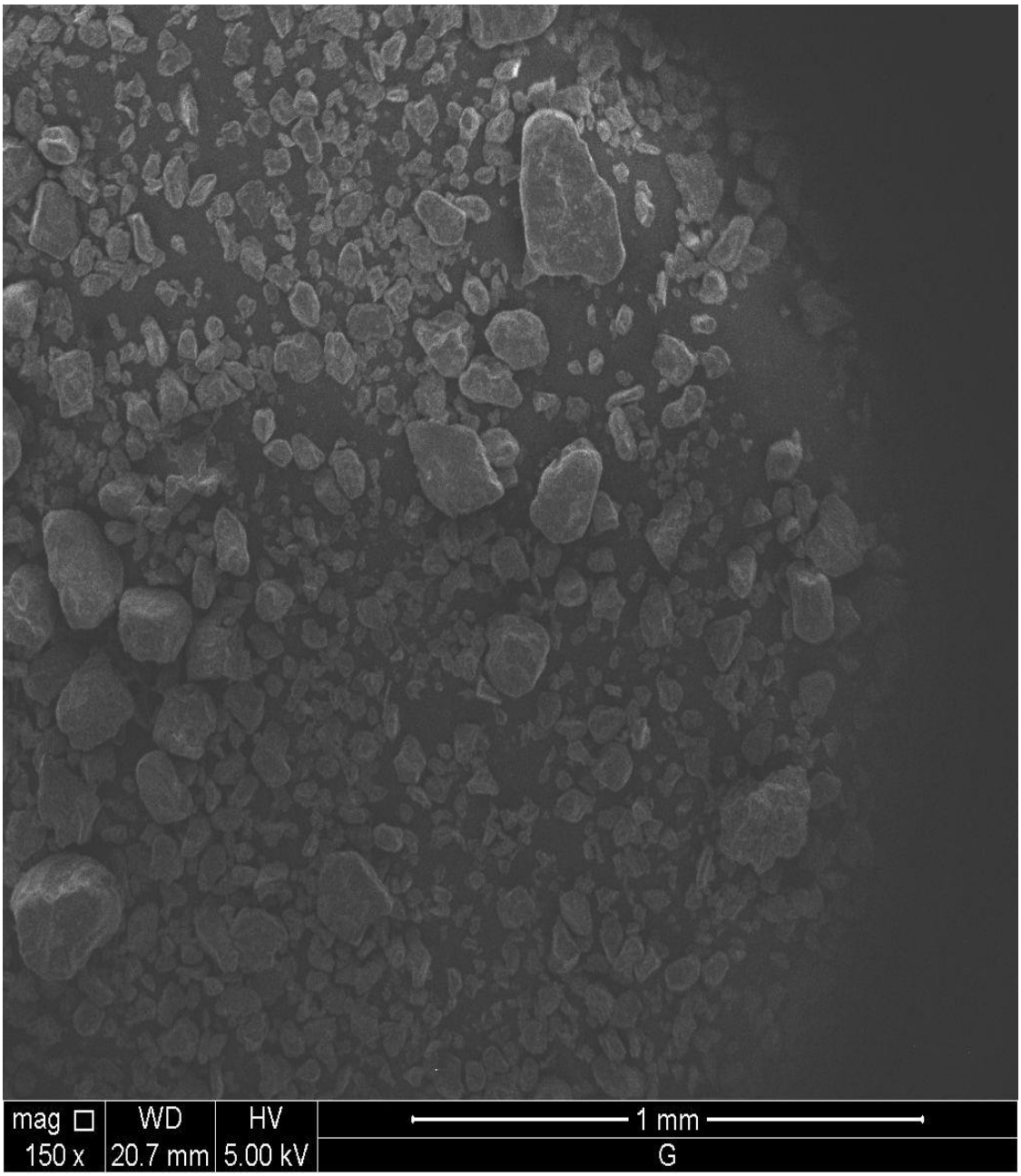


Plate 4.16: Micrograph of Sample 53:3.41 (x150 Magnification).

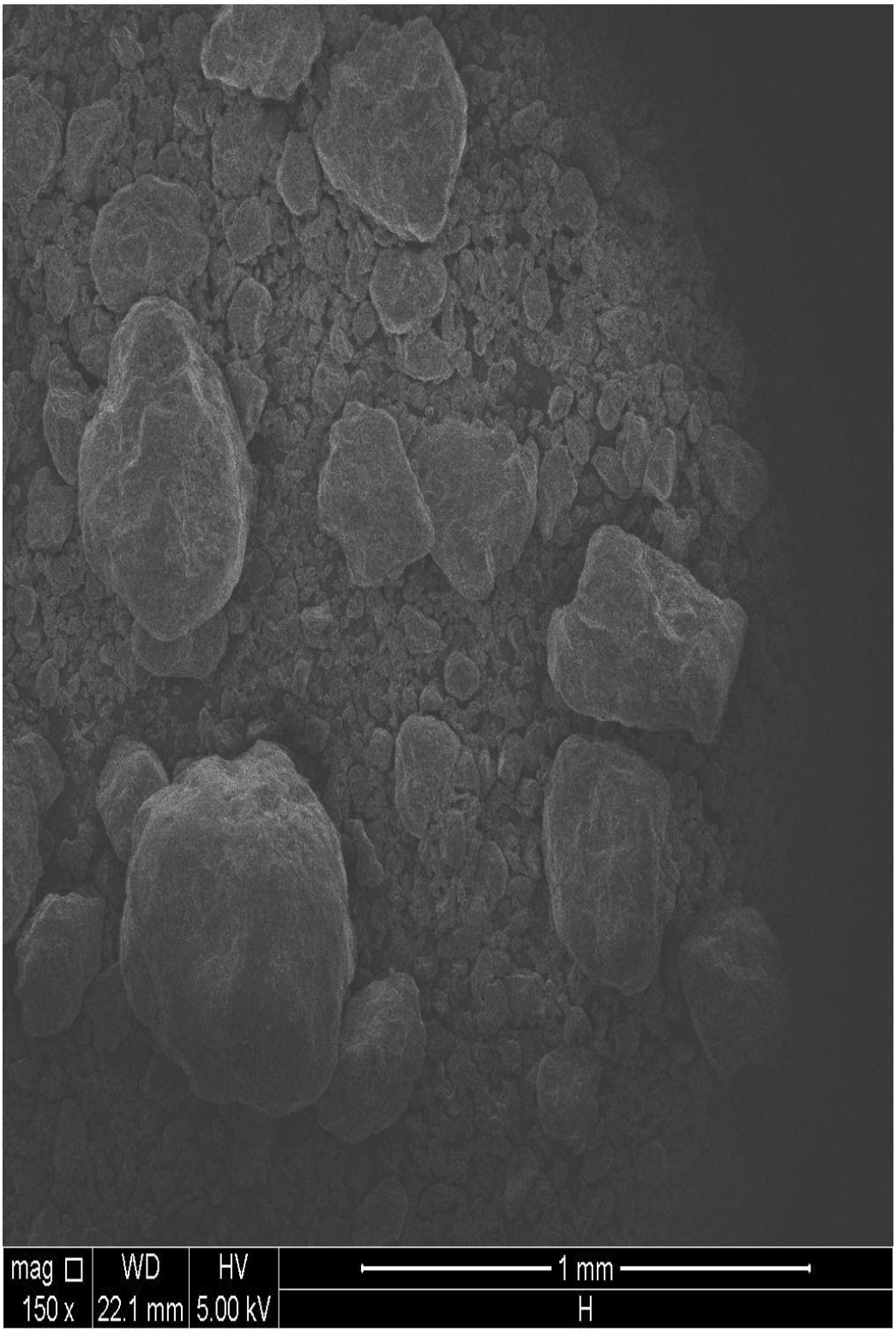


Plate 4.17: Micrograph of Sample 56:1 (x150 Magnification).

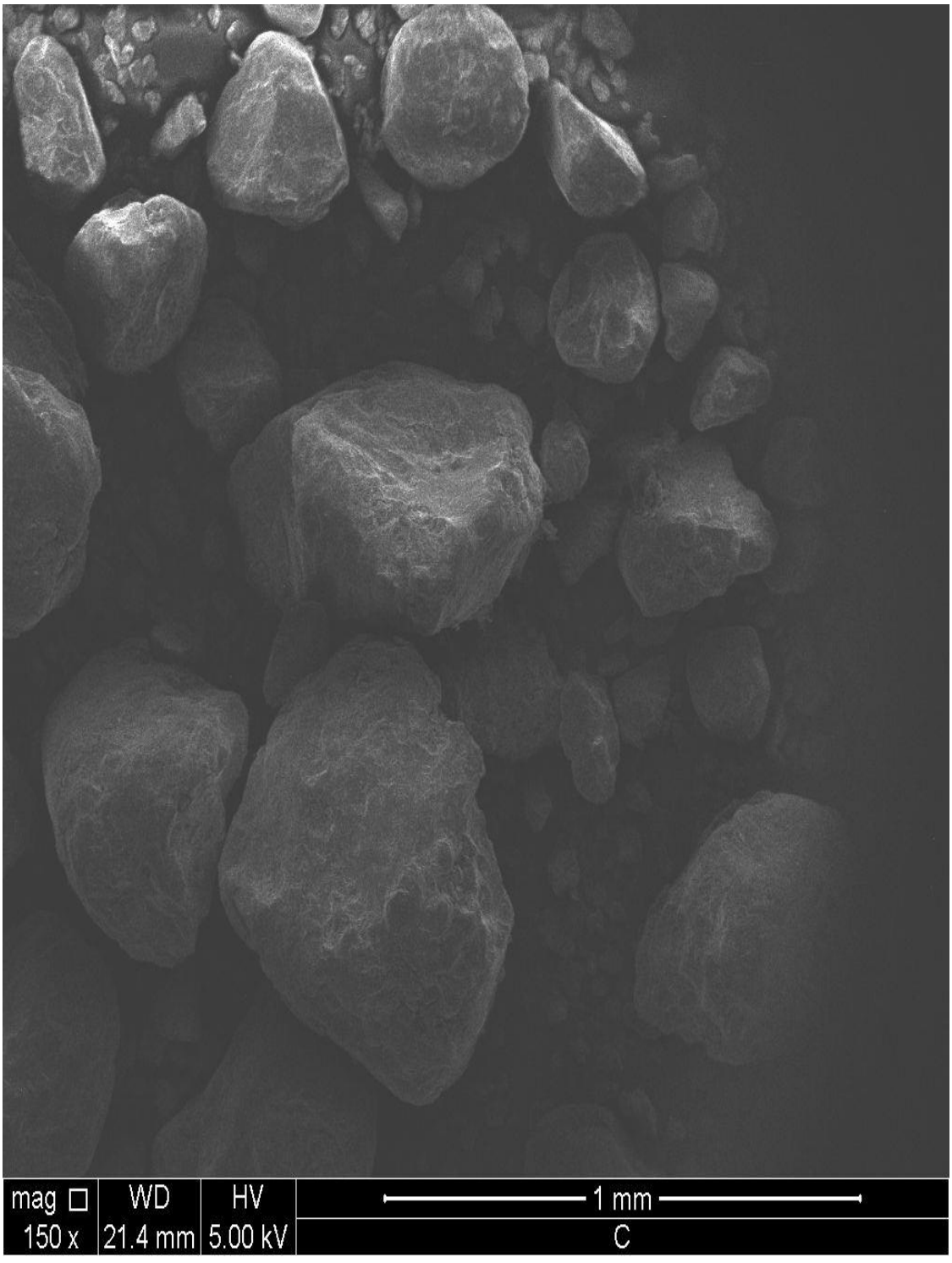


Plate 4.18: Micrograph of Sample 56:3 (x150 Magnification).

Table 4.30: Experimental Design of Processing Parameters of the Noodles with their Responses

Runs	Hydration level (%)	Steaming time (min.)	Hydrogen cyanide (mg/kg)	Cooking weight (%)	Cooking loss (%)	Chewiness (g)	Stickiness (g)	Yellowness
1	50	1	0.6	185.74	7.68	305.5	18.5	18.56
2	48.76	2	1.01	189.3	8.76	261.5	26.5	17.29
3	56	3	1.31	209.93	7.17	254.5	28	18.17
4	53	2	0.89	197.57	8.89	775	42.5	16.19
5	50	3	1.8	177.84	8.58	543.5	30	17.94
6	53	0.59	0.9	186.95	7.58	691.5	53.5	17.35
7	53	3.41	1.2	181.73	7.96	753.5	48	17.45
8	56	1	0.9	186.42	10.8	1082	68.5	16.91
9	53	2	0.73	201.95	8.8	791	52	16.68
10	53	2	0.7	208.96	8.17	800.35	56	15.91
11	53	2	0.98	205	8.42	777.8	55	16.36
12	53	2	0.7	202.39	8.77	821.5	57.5	16.61
13	57.24	2	0.73	196.61	9.06	610.5	54.5	17.08

Runs means experimental serial number

Table 4.31: ANOVA Results for Responses of the Noodles

Coefficients	Hydrogen cyanide (mg/kg)	Cooking yield (%)	Cooking loss (%)	Chewiness (g)	Stickiness (g)	Yellowness
A_0	1.13	1152.6	9.22	7.38E+05	2327.82	6.13
A	1.27E-05	232.29	0.45	11589.2	959.18	0.37
B	0.39	8.46	1.8	80224.07	169.08	0.076
A^2	0.05	158.66	0.29	2.43E+05	490.12	2.25
B^2	0.21	573.95	0.93	13183.91	74.33	3.18
AB	0.16	246.65	5.13	2.84E+05	676	0.88
A^3	5.30E-03	-	0.21	4.59	-	
B^3	0.18	-	1.33	57321.8	-	
R^2 (%)	89.03	85.03	95.21	99.52	85.82	82.4
Adeq. Prec.	9.16	7.24	15.18	40.62	9.76	6.23
Adj. R^2 (%)	73.66	74.34	88.49	98.84	75.69	69.82
F-Value	5.79	7.95	12.39	147.02	8.47	6.55
LoF	NS	NS	NS	NS	NS	NS
Model	Cubic	Quadratic	Cubic	Cubic	Quadratic	Quadratic

A_0 = Regression coefficient of constant, A = Linear regression constant of hydration level, B = Linear regression constant for steaming time, A^2 = Quadratic regression coefficient for level, B^2 = Quadratic regression coefficient for steaming time, AB = Interactive regression coefficient for hydration level and steaming time, R^2 = Coefficient of determination, LoF= Lack of Fit, Adeq. Prec.= Adequate Precision, Adj. R^2 = Adjusted R^2 and NS= non-significant.

80%, representing significant models. Similarly, lack of fit (LoF) tests for the responses were insignificant indicating good models fitness.

Similarly, it was observed that all the responses had adequate precision greater than 4 which is desirable and high adjusted R^2. This was corroborated with the works of Awolu *et al.* (2013) that opined that high R^2 and adjusted R^2 showed good model. The desirable solutions for the production of acceptable noodles were obtained and validated in the laboratory. The results of validation of the responses with their predicted values were displayed in Table 4.32. It was observed that the percentage of agreement of responses were greater than 80% for the two desirable noodles.

4.19 Sensory Evaluation of Noodles

The sensory evaluation of the two desirable noodles and commercial noodle was depicted in Table 4.33. Sensory scores for quality attributes of the two experimental noodles and commercial noodle (510) ranged from 5.53 which represents neither like nor dislike to 8.27 that denotes like very much. It was revealed that commercial noodle rated greatest in overall acceptability followed by sample 50:1. Sample 56:3 was rated lowest among the three noodles with the highest score of 6.73 (like moderately) for colour and least score of 5.53 (neither like nor dislike) for appearance. There were no significant differences in taste, colour, aroma, stickiness and chewiness of experimental noodles. The reason was not far fetched because the noodles were prepared from the same ingredients. This showed that difference in hydration level and steaming time did not significantly influence the taste, colour, aroma, stickiness and chewiness of experimental noodles.

4.20 Moisture Sorption Isotherm of Pro-vitamin A Cassava-Based Noodles

The impact of temperature on equilibrium moisture content (EMC) against water activity (a_w) of CF, AYBF and noodle samples were displayed in Figures 4.1, 4.2, 4.3 and Figure 4.4, respectively. It was noted that equilibrium moisture contents increased as temperature increased as reported by Ekta Jha *et al*. (2014). Similarly, equilibrium moisture content increased with rise in water activity This was also reported by Olapade (2010). The EMC values of cassava-African yam bean noodles varied from 0.012 to 0.142 for both temperatures 28 ^oC and 35 ^oC. The values obtained were lower

Table 4.32: Validation of Experimental and Predicted Results of the Noodles

Variables	Hydration level (%)	Steaming time (s)	Hydrogen cyanide (mg/ kg)	Cooking yield (%)	Cooking loss (%)	Chewiness (g)	Stickiness	Yellowness	Desirability
Predicted values	50	1	0.5	190.75	7.57	321.94	(-)21.59	18.18	0.801
Validated values	50	1	0.62	185.74	7.68	305.5	(-)18.5	18.56	
Percentage of agreement			80.65	97.37	98.57	94.89	85.69	97.95	
Percentage of deviation			19.35	2.63	1.43	5.11	14.31	2.05	
Predicted values	56	3	1.21	203.58	7.06	270.94	(-)34.29	17.95	0.766
Validated values	56	3	1.31	209.93	7.17	254.5	(-)28	18.17	
Percentage of agreement			92.37	96.98	98.47	93.93	81.66	98.79	
Percentage of deviation			7.63	3.02	1.53	6.07	18.34	1.21	

Table 4.33. Sensory Evaluation of Cassava-African Yam Bean and Commercial Noodles

Noodles codes	Appearance	Taste	Colour	Stickiness	Chewiness	Aroma	Overall Acceptability
50:1	$6.93\pm1.10_{b}$	$6.6\pm1.55_{b}$	$6.4\pm1.29_{b}$	$6.73\pm1.39_{ab}$	$6.73\pm1.54_{ab}$	$6.87\pm0.99_{ab}$	$7.07\pm1.03_{b}$
56:3	$5.53\pm1.96_{c}$	$5.67\pm1.8_{b}$	$6.73\pm1.03_{b}$	$5.93\pm1.58_{b}$	$6.13\pm1.46_{b}$	$6.22\pm1.87_{b}$	$6.07\pm1.1_{c}$
510	$8.07\pm0.88_{a}$	$8.13\pm0.74_{a}$	$8.13\pm0.99_{a}$	$7.4\pm1.06_{a}$	$7.67\pm0.38_{a}$	$7.33\pm0.38_{a}$	$8.27\pm0.8_{a}$

50:1: Experimental noodle with moisture content 50% and steamed at I min, 56:3: Experimental noodle with moisture content 56% and steamed at 3 min, while 510: Commercial noodle. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

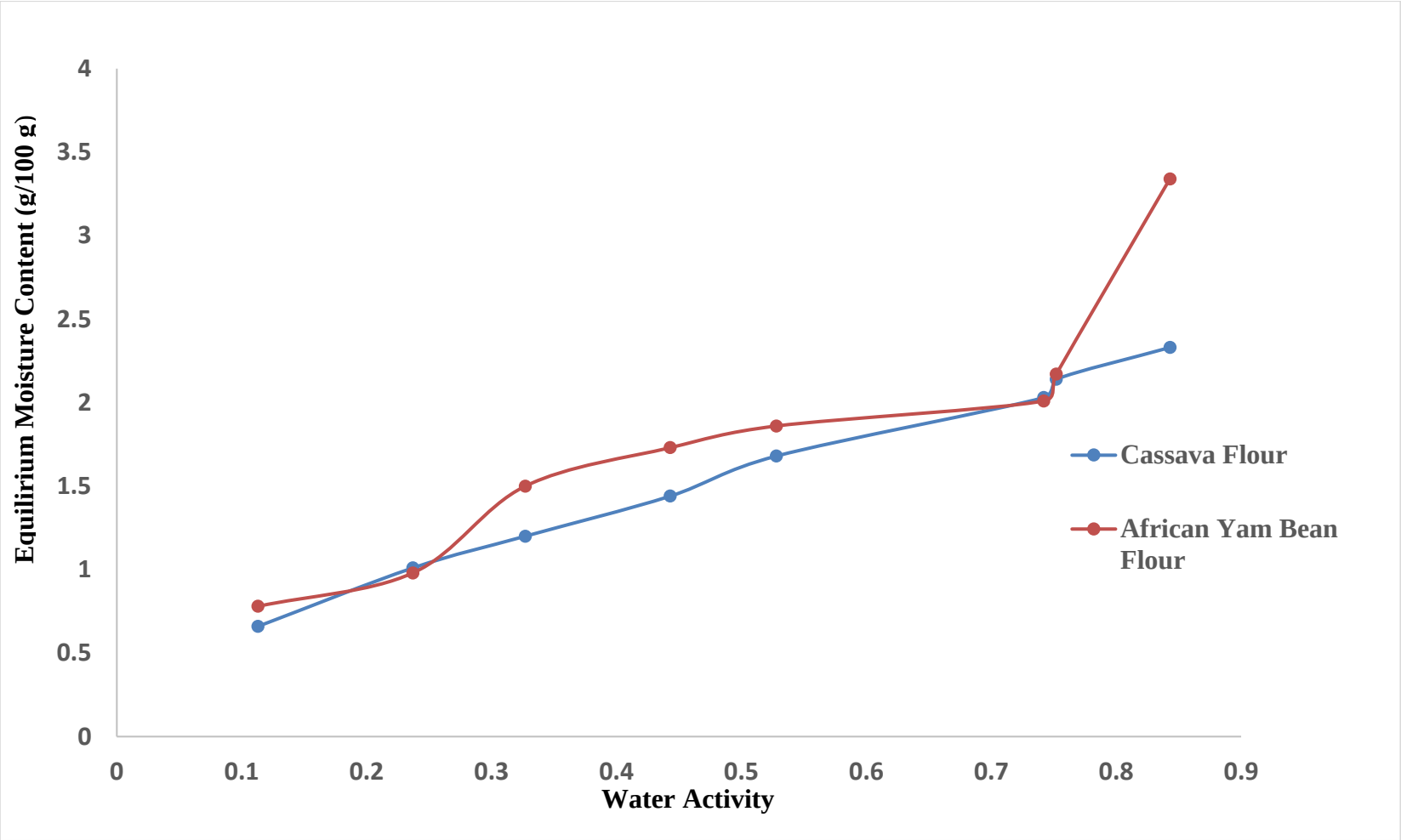


Figure 4.1: Sorption Isotherm of Vitamin A Enriched Cassava and African Yam Bean Flours at 28 oC

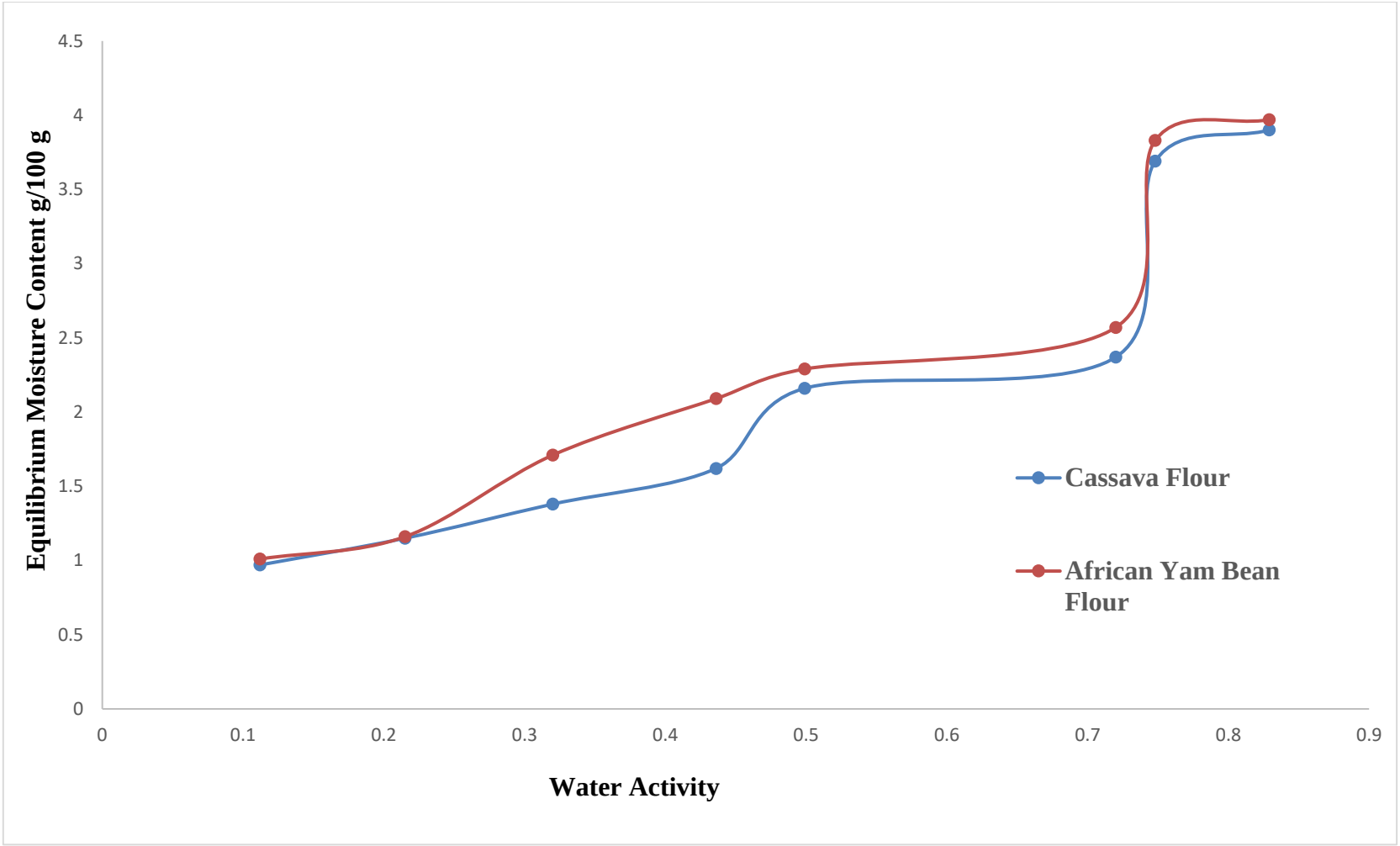


Figure 4.2: Sorption Isotherm of Vitamin A Enriched Cassava and African Yam Bean Flours at 35 ^{o}C

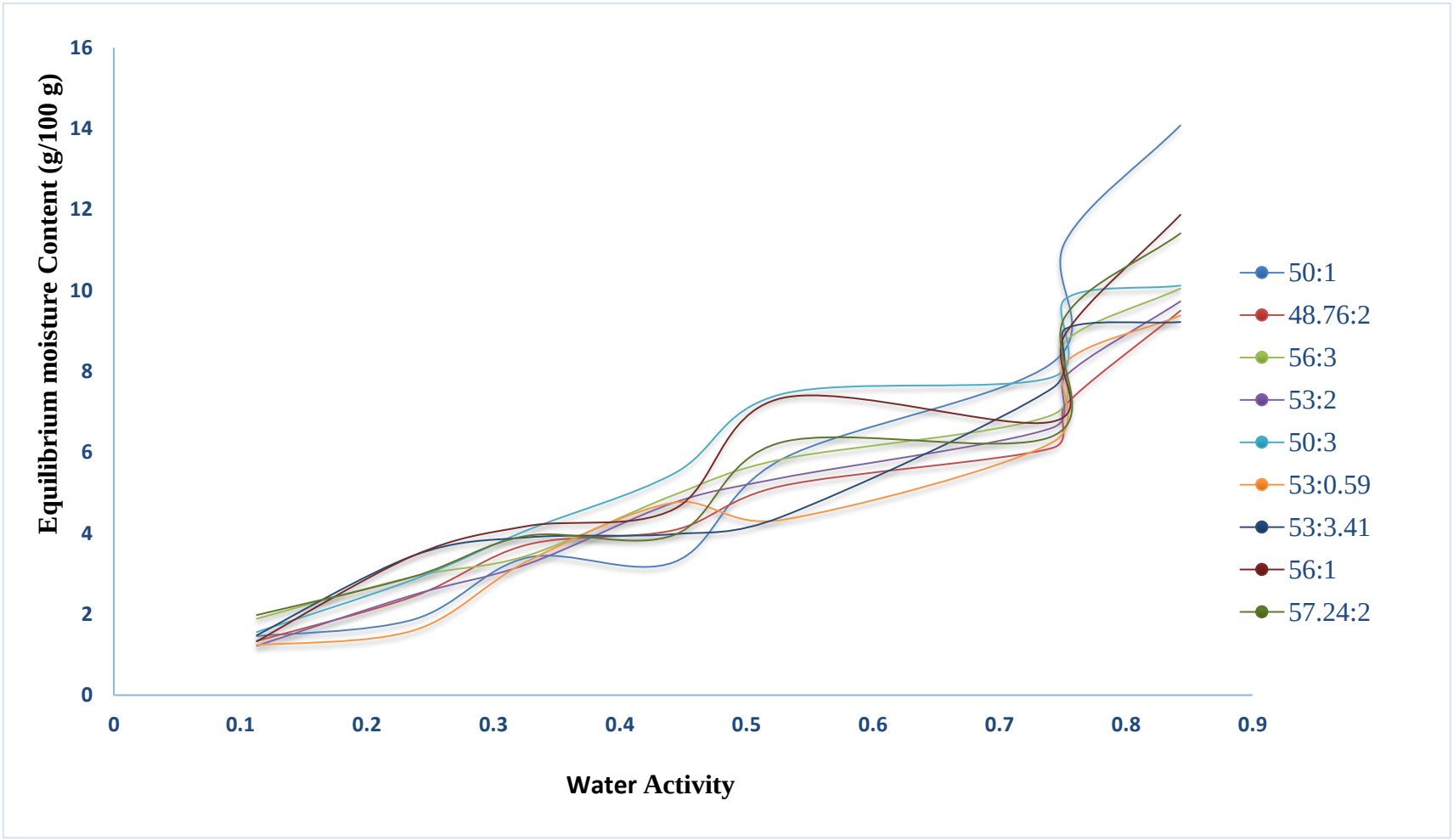


Figure 4.3: Sorption Isotherm of Vitamin A Enriched Cassava and African Yam Bean Noodles at 28 ^{o}C

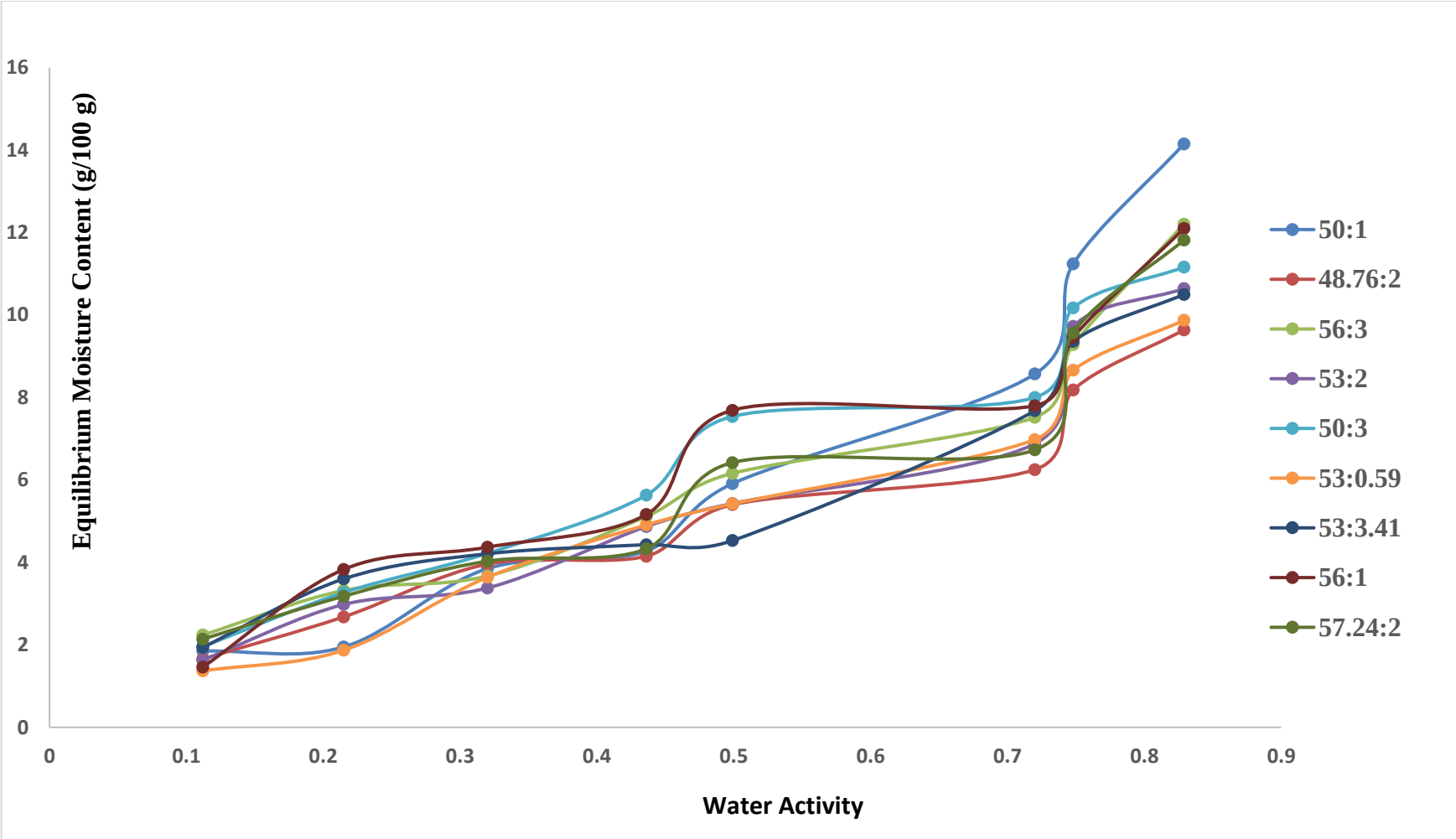


Figure 4.4: Sorption Isotherm of Vitamin A Enriched Cassava and African Yam Bean Noodles at 35 ^{o}C.

than those obtained from Olapade (2010) with values 0.024 to 0.156. It was noted that temperature had effect on equilibrium moisture content within the studied temperatures. The adsorption moisture isotherm of the noodles had type iv sorption isotherm.

4.21 Effect of Storage Conditions on Physical and Chemical Properties of the Noodles

Physical and chemical composition of two optimised noodles were determined during six months of storage for cassava-African yam bean noodles under three packaging materials. The packaging materials include low density polyethylene of 100 micron gauge (LDPE), high density polyethylene of 150 micron gauge (HDPE:150) and high density polyethylene of 200 micron gauge (HDPE:200). The effect of packaging materials on colour, moisture contents, microbiological status (total viable count, total mould and total yeast count), total beta carotene and total carotenoid contents were studied at two weeks interval during the storage duration, while beta carotene and carotenoid degradation were studied at four weeks interval.

The colour variations of samples 50:1 and 56:3 during storage are depicted on Tables 4.34 and 4.35 for the three packaging materials. It was revealed that the packaging material HDPE:200 had greater value for lightness and yellowness, while LDPE had lower values. This showed that HDPE:200 had higher colour retention capacity compared to HDPE:150 and LDPE as shown. The colours of samples stored in low density polyethylene and high density polyethylene were significantly different. Lightness and yellowness values for sample 50:1 varied from 77.59 to 37.29, 77.59 to 39.36, 77.59 to 40.72 and 18.56 to 13.86, 18.56 to 14.52, and 18.56 to 15.40 from zero day to the end of twelve weeks for LDPE, HDPE:150 and HDPE:200, respectively. Similarly, the lightness and yellowness values for sample 56:3 varied from 75.63 to 36.49, 75.63 to 39.06, 75.63 to 39.47 and 18.17 to 13.41, 18.17 to 14.36, 18.17 to 14.56 from zero day to the end of twelve weeks for LDPE, HDPE:150 and HDPE:200, respectively. It was observed that the packaging material comprising high density polyethylene had better colour retention capacity compared to low density polyethylene.

Table 4.34: Effect of Packaging Materials on Colour of 50:1 During Storage

Storage Periods	Packaging materials	Lightness (l*)	Reddish (a*)	Yellowness (b*)
Zero day		$77.59\pm0.17_{a}$	$0.62\pm0.08_{de}$	$18.56\pm0.07_{a}$
Two weeks	LDPE:100	$51.39\pm0.03_{d}$	$0.42\pm0.01_{e}$	$16.85\pm0.26_{fg}$
	HDPE:150	$54.30\pm0.64_{c}$	$0.68\pm0.15_{d}$	$17.98\pm0.31_{c}$
	HDPE:200	$59.28\pm2.53_{b}$	$1.07\pm0.50_{c}$	$18.34\pm0.16_{b}$
Four weeks	LDPE:100	$43.19\pm0.23_{h}$	$0.16\pm0.00_{f}$	$16.63\pm0.06_{gh}$
	HDPE:150	$45.33\pm0.12_{f}$	$0.72\pm0.06_{d}$	$17.65\pm0.07_{cd}$
	HDPE:200	$48.86\pm0.06_{e}$	$0.87\pm0.02_{cd}$	$17.96\pm0.12_{c}$
Six weeks	LDPE:100	$42.11\pm0,22_{i}$	$1.41\pm0.18_{b}$	$15.38\pm0.14_{i}$
	HDPE:150	$44.69\pm0.68_{fg}$	$0.68\pm0.11_{d}$	$17.08\pm0.35_{ef}$
	HDPE:200	$45.18\pm0.31_{f}$	$0.77\pm0.06_{d}$	$17.38\pm0.13_{de}$
Eight weeks	LDPE:100	$40.93\pm0.21_{j}$	$0.73\pm0.02_{d}$	$15.45\pm0.1_{i}$
	HDPE:150	$43.64\pm0.2_{gh}$	$0.27\pm0.01_{ef}$	$16.63\pm0.07_{gh}$
	HDPE:200	$44.69\pm0.68_{fg}$	$0.18\pm0.01_{f}$	$17.08\pm0.35_{ef}$
Ten weeks	LDPE:100	$39\pm0.61_{k}$	$0.23\pm0.05_{ef}$	$14.34\pm0.27_{j}$
	HDPE:150	$43.02\pm0.27_{hi}$	$0.16\pm0.01_{f}$	$16.31\pm0.16_{h}$
	HDPE:200	$43.84\pm0.2_{ghi}$	$0.16\pm0.01_{f}$	$16.67\pm0.07_{g}$
Twelve weeks	LDPE:100	$37.29\pm0.28_{l}$	$1.65\pm0.06_{a}$	$13.86\pm0.06_{k}$
	HDPE:150	$39.36\pm0.13_{k}$	$0.7\pm0.01_{d}$	$14.52\pm0.11_{j}$
	HDPE:200	$40.72\pm0.34_{j}$	$0.93\pm0.01_{cd}$	$15.40\pm0.28_{i}$

LDPE = Low density polyethylene, HDPE:150 = High density polyethylene of 150 micron gauge and HDPE:200 = High density polyethylene of 200 micron gauge. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

Table 4.35: Effect of Packaging Materials on Colour of 56:3 During Storage

Storage periods	Packaging materials	Lightness (l*)	Reddish (a*)	Yellowness (b*)
Zero day		$75.63\pm1.16_{a}$	$0.58\pm0.13_{fg}$	$18.17\pm0.25_{a}$
Two weeks	LDPE:100	$46.98\pm0.13_{c}$	$0.18\pm0.01_{i}$	$17.26\pm0.16_{c}$
	HDPE:150	$47.74\pm0.35_{c}$	$0.18\pm0.02_{i}$	$17.42\pm0.24_{c}$
	HDPE:200	$52.06\pm2.97_{b}$	$0.21\pm0.34_{hi}$	$18.1\pm0.16_{a}$
Four weeks	LDPE:100	$40.45\pm0.13_{fg}$	$0.9\pm0.05_{cd}$	$15.15\pm0.19_{f}$
	HDPE:150	$41.8\pm0.55_{ef}$	$0.9\pm0.03_{cd}$	$16.06\pm0.26_{d}$
	HDPE:200	$46.53\pm0.63_{c}$	$1.38\pm0.14_{b}$	$17.92\pm0.17_{ab}$
Six weeks	LDPE:100	$36.74\pm0.1_{i}$	$0.91\pm0.05_{cd}$	$14.30\pm0.1_{gh}$
	HDPE:150	$40.97\pm0.08_{f}$	$0.74\pm0.01_{def}$	$15.700.08_{e}$
	HDPE:200	$44.47\pm0.1_{d}$	$1.68\pm0.03_{a}$	$17.71\pm0.13_{b}$
Eight weeks	LDPE:100	$36.62\pm0.51_{i}$	$0.35\pm0.04_{gh}$	$13.80\pm0.26_{i}$
	HDPE:150	$38.98\pm0.45_{h}$	$0.18\pm0.01_{i}$	$14.28\pm0.1_{gh}$
	HDPE:200	$42.47\pm0.1_{e}$	$1.68\pm0.03_{a}$	$17.33\pm0.11_{c}$
Ten weeks	LDPE:100	$35.83\pm0.19_{i}$	$0.43\pm0.03_{g}$	$13.57\pm0.04_{ij}$
	HDPE:150	$38.80\pm0.48_{h}$	$0.7\pm0.01_{f}$	$14.16\pm0.13_{h}$
	HDPE:200	$40.65\pm0.32_{fg}$	$0.71\pm0.02_{ef}$	$15.34\pm0.15_{f}$
Twelve weeks	LDPE:100	$36.49\pm0.2_{i}$	$0.87\pm0.00_{cde}$	$13.41\pm0.14_{j}$
	HDPE:150	$39.06\pm0.34_{h}$	$0.66\pm0.02_{f}$	$14.36\pm0.04_{gh}$
	HDPE:200	$39.47\pm0.3_{gh}$	$0.73\pm0.06_{def}$	$14.56\pm0.22_{g}$

LDPE = Low density polyethylene, HDPE:150 = High density polyethylene of 150 micron gauge and HDPE:200 = High density polyethylene of 200 micron gauge.Values are means of three replicates ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

Moisture contents of the stored noodles are presented on Table 4.36. It was observed that moisture content of sample 50:1 rose from 7.39 to 7.83%, 7.39 to 7.68% and 7.39 to 7.55% for LDPE, HDPE:150 and HDPE:200, respectively from zero day of storage till twelve weeks of storage. Similarly, moisture content of sample 56:3 rose from 7.98 to 8.62%, 7.98 to 8.23% and 7.98 to 8.15% for LDPE, HDPE:150 and HDPE:200 respectively. Moisture content increase could be connected to both environmental condition of storage and kind of packaging material used. These results revealed that noodle samples stored in HDPE:200 had the highest capacity of maintaining quality attributes such as moisture barrier capacity compared to other packaging materials.

There were increase in microbial load of the samples stored under the three packaging materials throughout the storage periods as shown in Tables 4.37, 4.38 and 4.39 for total viable count, mould count and yeast count, respectively. Sample 56:3 stored in LDPE had the highest microbial load, while sample 50:1 stored at HDPE:200 had the least. The total viable count ranged from zero to $2.00x10^6$ colony forming unit per gram (cfu/g) and zero to $2.33x10^6$ cfu/g from zero day of storage to twelve weeks of storage for samples 50:1 and 56:3, respectively. Similarly, total mould and yeast count ranged from zero to $1.00x10^6$ and $1.00x10^6$ for sample 50:1 and zero to $1.33x10^6$ and zero to $1.00x10^6$ for sample 56:3, respectively. The increase in microbial load of cassava-African yam bean noodles might be associated with absorption of moisture during storage as suggested by Awoyale *et al*. (2014).

The total viable count of cassava-African yam bean noodles at the twelve weeks of storage was within the tolerable limit as recommended by the international microbiological standards (below 10^6 cfu/g). It also fell within the range reported by centre for food safety (10^5 to 10^6 cfu/g) as reported by Shobha *et al.* (2011). However, at fourteen weeks of storage, the total viable count of noodles were too numerous to count till the end of storage. The total mould and yeast count obtained in this work compared with ranges reported by Aran and Eke (1987) with values 10^5 to 10^6 cfu/g for cereal samples. Though, these were higher than those reported by Awoyale (2014) for cassava-based custard powder with values $0.3x10^4$ to $1.58x10^5$ and $0.41x10^4$ to $1.27x10^5$ during twenty four weeks of storage.

Table 4.36: Impact of Packaging Materials on Moisture of 50:1 and 56:3 During Storage

Samples	50:1-LDPE	50:1-HDPE:150	50:1-HDPE:200	56:3-LDPE	56:3-HDPE:150	563-HDPE:200
0 day	7.39	7.39	7.39	7.98	7.98	7.98
2nd week	$7.48\pm0.02_{c}$	$7.45\pm0.01_{c}$	$7.41\pm0.00_{cd}$	$8.23\pm0.05_{a}$	$8.03\pm0.05_{b}$	$8\pm0.00_{b}$
4th week	$7.53\pm0.04_{c}$	$7.47\pm0.02_{c}$	$7.43\pm0.00_{cd}$	$8.32\pm0.02_{a}$	$8.06\pm0.05_{b}$	$8.01\pm0.01_{b}$
6th week	$7.61\pm0.02_{d}$	$7.54\pm0.01_{d}$	$7.48\pm0.01_{cd}$	$8.43\pm0.08_{a}$	$8.1\pm0.04_{b}$	$8.05\pm0.01_{b}$
8th week	$7.73\pm0.05_{b}$	$7.6\pm0.02_{b}$	$7.5\pm0.71_{b}$	$8.48\pm0.09_{a}$	$8.13\pm0.05_{ab}$	$8.08\pm0.02_{ab}$
10th week	$7.77\pm0.06_{d}$	$7.62\pm0.01_{e}$	$7.51\pm0.02_{ef}$	$8.56\pm0.1_{a}$	$8.2\pm0.01_{b}$	$8.11\pm0.01_{c}$
12th week	$7.83\pm0.04_{c}$	$7.68\pm0.03_{d}$	$7.55\pm0.00_{e}$	$8.62\pm0.12_{a}$	$8.23\pm0.01_{b}$	$8.15\pm0.02_{b}$

LDPE = Low density polyethylene, HDPE:150 = High density polyethylene of 150 micron gauge and HDPE:200 = High density polyethylene of 200 micron gauge. 50:1: Experimental noodle with moisture content 50% and steamed at I min, while 56:3: Experimental noodle with moisture content 56% and steamed at 3 min. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

Table 4.37: Effect of Packaging Materials on Total Viable Count during Storage

	Samples	50:1			56:3		
	Dilution factor	10^{-2}	10^{-4}	10^{-6}	10^{-2}	10^{-4}	10^{-6}
Storage periods	Packaging						
Zero day	LDPE:100	0	0	0	1.00×10^{2}	0	0
	HDPE:150	0	0	0	0.33×10^{2}	0	0
	HDPE:200	0	0	0	0	0	0
Two weeks	LDPE:100	1.00×10^{2}	0.50×10^{4}	0	2.33×10^{2}	1.33×10^{4}	0.50×10^{6}
	HDPE:150	0.50×10^{2}	0.50×10^{4}	0	1.50×10^{2}	1.33×10^{4}	0
	HDPE:200	0	0	0	1.00×10^{2}	0.67×10^{4}	0
Four weeks	LDPE:100	2.00×10^{2}	1.50×10^{4}	1.00×10^{6}	3.50×10^{2}	1.67×10^{4}	1.00×10^{6}
	HDPE:150	1.33×10^{2}	1.00×10^{4}	0.50×10^{6}	3.00×10^{2}	1.50×10^{4}	0.50×10^{6}
	HDPE:200	1.00×10^{2}	0.50×10^{4}	0	2.00×10^{2}	0.67×10^{4}	0.50×10^{6}
Six weeks	LDPE:100	3.00×10^{2}	2.50×10^{4}	1.00×10^{6}	3.33×10^{2}	2.50×10^{4}	1.33×10^{6}
	HDPE:150	2.50×10^{2}	1.50×10^{4}	0.50×10^{6}	2.50×10^{2}	2.00×10^{4}	1.00×10^{6}
	HDPE:200	2.00×10^{2}	1.00×10^{4}	0	2.33×10^{2}	1.00×10^{4}	0.50×10^{6}
Eight weeks	LDPE:100	4.33×10^{2}	3.33×10^{4}	1.50×10^{6}	4.50×10^{2}	3.67×10^{4}	2.00×10^{6}
	HDPE:150	3.00×10^{2}	2.67×10^{4}	1.00×10^{6}	3.33×10^{2}	3.00×10^{4}	1.33×10^{6}
	HDPE:200	2.50×10^{2}	2.00×10^{4}	0.33×10^{6}	3.00×10^{2}	1.33×10^{4}	0.67×10^{6}
Ten weeks	LDPE:100	5.00×10^{2}	3.50×10^{4}	1.67×10^{6}	5.33×10^{2}	4.00×10^{4}	2.00×10^{6}
	HDPE:150	4.00×10^{2}	3.00×10^{4}	1.50×10^{6}	4.00×10^{2}	3.33×10^{4}	1.33×10^{6}
	HDPE:200	3.33×10^{2}	2.33×10^{4}	0.67×10^{6}	3.33×10^{2}	2.67×10^{4}	1.00×10^{6}
Twelve weeks	LDPE:100	5.3×10^{2}	3.67×10^{4}	2.00×10^{6}	5.67×10^{2}	4.00×10^{4}	2.33×10^{6}
	HDPE:150	4.5×10^{2}	2.67×10^{4}	1.33×10^{6}	5.00×10^{2}	2.33×10^{4}	1.33×10^{6}
	HDPE:200	3.5×10^{2}	2.50×10^{4}	1.00×10^{6}	4.00×10^{2}	2.00×10^{4}	1.00×10^{6}

LDPE= Low density polyethylene, HDPE:150 = High density polyethylene of 150 micron gauge and HDPE:200 = High density polyethylene of 200 micron gauge.

Table 4.38: Effect of Packaging Materials on Total Mould Count During Storage

	Samples	50:1			56:3		
	Dilution factor	10^{-2}	10^{-4}	10^{-6}	10^{-2}	10^{-4}	10^{-6}
Storage periods	Packaging						
Zero day	LDPE:100	0	0	0	$0.33x10^{2}$	0	0
	HDPE:150	0	0	0	0	0	0
	HDPE:200	0	0	0	0	0	0
Two weeks	LDPE:100	$1.00x10^{2}$	0	0	$1.00x10^{2}$	$0.33x10^{4}$	$0.67x10^{6}$
	HDPE:150	$0.67x10^{2}$	$0.33x10^{4}$	0	$0.67x10^{2}$	$0.50x10^{4}$	$0.33x10^{6}$
	HDPE:200	$0.50x10^{2}$	$0.33x10^{4}$	0	$0.33x10^{2}$	0	0
Four weeks	LDPE:100	$1.50x10^{2}$	$1.00x10^{4}$	$0.50x10^{6}$	$1.67x10^{2}$	$1.00x10^{4}$	$1.00x10^{6}$
	HDPE:150	$1.00x10^{2}$	$0.50x10^{4}$	$0.50x10^{6}$	$1.33x10^{2}$	0	0
	HDPE:200	$0.67x10^{2}$	$0.33x10^{4}$	0	$0.50\ x10^{2}$	0	0
Six weeks	LDPE:100	$2.00x10^{2}$	$0.67x10^{4}$	$0.50x10^{6}$	$2.00x10^{2}$	$1.33x10^{4}$	$1.00x10^{6}$
	HDPE:150	$1.33x10^{2}$	$0.50x10^{4}$	0	$1.33x10^{2}$	$1.00x10^{4}$	$0.67x10^{6}$
	HDPE:200	$1.00x10^{2}$	$0.50x10^{4}$	0	$1.00x10^{2}$	$0.67x10^{4}$	0
Eight weeks	LDPE:100	$2.00x10^{2}$	$1.33x10^{4}$	$0.33\ x10^{6}$	$2.00x10^{2}$	0	0
	HDPE:150	$1.33x10^{2}$	0	0	$1.67x10^{2}$	0	0
	HDPE:200	$1.00x10^{2}$	0	0	$1.00x10^{2}$	0	0
Ten weeks	LDPE:100	$2.33x10^{2}$	$1.50x10^{4}$	$1.00x10^{6}$	$2.50x10^{2}$	$1.67x10^{4}$	$1.00x10^{6}$
	HDPE:150	$1.50x10^{2}$	$0.67x10^{4}$	$0.50x10^{6}$	$1.67x10^{2}$	$1.33x10^{4}$	0
	HDPE:200	$1.33x10^{2}$	$0.50x10^{4}$	$0.33x10^{6}$	$1.33x10^{2}$	$1.00x10^{4}$	0
Twelve weeks	LDPE:100	$2.50x10^{2}$	$2.00x10^{4}$	$1.00x10^{6}$	$2.67x10^{2}$	$2.33x10^{4}$	$1.33x10^{6}$
	HDPE:150	$1.67x10^{2}$	$1.00x10^{4}$	$0.67x10^{6}$	$2.00x10^{2}$	$1.00x10^{4}$	$1.00x10^{6}$
	HDPE:200	$1.50x10^{2}$	$0.50x10^{4}$	0	$1.67x10^{2}$	$1.0x10^{4}$	0

LDPE = Low density polyethylene, HDPE:150 = High density polyethylene of 150 micron gauge and HDPE:200 = High density polyethylene of 200 microgauge.

Table 4.39: Effect of Packaging Materials on Total Yeast Count During Storage

	Samples	50:1			56:3		
	Dilution factor	10^{-2}	10^{-4}	10^{-6}	10^{-2}	10^{-4}	10^{-6}
Storage periods	Packaging						
Zero day	LDPE:100	0	0	0	$0.5x10^{2}$	0	0
	HDPE:150	0	0	0	0	0	0
	HDPE:200	0	0	0	0	0	0
Two weeks	LDPE:100	$1.00x10^{2}$	$0.67x10^{4}$	$0.67x10^{6}$	$1.00x10^{2}$	$0.67x10^{4}$	$0.50x10^{6}$
	HDPE:150	$0.50x10^{2}$	$0.33x10^{4}$	0	$0.67x10^{2}$	$0.50x10^{4}$	0
	HDPE:200	$0.33x10^{2}$	0	0	$0.50x10^{2}$	$0.330x10^{4}$	0
Four weeks	LDPE:100	$1.33x10^{2}$	$1.00x10^{4}$	$0.67x10^{6}$	$1.33x10^{2}$	$1.00x10^{4}$	$0.67x10^{6}$
	HDPE:150	$1.00x10^{2}$	$0.50x10^{4}$	0	$1.00x10^{2}$	$0.67x10^{4}$	0
	HDPE:200	$0.50x10^{2}$	0	0	$0.67x10^{2}$	$0.50x10^{4}$	0
Six weeks	LDPE:100	$1.67x10^{2}$	$1.00x10^{4}$	$1.00x10^{6}$	$2.00x10^{2}$	$1.33x10^{4}$	$1.00x10^{6}$
	HDPE:150	$1.00x10^{2}$	$0.33x10^{4}$	$0.33x10^{6}$	$1.33x10^{2}$	$1.00x10^{4}$	0
	HDPE:200	$0.67x10^{2}$	$0.33x10^{4}$	0	$1.0x10^{2}$	$1.00x10^{4}$	0
Eight weeks	LDPE:100	$2.00x10^{2}$	$1.00x10^{4}$	0	$2.33x10^{2}$	$1.50x10^{4}$	$1.00x10^{6}$
	HDPE:150	$1.67x10^{2}$	$0.67x10^{4}$	0	$1.67x10^{2}$	$1.00x10^{4}$	0
	HDPE:200	$0.33x10^{2}$	0	0	$1.33x10^{2}$	$1.00x10^{4}$	0
Ten weeks	LDPE:100	$2.33x10^{2}$	$2.00x10^{4}$	$1.00x10^{6}$	$2.67x10^{2}$	$2.00x10^{4}$	$1.00x10^{6}$
	HDPE:150	$2.00x10^{2}$	$1.33x10^{4}$	$0.67x10^{6}$	$2.00x10^{2}$	$1.33x10^{4}$	$0.33x10^{6}$
	HDPE:200	$1.00x10^{2}$	$1.00x10^{4}$	0	$1.33x10^{2}$	$1.00x10^{4}$	0
Twelve weeks	LDPE:100	$2.33x10^{2}$	$2.00x10^{4}$	$1.00x10^{6}$	$2.67x10^{2}$	$1.67x10^{4}$	$1.00x10^{6}$
	HDPE:150	$1.67x10^{2}$	$1.33x10^{4}$	$0.67x10^{6}$	$2.00x10^{2}$	$1.33x10^{4}$	$0.67x10^{6}$
	HDPE:200	$1.00x10^{2}$	$0.67x10^{4}$	$0.67x10^{6}$	$1.33x10^{2}$	$1.00x10^{4}$	$1.00x10^{6}$

LDPE = Low density polyethylene, HDPE:150 = High density polyethylene of 150 micron gauge and HDPE:200 = High density polyethylene of 200 micron gauge.

The effect of packaging materials on 13 cis, trans, 9cis, total beta carotene and total carotenoids contents of the two most desirable noodles are presented on Tables 4.40 and 4.41. The total beta carotene and total carotenoid contents of sample 50:1 varied from 5.47 to 3.97 ug/g and 7.1 to 5.15 from zero day of storage to twelve weeks of storage. Similarly, the total beta carotene and total carotenoids contents of sample 56:3 varied from 5.27 to 3.79 ug/g and 6.34 to 4.46 ug/g from zero day of storage to twelve weeks of storage. It was noted that the percentage of total beta carotene and total carotenoid degradation in low density polyethylene was 8.04 to 27.61% and 9.86 to 27.32% compared to that of high density polyethylene of 200 micron gauge with values ranged from 5.40 to 27.42% and 9.16 to 27.47% for twelve weeks of storage.for sample 50:1.

Likewise, the percentage of total beta carotene and carotenoid degradation in low density polyethylene was 8.92 to 30.36% and 20.51 to 29.65% compared to that of high density polyethylene of 200 micron gauge with values ranged from 3.99 to 28.08% and 19.72 to 26.81% for the period of storage for sample 56:3.

4.22 Nutritional Assessment of Casssava-African Yam Bean Noodles

There were five groups of eight rats per group. Each member of groups was presented in Appendix 18. The weekly and total diets consumption of the rats in each group were depicted in Figure 4.5. The results of the feeding consumption rate showed that rats fed with experimental diet (END 2) had highest feed consumption rate, whereas rats fed with nitrogen free diet had lowest. It was noted that rats fed with casein and experimental diets increased in weight during experimental periods. This showed that these rats were utilising their diets effectively. Meanwhile, rats fed with nitrogen free diet loss appetite and thus, loss weight throughout the feeding periods. The animals in this group became slimmer and fragile on daily basis due to their weight loss. This showed the importance of protein on the health status of the animals. Although, there was no death occurrence throughout the feeding periods.

The physical changes were noted on their skin, body weight and in their consumption rate. It was noted that rats fed with casein and experimental diets looked very well and strong throughout the twenty-one day of feeding periods. The weight changes experienced by the animals in all the groups were depicted in Figure 4.6. It was

Table 4.40: Effect of Packaging Materials on Total Beta Carotene and Carotenoid Content of 50:1 During Storage

Storage periods	13-cis (ug/g)	Trans (ug/g)	9-cis (ug/g)	Total BC (ug/g)	TC (ug/g)	% BC degradation	%TC degradation
Zero day	$1.51\pm0.01_{a}$	$2.56\pm0.02_{a}$	$1.19\pm0.00_{a}$	$5.47\pm0.00_{a}$	$7.1\pm0.00_{a}$		
4^{th} week LDPE	$1.28\pm0.05_{c}$	$2.56\pm0.1_{a}$	$1.18\pm0.01_{a}$	$5.03\pm0.01_{c}$	$6.4\pm0.03_{b}$	8.04%	9.86%
4^{th} week HDPE:200	$1.47\pm0.01_{ab}$	$2.55\pm0.02_{a}$	$1.17\pm0.02_{a}$	$5.19\pm0.00_{b}$	$6.45\pm0.01_{b}$	5.40%	9.16%
8^{th} week LDPE	$1.30\pm0.01_{c}$	$2.31\pm0.01_{c}$	$1.07\pm0.01_{c}$	$4.67\pm0.01_{e}$	$5.78\pm0.01_{c}$	14.63%	18.59%
8^{th} week HDPE:200	$1.44\pm0.01_{b}$	$2.36\pm0.01_{b}$	$1.10\pm0.01_{b}$	$4.9\pm0.01_{d}$	$5.82\pm0.01_{c}$	10.42%	18.03%
12^{th} week LDPE	$0.93\pm0.02_{e}$	$2.02\pm0.01_{d}$	$1.01\pm0.01_{d}$	$3.96\pm0.04_{f}$	$5.16\pm0.03_{d}$	27.61%	27.32%
12^{th} week HDPE:200	$0.99\pm0.02_{d}$	$1.99\pm0.01_{d}$	$1.00\pm0.02_{d}$	$3.97\pm0.05_{f}$	$5.15\pm0.1_{d}$	27.42%	27.47%

LDPE = Low density polyethylene, HDPE:200 = High density polyethylene of 200 micron gauge,

BC = Beta carotene and TC = Total carotenoid.

Table 4.41: Effect of Packaging Materials on Total Beta Carotene and Carotenoid Content of 56:3 during Storage

Storage periods	13-cis (ug/g)	Trans (ug/g)	9-cis (ug/g)	Total BC (ug/g)	TC (ug/g)	% BC degradation	%TC degradation
Zero day	$1.37\pm0.08_{a}$	$2.72\pm0.1_{a}$	$1.37\pm0.19_{a}$	$5.27\pm0.36_{a}$	$6.34\pm0.08_{a}$		
4th week LDPE	$1.27\pm0.01_{c}$	$2.41\pm0.01_{c}$	$1.12\pm0.01_{bc}$	$4.8\pm0.03_{b}$	$5.04\pm0.02_{b}$	8.92%	20.51%
4th week HDPE:200	$1.34\pm0.01_{ab}$	$2.54\pm0.01_{b}$	$1.18\pm0.01_{b}$	$5.06\pm0.01_{b}$	$5.09\pm0.01_{b}$	3.99%	19.72%
8th week LDPE	$0.95\pm0.01_{d}$	$1.95\pm0.01_{d}$	$0.95\pm0.01_{cd}$	$3.85\pm0.02_{c}$	$4.60\pm0.02_{c}$	26.95%	27.44%
8th week HDPE:200	$0.98\pm0.01_{d}$	$1.95\pm0.01_{d}$	$0.95\pm0.01_{cd}$	$3.88\pm0.01_{c}$	$4.74\pm0.00_{c}$	26.38%	25.24%
12th week LDPE	$0.94\pm0.01_{d}$	$1.86\pm0.01_{de}$	$0.88\pm0.01_{d}$	$3.67\pm0.03_{c}$	$4.46\pm0.12_{d}$	30.36%	29.65%
12th week HDPE:200	$0.96\pm0.01_{d}$	$1.80\pm0.01_{e}$	$1.04\pm0.01_{bcd}$	$3.79\pm0.03_{c}$	$4.64\pm0.04_{c}$	28.08%	26.81%

LDPE = Low density polyethylene, HDPE:200 = High density polyethylene of 200 micron gauge, BC = Beta carotene and TC = Total carotenoid.

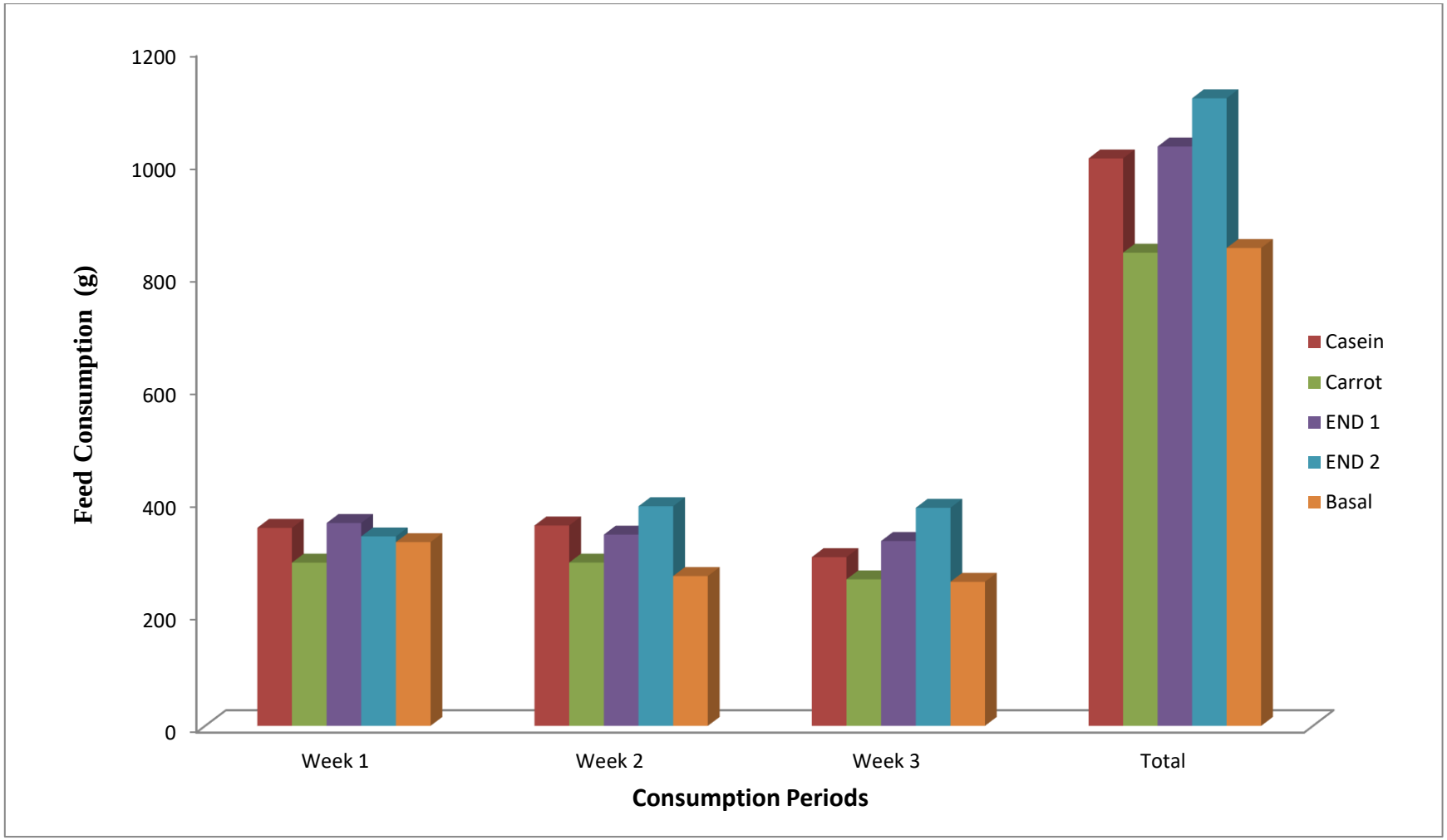


Figure 4.5: Feed Consumption During Experimental Periods

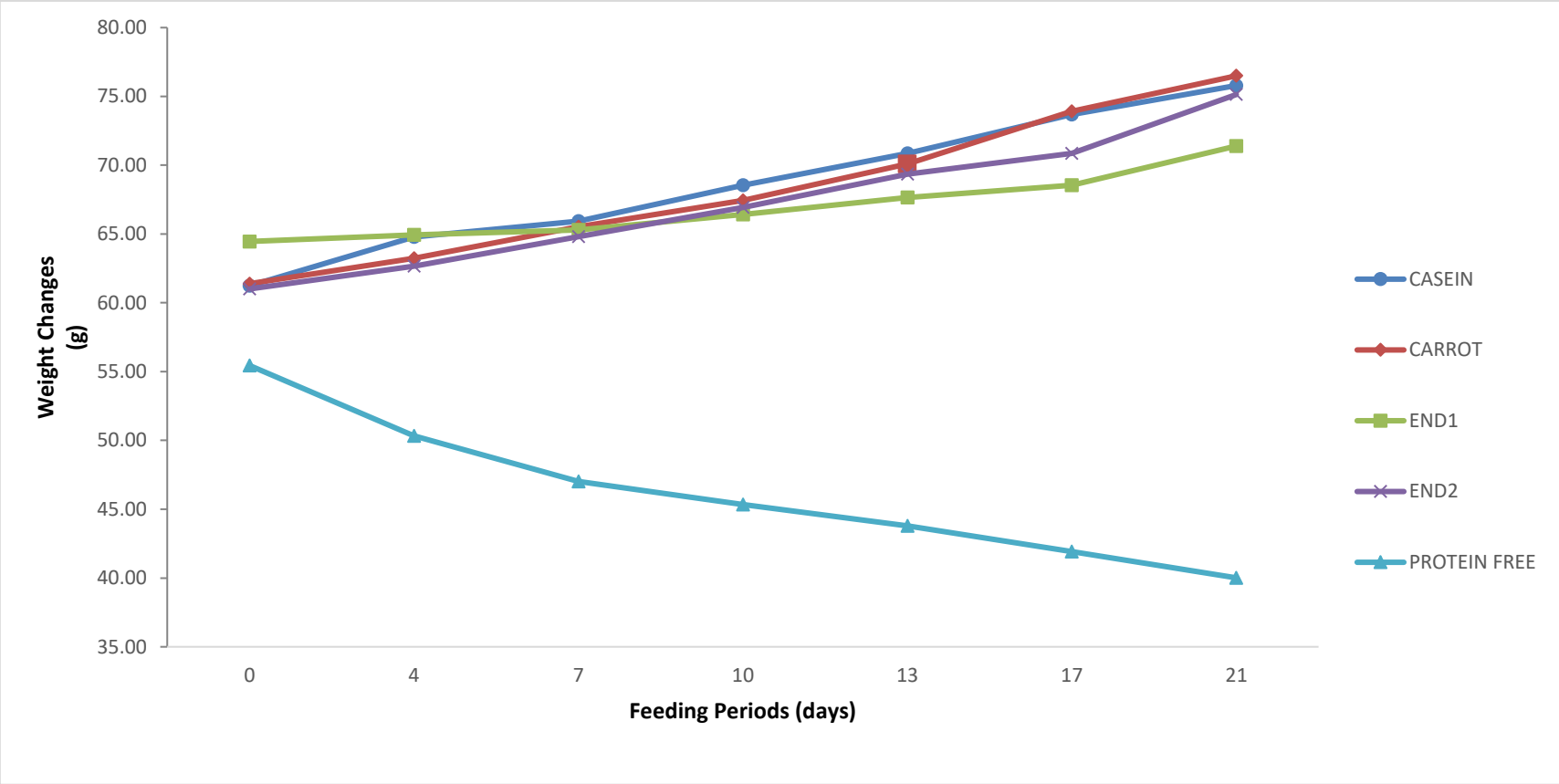


Figure 4.6: Weight Changes During Experimental Feeding

revealed that weights of animals consumed experimental and casein diets varied from 61.24 to 75.79 g, 61.39 to 76.5 g, 64.46 to 71.39g, 61.01 to 75.14g and 55.45 to 40.01 for casein, carrot, END 1, END 2 and nitrogen-free diets, respectively.

The effect of feed consumption on organs' developments is depicted on Table 4.42. The organs' weights of casein fed rats were not significantly different from those consumed experimental diets except weights of lungs that were different. The weights of the heart and liver obtained in this study fell within the ranges reported by Ijarotimi and Keshinro (2012) with values ranging from 0.22 to 0.58 g and 1.61 to 1.95, respectively. Furthermore, the weight of spleen obtained in this study were within those reported by Olapade (2010) with values ranging from 0.19 to 0.56 g.

4.22.1 Protein quality of rats fed with test diets

Protein quality of rats fed with test diets were depicted on Table 4.43. The feed intake, weight gain, biological values (BV) and net protein utilisation (NPU) of rats varied from 636.16±5.66 g to 933.96±3.54 g, zero to 28.54±0.71 g, 2±0.01 to 96.5±1.41% and 7±0.01 to 93.56±0.71%, respectively. Rats fed with END 2 had maximum feed consumption, while rats fed with basal diets had minimum. Rats fed with carrot diets had highest weight gain, whereas rats nourished with nitrogen-free diet experienced reduction in weight throughout the feeding period. The weight gain obtained in this study were within ranges reported by Abiose *et al*. (2015) with values ranging from 14.19 to 34.53 g. It was revealed that rats nourished with casein diet had maximum BV and NPU values, while rats nourished with basal diet had minimum . The rats fed with experimental and casein diets were significantly ($p \leq 0.05$) varied in their feed intake, weight gained, BV and NPU as depicted.

The protein efficiency, nitrogen intake, true protein digestibility and feed efficiency of the rats fed with test diets varied from zero to 2.37±0.71, 1.04±0.02 to 1.98±0.1, 3.5±0.71 to 97±0.01 and 0.07±0.05 to 0.2±0.01, respectively. These protein qualities were not significantly ($p \geq 0.05$) different in all group diets except basal diet that was significantly different. The protein efficiency and weight gain obtained compared with the ranges stated by Abiose *et al*. (2015) with values ranged from 0.95±0.05 to 2.87±0.35 and 14.18±5.45 to 63.02±5.42, respectively.

Table 4.42: Effect of Test Diets on Development of Organs

Diets	Heart/body weight *100	Kidney/body weight * 100	Liver/body weight * 100	Lung/body weight * 100	Spleen/body weight * 100
Casein	$0.39\pm0.05_{a}$	$0.76\pm0.09_{ab}$	$3.74\pm0.45_{a}$	$0.92\pm0.06_{c}$	$0.32\pm0.08_{a}$
Carrot	$0.39\pm0.09_{a}$	$0.78\pm0.18_{ab}$	$3.74\pm0.67_{a}$	$1.08\pm0.11_{abc}$	$0.29\pm0.11_{a}$
END1	$0.38\pm0.04_{a}$	$0.71\pm0.07_{b}$	$3.62\pm0.76_{a}$	$0.94\pm0.12_{bc}$	$0.36\pm0.17_{a}$
END2	$0.4\pm0.06_{a}$	$0.71\pm0.1_{b}$	$3.85\pm0.59_{a}$	$1.14\pm0.16_{a}$	$0.31\pm0.06_{a}$
Basal diet	$0.46\pm0.14_{a}$	$0.87\pm0.09_{a}$	$3.76\pm0.42_{a}$	$1.11\pm0.14_{ab}$	$0.28\pm0.06_{a}$

END 1 = First experimental noodle diet, END 2 = Second experimental noodle diet and basal diets. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscript within column are significantly ($p\leq0.05$) different.

Table 4.43: Protein Quality of Albino Rats Fed with Test Diets

Diets	Casein diet	Carrot diet	END 1	END 2	Nitrogen-free diet
Feed Intake (g)	$868.96\pm4.95_{c}$	$839.52\pm2.83_{d}$	$897.97\pm3.54_{b}$	$933.96\pm3.54_{a}$	$636.16\pm5.66_{e}$
Protein Efficiency (%)	$2.37\pm0.71_{a}$	$2.34\pm0.00_{a}$	$2.06\pm0.00_{a}$	$2.27\pm0.01_{a}$	0
Nitrogen intake (%)	$1.98\pm0.10_{a}$	$1.95\pm0.05_{a}$	$1.75\pm0.00_{a}$	$1.69\pm0.01_{a}$	$1.04\pm0.02_{b}$
Weight gain (g)	$25.24\pm0.71_{b}$	$28.54\pm0.71_{a}$	$22.49\pm0.71_{d}$	$23.98\pm1.41_{c}$	0
True protein digestibility (%)	$96\pm1.41_{a}$	$97\pm0.01_{a}$	$95.5\pm0.71_{a}$	$96\pm1.41_{a}$	$3.5\pm0.71_{b}$
Biological value (%)	$96.5\pm1.41_{a}$	$91.5\pm0.71_{b}$	$87\pm1.41_{c}$	$85\pm1.41_{d}$	$2\pm0.01_{e}$
Net protein utilisation (%)	$93.56\pm0.71_{a}$	$91.5\pm0.71_{b}$	$86.5\pm0.71_{c}$	$85\pm0.02_{d}$	$7\pm0.01_{e}$
Feed Efficiency (%)	$0.17\pm0.01_{a}$	$0.2\pm0.02_{a}$	$0.15\pm0.04_{a}$	$0.15\pm0.03_{a}$	$0.07\pm0.02_{b}$

END 1 = First experimental noodle diet, END 2 = Second experimental noodle diet. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscripts within row are significantly ($p\leq0.05$) different.

True protein digestibility and net protein utilisation of all diets obtained in this work compared with ranges stated by Famakin *et al*. (2016) with values ranged from 76.07 to 99.63% and 49.46 to 99.63 except values for the basal diet that were very low hence, did not fall in these ranges. The feed efficiency obtained compared with range stated by Olapade *et al*. (2015) with values ranged from 0.06 to 0.75%.

4.22.2 Haematological composition of the studied animals

The haematological composition of albino rats nourished with control and experimental diets at the begining, mid-period and at termination of the experiment are presented on Tables 4.44 and 4.45. Haemoglobin concentration of rats prior feeding and on eleventh day of feeding varied from 12.4 (control) to 14.3% (basal). Haemoglobin concentration of rats nourished with control and experimental diets were not significantly ($p \geq 0.05$) different at both eleventh day of feeding and termination stage except those fed with basal diet that was significantly different at the termination of feeding period.

As the feeding continued, haemoglobin concentration of rats nourished with experimental diets increased, except those nourished with basal diet. Reduction of haemoglobin concentration of rats nourished with basal diet could be the cause of weakness condition observed from rats in that group. The haemoglobin concentration obtained in this research compared with the ranges reported by Olapade *et al*. (2015) with values ranged from 11.73 to 14.37 g/dl with exclusion of rats fed with basal diet at termination of feeding period.

The pack cell volume (PCV) of the rats prior feeding (baseline) and after experimental feeding varied from 36.5% (END 1) to 43% (basal). There were no significant differences among the PCV of rats nourished with both experimental and baseline diets at eleventh day of feeding. Similarly, the PCV of all the diets were not significantly ($p \geq 0.05$) different at termination of experimental feeding. Meanwhile, the PCV of rats fed with basal diet reduced drastically at termination of experimental feeding. Probst *et al*. (2006) opined that proportion of PCV of rat varied from 34 to 57% with the average PCV of 45%. It was revealed that all the diets were within this range but lower than the average PCV of rats. The PCV obtained in this study matched with ranges reported by Soetan *et al.* (2017) and Abiose *et al*. (2015) with values 35 to

Table 4.44: Haematological Composition of Rats at Eleventh Day of Feeding

Diets	Haemoglobin (g/dl)	Pack Cell Volume (%)	Red Blood Cell ($x10^6$) (mm^3)	MCV (fl)	MCH (pg)	MCHC (g/dl)
Control	$12.4\pm0.05_a$	$38\pm0.02_a$	$6.8\pm0.12_{ab}$	$55.88\pm0.2_c$	$18.24\pm0.35_d$	$32.63\pm0.1_b$
Casein diet	$13.05\pm0.35_a$	$39.5\pm0.71_a$	$6.4\pm0.02_{ab}$	$61.72\pm0.9_{ab}$	$20.39\pm0.49_{ab}$	$33.04\pm0.30_a$
Carrot diet	$13.2\pm1.13_a$	$40\pm4.24_a$	$6.77\pm0.66_{ab}$	$59.08\pm0.47_b$	$19.50\pm0.24_c$	$33.00\pm0.68_a$
END 1	$12.52\pm1.34_a$	$36.5\pm3.54_a$	$5.81\pm0.76_b$	$62.82\pm2.12_a$	$21.55\pm0.44_a$	$34.30\pm0.43_a$
END 2	$12.5\pm0.00_a$	$37.5\pm0.71_a$	$6.3\pm0.04_{ab}$	$59.52\pm0.79_b$	$19.84\pm0.11_{bc}$	$33.33\pm0.63_a$
Basal diet	$14.3\pm0.14_a$	$43\pm0.00_a$	$7.2\pm0.01_a$	$59.72\pm0.12_b$	$19.86\pm0.16_{bc}$	$33.26\pm0.33_a$

END 1 = First experimental noodle diet, END 2= Second experimental noodle diet, MCV = mean corpuscular volume, MCH = mean corpuscular haemoglobin and MCHC = mean corpuscular haemoglobin concentration. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscripts within column are significantly ($p\leq0.05$) different.

Table 4.45: Haematological Composition of Rats at Twenty-One Days of Feeding

Diets	Haemoglobin (g/dl)	Pack Cell Volume (%)	Red Blood Cell ($x10^6$) (mm^3)	MCV (fl)	MCH (pg)	MCHC (g/dl)
Casein diet	$13.67\pm1.53_a$	$39.67\pm5.51_{ab}$	$6.67\pm0.58_a$	$59.48\pm0.58_{ab}$	$20.49\pm0.00_{ab}$	$34.46\pm0.53_a$
Carrot diet	$14.33\pm1.53_a$	$42.67\pm4.51_a$	$6.67\pm0.58_a$	$63.97\pm2.65_a$	$21.48\pm0.58_a$	$33.65\pm0.23_a$
END 1	$13\pm1.00_{ab}$	$38.33\pm3.22_{ab}$	$6.33\pm0.58_a$	$60.55\pm0.00_{ab}$	$20.54\pm0.58a_b$	$33.92\pm0.08_a$
END 2	$13\pm1.00_{ab}$	$39\pm4.58_{ab}$	$6\pm1.00_{ab}$	$65.00\pm2.65_a$	$21.67\pm0.58_a$	$33.33\pm0.66_a$
Basal diet	$10.67\pm1.16_b$	$33\pm1.73_b$	$5\pm0.00_b$	$66.00\pm3.46_a$	$21.34\pm1.53_a$	$32.33\pm0.14_b$

END 1 = First experimental noodle diet, END 2 = Second experimental noodle diet, MCV = mean corpuscular volume, MCH = mean corpuscular haemoglobin and MCHC = mean corpuscular haemoglobin concentration. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscripts within column are significantly ($p\leq0.05$) different.

49% and 23 to 46%, respectively.

According to Wynne and Edward (2003), PCV measures the proportion of full red blood cells in an entire blood after centrifugation. It is an easy and fast way of measuring the degree of anaemia and offers information similar to the haemoglobin concentration from nutritional point of view. Based on Hercberg *et al.* (1991), the PCV limit varied from 32% in children below age four to 40% in males older than 15 years of age. It was revealed that the PCV levels of all the diets were above the limit for children below age four.

The red blood cell obtained in this study varied from 5.81 x 10^6 to 7.2 x 10^6 mm^3 from zero day to eleventh day of feeding. The values obtained in this study were greater than those stated by Famakin *et al*. (2016) with values 3 x 10^6 mm^3 to 3.95 x 10^6 mm^3. It was revealed that red blood cells of rats nourished with basal diet reduced greatly at termination of feeding period. The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) of rats prior and after experimental feeding varied from 55.88 to 66 fl, 18.24 to 21.67 pg and 32.33 to 34.46 g/dl. The MCV and MCHC obtained in this research matched with ranges stated by Osigwe *et al*. (2017) and Soetan *et al*. (2017) with values 46.93 to 78.67 fl and 30.04 to 43.71 g/dl respectively.

The white blood cells (WBC) and platelet obtained in this study varied from 7.2 x10^6 to 10.2 x 10^6 and 1.9 x 10^5 to 5.84 x10^5 as exhibited in Table 4.46 and Table 4.47 respectively. Initially, WBC of all rats fed with diets increased. As the feeding continued, WBC and platelets of all the rats reduced enormously. The substantial decreased in WBC at the end of the feeding showed low levels of infection in the experimental rats since WBC fight against infections and diseases in the body. According to Adepeju *et al*. (2014), high level of platelet will lead to rise in bleeding and reduction in clotting time. This problem can be lessened with reduction in platelet as the feeding continued. This indicated that these experimental diets can sustain the health of the infants. It was also observed that the presence of PVAC-AYB diet significantly stabilised all the blood cells.

The lymphocyte, neutrophyl, monocyte and eosinophyl of the experimental diets

Table 4.46: Platelets and White Blood Cells Composition of Rats at Eleventh Day of Feeding

Diets	WBC x 10^6 (mm^3)	Platelet ($x10^5$)	Lymphocyte (%)	Neutrophyl (%)	Monocyte (%)	Eosinophyl (%)
Control	$7.2\pm0.10_b$	$5.84\pm100_a$	$76\pm1.05_a$	$20\pm0.5_b$	$2\pm0.09_a$	$2.00\pm0.65_a$
Casein diet	$9.38\pm45.96_a$	$2.4\pm410_b$	$67.50\pm2.12_a$	$30\pm2.83_a$	$1.5\pm0.71_a$	$1.00\pm0.00_a$
Carrot diet	$7.88\pm137.88_a$	$1.9\pm481_b$	$67.5\pm2.12_a$	$28.5\pm0.71_a$	$2\pm0.00_a$	$2.00\pm1.41_a$
END 1	$9.80\pm0.02_a$	$2.58\pm728_b$	$68.5\pm4.95_a$	$28\pm2.83_a$	$2\pm1.41_a$	$1.5\pm0.71_a$
END 2	$9.70\pm77.78_a$	$2.33\pm219_b$	$65.5\pm3.54_a$	$30.5\pm3.54_a$	$2.5\pm0.71_a$	$1.5\pm0.71_a$
Basal diet	$10.20\pm120.2_a$	$2.89\pm1252_b$	$72\pm1.41_a$	$25\pm1.41_a$	$2\pm1.41_a$	$1.00\pm1.41_a$

END 1 = First experimental noodle diet, END 2 = Second experimental noodle diet and WBC =white blood cells. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscripts within column are significantly ($p\leq0.05$) different.

Table 4.47: Platelets and White Blood Cells Composition of Rats at Twenty-One Days of Feeding

Diets	WBCx10^6 (mm^3)	Platelet (x10^5)	Lymphocyte (%)	Neutrophyl (%)	Monocyte (%)	Eosinophyl (%)
Casein diet	$7.27\pm317.23_a$	$1.34\pm274.65_a$	$67.00\pm4.36_a$	$29.00\pm4.36_a$	$2.00\pm0.00_a$	$2.00\pm0.00_a$
Carrot diet	$5.68\pm105.63_a$	$1.81\pm452.99_a$	$63.00\pm3.00_a$	$34.00\pm3.61_a$	$1\pm0.00_a$	$2.00\pm1.00_a$
END 1	$5.63\pm161.74_a$	$1.84\pm601.85_a$	$64.67\pm2.89_a$	$31.33\pm4.73_a$	$1.67\pm1.16_a$	$2.33\pm1.16_a$
END 2	$6.28\pm196.36_a$	$1.79\pm196.55_a$	$59.67\pm5.03_a$	$37.00\pm5.00_a$	$2\pm1.00_a$	$1.00\pm1.00_a$
Basal diet	$5.23\pm154.62_a$	$1.68\pm643.84_a$	$62.00\pm5.57_a$	$35.33\pm4.73_a$	$1.67\pm0.58_a$	$1.00\pm1.73_a$

END 1 = First experimental noodle diet, END 2 = Second experimental noodle diet and WBC =white blood cells. Values are means of triplicate ± standard deviation. Mean values of dissimilar subscripts within column are significantly ($p\leq0.05$) different.

varied from from 59.67 to 67%, 29 to 37%, 1.0 to 2.0% and 1.0 to 2.33%, respectively at termination of feeding period. White blood cells differentials of all the rats fed diets were not significantly ($p \geq 0.05$) different at termination of experimental periods as reported by Asyura *et al.* (2016).

4.22.3 Serum biochemistry of rats fed with test diets

Serum biochemistry composition of rats nourished with control and experimental diets are depicted in Table 4.48. The values of total protein and albumin compared well with those reported by Magda and Dalia (2013) with values ranged from 5.19 to 8.05 mg/dl and 2.49 to 4.26 mg/dl, respectively. It was revealed that total protein, albumin and globulin of all experimental rats were not significantly ($p \geq 0.05$) different from those of control. This might indicate normal function of the liver.

The compositions of serum liver indicator enzymes such as Aspartate-amino transferase (AST), Alanine-amino transferase (ALT) and Alkaline phosphatase (ALP) were exhibited in Figure 4.7. The values of these enzymes obtained in this study varied from 39.67 to 41.67 U/L, 29 to 31.33 U/L and 88 to 104.33 U/L for AST, ALT and ALP, respectively. It was noted that values of AST and ALT obtained in this study from all the groups matched well with those stated by Olatoye and Arueya (2017) with values 36.75 to 43.75 and 27.50 to 32.75, respectively. Furthermore, the enzymes of rats nourished with both experimental and control diets were not significantly ($p \geq 0.05$) different.

Serum creatinine and urea of animals fed with experimental and control diets varied from 16.4 to 17.07 and 0.57 to 0.67 respectively as exhibited in Figure 4.8. It was revealed that both creatinine and urea composition obtained in this work were not significantly ($p \geq 0.05$) different. Based on Oluwole *et al*. (2012), determination of serum creatinine is the best generally adopted index of renal function. Moreover, substantial rise in both creatinine and urea might be an indicator for renal dysfunction. Similarly, rise in urea level might be connected with inflammation of kidney, disturbance in blood circulation and urinary tract impediment (Lynda *et al*., 2009). The result obtained in this research indicated no substantial rise in both serum creatinine and urea which suggest proper functioning of kidney.

Table 4.48: Biochemistry Composition of Rats Fed with Test Diets

Diets	Protein (mg/dl)	Albumin (A) (mg/dl)	Globulin (G) (mg/dl)	A:G Ratio
Control	$7.4\pm0.25_{a}$	$2.9\pm0.32_{a}$	$4.5\pm0.23_{ab}$	$0.6\pm0.05_{ab}$
Casein diet	$7.77\pm0.57_{a}$	$2.87\pm0.21_{a}$	$4.87\pm0.36_{a}$	$0.59\pm0.00_{ab}$
Carrot diet	$7.67\pm0.15_{a}$	$2.6\pm0.35_{a}$	$4.87\pm0.25_{a}$	$0.54\pm0.06_{b}$
END 1	$7.8\pm0.53_{a}$	$3.17\pm0.21_{a}$	$4.63\pm0.32_{ab}$	$0.68\pm0.06_{a}$
END 2	$7.67\pm0.42_{a}$	$3.27\pm0.42_{a}$	$4.47\pm0.84_{ab}$	$0.8\pm0.10_{a}$
Basal Diet	$6.83\pm1.24_{a}$	$3.2\pm0.36_{a}$	$4.1\pm0.21_{b}$	$0.72\pm0.10_{a}$

END 1 denotes first experimental noodle diet, END 2 denotes second experimental noodle diet. Values are mean of triplicate ± standard deviation. Mean values of dissimilar subscripts within column are significantly ($p\leq0.05$) different.

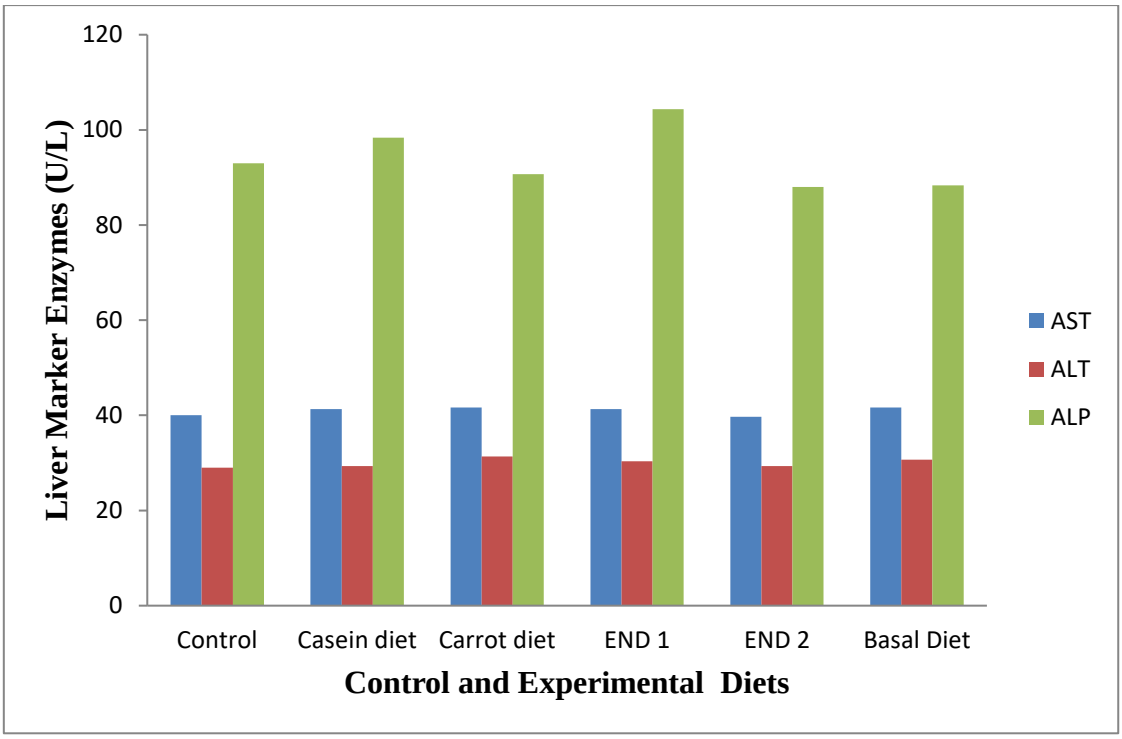


Figure 4.7: Liver Enzymes Composition of Rats Nourished with Test Diets

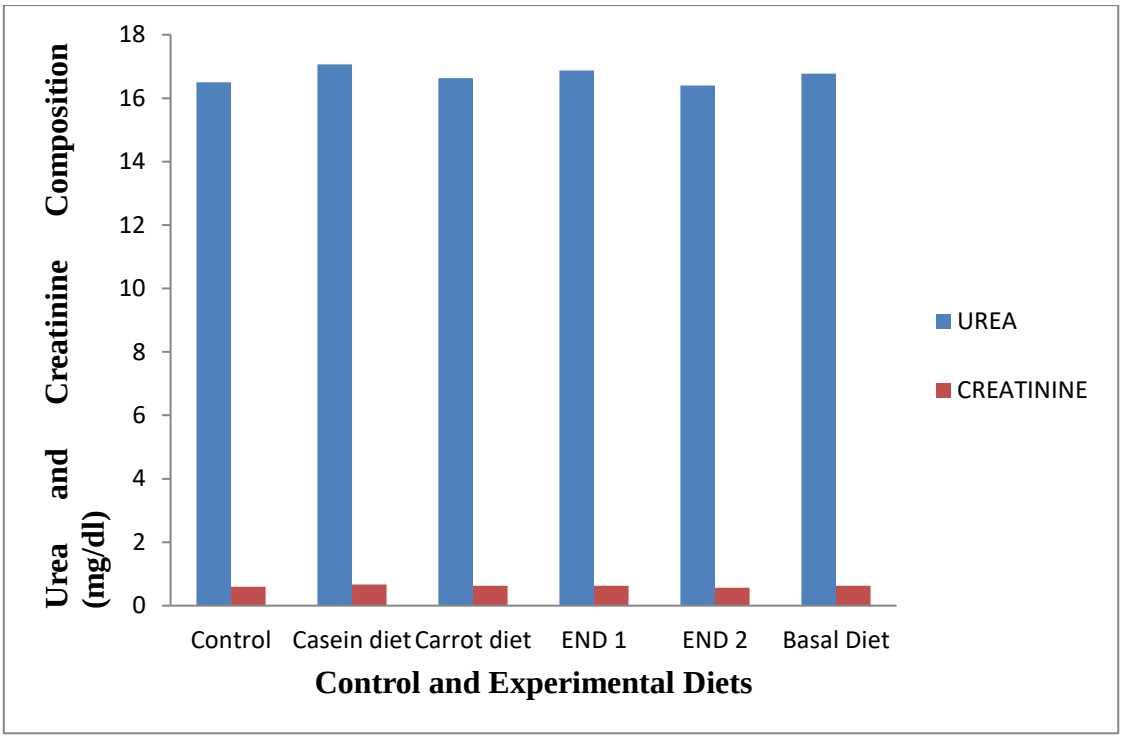


Figure 4.8: Urea and Creatinine Compositions of Rats Nourished with Test Diets

4.22.4 Serum mineral composition of rats nourished with experimental diets

Serum minerals compositions of rats nourished with control and experimental diets at eleventh day and twenty one days were depicted in Tables 4.49 and 4.50, respectively. These varied from 9.6 to 12.75 mg/dl, 4.3 to 5.7 mg/dl, 5.65 to 6.4 mg/dl, 44.72 to 96.47 ug/dl and 1.06 to 1.58 umol/l at eleventh day for calcium, potassium, phosphorus, iron and zinc, respectively. The calcium, potassium, phosphorus and zinc contents of all rats fed with experimental diets were not significantly ($p \geq 0.05$) different throughout the feeding periods. Rats nourished with control diet had least calcium content followed by those fed with basal diet at eleventh day of feeding. It was revealed that calcium, potassium, phosphorus and zinc contents of rats fed with experimental diets increased at termination of feeding periods.

Meanwhile, their iron contents decreased except those fed with END 1 and END 2. Rats nourished with experimental and basal diets were significantly ($p \leq 0.05$) different based on these minerals. It was noted that rats nourished with casein diet recorded maximum value whereas those nourished with basal diet recorded the least value of these minerals at termination of feeding period.

Based on Brown *et al*. (1998), cassava roots comprise of some substantial quantity of non-heme iron. These non-heme iron are derived from vegetable source and has been stated not to be easily accessible into the body unlike heme iron of animal origin that are well absorbed into the body. This might be the reason that serum iron contents of rats fed with experimental diets are not increasing as the feeding continued till the termination of feeding time. Hence, the iron contents of rats nourished with experimental and control diets were significantly ($p \leq 0.05$) different.

4.22.5 Histopathological properties of rats nourished with test diets

Heart and kidney of two randomly selected rats from all the rats were collected, cleaned, weighed and examined to serve as baseline study. Inspection of rat's heart before commencement of experimental feeding indicated that cardiomyocyte bundles appear normal and there was moderate congestion of the coronary blood vessels. Moreover, there was presence of few foci of bundles with hypertrophic cardiomyocytes showed by large nuclei. The photomicrographs of rat's heart and

Table 4.49: Serum Minerals Compositions of Rats Fed with Test Diets at Eleventh Day of Feeding

Diets	Calcium (mg/dl)	Potassium (mg/dl)	Phosphorus (mg/dl)	Iron (ug/dl)	Zinc (umol/l)
Control	$9.6\pm0.04_{c}$	$5.7\pm0.03_{a}$	$6\pm0.1_{a}$	$80.54\pm2.12_{ab}$	$1.38\pm0.05_{ab}$
Casein diet	$12.75\pm0.35_{a}$	$5.2\pm0.28_{a}$	$6.4\pm0.42_{a}$	$96.47\pm9.61_{a}$	$1.58\pm0.02_{a}$
Carrot diet	$12.00\pm1.49_{a}$	$4.5\pm0.71_{ab}$	$5.8\pm0.71_{a}$	$48.27\pm2.93_{cd}$	$1.49\pm0.23_{a}$
END 1	$11.8\pm1.13_{a}$	$4.65\pm0.21_{ab}$	$5.85\pm0.78_{a}$	$69.91\pm3.47_{b}$	$1.46\pm0.03_{a}$
END 2	$12.05\pm0.5_{a}$	$4.85\pm0.21_{ab}$	$5.75\pm0.78_{a}$	$65.75\pm0.78_{b}$	$1.44\pm0.07_{a}$
Basal diet	$11.05\pm0.00_{b}$	$4.3\pm0.00_{b}$	$5.65\pm0.5_{a}$	$44.72\pm0.4_{d}$	$1.06\pm0.16_{b}$

END 1= First experimental noodle diet, END 2 = Second experimental noodle diet. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscripts within column are significantly ($p\leq0.05$) different.

Table 4.50: Serum Minerals Compositions of Albino Rats Fed with Test Diets at Twenty One Days of Feeding

Diets	Calcium (mg/dl)	Potassium (mg/dl)	Phosphorus (mg/dl)	Iron (ug/dl)	Zinc (umol/l)
Casein diet	$12.83\pm0.84_{a}$	$5.28\pm0.36_{a}$	$6.43\pm0.875_{a}$	$80.11\pm4.83_{a}$	$1.69\pm0.01_{a}$
Carrot diet	$12.17\pm0.61_{a}$	$5.07\pm0.12_{ab}$	$6.53\pm0.15_{a}$	$47.50\pm3.02_{ab}$	$1.36\pm0.07_{ab}$
END 1	$12.53\pm0.81_{a}$	$4.93\pm0.49_{ab}$	$6.03\pm0.55_{ab}$	$69.08\pm19.25_{ab}$	$1.63\pm0.38_{a}$
END2	$12.87\pm1.10_{a}$	$4.83\pm0.56_{ab}$	$6.27\pm0.51_{ab}$	$69.70\pm13.67_{ab}$	$1.56\pm0.07_{a}$
Basal diet	$12.23\pm0.15_{a}$	$4.33\pm0.47_{b}$	$5.43\pm0.4_{b}$	$32.50\pm11.60_{b}$	$1.03\pm0.19_{b}$

END 1 = First experimental noodle diet, END 2 = Second experimental noodle diet.

Values are means of three replicates ± standard deviation. Mean values of dissimilar subscripts within column are significantly ($p\leq0.05$) different.

kidney fed with control and test diets are shown in Figures 4.9 and 4.10, correspondingly.

Comparing the rats' baseline organs with those fed with test diets, it was observed that cardiomyocyte bundles appear normal and vascular changes are inconspicuous in all the hearts of the rats except heart of rats nourished with basal diet that showed few foci of mild detachment of cardiomyocytes and mild increase of fibroblasts between cardiac muscle bundles. There were no observable lesion that deviated from control in the photomicrographs of all the kidney tissues in all the experimental groups. Therefore, there were no significant ($p \geq 0.05$) differences in kidneys of all rats nourished with test diets and baseline except rats nourished with basal diet that contained few foci of coagulation necrosis of tubular epithelial cells that might caused by the inability of blood vessels to deliver oxygen and essential nutrients such as absence of protein in their diets. It was noted that selected organs were significantly different from basal organs as depicted.

4.23. Bioavailability Study of Rats Fed with Test Diets

Serum beta carotene of rats nourished with control and experimental diets were assessed. It was revealed that colour of serum from rats nourished with control diet was colourless which suggested no traces of beta carotene. Meanwhile, the colour of serum obtained in rats fed with carrot based and cassava-African yam bean diets were not colourless but not sufficiently coloured to be detected by HPLC, the obtained carotenoid contents were too low to quantify its beta carotene. This might be due to degradation during storage in freezer prior the analysis (Tan *et al*., 2017).

4.23.1 Liver vitamin A of rats fed with test diets

Vitamin A composition of liver of rats nourished with control and experimental diets were depicted in Table 4.51. This revealed that liver of rats fed with carrot based diets had maximum vitamin A composition, while the liver of rats fed with basal diet had minimum. There were significant ($p \leq 0.05$) differences in liver vitamin A composition of rats in all the test diets.

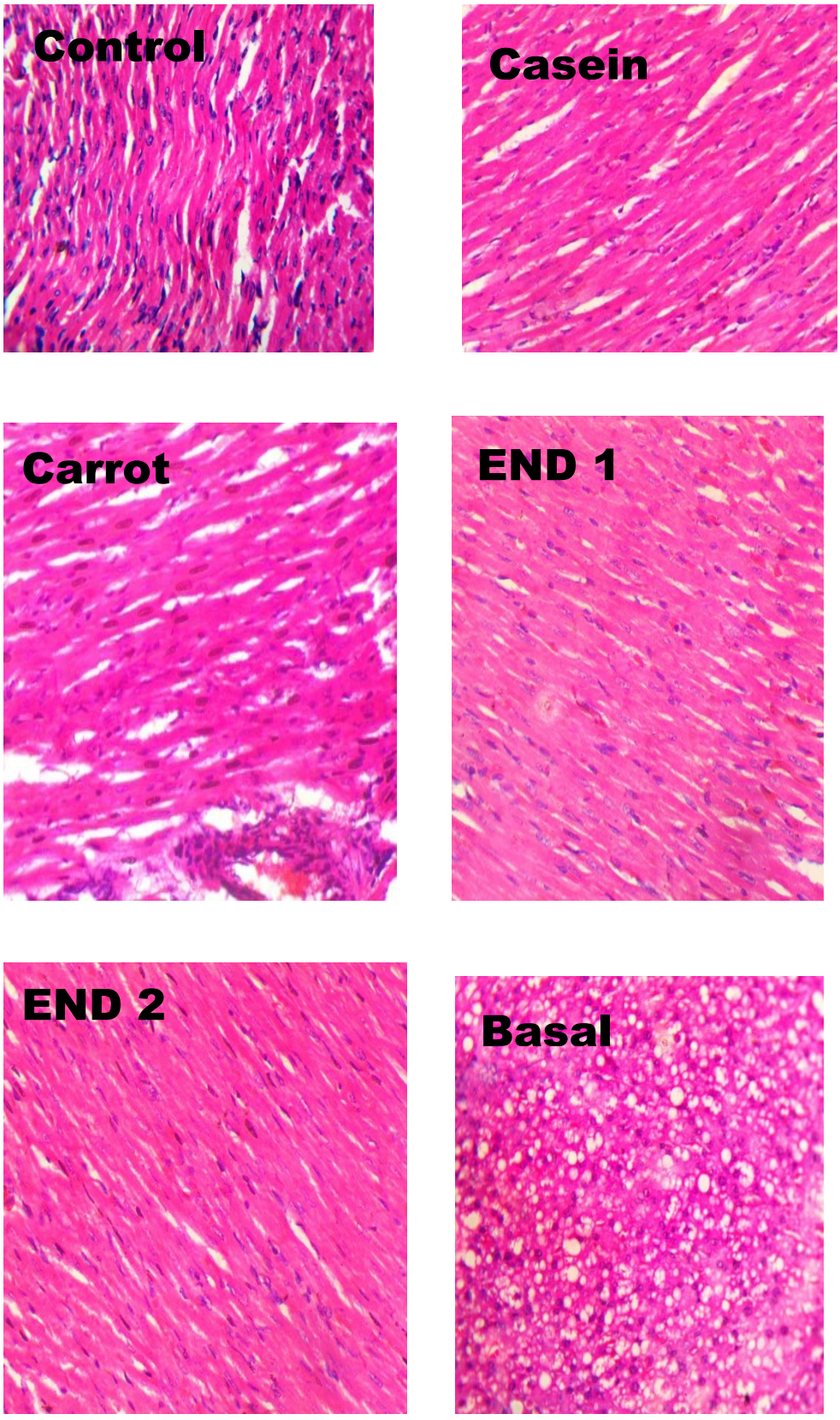


Figure 4.9: Photomicrograph of Rat's Heart Nourished with Control and Experimental Diets (x 400 magnification).

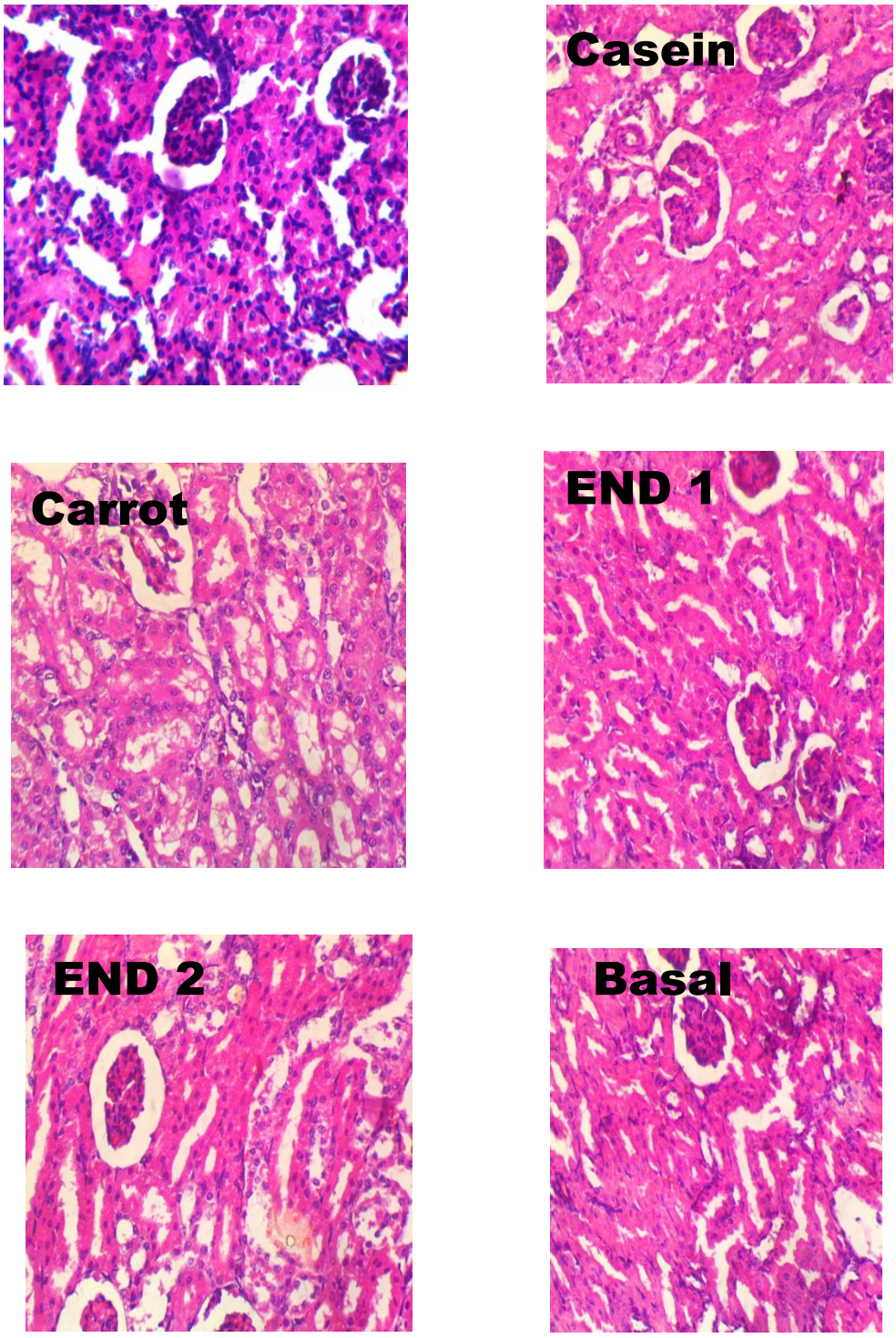


Figure 4.10: Photomicrograph of Rat's Kidney Nourished with Control and Experimental Diets (x 400 magnification).

Table 4.51: Liver Vitamin A Composition of Rats Fed with Test Diets

Diets	Liver Vitamin A (IU/g)
Control	$19.84 \pm 0.06_{e}$
Casein	$20.56 \pm 0.11_{d}$
Carrot	$35.9 \pm 0.05_{a}$
END 1	$34.7 \pm 0.05_{b}$
END 2	$27.9 \pm 0.05_{c}$
Basal	$13.92 \pm 0.05_{f}$

END 1 = First experimental noodle diet, END 2 = Second experimental noodle diet. Values are means of three replicates ± standard deviation. Mean values of dissimilar subscripts within column are significantly ($p \leq 0.05$) different.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Cassava-African yam bean noodles of acceptable nutritional, cooking and sensory qualities were developed from the mixtures of Pro-Vitamin A Cassava (PVAC) and African Yam Bean (AYB) flours. Cultivar of PVAC (07/593) was chosen because of its high dry matter and beta carotene contents, while AYB seeds of accession (TSs 94) was selected because of its highest protein content among screened accessions. Response Surface Methodology was applied to optimise the nutritional value of blend and processing parameters of noodles based on its chosen quality attributes.

The crude protein, ash, crude fibre, calcium, magnesium, zinc, iron, pH, titratable acidity and packed density increased, while carbohydrate and β-carotene contents of blend reduced with increase in AYBF inclusion in the blend. The proximate, cooking qualities, textural properties and overall acceptability of the noodles were significantly ($p \leq 0.05$) different. In addition, microstructure of the noodles was significantly different and there were clear morphological alterations among the noodles.

The quality attributes of noodles: colour, texture, microstructural characteristics as well as cooking qualities were affected by the ingredients and processing parameters. Both hydration level and steaming time influenced nutritional qualities of noodles. The most desirable noodle (50:1) compared with commercial noodle. Commercial noodle rated highest in overall acceptability followed by sample hydrated at 50% moisture content and steamed at 1 min. Of the three packaging materials, HDPE of 200 µm was the best based on colour, moisture content, β-carotene retention and microbiological qualities of the samples. The protein qualities of the desirable noodles compared well with that of casein diet.

The study demonstrated that acceptable fortified cassava noodles could be made from the blend of PVAC and AYB flours. These ingredients are part of our indigenous crops that are commonly grown in Nigeria. This is one of the efforts of adding value to these crops so as to boost our economy as well as creating a unique use for the crops. It has

also shown that the blend of PVAC and AYB flours could be a potential replacement to wheat flour in production of noodles. It could promote the utilisation of these indigenous crops in production of noodles and thus, contribute to the efforts of minimising the utilisation of imported wheat in food production. It could also boost cassava and African yam bean production and create employment opportunities if well harnessed.

5.2 Recommendations

More research should be done on breeding of PVAC roots that would have high capability of retaining as much as β-carotene as possible during and after processing. The technique developed for cassava-African yam bean noodles requires industrial testing. Quality standards for cassava-based noodles should be established. This would ease its adoption by small and medium enterprise. It would thus, increase the varieties of cassava-based products and generate more revenue for cassava and African yam bean farmers. The ratio of AYBF to CF should be increased to enhance protein quality of the noodles.

5.3 Contribution to Knowledge

The work contributed to improvement of nutritional qualities of fortified cassava noodles by fortifying provitamin A cassava flour with African yam bean flour in noodle production. Further contributions to knowledge in the research include provision of information on the following properties of fortified cassava noodles:

- Amino acid profiling
- Thermal properties
- Microstructural properties

Finally, the optimisation of major ingredients of flour blend and processing parameters (hydration level and steaming time) of fortified cassava noodles were investigated.

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APPENDIX

Appendix 1: African Yam Bean Plant

Appendix 2: Dried African Yam Bean Cobs

Appendix 3: African Yam Bean Seeds

Appendix 4: Cooked Cassava-African Yam Bean Noodle (50:1)

Appendix 5: Cooked Cassava-African Yam Bean Noodle (56:3)

Appendix 6: Cooked Indomie Noodle

Appendix 7: Questionnaire for the Comparative Sensory Evaluation of Yellow Fleshed Cassava-African Yam Bean Noodles and Commercial Noodle

Dear sir/ma,

This study is for research purpose. Kindly feel free to express your sincere opinion on each of the samples.

Date……..….

Kindly evaluate each of the noodle samples and indicate your preference for appearance, taste, colour, stickiness, chewiness, flavour and general acceptability. Assign each noodle with the following codes for each quality parameter.

9=Like tremendously

8=Like a lot

7=Like moderately

6=Like mildly

5=Neither like nor dislike

4=Dislike mildly

3=Dislike moderately

2=Dislike a lot

1= Dislike tremendously

Samples Appearance Taste Colour Stickiness Chewiness Flavour General Acceptability

501

563

510

Comment freely

……

……

……

Thank you.

Appendix 8: ANOVA of Sensory Evaluation Result

Quality attributes		Sum of Squares	df	Mean Square	F	Sig.
Appearance	Between Groups	48.311	2	24.156	12.433	.000
	Within Groups	81.600	42	1.943		
	Total	129.911	44			
Taste	Between Groups	46.533	2	23.267	11.275	.000
	Within Groups	86.667	42	2.063		
	Total	133.200	44			
Colour	Between Groups	25.378	2	12.689	10.196	.000
	Within Groups	52.267	42	1.244		
	Total	77.644	44			
Stickiness	Between Groups	16.178	2	8.089	4.386	.019
	Within Groups	77.467	42	1.844		
	Total	93.644	44			
Chewiness	Between Groups	17.911	2	8.956	4.949	.012
	Within Groups	76.000	42	1.810		
	Total	93.911	44			
Aroma	Between Groups	35.244	2	17.622	9.739	.000
	Within Groups	76.000	42	1.810		
	Total	111.244	44			
Overall Acceptability	Between Groups	36.400	2	18.200	18.735	.000
	Within Groups	40.800	42	.971		
	Total	77.200	44			

Appendix 9: ANOVA of Rats Fed Liver Vitamin A

		Addition of Squares	df	Mean Square	F	Sig.
Vitamin A	Between Groups	776.373	5	155.275	38418.450	.000
	Inside Groups	.024	6	.004		
	Overall	776.397	11			
Absorbance	Between Groups	305.869	5	61.174	149569.073	.000
	Inside Groups	.002	6	.000		
	Overall	305.871	11			

Appendix 10: Pressing Equipment

Appendix 11: Niji Lukas Flash Dryer

Appendix 12: FOSS Fibretec 2010 Unit

Appendix 13: High Performance Liquid Chromatography

Appendix 14: INSPECT Scanning Electron Microscope of Model S 50

Appendix 15: Applied Biosystems PTH Amino Acid Analyser

Appendix 16: KD2 Pro Thermal Properties Analyser

Appendix 17: Texture Profile Analyser of Model TVT-300XPH.

Appendix 18: Experimental Rats Fed with Test Diets

Rat consumed casein diet

Rat consumed basal diet

Rat consumed END 1 diet

Rat consumed END 2 diet

Rat consumed basal diet

Appendix 19: Stainless Steel Cages Used for the Animal Study